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Lifting Surface Performance Analysis for Horizontal Axis Wind Turbines

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LIFTING SURFACE PERFORMANCE ANALYSIS FOR HORIZONTAL AXIS WIND TURBINES

SUMMARY

The application of numerical lifting surface theory to the calculation of a horizontal axis wind turbine's aerodynamic characteristics and performance is developed, and its computer implementation as Program LSWT (Lifting Surface Wind Turbine) is described. The method employed has evolved from rotary wing and helicopter applications, and features a detailed prescribed wake. The wake model is extended from a hovering rotor experimental generalization by including the effect of the windmill brake state on the radial and axial displacement rates of the trailing vortex system.

Performance calculations are made by coupling the lifting surface circulation solution to a blade element analysis that incorporates two-dimensional airfoil characteristics as functions of angle of attack and Reynolds number. Several analytical stall models are also provided to extend the airfoil characteristics beyond the limits of available data.

Although the primary emphasis of the current work is on the steady performance problem, the method includes facilities to investigate the effects of wind shear profile, tower shadow, and off-axis shaft alignment. These influences are included in a quasi-steady sense, and also add additional displacement detail to the wake model.

Correlation of the method to measured wind turbine performance and comparisons to blade element momentum theory calculations provide validation, but also highlight the extreme sensitivity of predictions to the quality of early post stall airfoil behavior.

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NOMEMCLATURE

Symbol	Definition	Dimension
A	minimum nondimensional wake radius	
AR	aspect ratio	
A_1, A_2, B_1, B_2	coefficients of Viterna stall model equations	
A_{12}, A_{22}, B_{12}, B_{22}, A_{13}, A_{23}, B_{13}, B_{23}	coefficients of CMA stall model equations	
B	general boundary surface	
B_{pr}	base pressure factor (post stall)	
$\overline{C}$, C	contour direction unit vector, contour path	
C_T	rotor thrust coefficient	
$\overline{D}$, D	vector, scaler aerodynamic influence coefficients	ft^{-1}
D^*	aerodynamic influence coefficient, modified for non-potential lift response	ft^{-1}
$\tilde{D}$	aerodynamic influence coefficient, modified for quasi-steady effects	ft^{-1}
K	distributed circulation	ft^2/sec
$\tilde{K}$	ratio of disk average to target blade distributed circulation	
$\overline{N}$	positive normal vector	
P	discretized surface panel	
R	rotor radius; also used to nondimensionalize all geometry parameters	ft
S	lifting surface	
T	rotor thrust	lb

T_s	tower shadow velocity deficit fraction	
T1, T2, T3, T4	intermediate terms in vortex cylinder calculations	
V_a	axial impressed velocity	ft/sec
$\overline{V}_a$	referred axial impressed velocity	
V_{net}	net axial velocity through rotor	ft/sec
$\overline{V}_{net}$	referred net axial velocity through rotor	
V_r	blade element relative velocity	ft/sec
V_w	wind profile speed	ft/sec
V_{w_0}	reference wind speed	ft/sec
$\overline{V}_\infty$	freestream velocity vector	ft/sec
W	wake surface	
a	lift curve slope	rad^{-1}
a_e	effective linear lift curve slope	rad^{-1}
c	local blade chord	ft
c_d	airfoil drag coefficient	
$c_{d_{max}}$	airfoil maximum drag coefficient (post stall)	
c_{d_s}	airfoil drag coefficient at stall	
$c_{d_{45}}$	airfoil drag coefficient at 45 degrees	
$c_{d_{90}}$	airfoil drag coefficient at 90 degrees	
c_l	airfoil lift coefficient	

c_{l_r}	airfoil lift coefficient at recovery angle	
c_{l_s}	airfoil lift coefficient at stall	
$c_{l_{45}}$	airfoil lift coefficient at 45 degrees	
$c_{l_{90}}$	airfoil lift coefficient at 90 degrees	
c_m	airfoil moment coefficient	
c_s	leading edge suction force coefficient	
c_x, c_y, c_z	blade element aerodynamic force coefficient components	
c_x, c_y, c_z	induced velocity unit direction vector components	
e	wind profile exponent	
g_0	leading edge suction force parameter	
h	hub (shaft) height above ground	ft
i,j,k	Cartesian unit direction vector components	
k_a	wake axial settling rate due to impressed velocity transport	
$\bar{k}_a$	referred wake axial settling rate due to impressed velocity transport	
k_i	wake axial settling rate due to mean axial induced velocity transport	
k_r	radial contraction rate	
k_{r_h}	hover reference radial contraction rate	
k_z	wake axial settling rate	
$\bar{k}_z$	referred wake axial settling rate	
k_{z_h}	hover reference axial settling rate	

n_s	number of azimuthal integration steps in vortex cylinder calculations	
$\overline{q}$	vector induced velocity	ft/sec
$\overline{r}$, r	radial vector, radial coordinate	ft
v	mean axial induced velocity	ft/sec
$\overline{v}$	referred mean axial induced velocity	
v_x, v_z	blade element induced velocity components	ft/sec
v_h	mean hover axial induced velocity	ft/sec
x,y,z	Cartesian coordinates	ft
$(x/c)_{ref}$	chord reference station	
Γ_{te}	bound circulation	ft^2/sec
Λ	aerodynamic sweep angle	rad
Ω	rotor rotational speed	rad/sec
α	general angle of attack	rad
α_e	effective angle of attack	rad
α_g	geometric angle of attack	rad
α_i	induced angle of attack	rad
α_n	inflow angle of attack	rad
α_r	recovery angle of attack (post stall)	rad
α_{s_d}	drag stall angle of attack	rad
α_{s_l}	lift stall angle of attack	rad
α_w	wind angle of attack	rad
α_0	zero lift angle of attack	rad

α_{s_1}	horizontal shaft offset with respect to reference wind direction	rad
α_{s_2}	vertical shaft offset with respect to reference wind direction	rad
λ	wake radial contraction parameter	
λ_h	hover reference radial contraction parameter	
ψ	azimuth coordinate	rad
ψ_w	wake azimuth coordinate	rad
ψ_{mr}	azimuth increment over which inboard sheet forms into root vortex	rad
ψ_{mt}	azimuth increment over which outboard sheet forms into tip vortex	rad
ϕ	azimuthal integration variable in vortex cylinder calculations	rad
ρ	atmospheric density	$slug/ft^3$

Indices, Superscripts, and Subscripts

l	target point
k	source point
N	normal direction to surface
i	lifting surface panel row index
j	lifting surface panel column index, wake strip index
le	leading edge
m	maximum row index
n	maximum column index, or blade index
s	lifting surface
te	trailing edge
w	wake
1,2,3	local blade segment coordinate systems

a,b,c	field points
x,y,z	Cartesian vector components
r	radial component

INTRODUCTION

Wind energy conversion systems based on horizontal axis rotor configurations have evolved through the stages of technology demonstration to the level of a mature concept which now demands more rigorous methodology for analysis and design of an efficient, cost effective machine. In particular, a reliable, working methodology for aerodynamic design and performance prediction is a key technology element required to guide further development in this area.

Recent progress in the area of helicopter rotor hover performance analysis as described in References 1 through 3, has demonstrated a high level of predictive capability using numerical lifting surface theory combined with a distorted prescribed wake model. The objective of the present work is to extend applicable elements of this similar technology base to wind energy turbines and establish an aerodynamics methodology from which configuration concepts for performance benefits can be achieved.

This report describes the lifting surface method and the development of a generalized prescribed wake for wind turbine application. The method includes a comprehensive yet straightforward procedure to model complex blade geometry, a wake model which allows roll-up of tip and root vortices, and facilities for investigating quasi-steady effects of wind shear profile, tower shadow, and off-axis operation.

Detailed blade aerodynamics and system performance are calculated by combining the lifting surface method with a blade element analysis that incorporates two-dimensional airfoil lift, drag, and moment coefficients as functions of angle of attack and Reynolds number. High angle of attack analytical simulations are used to extend the supplied airfoil characteristics into stall. The method also incorporates a procedure to guarantee compatibility between the lifting surface circulation and the nonlinear sectional response impressed through the airfoils. Also, the use of lead-

ing edge suction forces in the calculation of the radial distribution of induced drag affords the most accurate prediction of torque, especially for low aspect ratio blades and those with advanced planforms or tips.

Implementation of the analysis as Fortran Program LSWT (Lifting Surface Wind Turbine) is also described, and an input guide, programming notes, source code listing, and examples of input and output files are provided as appendices to this report.

Examples of correlation of the present method to measured performance for one research and three commercial wind turbines demonstrate and validate the analysis. For all cases presented, calculations are also shown from a blade element momentum analysis. In constructing the cases for comparing the two analytical methods, the same blade geometry description, placement of solution stations, airfoil characteristics, and stall models were used down to the code level where possible. The lifting surface results show generally good agreement with measurements of power output at low to moderate wind speeds, and are consistently higher than the momentum analysis. At the wind speed for peak power and beyond the difference grows significantly, the lifting surface results still being higher. In this region the extreme sensitivity of the results to modeling of early post stall airfoil behavior is shown; however, with reasonable assumptions for the airfoil post stall characteristics the lifting surface method provides improved predictions of the peak power levels.

EXISTING METHODOLOGY

Because of experienced and knowledgeable users, analytical tools have always been available for evaluating limited modifications to established configurations. Such methods often contain empirical corrections designed to produce satisfactory performance correlation over an available data base. This is certainly the case with the traditional axial flow blade element momentum theory techniques which find wide use throughout rotary-wing analysis, and which are in popular use for wind system applications. Properly used, momentum theory is very valuable for rapid estimation of

integrated performance with minimal impact on computational resources. However, inherent assumptions in the theory limit its usefulness in producing detailed blade aerodynamic distributions for diagnostic or design information.

Originally derived for analysis of cruising propellers with very slight induced velocity, these procedures are more frequently applied to rotors in hover, and low speed climb or descent. In most applications adjustments to the theory are necessary, especially to provide correct levels of induced power. These corrections may be categorized as either modifying the radial distribution of induced velocity or the overall magnitude of the induced velocity.

Accuracy of Radial Loading

The category of corrections dealing with the modification of the radial induced velocity is the most familiar and includes the array of methods to approximate the physical boundary condition of zero loading at the streamwise edges, or tips of lifting blades. Most procedures are derived with various degrees of simplification from the original work of Prandtl and Betz as best described by Glauert (Reference 4). In concept the correction accounts for "tip losses" associated with a finite number of blades. That is, momentum theory always assumes an infinite number of lightly loaded blades of infinite aspect ratio, and thus non-zero loading at blade tips.

This assumption also equates to azimuthwise uniform induced velocity. Actually, there is an impulse of induced velocity from each blade's trailed wake causing the velocity at the blades to be higher than the disk average. It is also a particular blade's wake that causes that blade's loading to smoothly approach zero at the tip. However the tip loss approximation does not completely account for this effect since the tip loading is shaped by the blades finite planform as well. In this sense the tip loss approximates finite span, but cannot account for finite blade aspect ratio. Lifting line theory accounts for finite span, but still assumes infinite

aspect ratio. Blade planform effects can only be modeled with lifting surface theory, and accordingly, the emphasis of the analysis shifts from one of only predicting integrated performance to that of additionally calculating detailed distributions of aerodynamic parameters.

Influence of the Rotor's Vortex Wake

The second type of correction is needed to account for deviations in the true momentum flux from the ideal model. In actual flows the theoretical slipstream acceleration of axial induced velocity is never realized. This is because of radial leakage across the real wake boundary, the spiraling tip vortex trajectory, and diffusion mechanisms which cause dissipation of the wake cylinder. Thus, for a given level of thrust the axial impulse of induced velocity produced at the rotor disk must be higher than the theoretical in order to establish the momentum flux from far upstream to far downstream.

A correction for this effect is included in the empirical rotor work state models used to describe the mean velocity through the rotor as a function of the axial freestream velocity. These models have been derived, however, by setting the apparent flow through the rotor in either a disk or blade element momentum analysis to give agreement with measurements of thrust and power. The result is that a particular model is then strictly consistent only with the analysis used in its derivation, with assumed airfoil characteristics and profile drag levels, with the tip loss model, and with the accuracy of the measurements. References 5 and 6, describe wind turbine work state models based on Glauert's work. Although the importance of this consideration reduces with wind speed, Castles and Gray show striking differences and comment that Glauert's empirical formula is highly suspect at lower wind speeds (rotor descent rates) as the vortex ring state is approached.

LIFTING SURFACE METHOD WITH PRESCRIBED WAKE

Lifting surface theory with a realistic wake model thus reduces the

uncertainties discussed by eliminating the need for the tip loss correction, and by providing an inflow model with physical details. Further, the access that such an analysis provides for independently examining details leads to correct identification of modeling deficiencies and subsequent improvement.

In helicopter rotor aerodynamic analyses, the prescribed wake method has become the standard for performance prediction and blade design. Originally conceived by Gray (Reference 8), the approach was generalized by Landgrebe (Reference 9), and established by the broad experimental data base measured by Kocurek and Tangler (References 3). In the prescribed wake approach the complex distorted wake geometry is economically computed in terms of basic parameters which are themselves coupled to some primary variable of the analysis, such as thrust level. These coupling relationships are derived from experimental measurements of wake geometry.

Reference 10 describes the UTRC WECSPER analysis and shows the feasibility of the wake modeling approach for wind turbines. This method is extended from hovering rotor lifting line theory combined with a classical wake with modifications for nonuniform onset wind conditions. Although accommodations for a distorted wake are made in the analysis, no extensive evaluation of the required level of wake detail has been made. This is due in part to the lack of a systematically obtained experimental data base of wind turbine wake geometry.

The results obtained with the classical wake are encouraging and probably consistent with the relative pitch of the wake in hover compared to the wake additionally displaced by axial onset velocity. Also, the wind turbine's expanding wake places the tip vortices outside the rotor disk's perimeter, thus lessening their influence in comparison to their position for a rotor in hover. These observations suggest that wind turbine wake behavior is dominated by kinematic displacement and that distortions due to induced effects can be derived and superposed with sufficient accuracy from established techniques for prescribing hovering rotor wakes. This is then the approach taken in the present work.

NUMERICAL LIFTING SURFACE THEORY

The basic lifting surface method has evolved with emphasis on extended features which accommodate the special considerations for application to rotary wings such as summarized for calculation of helicopter hover performance in Reference 1. As illustrated in Figure 1, the horizontal axis rotor is described in a global Cartesian coordinate system with origin at the rotor hub, and aligned with the shaft. The shaft may have horizontal and vertical angular offsets from the principal wind direction. Positive rotation is in the right-handed sense, and a wind vector in the positive z-axis direction places the rotor in descent (normal turbine operation). Nose-up, positive, blade pitch and twist increment are defined when the blade leading edge is displaced in the positive z- direction. This system and convention are consistent with general rotor theory, and are required for self-consistent handling of the detailed geometry of the rotor lifting surface and wake model. This convention is opposite to most turbine analyses.

PANEL METHOD SOLUTION

The lifting surface theory is applied through a panel method formulation which is nonlinear in that all stream and induced velocity components are considered as well as a full three-dimensional thin surface representation of each blade. By using an influence coefficient formulation derived with vector analysis, a linear system is maintained without the usual neglect of radial flow at a blade or the assumption of small angles.

In the rotor fixed coordinate system, Laplace's equation governs the steady, irrotational flow, and an application of Greens's theorem (Reference 2) shows that all surfaces of discontinuity in the flow field may be replaced by a doublet sheet. For the present application all blades and trailing wakes are thus replaced. Further, the disturbance, or induced, velocity at point 1 due to the doublet sheet of net circulation strength K is

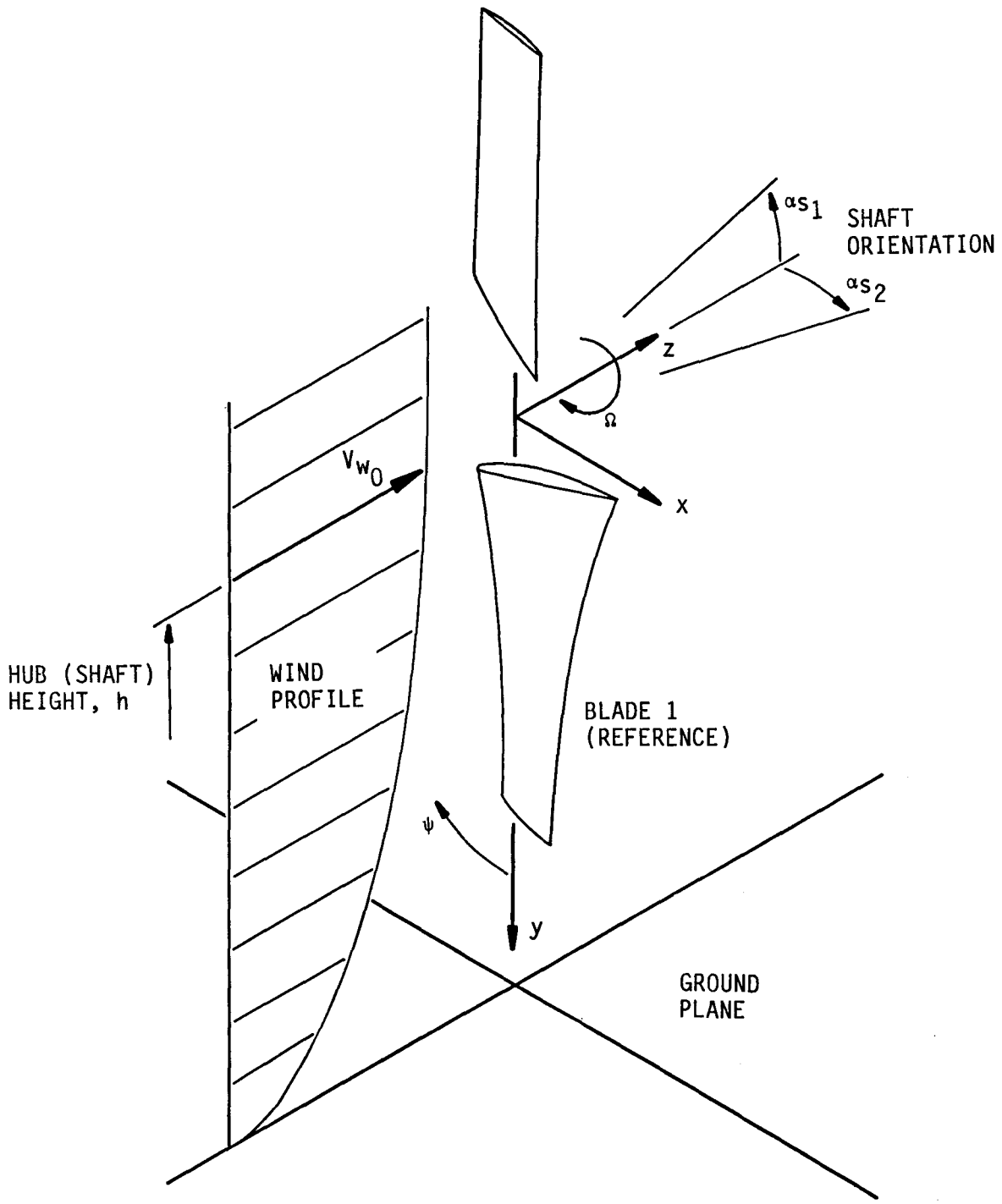


Figure 1. Horizontal Axis Wind Turbine Configuration and Reference Geometry Description.

$$\bar{q}_1 = \int_{S+W} \nabla_1 K \frac{\partial}{\partial \bar{N}} \frac{1}{4\pi r} \, dB \qquad (1)$$

where the subscript of the gradient operator denotes differentiation with respect to the coordinate variables at 1, and $\bar{N}$ is the positive normal vector on the surface.

The blade and wake surface (S+W) is then subdivided into small regions, or panels, P_k, and the circulation is approximated as uniform over each. Then the surface integration may be taken discretely over each panel and the contributions summed,

$$\bar{q}_1 = \sum_k K_k \int_{P_k} \nabla_1 \frac{\partial}{\partial \bar{N}_k} \frac{1}{4\pi r} \, dB \qquad (2)$$

The solution procedure can now be focused on calculating the vector aerodynamic influence coefficients (AIC's) defined by

$$\bar{D}_{1,k} = \int_{P_k} \nabla_1 \frac{\partial}{\partial \bar{N}_k} \frac{1}{4\pi r} \, dB \qquad (3)$$

which give the induced velocity influence at (x_1, y_1, z_1) per unit strength of the doublet panel P_k. Through Stoke's theorem the surface integration giving the AIC's is reduced to a contour integration about the perimeter C_k of P_k,

$$\bar{D}_{1,k} = \int_{C_k} - \frac{\bar{C} \times \bar{r}}{r^3} dC \qquad (4)$$

where $\overline{C}$ is the unit vector along the contour. Equation (4) is simply a statement of the well known Biot-Savart law for a closed vortex filament of unit strength.

By building the panel geometry solely from straight line elements then the contour integration of Equation (4) can be conveniently broken into separate intervals over each circuit element, and the resulting quantities summed to give the total contribution of the panel. The integral taken over a straight line vortex filament has a simple analytic solution given entirely by the Cartesian coordinates of the target point 1 and the end point of the filament. Calculation of the AIC's will be described in a later section.

The unknowns of the problem are now the circulation strengths of each panel, and their solution is obtained by forming a set of simultaneous linear algebraic equations based on Equation (2) while satisfying flow tangency on the blade surfaces and the Kutta condition at the trailing edges. The formulation is reduced by noting that at a point within panel P_1 on a blade surface, flow tangency requires

$$\overline{N}_1 \cdot (\overline{V}_\infty + \overline{q}_1) = 0 \tag{5}$$

Then the normalwash velocity at the panel

$$q_{N_1} = \overline{N}_1 \cdot \overline{q}_1 = -\overline{N}_1 \cdot \overline{V}_\infty \tag{6}$$

and the scalar influence coefficient

$$D_{1,k} = \overline{N}_1 \cdot \overline{D}_{1,k} \tag{7}$$

in combination with Equations (2) yield the basic relation of the present theory

$$q_{N_l} = \sum_k D_{l,k} K_k \qquad (8)$$

Since the wake must be force free, the circulation along a wake streamline is constant, and its value must be that of the circulation at the blade trailing edge at the point from which the wake streamline emanates. Enforcement of the Kutta condition at the trailing edge, which renders the blade surface circulation unique, further requires that the circulation be continuous. The wake panel idealization thus becomes a series of semi-infinite strips trailing aftward from the blade in the streamwise direction.

If an m by n array of panels are arranged on a blade surface as shown in Figure 2, in streamwise columns and spanwise rows, then associated with each surface column of panels is a wake strip. The indices i and j are used to identify the panel of the ith row and jth column, and the jth wake strip. The panels are numbered by rows so that panel P_l is indexed by

$$l = (i-1)n + j, \quad 1 \leq l \leq (m \cdot n) \qquad (9)$$

Equation (8) can be written for the l_{th} panel by taking separate summations for surface and wake contributions to the normalwash,

$$q_{N_l} = \sum_{k=1}^{(m \cdot n)} D_{s_{l,k}} K_k + \sum_{j=1}^{n} D_{w_{l,j}} K_{w_j} \qquad (10)$$

Specific enforcement of the Kutta condition allows the wake strip strengths K_w to be expressed as functions of the surface strengths K_k thus reducing the unknowns to just the surface distribution. This is accomplished by assuming that $(K_w/K_m)_j$ is the same as the ratio known from the two-dimensional solution. Equation (10) is then simplified to

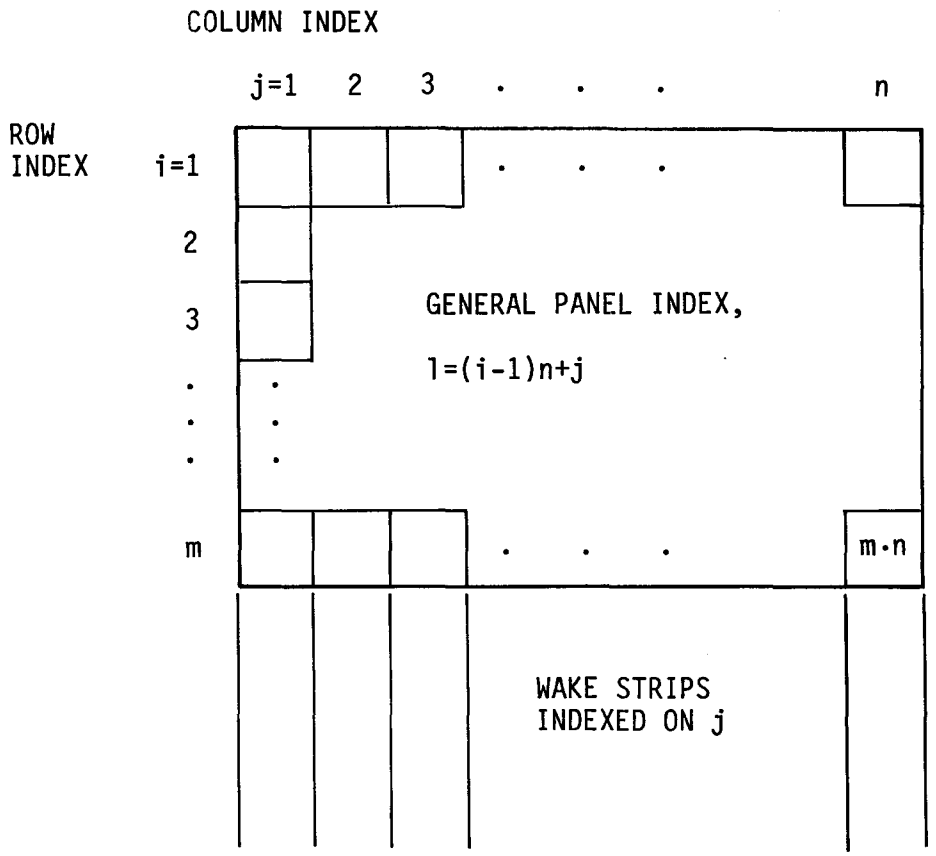


Figure 2. Schematic of General Surface Panel and Wake Strip Indexing Scheme.

$$q_{N_1} = \sum_{k=1}^{(m \cdot n)} (D_{sw})_{1,k} K_k \qquad (11)$$

Applying this equation to a collocation point at each surface panel P_1 on a target blade and accounting for the velocity induced by all source blades and wakes generates a system of (m•n) linear algebraic equations which are solved for the (m•n) unknown K_k. Thus, for given surface and wake geometry, the circulation produced in response to surface motion can be obtained.

CALCULATION OF AERODYNAMIC INFLUENCE COEFFICIENTS

The working equations for calculation of the AIC's are presented in this section. The primary calculations are for the discrete straight line vortex geometry of the idealized blade and wake surfaces. The far wake is optionally approximated by a vortex cylinder. In the following it is understood that coordinate variables have been normalized by unit radius R.

Line Vortex Induced Velocity

The following implementation of the Biot-Savart law in Cartesian coordinates is used to calculate the contributions to the AIC's from each vortex element. This formulation is derived from parametric integration of the governing vector equation. A source element is considered to run from point 'a' to point 'b' such that the direction from a to b is consistent with the right hand rule in view of the element's circulation sense. Point 'c' is the target point where the velocity is calculated. This geometry is sketched in Figure 3. With the parameter definitions

$$A = (x_a - x_c)^2 + (y_a - y_c)^2 + (z_a - z_c)^2$$

$$B = 2[(x_a - x_b)(x_c - x_a) + (y_a - y_b)(y_c - y_a) + (z_a - z_b)(z_c - z_a)]$$

$$C = (x_a - x_b)^2 + (y_a - y_b)^2 + (z_a - z_b)^2$$

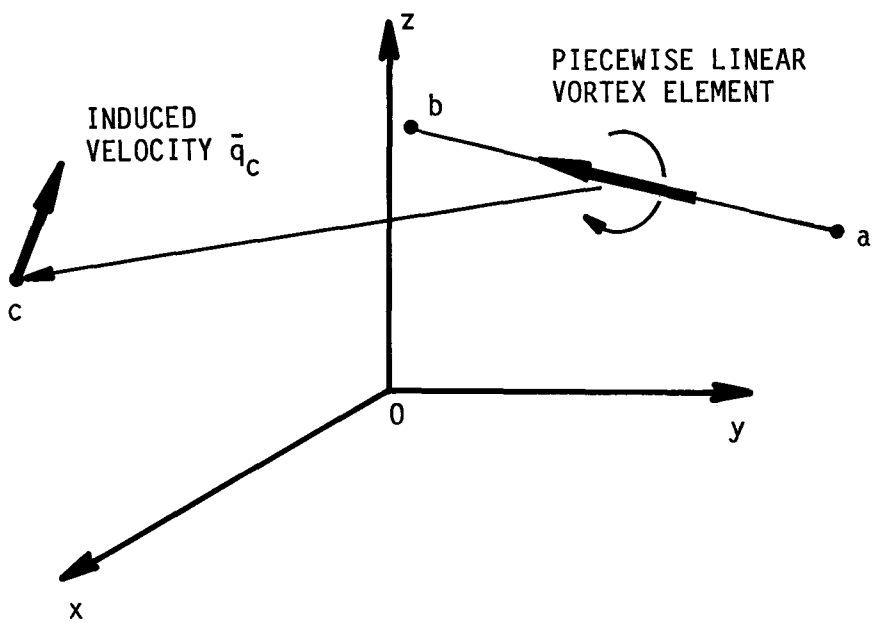


Figure 3. Coordinate System for Application of the Biot-Savart Law to a Linear Vortex Element.

and

$$Q = 4AC - B^2 \tag{12}$$

then the magnitude of the velocity induced at point c per unit vortex strength is for $Q \neq 0$,

$$|\overline{q}| = [1/(2\pi Q)][(2C+B)/(A+B+C)^{1/2} - B/A^{1/2}] \tag{13}$$

If $Q = 0$ then point c is collinear with a and b, and the velocity induced is zero. The cartesian vector components of the induced velocity are obtained by multiplying the velocity magnitude by the appropriate direction vector components which from the defined element geometry are

$$\begin{aligned} c_x &= (y_c-y_b)z_a + (y_a-y_c)z_b + (y_b-y_a)z_c \\ c_y &= (z_c-z_b)x_a + (z_a-z_c)x_b + (z_b-z_a)x_c \\ c_z &= (x_c-x_b)y_a + (x_a-x_c)y_b + (x_b-x_a)y_c \end{aligned} \tag{14}$$

giving

$$\overline{q} = |\overline{q}|[\ (c_x)i + (c_y)j + (c_z)k\ ] \tag{15}$$

Having now obtained the vector velocity induced by the element at the target point, the element's contribution to its surface panel or wake strip AIC is simply the scalar product of the velocity and the direction vector for the desired influence coefficient sense. This formulation is easily applied to the discrete geometry of the surface and wake model by systematically sweeping the coordinate arrays, calculating the influence of each straight line element in turn, while summing each element's contribution to the applicable AIC's.

Vortex Cylinder Induced Velocity

An optional analytical far wake is included in the analysis and modeled by extending each filament of the specified length discretized wake with a continuous, semi-infinite vortex cylinder. The influence of a vortex cylinder is calculated following the derivation presented by Miller in Reference 11, except that direct numerical integration is used exclusively instead of in combination with elliptic integrals. Direct integration is chosen since the number of steps required for accuracy is similar to the number of terms needed in the usual series representation of the elliptic integrals, and implementation is more straightforward.

Figure 4, shows the relative geometry of the target point c and the semi-infinite vortex cylinder of radius r_a. The mouth of the cylinder is located at the axial coordinate z_a. Following Miller's derivation, the axial and radial induced velocities due to a cylinder of unit strength density are given by

$$q_z = \frac{1}{4\pi R}\int_0^{2\pi} \frac{r_a(r_a - r_c\cos\phi)}{r_c^2 + r_a^2 - 2r_a r_c\cos\phi} \cdot \left(1 - \frac{z_a}{(r_c^2 + r_a^2 + z_a^2 - 2r_a r_c\cos\phi)^{1/2}}\right) d\phi \qquad (16)$$

$$q_r = \frac{1}{4\pi R}\int_0^{2\pi} \frac{r_a\cos\phi}{(r_c^2 + r_a^2 + z_a^2 - 2r_a r_c\cos\phi)^{1/2}}\, d\phi \qquad (17)$$

The tangential, or swirl, component due to the far wake is assumed to be negligible.

A simple numerical integration procedure for these expressions divides the interval into a number of steps which vary with the axial distance from

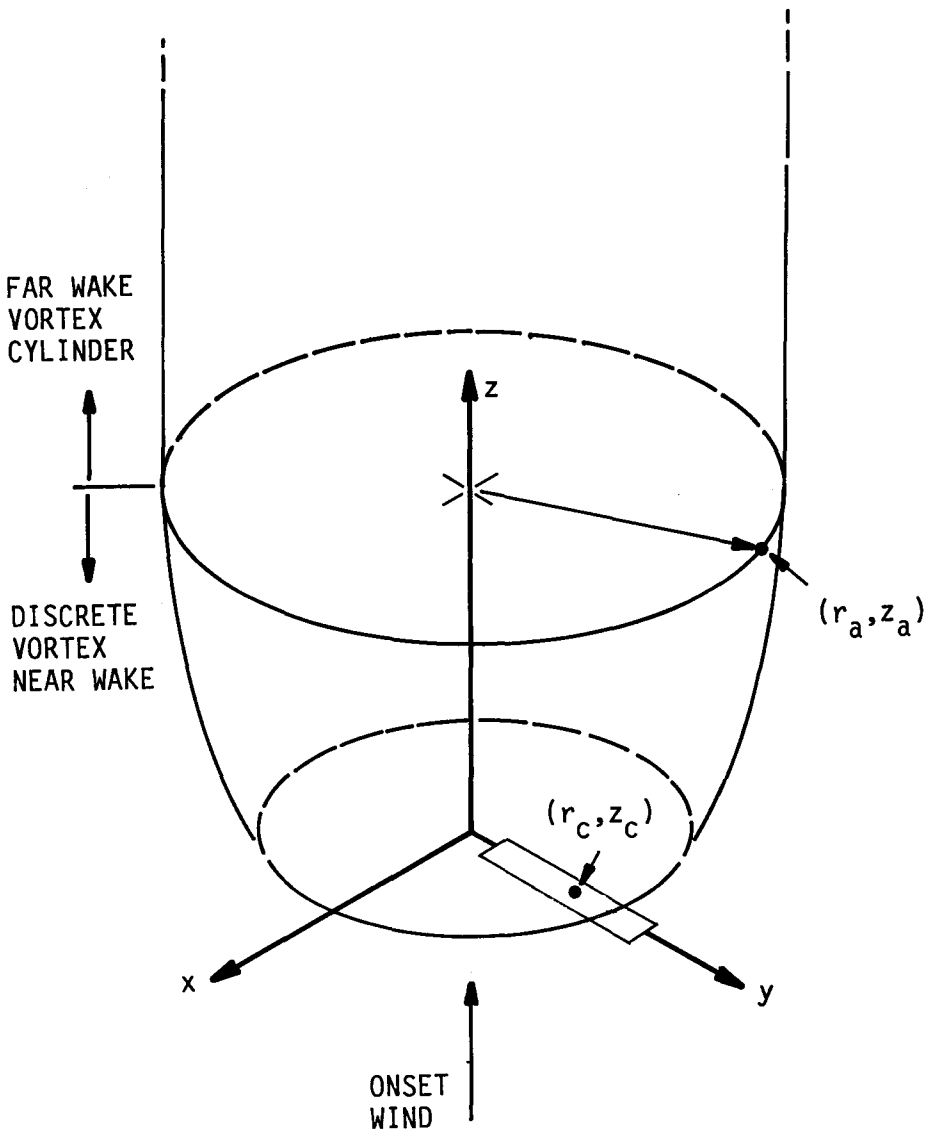


Figure 4. Coordinate System for Modeling of the Far Wake With a Semi-Infinite Vortex Cylinder.

the target point to the mouth of the vortex cylinder. If the distance is greater than unit radius then ten steps are used. Otherwise, the number of steps is calculated from

$$n_s = 100 - 90(|z_a - z_c|) \tag{18}$$

The step size is then $\Delta\phi = 2\pi/n_s$. If the value of ϕ is taken as the average over a step, and with the following definitions

$$T1 = r_a - r_c \cos\phi$$

$$T2 = r_c^2 + r_a^2 - 2r_a r_c \cos\phi$$

$$T3 = (r_a^2 + r_c^2 + (z_a - z_c)^2 - 2r_a r_c \cos\phi$$

$$T4 = \frac{\Delta\phi}{8\pi^2 k_z} \tag{19}$$

the cylindrical components of the induced velocity are then simply summed as

$$q_z = T4 \sum_i r_a (T1/T2)[1-(z_a - z_c)/T3] \tag{20}$$

$$q_r = T4 \sum_i r_a \cos\phi/T3 \tag{21}$$

The term T4 contains the axial settling rate k_z of the near wake, and thus sets the strength density of the vortex cylinder based on the pitch of the vortex spiral which feeds it.

The cartesian components of the radial induced velocity are resolved as

$$q_x = q_r(x_c/r_c) \tag{22}$$

$$q_y = q_r(x_c/r_c) \tag{23}$$

which together with the previously defined z-component yield the required AIC when combined as a scalar product at the target point c with its direction vector.

COMBINED LIFTING SURFACE - BLADE ELEMENT THEORY

A feature unique to the present method is a technique termed circulation response tailoring. This modification replaces the inherent linear sectional lift response characteristics of the potential flow theory with those derived from supplied two-dimensional airfoil coefficients. These coefficients are also used in a blade element strip integration to obtain performance characteristics. Thus, the loading from the circulation solution is fully compatible with the blade element performance analysis.

Inherent in any potential flow analysis is that the lift, or equivalently circulation, response to angle of attack is through the lift slope 2π. Consider a section of the lifting surface to be responding to an effective angle of attack defined relative to the local freestream. The effective angle of attack is the net result of the combined interference from all other sections of the lifting surface and wake, and defines the normalwash contribution for satisfying flow tangency which must be supplied by the self-induced velocity of a section. The section circulation which develops is that which will satisfy this partial velocity boundary condition. The circulation can be tailored then by modifying the self-induced velocity to preserve the boundary condition while allowing prescribed rates of circulation to develop.

The full derivation of this procedure is in Reference 2. Aerodynamic influence coefficients are calculated which give the self-induced velocity. These are actually just two-dimensional AIC's for the simple flat plate case. With this AIC denoted as D_{1s}, the self-induced velocity at a panel can be isolated, modified, and then recombined to form the final coefficient which will produce a sectional response with a lift slope of a_j. The modified response coefficient is

$$D^{*}_{1,k} = D_{1,k} + \left[\frac{2\pi}{a_j} - 1\right](D_{1s})_k \qquad (24)$$

when a source panel is in the same column as the target,

$$j(k) = j(1) \qquad (25)$$

and otherwise remains unchanged. In application the sectional lift slopes are nonconstant functions of angle of attack, and thus an iteration is required to produce consistency between the calculated circulation, which determines effective angle of attack, and the corresponding effective linear lift slope.

LIFTING SURFACE BLADE MODEL

The modeling and specification of blade geometric characteristics for development of the lifting surface panel grid is designed to provide maximum flexibility for a wide variety of configurations while maintaining simplicity of input data requirements. The goal is to have any restrictions be due to technical assumptions in the physical model rather than to any inability to represent the blade geometrically.

BLADE SEGMENTATION

To accomplish this, the concept of a segmented blade is adopted. By describing the blade as a series of spanwise segments, abrupt changes or even discontinuities in geometry or airfoil definition can be faithfully reproduced in the lifting surface idealization. Figure 5 shows a blade modeled with cuff, main blade body, and tip segments. As many as four completely independent segments can be utilized. This limit is selected only to set program array dimensions, and can of course be easily changed. Each segment is also described independently in the input data set. Thus, the input for the simplest case of a single segment blade is not complicated by this capability. For more than one segment, the geometric description is repeated for each in a completely parallel format.

Surface Panel Arrangement

The number and spanwise arrangement of panels on the blade surface is also specified individually for each blade segment, and is controlled through four grid options as illustrated in Figure 6. Within each segment the panels may be uniform in width, or in proportion to a cosine grid spacing. The cosine grid can be centered in order to provide denser paneling at both inboard and outboard blade segment edges, or biased only toward the inboard, or only toward the outboard edge. In practice the selection of a paneling scheme should allow denser definition in regions

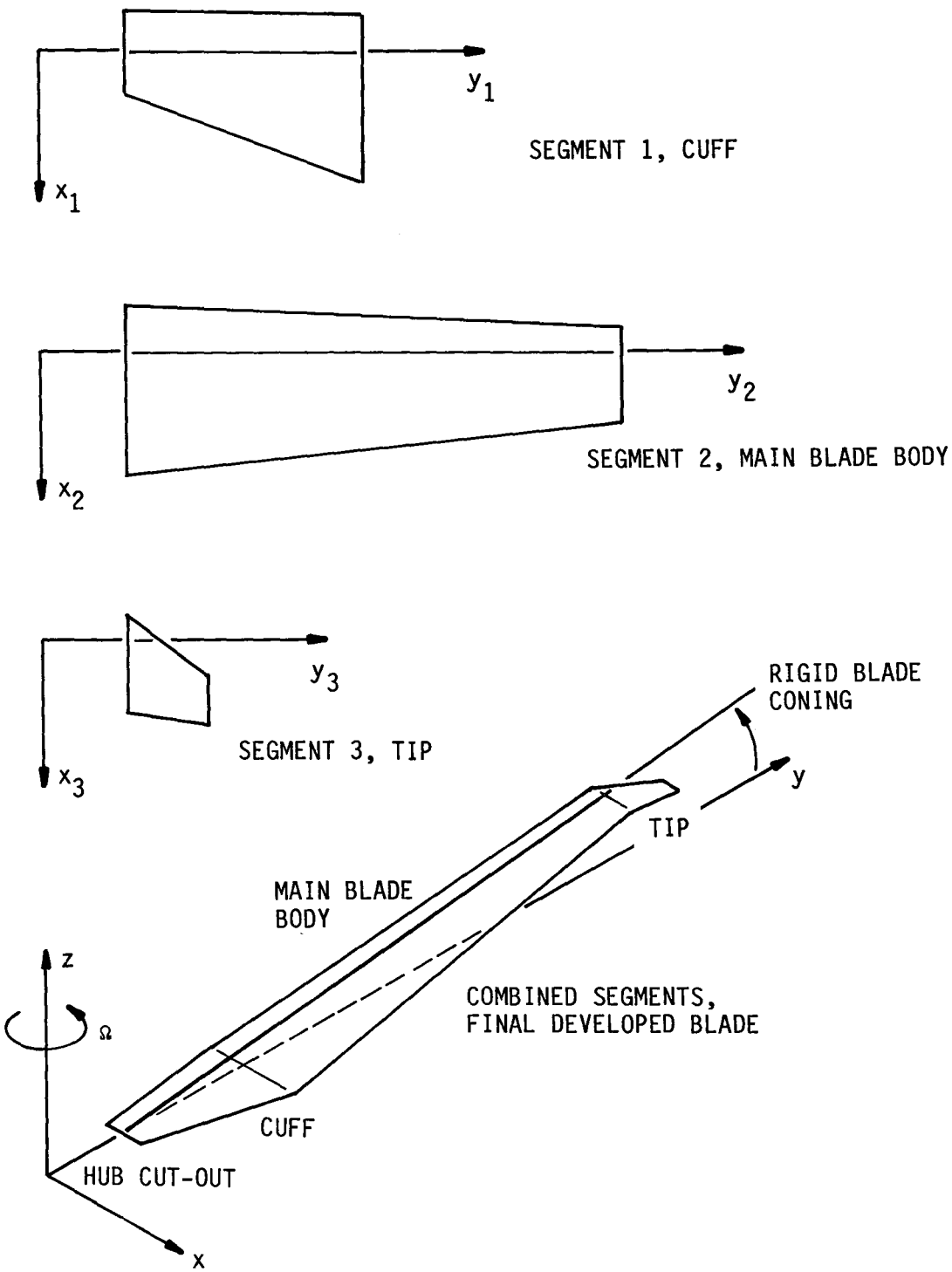


Figure 5. Development of Reference Blade Geometry From Segment Descriptions of Major Components.

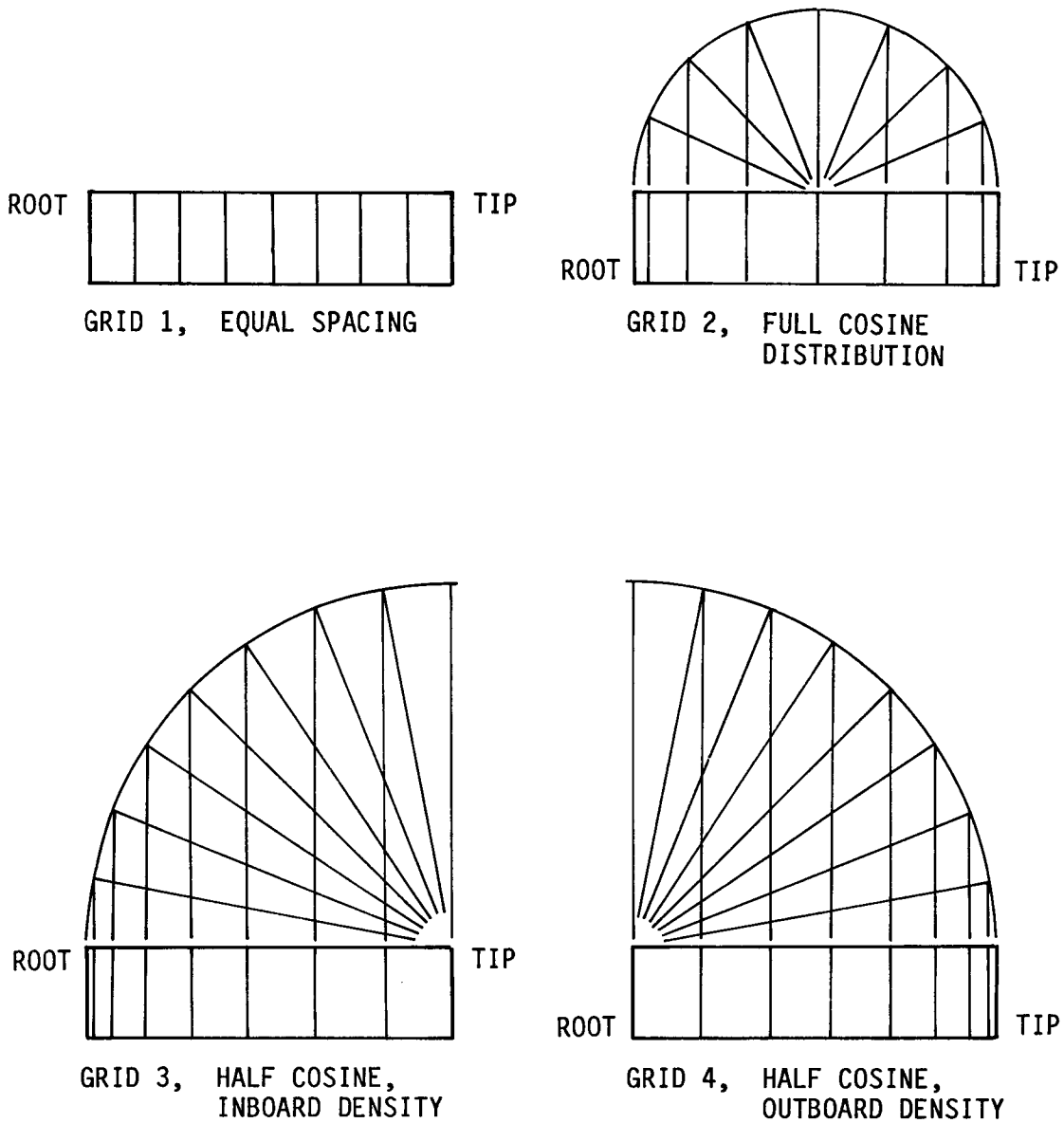


Figure 6. Spanwise Panel Distributions Corresponding to Blade Segment Grid Options.

which are anticipated to have larger gradients in surface loading. Grid generation is automated and requires no further user input.

In the chordwise direction the number of panels is constant for the entire blade. The chordwise arrangement is fixed and is based on a cosine grid biased toward the leading edge. This selection evolved from the work in References 2 and 3, as has the procedure for locating each panel's control, or normalwash collocation point. The numerical circulation solution is uniquely related to the location of these points and their optimized location greatly speeds solution convergence with respect to the number of panels employed. The chordwise locations are calculated from the known two-dimensional flat plate circulation distribution. This guarantees the correct self-induced velocity influence of each streamwise section of the lifting surface. Convergence of the solution then depends only upon a panel density which adequately accounts for the interference velocities from the remaining surface stations and the wake. The spanwise location of the collocation points is at the midspan of each panel. In general a 2 by 15 chordwise by spanwise grid of panels on the blade is sufficient.

Segment Description

The segment description begins with the number of spanwise panels, the type of grid desired, and the radial extent of the segment. Detailed segment geometry is supplied in a particular segments own axis system, although the same axis system may be used for all segments if convenient. Translations and rotations for each segment allow the segment to be placed in any desired location and orientation to form the developed blade. Thus the segment can be "built" in a convenient axis system and then placed in its proper location with respect to the rotor axis system.

Segment details are interpolated from piecewise linear radial distributions of chord, pitch increment due to twist, and planform offset (sweep). These distributions are supplied independently for each segment and are required to cover the radial extent of each. Also, the chord station $(x/c)_{ref}$ is specified which is used to initially align the chord

distribution along the segment span (y-axis). Figure 7 illustrates the effect of varying $(x/c)_{ref}$ for a tapered planform segment, The figure also shows how $(x/c)_{ref}$ is used in combination with an offset distribution to model a complex planform.

Airfoil Definition

The airfoil characteristics of a segment are defined by associating each span station of interest with tables of lift, drag and pitching moment coefficients which are bivarient with angle of attack and Reynold's number. A segment must have at least one airfoil defined. An airfoil may be defined over a range of the segment or at a point on the segment. As sketched in Figure 8, this allows regions of constant airfoil characteristics, transition regions bounded by defined airfoils, and butt joined airfoils. Within a transition region, the characteristics at an intermediate station are averaged from the bounding airfoils. In calculating the average, weighting is used in proportion to the distance to each bounding airfoil. Thus, at the exact center of a region a simple average results, and at the edge of a region the bounding airfoil is used exclusively.

REFERENCE BLADE DEVELOPMENT

The actual panel grid coordinates of the lifting surface are developed for a reference blade without displacements for collective pitch or flapping. The blade surface is then the warped surface of zero lift chordlines positioned by twist increments due to physical twist and the aerodynamic twist due to camber. This twist is applied about the segment y-axis. The zero lift line angle of attack is interpolated from the supplied airfoil tables. Rotations of the reference coordinates to pitch, azimuth, and flapping angles are subsequently performed as needed to create target and source blades for calculation of the AIC's.

The reference blade is built segment by segment. First, the untwisted planform is developed in the segment axis system from the chord and offset

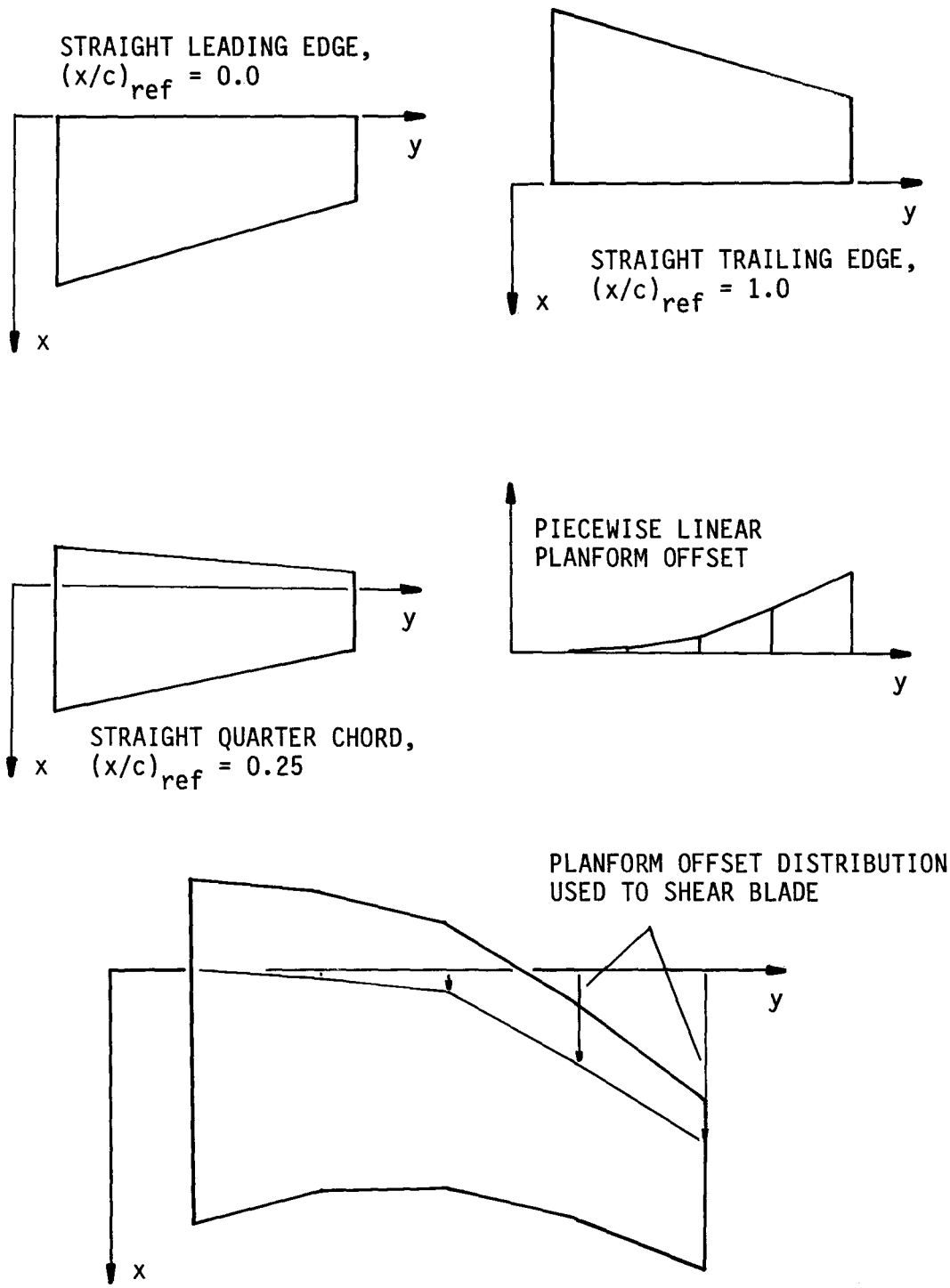


Figure 7. Modeling of Complex Planform With Segment Chord Reference Station $(x/c)_{ref}$ and Distributed Planform Offset.

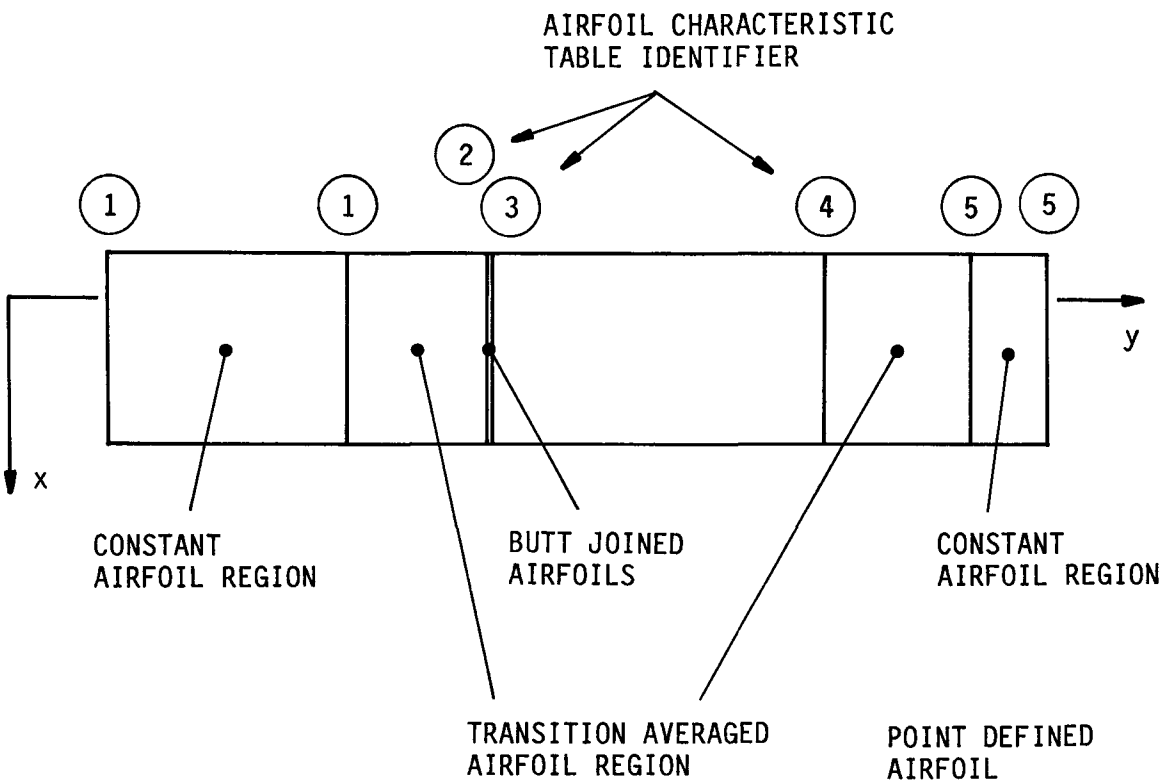


Figure 8. Association of Airfoil Characteristic Tables with Segment Spanwise Regions Allows Interpolation Between Tables.

distributions, and the reference chord station $(x/c)_{ref}$. Then the panel and collocation grid span stations are rotated about the segment y-axis through the combined physical and aerodynamic twist angle. Finally, y-, x-, and z- rotations about the segment axes, and x-, y-, z- translations are performed in the listed sequence to position the segment in the rotor axis system. For instance, if a common segment axis system is used then blade precone results from an x- rotation. If different systems are used for each segment then combinations of x- rotations and z- translations will provide the precone. As can be seen, several approaches through the blade development scheme can yield the same result. In all cases the user is cautioned to carefully check the output coordinate reports to verify the desired result.

GENERALIZED PRESCRIBED WAKE FOR AXIAL FLOW

The wake model for the wind turbine application is extended and simplified from those used for helicopter rotor hover analysis. The basic structural concept for the wake is that described by Gray in Reference 8, and reproduced here as Figure 9. Each blade's trailing wake is assumed to split into inboard and outboard sheets at the radial station corresponding to the blade's maximum bound circulation. The inboard sheet continues to settle in that form, and the outboard sheet quickly rolls to complete formation of a concentrated tip vortex. Although there is little experimental evidence of a concentrated root vortex, modeling capability is included in the wind turbine wake so that its analytical influence can be determined. This leads to the definition of an additional mid-sheet region, such that the inboard sheet can then roll-up to form a root vortex.

In hover these wake components are positioned through prescribed functions which give axial settling rates and radial contraction rates in terms of basic inflow parameters. Experimental measurements of the wake rates shows them to be primarily functions of the rotor thrust coefficient C_T

$$C_T = \frac{T}{\rho(\pi R^2)(\Omega R)^2} \tag{26}$$

which is related to the mean hover induced velocity v_h at the rotor disk as given by the actuator disk momentum theory,

$$v_h = (\Omega R)(C_T/2)^{1/2} \tag{27}$$

In describing the hovering wake the primary emphasis is on the tip vortex trajectory because the vortex remains in close proximity to the disk, and is the major source of induced velocity from the wake. Because of the proximity, the initial trajectory is also influenced by the local flow about the blade, and thus configuration parameters such as twist and taper

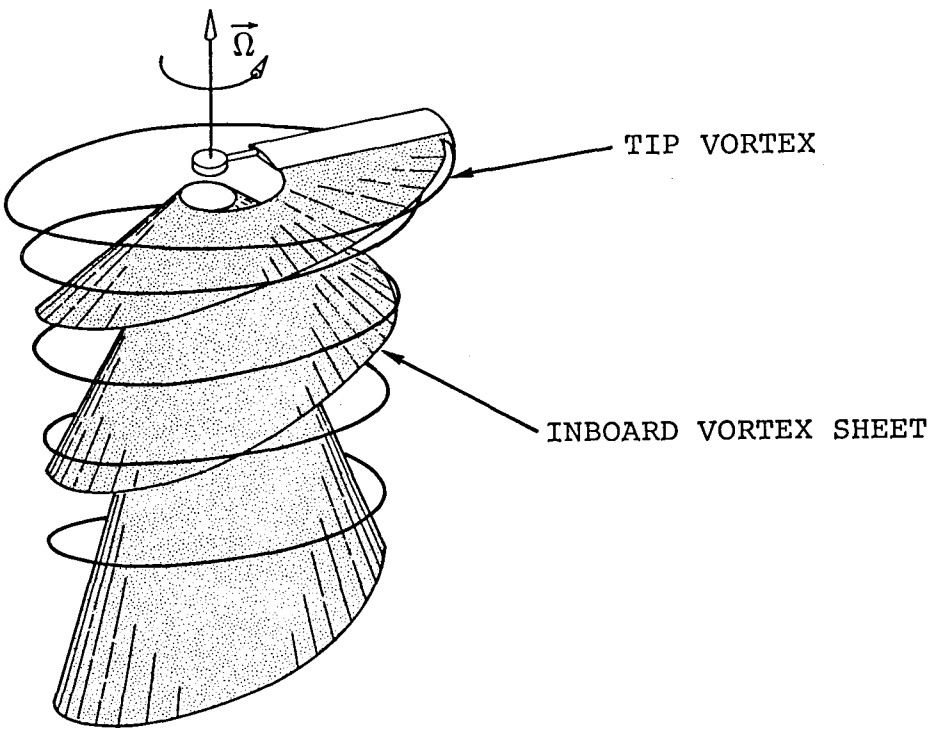


Figure 9. Gray's Concept of Hovering Rotor Wake Structure.

which influence the local aerodynamics. Figure 10, from Reference 3, shows measured axial and radial tip vortex trajectories of a hovering model rotor. The tip vortex initially settles at a near constant rate until passing beneath the following blade, at which time the additional induced velocity from the second blade's bound vorticity and wake increase the settling rate. The effects of subsequent blade passages appear minimal; thus, the secondary rate region is not significantly influenced by rotor details, and is dominated by the mean inflow of the rotor. The radial contraction behaves exponentially with increasing wake azimuth, reaching a minimum wake radius, after which the tip vortex trajectory usually becomes unstable as the vorticity diffuses.

This observed behavior is represented by parametric equations in ψ_w, the wake azimuth increment aft of the generating blade, of the form

$$z/R = k_z \psi_w \tag{28}$$

and

$$r/R = A+(1-A)e^{-\lambda\psi_w} \tag{29}$$

where k_z is the axial settling rate, λ is the contraction rate parameter, and A is the developed wake radius.

For the wind turbine case the trajectory rates will be augmented by the axial transport due to onset wind, which allows for some simplifications. First, note that the wake transport is attributable to induced and wind contributions. In the limit of very high wind speed there will be no induced effects because of the high pitch (settling rate) of the wake spiral. In this extreme all wake components, both sheet and concentrated vortices, will also experience the same transport, that due only to wind. It is further assumed then, that operating wind speeds are sufficiently high to require only mean induced effects to be included in describing wake trajectories, and that all wake component rates have the same induced contributions. The fact that the turbine wake will normally expand, rather than contract also supports this assumption since expansion results in increased displacement of the tip vortex trajectory away from the blade, even

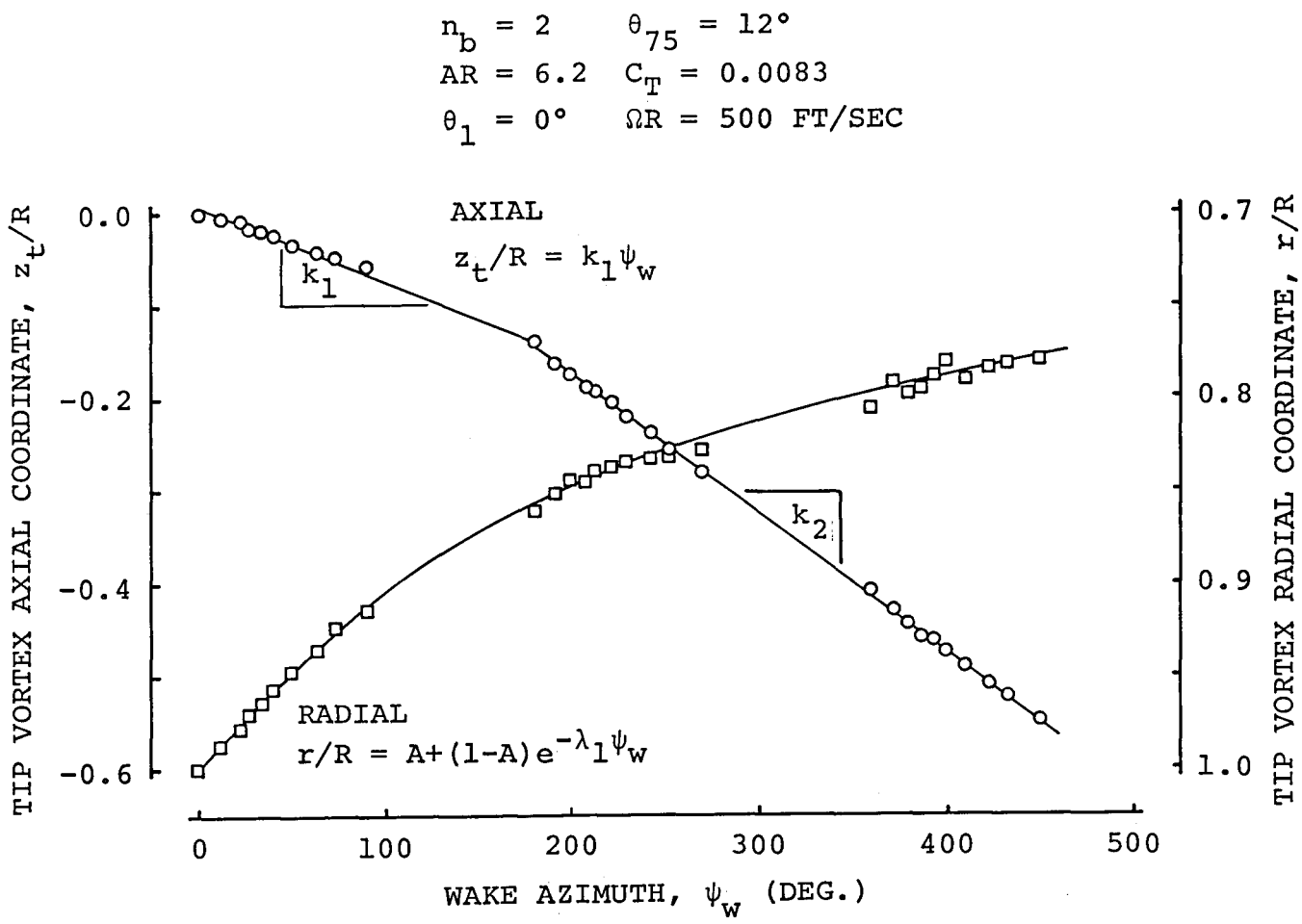


Figure 10. Model Rotor Tip Vortex Trajectory Measured From Schlieren Flow Visualization Photographs of Wake (Reference 3).

at lower wind speeds. Since only the wake position, and not the wake structure, is affected by these simplifications, then the model can be readily improved as better understanding or measurements are available.

The task is then to develop expressions for the turbine wake's axial and radial translation rates. Reference values in hover are first defined from the generalized expressions developed from measurements in Reference 3. The hover reference axial rate is taken as the secondary settling rate, and is given as

$$k_{z_h} = -(C_T)^{1/2} \tag{30}$$

The contraction rate parameter is generalized as

$$\lambda_h = 4.0(C_T)^{1/2} \tag{31}$$

But, defining contraction in terms of a displacement rate

$$k_{r_h} = \lambda_h/(k_{z_h}) \tag{32}$$

then the radial trajectory is more conveniently expressed as a function of the axial displacement,

$$r/R = A+(1-A)e^{-[k_{r_h}(z/R)]} \tag{33}$$

ROTOR WORK STATE EFFECT ON WAKE RATES

Equations (28) and (33) are the basic working expressions for generating the coordinates of the individual filaments of the wake, once the axial and radial displacement rates are modified to include the effects of wind speed. This wake rate modification is accomplished by forming an analogy between the rates and the average flow through the rotor as a function of the rotor work state.

The three basic rotor work (or flow) states are defined by the sense of the axial impressed velocity V_a (usually described as climb or descent rate in rotor terminology) through the rotor and by the presence or lack of an organized wake slipstream. A convenient format for describing the states is the plot of net flow through the rotor as a function of the axial impressed velocity. This format is generalized if all velocities are normalized by, or referred to, the absolute value in hover of the mean induced velocity from Equation (27). The referred axial, induced, and net velocities are then

$$\bar{V}_a = V_a/v_h \tag{34}$$

$$\bar{v} = v/v_h \tag{35}$$

and,

$$\bar{V}_{net} = \bar{V}_a + \bar{v} \tag{36}$$

The normal state extends from hover through climb, $\bar{V}_a \leq 0$. The impressed velocity and induced velocity are both downward through the rotor and $\bar{V}_{net} \leq \bar{v}$. From hover into descent the rotor enters the vortex ring state in which the induced velocity is opposed by the descent speed. At the center of this state the apparent net flow through the rotor vanishes, and the persistence of streamline flow through the rotor diminishes until a definite slipstream in the vicinity of the rotor fails to exist. Characteristically, a highly unstable air-body of recirculating flow develops about the rotor, from which the flow state is named. The limits of the vortex ring state are $0 \leq \bar{V}_a \leq 2$. At higher descent speeds the windmill brake state is entered and streamline flow reorganizes. This, of course, is the work state of primary interest for wind turbine analysis. In the normal and windmill brake states, because of the existence of a continuous streamtube, the disk momentum theory is applicable, and gives the mean induced velocity for the two states respectively as

$$\bar{v} = -\bar{V}_a/2 - [\ (\bar{V}_a/2)^2 + 1\ ]^{1/2} \tag{37}$$

and

$$\bar{v} = -\bar{V}_a/2 + [\ (\bar{V}_a/2)^2 - 1\ ]^{1/2} \tag{38}$$

In the vortex ring state, momentum theory fails to give observed results for the induced velocity because of the breakdown of the streamline structure of the flow. However, it does give approximate trends at the initial entry from hover at very low descent speeds. The complete description of the vortex ring region must therefore be accomplished with empirical relationships implied by the apparent mean induced velocity required to match experimental measurements of rotor thrust or torque to corresponding values calculated from momentum theory.

In wind turbine analyses, the most widely used empirical relationship between induced and axial stream velocity in the vortex ring state is that due to Glauert from his 1926 work (Reference 12). More recent (1951) measurements on rotors in descent made by Castles and Gray in Reference 7, show considerable discrepancy in comparison to Glauert's results. At a referred descent velocity of about 1.5, the turbulent wake begins its transition toward the organized streamlines of the windmill brake state. In this region the Glauert empirical curve yields about one-half the induced velocity as measured by Castles and Gray. Their data also agrees with helicopter measurements while in ideal autorotation, and the authors suggest that Glauert's data is in error because of unaccounted for changes in blade angle of his solid brass model rotor when under load. As the Glauert empirical model is in popular use in momentum analyses for wind turbines, this discrepancy could yield misleading results at low wind speeds.

For the present application, an empirical model based on Castles and Gray is preferred. Additionally, the work of Drees et al in Reference 13, supports that of Castles and Gray. This Reference also presents smoke flow visualization studies of the entire axial flow regime and provides a complete discussion of the flowfield behavior in the vortex ring state.

With a degree of idealization the apparent induced velocity in the vortex ring state can be simply represented by two linear functions as

$$\bar{v} = -\bar{V}_a - 1, \qquad 0 \leq \bar{V}_a \leq 1.5 \tag{39}$$

$$\bar{v} = 3\bar{V}_a - 7, \qquad \bar{V}_a \geq 1.5 \tag{40}$$

These relationships are plotted in the work state velocity diagram presented as Figure 11. A very interesting result seen in this format is that based on the Castles and Gray measurements, the net flow through the rotor from hover to $\overline{V}_a = 1.5$ is nominally constant and equal in magnitude to the induced velocity in hover.

With the preceding discussion in mind the behavior of the wake parameters in axial flow is now developed. It is first assumed that the net settling rate in the normal and windmill brake states is composed of an induced component and one due to the impressed axial velocity transport,

$$k_z = k_a + k_i \tag{41}$$

where

$$k_a = V_a/(\Omega R) \tag{42}$$

and where k_i is proportional to the induced velocity. Proceeding as before with the velocities, the settling rate components are referred to the reference value from hover

$$\begin{aligned} k_{z_h} &= |-(C_T)^{1/2}| \\ &= |\sqrt{2}\,[v_h/(\Omega R)]| \end{aligned} \tag{43}$$

yielding

$$\overline{k}_z = k_z/k_{z_h} \tag{44}$$

$$\overline{k}_a = \overline{V}_a/\sqrt{2} \tag{45}$$

The functionality of k_i is determined now by recognizing that the pitch of the wake vortex helix is given by the settling rate and that the induced velocity varies inversely with the pitch. Therefore

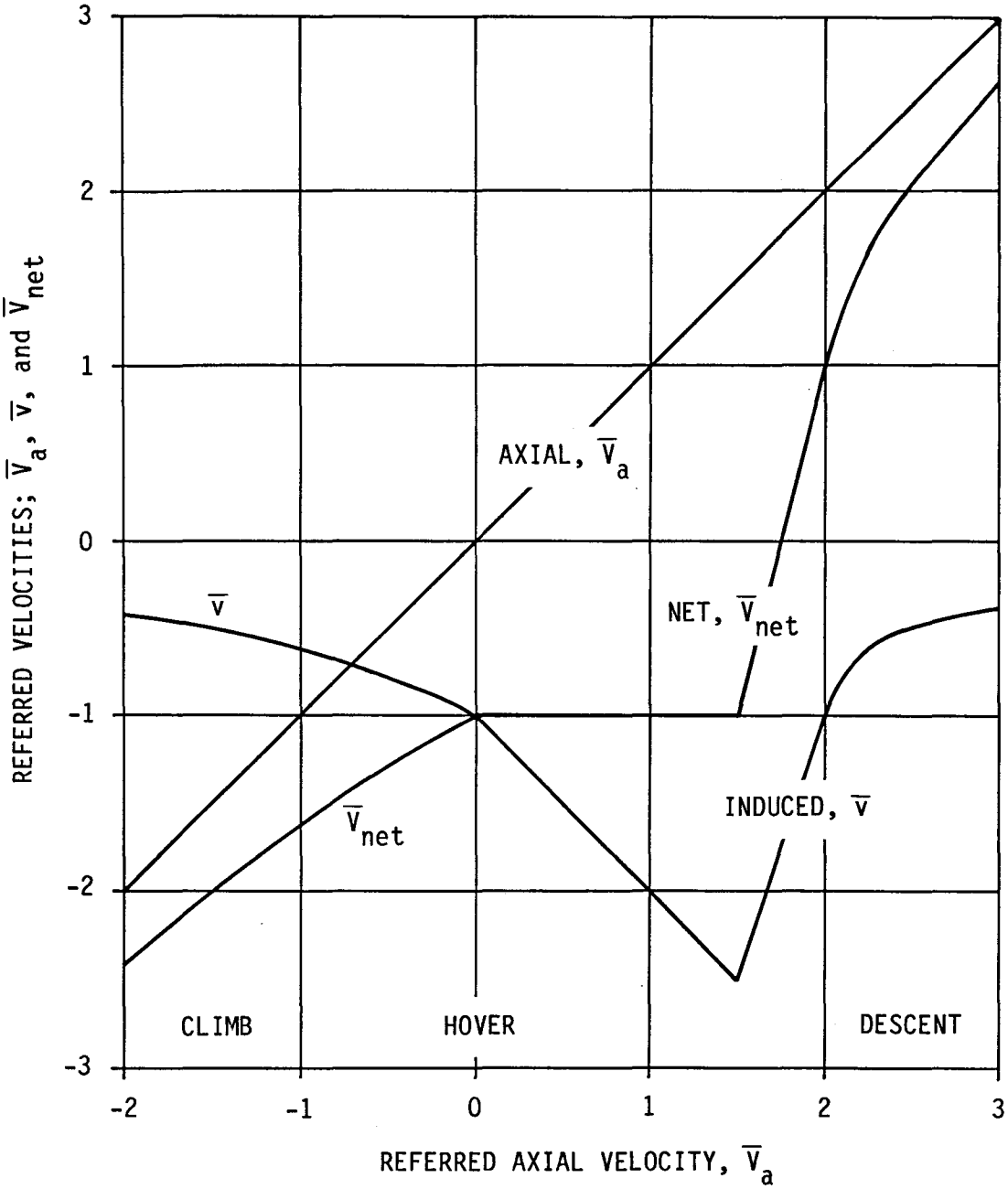


Figure 11. Rotor Work State Velocity Relationships in Axial Flow.

$$\bar{k}_z = \bar{k}_a + [\text{constant}]/\bar{k}_z \tag{46}$$

For the normal work state the constant is determined by matching the known conditions at hover, $\bar{k}_a = 0$ and $\bar{k}_z = -1$, giving the constant a value of 1. Then Equation (46) is solved to give the final expression for the settling rate for the normal work state,

$$\bar{k}_z = (\bar{k}_a/2) - [(\bar{k}_a/2)^2 + 1]^{1/2} \tag{47}$$

In the vortex ring state as previously noted, the organized streamline flow transitions to a complex large scale circulation about the rotor, and therefore the wake spiral most probably also becomes disorganized. However, in the prescribed wake model it is assumed that the integrity of the wake spiral remains, and thus its position should nominally represent the overall circulation of the flow. This is accomplished by recognizing at hover that the settling rate is purely due to induced velocity, but that the induced velocity is also the net flow through the rotor at this key point. It is further assumed that in the vortex ring state the settling rate continues to be proportional to the net flow. From Equations (39) and (40) the settling rate in the vortex ring state is simply given by

$$\bar{k}_z = \bar{V}_a + \bar{v} \tag{48}$$

$$\bar{k}_z = -1, \qquad 0 \leq \bar{V}_a \leq 1.5 \tag{49}$$

$$\bar{k}_z = 4\bar{V}_a - 7, \qquad 1.5 \leq \bar{V}_a \leq 2 \tag{50}$$

In addition to matching the end conditions at the axial velocity limits of the vortex ring state, note that the settling rate will also reduce to zero at $\bar{V}_a = 1.75$, (the wake will remain inplane with the rotor disk) and change sign (the wake will move from beneath the rotor, the upwind side, to the downwind side). This point corresponds to the ideal autorotation vertical descent speed at which the rotor flowfield is analogous to that of a solid disk; that is, there is no net axial flow. Thus the present modeling

approach at least intuitively models the accumulation of the wake into a vortex ring and the subsequent transition toward the windmill brake state.

Once into the windmill brake state the settling rate is modeled as in the normal state. Determining the constant in Equation (46) now at $\overline{V}_a = 2$ or $\overline{k}_a = 2$, and $\overline{k}_z = 1$, then the constant is $(1-\sqrt{2})$ and the settling rate is

$$\overline{k}_z = (\overline{k}_a/2) + [(\overline{k}_a/2)^2 + (1-\sqrt{2})]^{1/2} \qquad (51)$$

Figure 12 presents the work state diagram in terms of the settling rate as described by the several equations above, and the analogy to the velocity work state diagram is clearly seen.

The point at which the wake migrates from upwind to downwind of the rotor disk is also taken as the nominal condition when the radial character of the wake changes from contraction to expansion. Maintaining the form of Equation (33) for the wake radial coordinate throughout the axial regime,

$$r/R = A+(1-A)e^{-[k_r(z/R)]} \qquad (52)$$

Then the developed wake radius A and the rate parameter k_r variation with axial velocity must be determined. The reference value in hover of A = 0.78 is again taken from the experimental measurements of Reference 3. In the normal work state the wake will contract, but at a rate decreasing with axial velocity to a negligible value in the high speed limit such that contraction is also negligible, even if the developed wake radius remains at the hover value. Similarly, the developed radius of the expanding wake is of little importance in the other extreme of axial velocity, so that the developed wake expanded radius is only important at low speed. Without guiding experimental data, the value is set by assuming the same expansion increment as for contraction, thus giving as a function of the sign of the settling rate

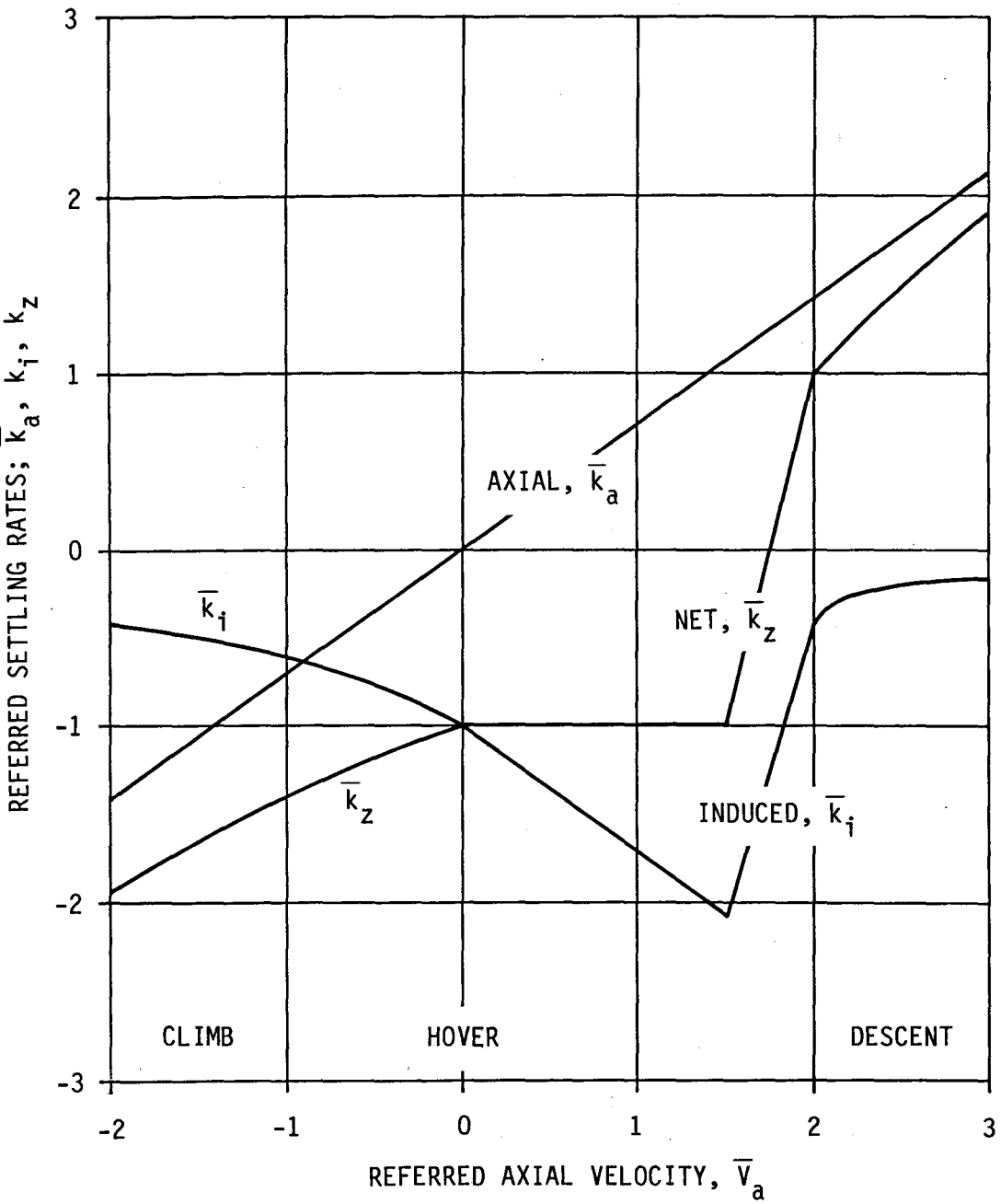


Figure 12. Rotor Work State Settling Rate Relationships in Axial Flow.

$$A = 1 + 0.22[\text{sign}(k_z)] \tag{53}$$

The rate parameter is assumed to be inversely proportional to the wake pitch which sets the radial induced velocities. This also provides the proper vanishing rate at the high speed axial velocity limits. With consideration for the required sign then

$$k_r = |k_{r_h}/\bar{k}_z|[\text{sign}(k_z)] \tag{54}$$

Equations (28) and (33) can now be used to generate the cylindrical coordinates of the wake as a function of the wake azimuth. The wake is composed of a number of trailers, each with an origin at the intersection of a blade surface panel boundary with the blade trailing edge, and the generating equations are adjusted with the appropriate offsets to match the origin (r_{te},z_{te}) of a particular trailer,

$$z/R = k_z(\psi_w-\psi_{te}) + (z_{te}/R) \tag{55}$$

$$r/R = (r_{te}/R)\{A+(1-A)e^{-[k_{r_h}(z-z_{te})/R]}\} \tag{56}$$

ROLLUP OF CONCENTRATED VORTICES

The implementation of the prescribed wake model is designed to allow the inboard and outboard sheets to roll up into concentrated root and tip vortices respectively. The rollup of the two vortices may be selected independently or in combination, and a portion of the wake called the mid-span sheet can be included without any rollup if desired. Also, the rollup mechanism can be suppressed altogether, fixed to include a series of specified trailers, or for the tip vortex allowed to vary through iteration to be compatible with the calculated radial bound circulation distribution. Compatibility is interpreted to mean that the inboard edge of the outboard sheet coincides with the radial position of the outermost maximum in the bound circulation distribution. The generality in selection of the rollup

is provided to allow exploration of the importance of the several wake structure elements and to accommodate future refinements of the wake model's structure as data and better understanding of the real wake become available.

Figure 13, shows the overall scheme of the wake grid and rollup options. The near wake extends from the blade trailing edge through one revolution. In the near wake the number of azimuth increments is increased toward the blade to improve the fidelity of the discrete, piecewise linear wake elements to the actual curved trajectory of the wake filament trailers. The number of azimuth increments per revolution in the nonuniform grid of the near wake is twice that specified in the uniform grid region that follows and continues to the truncation point. At the truncation of the uniform grid the wake can optionally be continued with the semi-infinite vortex cylinder described in a previous section.

The optional rollup process is described first by specifying the bounding indices of the trailers on the edges of a sheet that will develop into a concentrated vortex. Then the azimuth increment is specified over which the sheet will form into the vortex. The index of a trailer corresponds to the blade surface panel grid index from which the trailer emanates. As shown in Figure 14, the grid indices are a function of the number of panels spanwise within a blade segment, and the number of blade segments.

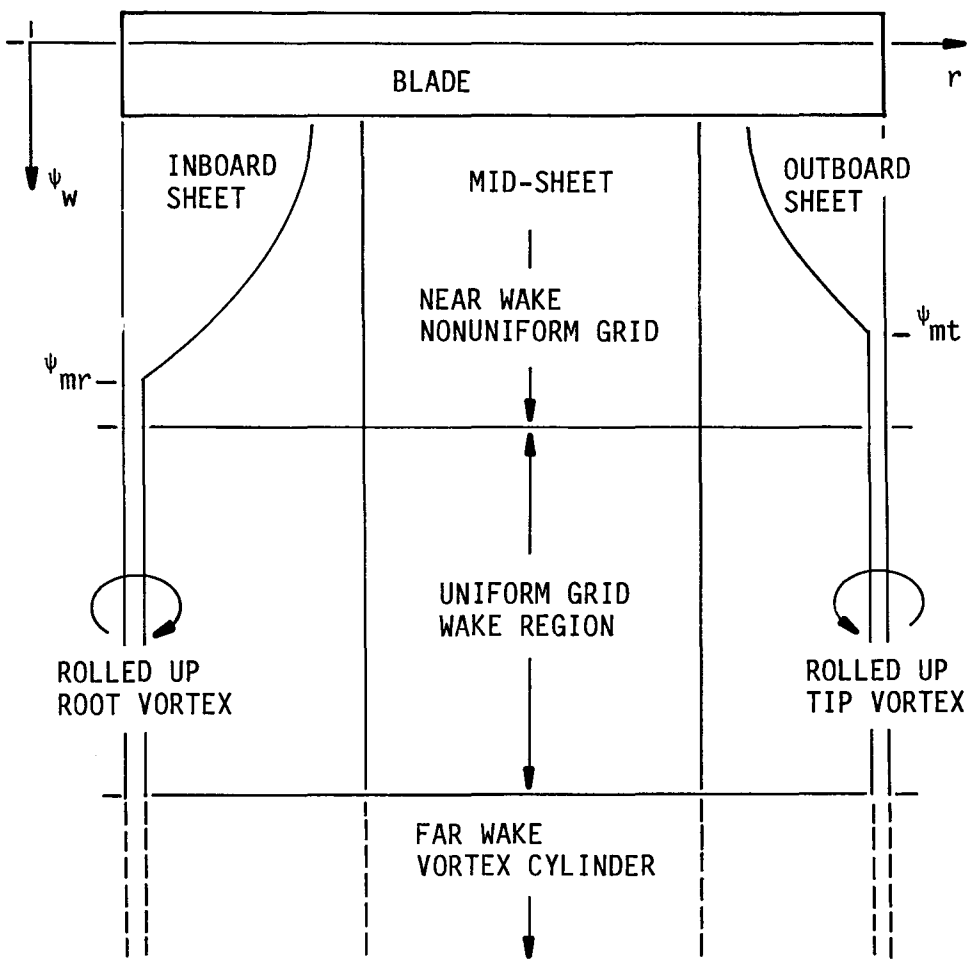


Figure 13. Schematic of Wake Grid Regions, Sheet Definitions, and Rollup Options.

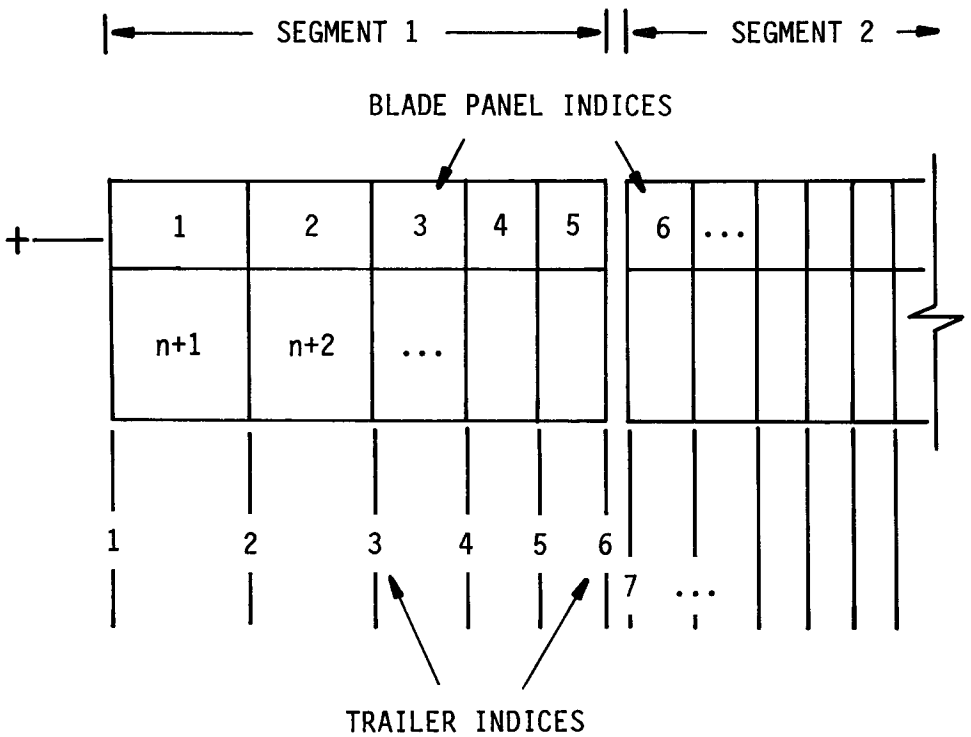


Figure 14. Panel, Panel Boundary Grid, and Wake Trailer Index Assignments.

With the general characteristics of the lifting surface theory and prescribed wake now defined, the overall solution procedure can be outlined. The principal steps in obtaining a converged solution of the detailed aerodynamics and integral performance are described in the flow chart of Figure 15. The major iteration cycle of the problem is to seek a thrust level and wake geometry which are mutually compatible at the specified blade pitch. Secondary iterations are performed to insure correspondence of the sectional effective linear lift curve slope with the potential flow circulation solution, and to develop the outboard sheet boundary and tip vortex rollup if optioned.

For given blade and rotor geometry, and with an iterative estimate of the wake settling and contraction rates, the discretized panel representation of the blade surfaces and wakes is developed in cartesian coordinates. Then an aerodynamic influence coefficient matrix is assembled from separate calculations of the component coefficients due to each blade's surface and wake. Gauss-Seidel iteration is used to obtain the circulation solution from the resulting linear equation system.

The blade element effective angle of attack is calculated from the circulation solution at each chordwise column of surface panels. The effective angle is related to the bound circulation, that is the value of distributed circulation at the trailing edge Γ_{te}, through the Kutta-Joukowski theorem,

$$\sin(\alpha_e) = \frac{2\Gamma_{te}}{a_e V_r c \cos(\Lambda)} \qquad (55)$$

where c is the blade element chord and

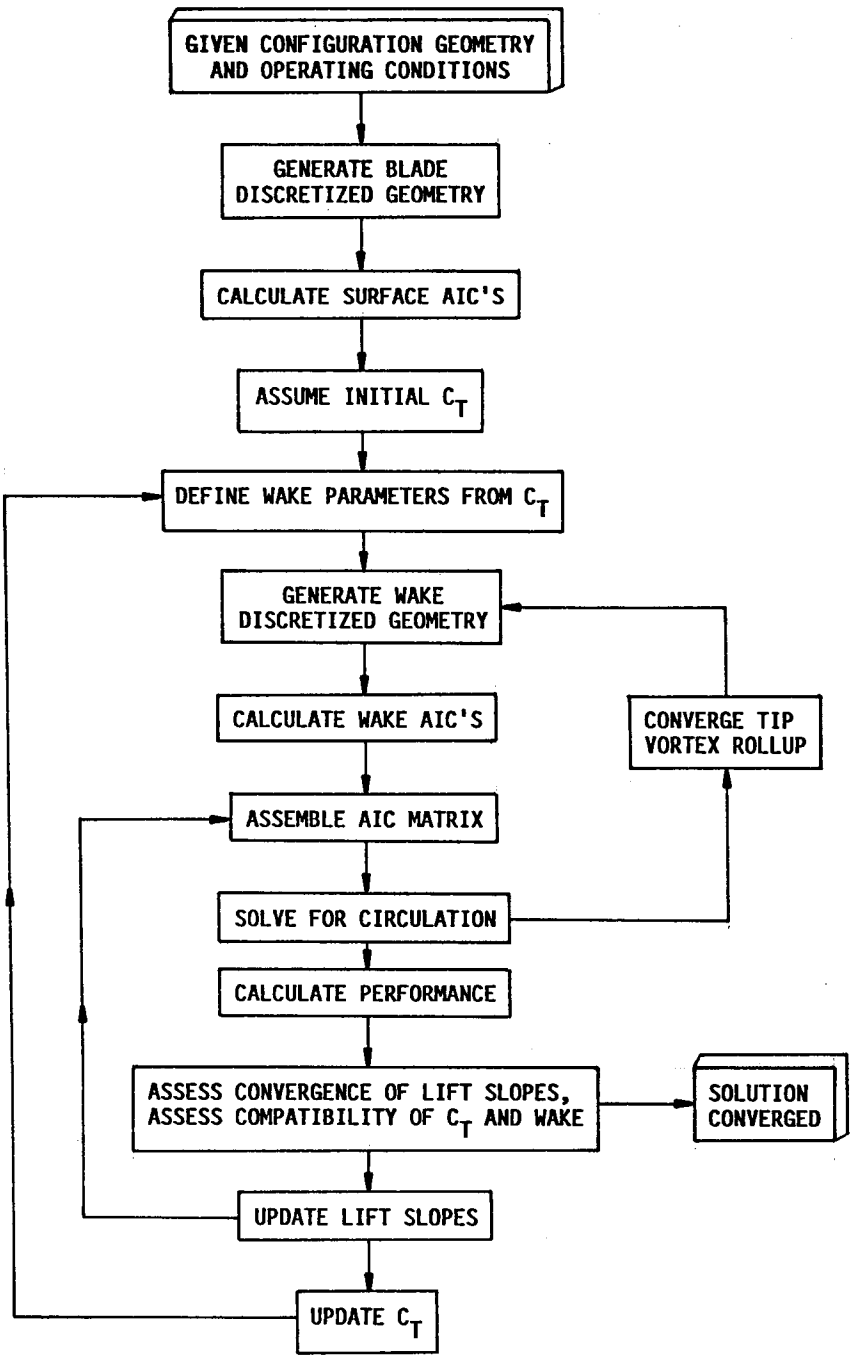


Figure 15. Flow Chart of Major Steps in Solution Procedure.

$$a_e = \frac{c_l}{\sin(\alpha_e)} \tag{56}$$

is the effective linear lift curve slope available from a previous iteration. The blade element relative velocity V_r contains the full freestream vector plus the induced swirl and downwash. It is calculated from the AIC's and the now known circulation, and the single blade element value of V_r is taken as the chordwise average value. The aerodynamic sweep angle Λ is the angle between the V_r vector and the blade element quarter chord. Also, the use of the large angle form of Equations (55) and (56) is required because of the very high angles that a wind turbine can encounter at high wind speeds when operating near peak power output.

Below stall, the total inflow angle is deduced from the difference between the geometric angle adjusted for zero lift line offset,

$$\alpha_n = \alpha_e - \alpha_g + \alpha_0 \tag{57}$$

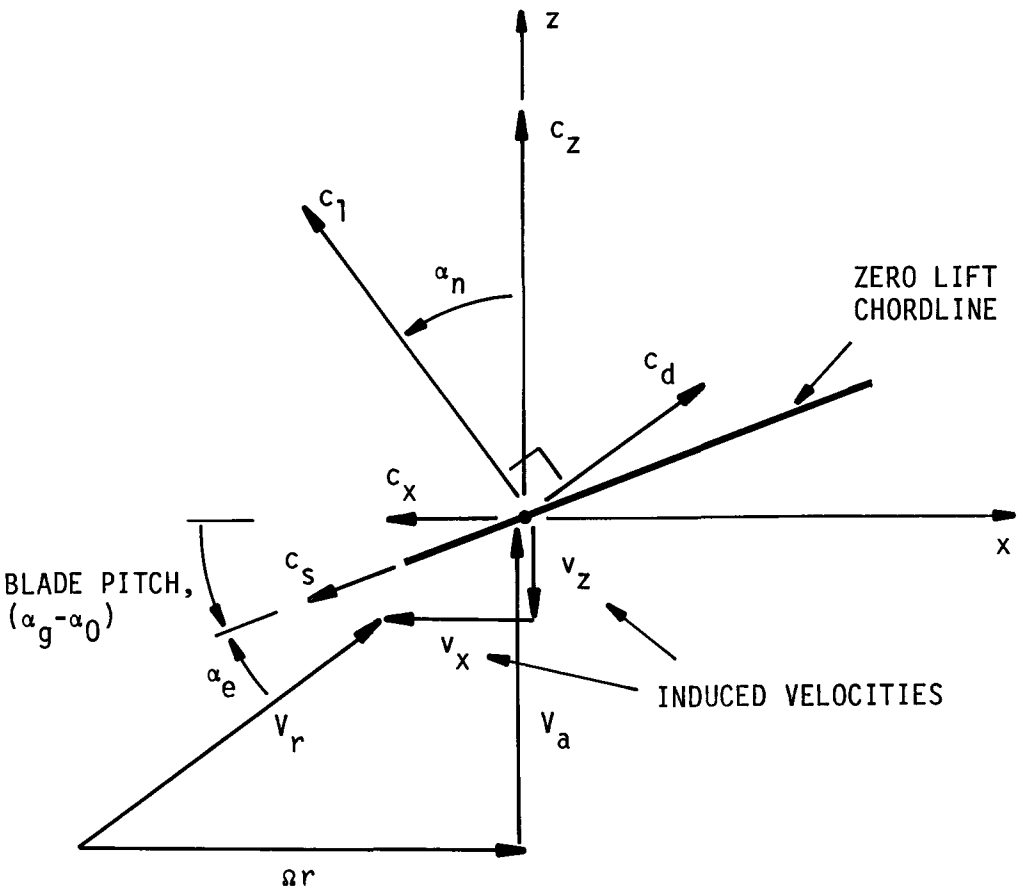
and the induced angle is then the difference between the total inflow angle and that due only to the axial freestream,

$$\alpha_i = \alpha_n - \alpha_w \tag{58}$$

The blade element airfoil lift and drag coefficients, c_l and c_d, are obtained from bivarient tables of two-dimensional coefficients as functions of angle of attack and Reynolds number. The coefficients are also corrected for sweep using infinite yawed wing theory and the blade element sweep angle Λ. The aerodynamic coefficients are then resolved as shown in Figure 16, into element z- and x-forces (thrust and torque forces) using the dynamic pressure based on V_r and the relations

$$c_z = c_l \cos(\alpha_n) + c_d \sin(\alpha_n) - c_s \sin(\alpha_g - \alpha_0) \tag{59}$$

$$c_x = c_l \sin(\alpha_n) + c_d \cos(\alpha_n) + c_s \cos(\alpha_g - \alpha_0) \tag{60}$$



NOTE: BLADE PITCH, INDUCED x,z-VELOCITIES, SUCTION FORCE INCREMENT, AND x-FORCE ARE NORMALLY NEGATIVE AS SHOWN

Figure 16. Velocity, Force Coefficient, and Angle of Attack Resolution at a Blade Element.

The element forces and torques are then integrated radially to give the final configuration performance. The coefficient c_s is the increment in leading edge suction force due to three-dimensional effects such as finite planform,

$$c_s = -\left(\frac{2r_{te}}{V_r\, c}\right)^2 \frac{(g_0{}^2-1)}{2\ \cos(\Lambda_{le})} \tag{61}$$

The two-dimensional portion of the suction force is assumed to be contained in the tabular airfoil coefficients. The suction force is proportional to the coefficient g_0 which is derived from the deviation near the leading edge of the chordwise circulation distribution from the two-dimensional flat plate value. The force acts in the chord plane, normal to the leading edge, and so is resolved through the leading edge sweep angle Λ_{le}. Further detail of the suction force calculation may be found in Reference 1.

In the pre-stall range of angles of attack the use of the effective linear lift curve slope causes the potential flow circulation response to match that of the airfoil characteristics. After stall occurs the procedure will still continue to match the calculated circulation to the stalled airfoil behavior. In this case the process is of course only simulating a very complex aerodynamic environment by forcing the blade element to stall in the sense of a two-dimensional airfoil. Furthermore, it is no longer clear how to relate any calculated leading edge suction increment to the fully separated real flow, or how to properly calculate the induced angle to resolve the element aerodynamic coefficients, which at high angles are themselves simply resolved from the normal pressure force. It is reasoned that the local flow should be dominated by the separation and so only the suction force already contained in the two-dimensional airfoil characteristics is considered post-stall. The effective angle of attack is continued to be calculated from Equation (55), but the total inflow and induced angles are now implied directly from the average chordwise velocity vector at the blade element. This approach is believed to more correctly resolve the separated flow force coefficients.

SIMULATION OF POST STALL AIRFOIL CHARACTERISTICS

Wind turbine aerodynamic calculations and performance estimates are additionally complicated by the fact that the blades are partially stalled for all wind conditions. As any practical analysis must rely on airfoil characteristics included through a blade element representation of the local performance quantities, considerable attention is given to modeling high angle of attack airfoil behavior. Most approaches are based on stalled flat plate aerodynamics with corrections to address suspected three-dimensionality of the stall phenomena.

Assuming the availability of reliable measurements up through the stall angle associated with maximum lift coefficient, and assuming that the fully separated flow is adequately modeled by the flat plate theory, then the transition region from stall onset to the point that the flow recovers to the flat plate behavior is of critical interest. This transition generally occurs in the angle of attack range from about 15 to 30 degrees, based on observation of the very limited amount of detailed experimental data in this range. Airfoil data is difficult to measure in this transition because both surface pressure and wake rake measurements become unreliable after stall, especially for the measurement of drag. Once the flow is fully separated, and assuming that two-dimensionality of the flow is maintained, then integration of surface pressure can yield reliable results.

The calculation of wind turbine peak power is very sensitive to the treatment of stall transition airfoil characteristics, and as yet there does not appear to be a completely satisfactory and validated model. In the implementation of the LSWT analysis several post-stall models are available in addition to directly using tables at high angles. These models include the Aerovironment, Inc. stalled flat plate model from Reference 6, the synthesis method developed by Viterna in Reference 14, and a method developed as part of the present work which allows more flexibility in selecting parameters to explore the sensitivity of the model. The Aerovironment method is included for completeness, but will not be

described in detail because it requires the transition region characteristics to be part of the supplied table.

VITERNA STALL MODEL

This method synthesizes the post stall lift and drag characteristics based on idealizing the stall such that the calculated torque at high angles of attack is constant. This requirement is based on the observation for some large scale turbines such as the NASA Mod-0, that the peak power remains relatively flat with increased wind speed. It should be noted that the derivation is strictly valid only for untwisted blades operating at flat pitch. The result is a set of analytical expressions giving c_l and c_d for all angles above that for stall.

A parameter in the method is the drag coefficient at $\alpha = 90$ degrees,

$$c_{d_{max}} = 1.11 + 0.018(AR) \qquad (62)$$

The variation of the maximum drag with aspect ratio AR is a correction for three-dimensionality based on the data presented in Reference 15, for fully stalled finite span flat plates. With the subscripts l, d, and s denoting respectively lift, drag, and the value of a parameter at stall, the Viterna model is described by the equation set

$$B_1 = c_{d_{max}}$$

$$B_2 = [c_{d_s} - B_1 \sin^2(\alpha_{s_d})]/\cos(\alpha_{s_d})$$

$$A_1 = B_1/2$$

$$A_2 = [c_{l_s} - c_{d_{max}} \sin(\alpha_{s_l})\cos(\alpha_{s_l})] \sin(\alpha_{s_l})/\cos^2(\alpha_{s_l})$$

$$c_l = 2A_1 \sin(\alpha)\cos(\alpha) + A_2 \cos^2(\alpha)/\sin(\alpha)$$
$$c_d = B_1 \sin^2(\alpha) + B_2 \cos(\alpha) \qquad (63)$$

In implementation the stall angles are the maximum angles contained in the airfoil tables of lift and drag coefficients, and the aspect ratio is based on the blade chord at 0.75 radius. The use of aspect ratio in this manner is really equivalent to the assumption that the entire blade stalls at once. If the radial extent of the stall were only partial then the degree of relief would intuitively be a function of a stalled elements proximity to a free edge, if in fact the stall region included either the blade root or tip. If the region were bounded by attached flows then it might be maintained more nearly as two-dimensional. Also, the relief is probably partially accounted for in the calculation of the radial load distribution itself. There are then a number of conceptual difficulties in making the aspect ratio analogy.

An additional uncertainty introduced by the synthesis is that it results in vary favorable ratios of lift to drag at $\alpha = 45$ degrees. This occurs in the synthesis because of the match to conditions at $\alpha = 90$ degrees, leaving the region above stall under constrained. At the 45 degree point exprimental data shows that the l/d is almost universally equal to unity, in agreement with flat plate theory.

CMA STALL MODEL

The procedure described now is an attempt to provide a more general model, one which is in agreement with stalled flat plate theory at higher angles where the flow is fully separated, which systematically generates the characteristics in the stall transition region, and over which a greater degree of parametric control can be exercised for refinement. The angle of attack range is considered in four regions as shown in Figure 17. Region 1 is the range up to stall in which the airfoil characteristics are assumed known.

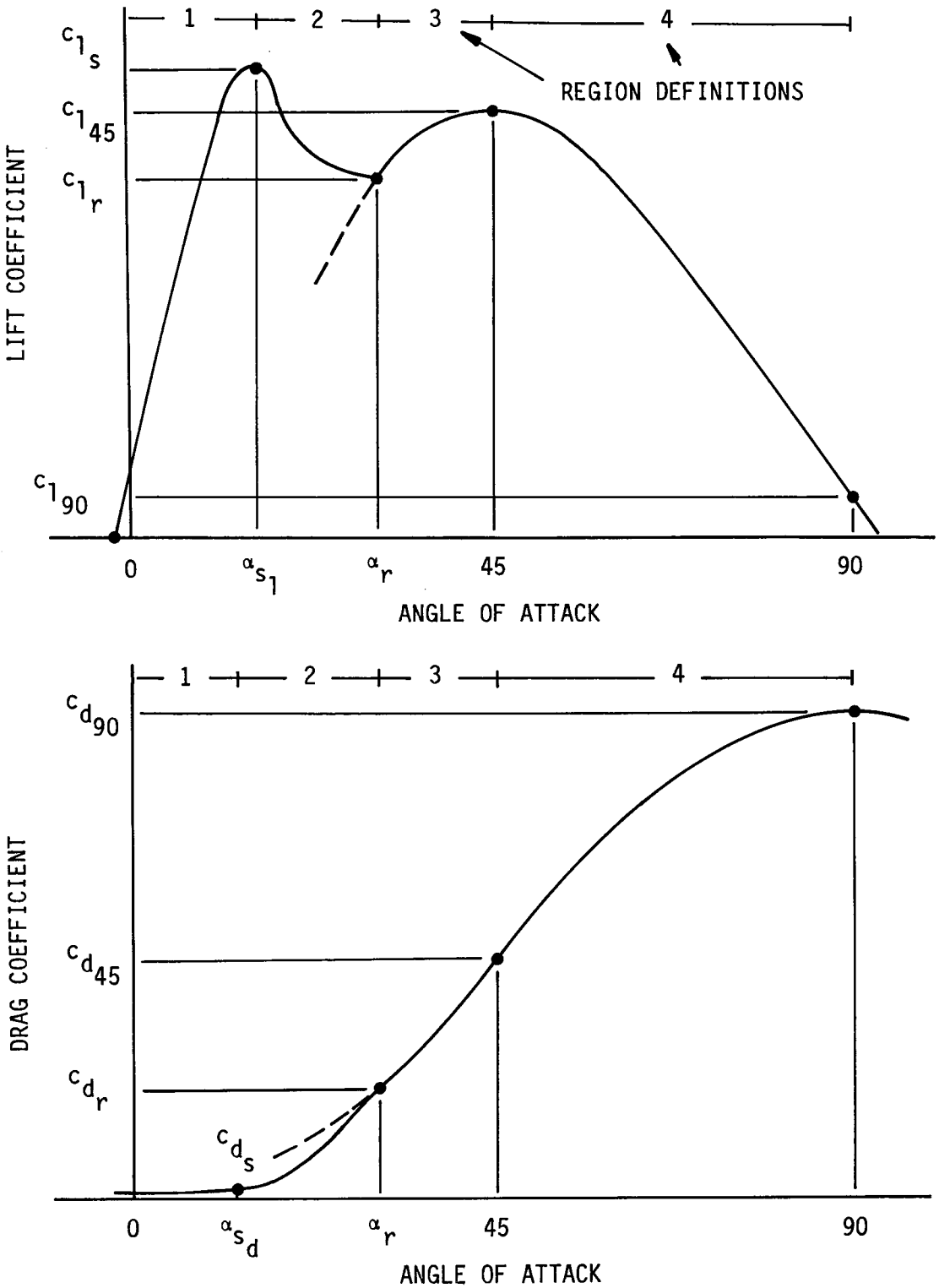


Figure 17. CMA Stall Model Region Definitions and Key Points for Matching Data.

Region 2 covers the range from stall to the recovery point after which the stalled flat plate theory is assumed to be valid. The characteristics at α = 45 degrees are specified as parameters, as is the angle of attack for recovery. With the subscript r denoting the recovery point, then the following functions, similar to those used by Viterna, provide a very systematic fairing of the region,

$$c_{l_r} = 2c_{l_{45}}\sin(\alpha_r)\cos(\alpha_r)$$

$$c_{d_r} = 2c_{d_{45}}\sin^2(\alpha_r)$$

$$A_{12} = [c_{l_r}\cos^2(\alpha_{s_l})\sin(\alpha_r) - c_{l_s}\cos^2(\alpha_r)\sin(\alpha_{s_l})]$$
$$/ \{2\cos(\alpha_{s_l})\cos(\alpha_r)[\sin^2(\alpha_r)\cos(\alpha_{s_l})$$
$$- \sin^2(\alpha_{s_l})\cos(\alpha_r)]\}$$

$$A_{22} = [c_{l_s} - 2A_{12}\sin(\alpha_{s_l})\cos(\alpha_{s_l})]\sin(\alpha_{s_l})/\cos^2(\alpha_{s_l})$$

$$B_{12} = [c_{d_s}\cos(\alpha_r) - c_{d_r}\cos(\alpha_{s_d})]$$
$$/ [\sin^3(\alpha_{s_d})\cos(\alpha_r) - \sin^3(\alpha_r)\cos(\alpha_{s_d})$$

$$B_{22} = [c_{d_r} - B_{12}\sin^3(\alpha_r)]/\cos(\alpha_r)$$

$$c_l = 2A_{12}\sin(\alpha)\cos(\alpha) + A_{22}\cos^2(\alpha)/\sin(\alpha)$$

$$c_d = B_{12}\sin^3(\alpha) + B_{22}\cos(\alpha) \qquad (64)$$

The recovery point concept was chosen based on review of airfoil characteristics from several sources including References 16, and 17. The latter reference is particularly insightful because it indicates a fairly general trend for the family of lift curves representing Reynolds number variation to merge toward a common point at an angle of attack of about 32 degrees. This Reynolds number independence at the recovery point supports the assumption that the flow is fully separated, and that stalled flat

plate behavior represents the airfoil, independent of the pre-stall characteristics.

Region 3 then continues to 45 degrees angle of attack. The factor B_{pr} is introduced to allow determination of the effect of relieving the base (leeward side) pressure of the stalled plate. The generating functions in this region are

$$A_{13} = 2c_{l_{45}} B_{pr}$$

$$A_{23} = [c_{l_r} - 2c_{l_{45}} B_{pr} \sin(\alpha_r)\cos(\alpha_r)]/[1 - 2\sin^2(\alpha_r)]$$

$$B_{13} = [c_{d_r} - 2\, c_{d_{45}} B_{pr} \cos(\alpha_r)]/[\sin^2(\alpha_r) - (\sqrt{2}/2)\cos(\alpha_r)]$$

$$B_{23} = (c_{d_{45}} B_{pr} - B_{13}/2)\sqrt{2}$$

$$c_l = A_{13}\sin(\alpha)\cos(\alpha) + A_{23}[1-2\sin^2(\alpha)]$$

$$c_d = B_{13}\sin^2(\alpha) + B_{23}\cos(\alpha) \qquad (65)$$

And finally Region 4, with selectable values at 90 degrees angle of attack is represented by

$$c_l = B_{pr}\{2c_{l_{45}} \sin(\alpha)\cos(\alpha) - c_{l_{90}}[1-2\sin^2(\alpha)]\}$$

$$c_d = B_{pr}[c_{d_{90}} \sin^2(\alpha) + (2c_{d_{45}} - c_{d_{90}})/\sqrt{2}\cos(\alpha)] \qquad (66)$$

This model provides the capability to adjust its characteristics to match whatever is known about the actual airfoil. Or, if little information is available, then it will provide a systematic basis to synthesize the high angle of attack behavior.

EXTENSIONS FOR QUASI-STEADY SOLUTION

The analysis as described thus far is based on axial symmetry of the onset wind and the problem geometry when viewed in a fixed coordinate system attached to a reference blade. The extensions described now are designed to permit investigation at an exploratory level of effects which cause the flowfield to be time variant. The quasi-steady approach calculates the aerodynamics of the reference blade as the rotor is indexed around the azimuth, and accounts for blade motion, nonuniform wind profile, and distortion of the wake. To simplify the analysis, the effects of all other blades are calculated with the assumption that their influence is represented through the average loading over the disk.

Rigid blade flapping and cyclic pitch motions with respect to the shaft axis are permitted as harmonic functions of azimuth. The shaft may be inclined both horizontally and vertically to the principal wind direction. Nonuniformity of the onset wind is included with a ground boundary layer profile and velocity deficit functions to represent the effects of tower shadow. The wind profile as a function of height above ground y and hub height h is given by,

$$V_w = V_{w_0}[(h-y)/h]^e \qquad (67)$$

Tower shadow in the form of a velocity deficit fraction T_s further modifies the wind profile to give the final axial velocity

$$V_a = V_w(1-T_s) \qquad (68)$$

The velocity deficit fraction can be supplied at an array of points in the x,y- plane at the rotor disk, or the formulation described in Reference 18, can be selected.

All of these effects enter the problem through the no normal flow through the blades boundary condition, and through perturbations in the wake transport. To position a particular wake trailer, for instance, the induced component of the wake rate parameter is based on the disk average thrust coefficient developed as the quasi-steady solution stabilizes. The transport due to the distorted onset wind must now be calculated locally in the field, and therefore the position of a particular point on the trailer is found by integrating the transport from the point's origin in the field as a function of time to its position later in time (azimuth).

The working equation of the circulation solution relates the normalwash required at the blade to the induced velocity produced by all blades and wakes, and was given by Equation (11). At panel 1 on blade n Equation (11) can be expanded to isolate the contributions from each blade and wake,

$$(q_{N_1})_n = \sum_b \left[\sum_k (D_{sw})_{1,k} K_k \right]_b \tag{69}$$

With the assumption that at the reference blade all other blade's effects are through disk average loading, then the K_k circulations at all blades other than the reference blade n are taken as disk average values. By defining the circulation ratio

$$\tilde{K}_k = K_k/(K_k)_n \tag{70}$$

then Equation (69) becomes

$$(q_{N_1})_n = \sum_b \left[\sum_k (D_{sw})_{1,k} \tilde{K}_k (K_k)_n \right]_b \tag{71}$$

The influence coefficients from all the blades and wakes can now be combined as

$$(\tilde{D}_{sw})_{1,k} = \sum_{b} \left[(D_{sw})_{1,k} \tilde{K}_k \right]_b \qquad (72)$$

giving the new working equation for the quasi-steady solution at the reference blade n as

$$(q_{N_1})_n = \sum_{k} (\tilde{D}_{sw})_{1,k} (K_k)_n \qquad (73)$$

Since the ratio $\tilde{K}_k$ is itself a function of the solution, then an iteration is set up around the linear system solution of Equation (73), beginning with an initial value of $\tilde{K}_k = 1$. The ratio is updated after each solution of Equation (73) until the process converges. The overall solution process begins at an initial azimuth and proceeds for a specified number of steps. As the solution progresses, disk averages of the aerodynamic and performance quantities of interest are developed and can be monitored to assess the dissipation of transients as the solution approaches the (periodic) steady state.

COMPARISON TO PERFORMANCE MEASUREMENTS

The initial assessment of the lifting surface prescribed wake analysis has been made based on comparisons to measured wind turbine power characteristics and to similar calculations made with a blade element momentum theory analysis. The four turbines chosen for this comparison represent a variety of power output capacities, physical sizes, and aerodynamic configurations, and include both research and commercial machines. The turbines and major features of their configurations are listed in Table 1.

Table 1.

Turbine	Radius (ft)	Number of Blades	Airfoil Family	Chord	Twist
NASA MOD-0	63.96	2	NACA 230xx	Tapered	Untwisted
ESI-54	27.0	2	NACA 230xx	Tapered	10° Linear
Carter 25	16.0	2	NACA 230xx	Tapered	Nonlinear
Enertech 1500	6.56	3	NACA 44xx	Tapered Tip	5° Linear

Appendix D contains Program LSWT input data file listings for each of the example turbines. These listings describe the details of each turbine's blade geometry, the source and values of the airfoil performance characteristics utilized, and the selection of analysis options. As yet no attempt has been made to optimize the selected analysis parameters. Those that appear in the input listings are recommended as a nominal configuration and are consistent across all cases presented. The measured rotor power data for the NASA MOD-0, ESI-54, and Carter 25 turbines was furnished by the contracting agency. For the latter two machines the source of the data was manufacturer's tests. The measured performance of the Enertech 1500 was obtained from Reference 19. All cases are for the turbines with

blades set to zero pitch at the tip; however, information is not available to confirm that chordline reference is consistently used.

The blade element momentum analysis used for comparison is a highly modified version of the PROP Code described in Reference 6. Technical modifications include the addition of the blade element drag coefficient in the expressions used to calculate both the inplane and axial inductions. There is some disagreement over the correctness of including this term in the induction. The argument against its inclusion is based on the assumption that the drag is substantially of viscous origin, and therefore does not contribute to the lift forces. At very low lift coefficients the drag of most airfoil sections is approximately 50% viscous and 50% pressure. At the high element angles of attack at which wind turbine blades operate, the drag is mostly due to pressure. In fact, when the flow is fully separated both the lift and drag are simply components of the normal pressure force. Therefore the drag should be included in the induction.

However, the major reason for modifying the PROP code is to minimize modeling differences between it and the lifting surface analysis. To accomplish this the PROP code was restructured to accept the identical geometry input and options, to utilize the same solution grid, to accept the same airfoil data tables, and to implement the same post-stall models as the LSWT code. In most cases identical code is now used in these areas in both programs. In the comparisons that follow the modified blade element code is referred to as BEWT (Blade Element Wind Turbine).

In all cases of BEWT calculations the Prandtl tip loss option was included. Some investigators are of the opinion that any tip loss factor should be supressed if a post stall synthesis such as the Viterna model is in effect. As previously discussed this model includes an aspect ratio correction to account for three-dimensionality, and thus it can be argued that the tip loss is not required. However, that concept is strictly valid only in the context of the actuator disk theory which treats the integral loading. The blade element theory addresses radial load distribution, and thus for consistency any corrections should be conceptualized and applied

at the element level. Also, recognize that in wake methods such as the present LSWT analysis, when local blade stations are stalled the radial loading must still tend to zero at the tip. Therefore, it is again consistent to include the tip loss in the blade element analysis.

Two sets of comparisons are presented in Figures 18 through 25. The first four figures show measured rotor power as a function of wind speed for the example turbines in comparison to calculations made with the LSWT and BEWT codes, and the Viterna stall model. In the second set of four figures the calculations use the CMA stall model.

Figure 18, for the MOD-0 turbine confirms the Viterna stall model objective of achieving constant torque at high wind speeds for this turbine, based on the BEWT result. The LSWT result substantially over predicts the performance from the wind speed for peak power and higher. Also, the offset in wind speed at a given power between the LSWT and BEWT calculations at the lower wind speeds is a persistent difference for all the cases studied. Because the MOD-0 is untwisted and uses a very thick airfoil section for structural reasons, the blades stall uniformly and thus offer a striking example of the sensitivity of calculations to modeling of the high angle airfoil characteristics. It should be noted that the airfoil characteristics for this case are taken at the 0.75 radius Reynolds number, whereas the other cases utilized interpolation on Reynolds number within the airfoil tables. The increasing twist of the other example turbines results in a gentler stall propagation with wind speed. The Carter 25 calculations are in closest agreement to each other, and also to the measured data. In Figure 21, for the Enertech 1500 the LSWT calculation with the Viterna stall model appears to follow the data fairly well at the high wind speed, but the actual data at the high end was taken with as much as 30 degrees of yaw. The measurements are suspect even though they were corrected for this presentation by the cube of the cosine rule. Also, for this case the LSWT calculations at low wind speeds exhibit considerable waviness, far in excess to any appearing for the other turbines. The source of this has not been identified, but is probably an analytical limit cycle introduced by the several strong sources of nonlinearity in the problem.

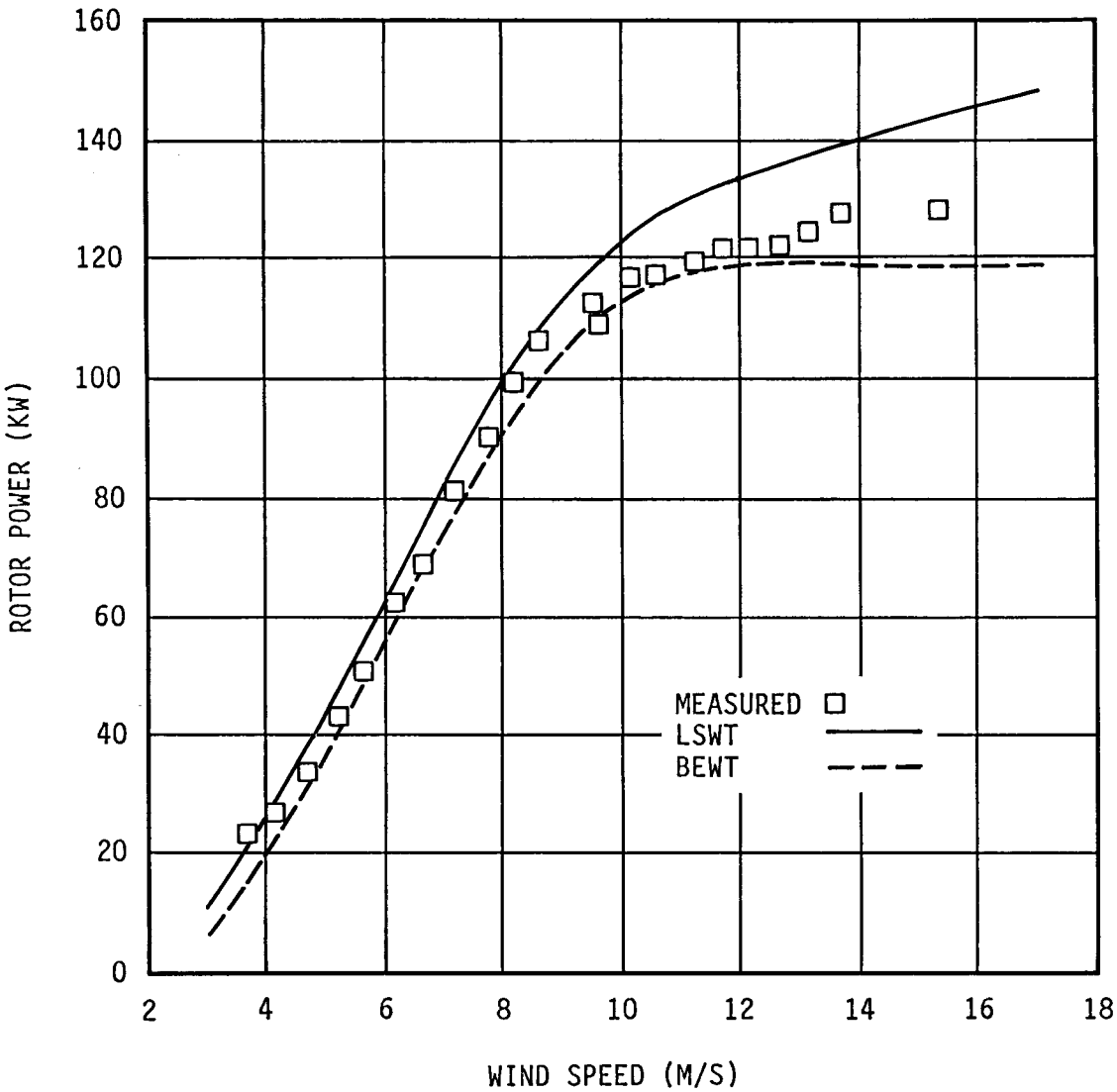


Figure 18. Comparison of Calculated and Measured Rotor Power, NASA MOD-0 Wind Turbine, Viterna Stall Model.

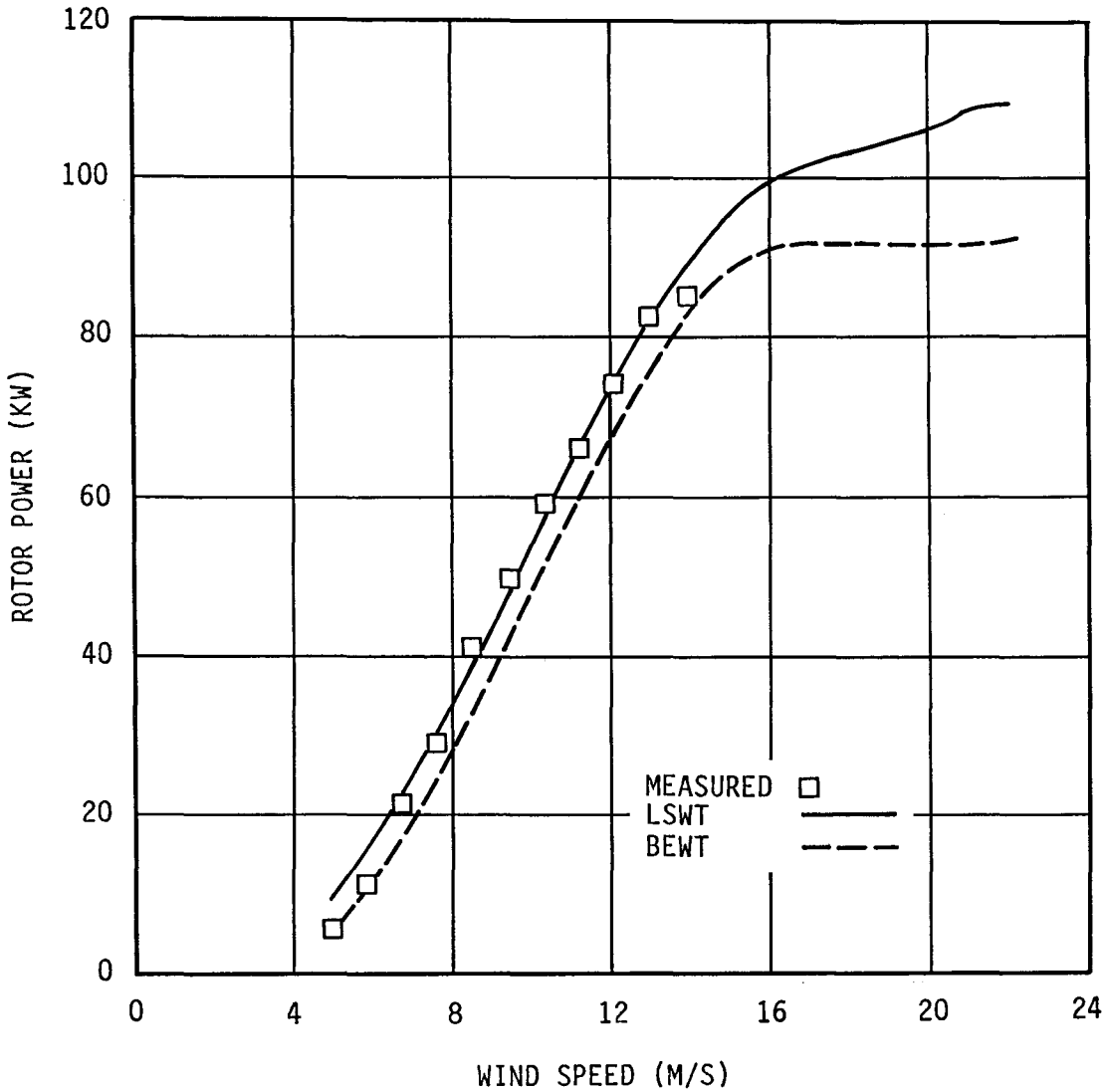


Figure 19. Comparison of Calculated and Measured Rotor Power, ESI-54 Wind Turbine, Viterna Stall Model.

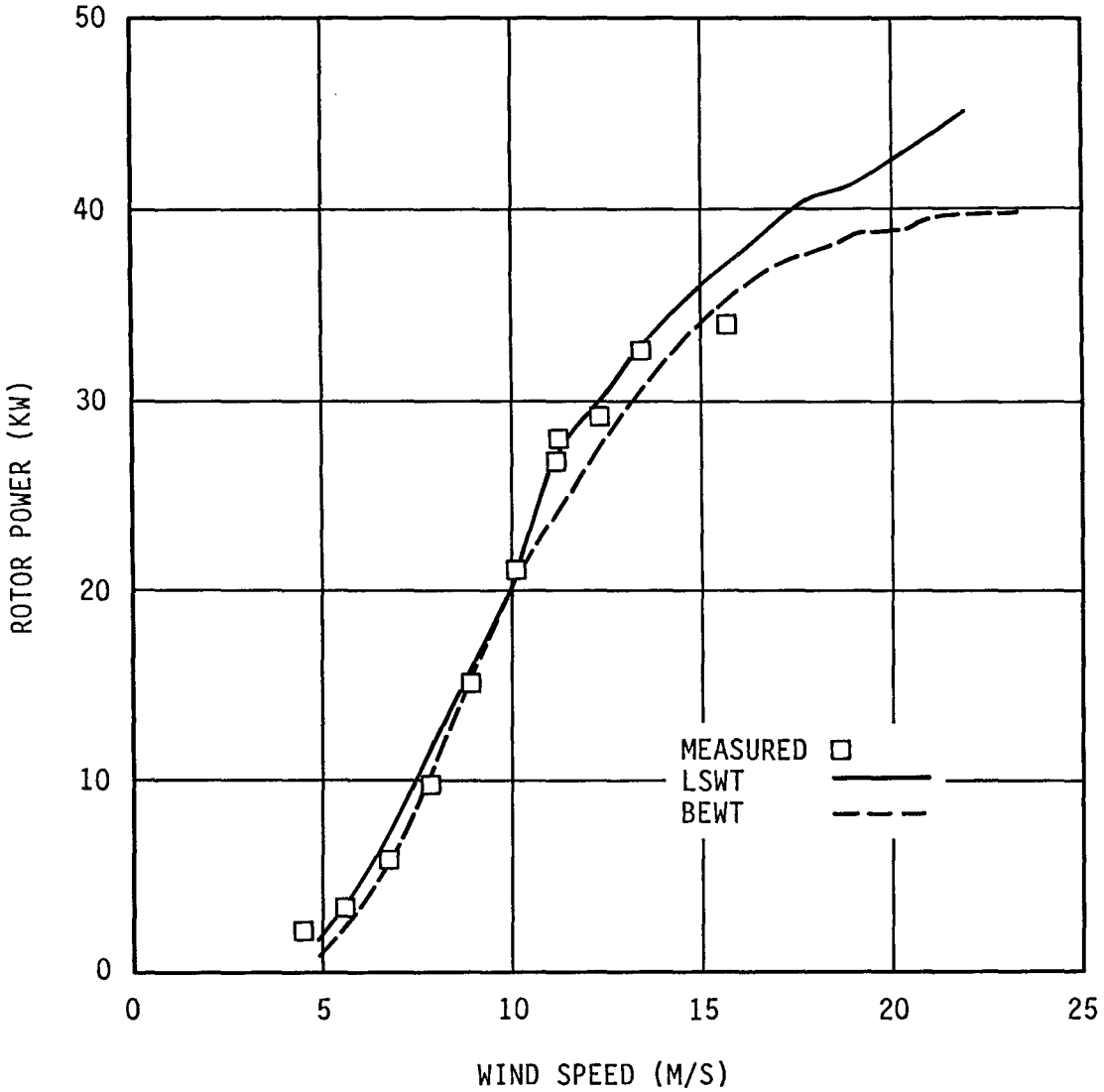


Figure 20. Comparison of Calculated and Measured Rotor Power, Carter 25 Wind Turbine, Viterna Stall Model.

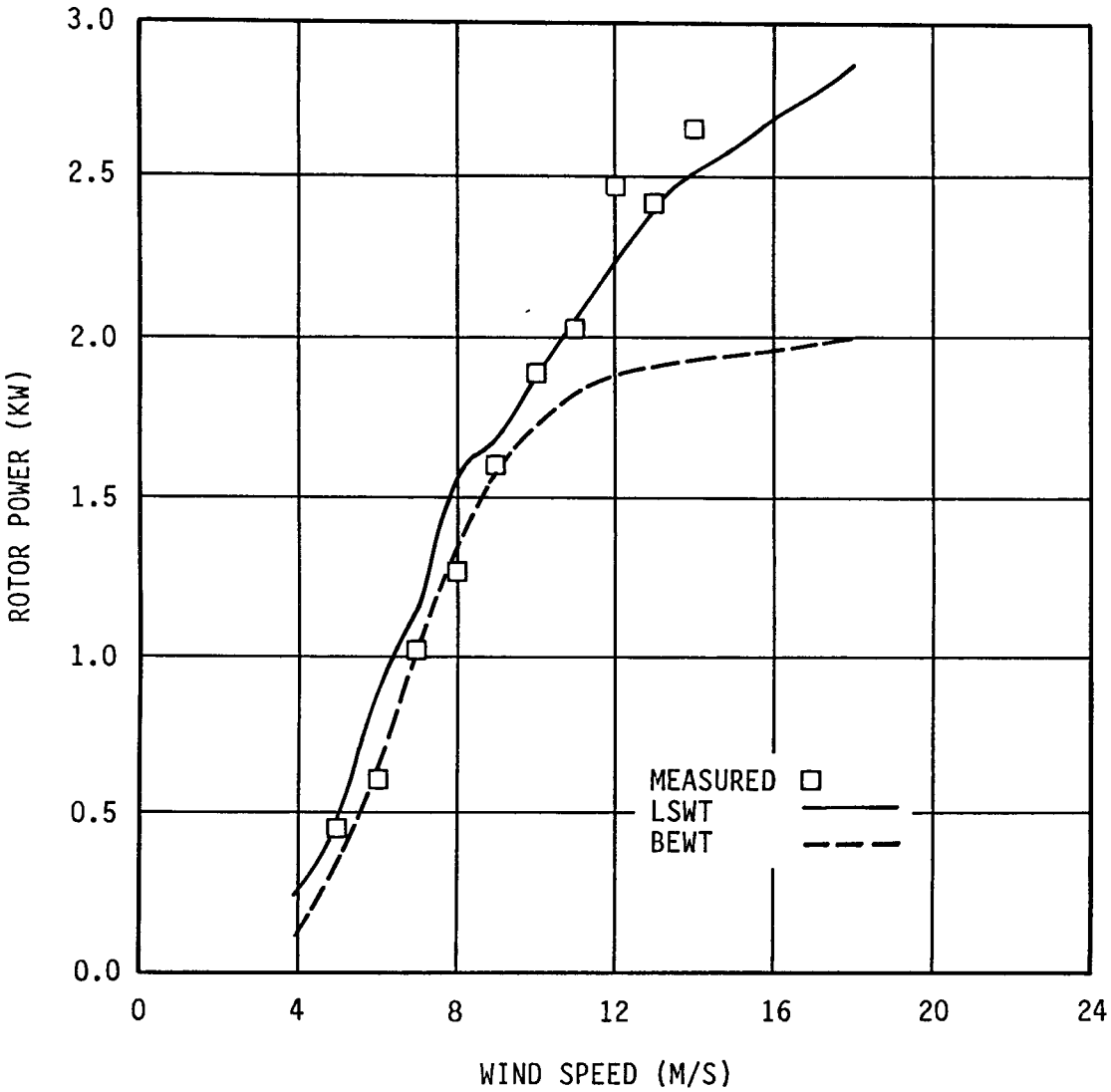


Figure 21. Comparison of Calculated and Measured Rotor Power, Enertech 1500 Wind Turbine, Viterna Stall Model.

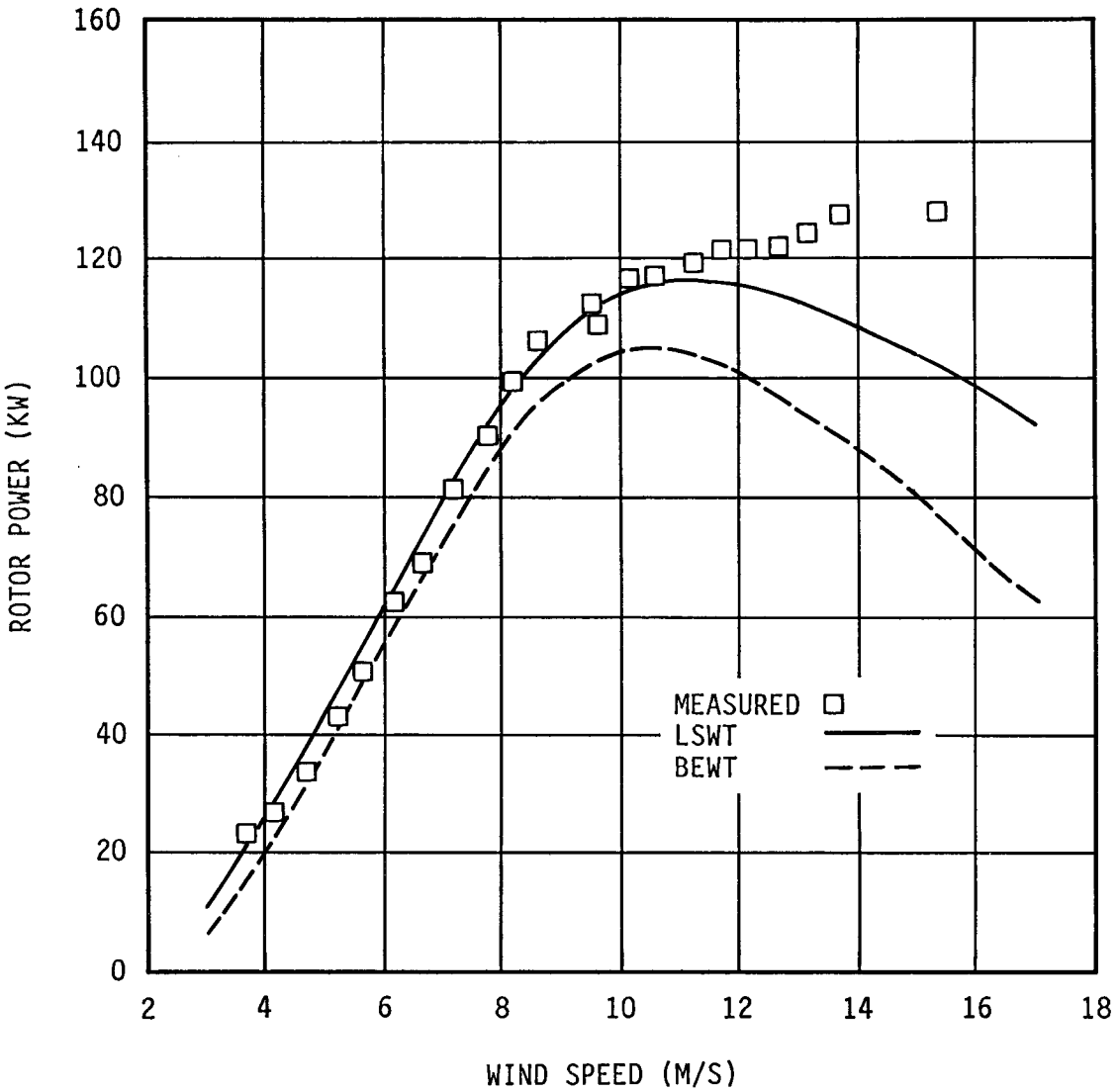


Figure 22. Comparison of Calculated and Measured Rotor Power, NASA MOD-0 Wind Turbine, CMA Stall Model.

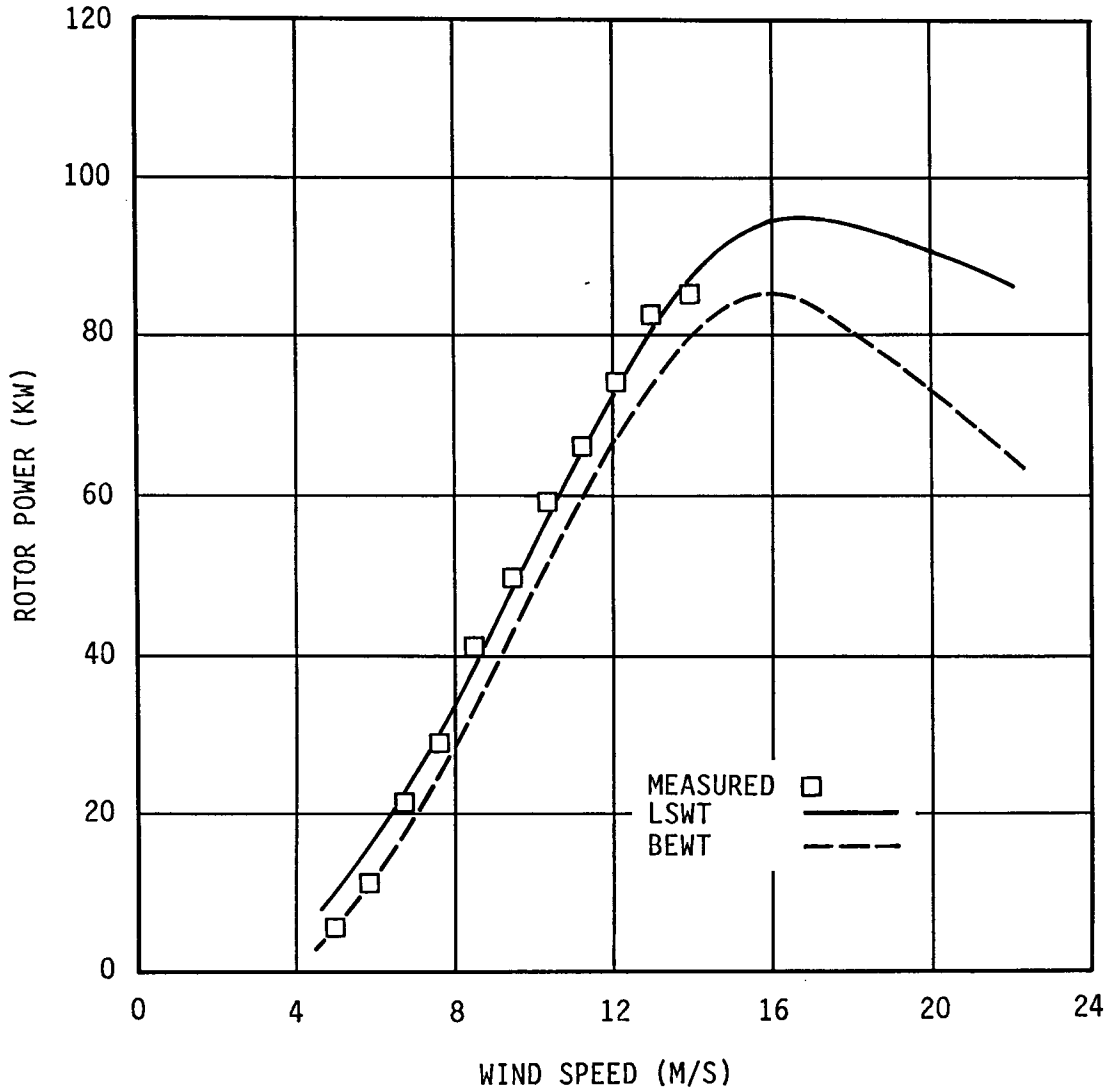


Figure 23. Comparison of Calculated and Measured Rotor Power, ESI-54 Wind Turbine, CMA Stall Model.

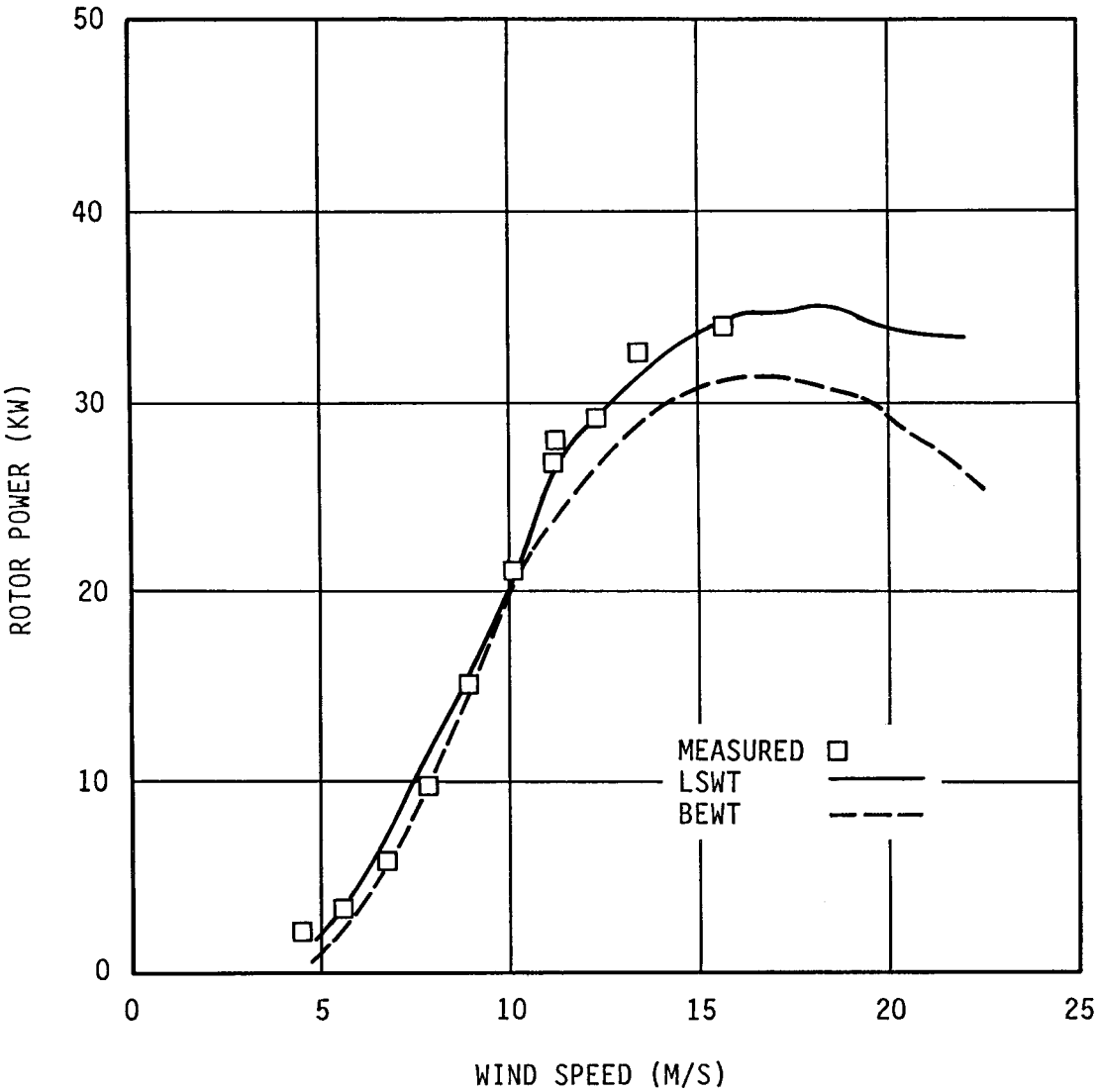


Figure 24. Comparison of Calculated and Measured Rotor Power, Carter 25 Wind Turbine, CMA Stall Model.

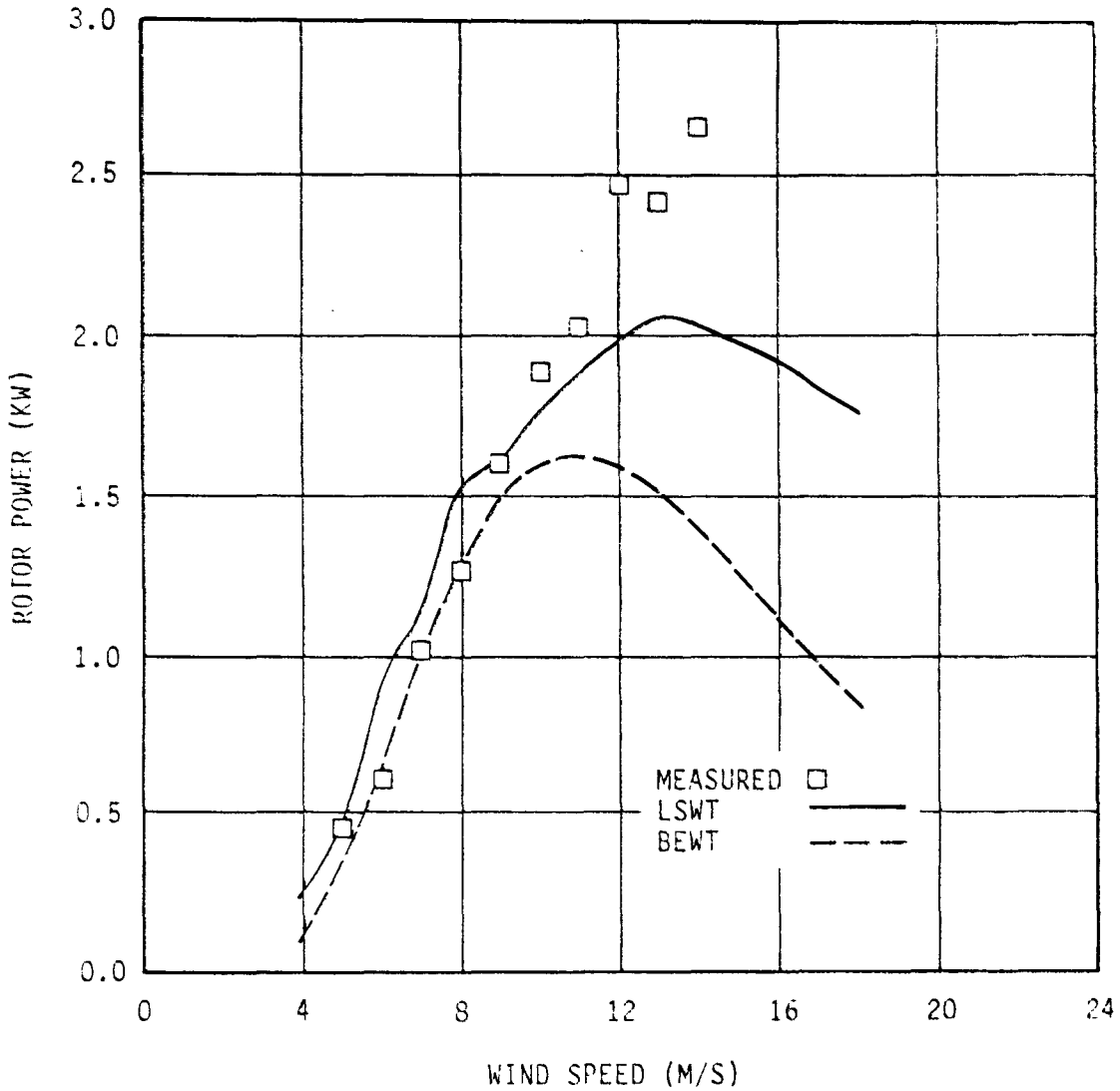


Figure 25. Comparison of Calculated and Measured Rotor Power, Enertech 1500 Wind Turbine, CMA Stall Model.

Overall the question remains as to the proper post-stall behavior and the different behavior of the two analytical methods which is emphasized when stall occurs. Since the Viterna empirical stall model was developed for use with blade element momentum methods, it is perhaps biased in that direction. Furthermore, the optimistic post stall power level calculated with the LSWT analysis is consistent with the favorable lift to drag ratios that the stall model produces in comparison to that expected from typical airfoil characteristics. This observation was in fact the motivation for developing the CMA stall model.

Figures 22 through 25, show the same comparisons as already made, but now with the new stall model. The key values in the stall model were set to realistic magnitudes guided by the flat plate characteristics given in Reference 15. This is as might be done without any knowledge of a particular airfoil's high angle behavior, resulting in

$$c_{l_{45}} = c_{d_{45}} = 1$$

$$c_{l_{90}} = 0$$

$$c_{d_{90}} = 2$$

$$\alpha_r = 32$$

In addition a value of $B_{pr} = 0.5960$, was chosen. This corresponds to the ratio of the maximum drag (at 90 degrees angle of attack) of a low aspect ratio flat plate to a two-dimensional flat plate. The reasoning is that rather than an aspect ratio effect venting the leeward side of the stalled region of a blade toward ambient pressure, the naturally occurring radial pressure gradient of the rotating system and large scale mixing would cause complete venting, independent of the position or extent of the stalled region. However, results thus far have indicated that this factor has insignificant effect for the present cases. The stall occurring in the peak power range of wind speeds is dominated by the stall transition characteristics rather than the characteristics at higher angles.

Figure 22, is the result for the MOD-0 turbine and shows that the LSWT calculation is now in much better agreement with the measured data up through peak power. At the very high wind speeds the calculations are now increasingly conservative. Similar differences with respect to the results with the Viterna model are seen for the other example cases. The overall agreement between measurements and the LSWT calculations using the new stall model for all of the example turbines is considered very good, with the exception of the high yaw angle data of the Enertech 1500 as previously noted. This suggests that the ability to predict peak power with the present method is improved over the blade element momentum method. Although these calculations should be viewed as preliminary, it is emphasized that careful modeling of the physical configurations in the LSWT analysis combined with straight forward estimates of the airfoil behavior produced these results.

CONCLUSIONS AND RECOMMENDATIONS

A comprehensive lifting surface analysis for horizontal axis wind turbine rotors has been developed and implemented, and the initial validation conducted for the prediction of steady rotor power output. The method uses a prescribed wake model extended from a helicopter hovering wake model with modifications for the axial flow regime of the wind turbine. The analysis now provides the opportunity to investigate and define the sensitivity of wind turbine aerodynamic calculations and performance estimates to much finer details of modeling than was previously possible. The important effects of proper representation of airfoil characteristics in the stall transition region was demonstrated and a new stall simulation model was developed from which refinements can be systematically made.

Several recommendations are in order to pursue further development of the method, and to clarify a number of physical issues, especially in regard to understanding and modeling stall aerodynamics. First, validation of the lifting surface method should be broadened and include detailed evaluation of modeling options, particularly those associated with the wake itself. With the flexibility of the present wake model it should be possible to establish the minimum model required to produce reliable results with minimum demand on computational resource.

Second, stall aerodynamics should be investigated to understand the theoretical requirements to extend both momentum theory and potential flow analysis methods into the stall regime. In conjunction with this, a better understanding of airfoil stall transition behavior should be sought, most probably guided by experimental investigations, the goal of which would be to establish a baseline from which methods to account for stall progression and three-dimensionality on the blade can be developed.

The importance of vortex ring work state induced velocity should be clarified, and the significant differences between the Glauert empirical model and conflicting experimental data should be reconciled.

Finally, to support validation of methods such as developed in the present work, a wind turbine data base should be established which contains documented physical characteristics, airfoil aerodynamic coefficients with sufficient definition in Reynolds's number and stall behavior, and substantiated benchmark aerodynamic and performance measurements for several representative wind turbines.

REFERENCES

1. Kocurek, J.D., Berkowitz, L.F., and Harris, F.D., "Hover Performance Methodology at Bell Helicopter Textron," Presented at the 36th Annual National Forum of the American Helicopter Society, Washington, D.C., Paper No. 80-3-1, May 1980.

2. Kocurek, J.D., A Lifting Surface Performance Analysis with Circulation Coupled Wake for Advanced Configuration Hovering Rotors, Ph.D. Dissertation, Texas A&M University, May 1978.

3. Kocurek, J.D., Tangler, J.L., " A Prescribed Wake Lifting Surface Hover Performance Analysis," Presented at the 32nd Annual National Forum of the American Helicopter Society, Washington, D.C., Paper No. 1001, May 1976.

4. Glauert, H., "Airplane Propellers," Vol. IV, Div. L of Aerodynamic Theory, W.F. Durand, ed., Julius Springer, Berlin, 1935.

5. Wilson, R.E., Lissaman, P.B.S., and Walker, S.M., "Aerodynamic Performance of Wind Turbines," Oregon State University, Research Applied to National Needs (RANN), under Grant no. AER74-04014 A03, 1976.

6. Hibbs, B., and Radkey, R.L., Calculating Rotor Performance with the Revised Prop Code, AeroVironment, Inc., Pasadena, California, Contract No. PFN-13470W, Prepared for Rockwell International Corporation, Energy Systems Group, Rocky Flats Plant, Wind Energy Research Center, Golden, Colorado, March 1984.

7. Castles, Jr.,W., and Gray, R.B., Empirical Relation Between Induced Velocity, Thrust, and Rate of Descent of a Helicopter Rotor as Determined by Wind-Tunnel Tests on Four Model Rotors, NACA TN 2474, Washington, D.C., October 1951.

8. Gray, R.B., An Aerodynamic Analysis of a Single Bladed Rotor in Hovering and Low Speed Forward Flight as Determined from the Smoke Studies of the Vorticity Distribution in the Wake, Princeton Aeronautical Engineering Department Report No. 356, September 1956.

9. Landgrebe, A.J., An Analytical and Experimental Investigation of Helicopter Rotor Hover Performance and Wake Geometry Characteristics, USAAMRDL Technical Report 71-24, Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, June 1971.

10. Egolf, T.A. and Landgrebe, A.J., "The UTRC Wind Energy Conversion System Performance Analysis for Horizontal Axis Wind Turbines (WECSPER)," Presented at the 2nd DOE/NASA Wind Turbine Dynamics Workshop, Cleveland, Ohio, February 1981.

11. Miller, R.H., Simplified Free Wake Analysis for Rotors, ASRL TR 194-3, Aeroelastic and Structures Research Laboratory, Department Aeronautics and Astronautics, Massachusetts, August 1981.

12. Glauert, H., "The Analysis of Experimental Results in the Windmill Brake and Vortex Ring States of an Airscrew," R. and M. No. 1026, British A.R.C.,February 1926.

13. Drees, J. M., Lucassen, L. R., and Hendal, W. P., "Airflow Through Helicopter Rotors in Vertical Flight," N.L.L. Report V.1535, December 1955.

14. Viterna, L. A. and Corrigan, R. D., "Fixed Pitch Rotot Performance of Large Horizontal Axis Wind Turbines," presented at the DOE/NASA Workshop on Large Horizontal Axis Wind Turbines, Cleveland, Ohio, July, 1981.

15. Hoerner, S. F., Fluid Dynamic Drag, Published by the Author, 1965.

16. Abbott, I.H., and von Doenhoff,A.E., Theory of Wing Sections, Dover Publications, Inc., 1958,pp. 8-30.

17. Jacobs, E. N. and Sherman, A., Airfoil Section Characteristics as Affected by Variations of the Reynolds Number, NACA Report 586.

18. Thresher, R.W., and Hershberg, E.L., Computer Analysis Of Wind Turbine Blade Static And Dynamic Loads, Mechanical Engineering Department, Oregon State University, Contract No. ASC76824JR, Prepared for Rockwell International Corporation, Energy Systems Group, Rocky Flats Plant, Wind Energy Research Center, Golden, Colorado, March 1984.

19. Tangler, J. L., Horizontal-Axis Wind System Rotor Performance Model Comparison, A Compendium, RFP-3508 UC-60, Rockwell International Corporation, February, 1983.

APPENDIX A

LSWT INPUT SEQUENCE GUIDE

LSWT INPUT SEQUENCE GUIDE

The input data set for computer program LSWT is organized into four groups of records described as INPUT SETS 1 through 4. INPUT SET 1 contains case set-up, control, and option parameters. The second set describes blade geometry in terms of piecewise linear radial distributions of planform parameters such as chord and pitch increment due to twist. The distribution of airfoils is also contained in this set.

The blade configuration of the turbine is described by as many as four independent segments. Each segment requires the input sequence in INPUT SET 2. Segment boundaries should be chosen to correspond to physical details of the blade such as changes in chord taper ratio, twist rate, and airfoil designation. Because the blade need not be continuous, the segmentation scheme can also be used to model actual breaks in the geometry as might correspond to a step change in local pitch.

INPUT SET 3 is optional and provides the additional information and options to run LSWT in quasi-steady mode. The fourth set contains bivarient tables of two-dimensional airfoil characteristics as functions angle of attack and Reynold's number, along with parameters for the several analytical stall models which may be selected.

In the following sections, record-by-record descriptions of the input set to LSWT are described. Each record contains a maximum of 72 characters, thus allowing for sequence numbers to be placed in columns 73-80. All numeric data, including integer switch and option values, is input in floating point notation in fields of ten columns formated as F10.0, with a maximum of seven fields per record.

INPUT SET 1, CASE SET-UP AND CONTROL OPTIONS

RECORD 1 (72A1) Case Identification

FIELD	NAME	DESCRIPTION
1-72	CASID	user notation to be displayed on report pages

RECORD 2A (7F10.0) Print Options Switches

1-10	IPRT1	surface grid and collocation point coordinates
	0.0	option off
	1.0	print each azimuth
	2.0	print initial azimuth only
	3.0	print reference blade position only
11-20	IPRT2	wake coordinates
	0.0	option off
	1.0	print each cycle
	2.0	print each azimuth
	3.0	print final azimuth only
21-30	IPRT3	blade element performance summary
	0.0	option off
	1.0	print each cycle
	2.0	print final cycle only
31-40	IPRT4	blade performance summary
	0.0	option off
	1.0	print each cycle
	2.0	print final cycle only
41-50	IPRT5	rotor performance summary
	0.0	option off
	1.0	print each cycle
	2.0	print final cycle only

51-60 IPRT6 wake parameter summary

0.0	option off
1.0	print each cycle
2.0	print final cycle only

61-70 IPRT7 controls printing of program trace markers to show timing and flow through major modules and subroutines.

0.0	option off
>0.0	print program trace to unit pointed to by IPRT7

RECORD 2B (7F10.0) Print Options, continued

1-10 IPRT8 controls printing of record image of input data set to the output listing

0.0	option off
1.0	print image of input data set

RECORD 3 (7F10.0) Tolerances

Program default tolerances are selected by entering a zero value for any tolerance. Any non-zero entry will be used to override the default. Convergence of any parameter occurs when the absolute value of the quantity

$$\frac{\text{(new value) - (old value)}}{\text{(new value)}} \leq \text{tolerance}$$

1-10 TOL1 convergence tolerance of Gauss-Seidel iterative solution for circulation. The default is 1.0E-05 for the inner solution. The outer solution tolerance is (TOL1)*10.

11-20 TOL2 sectional effective linear lift curve slope tolerance. The default is a function of the lift slope and is given by

```
1.0/ALS**2
```

or set to 1.0E-02, whichever is greater.

21-30 TOL3 wake parameter tolerance (axial settling rate). The default is 5.0E-02

RECORD 4 (7F10.0) Iteration Cycle Limits

Program default iteration cycle limits are selected by entering a zero value for any limit. Any non-zero entry will be used to override the default. The particular iteration will be halted after the specified number of cycles, regardless of the convergence state.

1-10	ICYL1	Gauss-Seidel iterative solution for circulation. The default for he inner solution is 100 cycles. The limit for the outer solution is (ICYL1)/5.
11-20	ICYL2	sectional effective linear lift curve slope. The default is four cycles.
21-30	ICYL3	wake parameters. The default is six cycles.
31-40	ICYL4	tip vortex rollup. The default is four cycles.

RECORD 5 (7F10.0)

1-10	ISTDY	Steady/Quasi-Steady Mode Switch
	0.0	case is steady, INPUT SET 3 must be omitted
	1.0	case is quasi-steady, INPUT SET 3 is required
11-20	RPM	rotor rotational speed (revolutions per min)
21-30	AMURAT	ratio of atmospheric viscosity to the standard day, sea-level value, $\mu_0 = 3.719 \times 10^{-7}$ slugs/ft-sec.
31-40	SIGMAP	ratio of atmospheric density to the standard day, sea-level value, $\rho_0 = 0.002378$ slugs/ft^3

RECORD 6 (7F10.0) Wind Speed Sweep Options

1-10	VWOIN	initial value of wind speed (dimension corresponds to value of VDIM input below)
11-20	DVWO	sweep increment of wind speed (dimension corresponds to value of VDIM input below)
21-30	NVWO	number of points in sweep
31-40	VDIM	Wind speed dimension switch
	0.0	ft/sec
	1.0	meters/sec
	2.0	miles per hour
	3.0	tip speed ratio

RECORD 7 (7F10.0) Rotor Collective Pitch

1-10	ALPSIN	initial value of blade pitch (deg)
11-20	DALP	sweep increment of blade pitch (deg)
21-30	NALP	number of points in sweep
31-40	THRUST	initial value of thrust (lbs)

RECORD 8 (7F10.0) Rotor Parameters

1-10	NBLDS	number of blades
11-20	MP	number of chordwise panels per blade ($1 \leq MP \leq 5$)
21-30	NSGMNT	number of blade segments per blade ($1 \leq NSGMNT \leq 4$)
31-40	RADIUS	reference radius used to make geometry and parameters non-dimensional (ft)

RECORD 9 (7F10.0) Wake Options

1-10	REVS	number of wake revolutions in discrete wake region
11-20	NWIPR	number of wake increments per revolution (this value will be automatically adjusted in the first revolution to provide a fine grid). Note: $(REVS + 1) * NWIPR + 1 \leq 133$
21-30	IFWAK	far wake option
	0.0	analytical far wake influence is not included in induced velocity calculations
	1.0	analytical far wake influence is included in induced velocity calculations.
31-40	PSIMR	azimuth increment over which inboard sheet will develop into root vortex
41-50	PSIMT	azimuth increment over which outboard sheet will develop into tip vortex
		Assure that values are chosen for PSIMR and PSIMT that clear the blade's trailing edge, and that complete vortex development within 360 deg.
51-60	IROLL	roll-up iteration option. Active only if outboard sheet and either mid- or inboard sheets are selected in RECORD 10.
	0.0	iteration supressed
	1.0	compatibility of tip vortex circulation and number of rolled-up wake filaments will be assured through iteration (ICYL4)

RECORD 10 Wake Sheet Filament Indices For Roll-up Specification

The wake may be divided into three sheet regions, an inboard sheet, a mid-sheet, and an outboard sheet. The bounding filaments for each sheet region are specified by their indices in RECORD 10. Any sheet region may be omitted by setting its bounding indices to zero. If an inboard or outboard sheet is selected, it will develop into a rolled-up vortex over the azimuth increment PSIMR or PSIMT, respectively, as given in RECORD 9. At least one sheet must be selected. Bounding indices must be sequential

At least one sheet must be selected. Bounding indices must be sequential from root to tip, and must be exclusive to a single region.

1-10	JS(1,1)	index of inboard filament of inboard sheet
11-20	JS(1,2)	index of outboard filament of inboard sheet
21-30	JS(2,1)	index of inboard filament of mid-sheet
31-40	JS(2,2)	index of outboard filament of mid-sheet
41-50	JS(3,1)	index of inboard filament of outboard sheet
51-60	JS(3,2)	index of outboard filament of outboard sheet

INPUT SET 2, BLADE SEGMENT DESCRIPTIONS

The blade is described by as many as four independent segments. Each segment requires the input sequence in INPUT SET 2. NSGMNT segment descriptions are required. The segments are numbered from inboard to outboard, and the segment descriptions must also be input in inboard to outboard sequence.

RECORD 1 (7F10.0) Segment Options And Parameters

1-10	NPS	number of spanwise panels on segment (The maximum number of panels for the blade is twenty. The minimum for each segment is one.)
11-20	NGRID	spanwise grid (panel boundary) option for segment
	1.0	equal spacing
	2.0	full cosine distribution
	3.0	half cosine, density increased inboard
	4.0	half cosine, density increased outboard
21-30	XOCREF	non-dimensional chord reference of input quantities
31-40	YSEG(1)	inboard extent of segment, (ft)
41-50	YSEG(2)	outboard extent of segment, (ft)

RECORD 2 (7F10.0) Segment Orientations

1-10	XTRAN	translations (ft) to place segment in desired position
11-20	YTRAN	
21-30	ZTRAN	
31-40	XROT	rotations (deg) to place segment in desired position
41-50	YROT	
51-60	ZROT	

RECORD 3 (7F10.0) Segment Chord Distribution

1-10 NCHORD number of chord inputs (2 < NCHORD < 24)

RECORD 4A [, 4B [, 4C [, 4D]]] (7F10.0)

1-10 YCHORD(1) blade stations (ft) at which piecewise linear chord distribution is specified

11-20 YCHORD(2)

... as required

61-70 YCHORD(7)

Continue with RECORDS 4B, 4C, AND 4D as required to input NCHORD values of YCHORD.

RECORD 5A [, 5B [, 5C [, 5D]]] (7F10.0)

1-10 CHORD(1) value of blade chord (ft) corresponding to the YCHORD stations input in RECORD 4

11-20 CHORD(2)

... as required

61-70 CHORD(7)

Continue with RECORDS 5B, 5C, and 5D as required to input NCHORD values of CHORD.

RECORD 6 (7F10.0) Segment Twist Distribution

1-10 NTWIST number of twist inputs (2 ≤ NTWIST ≤ 24)

RECORD 7A [, 7B [, 7C [, 7D]]] (7F10.0)

1-10 YTWIST(1) blade stations (ft) at which piecewise linear twist distribution is specified

11-20 YTWIST(2)

... as required

61-70 YTWIST(7)

Continue with RECORDS 7B, 7C, AND 7D as required to input NTWIST values of YTWIST.

RECORD 8A [, 8B [, 8C [, 8D]]] (7F10.0)

1-10 TWIST(1) value of blade twist increment (deg) corresponding to the YTWIST stations input in RECORD 7

11-20 TWIST(2)

... as required

61-70 TWIST(7)

Continue with RECORDS 8B, 8C, and 8D as required to input NTWIST values of TWIST.

RECORD 9 (7F10.0) Segment Planform Offset Distribution

1-10 NXAOFF number of planform offset inputs ($2 \leq NXAOFF \leq 24$)

RECORD 10A [, 10B [, 10C [, 10D]]] (7F10.0)

1-10 YXAOFF(1) blade stations (ft) at which piecewise linear planform sweep offset distribution is specified

11-20 YXAOFF(2)

... as required

61-70 YXAOFF(7)

Continue with RECORDS 10B, 10C, AND 10D as required to input NXAOFF values of YXAOFF.

RECORD 11A [, 11B [, 11C [, 11D]]] (7F10.0)

1-10 XAOFF(1) values of blade planform offset (ft) corresponding to the YXAOFF stations input in RECORD 10

11-20 XAOFF(2)

... as required

61-70 XAOFF(7)

Continue with RECORDS 11B, 11C, AND 11D as required to input NXAOFF values of XAOFF.

RECORD 12 (7F10.0) Segment Airfoil Distribution

1-10 NAFT number of airfoil region definition inputs, ($1 \leq NAFT \leq 24$)

RECORD 13A, ... (7F10.0)

1-10 IDAF(1) three digit airfoil table identification code

11-20 YAFT(1,1) inboard extent of this airfoil (ft)

21-30 YAFT(1,2) outboard extent of this airfoil (ft)

Continue with RECORDS 13B, ... as required to input NAFT records.

INPUT SET 3, Quasi-Steady Mode

Input set 3 is only required if ISTDY = 1 (Input set 1, Record 5), otherwise it must be omitted.

RECORD 1 (7F10.0) Azimuth Sweep

1-10	PSIRIN	initial value of azimuth at which blade 1 will be placed (deg)
11-20	DPSIR	sweep increment (deg)
21-30	NPSIR	number of points in sweep

RECORD 2 (7F10.0) Shaft Orientation and Wind Profile

1-10	ALPS1	shaft inclination with respect to wind, positive shaft down into wind.
11-20	ALPS2	shaft yaw with respect to wind, positive shaft right into wind
21-30	HO	hub height (ft) above ground
31-40	E	exponent of shape function for atmospheric boundary layer
41-50	ITSTYP	tower shadow model option
	0.0	tower shadow not included
	1.0	tower shadow equations used
	2.0	tower shadow table used

RECORD 3A (7F10.0) Tower Shadow Velocity Deficit Fraction Equations. Input Required If ITSTYP = 1, otherwise omit this RECORD.

For the equation option, the tower shadow velocity deficit fraction is defined from

$$T_s(\psi) = t_0 + t_p \cos[p(\psi - \psi_s)] \quad \text{for } \psi_s - \psi_0 < \psi < \psi_s + \psi_0$$

$T_s(\psi) = 0$, elsewhere

1-10	TO	t_0
11-20	TP	t_p
21-30	TPO	ψ_0 (deg)
31-40	TPS	ψ_s (deg)
41-50	TK	k, defines $p = 2\pi k/(2\psi_0)$

RECORD 3B (7F10.0) Tower Shadow Velocity Deficit Fraction Table. Input Required If ITSTYP = 2, otherwise omit RECORDS 3B-5B.

1-10	NXTS	number of X-grid entries
11-20	NYTS	number of Y-grid entries

The table size is based on the combination of NXTS and NYTS subject to the constraint

$$8 \leq NXTS+NYTS+(NXTS*NYTS) \leq 100$$

The program stores the table internally in the array TSTAB(I) where table members and indices are as follows:

X-grid locations	$1 \leq I \leq NXTS$
Y-grid locations	$(NXTS+1) \leq I \leq (NXTS+NYTS)$
velocity deficit coefficients	$(NXTS+NYTS+1) \leq I \leq (NXTS+NYTS+(NXTS*NYTS))$

The minimum table requires four grid point locations (two each of X-grid and Y- grid) and four velocity deficit coefficients. The program will interpolate the table for a velocity deficit coefficient for all blade collocation point locations and for all wake filament trajectory points. If the program requires a value of the velocity deficit coefficient outside the rectangle specified by the grid locations, then it will be assumed that there is no deficit for that point.

RECORD 4A, ... (10X,6F10.0) Tower Shadow Table X-Grid Locations

11-20 TSTAB(1) values of X-grid locations (ft)

21-30 TSTAB(2)

... as required

61-70 TSTAB(7)

Continue with RECORDS 4B, ... as required to input NXTS values of the X-grid location

RECORD 5A (7F10.0) Tower Shadow Table Y-Grid Locations

1-10 TSTAB(NXTS+1) value of Y-grid location (ft)

11-20 TSTAB(NXTS+NYTS+1) velocity deficit coefficients

21-30 TSTAB(NXTS+NYTS+2)

... as required

61-70 TSTAB(NXTS+NYTS+6)

Continue with RECORDS 5B, ... as required to input NXTS values of velocity deficit coefficients for this Y-grid location.

RECORD 5B, ... (10X,6F10.0) Velocity Deficit Fraction Coefficients, Continued

11-20 TSTAB(NXTS+NYTS+7) velocity deficit fraction coefficients

21-30 TSTAB(NXTS+NYTS+8)

... as required

61-70 TSTAB(NXTS+NYTS+12)

Continue with RECORDS 5C, ... as required to input NXTS values of velocity deficit coefficients for this Y-grid location.

RECORD 6 (7F10.0) Flapping Motion Coefficients

1-10	NBH	number of harmonics in series ($0 \leq NBH \leq 5$)
11-20	AB(1,1)	constant coefficient

RECORD 7 (7F10.0) Sine Terms

1-10	AB(2,1)	coefficients of sine terms (deg)
11-20	AB(3,1)	
... as required to input NBH coefficients		
41-50	AB(6,1)	

RECORD 8 (7F10.0) Cosine Terms

1-10	AB(2,2)	coefficients of cosine terms (deg)
11-20	AB(3,2)	
... as required to input NBH coefficients		
41-50	AB(6,2)	

RECORD 9 (7F10.0) Cyclic Motion Coefficients

1-10	NTH	number of harmonics in series ($0 \leq NTH \leq 5$)
11-20	AT(1,1)	constant coefficient

RECORD 10 (7F10.0) Sine Terms

1-10	AT(2,1)	coefficients of sine terms (deg)
11-20	AT(3,1)	
... as required to input NTH coefficients		
41-50	AT(6,1)	

RECORD 11 (7F10.0) Cosine Terms

1-10	AT(2,2)	coefficients of cosine terms (deg)
11-20	AT(3,2)	
... as required to input NTH coefficients		
41-50	AT(6,2)	

INPUT SET 4, AIRFOIL DATA TABLES

Two-dimensional bivarient airfoil tables provide lift, drag, and pitching moment coefficient characteristics as functions of angle of attack and Reynold's number. Each airfoil data table requires the input sequence in INPUT SET 4. The number of tables required depends upon the airfoil descriptions specified in INPUT SET(S) 2. At least one table must be input. The program is dimensioned to accomodate a maximum of four tables. Each table's size is such that any combination of its size parameters (RECORD 3 of this set) must meet the constraints

$$NACL+NRCL+(NACL*NRCL) \leq 200$$

$$NACD+NRCD+(NACD*NRCD) \leq 200$$

$$NACM+NRCM+(NACM*NRCM) \leq 100$$

The program stores each table internally in a column (JAFT) of the arrays CxTAB(I,JAFT), where 'x' represents 'L' for a lift table , 'D' for a drag table or 'M' for a pitching moment. The storage array column contains the table members in the following sequence:

Reynolds numbers	$1 \leq I \leq NRCx$
Angles Of Attack	$(NRCx+1) \leq I \leq (NRCx+NACx)$
Aero-Coefficients	$(NRCx+NACx+1) \leq I \leq (NRCx+NACx+(NRCx*NACx))$

The minimum size table requires NACx = 2, and NRCx = 1. In this case the interpolation on Reynold's number is suppressed and the one value of Reynold's number input is for reference only. Also the table must contain suficient data so that the angle for zero lift may be determined.

RECORD 1 (7F10.0) Number Of Tables, Stall Option

1-10 NAFT number of tables to be input ($1 \leq NAFT \leq 4$)

11-20 IAFTEX analytical stall region option

0.0	tables will be extrapolated for angles outside of range
1.0	stalled flat plate model
2.0	Viterna's stall model
3.0	CMA stall model

RECORD 2 (F10.0, A62) Airfoil Table ID

1-10	IDAFT(1)	table identifier (3-digit number)
11-72	TITLE	descriptive information

RECORD 3 (7F10.0) Table Size Parameters

1-10	NRCL	number of Reynolds numbers in lift table
11-20	NACL	number of angles of attack in lift table
21-30	NRCD	number of Reynolds numbers in drag table
31-40	NACD	number of angles of attack in drag table
41-50	NRCM	number of Reynolds numbers in moment table
51-60	NACM	number of angles of attack in moment table

RECORD 4, ... (7F10.0) Stall Model Parameters

This record is included to allow convenient access to stall model parameters used in the present implementation, and for future refinement of these models. The first field in the record is the thickness to chord ratio for the airfoil described by the present table. Six subsequent fields are available to pass parameters to the stall models. The current input requirements are dependent upon the selected stall model as shown.

1-10 AFTOC thickness to chord ratio of airfoil

For IAFTEX = 0.0 or 1.0, no further input is required for this record.

For IAFTEX = 2.0, input the blade aspect ratio to be used in the Viterna stall model. No further input is required for this record.

11-20 AR

For IAFTEX = 3.0, input the stall region delimiters used in the CMA stall model.

11-20	ALPR	angle of attack (deg) at which table coefficients recover to and follow the analytical model
21-30	CL45	lift coefficient at 45 degrees
31-40	CD45	drag coefficient at 45 degrees
41-50	CL90	lift coefficient at 90 degrees
51-60	CD90	drag coefficient at 90 degrees
61-70	BPR	base pressure relief factor which will multiply coefficients at angles above ALPR

RECORD 5A, ... (10X,6F10) Lift Table Reynolds Numbers

11-20	CLTAB(1)	values of Reynolds number, ratioed to 10^6
21-30	CLTAB(2)	
...	as required	
61-70	CLTAB(6)	

Continue with RECORDS 5B, ... as required to input NRCL values of Reynolds number.

RECORD 6A (7F10) Angle Of Attack And Lift Coefficients

1-10	CLTAB(NRCL+1)	angle of attack (deg)
11-20	CLTAB(NRCL+NACL+1)	lift coefficients for this angle of attack
21-30	CLTAB(NRCL+NACL+2)	
...	as required	
61-70	CLTAB(NRCL+NACL+6)	

Continue with RECORDS 6B, ... as required to input NRCL values of lift coefficient for this angle of attack.

RECORD 6B (10X,6F10) Lift Coefficients, Continued

11-20	CLTAB(NRCL+NACL+7)	lift coefficients for this angle of attack, continued
21-30	CLTAB(NRCL+NACL+8)	
...	as required	
61-70	CLTAB(NRCL+NACL+12)	

Continue with RECORDS 6C, ... as required to input NRCL values of lift coefficient for this angle of attack.

Repeat RECORDS 6 format for next angle of attack and corresponding lift coefficients, until NACL angles of attack have been input.

RECORD 7A, ... (10X,6F10) Drag Table Reynolds Numbers

11-20	CDTAB(1)	values of Reynolds number, ratioed to 10^6
21-30	CDTAB(2)	
...	as required	
61-70	CDTAB(6)	

Continue with RECORDS 7B, ... as required to input NRCD values of Reynolds number.

RECORD 8A (7F10) Angle Of Attack And Drag Coefficients

1-10	CDTAB(NRCD+1)	angle of attack (deg)
11-20	CDTAB(NRCD+NACD+1)	drag coefficients for this angle of attack
21-30	CDTAB(NRCD+NACD+2)	

... as required

61-70 CDTAB(NRCD+NACD+6)

Continue with RECORDS 8B, ... as required to input NRCD values of drag coefficient for this angle of attack.

RECORD 8B (10X,6F10) Drag Coefficients, Continued

11-20 CDTAB(NRCD+NACD+7) drag coefficients for this angle of attack, continued

21-30 CDTAB(NRCD+NACD+8)

... as required

61-70 CDTAB(NRCD+NACD+12)

Continue with RECORDS 8C, ... as required to input NRCD values of drag coefficient for this angle of attack.

Repeat RECORDS 8 format for next angle of attack and corresponding drag coefficients, until NACD angles of attack have been input.

RECORD 9A, ... (10X,6F10) Moment Table Reynolds Numbers

11-20 CMTAB(1) values of Reynolds number, ratioed to 10^6

21-30 CMTAB(2)

... as required

61-70 CMTAB(6)

Continue with RECORDS 9B, ... as required to input NRCM values of Reynolds number.

RECORD 10A (7F10) Angle of Attack And Moment Coefficients

1-10 CMTAB(NRCM+1) angle of attack (deg)

11-20 CMTAB(NRCM+NACM+1) moment coefficients for this angle of attack

21-30 CMTAB(NRCM+NACM+2)

... as required

61-70 CMTAB(NRCM+NACM+6)

Continue with RECORDS 10B, ... as required to input NRCM values of moment coefficient for this angle of attack.

RECORD 10B (10X,6F10) Moment Coefficients, Continued

11-20 CMTAB(NRCM+NACM+7) moment coefficients for this angle of attack, continued

21-30 CMTAB(NRCM+NACM+8)

... as required

61-70 CMTAB(NRCM+NACM+12)

Continue with RECORDS 10C, ... as required to input NRCM values of moment coefficient for this angle of attack.

Repeat RECORDS 10 format for next angle of attack and corresponding moment coefficients, until NACM angles of attack have been input.

APPENDIX B

PROGRAM AND INSTALLATION NOTES

PROGRAM AND INSTALLATION NOTES

The Program LSWT source code is written in FORTRAN and should be installable on most host systems with only minor modifications for compatibility with system dependent interfaces. Program LSWT was developed and is currently implemented under the Microsoft FORTRAN compiler, Version 3.2, for the MS-DOS Operating System on the IBM PC class of microcomputers. Language extensions have been avoided so that the program can be installed using any FORTRAN compiler designed to the '66 or '77 standard. Program LSWT is computationally intensive and therefore fully expanded hardware including a floating point accelerator is highly recommended.

The LSWT source code is maintained in eight files or modules of functionally related subprogram units. Table B-1 describes each module and lists its subprograms. This grouping arrangement and file sizing are recommended for convenient program maintenance and compatibility with editors. A complete listing of Program LSWT is provided as Appendix C.

SYSTEM INTERFACE

Source module LSWT07 contains all code required to interface Program LSWT to the host system. This module is presently designed toward a foreground execution environment as typically found on a single-user microcomputer system. All files are managed from within the program, and particular file specifications for standard input and output are prompted from and supplied by the user at execution time. To accomplish this, subroutines CLRSCN and LOCATE are provided for console screen handling. these use standard escape sequences for ANSI compatible terminal devices. Note that the use of this capability on an IBM PC type computer requires the ANSI.SYS device driver be installed when the operating system is booted. For other terminal types the screen handling routines must be modified appropriately. For Program LSWT installation in a batch type environment these interfaces may be completely eliminated, provided that the program

TABLE B-1. LSWT PROGRAM MODULE SUMMARY

Module/Subroutine	Function
LSWT01.FOR	Executives and Utilities
MAIN	Main Program and Executive
INTLS	Initialize Lift Curve Slopes
EXINT	Initialize Program
EXBLD	Generate Reference Blade Geometry
EXAIC	Aerodynamic Influence Coefficients
EXSLV	Lifting Surface Solution
BVTINT	Bi-Varient Table Interpolation
ZROLFT	Determine Zero Lift LIne From Airfoil Tables
LSWT02.FOR	Lifting Surface Core Analysis
AICDLS	Calculate 2-D Aerodynamic Influence Coefficients
AICDS	Calculate Lifting Surface AIC's
AICDW	Calculate Wake AIC's
AICDSW	Assemble AIC Matrix From Components
GSITER	Solve Linear Equations By Gauss-Seidel Iteration
VLINE	Calculate Velocity Induced By Line Vortex
VCYLN	Calculate Velocity Induced By Vortex Cylinder
LSWT03.FOR	Blade And Rotor Geometry
GRID	Generate Blade Surface Grid System
COLCRD	Calculate Location Of Collocation Points
RFSURF	Develop Reference Blade Surface Geometry
AFTLOC	Determine Airfoil Table Indices At Solution Stations
LINTRP	Perform Linear Interpolation Of Geometry Parameters
ROTATE	Perform Rotation Transformation Of Coordinates
PSURF	Place Reference Blade At Target Position
VPANG	Calculates The Sine Of Angle Between Two Vectors
LSWT04.FOR	Prescribed Wake Geometry
PREWAK	Generate Prescribed Wake
FILMNT	Calculate Wake Filament Coordinates
FILROL	Calculate Rolled-Up Wake Filament Coordinates
PWAKE	Position Reference Wake Coordinates
WAKPRM	Determine Prescribed Wake Parameters
WAKUPD	Update Wake Parameters
ROLNDX	Update Wake Sheet Indices For Roll-Up Iteration

TABLE B-1 (CONTINUED)

Module/Subroutine	Function
LSWT05.FOR	Program Input
READIN	Main Input Subroutine
READAF	Set Up To Read Airfoil Tables
REDTAB	Read Tables
LSWT06.FOR	Program Output Reports
OUT1	Report Reference Blade Surface Coordinates
OUT2	Report Reference Blade's Wake Coordinates
OUT3	Report Blade Element Aerodynamic Characteristics
OUT4	Report Blade Performance Summary
OUT5	Report Rotor Performance Summary
OUT6	Report Wake Parameters And Work State
OUT8	Report Record Image Of Input File
HEADER	Write Banner And Case Information On Report Pages
APPEND	Append IOBUFFER File To Standard Output File
LSWT07.FOR	System Interface
IOINIT	Initialze I/O System
IOFNSH	Close I/O System
TRACE	Generate Program Position And Timing Markers
TIMER	Interface To System Clock
LOCATE	Position Console Display Cursor
CLRSCN	Clear Console Display
LSWT08.FOR	Aerodynamic Calculations
WNDPRO	Determine Wind Profile
FLPVEL	Calculate Blade Flapping Velocity
NRMLBC	Impose Normalwash Boundary Condition
CIRPRM	Calculate Circulation Parameters
BEVEL	Calculate Blade Element Velocities
CWAVG	Calculate Chordwise Parameter Average
BEALPH	Calculate Blade Element Angles Of Attack
AFCOEF	Calculate Airfoil Aerodynamic Coefficients
AFTEXT	Calculate Airfoil Post Stall Characteristics
AEROPF	Calculate Aerodynamic Performance

file system (FORTRAN Unit Numbers) can be associated with external devices or files on external devices, and managed from the operating system's command language.

Program timing information is available from subroutine TIMER. Within TIMER, a call is made to system dependent subroutine SYSTIM which reads the system clock and returns the time in hours, minutes, seconds, and hundredths of seconds. TIMER calculates lapsed time and reports it to the output stream. The SYSTIM interface subroutine (or a dummy routine) must be provided for the particular host system. This is the only non-FORTRAN code required by Program LSWT. An implementation of SYSTIM written in assembly language for the IBM PC family of processors is included in Appendix C.

LSWT FILE SYSTEM

The file system is initialized in subroutine IOINIT where default unit numbers are assigned to integer variable unit pointers. These variable pointers are passed to the subprograms requiring them through a common block. All program references to I/O units are made to these pointers, thus the actual unit number assignment is only required in IOINIT. The variables used for the I/O units and the function of each file are outlined in Table B-2.

IOU1 is associated with the system console device for both input and output. The remaining units fall into two categories. IOU5 through IOU8 are the usual sequential, formatted I/O files. IOU10 through IOU13 are auxiliary mass storage files required for temporary retention of large arrays during program execution. These files are direct access and unformatted. The record lengths and formulas for calculation of actual space requirements for these files is included in the commented listing of IOINIT. The use of this file structure minimizes program internal storage requirements by requiring, for instance, only one column of the influence coefficient matrix of the linear equation system to be resident at any time.

TABLE B-2. FILE SYSTEM DESCRIPTION

Unit	Use
IOU1	Console
IOU5	Standard Input
IOU6	Standard Output
IOU7	Trace File (Not An Actual File, Only Points to Another Output Unit)
IOU8	Temporary Output Buffer
IOU10	Mass Storage File For Blade Surface AIC's
IOU11	Mass Storage File For Wake AIC's
IOU12	Mass Storage File For Combined AIC Array
IOU13	Mass Storage File For Wake Coordinates

COMMON BLOCK STRUCTURE

Program LSWT common blocks are maintained in individual files and combined with the source code through INCLUDE statements at compile time. The format of the file names is the actual name of a particular block with the extension '.CMN' appended. This insures that common variables share the same name and dimensions across all program units. Also, rather than listing the included common files directly in a particular subprogram, a single include file for each subprogram is used, and this file lists the individual common files. The naming convention for these list files uses the subprogram name with the extension '.CML' appended. The common block file names and the common list file names along with their contents are given in Table B-3 and Table B-4, respectively.

TABLE B-3. COMMON BLOCK FILES

```
FILE: 'AFTABL.CMN'

      COMMON/ AFTABL / NAFT,   IDAFT(4),       AFTOC(4),       IAFTEX,
     1                 STP1(4),          STP2(4),          STP3(4),
     2                 STP4(4),          STP5(4),          STP6(4),
     3                 CLTAB(200,4),     NRCL(4),          NACL(4),
     4                 CDTAB(200,4),     NRCD(4),          NACD(4),
     5                 CMTAB(100,4),     NRCM(4),          NACM(4)


FILE: 'ALSLP.CMN'

      COMMON/ ALSLP  / ALS(20),         ALSNEW(20),      ALSOLD(20)


FILE: 'BELOAD.CMN'

      COMMON/ BELOAD / DFX(20),         DFXI(20),        DFXP(20),
     1                 DFZ(20),         DFZI(20),        DFZP(20),
     2                 DQ(20),          DQI(20),         DQP(20),
     3                 DPM(20)


FILE: 'BLDELE.CMN'

      COMMON/ BLDELE / XCLE(20),        YCG(20),         RBE(20),
     1                 DBES(20),        CLAMLE(20),      CLAMQC(20),
     2                 CHDCGL(20),      BETAL(20),       AFTWF(20),
     3                 JTAB(20,2),      TOC(20),         RE(20),
     4                 CLT(20),         CDT(20),         CMT(20),
     5                 CDS(20)


FILE: 'BLLOAD.CMN'

      COMMON/ BLLOAD / CTRB,   CQRB,   CTWB,   CPWB,   BTHRST, BTORQ,
     1                 BTORQI, BTORQP, BPWR,   BPWRP,  BPWRI,  BPMOMT


FILE: 'CALPHA.CMN'

      COMMON/ CALPHA / ALPHAG(20),      ALPHAE(20),      ALPHAW(20),
     1                 ALPHAN(20),      ALPHAI(20),      AZLLC(20),
     2                 TWSTCG(20)


FILE: 'CASE.CMN'

      COMMON/ CASE   / IPOINT, ALPHAD, VWOD,   IVDIM,  VWFAC,  PSIRD,
     1                 CASEID
```

TABLE B-3 (CONTINUED)

```
FILE: 'CCIRC.CMN'

      COMMON/ CCIRC  / CIRC(100),      DCIRC(100),     ACIRC(100),
     1                 CIRCR(100),     BCIRC(20),      GO(20),
     2                 TECF,           AKM(6),         XKM(5)


FILE: 'CDLS.CMN'

      COMMON/ CDLS   / DLS(25)


FILE: 'CGRID.CMN'

      COMMON/ CGRID  / NGRID(4),       XG(6),  YG(24), XCG(5)


FILE: 'CIPRT.CMN'

      COMMON/ CIPRT  / IPRT1,  IPRT2,  IPRT3,  IPRT4,  IPRT5,  IPRT6,
     1                 IPRT7,  IPRT8


FILE: 'CONFIG.CMN'

      COMMON/ CONFIG / XOCREF(4),      YSEG(4,2),      JCHORD(4,2),
     1                 YCHORD(24),     CHORD(24),      JTWIST(4,2),
     2                 YTWIST(24),     TWIST(24),      JXAOFF(4,2),
     3                 YXAOFF(24),     XAOFF(24),      JAFT(4,2),
     4                 YAFT(24,2),     IDAF(24),       XTRAN(4),
     5                 YTRAN(4),       ZTRAN(4),       XROT(4),
     6                 YROT(4),        ZROT(4)


FILE: 'CONSTS.CMN'

      COMMON/ CONSTS / PI,     RPD


FILE: 'CONTRL.CMN'

      COMMON/ CONTRL / TOL1,   TOL2,   TOL3,   ICYL1,  ICYL2,  ICYL3,
     1                 ICYL4


FILE: 'CTCON.CMN'

      COMMON/ CTCON  / CTRIN, CTROUT, CTRUPD
```

TABLE B-3 (CONTINUED)

```
FILE: 'CTIMER.CMN'

      COMMON/ CTIMER / H0,     M0,     S0,     D0,     H1,     M1,
     1                 S1,     D1

FILE: 'CVLCTY.CMN'

      COMMON/ CVLCTY / VFS1(5,20),     VFS2(5,20),     VFS3(5,20),
     1                 VFS1M(20),      VFS2M(20),      VFS3M(20),
     2                 VI1(5,20),      VI2(5,20),      VI3(5,20),
     3                 VI1M(20),       VI2M(20),       VI3M(20),
     4                 VREL(20),       VIND(20),       QREL(20)

FILE: 'CWIND.CMN'

      COMMON/ CWIND  / ALPS1,  ALPS2,  H0,     VW0,    E,
     1                 ITSTYP, TSTAB(100),     NXTS,   NYTS,
     2                 T0,     TP,     TP0,    TPS,    TK,
     3                 AB(5,2),        AT(5,2)

FILE: 'GVINT.CMN'

      COMMON/ GVINT  / XA,     YA,     ZA,     XB,     YB,     ZB,
     1                 XC,     YC,     ZC,     AN1C,   AN2C,   AN3C,
     2                 AT1C,   AT2C,   AT3C

FILE: 'IFLAGS.CMN'

      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG

FILE: 'NMWSH.CMN'

      COMMON/ NMWSH  / NRMWSH(100)

FILE: 'PARMS.CMN'

      COMMON/ PARMS  / RADIUS, OMEGA,  OMEGAR, RHO,    AMU

FILE: 'PNLCRD.CMN'

      COMMON/ PNLCRD / XS(6,24),       YS(6,24),       ZS(6,24),
     1                 XCOL(5,20),     YCOL(5,20),     ZCOL(5,20)
```

TABLE B-3 (CONTINUED)

```
FILE: 'PNLNDX.CMN'

      COMMON/ PNLNDX / MP,              NP,              NPANEL,
     1                 MP1,             NP1,             NPNLSQ,
     2                 NSGMNT,          JGLIM(4,2),      JCGLIM(4,2),
     3                 NPS(4),          NBLDS

FILE: 'PNLVEC.CMN'

      COMMON/ PNLVEC / AN1(5,20),      AN2(5,20),       AN3(5,20),
     1                 AT1(5,20),      AT2(5,20),       AT3(5,20),
     2                 AQC1(20),       AQC2(20),        AQC3(20)

FILE: 'REFSUR.CMN'

      COMMON/ REFSUR / XSR(6,24),      YSR(6,24),       ZSR(6,24),
     1                 XCOLR(5,20),    YCOLR(5,20),     ZCOLR(5,20),
     2                 AN1R(5,20),     AN2R(5,20),      AN3R(5,20),
     3                 AT1R(5,20),     AT2R(5,20),      AT3R(5,20)

FILE: 'RTLOAD.CMN'

      COMMON/ RTLOAD / CTRR,   CQRR,   CTWR,   CPWR,   RTHRST, RTORQ,
     1                 RTORQP, RTORQI, RPWR,   RPWRP,  RPWRI,  CTR,
     2                 CQR,    CTW,    CPW,    THRST,  TORQ,   TORQP,
     3                 TORQI,  PWR,    PWRP,   PWRI,   RPMOMT, PMOMT

FILE: 'SWEEP.CMN'

      COMMON/ SWEEP  / ALPSIN, DALP,   NALP,   VWOIN,  DVWO,   NVWO,
     1                 PSIRIN, DPSIR,  NPSIR

FILE: 'UNITS.CMN'

      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,
     1                 IOU10,  IOU11,  IOU12,  IOU13

FILE: 'WAKCRD.CMN'

      COMMON/ WAKCRD / XW(133,24),     YW(133,24),      ZW(133,24)
```

TABLE B-3 (CONCLUDED)

```
FILE: 'WAKNDX.CMN'

      COMMON/ WAKNDX / REVS,          NWIPR,          NWI,
     1                 KMAX(24),      IFWAK,          JS(3,2),
     2                 PSIMR,         PSIMT,          IROLL

FILE: 'WRATES.CMN'

      COMMON/ WRATES / AKZW,   AKZI,   AKZ,    AKR,    A,      AKB,
     1                 CTRW,   AKZO,   ALAMO,  AKRO,   VAXB,   VNUB
```

TABLE B-4. COMMON BLOCK LIST FILES

```
FILE: 'AEROPF.CML'

$INCLUDE: 'BELOAD.CMN'
$INCLUDE: 'BLDELE.CMN'
$INCLUDE: 'BLLOAD.CMN'
$INCLUDE: 'CALPHA.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'CTCON.CMN'
$INCLUDE: 'CVLCTY.CMN'
$INCLUDE: 'CWIND.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'PARMS.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'RTLOAD.CMN'
$INCLUDE: 'UNITS.CMN'


FILE: 'AFCOEF.CML'

$INCLUDE: 'AFTABL.CMN'
$INCLUDE: 'BLDELE.CMN'
$INCLUDE: 'CCIRC.CMN'
$INCLUDE: 'CONSTS.CMN'


FILE: 'AFTEXT.CML'

$INCLUDE: 'AFTABL.CMN'
$INCLUDE: 'CALPHA.CMN'
$INCLUDE: 'CONSTS.CMN'


FILE: 'AFTLOC.CML'

$INCLUDE: 'AFTABL.CMN'
$INCLUDE: 'CONFIG.CMN'


FILE: 'AICDLS.CML'

$INCLUDE: 'CDLS.CMN'
$INCLUDE: 'CGRID.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'CCIRC.CMN'
```

TABLE B-4 (CONTINUED)

```
FILE: 'AICDS.CML'

$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'GVINT.CMN'
$INCLUDE: 'PNLCRD.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'PNLVEC.CMN'
$INCLUDE: 'UNITS.CMN'


FILE: 'AICDSW.CML'

$INCLUDE: 'ALSLP.CMN'
$INCLUDE: 'BLDELE.CMN'
$INCLUDE: 'CCIRC.CMN'
$INCLUDE: 'CDLS.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'PARMS.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'UNITS.CMN'


FILE: 'AICDW.CML'

$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'GVINT.CMN'
$INCLUDE: 'PNLCRD.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'PNLVEC.CMN'
$INCLUDE: 'UNITS.CMN'
$INCLUDE: 'WAKCRD.CMN'
$INCLUDE: 'WAKNDX.CMN'


FILE: 'BEALPH.CML'

$INCLUDE: 'ALSLP.CMN'
$INCLUDE: 'BLDELE.CMN'
$INCLUDE: 'CALPHA.CMN'
$INCLUDE: 'CCIRC.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'CONTRL.CMN'
$INCLUDE: 'CVLCTY.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'PARMS.CMN'
$INCLUDE: 'PNLNDX.CMN'
```

TABLE B-4 (CONTINUED)

```
FILE: 'BEVEL.CML'

$INCLUDE: 'ALSLP.CMN'
$INCLUDE: 'BLDELE.CMN'
$INCLUDE: 'CCIRC.CMN'
$INCLUDE: 'CDLS.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'CVLCTY.CMN'
$INCLUDE: 'PARMS.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'PNLVEC.CMN'
$INCLUDE: 'UNITS.CMN'


FILE: 'CIRPRM.CML'

$INCLUDE: 'CCIRC.CMN'
$INCLUDE: 'PNLNDX.CMN'


FILE: 'CLRSCN.CML'

$INCLUDE: 'UNITS.CMN'


FILE: 'COLCRD.CML'

$INCLUDE: 'CCIRC.CMN'
$INCLUDE: 'CGRID.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'UNITS.CMN'


FILE: 'CWAVG.CML'

$INCLUDE: 'CGRID.CMN'
$INCLUDE: 'PNLNDX.CMN'


FILE: 'EXAIC.CML'

$INCLUDE: 'CIPRT.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'PNLNDX.CMN'
```

TABLE B-4 (CONTINUED)

```
FILE: 'EXBLD.CML'

$INCLUDE: 'CIPRT.CMN'


FILE: 'EXINI.CML'

$INCLUDE: 'CONSTS.CMN'


FILE: 'EXINT.CML'

$INCLUDE: 'CIPRT.CMN'
$INCLUDE: 'CONSTS.CMN'


FILE: 'EXSLV.CML'

$INCLUDE: 'CASE.CMN'
$INCLUDE: 'CCIRC.CMN'
$INCLUDE: 'CIPRT.CMN'
$INCLUDE: 'CONTRL.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'UNITS.CMN'
$INCLUDE: 'WAKNDX.CMN'


FILE: 'FILMNT.CML'

$INCLUDE: 'CIPRT.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'CWIND.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'PNLCRD.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'UNITS.CMN'
$INCLUDE: 'WAKCRD.CMN'
$INCLUDE: 'WAKNDX.CMN'
$INCLUDE: 'WRATES.CMN'
```

TABLE B-4 (CONTINUED)

```
FILE: 'FILROL.CML'

$INCLUDE: 'CIPRT.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'PNLCRD.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'UNITS.CMN'
$INCLUDE: 'WAKCRD.CMN'
$INCLUDE: 'WAKNDX.CMN'


FILE: 'FLPVEL.CML'

$INCLUDE: 'CWIND.CMN'
$INCLUdE: 'PARMS.CMN'


FILE: 'GRID.CML'

$INCLUDE: 'CGRID.CMN'
$INCLUDE: 'CONFIG.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'PNLNDX.CMN'


FILE: 'GSITER.CML'

$INCLUDE: 'CCIRC.CMN'
$INCLUDE: 'CONTRL.CMN'
$INCLUDE: 'NMWSH.CMN'
$INCLUDE: 'PARMS.CMN'
$INCLUDE: 'UNITS.CMN'


FILE: 'HEADER.CML'

$INCLUDE: 'CASE.CMN'


FILE: 'INTLS.CML'

$INCLUDE: 'AFTABL.CMN'
$INCLUDE: 'ALSLP.CMN'
$INCLUDE: 'BLDELE.CMN'
$INCLUDE: 'CALPHA.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'CWIND.CMN'
$INCLUDE: 'PARMS.CMN'
$INCLUDE: 'PNLNDX.CMN'
```

TABLE B-4 (CONTINUED)

```
FILE: 'IOFNSH.CML'

$INCLUDE: 'UNITS.CMN'


FILE: 'IOINIT.CML'

$INCLUDE: 'UNITS.CMN'


FILE: 'LOCATE.CML'

$INCLUDE: 'UNITS.CMN'


FILE: 'MAIN.CML'

$INCLUDE: 'CASE.CMN'
$INCLUDE: 'CCIRC.CMN'
$INCLUDE: 'CIPRT.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'CONTRL.CMN'
$INCLUDE: 'CWIND.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'SWEEP.CMN'
$INCLUDE: 'UNITS.CMN'


FILE: 'NRMLBC.CML'

$INCLUDE: 'CCIRC.CMN'
$INCLUDE: 'CVLCTY.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'NMWSH.CMN'
$INCLUDE: 'PARMS.CMN'
$INCLUDE: 'PNLCRD.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'PNLVEC.CMN'
$INCLUDE: 'UNITS.CMN'


FILE: 'OUT1.CML'

$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'PNLCRD.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'UNITS.CMN'
```

TABLE B-4 (CONTINUED)

```
FILE: 'OUT2.CML'

$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'UNITS.CMN'
$INCLUDE: 'WAKCRD.CMN'
$INCLUDE: 'WAKNDX.CMN'


FILE: 'OUT3.CML'

$INCLUDE: 'ALSLP.CMN'
$INCLUDE: 'BELOAD.CMN'
$INCLUDE: 'BLDELE.CMN'
$INCLUDE: 'CALPHA.CMN'
$INCLUDE: 'CCIRC.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'CVLCTY.CMN'
$INCLUDE: 'PARMS.CMN'
$INCLUDE: 'PNLNDX.CMN'


FILE: 'OUT4.CML'

$INCLUDE: 'BLLOAD.CMN'
$INCLUDE: 'CONSTS.CMN'


FILE: 'OUT5.CML'

$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'RTLOAD.CMN'
$INCLUDE: 'UNITS.CMN'


FILE: 'OUT6.CML'

$INCLUDE: 'UNITS.CMN'
$INCLUDE: 'WRATES.CMN'


FILE: 'OUT8.CML'

$INCLUDE: 'UNITS.CMN'
```

TABLE B-4 (CONTINUED)

```
FILE: 'PREWAK.CML'

$INCLUDE: 'CIPRT.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'UNITS.CMN'
$INCLUDE: 'WAKNDX.CMN'


FILE: 'PSURF.CML'

$INCLUDE: 'BLDELE.CMN'
$INCLUDE: 'CALPHA.CMN'
$INCLUDE: 'CONFIG.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'CWIND.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'PNLCRD.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'PNLVEC.CMN'
$INCLUDE: 'REFSUR.CMN'
$INCLUDE: 'UNITS.CMN'


FILE: 'PWAKE.CML'

$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'UNITS.CMN'
$INCLUDE: 'WAKCRD.CMN'
$INCLUDE: 'WAKNDX.CMN'


 ILE: 'READAF.CML'
$INCLUDE: 'AFTABL.CMN'
$INCLUDE: 'UNITS.CMN'
```

TABLE B-4 (CONTINUED)

```
FILE: 'READIN.CML'

$INCLUDE: 'CASE.CMN'
$INCLUDE: 'CGRID.CMN'
$INCLUDE: 'CIPRT.CMN'
$INCLUDE: 'CONFIG.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'CONTRL.CMN'
$INCLUDE: 'CTCON.CMN'
$INCLUDE: 'CWIND.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'PARMS.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'SWEEP.CMN'
$INCLUDE: 'UNITS.CMN'
$INCLUDE: 'WAKNDX.CMN'


FILE: 'REDTAB.CML'

$INCLUDE: 'UNITS.CMN'


FILE: 'RFSURF.CML'

$INCLUDE: 'AFTABL.CMN'
$INCLUDE: 'BLDELE.CMN'
$INCLUDE: 'CALPHA.CMN'
$INCLUDE: 'CGRID.CMN'
$INCLUDE: 'CONFIG.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'CWIND.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'PARMS.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'PNLVEC.CMN'
$INCLUDE: 'REFSUR.CMN'
$INCLUDE: 'UNITS.CMN'


FILE: 'ROLNDX.CML'

$INCLUDE: 'CCIRC.CMN'
$INCLUDE: 'CONTRL.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'PNLNDX.CMN'
$INCLUDE: 'WAKNDX.CMN'
```

TABLE B-4 (CONTINUED)

```
FILE: 'TIMER.CML'

$INCLUDE: 'CTIMER.CMN'
$INCLUDE: 'UNITS.CMN'


FILE: 'TRACE.CML'

$INCLUDE: 'CIPRT.CMN'
$INCLUDE: 'UNITS.CMN'


FILE: 'VCYLN.CML'

$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'GVINT.CMN'
$INCLUDE: 'WRATES.CMN'


FILE: 'VLINE.CML'

$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'GVINT.CMN'


FILE: 'WAKPRM.CML'

$INCLUDE:FILE: 'CTCON.CMN'

$INCLUdE: 'CWIND.CMN'
$INCLUDE: 'PARMS.CMN'
$INCLUDE: 'WRATES.CMN'


FILE: 'WAKUPD.CML'

$INCLUDE: 'CIPRT.CMN'
$INCLUDE: 'CONTRL.CMN'
$INCLUDE: 'CTCON.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'WRATES.CMN'


FILE: 'WNDPRO.CML'

$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'CWIND.CMN'
$INCLUDE: 'IFLAGS.CMN'
$INCLUDE: 'PARMS.CMN'
```

TABLE B-4 (CONCLUDED)

```
FILE: 'ZROLFT.CML'

$INCLUDE: 'AFTABL.CMN'
$INCLUDE: 'CONSTS.CMN'
$INCLUDE: 'UNITS.CMN'
```

APPENDIX C

PROGRAM LSWT SOURCE LISTING

```
C     ************************************************************************00000010
C     ************************************************************************00000020
C                                                                               00000030
C     LSWT VERSION 1.00  RELEASED MAY 1986                                      00000040
C                                                                               00000050
C     HORIZONTAL AXIS WIND TURBINE AERODYNAMIC PERFORMANCE ANALYSIS             00000060
C     BASED ON LIFTING SURFACE THEORY WITH PRESCRIBED WAKE                      00000070
C                                                                               00000080
C     TECHNICAL DEVELOPMENT AND PROGRAMMING BY                                  00000090
C     J. DAVID KOCUREK                                                          00000100
C     COMPUTATIONAL METHODOLOGY ASSOCIATES                                      00000110
C                                                                               00000120
C     DEVELOPED UNDER MICROSOFT FORTRAN77, VERSION 3.20 (MS-DOS)                00000130
C                                                                               00000140
C     ************************************************************************00000150
C     ************************************************************************00000160
```

```
C     ************************************************************************00000010
C                                                                               00000020
C     LSWT01(MAIN)                                                              00000030
C                                                                               00000040
C     ************************************************************************00000050
C                                                                               00000060
      PROGRAM MAIN                                                              00000070
C                                                                               00000080
      COMMON/ CASE   / IPOINT, ALPHAD, VWOD,   IVDIM,  VWFAC,  PSIRD,           00000090
     1                 CASEID                                                   00000100
      COMMON/ CCIRC  / CIRC(100),      DCIRC(100),     ACIRC(100),              00000110
     1                 CIRCR(100),     BCIRC(20),      GO(20),                  00000120
     2                 TECF,           AKM(6),         XKM(5)                   00000130
      COMMON/ CIPRT  / IPRT1,  IPRT2,  IPRT3,  IPRT4,  IPRT5,  IPRT6,           00000140
     1                 IPRT7,  IPRT8                                            00000150
      COMMON/ CONSTS / PI,     RPD                                              00000160
      COMMON/ CONTRL / TOL1,   TOL2,   TOL3,   ICYL1,  ICYL2,  ICYL3,           00000170
     1                 ICYL4                                                    00000180
      COMMON/ CWIND  / ALPS1,  ALPS2,  HO,     VWO,    E,                      00000190
     1                 ITSTYP, TSTAB(100),     NXTS,   NYTS,                   00000200
     2                 TO,     TP,     TPO,    TPS,    TK,                     00000210
     3                 AB(5,2),        AT(5,2)                                 00000220
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                           00000230
      COMMON/ PNLNDX / MP,             NP,             NPANEL,                  00000240
     1                 MP1,            NP1,            NPNLSQ,                  00000250
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),             00000260
     3                 NPS(4),         NBLDS                                    00000270
      COMMON/ SWEEP  / ALPSIN, DALP,   NALP,   VWOIN,  DVWO,   NVWO,           00000280
     1                 PSIRIN, DPSIR,  NPSIR                                    00000290
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,                    00000300
     1                 IOU10,  IOU11,  IOU12,  IOU13                            00000310
C                                                                               00000320
C     ************************************************************************00000330
C                                                                               00000340
C     OPEN DISK I/O FILES                                                       00000350
C                                                                               00000360
      CALL IOINIT                                                               00000370
C                                                                               00000380
C     INITIALIZE START TIME                                                     00000390
C                                                                               00000400
      CALL TIMER(1)                                                             00000410
      CALL TIMER(3)                                                             00000420
C                                                                               00000430
C     CALL INITIALIZATION AND INPUT EXECUTIVE SUBROUTINE                        00000440
C                                                                               00000450
      CALL EXINT                                                                00000460
      IF(IPRT7.GT.0) CALL TRACE('EXINT ')                                       00000470
C                                                                               00000480
      IPOINT = 0                                                                00000490
C                                                                               00000500
C     ------------------------------                                            00000510
C     LOOP 7000 SWEEPS GEOMETRIC PITCH                                          00000520
```

```
C     -------------------------------                                  00000530
C                                                                      00000540
      DO 7000   IALP = 1,NALP                                          00000550
C                                                                      00000560
      ALPHAS = ALPSIN+(IALP-1)*DALP                                    00000570
      ALPHAD = ALPHAS/RPD                                              00000580
C                                                                      00000590
C     --------------------------                                       00000600
C     LOOP 6000 SWEEPS WIND SPEED                                      00000610
C     --------------------------                                       00000620
C                                                                      00000630
      DO 6000  IVWO = 1,NVWO                                           00000640
C                                                                      00000650
      IPOINT = IPOINT + 1                                              00000660
      VWO = VWOIN+(IVWO-1)*DVWO                                        00000670
      IF(IVDIM.EQ.3) VWO = 1.0/VWO/VWFAC                               00000680
      VWOD = VWO*VWFAC                                                 00000690
      IF(IVDIM.EQ.3) VWOD = 1.0 / VWOD                                 00000700
      IF( (NVWO.EQ.1) .AND. (IALP.GT.1) ) GO TO 110                    00000710
C                                                                      00000720
C     CALL BLADE GEOMETRY EXECUTIVE SUBROUTINE                         00000730
C                                                                      00000740
      CALL EXBLD                                                       00000750
      IF(IPRT7.GT.0) CALL TRACE('EXBLD ')                              00000760
C                                                                      00000770
      IF(IPOINT.GT.1) GO TO 110                                        00000780
C                                                                      00000790
C     REFERENCE BLADE GEOMETRY REPORT, IPRT = 3, IPOINT = 1            00000800
C                                                                      00000810
      IF(IPRT1.EQ.3) CALL PSURF(0.0,0.0,1)                             00000820
      IF(IPRT1.EQ.3) CALL OUT1(0)                                      00000830
C                                                                      00000840
C     GET INITIAL LIFT SLOPE (FIRST POINT ONLY)                        00000850
C                                                                      00000860
      CALL INTLS(ALPHAS)                                               00000870
C                                                                      00000880
C     INITIALIZE CIRCULATION ARRAYS                                    00000890
C                                                                      00000900
      DO 100  J = 1, NPANEL                                            00000910
      CIRC(J) = 0.0                                                    00000920
      CIRCR(J) = 1.0                                                   00000930
  100 CONTINUE                                                         00000940
C                                                                      00000950
  110 CONTINUE                                                         00000960
C                                                                      00000970
C     ------------------------------------------------------------     00000980
C     LOOP 5000 SWEEPS AZIMUTH FOR QUASI-STEADY CASE, ELSE ONE POINT   00000990
C     ------------------------------------------------------------     00001000
C                                                                      00001010
      IF(ISTDY.EQ.1) GO TO 200                                         00001020
C                                                                      00001030
      PSIRIN = 0.0                                                     00001040
```

```
      DPSIR  = 0.0                                                    00001050
      NPSIR  = 1                                                      00001060
C                                                                     00001070
  200 CONTINUE                                                        00001080
C                                                                     00001090
      DO 5000   IPSIR = 1,NPSIR                                       00001100
C                                                                     00001110
      PSIR = PSIRIN+(IPSIR-1)*DPSIR                                   00001120
      PSIRD = PSIR/RPD                                                00001130
C                                                                     00001140
      IF((IPRT1.NE.1) .AND. (IPRT1.NE.2)) GO TO 400                   00001150
      IF((IPRT1.EQ.2) .AND. (IPSIR.GT.1)) GO TO 400                   00001160
C                                                                     00001170
C     BLADE GEOMETRY REPORT, IPRT = 1,2                               00001180
C                                                                     00001190
      PSIBS = 2.0*PI/NBLDS                                            00001200
C                                                                     00001210
      DO 300 ITBLD = 1, NBLDS                                         00001220
      PSITB = PSIR-(ITBLD-1)*PSIBS                                    00001230
      CALL PSURF(ALPHAS,PSITB,1)                                      00001240
      CALL OUT1(ITBLD)                                                00001250
  300 CONTINUE                                                        00001260
C                                                                     00001270
  400 CONTINUE                                                        00001280
C                                                                     00001290
C     SET SWITCH SO SURFACE AIC'S WILL BE CALCULATED ONLY ONCE        00001300
C     PER AZIMUTH                                                     00001310
C                                                                     00001320
      IAICDS = 0                                                      00001330
C                                                                     00001340
C     ---------------------------------                               00001350
C     LOOP 4000 CONVERGES PRESCRIBED WAKE                             00001360
C     ---------------------------------                               00001370
C                                                                     00001380
      IWCYLM = ICYL3                                                  00001390
      IF(ICYL3.EQ.0) IWCYLM = 6                                       00001400
C                                                                     00001410
      DO 4000   IWCYL = 1, IWCYLM                                     00001420
C                                                                     00001430
C     ---------------------------------                               00001440
C     LOOP 3000 CONVERGES ROLL-UP OPTION                              00001450
C     ---------------------------------                               00001460
C                                                                     00001470
      IRCYLM = ICYL4                                                  00001480
      IF(ICYL4.EQ.0) IRCYLM = 4                                       00001490
C                                                                     00001500
      DO 3000  IRCYL = 1,IRCYLM                                       00001510
C                                                                     00001520
C     ------------------------------------------------                00001530
C     LOOP 2000 SWEEPS TARGET BLADES, BLADE ONE AT PSIR               00001540
C     ------------------------------------------------                00001550
C                                                                     00001560
```

```
      ITBLDM = NBLDS                                                    00001570
      IF(ISTDY.EQ.0) ITBLDM = 1                                         00001580
C                                                                       00001590
C     CLEAR OUTPUT BUFFER                                               00001600
C                                                                       00001610
      REWIND IOU8                                                       00001620
C                                                                       00001630
      DO 2000 ITBLD = 1,ITBLDM                                          00001640
C                                                                       00001650
C     CALL AERODYNAMIC INFLUENCE COEFFICIENT EXECUTIVE                  00001660
C                                                                       00001670
      CALL EXAIC(ALPHAS,PSIR,ITBLD,IAICDS)                              00001680
      IF(IPRT7.GT.0) CALL TRACE('EXAIC ')                               00001690
C                                                                       00001700
C     RESET SWITCH SO SURFACE AIC'S WILL NOT BE RECALCULATED            00001710
C                                                                       00001720
      IAICDS = 1                                                        00001730
C                                                                       00001740
C     ------------------------------------------------                  00001750
C     LOOP 1000 CONVERGES EFFECTIVE LINEAR LIFT CURVE SLOPE             00001760
C     ------------------------------------------------                  00001770
C                                                                       00001780
      ISCYLM = ICYL2                                                    00001790
      IF(ICYL2.EQ.0) ISCYLM = 4                                         00001800
C                                                                       00001810
      DO 1000  ISCYL = 1,ISCYLM                                         00001820
C                                                                       00001830
C     CALL SOLUTION EXECUTIVE                                           00001840
C                                                                       00001850
      CALL EXSLV(ITBLD,PSIR,IPSIR,ISCYL)                                00001860
      IF(IPRT7.GT.0) CALL TRACE('EXSLV ')                               00001870
C                                                                       00001880
C     CHECK FOR CONVERGENCE OF LINEAR LIFT CURVE SLOPES                 00001890
C                                                                       00001900
      IF(LSFLAG.EQ.0) GO TO 1500                                        00001910
      IF(IWFLAG.EQ.1) GO TO 1500                                        00001920
      IF(IRFLAG.EQ.1) GO TO 1500                                        00001930
C                                                                       00001940
C     --------                                                          00001950
 1000 CONTINUE                                                          00001960
C     --------                                                          00001970
C                                                                       00001980
 1500 CONTINUE                                                          00001990
C                                                                       00002000
C     REPORT WAKE PARAMETERS, IPRT6 = 1                                 00002010
C                                                                       00002020
      IF(IPRT6.EQ.1) CALL OUT6                                          00002030
C                                                                       00002040
C     REPORT WAKE COORDINATES, IPRT2=1                                  00002050
C                                                                       00002060
      IF(IPRT2.EQ.1) CALL OUT2(ITBLD,PSIR)                              00002070
C                                                                       00002080
```

```
C     BLADE ELEMENT PERFORMANCE SUMMARY,IPRT3 = 1                          00002090
C                                                                          00002100
      IF(IPRT3.EQ.1) CALL OUT3(ITBLD,IOU6)                                 00002110
C                                                                          00002120
C     BLADE PERFORMANCE SUMMARY, IPRT4 = 1                                 00002130
C                                                                          00002140
      IF(IPRT4.EQ.1) CALL OUT4(ITBLD,IOU6)                                 00002150
C                                                                          00002160
C     ROTOR SUMMARY PERFORMANCE, IPRT5 = 1                                 00002170
C                                                                          00002180
      IF(IPRT5.EQ.1) CALL OUT5                                             00002190
C                                                                          00002200
C     LOAD OUTPUT BUFFER AS REQUESTED                                      00002210
C                                                                          00002220
      IF((IPRT3.EQ.2) .OR. (IPRT3.EQ.3)) CALL OUT3(ITBLD,IOU8)             00002230
      IF((IPRT4.EQ.2) .OR. (IPRT4.EQ.3)) CALL OUT4(ITBLD,IOU8)             00002240
C                                                                          00002250
      IF(ISTDY.EQ.0) GO TO 2000                                            00002260
C                                                                          00002270
C     UPDATE AZIMUTH AVERAGE FOR ITBLD'S NEW CIRCULATION                   00002280
C                                                                          00002290
      DO 1600  J = 1,NPANEL                                               00002300
      IF(ITBLD.EQ.1) ACIRC(J) = CIRC(J)/NBLDS                              00002310
      IF(ITBLD.GT.1) ACIRC(J) = ACIRC(J)+CIRC(J)/NBLDS                     00002320
 1600 CONTINUE                                                             00002330
C                                                                          00002340
C     --------                                                             00002350
 2000 CONTINUE                                                             00002360
C     --------                                                             00002370
C                                                                          00002380
C     CHECK FOR CONVERGENCE OF ROLL-UP                                     00002390
C                                                                          00002400
      IF(IWFLAG.EQ.1) GO TO 3500                                           00002410
      IF(IRFLAG.EQ.0) GO TO 3500                                           00002420
C                                                                          00002430
C     --------                                                             00002440
 3000 CONTINUE                                                             00002450
C     --------                                                             00002460
C                                                                          00002470
 3500 CONTINUE                                                             00002480
C                                                                          00002490
C     CHECK FOR CONVERGENCE OF WAKE                                        00002500
C                                                                          00002510
      IF(IWFLAG.EQ.0) GO TO 4100                                           00002520
C                                                                          00002530
C     --------                                                             00002540
 4000 CONTINUE                                                             00002550
C     --------                                                             00002560
C                                                                          00002570
 4100 CONTINUE                                                             00002580
C                                                                          00002590
C     REPORT WAKE PARAMETERS,IPRT6 = 2                                     00002600
```

```
C                                                                       00002610
      IF(IPRT6.EQ.2) CALL OUT6                                          00002620
C                                                                       00002630
C     REPORT WAKE COORDINATES, IPRT2 = 2                                00002640
C                                                                       00002650
      IF(IPRT2.NE.2) GO TO 4300                                         00002660
C                                                                       00002670
      ITBLDM = NBLDS                                                    00002680
      IF(ISTDY.EQ.0) ITBLDM = 1                                         00002690
      DO 4200  ITBLD = 1,ITBLDM                                         00002700
      IF(IPRT2.EQ.2) CALL OUT2(ITBLD,PSIR)                              00002710
 4200 CONTINUE                                                          00002720
C                                                                       00002730
 4300 CONTINUE                                                          00002740
C                                                                       00002750
C     BLADE ELEMENT AND/OR BLADE SUMMARY PERFORMANCE,                   00002760
C     IPRT3 = 2, AND/OR IPRT4 = 2 (RESTORE FROM BUFFER)                 00002770
C                                                                       00002780
      IF((IPRT3.EQ.2) .OR. (IPRT4.EQ.2)) CALL APPEND(IOU8,IOU6,132,0)   00002790
C                                                                       00002800
C     ROTOR SUMMARY PERFORMANCE, IPRT5 = 2                              00002810
C                                                                       00002820
      IF(IPRT5.EQ.2) CALL OUT5                                          00002830
C                                                                       00002840
      IF(ISTDY.EQ.0) GO TO 4500                                         00002850
C                                                                       00002860
C     UPDATE DISK AVERAGE CIRCULATION FOR THIS AZIMUTH                  00002870
C                                                                       00002880
      DO 4400 J = 1, NPANEL                                             00002890
      IF(IPSIR.EQ.1) DCIRC(J) = ACIRC(J)/IPSIR                          00002900
      IF(IPSIR.GT.1) DCIRC(J) = (DCIRC(J)*(IPSIR-1)+ACIRC(J))/IPSIR     00002910
 4400 CONTINUE                                                          00002920
C                                                                       00002930
 4500 CONTINUE                                                          00002940
C                                                                       00002950
C     --------                                                          00002960
 5000 CONTINUE                                                          00002970
C     --------                                                          00002980
C                                                                       00002990
C     REPORT WAKE PARAMETERS,IPRT6 = 3                                  00003000
C                                                                       00003010
      IF(IPRT6.EQ.3) CALL OUT6                                          00003020
C                                                                       00003030
C     REPORT WAKE COORDINATES, IPRT2 = 3                                00003040
C                                                                       00003050
      IF(IPRT2.NE.3) GO TO 5200                                         00003060
C                                                                       00003070
      ITBLDM = NBLDS                                                    00003080
      IF(ISTDY.EQ.0) ITBLDM = 1                                         00003090
      DO 5100  ITBLD = 1,ITBLDM                                         00003100
      IF(IPRT2.EQ.3) CALL OUT2(ITBLD,PSIR)                              00003110
 5100 CONTINUE                                                          00003120
```

```
C                                                                       00003130
 5200 CONTINUE                                                          00003140
C                                                                       00003150
C     BLADE ELEMENT AND/OR BLADE SUMMARY PERFORMANCE,                   00003160
C     IPRT3 = 3, AND/OR IPRT4 = 3 (RESTORE FROM BUFFER)                 00003170
C                                                                       00003180
      IF((IPRT3.EQ.3) .OR. (IPRT4.EQ.3)) CALL APPEND(IOU8,IOU6,132,0)   00003190
C                                                                       00003200
C     ROTOR SUMMARY PERFORMANCE, IPRT5 = 3                              00003210
C                                                                       00003220
      IF(IPRT5.EQ.3) CALL OUT5                                          00003230
C                                                                       00003240
C     CONVERGENCE MESSAGES FOR THIS POINT                               00003250
C                                                                       00003260
      IF(LSFLAG.EQ.1) WRITE(IOU6,1001) ISCYLM                           00003270
 1001 FORMAT('0',4X,41('*')/                                            00003280
     1       ' ',4X,'LIFT SLOPES NOT CONVERGED AFTER ',I2,' CYCLES'/    00003290
     2       ' ',4X,41('*'))                                           00003300
C                                                                       00003310
      IF(IRFLAG.EQ.1) WRITE(IOU6,3001) IRCYLM                           00003320
 3001 FORMAT('0',4X,41('*')/                                            00003330
     1       ' ',4X,'ROLL-UP NOT CONVERGED AFTER ',I2,' ITERATIONS'/    00003340
     2       ' ',4X,41('*'))                                           00003350
C                                                                       00003360
      IF(IWFLAG.EQ.1) WRITE(IOU6,4001) IWCYLM                           00003370
 4001 FORMAT('0',4X,38('*')/                                            00003380
     1       ' ',4X,'WAKE NOT CONVERGED AFTER ',I2,' ITERATIONS'/       00003390
     2       ' ',4X,38('*'))                                           00003400
C                                                                       00003410
C     --------                                                          00003420
 6000 CONTINUE                                                          00003430
C     --------                                                          00003440
C                                                                       00003450
C     --------                                                          00003460
 7000 CONTINUE                                                          00003470
C     --------                                                          00003480
C                                                                       00003490
C     DISPLAY TOTAL TIME                                                00003500
C                                                                       00003510
      CALL TIMER(2)                                                     00003520
C                                                                       00003530
C     CLOSE DISK I/O FILES                                              00003540
C                                                                       00003550
      CALL IOFNSH                                                       00003560
C                                                                       00003570
      STOP ' '                                                          00003580
      END                                                               00003590
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT01(INTLS)                                                      00000030
C                                                                        00000040
C     CALCULATES THE INITIAL ESTIMATE OF THE EFFECTIVE LINEAR LIFT CURVE00000050
C     SLOPE AT EACH BLADE SOLUTION STATION                               00000060
C                                                                        00000070
C     ******************************************************************00000080
C                                                                        00000090
      SUBROUTINE INTLS(ALPHAS)                                           00000100
C                                                                        00000110
      COMMON/ AFTABL / NAFT,   IDAFT(4),       AFTOC(4),       IAFTEX,  00000120
     1                 STP1(4),        STP2(4),        STP3(4),         00000130
     2                 STP4(4),        STP5(4),        STP6(4),         00000140
     3                 CLTAB(200,4),   NRCL(4),        NACL(4),         00000150
     4                 CDTAB(200,4),   NRCD(4),        NACD(4),         00000160
     5                 CMTAB(100,4),   NRCM(4),        NACM(4)          00000170
      COMMON/ ALSLP  / ALS(20),        ALSNEW(20),     ALSOLD(20)       00000180
      COMMON/ BLDELE / XCLE(20),       YCG(20),        RBE(20),         00000190
     1                 DBES(20),       CLAMLE(20),     CLAMQC(20),      00000200
     2                 CHDCGL(20),     BETAL(20),      AFTWF(20),       00000210
     3                 JTAB(20,2),     TOC(20),        RE(20),          00000220
     4                 CLT(20),        CDT(20),        CMT(20),         00000230
     5                 CDS(20)                                          00000240
      COMMON/ CALPHA / ALPHAG(20),     ALPHAE(20),     ALPHAW(20),      00000250
     1                 ALPHAN(20),     ALPHAI(20),     AZLLC(20),       00000260
     2                 TWSTCG(20)                                       00000270
      COMMON/ CONSTS / PI,     RPD                                       00000280
      COMMON/ CWIND  / ALPS1,  ALPS2,  HO,     VWO,    E,               00000290
     1                 ITSTYP, TSTAB(100),     NXTS,   NYTS,            00000300
     2                 TO,     TP,     TPO,    TPS,    TK,              00000310
     3                 AB(5,2),        AT(5,2)                          00000320
      COMMON/ PARMS  / RADIUS, OMEGA,  OMEGAR, RHO,    AMU              00000330
      COMMON/ PNLNDX / MP,             NP,             NPANEL,          00000340
     1                 MP1,            NP1,            NPNLSQ,          00000350
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),     00000360
     3                 NPS(4),         NBLDS                            00000370
C                                                                        00000380
C     ******************************************************************00000390
C                                                                        00000400
C     INITIAL VALUE OF LINEAR LIFT SLOPE                                 00000410
C                                                                        00000420
      DO 200   J = 1,NP                                                  00000430
C                                                                        00000440
      VEL = SQRT(VWO**2+(OMEGAR*RBE(J))**2)                              00000450
      REN = RHO*VEL*CHDCGL(J)*RADIUS/AMU                                 00000460
C                                                                        00000470
      ALTAB = ALPHAS/2.0-AZLLC(J)+ATAN(VWO/OMEGAR/RBE(J))                00000480
      IF (ABS(AZLLC(J)).LT.1.0E-04.AND.ABS(ALTAB).LT.1.0E-04)            00000490
     1   ALTAB = AZLLC(J)/RPD + 1.0                                      00000500
      CALL AFCOEF(J,ALTAB,REN,CL,CD,CM,INOREX)                           00000510
C                                                                        00000520
```

```
C     INITIAL ESTIMATE OF EFFECTIVE LINEAR LIFT SLOPE USING LEADING     00000530
C     EDGE ANGLE TO CORRECT FOR SWEEP - LATER UPDATES WILL USE          00000540
C     AERODYNAMIC SWEEP                                                 00000550
C                                                                       00000560
      ALTAB  = ALTAB*RPD                                                00000570
      ALS(J) = CL/(ALTAB-AZLLC(J)) * CLAMLE(J)                          00000580
C                                                                       00000590
  200 CONTINUE                                                          00000600
C                                                                       00000610
      RETURN                                                            00000620
      END                                                               00000630
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT01(EXINT)                                                            00000030
C                                                                              00000040
C     PERFORMS INITIALIZATION OF CONSANTS, CALLS INPUT SUBROUTINE, AND         00000050
C     REPORTS RECORD IMAGE OF INPUT                                            00000060
C                                                                              00000070
C     ************************************************************************00000080
C                                                                              00000090
      SUBROUTINE EXINT                                                         00000100
C                                                                              00000110
      COMMON/ CIPRT  / IPRT1,  IPRT2,  IPRT3,  IPRT4,  IPRT5,  IPRT6,          00000120
     1                 IPRT7,  IPRT8                                           00000130
      COMMON/ CONSTS / PI,     RPD                                             00000140
C                                                                              00000150
C     ************************************************************************00000160
C                                                                              00000170
      PI = ACOS(-1.0)                                                          00000180
      RPD = PI/180.0                                                           00000190
C                                                                              00000200
C     CALL INPUT SUBROUTINE                                                    00000210
C                                                                              00000220
      CALL READIN                                                              00000230
      IF(IPRT7.GT.0) CALL TRACE('READIN')                                      00000240
C                                                                              00000250
C     OUTPUT RECORD IMAGE OF INPUT, IPRT8 = 1                                  00000260
C                                                                              00000270
      IF(IPRT8.EQ.1) CALL OUT8                                                 00000280
C                                                                              00000290
      RETURN                                                                   00000300
      END                                                                      00000310
```

Source File: **LSWT01.FOR** Program Unit: **EXBLD**

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT01(EXBLD)                                                            00000030
C                                                                              00000040
C     BLADE GEOMETRY EXECUTIVE                                                 00000050
C                                                                              00000060
C     ************************************************************************00000070
C                                                                              00000080
      SUBROUTINE EXBLD                                                         00000090
C                                                                              00000100
      COMMON/ CIPRT  / IPRT1,  IPRT2,  IPRT3,  IPRT4,  IPRT5,  IPRT6,          00000110
     1                 IPRT7,  IPRT8                                           00000120
C                                                                              00000130
C     ************************************************************************00000140
C                                                                              00000150
C     GENERATE NONDIMENSIONAL PANEL GRID AND                                   00000160
C     COLLOCATION POINTS                                                       00000170
C                                                                              00000180
      CALL GRID                                                                00000190
      IF(IPRT7.GT.0) CALL TRACE('GRID  ')                                      00000200
C                                                                              00000210
C     CALCULATE TWO-DIMENSIONAL AIC'S                                          00000220
C                                                                              00000230
      CALL AICDLS                                                              00000240
      IF(IPRT7.GT.0) CALL TRACE('AICDLS')                                      00000250
C                                                                              00000260
C     GENERATE REFERENCE SURFACE PANEL COORDINATES                             00000270
C                                                                              00000280
      CALL RFSURF                                                              00000290
      IF(IPRT7.GT.0) CALL TRACE('RFSURF')                                      00000300
C                                                                              00000310
      RETURN                                                                   00000320
      END                                                                      00000330
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT01(EXAIC)                                                      00000030
C                                                                        00000040
C     AERODYNAMIC INFLUENCE COEFFICIENT EXECUTIVE                        00000050
C                                                                        00000060
C     ******************************************************************00000070
C                                                                        00000080
      SUBROUTINE EXAIC(ALPHAS,PSIR,ITBLD,IAICDS)                         00000090
C                                                                        00000100
      COMMON/ CIPRT  / IPRT1,  IPRT2,  IPRT3,  IPRT4,  IPRT5,  IPRT6,    00000110
     1                 IPRT7,  IPRT8                                     00000120
      COMMON/ CONSTS / PI,     RPD                                       00000130
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                    00000140
      COMMON/ PNLNDX / MP,             NP,             NPANEL,           00000150
     1                 MP1,            NP1,            NPNLSQ,           00000160
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),      00000170
     3                 NPS(4),         NBLDS                             00000180
C                                                                        00000190
C     ******************************************************************00000200
C                                                                        00000210
C     AZIMUTH OF TARGET BLADE                                            00000220
C                                                                        00000230
      PSIBS = 2.0*PI/NBLDS                                               00000240
      PSITB = PSIR-(ITBLD-1)*PSIBS                                       00000250
C                                                                        00000260
C     SWEEP SOURCE BLADES                                                00000270
C                                                                        00000280
      DO 200   ISBLD = 1,NBLDS                                           00000290
C                                                                        00000300
C     AZIMUTH OF SOURCE BLADE                                            00000310
C                                                                        00000320
      PSISB = PSIR-(ISBLD-1)*PSIBS                                       00000330
C                                                                        00000340
C     POSITION SURFACE                                                   00000350
C                                                                        00000360
      CALL PSURF(ALPHAS,PSISB,ISBLD)                                     00000370
      IF(IPRT7.GT.0) CALL TRACE('PSURF ')                                00000380
C                                                                        00000390
C     SURFACE INFLUENCE COEFFICIENTS OF SOURCE ON TARGET                 00000400
C     (THESE ARE CALCULATED ONLY ONCE PER CASE SINCE RELATIVE            00000410
C     POSITION OF BLADES TO EACH OTHER IS FIXED)                         00000420
C                                                                        00000430
      IF(IAICDS.EQ.0) CALL AICDS(ISBLD)                                  00000440
      IF((IAICDS.EQ.0) .AND. (IPRT7.GT.0)) CALL TRACE('AICDS ')          00000450
C                                                                        00000460
C     CALCULATE WAKE GEOMETRY OF SOURCE BLADE                            00000470
C                                                                        00000480
      IF(ISTDY.EQ.0.AND.ISBLD.GT.1) GO TO 100                            00000490
C                                                                        00000500
      CALL PREWAK(PSISB,ISBLD)                                           00000510
      IF(IPRT7.GT.0) CALL TRACE('PREWAK')                                00000520
```

```
C                                                                       00000530
      IF(ISTDY.EQ.0) CALL PWAKE                                         00000540
      IF((ISTDY.EQ.0) .AND. (IPRT7.GT.0)) CALL TRACE('PWAKE ')          00000550
C                                                                       00000560
  100 CONTINUE                                                          00000570
C                                                                       00000580
C     WAKE INFLUENCE COEFFICIENTS OF SOURCE ON TARGET                   00000590
C                                                                       00000600
      CALL AICDW(ISBLD)                                                 00000610
      IF(IPRT7.GT.0) CALL TRACE('AICDW ')                               00000620
C                                                                       00000630
  200 CONTINUE                                                          00000640
C                                                                       00000650
      RETURN                                                            00000660
      END                                                               00000670
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWTO1(EXSLV)                                                            00000030
C                                                                              00000040
C     CIRCULATION SOLUTION EXECUTIVE                                           00000050
C                                                                              00000060
C     ************************************************************************00000070
C                                                                              00000080
      SUBROUTINE EXSLV(ITBLD,PSIR,IPSIR,ISCYL)                                 00000090
C                                                                              00000100
      COMMON/ CASE   / IPOINT, ALPHAD, VWOD,   IVDIM,  VWFAC,  PSIRD,          00000110
     1                 CASEID                                                  00000120
      COMMON/ CCIRC  / CIRC(100),      DCIRC(100),     ACIRC(100),             00000130
     1                 CIRCR(100),     BCIRC(20),      GO(20),                 00000140
     2                 TECF,           AKM(6),         XKM(5)                  00000150
      COMMON/ CIPRT  / IPRT1,  IPRT2,  IPRT3,  IPRT4,  IPRT5,  IPRT6,          00000160
     1                 IPRT7,  IPRT8                                           00000170
      COMMON/ CONTRL / TOL1,   TOL2,   TOL3,   ICYL1,  ICYL2,  ICYL3,          00000180
     1                 ICYL4                                                   00000190
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                          00000200
      COMMON/ PNLNDX / MP,             NP,             NPANEL,                 00000210
     1                 MP1,            NP1,            NPNLSQ,                 00000220
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),            00000230
     3                 NPS(4),         NBLDS                                   00000240
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,                   00000250
     1                 IOU10,  IOU11,  IOU12,  IOU13                           00000260
      COMMON/ WAKNDX / REVS,           NWIPR,          NWI,                    00000270
     1                 KMAX(24),       IFWAK,          JS(3,2),                00000280
     2                 PSIMR,          PSIMT,          IROLL                   00000290
C                                                                              00000300
C     ************************************************************************00000310
C                                                                              00000320
C     CALCULATE NORMAL BOUNDARY CONDITION                                      00000330
C                                                                              00000340
      PSIT = PSIR-(2.0*PI)/NBLDS*(ITBLD-1)                                     00000350
C                                                                              00000360
      CALL NRMLBC(PSIT)                                                        00000370
      IF(IPRT7.GT.0) CALL TRACE('NRMLBC')                                      00000380
C                                                                              00000390
      IF(ISTDY.EQ.0) GOTO 200                                                  00000400
C                                                                              00000410
C     PREPARE FOR OUTER SOLUTION OF CIRCULATION                                00000420
C                                                                              00000430
      TOLMAX = 1.0E-05                                                         00000440
      IF(TOL1.GT.0.0) TOLMAX = TOL1                                            00000450
      TOLMAX = TOLMAX*100.0                                                    00000460
C                                                                              00000470
C     INITIALIZE CONVERGENCE CHECK                                             00000480
C                                                                              00000490
      SUMCR = 0.0                                                              00000500
C                                                                              00000510
C     ALLOW ITCYLM CYLES TO CONVERGE                                           00000520
```

```
C                                                                       00000530
      ITCYLM = ICYL1                                                    00000540
      IF(ITCYLM.EQ.0) ITCYLM = 100                                      00000550
      ITCYLM = ITCYLM/20                                                00000560
C                                                                       00000570
C     INITIALIZE CIRCULATION RATIO                                      00000580
C                                                                       00000590
      DO 100 J = 1, NPANEL                                              00000600
      CIRCR(J) = 1.0                                                    00000610
  100 CONTINUE                                                          00000620
C                                                                       00000630
  200 CONTINUE                                                          00000640
C                                                                       00000650
C     LOOP 1000 CONVERGES CIRCULATION OUTER SOLUTION                    00000660
C                                                                       00000670
      IF(ISTDY.EQ.0) ITCYLM = 1                                         00000680
C                                                                       00000690
      DO 1000 ITCYL = 1, ITCYLM                                         00000700
C                                                                       00000710
C     ASSEMBLE INFLUENCE COEFFICIENT MATRIX                             00000720
C                                                                       00000730
      CALL AICDSW(ITBLD)                                                00000740
      IF(IPRT7.GT.0) CALL TRACE('AICDSW')                               00000750
C                                                                       00000760
C     SOLVE LINEAR EQUATION SYSTEM BY GAUSS-SEIDEL ITERATION            00000770
C                                                                       00000780
      CALL GSITER(NPANEL)                                               00000790
      IF(IPRT7.GT.0) CALL TRACE('GSITER')                               00000800
C                                                                       00000810
      IF(ISTDY.EQ.0) GO TO 1100                                         00000820
C                                                                       00000830
      IF(IPOINT*IPSIR.EQ.1) GO TO 1100                                  00000840
C                                                                       00000850
C     UPDATE CIRCULATION RATIO PARAMETER                                00000860
C                                                                       00000870
      SUMCRP = 0.0                                                      00000880
      DO 300   J = 1, NPANEL                                            00000890
      CIRCRI = CIRCR(J)                                                 00000900
      CIRCRO = DCIRC(J)/CIRC(J)                                         00000910
      CIRCR(J) = 0.5*(CIRCRO-CIRCRI)+CIRCRI                             00000920
      SUMCRP=SUMCRP + ABS(CIRCRO)                                       00000930
  300 CONTINUE                                                          00000940
C                                                                       00000950
C     CHECK CONVERGENCE                                                 00000960
C                                                                       00000970
      TOL = ABS((SUMCRP-SUMCR)/SUMCRP)                                  00000980
      IF(TOL.LE.TOLMAX) GO TO 1100                                      00000990
C                                                                       00001000
      SUMCR = SUMCRP                                                    00001010
C                                                                       00001020
 1000 CONTINUE                                                          00001030
C                                                                       00001040
```

```
 1100 CONTINUE                                                          00001050
C                                                                       00001060
C     CALCULATE CIRCULATION PARAMETERS                                  00001070
C                                                                       00001080
      CALL CIRPRM                                                       00001090
      IF(IPRT7.GT.0) CALL TRACE('CIRPRM')                               00001100
C                                                                       00001110
C     IF OPTIONED, CHECK ROLL-UP COMPATABILITY WITH LOADING             00001120
C                                                                       00001130
      IRFLAG = 0                                                        00001140
      IF(IROLL.EQ.1) CALL ROLNDX                                        00001150
      IF((IROLL.EQ.1) .AND. (IPRT7.GT.0)) CALL TRACE('ROLNDX')          00001160
C                                                                       00001170
C     CALCULATE BLADE ELEMENT VELOCITIES                                00001180
C                                                                       00001190
      CALL BEVEL(PSIT)                                                  00001200
      IF(IPRT7.GT.0) CALL TRACE('BEVEL ')                               00001210
C                                                                       00001220
C     CALCULATE BLADE ELEMENT ALPHAS                                    00001230
C                                                                       00001240
      CALL BEALPH                                                       00001250
      IF(IPRT7.GT.0) CALL TRACE('BEALPH')                               00001260
C                                                                       00001270
C     CALCULATE BLADE AND ROTOR PERFORMANCE                             00001280
C                                                                       00001290
      CALL AEROPF(ITBLD,IPSIR,ISCYL)                                    00001300
      IF(IPRT7.GT.0) CALL TRACE('AEROPF')                               00001310
C                                                                       00001320
C     CHECK FOR CONVERGENCE OF WAKE PARAMETERS                          00001330
C                                                                       00001340
      CALL WAKUPD                                                       00001350
      IF(IPRT7.GT.0) CALL TRACE('WAKUPD')                               00001360
C                                                                       00001370
      RETURN                                                            00001380
      END                                                               00001390
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT01(BVTINT)                                                           00000030
C                                                                              00000040
C     PERFORMS A TABLE LOOKUP OF Y=F(X) OR Y=F(X,Z) USING BISECTION            00000050
C     ITERATION TO LOCATE TARGETS.  LINEAR INTERPOLATION IS USED TO            00000060
C     CALCULATE Y FROM TABLE MEMBERS.                                          00000070
C                                                                              00000080
C     RETURNS INOREX TO INDICATE TARGET POSITION IN X RANGE IF Y=F(X),         00000090
C     OR IN Z RANGE IF Y=F(X,Z).                                               00000100
C                                                                              00000110
C            INOREX = -1  IF EXTRAPOLATION BELOW RANGE                         00000120
C                     0   IF INTERPOLATION WITHIN RANGE                        00000130
C                     1   IF EXTRAPOLATION ABOVE RANGE                        00000140
C                                                                              00000150
C     ************************************************************************00000160
C                                                                              00000170
      SUBROUTINE BVTINT(X,Y,Z,NX,NZ,TABLE,INOREX)                              00000180
C                                                                              00000190
      DIMENSION TABLE(1)                                                       00000200
C                                                                              00000210
C     ************************************************************************00000220
C                                                                              00000230
C     FIRST PASS IS TO LOCATE X TARGET POSITION AMONG TABLE MEMBERS,           00000240
C     SECOND PASS IS FOR Z TARGET IF REQUIRED.                                 00000250
C                                                                              00000260
      IPASS  = 1                                                               00000270
      TARGET = X                                                               00000280
      NMAX   = NX                                                              00000290
      NL     = 1                                                               00000300
      NH     = NX                                                              00000310
      NLOW   = NL                                                              00000320
      NMID   = NMAX/2                                                          00000330
      NHIGH  = NMAX                                                            00000340
C                                                                              00000350
  100 CONTINUE                                                                 00000360
      IF(NMAX.LE.2) GO TO 500                                                  00000370
C                                                                              00000380
C     DETERMINE WHICH TABLE HALF TARGET IS IN                                  00000390
C                                                                              00000400
  110 CONTINUE                                                                 00000410
      IF(TARGET-TABLE(NMID)) 200,300,400                                       00000420
C                                                                              00000430
  200 CONTINUE                                                                 00000440
C                                                                              00000450
C     TARGET IS BELOW MIDPOINT MEMBER                                          00000460
C                                                                              00000470
      NHALF = (NMID-NLOW)/2                                                    00000480
      IF(NHALF) 220,220,210                                                    00000490
  210 CONTINUE                                                                 00000500
      NHIGH = NMID                                                             00000510
      NMID  = NLOW+NHALF                                                       00000520
```

```
      GO TO 110                                                    00000530
  220 CONTINUE                                                     00000540
      NL = NLOW                                                    00000550
      NH = NMID                                                    00000560
      GO TO 500                                                    00000570
C                                                                  00000580
C     TARGET EQUAL TO MIDPOINT MEMBER                              00000590
C                                                                  00000600
  300 CONTINUE                                                     00000610
      NL = NMID-1                                                  00000620
      NH = NMID                                                    00000630
      GO TO 500                                                    00000640
C                                                                  00000650
  400 CONTINUE                                                     00000660
C                                                                  00000670
C     TARGET IS ABOVE MIDPOINT MEMBER                              00000680
C                                                                  00000690
      NHALF = (NHIGH-NMID)/2                                       00000700
      IF(NHALF) 420,420,410                                        00000710
  410 CONTINUE                                                     00000720
      NLOW = NMID                                                  00000730
      NMID = NLOW+NHALF                                            00000740
      GO TO 110                                                    00000750
  420 CONTINUE                                                     00000760
      NL = NMID                                                    00000770
      NH = NHIGH                                                   00000780
C                                                                  00000790
  500 CONTINUE                                                     00000800
C                                                                  00000810
C     TARGET LOCATED                                               00000820
C                                                                  00000830
      GO TO (600,700), IPASS                                       00000840
C                                                                  00000850
  600 CONTINUE                                                     00000860
      NLX = NL                                                     00000870
      NHX = NH                                                     00000880
      NLZ = NX+1                                                   00000890
C                                                                  00000900
C     RESET TO FIND Z POSITION IF REQUIRED                         00000910
C                                                                  00000920
      IF(NZ.LE.0) GO TO 800                                        00000930
      IPASS  = 2                                                   00000940
      TARGET =  Z                                                  00000950
      NMAX   = NZ                                                  00000960
      NL     = NX+1                                                00000970
      NH     = NX+NZ                                               00000980
      NLOW   = NL                                                  00000990
      NMID   = NLOW+NMAX/2                                         00001000
      NHIGH  = NX+NMAX                                             00001010
      GO TO 100                                                    00001020
C                                                                  00001030
  700 CONTINUE                                                     00001040
```

```
      NLZ = NL                                                          00001050
      NHZ = NH                                                          00001060
C                                                                       00001070
  800 CONTINUE                                                          00001080
C                                                                       00001090
C     INTERPOLATE IN X AT LOW Z POSITION                                00001100
C                                                                       00001110
      XL   = TABLE(NLX)                                                 00001120
      XH   = TABLE(NHX)                                                 00001130
      NTAB = (NX+NZ)+(NLZ-NX-1)*NX+NLX                                  00001140
      YL   = TABLE(NTAB)                                                00001150
      YH   = TABLE(NTAB+1)                                              00001160
      IF(NX.EQ.1) YLOW = YL                                             00001170
      IF(NX.GT.1) YLOW = ((YH-YL)/(XH-XL))*(X-XL)+YL                    00001180
C                                                                       00001190
C     SET INOREX FOR X RANGE                                            00001200
C                                                                       00001210
      INOREX = 0                                                        00001220
      IF(X.LT.XL) INORX = -1                                            00001230
      IF(X.GT.XH) INORX = 1                                             00001240
C                                                                       00001250
C     RETURN IF Y = F(X) ONLY                                           00001260
C                                                                       00001270
      Y = YLOW                                                          00001280
      IF(NZ.LE.0) GO TO 900                                             00001290
C                                                                       00001300
C     INTERPOLATE IN X AT HIGH Z POSITION                               00001310
C                                                                       00001320
      ZL   = TABLE(NLZ)                                                 00001330
      ZH   = TABLE(NHZ)                                                 00001340
      NTAB = NTAB+NX                                                    00001350
      YL   = TABLE(NTAB)                                                00001360
      YH   = TABLE(NTAB+1)                                              00001370
      IF(NX.EQ.1) YHIGH = YL                                            00001380
      IF(NX.GT.1) YHIGH = ((YH-YL)/(XH-XL))*(X-XL)+YL                   00001390
C                                                                       00001400
C     INTERPOLATE IN Z                                                  00001410
C                                                                       00001420
      IF(NZ.EQ.1) Y = YLOW                                              00001430
      IF(NZ.GT.1) Y = (YHIGH-YLOW)/(ZH-ZL)*(Z-ZL)+YLOW                  00001440
C                                                                       00001450
C     RESET INOREX FOR Z RANGE                                          00001460
C                                                                       00001470
      INOREX = 0                                                        00001480
      IF(Z.LT.ZL) INOREX=-1                                             00001490
      IF(Z.GT.ZH) INOREX=1                                              00001500
C                                                                       00001510
  900 CONTINUE                                                          00001520
C                                                                       00001530
      RETURN                                                            00001540
      END                                                               00001550
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT01(ZROLFT)                                                     00000030
C                                                                        00000040
C     USES BISECTION ITERATION TO LOCATE THE ZERO LIFT LINE ANGLE AT     00000050
C     A SPECIFIED REYNOLDS NUMBER FROM BIVARIENT AIRFOIL TABLES.  IF     00000060
C     MUTIPLE TABLES DEFINE AIRFOIL THEN THE RESULT IS AVERAGED BETWEEN 00000070
C     TABLES.                                                            00000080
C                                                                        00000090
C     ******************************************************************00000100
C                                                                        00000110
      SUBROUTINE ZROLFT(ALPO,RE,JTAB1,JTAB2,AFTWF)                       00000120
C                                                                        00000130
      COMMON/ AFTABL / NAFT,   IDAFT(4),       AFTOC(4),       IAFTEX,   00000140
     1                 STP1(4),        STP2(4),        STP3(4),          00000150
     2                 STP4(4),        STP5(4),        STP6(4),          00000160
     3                 CLTAB(200,4),   NRCL(4),        NACL(4),          00000170
     4                 CDTAB(200,4),   NRCD(4),        NACD(4),          00000180
     5                 CMTAB(100,4),   NRCM(4),        NACM(4)           00000190
      COMMON/ CONSTS / PI,     RPD                                        00000200
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,             00000210
     1                 IOU10,  IOU11,  IOU12,  IOU13                     00000220
C                                                                        00000230
C     ******************************************************************00000240
C                                                                        00000250
C     FIRST PASS IS FOR JTAB1 AIRFOIL, SECOND PASS FOR JTAB2 IF REQUIRED 00000260
C                                                                        00000270
      JTAB = JTAB1                                                       00000280
      IPASS = 1                                                          00000290
C                                                                        00000300
   50 CONTINUE                                                           00000310
C                                                                        00000320
C     SET INITIAL GUESS TO ZERO AND SENSE DIRECTION TO MARCH FOR TRAP    00000330
C                                                                        00000340
      ALPO = 0.0                                                         00000350
      CALL BVTINT(RE,CL,ALPO,NRCL(JTAB),NACL(JTAB),CLTAB(1,JTAB),INOREX) 00000360
      IF(CL) 100,500,200                                                 00000370
C                                                                        00000380
  100 CONTINUE                                                           00000390
C                                                                        00000400
C     SEARCH IN POSITIVE DIRECTION ON ALPHA                              00000410
C                                                                        00000420
      AL1 = ALPO                                                         00000430
      DO 120   ICOUNT = 1,20                                             00000440
      AL2 = AL1+1.0                                                      00000450
      ALPO = AL2                                                         00000460
      CALL BVTINT(RE,CL,ALPO,NRCL(JTAB),NACL(JTAB),CLTAB(1,JTAB),INOREX) 00000470
      IF(CL) 110,500,300                                                 00000480
  110 CONTINUE                                                           00000490
      AL1 = AL2                                                          00000500
  120 CONTINUE                                                           00000510
      GO TO 450                                                          00000520
```

```
C                                                                       00000530
  200 CONTINUE                                                          00000540
C                                                                       00000550
C     SEARCH IN NEGATIVE DIRECTION ON ALPHA                             00000560
C                                                                       00000570
      AL2 = ALPO                                                        00000580
      DO 220   ICOUNT = 1,20                                            00000590
      AL1 = AL2-1.0                                                     00000600
      ALPO = AL1                                                        00000610
      CALL BVTINT(RE,CL,ALPO,NRCL(JTAB),NACL(JTAB),CLTAB(1,JTAB),INOREX)00000620
      IF(CL) 300,500,210                                                00000630
  210 CONTINUE                                                          00000640
      AL2 = AL1                                                         00000650
  220 CONTINUE                                                          00000660
      GO TO 450                                                         00000670
C                                                                       00000680
  300 CONTINUE                                                          00000690
C                                                                       00000700
C     ALPHA FOR ZERO LIFT HAS BEEN TRAPPED                              00000710
C                                                                       00000720
      DO 400   ICOUNT = 1,20                                            00000730
      ALPO = (AL1+AL2)/2.0                                              00000740
      CALL BVTINT(RE,CL,ALPO,NRCL(JTAB),NACL(JTAB),CLTAB(1,JTAB),INOREX)00000750
      IF(ABS(CL).LE.1.0E-04) GO TO 500                                  00000760
      IF(CL) 410,500,420                                                00000770
  410 CONTINUE                                                          00000780
      AL1 = ALPO                                                        00000790
      GO TO 400                                                         00000800
  420 CONTINUE                                                          00000810
      AL2 = ALPO                                                        00000820
  400 CONTINUE                                                          00000830
C                                                                       00000840
  450 CONTINUE                                                          00000850
C                                                                       00000860
C     REPORT FAILURE AND HALT EXECUTION                                 00000870
C                                                                       00000880
      WRITE(IOU6,10)                                                    00000890
   10 FORMAT('0',4X,49('*')/                                            00000900
     1       ' ',4X,'FAILURE TO FIND ZERO LIFT LINE...EXECUTION HALTED'/00000910
     2       ' ',4X,49('*'))                                            00000920
C                                                                       00000930
      STOP ' '                                                          00000940
C                                                                       00000950
  500 CONTINUE                                                          00000960
C                                                                       00000970
C     ZERO LIFT ALPHA FOUND FOR THIS PASS, RESET PARAMETERS AND REPEAT  00000980
C     FOR SECOND TABLE IF REQUIRED                                      00000990
C                                                                       00001000
      IF(JTAB1.EQ.JTAB2) GO TO 700                                      00001010
      IF(IPASS.EQ.2)     GO TO 600                                      00001020
      IPASS = 2                                                         00001030
      ALPO1 = ALPO                                                      00001040
```

```
      JTAB = JTAB2                                                    00001050
      GO TO 50                                                        00001060
C                                                                     00001070
  600 CONTINUE                                                        00001080
C                                                                     00001090
C     ZERO LIFT LINE AVERAGED BETWEEN TABLES                          00001100
C                                                                     00001110
      ALP0 = ALP0*AFTWF+ALP01*(1.0-AFTWF)                             00001120
C                                                                     00001130
  700 CONTINUE                                                        00001140
      ALP0 = ALP0*RPD                                                 00001150
C                                                                     00001160
      RETURN                                                          00001170
      END                                                             00001180
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT02(AICDLS)                                                     00000030
C                                                                        00000040
C     CALCULATES TWO-DIMENSIONAL SELF-INDUCED INFLUENCE COEFFICIENTS     00000050
C                                                                        00000060
C     ******************************************************************00000070
C                                                                        00000080
      SUBROUTINE AICDLS                                                  00000090
C                                                                        00000100
      COMMON/ CDLS   / DLS(25)                                           00000110
      COMMON/ CGRID  / NGRID(4),       XG(6),  YG(24), XCG(5)            00000120
      COMMON/ CONSTS / PI,     RPD                                       00000130
      COMMON/ PNLNDX / MP,             NP,             NPANEL,           00000140
     1                 MP1,            NP1,            NPNLSQ,           00000150
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),      00000160
     3                 NPS(4),         NBLDS                             00000170
      COMMON/ CCIRC  / CIRC(100),      DCIRC(100),     ACIRC(100),       00000180
     1                 CIRCR(100),     BCIRC(20),      GO(20),           00000190
     2                 TECF,           AKM(6),         XKM(5)            00000200
C                                                                        00000210
C     ******************************************************************00000220
C                                                                        00000230
      002PI = 1.0/2.0/PI                                                 00000240
C                                                                        00000250
C     SELECT COLLOCATION POINT ON SEGMENT                                00000260
C                                                                        00000270
      DO 200 M = 1, MP                                                   00000280
C                                                                        00000290
C     SWEEP VORTEX FILAMENTS ON SURFACE                                  00000300
C                                                                        00000310
      DO 100 I = 1, MP                                                   00000320
      DXL = XCG(M)-XG(I)                                                 00000330
      DXT = XCG(M)-XG(I+1)                                               00000340
      ISTR = (I-1)*MP+M                                                  00000350
      DLS(ISTR) = -002PI*(1.0/DXL-1.0/DXT)                               00000360
  100 CONTINUE                                                           00000370
C                                                                        00000380
C     WAKE FILAMENT                                                      00000390
C                                                                        00000400
      DW = -002PI/DXT                                                    00000410
      ISTR = MP**2                                                       00000420
      DLS(ISTR) = DLS(ISTR)+TECF*DW                                      00000430
  200 CONTINUE                                                           00000440
C                                                                        00000450
      RETURN                                                             00000460
      END                                                                00000470
```

```
C     ***************************************************************** 00000010
C                                                                       00000020
C     LSWT02(AICDS)                                                     00000030
C                                                                       00000040
C     CALCULATES THE INFLUENCE COEFFICIENTS DUE TO THE LIFTING SURFACE  00000050
C                                                                       00000060
C     ***************************************************************** 00000070
C                                                                       00000080
      SUBROUTINE AICDS(IBLD)                                            00000090
C                                                                       00000100
      DIMENSION  DSN(100),DST(100)                                      00000110
C                                                                       00000120
      COMMON/ CONSTS / PI,     RPD                                      00000130
      COMMON/ GVINT  / XA,     YA,     ZA,     XB,     YB,     ZB,      00000140
     1                 XC,     YC,     ZC,     AN1C,   AN2C,   AN3C,    00000150
     2                 AT1C,   AT2C,   AT3C                             00000160
      COMMON/ PNLCRD / XS(6,24),       YS(6,24),       ZS(6,24),        00000170
     1                 XCOL(5,20),     YCOL(5,20),     ZCOL(5,20)       00000180
      COMMON/ PNLNDX / MP,             NP,             NPANEL,          00000190
     1                 MP1,            NP1,            NPNLSQ,          00000200
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),     00000210
     3                 NPS(4),         NBLDS                            00000220
      COMMON/ PNLVEC / AN1(5,20),      AN2(5,20),      AN3(5,20),       00000230
     1                 AT1(5,20),      AT2(5,20),      AT3(5,20),       00000240
     2                 AQC1(20),       AQC2(20),       AQC3(20)         00000250
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,            00000260
     1                 IOU10,  IOU11,  IOU12,  IOU13                    00000270
C                                                                       00000280
C     ***************************************************************** 00000290
C                                                                       00000300
C     SELECT COLLOCATION POINT                                          00000310
C                                                                       00000320
      DO 400   M = 1,MP                                                 00000330
      DO 400   N = 1,NP                                                 00000340
      LP = (M-1)*NP+N                                                   00000350
      XC = XCOL(M,N)                                                    00000360
      YC = YCOL(M,N)                                                    00000370
      ZC = ZCOL(M,N)                                                    00000380
      AN1C = AN1(M,N)                                                   00000390
      AN2C = AN2(M,N)                                                   00000400
      AN3C = AN3(M,N)                                                   00000410
      AT1C = AT1(M,N)                                                   00000420
      AT2C = AT2(M,N)                                                   00000430
      AT3C = AT3(M,N)                                                   00000440
C                                                                       00000450
C     INITIALIZE ROW OF COEFFICIENTS                                    00000460
C                                                                       00000470
      DO 100   I = 1,NPANEL                                             00000480
      DSN(I) = 0.0                                                      00000490
      DST(I) = 0.0                                                      00000500
  100 CONTINUE                                                          00000510
C                                                                       00000520
```

```
C     SWEEP ALONG SPANWISE ELEMENTS IN CHORDWISE SEQUENCE                00000530
C                                                                        00000540
      DO 200   I = 1,MP1                                                 00000550
C                                                                        00000560
      DO 200   JSEG = 1,NSGMNT                                           00000570
      JG1  = JGLIM(JSEG,1)                                               00000580
      JG2  = JG1+NPS(JSEG)-1                                             00000590
      JCG1 = JCGLIM(JSEG,1)                                              00000600
      JCG2 = JCGLIM(JSEG,2)                                              00000610
C                                                                        00000620
      DO 200   J = JG1,JG2                                               00000630
      JCG = JCG1 + (J-JG1)                                               00000640
      XA  = XS(I,J)                                                      00000650
      YA  = YS(I,J)                                                      00000660
      ZA  = ZS(I,J)                                                      00000670
      JP1 = J + 1                                                        00000680
      XB  = XS(I,JP1)                                                    00000690
      YB  = YS(I,JP1)                                                    00000700
      ZB  = ZS(I,JP1)                                                    00000710
C                                                                        00000720
      CALL VLINE(AIN,AIT)                                                00000730
C                                                                        00000740
      KPP = (I-1)*NP + JCG                                               00000750
      KPM = (I-2)*NP + JCG                                               00000760
      IF(I.LT.MP1)  DSN(KPP) = DSN(KPP) + AIN                            00000770
      IF(I.GT.1)    DSN(KPM) = DSN(KPM) - AIN                            00000780
      IF(I.LT.MP1)  DST(KPP) = DST(KPP) + AIT                            00000790
      IF(I.GT.1)    DST(KPM) = DST(KPM) - AIT                            00000800
C                                                                        00000810
  200 CONTINUE                                                           00000820
C                                                                        00000830
C     SWEEP ALONG CHORDWISE FILAMENTS IN SPANWISE SEQUENCE               00000840
C                                                                        00000850
      DO 300   JSEG = 1,NSGMNT                                           00000860
      JG1  = JGLIM(JSEG,1)                                               00000870
      JG2  = JGLIM(JSEG,2)                                               00000880
      JCG1 = JCGLIM(JSEG,1)                                              00000890
      JCG2 = JCGLIM(JSEG,2)                                              00000900
C                                                                        00000910
      DO 300   J = JG1,JG2                                               00000920
C                                                                        00000930
      JCG = JCG1 + (J-JG1)                                               00000940
C                                                                        00000950
      DO 300   I = 1,MP                                                  00000960
C                                                                        00000970
      IP1 = I + 1                                                        00000980
      XA  = XS(I,J)                                                      00000990
      YA  = YS(I,J)                                                      00001000
      ZA  = ZS(I,J)                                                      00001010
      XB  = XS(IP1,J)                                                    00001020
      YB  = YS(IP1,J)                                                    00001030
      ZB  = ZS(IP1,J)                                                    00001040
```

```
C                                                                       00001050
      CALL VLINE(AIN,AIT)                                               00001060
C                                                                       00001070
      KPM = (I-1)*NP + JCG                                              00001080
      KPP = (I-1)*NP + (JCG-1)                                          00001090
      IF(J.LT.JG2) DSN(KPM) = DSN(KPM) - AIN                            00001100
      IF(J.GT.JG1) DSN(KPP) = DSN(KPP) + AIN                            00001110
      IF(J.LT.JG2) DST(KPM) = DST(KPM) - AIT                            00001120
      IF(J.GT.JG1) DST(KPP) = DST(KPP) + AIT                            00001130
C                                                                       00001140
  300 CONTINUE                                                          00001150
C                                                                       00001160
C     WRITE ROW OF COEFFICIENTS TO DISK                                 00001170
C                                                                       00001180
      IRECN = NPANEL*(IBLD-1) + LP                                      00001190
      IRECT = (NPANEL*NBLDS) + IRECN                                    00001200
      WRITE(IOU10, REC = IRECN) (DSN(J), J = 1,NPANEL)                  00001210
      WRITE(IOU10, REC = IRECT) (DST(J), J = 1,NPANEL)                  00001220
C                                                                       00001230
  400 CONTINUE                                                          00001240
C                                                                       00001250
      RETURN                                                            00001260
      END                                                               00001270
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWTO2(AICDW)                                                      00000030
C                                                                        00000040
C     CALCULATES THE INFLUENCE COEFFICIENTS DUE TO THE TRAILING WAKE     00000050
C                                                                        00000060
C     ******************************************************************00000070
C                                                                        00000080
      SUBROUTINE AICDW(IBLD)                                             00000090
C                                                                        00000100
      DIMENSION DWN(20),DWT(20)                                          00000110
C                                                                        00000120
      COMMON/ CONSTS / PI,     RPD                                       00000130
      COMMON/ GVINT  / XA,     YA,     ZA,     XB,     YB,     ZB,       00000140
     1                 XC,     YC,     ZC,     AN1C,   AN2C,   AN3C,     00000150
     2                 AT1C,   AT2C,   AT3C                              00000160
      COMMON/ PNLCRD / XS(6,24),       YS(6,24),       ZS(6,24),         00000170
     1                 XCOL(5,20),     YCOL(5,20),     ZCOL(5,20)        00000180
      COMMON/ PNLNDX / MP,             NP,             NPANEL,           00000190
     1                 MP1,            NP1,            NPNLSQ,           00000200
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),      00000210
     3                 NPS(4),         NBLDS                             00000220
      COMMON/ PNLVEC / AN1(5,20),      AN2(5,20),      AN3(5,20),        00000230
     1                 AT1(5,20),      AT2(5,20),      AT3(5,20),        00000240
     2                 AQC1(20),       AQC2(20),       AQC3(20)          00000250
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,             00000260
     1                 IOU10,  IOU11,  IOU12,  IOU13                     00000270
      COMMON/ WAKCRD / XW(133,24),     YW(133,24),     ZW(133,24)        00000280
      COMMON/ WAKNDX / REVS,           NWIPR,          NWI,              00000290
     1                 KMAX(24),       IFWAK,          JS(3,2),          00000300
     2                 PSIMR,          PSIMT,          IROLL             00000310
C                                                                        00000320
C     ******************************************************************00000330
C                                                                        00000340
C     READ SOURCE BLADE WAKE COORDINATES FROM DISK                       00000350
C                                                                        00000360
      DO 50   J = 1,NP1                                                  00000370
      IREC = (IBLD-1)*NP1+J                                              00000380
      READ(IOU13, REC = IREC) (XW(K,J),YW(K,J),ZW(K,J), K = 1,KMAX(J))   00000390
   50 CONTINUE                                                           00000400
C                                                                        00000410
C     SELECT COLLOCATION POINT                                           00000420
C                                                                        00000430
      DO 500   M = 1,MP                                                  00000440
      DO 500   N = 1,NP                                                  00000450
C                                                                        00000460
      LP = (M-1)*NP+N                                                    00000470
      XC = XCOL(M,N)                                                     00000480
      YC = YCOL(M,N)                                                     00000490
      ZC = ZCOL(M,N)                                                     00000500
      AN1C = AN1(M,N)                                                    00000510
      AN2C = AN2(M,N)                                                    00000520
```

```
      AN3C = AN3(M,N)                                                   00000530
      AT1C = AT1(M,N)                                                   00000540
      AT2C = AT2(M,N)                                                   00000550
      AT3C = AT3(M,N)                                                   00000560
C                                                                       00000570
C     INITIALIZE COEFFICIENT MATRICES' ROWS                             00000580
C                                                                       00000590
      DO 100   J = 1,NP                                                 00000600
      DWN(J) = 0.0                                                      00000610
      DWT(J) = 0.0                                                      00000620
  100 CONTINUE                                                          00000630
C                                                                       00000640
C     SWEEP SPANWISE ALONG WAKE LEADING EDGE                            00000650
C                                                                       00000660
      DO 200   JSEG = 1,NSGMNT                                          00000670
C                                                                       00000680
      JG1  = JGLIM(JSEG,1)                                              00000690
      JG2  = JGLIM(JSEG,2)                                              00000700
      JCG1 = JCGLIM(JSEG,1)                                             00000710
      JCG2 = JCGLIM(JSEG,2)                                             00000720
C                                                                       00000730
      DO 200   J = JG1,JG2-1                                            00000740
C                                                                       00000750
      JCG = JCG1+(J-JG1)                                                00000760
C                                                                       00000770
C     ASSIGN END POINT COORDINATES TO VORTEX SEGMENT                    00000780
C                                                                       00000790
      XA  = XW(1,J)                                                     00000800
      YA  = YW(1,J)                                                     00000810
      ZA  = ZW(1,J)                                                     00000820
      JP1 = J+1                                                         00000830
      XB  = XW(1,JP1)                                                   00000840
      YB  = YW(1,JP1)                                                   00000850
      ZB  = ZW(1,JP1)                                                   00000860
C                                                                       00000870
      CALL VLINE(AIN,AIT)                                               00000880
C                                                                       00000890
      DWN(JCG) = DWN(JCG)+AIN                                           00000900
      DWT(JCG) = DWT(JCG)+AIT                                           00000910
C                                                                       00000920
  200 CONTINUE                                                          00000930
C                                                                       00000940
C     SWEEP TRAILERS AND CALCULATE CONTRIBUTION OF EACH                 00000950
C                                                                       00000960
      DO 400   JSEG = 1,NSGMNT                                          00000970
C                                                                       00000980
      JG1  = JGLIM(JSEG,1)                                              00000990
      JG2  = JGLIM(JSEG,2)                                              00001000
      JCG1 = JCGLIM(JSEG,1)                                             00001010
      JCG2 = JCGLIM(JSEG,2)                                             00001020
C                                                                       00001030
      DO 400   J = JG1,JG2                                              00001040
```

```
C                                                                       00001050
      JCG = JCG1+(J-JG1)                                                00001060
      K1 = 1                                                            00001070
      K2 = KMAX(J)-1                                                    00001080
      IFWSKP = 0                                                        00001090
      ISTORE = 0                                                        00001100
C                                                                       00001110
C     CHECK IF WITHIN INBOARD OR OUTBOARD SHEET                         00001120
C                                                                       00001130
      IF(JS(1,1).LE.J .AND. J.LE.JS(1,2)) GO TO 301                     00001140
      IF(JS(3,1).LE.J .AND. J.LE.JS(3,2)) GO TO 301                     00001150
      GO TO 300                                                         00001160
C                                                                       00001170
  301 CONTINUE                                                          00001180
      IFWSKP = 1                                                        00001190
C                                                                       00001200
C     SET AZIMUTH LIMITS FOR FIRST PASS ALONG ROLLED-UP VORTEX          00001210
C                                                                       00001220
      IF(J.EQ.1)   K2 = KMAX(2)-1                                       00001230
      IF(J.EQ.NP1) K2 = KMAX(NP1-1)-1                                   00001240
C                                                                       00001250
C     SUM INFLUENCES OF ELEMENTS ALONG TRAILER                          00001260
C                                                                       00001270
  300 CONTINUE                                                          00001280
C                                                                       00001290
      AINS = 0.0                                                        00001300
      AITS = 0.0                                                        00001310
C                                                                       00001320
      DO 310   K = K1,K2                                                00001330
C                                                                       00001340
      XA  = XW(K,J)                                                     00001350
      YA  = YW(K,J)                                                     00001360
      ZA  = ZW(K,J)                                                     00001370
      KP1 = K+1                                                         00001380
      XB  = XW(KP1,J)                                                   00001390
      YB  = YW(KP1,J)                                                   00001400
      ZB  = ZW(KP1,J)                                                   00001410
C                                                                       00001420
      CALL VLINE(AIN,AIT)                                               00001430
C                                                                       00001440
      AINS = AINS+AIN                                                   00001450
      AITS = AITS+AIT                                                   00001460
C                                                                       00001470
  310 CONTINUE                                                          00001480
C                                                                       00001490
      IF(IFWAK.EQ.0)  GO TO 320                                         00001500
      IF(IFWSKP.EQ.1) GO TO 320                                         00001510
C                                                                       00001520
C     CALCULATE FAR WAKE CONTRIBUTION FROM CYLINDER REPRESENTATION      00001530
C                                                                       00001540
      XA = XB                                                           00001550
      YA = YB                                                           00001560
```

```
      ZA = ZB                                                          00001570
C                                                                      00001580
      CALL VCYLN(AIN,AIT)                                              00001590
C                                                                      00001600
      AINS = AINS+AIN                                                  00001610
      AITS = AITS+AIT                                                  00001620
C                                                                      00001630
  320 CONTINUE                                                         00001640
C                                                                      00001650
      IF(ISTORE.EQ.1) GO TO 350                                        00001660
C                                                                      00001670
C     STORE SHEET TRAILER AIC INTO COEFFICIENT ARRAY BUFFERS           00001680
C                                                                      00001690
      JP = JCG-1                                                       00001700
      JM = JCG                                                         00001710
      IF(J.LT.JG2)  DWN(JM) = DWN(JM)-AINS                             00001720
      IF(J.GT.JG1)  DWN(JP) = DWN(JP)+AINS                             00001730
      IF(J.LT.JG2)  DWT(JM) = DWT(JM)-AITS                             00001740
      IF(J.GT.JG1)  DWT(JP) = DWT(JP)+AITS                             00001750
C                                                                      00001760
      IF(J.NE.1 .AND. J.NE.NP1) GO TO 400                              00001770
C                                                                      00001780
C     RESET FOR SECOND PASS ALONG ROLLED-UP ROOT OR TIP VORTEX         00001790
C                                                                      00001800
C     CHECK IF ROOT VORTEX IS ROLLED-UP                                00001810
C                                                                      00001820
      IF(J.EQ.1 .AND. JS(1,1).EQ.0) GO TO 400                          00001830
C                                                                      00001840
C     CHECK IF TIP VORTEX IS ROLLED-UP                                 00001850
C                                                                      00001860
      IF(J.EQ.NP1 .AND. JS(3,1).EQ.0) GO TO 400                        00001870
C                                                                      00001880
C     DETERMINE AIC STORAGE INDEX                                      00001890
C                                                                      00001900
      IF(J.EQ.1)   JROLL = JS(1,2)                                     00001910
      IF(J.EQ.NP1) JROLL = JS(3,1)                                     00001920
C                                                                      00001930
C     FIND SEGMENT OF ROLLED UP VORTEX                                 00001940
C                                                                      00001950
      DO 330 JSEG2=1,NSGMNT                                            00001960
      IF(JGLIM(JSEG2,1).LE.JROLL .AND.                                 00001970
     1   JROLL.LE.JGLIM(JSEG2,2)) GO TO 340                            00001980
  330 CONTINUE                                                         00001990
C                                                                      00002000
  340 CONTINUE                                                         00002010
C                                                                      00002020
      JCG = JCGLIM(JSEG2,1)+(JROLL-JGLIM(JSEG2,1))                     00002030
      IF(J.EQ.NP1) JCG = JCG-1                                         00002040
C                                                                      00002050
      K1 = K2+1                                                        00002060
      K2 = KMAX(J)-1                                                   00002070
      IFWSKP = 0                                                       00002080
```

```
      ISTORE = 1                                                        00002090
C                                                                       00002100
      GO TO 300                                                         00002110
C                                                                       00002120
  350 CONTINUE                                                          00002130
C                                                                       00002140
C     STORE ROLLED-UP VORTEX AIC INTO COEFFICIENT ARRAY BUFFER          00002150
C                                                                       00002160
      IF(J.EQ.1)    DWN(JCG) = DWN(JCG)-AINS                            00002170
      IF(J.EQ.NP1)  DWN(JCG) = DWN(JCG)+AINS                            00002180
      IF(J.EQ.1)    DWT(JCG) = DWT(JCG)-AITS                            00002190
      IF(J.EQ.NP1)  DWT(JCG) = DWT(JCG)+AITS                            00002200
C                                                                       00002210
  400 CONTINUE                                                          00002220
C                                                                       00002230
C     WRITE COEFFICIENT MATRICES' ROWS TO DISK                          00002240
C                                                                       00002250
      IRECN = NPANEL*(IBLD-1)+LP                                        00002260
      IRECT = NPANEL*NBLDS+IRECN                                        00002270
      WRITE(IOU11,REC=IRECN) (DWN(J), J = 1,NP)                         00002280
      WRITE(IOU11,REC=IRECT) (DWT(J), J = 1,NP)                         00002290
C                                                                       00002300
  500 CONTINUE                                                          00002310
C                                                                       00002320
      RETURN                                                            00002330
      END                                                               00002340
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT02(AICDSW)                                                     00000030
C                                                                        00000040
C     ASSEMBLES THE AERODYNAMIC INFLUENCE COEFFICIENTS OF THE LIFTING    00000050
C     SURFACE AND TRAILED WAKE BY COMBINING THROUGH THE KUTTA CONDITION.00000060
C     THE SELF-INDUCED COMPONENT OF THE AIC'S IS THEN MODIFIED FOR       00000070
C     NON-POTENTIAL LIFT CURVE SLOPE.                                    00000080
C                                                                        00000090
C     ******************************************************************00000100
C                                                                        00000110
      SUBROUTINE AICDSW(ITBLD)                                           00000120
C                                                                        00000130
      DIMENSION DSWN(100),DSWT(100),DSN(100),DST(100),DWN(20),DWT(20)    00000140
C                                                                        00000150
      COMMON/ ALSLP  / ALS(20),        ALSNEW(20),     ALSOLD(20)        00000160
      COMMON/ BLDELE / XCLE(20),       YCG(20),        RBE(20),          00000170
     1                 DBES(20),       CLAMLE(20),     CLAMQC(20),       00000180
     2                 CHDCGL(20),     BETAL(20),      AFTWF(20),        00000190
     3                 JTAB(20,2),     TOC(20),        RE(20),           00000200
     4                 CLT(20),        CDT(20),        CMT(20),          00000210
     5                 CDS(20)                                           00000220
      COMMON/ CCIRC  / CIRC(100),      DCIRC(100),     ACIRC(100),       00000230
     1                 CIRCR(100),     BCIRC(20),      GO(20),           00000240
     2                 TECF,           AKM(6),         XKM(5)            00000250
      COMMON/ CDLS   / DLS(25)                                           00000260
      COMMON/ CONSTS / PI,     RPD                                       00000270
      COMMON/ PARMS  / RADIUS, OMEGA,  OMEGAR, RHO,    AMU               00000280
      COMMON/ PNLNDX / MP,             NP,             NPANEL,           00000290
     1                 MP1,            NP1,            NPNLSQ,           00000300
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),      00000310
     3                 NPS(4),         NBLDS                             00000320
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,             00000330
     1                 IOU10,  IOU11,  IOU12,  IOU13                     00000340
C                                                                        00000350
C     ******************************************************************00000360
C                                                                        00000370
C     SWEEP TARGET PANELS (SOLUTION POINTS)                              00000380
C                                                                        00000390
      DO 600   LP = 1,NPANEL                                             00000400
C                                                                        00000410
C     INITIALIZE COEFFICIENT MATRICES' ROWS                              00000420
C                                                                        00000430
      DO 100   KP = 1,NPANEL                                             00000440
      DSWN(KP) = 0.0                                                     00000450
      DSWT(KP) = 0.0                                                     00000460
  100 CONTINUE                                                           00000470
C                                                                        00000480
C     COMBINE INFLUENCES OF ALL BLADES AND WAKES                         00000490
C                                                                        00000500
      DO 400   ISBLD = 1,NBLDS                                           00000510
C                                                                        00000520
```

```
C     READ ROWS LP OF COEFFICIENT MATRICES FROM DISK                    00000530
C                                                                       00000540
      IRECN = NPANEL*(ISBLD-1)+LP                                       00000550
      IRECT = NPANEL*NBLDS+IRECN                                        00000560
C                                                                       00000570
C     SURFACE                                                           00000580
C                                                                       00000590
      READ(IOU10, REC = IRECN) (DSN(J), J = 1,NPANEL)                   00000600
      READ(IOU10, REC = IRECT) (DST(J), J = 1,NPANEL)                   00000610
C                                                                       00000620
C     WAKE                                                              00000630
C                                                                       00000640
      READ(IOU11, REC = IRECN) (DWN(J), J = 1,NP)                       00000650
      READ(IOU11, REC = IRECT) (DWT(J), J = 1,NP)                       00000660
C                                                                       00000670
C     ADD SURFACE AND WAKE COEFFICIENTS                                 00000680
C                                                                       00000690
      KP1 = 1                                                           00000700
      KP2 = (MP-2)*NP+NP                                                00000710
C                                                                       00000720
      DO 200   KP = KP1,KP2                                             00000730
      CIRRAT = CIRCR(KP)                                                00000740
      IF(ISBLD.EQ.ITBLD) CIRRAT = 1.0                                   00000750
      DSWN(KP) = DSWN(KP) + (DSN(KP) * CIRRAT)                          00000760
      DSWT(KP) = DSWT(KP) + (DST(KP) * CIRRAT)                          00000770
  200 CONTINUE                                                          00000780
C                                                                       00000790
C     WAKE IS COMBINED THROUGH THE KUTTA CONDITION, EXPRESSED BY THE    00000800
C     RATIO TECF OF WAKE CIRCULATION TO TRAILING EDGE PANEL CIRCULATION 00000810
C                                                                       00000820
      KP1 = KP2+1                                                       00000830
      KP2 = NPANEL                                                      00000840
C                                                                       00000850
      DO 300   KP = KP1,KP2                                             00000860
      JW = KP-KP1+1                                                     00000870
      CIRRAT = CIRCR(KP)                                                00000880
      IF(ISBLD.EQ.ITBLD) CIRRAT = 1.0                                   00000890
      DSWN(KP) = DSWN(KP) + ((DSN(KP) + TECF * DWN(JW)) * CIRRAT)       00000900
      DSWT(KP) = DSWT(KP) + ((DST(KP) + TECF * DWT(JW)) * CIRRAT)       00000910
  300 CONTINUE                                                          00000920
C                                                                       00000930
  400 CONTINUE                                                          00000940
C                                                                       00000950
C     MODIFY FOR NON-POTENTIAL SECTIONAL LIFT CURVE SLOPE               00000960
C                                                                       00000970
      LPJ = LP-((LP-1)/NP)*NP                                           00000980
      LPI = (LP-1)/NP+1                                                 00000990
C                                                                       00001000
      DO 500   I = 1,MP                                                 00001010
      ISTRLS = (I-1)*MP+LPI                                             00001020
      KP = (I-1)*NP+LPJ                                                 00001030
      DSWN(KP) = DSWN(KP)+(2.0*PI/ALS(LPJ)-1.0)*DLS(ISTRLS)/CHDCGL(LPJ) 00001040
```

```
  500 CONTINUE                                                          00001050
C                                                                       00001060
C     WRITE COMBINED COEFFICIENT MATRIX ROW LP TO DISK                  00001070
C                                                                       00001080
      IRECN = LP                                                        00001090
      IRECT = NPANEL+LP                                                 00001100
      WRITE(IOU12, REC = IRECN) (DSWN(KP), KP = 1,NPANEL)               00001110
      WRITE(IOU12, REC = IRECT) (DSWT(KP), KP = 1,NPANEL)               00001120
C                                                                       00001130
  600 CONTINUE                                                          00001140
C                                                                       00001150
      RETURN                                                            00001160
      END                                                               00001170
```

```
C     ************************************************************************00000010
C                                                                               00000020
C     LSWTO2(GSITER)                                                            00000030
C                                                                               00000040
C     GAUSS-SEIDEL ITERATIVE SOLUTION OF LINEAR SIMULTANEOUS EQUATIONS          00000050
C     OF THE FORM {A}[X] = [B]                                                  00000060
C                                                                               00000070
C     ************************************************************************00000080
C                                                                               00000090
      SUBROUTINE GSITER(N)                                                      00000100
C                                                                               00000110
      DIMENSION A(100),X(100),B(100)                                            00000120
C                                                                               00000130
      COMMON/ CCIRC  / CIRC(100),      DCIRC(100),     ACIRC(100),              00000140
     1                 CIRCR(100),     BCIRC(20),      GO(20),                  00000150
     2                 TECF,           AKM(6),         XKM(5)                   00000160
      COMMON/ CONTRL / TOL1,   TOL2,   TOL3,   ICYL1,  ICYL2,  ICYL3,           00000170
     1                 ICYL4                                                    00000180
      COMMON/ NMWSH  / NRMWSH(100)                                              00000190
      COMMON/ PARMS  / RADIUS, OMEGA,  OMEGAR, RHO,    AMU                      00000200
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,                    00000210
     1                 IOU10,  IOU11,  IOU12,  IOU13                            00000220
C                                                                               00000230
      EQUIVALENCE (X,CIRC), (B,NRMWSH)                                          00000240
C                                                                               00000250
C     ************************************************************************00000260
C                                                                               00000270
C     NORMALIZE SOLUTION VECTOR                                                 00000280
C                                                                               00000290
      SCLFAC = OMEGAR*RADIUS                                                    00000300
      DO 50   I = 1,N                                                           00000310
      X(I) = X(I)/SCLFAC                                                        00000320
   50 CONTINUE                                                                  00000330
C                                                                               00000340
C     SET MAXIMUM TOLERANCE                                                     00000350
C                                                                               00000360
      TOLMAX = 1.0E-05                                                          00000370
      IF(TOL1.GT.0.0) TOLMAX = TOL1                                             00000380
C                                                                               00000390
C     INITIALIZE CONVERGENCE CHECK                                              00000400
C                                                                               00000410
      SUMX = 0.0                                                                00000420
C                                                                               00000430
C     ALLOW ITCYLM CYLES TO CONVERGE                                            00000440
C                                                                               00000450
      ITCYLM = ICYL1                                                            00000460
      IF(ITCYLM.EQ.0) ITCYLM = 100                                              00000470
C                                                                               00000480
      DO 100   ITCYL = 1,ITCYLM                                                 00000490
C                                                                               00000500
      SUMXP = 0.0                                                               00000510
C                                                                               00000520
```

```
      DO 200   I = 1,N                                                  00000530
C                                                                       00000540
C     READ ROW I OF COEFFICIENT MATRIX INTO A                           00000550
C                                                                       00000560
      READ(IOU12, REC = I) (A(J), J = 1,N)                              00000570
C                                                                       00000580
C     CALCULATE NEW APPROXIMATION TO X(I)                               00000590
C                                                                       00000600
      AX = B(I)+A(I)*X(I)                                               00000610
C                                                                       00000620
      DO 300   J = 1,N                                                  00000630
      AX = AX-A(J)*X(J)                                                 00000640
  300 CONTINUE                                                          00000650
C                                                                       00000660
      X(I) = 0.5*(AX/A(I) - X(I)) + X(I)                                00000670
C                                                                       00000680
C     SUM X VECTOR FOR CONVERGENCE CHECK                                00000690
C                                                                       00000700
      SUMXP = SUMXP+ABS(X(I))                                           00000710
C                                                                       00000720
  200 CONTINUE                                                          00000730
C                                                                       00000740
      TOL = ABS((SUMXP-SUMX)/SUMXP)                                     00000750
      IF(TOL.LE.TOLMAX) GO TO 500                                       00000760
C                                                                       00000770
      SUMX = SUMXP                                                      00000780
C                                                                       00000790
  100 CONTINUE                                                          00000800
C                                                                       00000810
C     SOLUTION VECTOR NOT CONVERGED WITHIN ITMAX ITERATIONS             00000820
C                                                                       00000830
      WRITE(IOU6,10) ITCYLM,TOL,TOLMAX                                  00000840
   10 FORMAT('1',9X,'*** ERROR *** SUBROUTINE GSITER',/                 00000850
     1       ' ',9X,'CONVERGENCE NOT OBTAINED AT ITERATION ',I3,/       00000860
     2       ' ',9X,'CURRENT TOLERANCE   =',1PE12.4,/                   00000870
     3       ' ',9X,'ALLOWABLE TOLERANCE =',1PE12.4)                    00000880
C                                                                       00000890
      STOP ' '                                                          00000900
C                                                                       00000910
  500 CONTINUE                                                          00000920
C                                                                       00000930
C     RESCALE SOLUTION VECTOR                                           00000940
C                                                                       00000950
      DO 700   I = 1,N                                                  00000960
      X(I) = X(I)*SCLFAC                                                00000970
  700 CONTINUE                                                          00000980
C                                                                       00000990
      RETURN                                                            00001000
      END                                                               00001010
```

Source File: **LSWT02.FOR** Program Unit: **VLINE**

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT02(VLINE)                                                            00000030
C                                                                              00000040
C     APPLIES THE BIOT-SAVART LAW TO CALCULATE THE VELOCITY INDUCED BY         00000050
C     A FINITE LENGTH LINE VORTEX OF UNIT STRENGTH                             00000060
C                                                                              00000070
C     ************************************************************************00000080
C                                                                              00000090
      SUBROUTINE VLINE(AIN,AIT)                                                00000100
C                                                                              00000110
      COMMON/ CONSTS / PI,     RPD                                             00000120
      COMMON/ GVINT  / XA,     YA,     ZA,     XB,     YB,     ZB,             00000130
     1                 XC,     YC,     ZC,     AN1C,   AN2C,   AN3C,           00000140
     2                 AT1C,   AT2C,   AT3C                                    00000150
C                                                                              00000160
C     ************************************************************************00000170
C                                                                              00000180
      A  = (XA-XC)**2 + (YA-YC)**2 + (ZA-ZC)**2                                00000190
      B  = 2.0*( (XA-XB)*(XC-XA) + (YA-YB)*(YC-YA) + (ZA-ZB)*(ZC-ZA) )         00000200
      C  = (XA-XB)**2 + (YA-YB)**2 + (ZA-ZB)**2                                00000210
C                                                                              00000220
      C1 = (YC-YB)*ZA + (YA-YC)*ZB + (YB-YA)*ZC                                00000230
      C2 = (ZC-ZB)*XA + (ZA-ZC)*XB + (ZB-ZA)*XC                                00000240
      C3 = (XC-XB)*YA + (XA-XC)*YB + (XB-XA)*YC                                00000250
C                                                                              00000260
      Q  = 4.0*A*C - B**2                                                      00000270
C                                                                              00000280
C     POINTS ARE COLINEAR IF Q=0, THEN QB=0                                    00000290
C                                                                              00000300
      QB = 0.0                                                                 00000310
      IF(ABS(Q).GT.(1.0E-10)) QB = 2.0/Q*((2.0*C+B)/SQRT(A+B+C)                00000320
     1                            -B/SQRT(A))/4.0/PI                           00000330
C                                                                              00000340
      Q1 = C1*QB                                                               00000350
      Q2 = C2*QB                                                               00000360
      Q3 = C3*QB                                                               00000370
C                                                                              00000380
      AIN = AN1C*Q1 + AN2C*Q2 + AN3C*Q3                                        00000390
      AIT = AT1C*Q1 + AT2C*Q2 + AT3C*Q3                                        00000400
C                                                                              00000410
      RETURN                                                                   00000420
      END                                                                      00000430
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT02(VCYLN)                                                      00000030
C                                                                        00000040
C     USES DIRECT NUMERICAL INTEGRATION TO CALCULATE THE VELOCITY        00000050
C     INDUCED BY A SEMI-INFINITE VORTEX CYLINDER OF UNIT STRENGTH        00000060
C                                                                        00000070
C     ******************************************************************00000080
C                                                                        00000090
      SUBROUTINE VCYLN(AIN,AIT)                                          00000100
C                                                                        00000110
      COMMON/ CONSTS / PI,     RPD                                       00000120
      COMMON/ GVINT  / XA,     YA,     ZA,     XB,     YB,     ZB,       00000130
     1                 XC,     YC,     ZC,     AN1C,   AN2C,   AN3C,     00000140
     2                 AT1C,   AT2C,   AT3C                              00000150
      COMMON/ WRATES / AKZW,   AKZI,   AKZ,    AKR,    A,      AKB,      00000160
     1                 CTRW,   AKZO,   ALAMO,  AKRO,   VAXB,   VNUB      00000170
C                                                                        00000180
C     ******************************************************************00000190
C                                                                        00000200
      RC  = SQRT(XC**2+YC**2)                                            00000210
      RA  = SQRT(XA**2+YA**2)                                            00000220
      ZAC = ZA-ZC                                                        00000230
      ZAC = ZAC*SIGN(1.0,AKZW)                                           00000240
      AKZ = AKZW+AKZI                                                    00000250
C                                                                        00000260
C     SET STEP SIZE PROPORTIONAL TO Z                                    00000270
C                                                                        00000280
      STEPS = 10.0                                                       00000290
      ABSZ  = ABS(ZAC)                                                   00000300
      IF(ABSZ.LT.1.0) STEPS = -90.0*ABSZ+100.0                           00000310
      ISTEPS = IFIX(STEPS)                                               00000320
      STEPS  = FLOAT(ISTEPS)                                             00000330
      DPHI   = 2.0*PI/STEPS                                              00000340
C                                                                        00000350
C     INITIALIZE NUMERICAL INTEGRATION                                   00000360
C                                                                        00000370
      PHI = DPHI/2.0                                                     00000380
      VZ  = 0.0                                                          00000390
      VR  = 0.0                                                          00000400
C                                                                        00000410
      DO 100   I = 1,ISTEPS                                              00000420
C                                                                        00000430
      T1 = RA-RC*COS(PHI)                                                00000440
      T2 = RC**2+RA**2-2.0*RA*RC*COS(PHI)                                00000450
      T3 = SQRT(RC**2+RA**2+ZAC**2-2.0*RA*RC*COS(PHI))                   00000460
C                                                                        00000470
C     AXIAL VELOCITY INDUCED BY SEMI-INFINITE VORTEX CYLINDER            00000480
C                                                                        00000490
      VZ = VZ+RA*T1/T2*(1.0-ZAC/T3)                                      00000500
C                                                                        00000510
C     RADIAL VELOCITY INDUCED BY SEMI-INFINITE VORTEX CYLINDER           00000520
```

```
C                                                                       00000530
      VR = VR+RA*COS(PHI)/T3                                            00000540
C                                                                       00000550
      PHI = PHI+DPHI                                                    00000560
C                                                                       00000570
  100 CONTINUE                                                          00000580
C                                                                       00000590
      T4 = -DPHI/8.0/PI**2/AKZ                                          00000600
      T4 = T4*SIGN(1.0,AKZ)                                             00000610
      VZ = VZ*T4                                                        00000620
      VR = VR*T4                                                        00000630
C                                                                       00000640
C     RESOLVE FROM CYLINDRICAL TO CARTESIAN                             00000650
C                                                                       00000660
      VX = VR*XC/RC                                                     00000670
      VY = VR*YC/RC                                                     00000680
C                                                                       00000690
C     NORMAL AND TANGENTIAL INFLUENCE COEFFICIENT COMPONENTS            00000700
C                                                                       00000710
      AIN = AN1C*VX + AN2C*VY + AN3C*VZ                                 00000720
      AIT = AT1C*VX + AT2C*Q2 + AT3C*VZ                                 00000730
C                                                                       00000740
      RETURN                                                            00000750
      END                                                               00000760
```

```
C     ***********************************************************************00000010
C                                                                             00000020
C     LSWT03(GRID)                                                            00000030
C                                                                             00000040
C     GENERATES NONDIMENSIONAL GRID COORDINATES FOR PANEL AND                 00000050
C     COLLOCATION POINT LAYOUT.                                               00000060
C                                                                             00000070
C     CHORDWISE GRID IS A HALF-COSINE DISTRIBUTION BIASED TOWARD THE          00000080
C     LEADING EDGE.                                                           00000090
C                                                                             00000100
C     SPANWISE GRID IS OPTIONED ON 'NGRID' FOR EACH SEGMENT:                  00000110
C         NGRID=1     EQUAL SPACING                                         00000120
C         NGRID=2     FULL-COSINE                                           00000130
C         NGRID=3     HALF-COSINE BIASED INBOARD                            00000140
C         NGRID=4     HALF-COSINE BIASED OUTBOARD                           00000150
C                                                                             00000160
C     ***********************************************************************00000170
C                                                                             00000180
      SUBROUTINE GRID                                                         00000190
C                                                                             00000200
      COMMON/ CGRID  / NGRID(4),       XG(6),  YG(24), XCG(5)               00000210
      COMMON/ CONFIG / XOCREF(4),      YSEG(4,2),      JCHORD(4,2),         00000220
     1                 YCHORD(24),     CHORD(24),      JTWIST(4,2),         00000230
     2                 YTWIST(24),     TWIST(24),      JXAOFF(4,2),         00000240
     3                 YXAOFF(24),     XAOFF(24),      JAFT(4,2),           00000250
     4                 YAFT(24,2),     IDAF(24),       XTRAN(4),            00000260
     5                 YTRAN(4),       ZTRAN(4),       XROT(4),             00000270
     6                 YROT(4),        ZROT(4)                              00000280
      COMMON/ CONSTS / PI,     RPD                                          00000290
      COMMON/ PNLNDX / MP,             NP,             NPANEL,              00000300
     1                 MP1,            NP1,            NPNLSQ,              00000310
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),         00000320
     3                 NPS(4),         NBLDS                                00000330
C                                                                             00000340
C     ***********************************************************************00000350
C                                                                             00000360
      MP1 = MP+1                                                              00000370
C                                                                             00000380
C     CHORDWISE GRID                                                          00000390
C                                                                             00000400
      DPHI = PI/2.0/MP                                                        00000410
C                                                                             00000420
      DO 100   I = 1,MP1                                                      00000430
      PHI = (I-1)*DPHI                                                        00000440
      XG(I) = 1.0-COS(PHI)                                                    00000450
  100 CONTINUE                                                                00000460
C                                                                             00000470
C     SPANWISE GRID FOR EACH SEGMENT                                          00000480
C                                                                             00000490
      JG2  = 0                                                                00000500
      JCG2 = 0                                                                00000510
C                                                                             00000520
```

```
      DO 1000   JSEG = 1,NSGMNT                                    00000530
C                                                                  00000540
      JG1 = JG2+1                                                  00000550
      JG2 = JG1+NPS(JSEG)                                          00000560
      JGLIM(JSEG,1) = JG1                                          00000570
      JGLIM(JSEG,2) = JG2                                          00000580
      JCG1 = JCG2+1                                                00000590
      JCG2 = JCG1+NPS(JSEG)-1                                      00000600
      JCGLIM(JSEG,1) = JCG1                                        00000610
      JCGLIM(JSEG,2) = JCG2                                        00000620
      DYSEG = YSEG(JSEG,2)-YSEG(JSEG,1)                            00000630
      YG1   = YSEG(JSEG,1)                                         00000640
C                                                                  00000650
      GO TO (200,300,400,500), NGRID(JSEG)                         00000660
C                                                                  00000670
C     EQUAL SPACING                                                00000680
C                                                                  00000690
  200 CONTINUE                                                     00000700
      DELY = DYSEG/NPS(JSEG)                                       00000710
C                                                                  00000720
      DO 250   J = JG1,JG2                                         00000730
      YG(J) = DELY*(J-JG1)+YG1                                     00000740
  250 CONTINUE                                                     00000750
C                                                                  00000760
      GO TO 1000                                                   00000770
C                                                                  00000780
C     FULL-COSINE SPACING                                          00000790
C                                                                  00000800
  300 CONTINUE                                                     00000810
      DPHI = PI/NPS(JSEG)                                          00000820
C                                                                  00000830
      DO 350   J = JG1,JG2                                         00000840
      PHI = PI-(J-JG1)*DPHI                                        00000850
      YG(J) = (1.0+COS(PHI))/2.0*DYSEG+YG1                         00000860
  350 CONTINUE                                                     00000870
C                                                                  00000880
      GO TO 1000                                                   00000890
C                                                                  00000900
C     HALF-COSINE BIASED INBOARD                                   00000910
C                                                                  00000920
  400 CONTINUE                                                     00000930
      DPHI = PI/2.0/NPS(JSEG)                                      00000940
C                                                                  00000950
      DO 450   J = JG1,JG2                                         00000960
      PHI = PI-(J-JG1)*DPHI                                        00000970
      YG(J) = (1.0+COS(PHI))*DYSEG+YG1                             00000980
  450 CONTINUE                                                     00000990
C                                                                  00001000
      GO TO 1000                                                   00001010
C                                                                  00001020
C     HALF-COSINE BIASED OUTBOARD                                  00001030
C                                                                  00001040
```

```
  500 CONTINUE                                                    00001050
      DPHI = PI/2.0/NPS(JSEG)                                     00001060
      DO 550   J = JG1,JG2                                        00001070
C                                                                 00001080
      PHI = PI/2.0-(J-JG1)*DPHI                                   00001090
      YG(J) = COS(PHI)*DYSEG+YG1                                  00001100
  550 CONTINUE                                                    00001110
C                                                                 00001120
 1000 CONTINUE                                                    00001130
C                                                                 00001140
C     PANEL INDEX PARAMETERS                                      00001150
C                                                                 00001160
      NP  = JCGLIM(NSGMNT,2)                                      00001170
      NP1 = JGLIM(NSGMNT,2)                                       00001180
      NPANEL = MP*NP                                              00001190
      NPNLSQ = NPANEL**2                                          00001200
C                                                                 00001210
C     COLLOCATION POINT GRID                                      00001220
C                                                                 00001230
      CALL COLCRD                                                 00001240
C                                                                 00001250
      RETURN                                                      00001260
      END                                                         00001270
```

Source File: **LSWT03.FOR** Program Unit: **COLCRD**

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT03(COLCRD)                                                     00000030
C                                                                        00000040
C     CALCULATES THE NONDIMENSIONAL CHORDWISE LOCATION OF COLLOCATION    00000050
C     POINTS BASED ON TWO-DIMENSIONAL MEAN CIRCULATION                   00000060
C                                                                        00000070
C     ******************************************************************00000080
C                                                                        00000090
      SUBROUTINE COLCRD                                                  00000100
C                                                                        00000110
      COMMON/ CCIRC  / CIRC(100),      DCIRC(100),     ACIRC(100),       00000120
     1                 CIRCR(100),     BCIRC(20),      GO(20),           00000130
     2                 TECF,           AKM(6),         XKM(5)            00000140
      COMMON/ CGRID  / NGRID(4),       XG(6),  YG(24), XCG(5)            00000150
      COMMON/ CONSTS / PI,     RPD                                       00000160
      COMMON/ PNLNDX / MP,             NP,             NPANEL,           00000170
     1                 MP1,            NP1,            NPNLSQ,           00000180
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),      00000190
     3                 NPS(4),         NBLDS                             00000200
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,             00000210
     1                 IOU10,  IOU11,  IOU12,  IOU13                     00000220
C                                                                        00000230
C     ******************************************************************00000240
C                                                                        00000250
C     MEAN CIRCULATION OVER EACH PANEL                                   00000260
C                                                                        00000270
      DO 500   I = 1,MP                                                  00000280
C                                                                        00000290
      PHI1 = ACOS(1.0-2.0*XG(I))                                         00000300
      PHI2 = ACOS(1.0-2.0*XG(I+1))                                       00000310
C                                                                        00000320
      AI1   = SIN(PHI1)-PHI1*COS(PHI1)+PHI1/2.0                          00000330
     1        -SIN(PHI1)*COS(PHI1)/2.0                                   00000340
      AI2   = SIN(PHI2)-PHI2*COS(PHI2)+PHI2/2.0                          00000350
     1        -SIN(PHI2)*COS(PHI2)/2.0                                   00000360
      AKBAR = 1.0/2.0/(XG(I+1)-XG(I))*(AI2-AI1)                          00000370
C                                                                        00000380
      DO 300   ITER = 1,20                                               00000390
      PHIC = (PHI1+PHI2)/2.0                                             00000400
      FUNCT = PHIC+SIN(PHIC)-AKBAR                                       00000410
      IF(ABS(FUNCT).LE.1.0E-05) GO TO 400                                00000420
      IF(FUNCT) 100,400,200                                              00000430
  100 PHI1 = PHIC                                                        00000440
      GO TO 300                                                          00000450
  200 PHI2 = PHIC                                                        00000460
  300 CONTINUE                                                           00000470
C                                                                        00000480
      WRITE(IOU6,10) MP,I                                                00000490
   10 FORMAT('0',9X,'XKM ITERATIONS EXCEEDED, MP=',I2,2X,',I=',I2)       00000500
      IEND = 1                                                           00000510
      GO TO 99                                                           00000520
```

```
C                                                                       00000530
  400 CONTINUE                                                          00000540
      XKM(I) = (1.0-COS(PHIC))/2.0                                      00000550
      AKM(I) = AKBAR/PI                                                 00000560
C                                                                       00000570
  500 CONTINUE                                                          00000580
C                                                                       00000590
      AKM(MP1) = 1.0                                                    00000600
C                                                                       00000610
C     CHORDWISE VELOCITY ZERO OF EACH PANEL                             00000620
C                                                                       00000630
      DO 1100   I = 1,MP                                                00000640
C                                                                       00000650
      X1 = XG(I)                                                        00000660
      X2 = XG(I+1)                                                      00000670
C                                                                       00000680
      DO 900   ITER = 1,40                                              00000690
      XVN = (X1+X2)/2.0                                                 00000700
      VN  = AKM(1)/(XVN-XG(1))                                          00000710
C                                                                       00000720
      DO 600   J = 1,MP                                                 00000730
      VN = VN+(AKM(J+1)-AKM(J))/(XVN-XG(J+1))                           00000740
  600 CONTINUE                                                          00000750
C                                                                       00000760
      FUNCT = VN-2.0                                                    00000770
      IF(ABS(FUNCT).LE.1.0E-05) GO TO 1000                              00000780
      IF(FUNCT) 700,1000,800                                            00000790
  700 X2 = XVN                                                          00000800
      GO TO 900                                                         00000810
  800 X1 = XVN                                                          00000820
C                                                                       00000830
  900 CONTINUE                                                          00000840
      WRITE(IOU6,12) MP,I                                               00000850
   12 FORMAT('0',9X,'XCG ITERATIONS EXCEEDED, MP=',I2,2X,', I=',I2)     00000860
      IEND = 1                                                          00000870
      GO TO 99                                                          00000880
C                                                                       00000890
 1000 CONTINUE                                                          00000900
      XCG(I) = XVN                                                      00000910
C                                                                       00000920
 1100 CONTINUE                                                          00000930
C                                                                       00000940
      PHIM = ACOS(1.0-2.0*XKM(MP))                                      00000950
      TECF = PI/(PHIM+SIN(PHIM))                                        00000960
C                                                                       00000970
   99 CONTINUE                                                          00000980
C                                                                       00000990
      RETURN                                                            00001000
      END                                                               00001010
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT03(RFSURF)                                                     00000030
C                                                                        00000040
C     GENERATES THE PANEL CORNER AND COLLOCATION POINT CARTESIAN         00000050
C     COORDINATES OF THE LIFTING SURFACE AT REFERENCE POSITION           00000060
C                                                                        00000070
C     ******************************************************************00000080
C                                                                        00000090
      SUBROUTINE RFSURF                                                  00000100
C                                                                        00000110
      COMMON/ AFTABL / NAFT,   IDAFT(4),       AFTOC(4),       IAFTEX,   00000120
     1                 STP1(4),        STP2(4),        STP3(4),          00000130
     2                 STP4(4),        STP5(4),        STP6(4),          00000140
     3                 CLTAB(200,4),   NRCL(4),        NACL(4),          00000150
     4                 CDTAB(200,4),   NRCD(4),        NACD(4),          00000160
     5                 CMTAB(100,4),   NRCM(4),        NACM(4)           00000170
      COMMON/ BLDELE / XCLE(20),       YCG(20),        RBE(20),          00000180
     1                 DBES(20),       CLAMLE(20),     CLAMQC(20),       00000190
     2                 CHDCGL(20),     BETAL(20),      AFTWF(20),        00000200
     3                 JTAB(20,2),     TOC(20),        RE(20),           00000210
     4                 CLT(20),        CDT(20),        CMT(20),          00000220
     5                 CDS(20)                                           00000230
      COMMON/ CALPHA / ALPHAG(20),     ALPHAE(20),     ALPHAW(20),       00000240
     1                 ALPHAN(20),     ALPHAI(20),     AZLLC(20),        00000250
     2                 TWSTCG(20)                                        00000260
      COMMON/ CGRID  / NGRID(4),       XG(6),  YG(24), XCG(5)            00000270
      COMMON/ CONFIG / XOCREF(4),      YSEG(4,2),      JCHORD(4,2),      00000280
     1                 YCHORD(24),     CHORD(24),      JTWIST(4,2),      00000290
     2                 YTWIST(24),     TWIST(24),      JXAOFF(4,2),      00000300
     3                 YXAOFF(24),     XAOFF(24),      JAFT(4,2),        00000310
     4                 YAFT(24,2),     IDAF(24),       XTRAN(4),         00000320
     5                 YTRAN(4),       ZTRAN(4),       XROT(4),          00000330
     6                 YROT(4),        ZROT(4)                           00000340
      COMMON/ CONSTS / PI,     RPD                                       00000350
      COMMON/ CWIND  / ALPS1,  ALPS2,  HO,     VWO,    E,                00000360
     1                 ITSTYP, TSTAB(100),     NXTS,   NYTS,           00000370
     2                 TO,     TP,     TPO,    TPS,    TK,             00000380
     3                 AB(5,2),        AT(5,2)                           00000390
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                    00000400
      COMMON/ PARMS  / RADIUS, OMEGA,  OMEGAR, RHO,    AMU               00000410
      COMMON/ PNLNDX / MP,             NP,             NPANEL,           00000420
     1                 MP1,            NP1,            NPNLSQ,           00000430
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),      00000440
     3                 NPS(4),         NBLDS                             00000450
      COMMON/ PNLVEC / AN1(5,20),      AN2(5,20),      AN3(5,20),        00000460
     1                 AT1(5,20),      AT2(5,20),      AT3(5,20),        00000470
     2                 AQC1(20),       AQC2(20),       AQC3(20)          00000480
      COMMON/ REFSUR / XSR(6,24),      YSR(6,24),      ZSR(6,24),        00000490
     1                 XCOLR(5,20),    YCOLR(5,20),    ZCOLR(5,20),      00000500
     2                 AN1R(5,20),     AN2R(5,20),     AN3R(5,20),       00000510
     3                 AT1R(5,20),     AT2R(5,20),     AT3R(5,20)        00000520
```

```
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,           00000530
     1                 IOU10,  IOU11,  IOU12,  IOU13                   00000540
C                                                                      00000550
C     ****************************************************************00000560
C                                                                      00000570
C     LOOP THROUGH SEGMENTS                                            00000580
C                                                                      00000590
      DO 400   JSEG = 1,NSGMNT                                         00000600
C                                                                      00000610
      JG1  = JGLIM(JSEG,1)                                             00000620
      JG2  = JGLIM(JSEG,2)                                             00000630
      JCG1 = JCGLIM(JSEG,1)                                            00000640
      JCG2 = JCGLIM(JSEG,2)                                            00000650
C                                                                      00000660
C     LOOP 100 GENERATES PANEL COORDINATES                             00000670
C                                                                      00000680
      DO 100   JG = JG1,JG2                                            00000690
C                                                                      00000700
      CALL LINTRP(YG(JG),CHDGL,JCHORD(JSEG,1),JCHORD(JSEG,2),          00000710
     1            YCHORD,CHORD)                                        00000720
      CALL LINTRP(YG(JG),XGOFF,JXAOFF(JSEG,1),JXAOFF(JSEG,2),          00000730
     1            YXAOFF,XAOFF)                                        00000740
C                                                                      00000750
      XLE = XGOFF-XOCREF(JSEG)*CHDGL                                   00000760
C                                                                      00000770
      CALL AFTLOC(YG(JG),JSEG,JTAB1,JTAB2,AFWF,IEND)                   00000780
C                                                                      00000790
      RG = YG(JG)                                                      00000800
      ZG = 0.0                                                         00000810
      CALL ROTATE(RG,ZG,XROT(JSEG))                                    00000820
      RG = RG + YTRAN(JSEG)                                            00000830
      ZG = ZG + ZTRAN(JSEG)                                            00000840
      IF (ISTDY.EQ.1) BETA0 = AB(1,1)                                  00000850
      IF (ISTDY.EQ.1) CALL ROTATE(RG,ZG,BETA0)                         00000860
      VELGL = SQRT(VW0**2+(OMEGAR*RG)**2)                              00000870
      REGL = RHO*VELGL*CHDGL*RADIUS/AMU                                00000880
C                                                                      00000890
      CALL ZROLFT(AZLL,REGL,JTAB1,JTAB2,AFWF)                          00000900
C                                                                      00000910
      CALL LINTRP(YG(JG),TWSTG,JTWIST(JSEG,1),JTWIST(JSEG,2),          00000920
     1            YTWIST,TWIST)                                        00000930
C                                                                      00000940
      ALPT = TWSTG-AZLL                                                00000950
C                                                                      00000960
      DO 100   I = 1,MP1                                               00000970
C                                                                      00000980
      XSR(I,JG) = XLE+XG(I)*CHDGL                                      00000990
      YSR(I,JG) = YG(JG)                                               00001000
      ZSR(I,JG) = 0.0                                                  00001010
C                                                                      00001020
C     ROTATE TO ZERO LIFT LINE PLUS TWIST INCREMENT                    00001030
C                                                                      00001040
```

```
      CALL ROTATE(ZSR(I,JG),XSR(I,JG),ALPT)                              00001050
C                                                                        00001060
C     APPLY SEGMENT INPUT ROTATIONS                                      00001070
C                                                                        00001080
      CALL ROTATE(ZSR(I,JG),XSR(I,JG),YROT(JSEG))                        00001090
      CALL ROTATE(YSR(I,JG),ZSR(I,JG),XROT(JSEG))                        00001100
      CALL ROTATE(XSR(I,JG),YSR(I,JG),ZROT(JSEG))                        00001110
C                                                                        00001120
C     APPLY SEGMENT INPUT TRANSLATIONS                                   00001130
C                                                                        00001140
      XSR(I,JG) = XSR(I,JG)+XTRAN(JSEG)                                  00001150
      YSR(I,JG) = YSR(I,JG)+YTRAN(JSEG)                                  00001160
      ZSR(I,JG) = ZSR(I,JG)+ZTRAN(JSEG)                                  00001170
C                                                                        00001180
  100 CONTINUE                                                           00001190
C                                                                        00001200
C     LOOP 300 GENERATES COLLOCATION POINT COORDINATES,                  00001210
C     PANEL ORIENTATION VECTORS, AND SOME SWEEP PARAMETERS               00001220
C                                                                        00001230
      DO 300   JCG = JCG1,JCG2                                           00001240
C                                                                        00001250
      JG = JG1+JCG-JCG1                                                  00001260
C                                                                        00001270
C     PANEL GRID CENTER COORDINATE, BLADE ELEMENT SPAN                   00001280
C                                                                        00001290
      YCG(JCG) = (YG(JG+1)+YG(JG))/2.0                                   00001300
      XBE = 0.0                                                          00001310
      YBE = YCG(JCG)                                                     00001320
      ZBE = 0.0                                                          00001330
      CALL ROTATE(ZBE,XBE,YROT(JSEG))                                    00001340
      CALL ROTATE(YBE,ZBE,XROT(JSEG))                                    00001350
      CALL ROTATE(XBE,YBE,ZROT(JSEG))                                    00001360
      XBE = XBE + XTRAN(JSEG)                                            00001370
      YBE = YBE + YTRAN(JSEG)                                            00001380
      ZBE = ZBE + ZTRAN(JSEG)                                            00001390
      RBE(JCG) = SQRT(XBE**2+YBE**2)                                     00001400
      IF (ISTDY.EQ.1) BETA0 = AB(1,1)                                    00001410
      IF (ISTDY.EQ.1) CALL ROTATE(YBE,ZBE,BETA0)                         00001420
      DBES(JCG) = YG(JG+1)-YG(JG)                                        00001430
C                                                                        00001440
C     LEADING AND TRAILING EDGE, AND QUARTER CHORD DIRECTION VECTORS     00001450
C     FOR USE IN SWEEP CALCULATIONS                                      00001460
C                                                                        00001470
      ALE1 = XSR(1,JG+1) - XSR(1,JG)                                     00001480
      ALE2 = YSR(1,JG+1) - YSR(1,JG)                                     00001490
      ALE3 = ZSR(1,JG+1) - ZSR(1,JG)                                     00001500
C                                                                        00001510
      ATE1 = XSR(MP1,JG+1) - XSR(MP1,JG)                                 00001520
      ATE2 = YSR(MP1,JG+1) - YSR(MP1,JG)                                 00001530
      ATE3 = ZSR(MP1,JG+1) - ZSR(MP1,JG)                                 00001540
C                                                                        00001550
      AQC1(JCG) = ALE1 + 0.25*(ATE1-ALE1)                                00001560
```

```
      AQC2(JCG) = ALE2 + 0.25*(ATE2-ALE2)                                00001570
      AQC3(JCG) = ALE3 + 0.25*(ATE3-ALE3)                                00001580
C                                                                        00001590
C     PUT QUARTER CHORD VECTOR BACK INTO BLADE ELEMENT REFERENCE          00001600
C                                                                        00001610
      ANGLE = - XROT(JSEG)                                               00001620
      CALL ROTATE(AQC2(JCG),AQC3(JCG),ANGLE)                             00001630
C                                                                        00001640
      CALL LINTRP(YCG(JCG),CHDCGL(JCG),JCHORD(JSEG,1),JCHORD(JSEG,2),    00001650
     1            YCHORD,CHORD)                                          00001660
      CALL LINTRP(YCG(JCG),XCGOFF,JXAOFF(JSEG,1),JXAOFF(JSEG,2),         00001670
     1            YXAOFF,XAOFF)                                          00001680
C                                                                        00001690
      XCLE(JCG) = XCGOFF-XOCREF(JSEG)*CHDCGL(JCG)                        00001700
C                                                                        00001710
C     GET ZERO LIFT LINE, THICKNESS, AND TWIST                           00001720
C                                                                        00001730
      CALL AFTLOC(YCG(JCG),JSEG,JTAB(JCG,1),JTAB(JCG,2),AFTWF(JCG),IEND)00001740
C                                                                        00001750
      TOC1 = AFTOC(JTAB(JCG,1))                                          00001760
      TOC2 = AFTOC(JTAB(JCG,2))                                          00001770
      TOC(JCG) = TOC2*AFTWF(JCG)+TOC1*(1.0-AFTWF(JCG))                   00001780
      VELCGL = SQRT(VWO**2+(OMEGAR*RBE(JCG))**2)                         00001790
      RECGL  = RHO*VELCGL*CHDCGL(JCG)*RADIUS/AMU                         00001800
C                                                                        00001810
      CALL ZROLFT(AZLLC(JCG),RECGL,JTAB(JCG,1),JTAB(JCG,2),AFTWF(JCG))   00001820
C                                                                        00001830
      CALL LINTRP(YCG(JCG),TWSTCG(JCG),JTWIST(JSEG,1),JTWIST(JSEG,2),    00001840
     1            YTWIST,TWIST)                                          00001850
C                                                                        00001860
C     ROTATE TO ZERO LIFT LINE PLUS TWIST INCREMENT                      00001870
C                                                                        00001880
      ALPT = TWSTCG(JCG)-AZLLC(JCG)                                      00001890
C                                                                        00001900
      DO 200   I = 1,MP                                                 00001910
C                                                                        00001920
      XCOLR(I,JCG) = XCLE(JCG)+XCG(I)*CHDCGL(JCG)                        00001930
      YCOLR(I,JCG) = YCG(JCG)                                            00001940
      ZCOLR(I,JCG) = 0.0                                                 00001950
C                                                                        00001960
      CALL ROTATE(ZCOLR(I,JCG),XCOLR(I,JCG),ALPT)                        00001970
C                                                                        00001980
C     REFERENCE PANEL DIRECTION VECTORS                                  00001990
C                                                                        00002000
      AN1R(I,JCG) = 0.0                                                  00002010
      AN2R(I,JCG) = 0.0                                                  00002020
      AN3R(I,JCG) = 1.0                                                  00002030
C                                                                        00002040
      CALL ROTATE(AN3R(I,JCG),AN1R(I,JCG),ALPT)                          00002050
C                                                                        00002060
      AT1R(I,JCG) = 1.0                                                  00002070
      AT2R(I,JCG) = 0.0                                                  00002080
```

```
      AT3R(I,JCG) = 0.0                                                 00002090
C                                                                       00002100
      CALL ROTATE(AT3R(I,JCG),AT1R(I,JCG),ALPT)                         00002110
C                                                                       00002120
C     APPLY SEGMENT INPUT ROTATIONS                                     00002130
C                                                                       00002140
      CALL ROTATE(ZCOLR(I,JCG),XCOLR(I,JCG),YROT(JSEG))                 00002150
      CALL ROTATE(YCOLR(I,JCG),ZCOLR(I,JCG),XROT(JSEG))                 00002160
      CALL ROTATE(XCOLR(I,JCG),YCOLR(I,JCG),ZROT(JSEG))                 00002170
C                                                                       00002180
      CALL ROTATE(AN3R(I,JCG),AN1R(I,JCG),YROT(JSEG))                   00002190
      CALL ROTATE(AN2R(I,JCG),AN3R(I,JCG),XROT(JSEG))                   00002200
      CALL ROTATE(AN1R(I,JCG),AN2R(I,JCG),ZROT(JSEG))                   00002210
C                                                                       00002220
      CALL ROTATE(AT3R(I,JCG),AT1R(I,JCG),YROT(JSEG))                   00002230
      CALL ROTATE(AT2R(I,JCG),AT3R(I,JCG),XROT(JSEG))                   00002240
      CALL ROTATE(AT1R(I,JCG),AT2R(I,JCG),ZROT(JSEG))                   00002250
C                                                                       00002260
C     APPLY SEGMENT INPUT TRANSLATIONS                                  00002270
C                                                                       00002280
      XCOLR(I,JCG) = XCOLR(I,JCG)+XTRAN(JSEG)                           00002290
      YCOLR(I,JCG) = YCOLR(I,JCG)+YTRAN(JSEG)                           00002300
      ZCOLR(I,JCG) = ZCOLR(I,JCG)+ZTRAN(JSEG)                           00002310
C                                                                       00002320
  200 CONTINUE                                                          00002330
C                                                                       00002340
C     COSINE OF LEADING EDGE SWEEP ANGLE                                00002350
C                                                                       00002360
      CALL VPANG(ALE1,ALE2,ALE3,AT1R(1,JCG),AT2R(1,JCG),AT3R(1,JCG),    00002370
     1           CLAMLE(JCG))                                           00002380
C                                                                       00002390
  300 CONTINUE                                                          00002400
C                                                                       00002410
  400 CONTINUE                                                          00002420
C                                                                       00002430
      RETURN                                                            00002440
      END                                                               00002450
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT03(AFTLOC)                                                     00000030
C                                                                        00000040
C     ASSIGNS AIRFOIL TABLE STORAGE LOCATION INDICES TO BLADE GRID       00000050
C     STATION Y                                                          00000060
C                                                                        00000070
C     ******************************************************************00000080
C                                                                        00000090
      SUBROUTINE AFTLOC(Y,JSEG,JTAB1,JTAB2,AFTWF,IEND)                   00000100
C                                                                        00000110
      COMMON/ AFTABL / NAFT,   IDAFT(4),       AFTOC(4),       IAFTEX,  00000120
     1                 STP1(4),        STP2(4),        STP3(4),         00000130
     2                 STP4(4),        STP5(4),        STP6(4),         00000140
     3                 CLTAB(200,4),   NRCL(4),        NACL(4),         00000150
     4                 CDTAB(200,4),   NRCD(4),        NACD(4),         00000160
     5                 CMTAB(100,4),   NRCM(4),        NACM(4)          00000170
      COMMON/ CONFIG / XOCREF(4),      YSEG(4,2),      JCHORD(4,2),      00000180
     1                 YCHORD(24),     CHORD(24),      JTWIST(4,2),      00000190
     2                 YTWIST(24),     TWIST(24),      JXAOFF(4,2),      00000200
     3                 YXAOFF(24),     XAOFF(24),      JAFT(4,2),        00000210
     4                 YAFT(24,2),     IDAF(24),       XTRAN(4),         00000220
     5                 YTRAN(4),       ZTRAN(4),       XROT(4),          00000230
     6                 YROT(4),        ZROT(4)                           00000240
C                                                                        00000250
C     ******************************************************************00000260
C                                                                        00000270
      IEND = 0                                                           00000280
C                                                                        00000290
C     SET SEGMENT PARAMETERS                                             00000300
C                                                                        00000310
      J1 = JAFT(JSEG,1)                                                  00000320
      J2 = JAFT(JSEG,2)                                                  00000330
C                                                                        00000340
C     CHECK THAT Y IS WITHIN RANGE, AND IF NOT SET LOCATION INDICES      00000350
C     TO APPROPRIATE BOUNDING TABLES FOR THIS SEGMENT                    00000360
C                                                                        00000370
      IDAF1 = IDAF(J1)                                                   00000380
      IDAF2 = IDAF(J1)                                                   00000390
      IF(Y.LT.YAFT(J1,1)) GO TO 400                                      00000400
      IDAF1 = IDAF(J2)                                                   00000410
      IDAF2 = IDAF(J2)                                                   00000420
      IF(Y.GT.YAFT(J2,2)) GO TO 400                                      00000430
C                                                                        00000440
C     TRAP Y WITHIN TABLE RANGE                                          00000450
C                                                                        00000460
      DO 100   J = J1,J2                                                 00000470
      IF(Y.GE.YAFT(J,1).AND.Y.LE.YAFT(J,2)) GO TO 200                    00000480
      IF(Y.LT.YAFT(J+1,1))                  GO TO 300                    00000490
  100 CONTINUE                                                           00000500
C                                                                        00000510
  200 CONTINUE                                                           00000520
```

```
C                                                                       00000530
C     Y IS WITHIN AIRFOIL TABLE RANGE                                   00000540
C                                                                       00000550
      IDAF1 = IDAF(J)                                                   00000560
      IDAF2 = IDAF(J)                                                   00000570
      AFTWF = 0.50                                                      00000580
      IF(J.EQ.J2) GO TO 400                                             00000590
C                                                                       00000600
C     CHECK FOR Y EQUAL TO AIRFOIL DISCONTINUITY STATION                00000610
C                                                                       00000620
      IF(Y.NE.YAFT(J+1,1)) GO TO 400                                    00000630
      IDAF2 = IDAF(J+1)                                                 00000640
      AFTWF = 0.50                                                      00000650
      GO TO 400                                                         00000660
C                                                                       00000670
  300 CONTINUE                                                          00000680
C                                                                       00000690
C     Y IS IN TRANSITION REGION BETWEEN AIRFOIL TABLE RANGES            00000700
C                                                                       00000710
      IDAF1 = IDAF(J)                                                   00000720
      IDAF2 = IDAF(J+1)                                                 00000730
      AFTWF = 0.50                                                      00000740
      IF(YAFT(J+1,1)-YAFT(J,2).LT.1.0E-05) GO TO 400                    00000750
      AFTWF = (Y-YAFT(J,2))/(YAFT(J+1,1)-YAFT(J,2))                     00000760
C                                                                       00000770
  400 CONTINUE                                                          00000780
C                                                                       00000790
C     ASSIGN TABLE LOCATION INDEX BY MATCHING IDAF TO IDAFT             00000800
C                                                                       00000810
      JTAB1 = 0                                                         00000820
      JTAB2 = 0                                                         00000830
C                                                                       00000840
      DO 500   J = 1,NAFT                                               00000850
      IF(IDAF1.EQ.IDAFT(J)) JTAB1 = J                                   00000860
      IF(IDAF2.EQ.IDAFT(J)) JTAB2 = J                                   00000870
  500 CONTINUE                                                          00000880
C                                                                       00000890
      IF(JTAB1.EQ.0.OR.JTAB2.EQ.0) IEND = 1                             00000900
C                                                                       00000910
      RETURN                                                            00000920
      END                                                               00000930
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT03(LINTRP)                                                           00000030
C                                                                              00000040
C     PERFORMS A LINEAR INTERPOLATION OF A PIECEWISE LINEAR FUNCTION.          00000050
C     IF TARGET IS OUTSIDE RANGE, THEN EXTRAPOLATION IS USED.                  00000060
C                                                                              00000070
C     ************************************************************************00000080
C                                                                              00000090
      SUBROUTINE LINTRP(YINT,FINT,JF1,JF2,YF,F)                                00000100
C                                                                              00000110
      DIMENSION YF(1),F(1)                                                     00000120
C                                                                              00000130
C     ************************************************************************00000140
C                                                                              00000150
      DO 100   J = JF1+1,JF2                                                   00000160
      IF(YF(J-1).LE.YINT.AND.YINT.LE.YF(J)) GO TO 200                          00000170
  100 CONTINUE                                                                 00000180
C                                                                              00000190
      IF(YINT.LT.YF(JF1)) J = JF1+1                                            00000200
      IF(YINT.GT.YF(JF2)) J = JF2                                              00000210
C                                                                              00000220
  200 CONTINUE                                                                 00000230
      DFDY = (F(J)-F(J-1))/(YF(J)-YF(J-1))                                     00000240
      FINT = DFDY*(YINT-YF(J-1))+F(J-1)                                        00000250
C                                                                              00000260
      RETURN                                                                   00000270
      END                                                                      00000280
```

Source File: **LSWT03.FOR** Program Unit: **ROTATE**

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT03(ROTATE)                                                           00000030
C                                                                              00000040
C     PERFORMS THE ROTATION THROUGH ANGLE OF (X,Y).  X-AXIS INTO Y-AXIS 00000050
C     IS POSITIVE FOR POSITIVE ANGLE.                                          00000060
C                                                                              00000070
C     ************************************************************************00000080
C                                                                              00000090
      SUBROUTINE ROTATE(X,Y,ANGLE)                                             00000100
C                                                                              00000110
C     ************************************************************************00000120
C                                                                              00000130
      SINANG = SIN(ANGLE)                                                      00000140
      COSANG = COS(ANGLE)                                                      00000150
C                                                                              00000160
      XP = X*COSANG-Y*SINANG                                                   00000170
      YP = X*SINANG+Y*COSANG                                                   00000180
      X = XP                                                                   00000190
      Y = YP                                                                   00000200
C                                                                              00000210
      RETURN                                                                   00000220
      END                                                                      00000230
```

```
C     ***************************************************************00000010
C                                                                     00000020
C     LSWT03(PSURF)                                                   00000030
C                                                                     00000040
C     POSITIONS REFERENCE SURFACE TO ACCOUNT FOR BLADE PITCH, AZIMUTH,  00000050
C     AND FLAPPING.  IBLD=1 ACTS UPON BOTH GRID AND COLLOCATION POINT   00000060
C     COORDINATES.  IBLD>1 ACTS ONLY UPON GRID COORDINATES.             00000070
C                                                                     00000080
C     ***************************************************************00000090
C                                                                     00000100
      SUBROUTINE PSURF(ALPHAS,PSI,IBLD)                               00000110
C                                                                     00000120
      COMMON/ BLDELE / XCLE(20),       YCG(20),       RBE(20),        00000130
     1                 DBES(20),       CLAMLE(20),    CLAMQC(20),     00000140
     2                 CHDCGL(20),     BETAL(20),     AFTWF(20),      00000150
     3                 JTAB(20,2),     TOC(20),       RE(20),         00000160
     4                 CLT(20),        CDT(20),       CMT(20),        00000170
     5                 CDS(20)                                        00000180
      COMMON/ CALPHA / ALPHAG(20),     ALPHAE(20),    ALPHAW(20),     00000190
     1                 ALPHAN(20),     ALPHAI(20),    AZLLC(20),      00000200
     2                 TWSTCG(20)                                     00000210
      COMMON/ CONFIG / XOCREF(4),      YSEG(4,2),     JCHORD(4,2),    00000220
     1                 YCHORD(24),     CHORD(24),     JTWIST(4,2),    00000230
     2                 YTWIST(24),     TWIST(24),     JXAOFF(4,2),    00000240
     3                 YXAOFF(24),     XAOFF(24),     JAFT(4,2),      00000250
     4                 YAFT(24,2),     IDAF(24),      XTRAN(4),       00000260
     5                 YTRAN(4),       ZTRAN(4),      XROT(4),        00000270
     6                 YROT(4),        ZROT(4)                        00000280
      COMMON/ CONSTS / PI,     RPD                                    00000290
      COMMON/ CWIND  / ALPS1,  ALPS2,  HO,     VWO,    E,            00000300
     1                 ITSTYP, TSTAB(100),     NXTS,   NYTS,         00000310
     2                 TO,     TP,     TPO,    TPS,    TK,           00000320
     3                 AB(5,2),        AT(5,2)                        00000330
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                 00000340
      COMMON/ PNLCRD / XS(6,24),       YS(6,24),      ZS(6,24),       00000350
     1                 XCOL(5,20),     YCOL(5,20),    ZCOL(5,20)      00000360
      COMMON/ PNLNDX / MP,             NP,            NPANEL,         00000370
     1                 MP1,            NP1,           NPNLSQ,         00000380
     2                 NSGMNT,         JGLIM(4,2),    JCGLIM(4,2),    00000390
     3                 NPS(4),         NBLDS                          00000400
      COMMON/ PNLVEC / AN1(5,20),      AN2(5,20),     AN3(5,20),      00000410
     1                 AT1(5,20),      AT2(5,20),     AT3(5,20),      00000420
     2                 AQC1(20),       AQC2(20),      AQC3(20)        00000430
      COMMON/ REFSUR / XSR(6,24),      YSR(6,24),     ZSR(6,24),      00000440
     1                 XCOLR(5,20),    YCOLR(5,20),   ZCOLR(5,20),    00000450
     2                 AN1R(5,20),     AN2R(5,20),    AN3R(5,20),     00000460
     3                 AT1R(5,20),     AT2R(5,20),    AT3R(5,20)      00000470
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,         00000480
     1                 IOU10,  IOU11,  IOU12,  IOU13                  00000490
C                                                                     00000500
C     ***************************************************************00000510
C                                                                     00000520
```

```
      ALPHAP = ALPHAS                                                   00000530
      IF(ISTDY.EQ.0) GO TO 130                                          00000540
C                                                                       00000550
C     FLAPPING ANGULAR DISPLACEMENT                                     00000560
C                                                                       00000570
      BETA = AB(1,1)                                                    00000580
      NBH  = AB(1,2)+0.1                                                00000590
      DO 110   N = 1,NBH                                                00000600
      BETA = BETA+AB(N+1,1)*COS(N*PSI)+AB(N+1,2)*SIN(N*PSI)             00000610
  110 CONTINUE                                                          00000620
C                                                                       00000630
C     CYCLIC PITCH                                                      00000640
C                                                                       00000650
      ALPHAC = AT(1,1)                                                  00000660
      NTH    = AT(1,2)+0.1                                              00000670
      DO 120   N = 1,NTH                                                00000680
      ALPHAC = ALPHAC+AT(N+1,1)*COS(N*PSI)+AT(N+1,2)*SIN(N*PSI)         00000690
  120 CONTINUE                                                          00000700
C                                                                       00000710
C     TOTAL PITCH ANGLE CHANGE FROM REFERENCE BLADE VALUE               00000720
C                                                                       00000730
      ALPHAP = ALPHAP+ALPHAC                                            00000740
C                                                                       00000750
  130 CONTINUE                                                          00000760
C                                                                       00000770
      DO 100   I = 1,MP1                                                00000780
      DO 100   J = 1,NP1                                                00000790
C                                                                       00000800
C     LOAD SURFACE PANEL COORDINATES FROM REFERENCE SET                 00000810
C                                                                       00000820
      XS(I,J) = XSR(I,J)                                                00000830
      YS(I,J) = YSR(I,J)                                                00000840
      ZS(I,J) = ZSR(I,J)                                                00000850
C                                                                       00000860
C     ROTATE TO PITCH ABOUT Y-AXIS                                      00000870
C                                                                       00000880
      CALL ROTATE(ZS(I,J),XS(I,J),ALPHAP)                               00000890
C                                                                       00000900
C     ROTATE TO BETA ABOUT X-AXIS                                       00000910
C                                                                       00000920
      IF(ISTDY.EQ.1) CALL ROTATE(YS(I,J),ZS(I,J),BETA)                  00000930
C                                                                       00000940
C     ROTATE TO PSI ABOUT Z-AXIS                                        00000950
C                                                                       00000960
      CALL ROTATE(XS(I,J),YS(I,J),PSI)                                  00000970
C                                                                       00000980
  100 CONTINUE                                                          00000990
C                                                                       00001000
      IF(IBLD.GT.1) GO TO 400                                           00001010
C                                                                       00001020
      DO 300   JSEG = 1, NSGMNT                                         00001030
      JCG1 = JCGLIM(JSEG,1)                                             00001040
```

```
      JCG2 = JCGLIM(JSEG,2)                                              00001050
      DO 300   J = JCG1, JCG2                                            00001060
      DO 200   I = 1, MP                                                 00001070
C                                                                        00001080
C     LOAD PANEL COLLOCATION COORDINATES FROM REFERENCE SET              00001090
C                                                                        00001100
      XCOL(I,J) = XCOLR(I,J)                                             00001110
      YCOL(I,J) = YCOLR(I,J)                                             00001120
      ZCOL(I,J) = ZCOLR(I,J)                                             00001130
C                                                                        00001140
C     ROTATE TO PITCH ABOUT Y-AXIS                                       00001150
C                                                                        00001160
      CALL ROTATE(ZCOL(I,J),XCOL(I,J),ALPHAP)                            00001170
C                                                                        00001180
C     ROTATE TO BETA ABOUT X-AXIS                                        00001190
C                                                                        00001200
      IF(ISTDY.EQ.1) CALL ROTATE(YCOL(I,J),ZCOL(I,J),BETA)               00001210
C                                                                        00001220
C     ROTATE TO PSI ABOUT Z-AXIS                                         00001230
C                                                                        00001240
      CALL ROTATE(XCOL(I,J),YCOL(I,J),PSI)                               00001250
C                                                                        00001260
C     LOAD PANEL ORIENTATION VECTORS FROM REFERENCE SET                  00001270
C                                                                        00001280
      AN1(I,J) = AN1R(I,J)                                               00001290
      AN2(I,J) = AN2R(I,J)                                               00001300
      AN3(I,J) = AN3R(I,J)                                               00001310
C                                                                        00001320
      AT1(I,J) = AT1R(I,J)                                               00001330
      AT2(I,J) = AT2R(I,J)                                               00001340
      AT3(I,J) = AT3R(I,J)                                               00001350
C                                                                        00001360
C     REPEAT PROCEEDURES AS ABOVE                                        00001370
C                                                                        00001380
      CALL ROTATE(AN3(I,J),AN1(I,J),ALPHAP)                              00001390
      CALL ROTATE(AT3(I,J),AT1(I,J),ALPHAP)                              00001400
C                                                                        00001410
      IF(ISTDY.EQ.1) CALL ROTATE(AN2(I,J),AN3(I,J),BETA)                 00001420
      IF(ISTDY.EQ.1) CALL ROTATE(AT2(I,J),AT3(I,J),BETA)                 00001430
C                                                                        00001440
      CALL ROTATE(AN1(I,J),AN2(I,J),PSI)                                 00001450
      CALL ROTATE(AT1(I,J),AT2(I,J),PSI)                                 00001460
                                                                         00001470
  200 CONTINUE                                                           00001480
C                                                                        00001490
C     ELEMENT GEOMETRIC ANGLE OF ATTACK                                  00001500
C                                                                        00001510
      ALPHAG(J) = ALPHAP+TWSTCG(J)                                       00001520
C                                                                        00001530
C     BLADE ELEMENT INCLINATION FROM X-Y PLANE (LOCAL CONING + FLAPPING)00001540
C                                                                        00001550
      BETAL(J) = XROT(JSEG)                                              00001560
```

```
      IF(ISTDY.EQ.1) BETAL(J) = BETAL(J) + BETA                    00001570
C                                                                  00001580
  300 CONTINUE                                                     00001590
C                                                                  00001600
  400 CONTINUE                                                     00001610
C                                                                  00001620
      RETURN                                                       00001630
      END                                                          00001640
```

```
C     ***********************************************************************00000010
C                                                                             00000020
C     LSWT03(VPANG)                                                           00000030
C                                                                             00000040
C     RETURNS THE SINE 'SINTH' OF THE ANGLE BETWEEN THE VECTORS 'A' AND       00000050
C     'B' BASED ON THE DEFINITION OF THE VECTOR PRODUCT                       00000060
C                                                                             00000070
C     ***********************************************************************00000080
C                                                                             00000090
      SUBROUTINE VPANG(AX,AY,AZ,BX,BY,BZ,SINTH)                               00000100
C                                                                             00000110
C     ***********************************************************************00000120
C                                                                             00000130
      AXBX = AY*BZ - AZ*BY                                                    00000140
      AXBY = AZ*BX - AX*BZ                                                    00000150
      AXBZ = AX*BY - AY*BX                                                    00000160
C                                                                             00000170
      ASQ   = AX**2   + AY**2   + AZ**2                                       00000180
      BSQ   = BX**2   + BY**2   + BZ**2                                       00000190
      AXBSQ = AXBX**2 + AXBY**2 + AXBZ**2                                     00000200
C                                                                             00000210
      SINTH = SQRT(AXBSQ/(ASQ*BSQ))                                           00000220
      IF(SINTH.GT.1.0) SINTH = 1.0                                            00000230
C                                                                             00000240
      RETURN                                                                  00000250
      END                                                                     00000260
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT04(PREWAK)                                                     00000030
C                                                                        00000040
C     GENERATES THE DISCRETIZED WAKE VORTEX FILAMENTS OF THE PRESCRIBED  00000050
C     WAKE MODEL                                                         00000060
C                                                                        00000070
C     ******************************************************************00000080
C                                                                        00000090
      SUBROUTINE PREWAK(PSIBIN,IBLD)                                     00000100
C                                                                        00000110
      COMMON/ CIPRT  / IPRT1,  IPRT2,  IPRT3,  IPRT4,  IPRT5,  IPRT6,    00000120
     1                 IPRT7,  IPRT8                                     00000130
      COMMON/ CONSTS / PI,     RPD                                       00000140
      COMMON/ PNLNDX / MP,             NP,             NPANEL,           00000150
     1                 MP1,            NP1,            NPNLSQ,           00000160
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),      00000170
     3                 NPS(4),         NBLDS                             00000180
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,             00000190
     1                 IOU10,  IOU11,  IOU12,  IOU13                     00000200
      COMMON/ WAKNDX / REVS,           NWIPR,          NWI,              00000210
     1                 KMAX(24),       IFWAK,          JS(3,2),          00000220
     2                 PSIMR,          PSIMT,          IROLL             00000230
C                                                                        00000240
C     ******************************************************************00000250
C                                                                        00000260
C     PUT PSIB IN 0-->2*PI RANGE                                         00000270
C                                                                        00000280
      PSIB = 2.0*PI*(PSIBIN/2.0/PI-IFIX(PSIBIN/2.0/PI))                  00000290
C                                                                        00000300
C     AZIMUTH INCREMENT PARAMETERS                                       00000310
C                                                                        00000320
      ANWI = REVS*NWIPR                                                  00000330
      NWI  = IFIX(ANWI)                                                  00000340
      IF(ANWI-NWI.GT.0.5) NWI = NWI+1                                    00000350
      NWI  = NWI+NWIPR+1                                                 00000360
C                                                                        00000370
      DO 100   J = 1,JGLIM(NSGMNT,2)                                     00000380
      KMAX(J) = NWI                                                      00000390
  100 CONTINUE                                                           00000400
C                                                                        00000410
C     GET WAKE PARAMETERS                                                00000420
C                                                                        00000430
      CALL WAKPRM                                                        00000440
      IF(IPRT7.GT.0) CALL TRACE('WAKPRM')                                00000450
C                                                                        00000460
      IF(JS(1,1).EQ.0) GO TO 200                                         00000470
C                                                                        00000480
C     ROOT VORTEX FILAMENT                                               00000490
C                                                                        00000500
      J1 = JS(1,1)                                                       00000510
      J2 = J1                                                            00000520
```

```
C                                                                       00000530
      CALL FILMNT(J1,J2,IBLD,PSIB)                                      00000540
C                                                                       00000550
  200 CONTINUE                                                          00000560
C                                                                       00000570
      IF(JS(3,1).EQ.0) GO TO 300                                        00000580
C                                                                       00000590
C     TIP VORTEX FILAMENT                                               00000600
C                                                                       00000610
      J1 = JS(3,2)                                                      00000620
      J2 = J1                                                           00000630
C                                                                       00000640
      CALL FILMNT(J1,J2,IBLD,PSIB)                                      00000650
C                                                                       00000660
  300 CONTINUE                                                          00000670
C                                                                       00000680
      IF(JS(2,1).EQ.0) GO TO 400                                        00000690
C                                                                       00000700
C     MID-SHEET                                                         00000710
C                                                                       00000720
      J1 = JS(2,1)                                                      00000730
      J2 = JS(2,2)                                                      00000740
C                                                                       00000750
      CALL FILMNT(J1,J2,IBLD,PSIB)                                      00000760
C                                                                       00000770
  400 CONTINUE                                                          00000780
C                                                                       00000790
      IF(JS(1,1).EQ.0) GO TO 500                                        00000800
C                                                                       00000810
C     INBOARD SHEET ROLLUP                                              00000820
C                                                                       00000830
      J1 = JS(1,1)                                                      00000840
      J2 = JS(1,2)                                                      00000850
      JM = J1                                                           00000860
C                                                                       00000870
      CALL FILROL(JM,J1,J2,IBLD,PSIB)                                   00000880
C                                                                       00000890
  500 CONTINUE                                                          00000900
C                                                                       00000910
      IF(JS(3,1).EQ.0) GO TO 600                                        00000920
C                                                                       00000930
C     OUTBOARD SHEET ROLLUP                                             00000940
C                                                                       00000950
      J1 = JS(3,1)                                                      00000960
      J2 = JS(3,2)                                                      00000970
      JM = J2                                                           00000980
C                                                                       00000990
      CALL FILROL(JM,J1,J2,IBLD,PSIB)                                   00001000
C                                                                       00001010
  600 CONTINUE                                                          00001020
C                                                                       00001030
      RETURN                                                            00001040
```

```
      END                                                          00001050
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT04(FILMNT)                                                     00000030
C                                                                        00000040
C     CALCULATES THE TRAJECTORY OF A FILAMENT USING THE PRESCRIBED WAKE  00000050
C     EQUATIONS FOR ROOT AND TIP VORTICES AND MID-SHEET                  00000060
C                                                                        00000070
C     ******************************************************************00000080
C                                                                        00000090
      SUBROUTINE FILMNT(J1,J2,IBLD,PSIB)                                 00000100
C                                                                        00000110
      COMMON/ CIPRT  / IPRT1,  IPRT2,  IPRT3,  IPRT4,  IPRT5,  IPRT6,    00000120
     1                 IPRT7,  IPRT8                                     00000130
      COMMON/ CONSTS / PI,     RPD                                       00000140
      COMMON/ CWIND  / ALPS1,  ALPS2,  H0,     VW0,    E,               00000150
     1                 ITSTYP, TSTAB(100),     NXTS,   NYTS,            00000160
     2                 T0,     TP,     TP0,    TPS,    TK,              00000170
     3                 AB(5,2),        AT(5,2)                          00000180
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                    00000190
      COMMON/ PNLCRD / XS(6,24),       YS(6,24),       ZS(6,24),         00000200
     1                 XCOL(5,20),     YCOL(5,20),     ZCOL(5,20)        00000210
      COMMON/ PNLNDX / MP,             NP,             NPANEL,           00000220
     1                 MP1,            NP1,            NPNLSQ,           00000230
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),      00000240
     3                 NPS(4),         NBLDS                             00000250
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,            00000260
     1                 IOU10,  IOU11,  IOU12,  IOU13                     00000270
      COMMON/ WAKCRD / XW(133,24),     YW(133,24),     ZW(133,24)        00000280
      COMMON/ WAKNDX / REVS,           NWIPR,          NWI,              00000290
     1                 KMAX(24),       IFWAK,          JS(3,2),          00000300
     2                 PSIMR,          PSIMT,          IROLL             00000310
      COMMON/ WRATES / AKZW,   AKZI,   AKZ,    AKR,    A,      AKB,      00000320
     1                 CTRW,   AKZ0,   ALAM0,  AKR0,   VAXB,   VNUB      00000330
C                                                                        00000340
C     ******************************************************************00000350
C                                                                        00000360
C     MAXIMUM WAKE RADIUS AT BLADE TRAILING EDGE                         00000370
C                                                                        00000380
      RWMAX = SQRT(XS(MP1,NP1)**2+YS(MP1,NP1)**2+ZS(MP1,NP1)**2)         00000390
C                                                                        00000400
      IF(ISTDY.EQ.0) CALL WNDPRO(0,0.0,0.0,0.0,VW1,VW2,VW3,AKZW)         00000410
      IF((ISTDY.EQ.0) .AND. (IPRT7.GT.0)) CALL TRACE('WNDPRO')           00000420
C                                                                        00000430
      DO 500   J = J1,J2                                                 00000440
C                                                                        00000450
C     STARTING COORDINATE  OF TRAILER FILAMENT IS BLADE TRAILING EDGE    00000460
C                                                                        00000470
      XF0  = XS(MP1,J)                                                   00000480
      YF0  = YS(MP1,J)                                                   00000490
      ZF0  = ZS(MP1,J)                                                   00000500
      RF0    = SQRT(XF0**2+YF0**2+ZF0**2)                                00000510
      RRATIO = RF0/RWMAX                                                 00000520
```

```
C                                                                       00000530
      XP = XFO                                                          00000540
      YP = YFO                                                          00000550
      CALL ROTATE(XP,YP,-PSIB)                                          00000560
      PSIO = ATAN2(-XP,YP)                                              00000570
      IF(PSIO.GT.0.0) PSIO = PSIO-2.0*PI                                00000580
      PSIO = PSIO+PSIB                                                  00000590
C                                                                       00000600
C     GENERATE FILAMENT COORDINATES                                     00000610
C                                                                       00000620
      XW(1,J) = XFO                                                     00000630
      YW(1,J) = YFO                                                     00000640
      ZW(1,J) = ZFO                                                     00000650
C                                                                       00000660
      IF(ISTDY.EQ.0) GO TO 110                                          00000670
C                                                                       00000680
      BETAB = AB(1,1)                                                   00000690
      NBH   = IFIX(AB(1,2)+0.1)                                         00000700
      DO 100   N = 1,NBH                                                00000710
      BETAB = BETAB+AB(N+1,1)*COS(N*PSIB)+AB(N+1,2)*SIN(N*PSIB)         00000720
  100 CONTINUE                                                          00000730
C                                                                       00000740
  110 CONTINUE                                                          00000750
C                                                                       00000760
C     SWEEP AZIMUTH GRID                                                00000770
C                                                                       00000780
      FNWI = FLOAT(NWIPR)                                               00000790
      DO 400 K = 2,KMAX(J)                                              00000800
      FKM1 = FLOAT(K-1)                                                 00000810
      IF(K.LE.2*NWIPR+1) PSIW = PSIO-(2.0*PI-(PSIB-PSIO))*              00000820
     1                          (FKM1/(2.0*FNWI))**2                    00000830
      IF(K.GT.2*NWIPR+1) PSIW = PSIB-2.0*PI/FNWI*(FKM1-FNWI)            00000840
C                                                                       00000850
      IF(ISTDY.EQ.0) GO TO 210                                          00000860
      BETAW = AB(1,1)                                                   00000870
      PSIOW = PSIW+(PSIB-PSIO)                                          00000880
      DO 200   N = 1,NBH                                                00000890
      BETAW = BETAW+AB(N+1,1)*COS(N*PSIOW)+AB(N+1,2)*SIN(N*PSIOW)       00000900
  200 CONTINUE                                                          00000910
C                                                                       00000920
  210 CONTINUE                                                          00000930
C                                                                       00000940
C     RELOCATE STARTING COORDINATES BACK IN AZIMUTH (TIME)              00000950
C                                                                       00000960
      XF = XFO                                                          00000970
      YF = YFO                                                          00000980
      ZF = ZFO                                                          00000990
C                                                                       00001000
      IF(ISTDY.EQ.1) CALL ROTATE(YF,ZF,BETAW-BETAB)                     00001010
      CALL ROTATE(XF,YF,PSIW-PSIO)                                      00001020
C                                                                       00001030
      IF(ISTDY.EQ.0) GO TO 220                                          00001040
```

```
C                                                                       00001050
C     TRANSFORM INITIAL POINT TO WIND AXIS FOR INTEGRATION              00001060
C                                                                       00001070
      CALL ROTATE(ZF,XF,ALPS2)                                          00001080
      CALL ROTATE(YF,ZF,ALPS1)                                          00001090
C                                                                       00001100
  220 CONTINUE                                                          00001110
C                                                                       00001120
C     INTEGRATE WITH KS STEPS OVER TIME TO GET PRESENT POSITION         00001130
C                                                                       00001140
      KS = K                                                            00001150
      IF(ISTDY.EQ.0) KS = 1                                             00001160
      DPSI = -(PSIW-PSI0)/KS                                            00001170
      PSIF = ATAN2(-XF,YF)                                              00001180
C                                                                       00001190
      DO 300   I = 1,KS                                                00001200
C                                                                       00001210
C     GET SETTLING RATE DUE TO WIND PROFILE                             00001220
C                                                                       00001230
      IF(ISTDY.EQ.1) CALL WNDPRO(0,XF,YF,ZF,VW1,VW2,VW3,AKZW)           00001240
C                                                                       00001250
C     UPDATE TRAILER COORDINATE FOR THIS STEP                           00001260
                                                                        00001270
      ZF = ZF+(AKZW+AKZI)*DPSI                                          00001280
      RF = RRATIO*(A+(1-A)*EXP(-AKR*(ZF-ZF0)))                          00001290
      XF = -RF*SIN(PSIF)                                                00001300
      YF = RF*COS(PSIF)                                                 00001310
C                                                                       00001320
  300 CONTINUE                                                          00001330
C                                                                       00001340
      IF(ISDTY.EQ.0) GO TO 310                                          00001350
C                                                                       00001360
C     TRANSFORM BACK TO SHAFT AXIS                                      00001370
C                                                                       00001380
      CALL ROTATE(YF,ZF,-ALPS1)                                         00001390
      CALL ROTATE(ZF,XF,-ALPS2)                                         00001400
      RF = SQRT(XF**2+YF**2)                                            00001410
C                                                                       00001420
  310 CONTINUE                                                          00001430
C                                                                       00001440
C     SAVE FILAMENT INTO STORAGE ARRAY                                  00001450
C                                                                       00001460
      XW(K,J) = XF                                                      00001470
      YW(K,J) = YF                                                      00001480
      ZW(K,J) = ZF                                                      00001490
C                                                                       00001500
  400 CONTINUE                                                          00001510
C                                                                       00001520
C     LOAD FILAMENT COORDINATES INTO DISK FILE                          00001530
C                                                                       00001540
      IREC = (IBLD-1)*NP1+J                                             00001550
      WRITE(IOU13, REC = IREC) (XW(K,J),YW(K,J),ZW(K,J), K = 1,KMAX(J)) 00001560
```

```
C                                                                       00001570
  500 CONTINUE                                                          00001580
C                                                                       00001590
      RETURN                                                            00001600
      END                                                               00001610
```

```
C     ********************************************************************00000010
C                                                                          00000020
C     LSWT04(FILROL)                                                       00000030
C                                                                          00000040
C     FAIRS INBOARD OR OUTBOARD SHEET FILAMENTS FROM BLADE TO MERGE        00000050
C     POINT ON ROOT OR TIP VORTEX TRAJECTORY RESPECTIVELY                  00000060
C                                                                          00000070
C     ********************************************************************00000080
C                                                                          00000090
      SUBROUTINE FILROL(JM,J1,J2,IBLD,PSIB)                                00000100
C                                                                          00000110
      COMMON/ CIPRT  / IPRT1,  IPRT2,  IPRT3,  IPRT4,  IPRT5,  IPRT6,      00000120
     1                 IPRT7,  IPRT8                                       00000130
      COMMON/ CONSTS / PI,     RPD                                         00000140
      COMMON/ PNLCRD / XS(6,24),       YS(6,24),       ZS(6,24),           00000150
     1                 XCOL(5,20),     YCOL(5,20),     ZCOL(5,20)          00000160
      COMMON/ PNLNDX / MP,             NP,             NPANEL,             00000170
     1                 MP1,            NP1,            NPNLSQ,             00000180
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),        00000190
     3                 NPS(4),         NBLDS                               00000200
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,               00000210
     1                 IOU10,  IOU11,  IOU12,  IOU13                       00000220
      COMMON/ WAKCRD / XW(133,24),     YW(133,24),     ZW(133,24)          00000230
      COMMON/ WAKNDX / REVS,           NWIPR,          NWI,                00000240
     1                 KMAX(24),       IFWAK,          JS(3,2),            00000250
     2                 PSIMR,          PSIMT,          IROLL               00000260
C                                                                          00000270
C     ********************************************************************00000280
C                                                                          00000290
C     READ COORDINATES FROM DISK FILE FOR FILAMENT TO MERGE INTO           00000300
C                                                                          00000310
      IREC = (IBLD-1)*NP1+JM                                               00000320
      READ(IOU13, REC = IREC) (XW(K,JM),YW(K,JM),ZW(K,JM), K=1,KMAX(JM))00000330
C                                                                          00000340
C     SEARCH TO LOCATE MERGE POINT NEAREST DESIRED AZIMUTH                 00000350
C                                                                          00000360
      IF(JM.EQ.J1) PSIMIN = PSIMR+PSIB                                     00000370
      IF(JM.EQ.J2) PSIMIN = PSIMT+PSIB                                     00000380
C                                                                          00000390
      DO 100   K = 1,KMAX(JM)                                              00000400
C                                                                          00000410
      XM   = XW(K,JM)                                                      00000420
      YM   = YW(K,JM)                                                      00000430
      CALL ROTATE(XM,YM,-PSIB)                                             00000440
      PSIM = ATAN2(-XM,YM)                                                 00000450
      IF(PSIM.GT.0.0) PSIM = PSIM-2.0*PI                                   00000460
      PSIM = PSIM+PSIB                                                     00000470
C                                                                          00000480
      IF(PSIM.LE.PSIMIN) GO TO 200                                         00000490
C                                                                          00000500
  100 CONTINUE                                                             00000510
C                                                                          00000520
```

```
  200 CONTINUE                                                          00000530
C                                                                       00000540
      KM = K                                                            00000550
      RM = SQRT(XW(KM,JM)**2+YW(KM,JM)**2)                              00000560
      ZM = ZW(KM,JM)                                                    00000570
C                                                                       00000580
      RMM1 = SQRT(XW(KM-1,JM)**2+YW(KM-1,JM)**2)                        00000590
      XM   = XW(KM-1,JM)                                                00000600
      YM   = YW(KM-1,JM)                                                00000610
      CALL ROTATE(XM,YM,-PSIB)                                          00000620
      PSIMM1 = ATAN2(-XM,YM)                                            00000630
      IF(PSIMM1.GT.0.0) PSIMM1 = PSIMM1-2.0*PI                          00000640
      PSIMM1 = PSIMM1+PSIB                                              00000650
C                                                                       00000660
      RMP1 = SQRT(XW(KM+1,JM)**2+YW(KM+1,JM)**2)                        00000670
      XM   = XW(KM+1,JM)                                                00000680
      YM   = YW(KM+1,JM)                                                00000690
      CALL ROTATE(XM,YM,-PSIB)                                          00000700
      PSIMP1 = ATAN2(-XM,YM)                                            00000710
      IF(PSIMP1.GT.0.0) PSIMP1 = PSIMP1-2.0*PI                          00000720
      PSIMP1 = PSIMP1+PSIB                                              00000730
C                                                                       00000740
      AA = ((RMP1-RMM1)/(PSIMP1-PSIMM1)+(RMM1-RM)/(PSIM-PSIMM1))/       00000750
     1     ((PSIMP1**2-PSIMM1**2)/(PSIMP1-PSIMM1)-(PSIM**2-PSIMM1**2)/  00000760
     2     (PSIM-PSIMM1))                                               00000770
      BB = (RM-RMM1)/(PSIM-PSIMM1)-(PSIM**2-PSIMM1**2)/(PSIM-PSIMM1)*AA 00000780
C                                                                       00000790
      RMP = 2.0*AA*PSIM+BB                                              00000800
C                                                                       00000810
C     SWEEP RADIALLY                                                    00000820
C                                                                       00000830
      IF(JM.EQ.J1) J1 = J1+1                                            00000840
      IF(JM.EQ.J2) J2 = J2-1                                            00000850
      DO 300   J = J1,J2                                                00000860
C                                                                       00000870
C     STARTING COORDINATE  OF TRAILER FILAMENT IS BLADE TRAILING EDGE   00000880
C                                                                       00000890
      XF0  = XS(MP1,J)                                                  00000900
      YF0  = YS(MP1,J)                                                  00000910
      ZF0  = ZS(MP1,J)                                                  00000920
      RF0  = SQRT(XF0**2+YF0**2)                                        00000930
C                                                                       00000940
      XP = XF0                                                          00000950
      YP = YF0                                                          00000960
      CALL ROTATE(XP,YP,-PSIB)                                          00000970
      PSI0 = ATAN2(-XP,YP)                                              00000980
      IF(PSI0.GT.0.0) PSI0 = PSI0-2.0*PI                                00000990
      PSI0 = PSI0+PSIB                                                  00001000
C                                                                       00001010
      XW(1,J) = XF0                                                     00001020
      YW(1,J) = YF0                                                     00001030
      ZW(1,J) = ZF0                                                     00001040
```

```
C                                                                       00001050
C     FAIRING CONSTANTS                                                 00001060
C                                                                       00001070
      DPSI = PSIM-PSIO                                                  00001080
      AA   = (2.0*RFO+RMP*DPSI-2.0*RM)/DPSI**3                          00001090
      BB   = (RMP-3.0*AA*DPSI**2)/2.0/DPSI                              00001100
      ZSLP = (ZM-ZFO)/(PSIM-PSIO)                                       00001110
C                                                                       00001120
C     SET LENGTH INDEX TO KM                                            00001130
C                                                                       00001140
      KMAX(J) = KM                                                      00001150
C                                                                       00001160
C     SWEEP AND GENERATE AZIMUTH GRID                                   00001170
C                                                                       00001180
      FKMM1 = FLOAT(KM-1)                                               00001190
C                                                                       00001200
      DO 400   K = 2,KM                                                 00001210
C                                                                       00001220
      FKM1 = FLOAT(K-1)                                                 00001230
      PSIW = PSIO+(PSIM-PSIO)*(FKM1/FKMM1)**2                           00001240
      DPSI = PSIW-PSIO                                                  00001250
C                                                                       00001260
C     FAIR FROM TRAILING EDGE TO MERGE POINT WITH CUBIC IN AZIMUTH      00001270
C     FOR R AND LINEAR IN AZIMUTH FOR Z                                 00001280
C                                                                       00001290
      RF = AA*DPSI**3+BB*DPSI**2+RFO                                    00001300
      ZF = ZSLP*DPSI+ZFO                                                00001310
      XF = -RF*SIN(PSIW)                                                00001320
      YF = RF*COS(PSIW)                                                 00001330
C                                                                       00001340
C     SAVE COORDINATE INTO STORAGE ARRAY                                00001350
C                                                                       00001360
      XW(K,J) = XF                                                      00001370
      YW(K,J) = YF                                                      00001380
      ZW(K,J) = ZF                                                      00001390
C                                                                       00001400
  400 CONTINUE                                                          00001410
C                                                                       00001420
C     LOAD FILAMENT COORDINATES INTO DISK FILE                          00001430
C                                                                       00001440
      IREC = (IBLD-1)*NP1+J                                             00001450
      WRITE(IOU13, REC = IREC) (XW(K,J),YW(K,J),ZW(K,J), K = 1,KMAX(J)) 00001460
C                                                                       00001470
  300 CONTINUE                                                          00001480
C                                                                       00001490
      RETURN                                                            00001500
      END                                                               00001510
```

```
C     ***************************************************************00000010
C                                                                     00000020
C     LSWT04(PWAKE)                                                   00000030
C                                                                     00000040
C     POSITIONS THE WAKE COORDINATES FOR EACH BLADE IF ISTDY = 0      00000050
C                                                                     00000060
C     ***************************************************************00000070
C                                                                     00000080
      SUBROUTINE PWAKE                                                00000090
C                                                                     00000100
      COMMON/ CONSTS / PI,     RPD                                    00000110
      COMMON/ PNLNDX / MP,             NP,             NPANEL,      00000120
     1                 MP1,            NP1,            NPNLSQ,      00000130
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2), 00000140
     3                 NPS(4),         NBLDS                        00000150
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,        00000160
     1                 IOU10,  IOU11,  IOU12,  IOU13                00000170
      COMMON/ WAKCRD / XW(133,24),     YW(133,24),     ZW(133,24)   00000180
      COMMON/ WAKNDX / REVS,           NWIPR,          NWI,         00000190
     1                 KMAX(24),       IFWAK,          JS(3,2),     00000200
     2                 PSIMR,          PSIMT,          IROLL        00000210
C                                                                     00000220
C     ***************************************************************00000230
C                                                                     00000240
C     BLADE SPACING AZIMUTH INCREMENT                                 00000250
C                                                                     00000260
      PSIBS = 2.0*PI/NBLDS                                            00000270
C                                                                     00000280
C     ROTATION TO POSITION OF FOLLOWING BLADE IS NEGATIVE             00000290
C                                                                     00000300
      DELPSI = -PSIBS                                                 00000310
C                                                                     00000320
C     SWEEP BLADE AZIMUTH POSITION                                    00000330
C                                                                     00000340
      DO 300   IBLD = 2,NBLDS                                         00000350
C                                                                     00000360
C     SWEEP TRAILERS                                                  00000370
C                                                                     00000380
      DO 200   J = 1,NP1                                              00000390
C                                                                     00000400
C     READ PREVIOUS BLADE'S TRAILER COORDINATES FROM DISK FILE        00000410
C                                                                     00000420
      IREC = (IBLD-2)*NP1+J                                           00000430
      READ(IOU13, REC = IREC) (XW(K,J),YW(K,J),ZW(K,J), K = 1,KMAX(J)) 00000440
C                                                                     00000450
C     PLACE THIS TRAILER AT NEXT AZIMUTH                              00000460
C                                                                     00000470
      DO 100   K = 1,KMAX(J)                                          00000480
      CALL ROTATE(XW(K,J),YW(K,J),DELPSI)                             00000490
  100 CONTINUE                                                        00000500
C                                                                     00000510
C     WRITE TO DISK FILE                                              00000520
```

```
C                                                                       00000530
      IREC = (IBLD-1)*NP1+J                                             00000540
      WRITE(IOU13, REC = IREC) (XW(K,J),YW(K,J),ZW(K,J), K = 1,KMAX(J)) 00000550
C                                                                       00000560
  200 CONTINUE                                                          00000570
C                                                                       00000580
  300 CONTINUE                                                          00000590
C                                                                       00000600
      RETURN                                                            00000610
      END                                                               00000620
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT04(WAKPRM)                                                     00000030
C                                                                        00000040
C     ADJUSTS REFERENCE WAKE PARAMETERS BASED ON THE WORKING STATE OF    00000050
C     THE ROTOR                                                          00000060
C                                                                        00000070
C     ******************************************************************00000080
C                                                                        00000090
      SUBROUTINE WAKPRM                                                  00000100
C                                                                        00000110
      COMMON/ CTCON  / CTRIN,  CTROUT, CTRUPD                            00000120
      COMMON/ CWIND  / ALPS1,  ALPS2,  HO,     VWO,    E,                00000130
     1                 ITSTYP, TSTAB(100),     NXTS,   NYTS,           00000140
     2                 TO,     TP,     TPO,    TPS,    TK,             00000150
     3                 AB(5,2),        AT(5,2)                          00000160
      COMMON/ PARMS  / RADIUS, OMEGA,  OMEGAR, RHO,    AMU               00000170
      COMMON/ WRATES / AKZW,   AKZI,   AKZ,    AKR,    A,      AKB,      00000180
     1                 CTRW,   AKZO,   ALAMO,  AKRO,   VAXB,   VNUB      00000190
C                                                                        00000200
C     ******************************************************************00000210
C                                                                        00000220
C     CALCULATE MOMENTUM INDUCED VELOCITY RATIO                          00000230
C                                                                        00000240
      CTRW  =  CTRIN                                                     00000250
      SGNCT =  SIGN(1.0,CTRW)                                            00000260
      VNUO  = OMEGAR*SGNCT*SQRT(ABS(CTRW)/2.0)                           00000270
      VAXB  = VWO/VNUO                                                   00000280
      AKAXB = VAXB/SQRT(2.0)                                             00000290
C                                                                        00000300
      IF(VAXB.GE.2.0) GO TO 100                                          00000310
      IF(VAXB.GE.1.5) GO TO 200                                          00000320
      IF(VAXB.GE.0.0) GO TO 300                                          00000330
      GO TO 400                                                          00000340
C                                                                        00000350
  100 CONTINUE                                                           00000360
C                                                                        00000370
C     WINDMILL BRAKE STATE                                               00000380
C                                                                        00000390
      VNUB = -VAXB/2.0+SQRT((VAXB/2.0)**2-1)                             00000400
      AKB  =  AKAXB/2.0+SQRT((AKAXB/2.0)**2+1.0-SQRT(2.0))               00000410
      GO TO 500                                                          00000420
C                                                                        00000430
  200 CONTINUE                                                           00000440
C                                                                        00000450
C     VORTEX RING STATE, PAST REGION OF ROUGHNESS                        00000460
C                                                                        00000470
      VNUB = 3.0*VAXB-7.0                                                00000480
      AKB  = VAXB+VNUB                                                   00000490
      GO TO 500                                                          00000500
C                                                                        00000510
  300 CONTINUE                                                           00000520
```

```
C                                                                       00000530
C     VORTEX RING STATE, THROUGH REGION OF ROUGHNESS                    00000540
C                                                                       00000550
      VNUB = -VAXB-1.0                                                  00000560
      AKB  =  VAXB+VNUB                                                 00000570
      GO TO 500                                                         00000580
C                                                                       00000590
  400 CONTINUE                                                          00000600
C                                                                       00000610
C     NORMAL WORKING STATE                                              00000620
C                                                                       00000630
      VNUB = -VAXB/2.0-SQRT((VAXB/2.0)**2+1.0)                          00000640
      AKB  =  AKAXB/2.0-SQRT((AKAXB/2.0)**2+1.0)                        00000650
C                                                                       00000660
  500 CONTINUE                                                          00000670
C                                                                       00000680
C     SET REFERENCE WAKE PARAMETERS                                     00000690
C                                                                       00000700
      AKZ0  = -SGNCT*SQRT(ABS(CTRW))                                    00000710
      ALAM0 =  4.0*SQRT(ABS(CTRW))                                      00000720
      AKR0  =  ALAM0/AKZ0                                               00000730
C                                                                       00000740
C     MODIFY REFERENCE VALUES BY VELOCITY RATIO                         00000750
C                                                                       00000760
      AKZW =  VW0/OMEGAR                                                00000770
      AKZ  = -AKZ0*AKB                                                  00000780
      AKZI =  AKZ-AKZW                                                  00000790
C                                                                       00000800
      AKR = ABS(AKR0/AKB)                                               00000810
      AKR = SIGN(AKR,AKZ)                                               00000820
      A   = 1.0+0.22*SIGN(1.0,AKZ)                                      00000830
C                                                                       00000840
      RETURN                                                            00000850
      END                                                               00000860
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT04(WAKUPD)                                                           00000030
C                                                                              00000040
C     CHECKS WAKE PARAMETER CONVERGENCE AND CALCULATES NEW VALUES BASED        00000050
C     ON MOST RECENT ITERATION                                                 00000060
C                                                                              00000070
C     ************************************************************************00000080
C                                                                              00000090
      SUBROUTINE WAKUPD                                                        00000100
C                                                                              00000110
      COMMON/ CIPRT  / IPRT1,  IPRT2,  IPRT3,  IPRT4,  IPRT5,  IPRT6,          00000120
     1                 IPRT7,  IPRT8                                           00000130
      COMMON/ CONTRL / TOL1,   TOL2,   TOL3,   ICYL1,  ICYL2,  ICYL3,          00000140
     1                 ICYL4                                                   00000150
      COMMON/ CTCON  / CTRIN,  CTROUT, CTRUPD                                  00000160
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                          00000170
      COMMON/ WRATES / AKZW,   AKZI,   AKZ,    AKR,    A,      AKB,            00000180
     1                 CTRW,   AKZO,   ALAMO,  AKRO,   VAXB,   VNUB            00000190
C                                                                              00000200
C     ************************************************************************00000210
C                                                                              00000220
C     SAVE CURRENT VALUES                                                      00000230
C                                                                              00000240
      AKZ1   = AKZW+AKZI                                                       00000250
      AKR1   = AKR                                                             00000260
      CT1    = CTRIN                                                           00000270
      CTRUPD = (CTRIN+CTROUT)/2.0                                              00000280
C                                                                              00000290
C     GET NEW VALUES                                                           00000300
C                                                                              00000310
      CTRIN = CTROUT                                                           00000320
C                                                                              00000330
      CALL WAKPRM                                                              00000340
C                                                                              00000350
      IF(IPRT6.EQ.1) CALL OUT6                                                 00000360
C                                                                              00000370
      AKZ2 = AKZW+AKZI                                                         00000380
      AKR2 = AKR                                                               00000390
C                                                                              00000400
C     CHECK CONVERGENCE                                                        00000410
C                                                                              00000420
      IWFLAG = 0                                                               00000430
      TOLMAX = 0.05                                                            00000440
      IF(TOL3.GT.0.0) TOLMAX = TOL3                                            00000450
      TOLKZ  = ABS((AKZ2-AKZ1)/AKZ2)                                           00000460
      TOLKR  = ABS((AKR2-AKR1)/AKR2)                                           00000470
      IF(TOLKZ.GT.TOLMAX) IWFLAG = 1                                           00000480
      CTRIN = CTRUPD                                                           00000490
C                                                                              00000500
      CALL WAKPRM                                                              00000510
C                                                                              00000520
```

```
      IF(IPRT6.EQ.1) CALL OUT6                                  00000530
C                                                               00000540
      RETURN                                                    00000550
      END                                                       00000560
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT04(ROLNDX)                                                           00000030
C                                                                              00000040
C     UPDATES WAKE SHEET INDICES FOR COMPATABILITY WITH RADIAL                 00000050
C     CIRCULATION DISTRIBUTION                                                 00000060
C                                                                              00000070
C     ************************************************************************00000080
C                                                                              00000090
      SUBROUTINE ROLNDX                                                        00000100
C                                                                              00000110
      COMMON/ CCIRC  / CIRC(100),      DCIRC(100),     ACIRC(100),             00000120
     1                 CIRCR(100),     BCIRC(20),      GO(20),                 00000130
     2                 TECF,           AKM(6),         XKM(5)                  00000140
      COMMON/ CONTRL / TOL1,   TOL2,   TOL3,   ICYL1,  ICYL2,  ICYL3,          00000150
     1                 ICYL4                                                   00000160
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                          00000170
      COMMON/ PNLNDX / MP,             NP,             NPANEL,                 00000180
     1                 MP1,            NP1,            NPNLSQ,                 00000190
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),            00000200
     3                 NPS(4),         NBLDS                                   00000210
      COMMON/ WAKNDX / REVS,           NWIPR,          NWI,                    00000220
     1                 KMAX(24),       IFWAK,          JS(3,2),                00000230
     2                 PSIMR,          PSIMT,          IROLL                   00000240
C                                                                              00000250
C     ************************************************************************00000260
C                                                                              00000270
C     SEARCH FROM TIP INBOARD FOR FIRST MAXIMUM IN BOUND CIRCULATION           00000280
C                                                                              00000290
      JMAX   = NP                                                              00000300
C                                                                              00000310
      DO 100  JJ = 2,NP                                                        00000320
      J = NP-JJ+1                                                              00000330
      IF(BCIRC(J).LT.BCIRC(J+1)) GO TO 150                                     00000340
      JMAX = J                                                                 00000350
  100 CONTINUE                                                                 00000360
C                                                                              00000370
  150 CONTINUE                                                                 00000380
C                                                                              00000390
C     GET CORRESPONDING SEGMENT                                                00000400
C                                                                              00000410
      DO 200  JSEG = 1,NSGMNT                                                  00000420
      IF((JCGLIM(JSEG,1).LE.JMAX) .AND. (JMAX.LE.JCGLIM(JSEG,2)))              00000430
     1    JSEGM = JSEG                                                         00000440
  200 CONTINUE                                                                 00000450
C                                                                              00000460
C     INBOARD INDEX OF OUTBOARD SHEET CORRESPONDS TO OUTBOARD                  00000470
C     GRIDLINE INDEX OF THE JMAX PANEL                                         00000480
C                                                                              00000490
      JROLL = (JMAX-JCGLIM(JSEGM,1)+1) + JGLIM(JSEGM,1)                        00000500
C                                                                              00000510
C     SET CONVERGENCE STATUS FLAG                                              00000520
```

```
C                                                                       00000530
      IF(JROLL.NE.JS(3,1)) IRFLAG = 1                                   00000540
C                                                                       00000550
C     RETURN IF NO CHANGE IN ROLL-UP                                    00000560
C                                                                       00000570
      IF(IRFLAG.EQ.0) GO TO 400                                         00000580
C                                                                       00000590
C     ADJUST OUTBOARD SHEET INDEX                                       00000600
C                                                                       00000610
      JS(3,1) = JROLL                                                   00000620
C                                                                       00000630
C     ADJUST MID-SHEET OUTER BOUNDARY IF OPTIONED                       00000640
C                                                                       00000650
      IF(JS(2,2).EQ.0) GO TO 300                                        00000660
      JS(2,2) = JROLL-1                                                 00000670
C                                                                       00000680
C     MAKE SURE AT LEAST ONE FILAMENT IS LEFT                           00000690
C                                                                       00000700
      IF(JS(2,2).GE.JS(2,1)) GO TO 400                                  00000710
      IF(JS(1,2).EQ.0) GO TO 250                                        00000720
      JS(2,1) = 0                                                       00000730
      JS(2,2) = 0                                                       00000740
      GO TO 300                                                         00000750
  250 CONTINUE                                                          00000760
      JS(2,1) = 1                                                       00000770
      JS(2,2) = 1                                                       00000780
      JS(3,1) = JS(1,2) + 1                                             00000790
      GO TO 400                                                         00000800
C                                                                       00000810
  300 CONTINUE                                                          00000820
C                                                                       00000830
C     OTHERWISE, ADJUST INBOARD SHEET OUTER BOUNDARY                    00000840
C                                                                       00000850
      JS(1,2) = JROLL-1                                                 00000860
      IF(JS(1,2).GE.JS(1,1)) GO TO 400                                  00000870
      JS(1,1) = 1                                                       00000880
      JS(1,2) = 1                                                       00000890
      JS(3,1) = JS(1,2) + 1                                             00000900
C                                                                       00000910
  400 CONTINUE                                                          00000920
C                                                                       00000930
      RETURN                                                            00000940
      END                                                               00000950
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT05(READIN)                                                     00000030
C                                                                        00000040
C     DIRECTS ALL PROGRAM INPUT                                          00000050
C                                                                        00000060
C     ******************************************************************00000070
C                                                                        00000080
      SUBROUTINE READIN                                                  00000090
C                                                                        00000100
      CHARACTER CASEID*72                                                00000110
C                                                                        00000120
      COMMON/ CASE   / IPOINT, ALPHAD, VWOD,   IVDIM,  VWFAC,  PSIRD,    00000130
     1                 CASEID                                            00000140
      COMMON/ CGRID  / NGRID(4),       XG(6),  YG(24), XCG(5)            00000150
      COMMON/ CIPRT  / IPRT1,  IPRT2,  IPRT3,  IPRT4,  IPRT5,  IPRT6,    00000160
     1                 IPRT7,  IPRT8                                     00000170
      COMMON/ CONFIG / XOCREF(4),      YSEG(4,2),      JCHORD(4,2),      00000180
     1                 YCHORD(24),     CHORD(24),      JTWIST(4,2),      00000190
     2                 YTWIST(24),     TWIST(24),      JXAOFF(4,2),      00000200
     3                 YXAOFF(24),     XAOFF(24),      JAFT(4,2),        00000210
     4                 YAFT(24,2),     IDAF(24),       XTRAN(4),         00000220
     5                 YTRAN(4),       ZTRAN(4),       XROT(4),          00000230
     6                 YROT(4),        ZROT(4)                           00000240
      COMMON/ CONSTS / PI,     RPD                                       00000250
      COMMON/ CONTRL / TOL1,   TOL2,   TOL3,   ICYL1,  ICYL2,  ICYL3,    00000260
     1                 ICYL4                                             00000270
      COMMON/ CTCON  / CTRIN,  CTROUT, CTRUPD                            00000280
      COMMON/ CWIND  / ALPS1,  ALPS2,  HO,     VWO,    E,               00000290
     1                 ITSTYP, TSTAB(100),     NXTS,   NYTS,            00000300
     2                 TO,     TP,     TPO,    TPS,    TK,              00000310
     3                 AB(5,2),        AT(5,2)                          00000320
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                    00000330
      COMMON/ PARMS  / RADIUS, OMEGA,  OMEGAR, RHO,    AMU              00000340
      COMMON/ PNLNDX / MP,             NP,             NPANEL,          00000350
     1                 MP1,            NP1,            NPNLSQ,          00000360
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),     00000370
     3                 NPS(4),         NBLDS                            00000380
      COMMON/ SWEEP  / ALPSIN, DALP,   NALP,   VWOIN,  DVWO,   NVWO,    00000390
     1                 PSIRIN, DPSIR,  NPSIR                            00000400
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,           00000410
     1                 IOU10,  IOU11,  IOU12,  IOU13                    00000420
      COMMON/ WAKNDX / REVS,           NWIPR,          NWI,             00000430
     1                 KMAX(24),       IFWAK,          JS(3,2),         00000440
     2                 PSIMR,          PSIMT,          IROLL            00000450
C                                                                        00000460
C     ******************************************************************00000470
C                                                                        00000480
      REWIND IOU5                                                        00000490
C                                                                        00000500
C     ------------------------                                           00000510
C     RECORD SET 1, CASE SETUP                                           00000520
```

```
C     ----------------------                                          00000530
C                                                                     00000540
      READ(IOU5,10) CASEID                                            00000550
   10 FORMAT(A72)                                                     00000560
C                                                                     00000570
C     PRINT SWITCHES                                                  00000580
C                                                                     00000590
      READ (IOU5,11) APRT1,APRT2,APRT3,APRT4,APRT5,APRT6,APRT7        00000600
      READ (IOU5,11) APRT8                                            00000610
   11 FORMAT(7F10.0)                                                  00000620
      IPRT1 = IFIX(APRT1+0.1)                                         00000630
      IPRT2 = IFIX(APRT2+0.1)                                         00000640
      IPRT3 = IFIX(APRT3+0.1)                                         00000650
      IPRT4 = IFIX(APRT4+0.1)                                         00000660
      IPRT5 = IFIX(APRT5+0.1)                                         00000670
      IPRT6 = IFIX(APRT6+0.1)                                         00000680
      IPRT7 = IFIX(APRT7+0.1)                                         00000690
      IPRT8 = IFIX(APRT8+0.1)                                         00000700
C                                                                     00000710
C     OUTPUT POINTER FOR TRACE OPTION                                 00000720
C                                                                     00000730
      IOU7 = IPRT7                                                    00000740
      IF(IPRT7.EQ.1) IOU7 = 0                                         00000750
C                                                                     00000760
C     TOLERANCES                                                      00000770
C                                                                     00000780
      READ(IOU5,11) TOL1,TOL2,TOL3                                    00000790
C                                                                     00000800
C     ITERATION CYCLE LIMITS                                          00000810
C                                                                     00000820
      READ(IOU5,11) AICYL1,AICYL2,AICYL3,AICYCL4                      00000830
      ICYL1 = IFIX(AICYL1+0.1)                                        00000840
      ICYL2 = IFIX(AICYL2+0.1)                                        00000850
      ICYL3 = IFIX(AICYL3+0.1)                                        00000860
      ICYL4 = IFIX(AICYL4+0.1)                                        00000870
C                                                                     00000880
C     STREAM CONDITIONS AND PITCH SWEEP                               00000890
C                                                                     00000900
      READ(IOU5,11) AISTDY,RPM,AMURAT,SIGMAP                          00000910
      ISTDY = IFIX(AISTDY + 0.1)                                      00000920
      AMU   = 3.719E-07*AMURAT                                        00000930
      RHO   = 0.002378*SIGMAP                                         00000940
C                                                                     00000950
      READ(IOU5,11) VWOIN,DVWO,ANVWO,VDIM                             00000960
      NVWO  = IFIX(ANVWO+0.1)                                         00000970
      IVDIM = IFIX(VDIM+0.1)                                          00000980
C                                                                     00000990
      READ(IOU5,11) ALPSIN,DALP,ANALP,THRUST                          00001000
      ALPSIN = ALPSIN*RPD                                             00001010
      DALP   = DALP*RPD                                               00001020
      NALP   = ANALP+0.1                                              00001030
C                                                                     00001040
```

```
C     CONFIGURATION PARAMETERS                                          00001050
C                                                                       00001060
      READ(IOU5,11) ABLDS,AMP,ASGMNT,RADIUS                             00001070
      NBLDS  = IFIX(ABLDS+0.1)                                          00001080
      MP     = IFIX(AMP+0.1)                                            00001090
      NSGMNT = IFIX(ASGMNT+0.1)                                         00001100
      OMEGAR = RPM*2*PI*RADIUS/60.0                                     00001110
      OMEGA  = OMEGAR/RADIUS                                            00001120
      CTRIN  = THRUST/(RHO*PI*RADIUS**2*OMEGAR**2)                      00001130
      CTROUT = CTRIN                                                    00001140
C                                                                       00001150
C     PUT VWOIN, DVWO INTO WORKING DIMENSIONS (FT/SEC)                  00001160
C                                                                       00001170
C            IVDIM   INPUT DIMENSION                                    00001180
C              0       FT/SEC                                           00001190
C              1       M/SEC                                            00001200
C              2       MPH                                              00001210
C              3       TIP SPEED RATIO                                  00001220
C                                                                       00001230
      GO TO (50,51,52,53), IVDIM + 1                                    00001240
C                                                                       00001250
   50 CONTINUE                                                          00001260
      VWFAC = 1.0                                                       00001270
      GO TO 60                                                          00001280
C                                                                       00001290
   51 CONTINUE                                                          00001300
      VWFAC = 0.304800                                                  00001310
      GO TO 60                                                          00001320
C                                                                       00001330
   52 CONTINUE                                                          00001340
      VWFAC = 15.0 / 22.0                                               00001350
      GO TO 60                                                          00001360
C                                                                       00001370
   53 CONTINUE                                                          00001380
      VWFAC = 1.0 / OMEGAR                                              00001390
C                                                                       00001400
C     CHECK FOR DVWO = 0.0, AND HANDLE, THEN RESTRICT TO ONE POINT      00001410
C                                                                       00001420
      IF(DVWO.LE.1.0E-06) NVWO = 1                                      00001430
      GO TO 70                                                          00001440
C                                                                       00001450
   60 CONTINUE                                                          00001460
C                                                                       00001470
      VWOIN = VWOIN / VWFAC                                             00001480
      DVWO  = DVWO  / VWFAC                                             00001490
C                                                                       00001500
   70 CONTINUE                                                          00001510
C                                                                       00001520
C     WAKE LENGTH PARAMETERS                                            00001530
C                                                                       00001540
      READ(IOU5,11) REVS,ANWIPR,AIFWAK,PSIMR,PSIMT, AROLL               00001550
      NWIPR = IFIX(ANWIPR+0.1)                                          00001560
```

```
      IFWAK = IFIX(AIFWAK+0.1)                                          00001570
      PSIMR = -PSIMR*RPD                                                00001580
      PSIMT = -PSIMT*RPD                                                00001590
      IROLL = IFIX(AROLL+0.1)                                           00001600
C                                                                       00001610
      READ(IOU5,11) AJS11,AJS12,AJS21,AJS22,AJS31,AJS32                 00001620
C                                                                       00001630
      JS(1,1) = IFIX(AJS11+0.1)                                         00001640
      JS(1,2) = IFIX(AJS12+0.1)                                         00001650
      IF(JS(1,1).EQ.0) JS(1,2) = 0                                      00001660
      IF(JS(1,2).EQ.0) JS(1,1) = 0                                      00001670
C                                                                       00001680
      JS(2,1) = IFIX(AJS21+0.1)                                         00001690
      JS(2,2) = IFIX(AJS22+0.1)                                         00001700
      IF(JS(2,1).EQ.0) JS(2,2) = 0                                      00001710
      IF(JS(2,2).EQ.0) JS(2,1) = 0                                      00001720
C                                                                       00001730
      JS(3,1) = IFIX(AJS31+0.1)                                         00001740
      JS(3,2) = IFIX(AJS32+0.1)                                         00001750
      IF(JS(3,1).EQ.0) JS(3,2) = 0                                      00001760
      IF(JS(3,2).EQ.0) JS(3,1) = 0                                      00001770
C                                                                       00001780
C     SET IROLL = 0 IF SELECTION NOT CORRECT                            00001790
C                                                                       00001800
      IF(JS(3,2).EQ.0) IROLL = 0                                        00001810
      IF((JS(2,2).EQ.0) .AND. (JS(1,2).EQ.0)) IROLL = 0                 00001820
C                                                                       00001830
C     --------------------------------                                  00001840
C     RECORD SET 2, SEGMENT DESCRIPTION                                 00001850
C     --------------------------------                                  00001860
C                                                                       00001870
      DO 500   JSEG = 1,NSGMNT                                          00001880
C                                                                       00001890
      READ(IOU5,11) ANPS,ANGRID,XOCREF(JSEG),YSEG(JSEG,1),YSEG(JSEG,2)  00001900
      READ(IOU5,11) XTRAN(JSEG),YTRAN(JSEG),ZTRAN(JSEG),                00001910
     1              XROT(JSEG),YROT(JSEG),ZROT(JSEG)                    00001920
      NPS(JSEG)    = IFIX(ANPS+0.1)                                     00001930
      NGRID(JSEG)  = IFIX(ANGRID+0.1)                                   00001940
      YSEG(JSEG,1) = YSEG(JSEG,1)/RADIUS                                00001950
      YSEG(JSEG,2) = YSEG(JSEG,2)/RADIUS                                00001960
      XTRAN(JSEG)  = XTRAN(JSEG)/RADIUS                                 00001970
      YTRAN(JSEG)  = YTRAN(JSEG)/RADIUS                                 00001980
      ZTRAN(JSEG)  = ZTRAN(JSEG)/RADIUS                                 00001990
      XROT(JSEG)   = XROT(JSEG)*RPD                                     00002000
      YROT(JSEG)   = YROT(JSEG)*RPD                                     00002010
      ZROT(JSEG)   = ZROT(JSEG)*RPD                                     00002020
C                                                                       00002030
C     CHORD DISTRIBUTION                                                00002040
C                                                                       00002050
      READ(IOU5,11) ACHORD                                              00002060
      NCHORD = IFIX(ACHORD+0.1)                                         00002070
      J1 = 1                                                            00002080
```

```
      IF(JSEG.GT.1) J1 = JCHORD(JSEG-1,2)+1                          00002090
      J2 = J1+NCHORD-1                                               00002100
      READ(IOU5,11) (YCHORD(J), J = J1,J2)                           00002110
      READ(IOU5,11) (CHORD(J),  J = J1,J2)                           00002120
C                                                                    00002130
      DO 100   J = J1,J2                                             00002140
      YCHORD(J) = YCHORD(J)/RADIUS                                   00002150
      CHORD(J)  = CHORD(J)/RADIUS                                    00002160
  100 CONTINUE                                                       00002170
C                                                                    00002180
      JCHORD(JSEG,1) = J1                                            00002190
      JCHORD(JSEG,2) = J2                                            00002200
C                                                                    00002210
C     TWIST DISTRIBUTION                                             00002220
C                                                                    00002230
      READ(IOU5,11) ATWIST                                           00002240
      NTWIST = IFIX(ATWIST+0.1)                                      00002250
      J1 = 1                                                         00002260
      IF(JSEG.GT.1) J1 = JTWIST(JSEG-1,2)+1                          00002270
      J2 = J1+NTWIST-1                                               00002280
      READ(IOU5,11) (YTWIST(J), J = J1,J2)                           00002290
      READ(IOU5,11) (TWIST(J),  J = J1,J2)                           00002300
C                                                                    00002310
      DO 200   J = J1,J2                                             00002320
      YTWIST(J) = YTWIST(J)/RADIUS                                   00002330
      TWIST(J)  = TWIST(J)*RPD                                       00002340
  200 CONTINUE                                                       00002350
C                                                                    00002360
      JTWIST(JSEG,1) = J1                                            00002370
      JTWIST(JSEG,2) = J2                                            00002380
C                                                                    00002390
C     INPUT REFERENCE AXIS OFFSETS                                   00002400
C                                                                    00002410
      READ(IOU5,11) AXAOFF                                           00002420
      NXAOFF = IFIX(AXAOFF+0.1)                                      00002430
      J1 = 1                                                         00002440
      IF(JSEG.GT.1) J1 = JXAOFF(JSEG-1,2)+1                          00002450
      J2 = J1+NXAOFF-1                                               00002460
      READ(IOU5,11) (YXAOFF(J), J = J1,J2)                           00002470
      READ(IOU5,11) (XAOFF(J),  J = J1,J2)                           00002480
C                                                                    00002490
      DO 300   J = J1,J2                                             00002500
      YXAOFF(J) = YXAOFF(J)/RADIUS                                   00002510
      XAOFF(J)  = XAOFF(J)/RADIUS                                    00002520
  300 CONTINUE                                                       00002530
C                                                                    00002540
      JXAOFF(JSEG,1) = J1                                            00002550
      JXAOFF(JSEG,2) = J2                                            00002560
C                                                                    00002570
C     AIRFOIL TABLE IDENTIFIERS                                      00002580
C                                                                    00002590
      READ(IOU5,11) ANAFT                                            00002600
```

```
      NAFT = IFIX(ANAFT+0.1)                                          00002610
      J1 = 1                                                          00002620
      IF(JSEG.GT.1) J1 = JAFT(JSEG-1,2)+1                             00002630
      J2 = J1+NAFT-1                                                  00002640
C                                                                     00002650
      DO 400   J = J1,J2                                              00002660
      READ(IOU5,11) AIDAF,YAFT1,YAFT2                                 00002670
      IDAF(J)   = IFIX(AIDAF+0.1)                                     00002680
      YAFT(J,1) = YAFT1/RADIUS                                        00002690
      YAFT(J,2) = YAFT2/RADIUS                                        00002700
  400 CONTINUE                                                        00002710
C                                                                     00002720
      JAFT(JSEG,1) = J1                                               00002730
      JAFT(JSEG,2) = J2                                               00002740
C                                                                     00002750
  500 CONTINUE                                                        00002760
C                                                                     00002770
C     BYPASS RECORD SET 3 IF IN STEADY MODE                           00002780
C                                                                     00002790
      IF(ISTDY.EQ.0) GO TO 800                                        00002800
C                                                                     00002810
C     ----------------------------                                    00002820
C     RECORD SET 3, NON-STEADY MODE                                   00002830
C     ----------------------------                                    00002840
C                                                                     00002850
      READ(IOU5,11) PSIRIN,DPSIR,APSIR                                00002860
      PSIRIN = PSIRIN*RPD                                             00002870
      DPSIR  = DPSIR*RPD                                              00002880
      NPSIR  = IFIX(APSIR+0.1)                                        00002890
C                                                                     00002900
C     SHAFT AXIS ORIENTATION AND WIND PROFILE                         00002910
C                                                                     00002920
      READ(IOU5,11) ALPS1,ALPS2,HO,E,ATSTYP                           00002930
      ALPS1 = ALPS1*RPD                                               00002940
      ALPS2 = ALPS2*RPD                                               00002950
      ITSTYP = IFIX(ATSTYP+0.1)                                       00002960
      GO TO (552,550,551), ITSTYP+1                                   00002970
C                                                                     00002980
  550 CONTINUE                                                        00002990
C                                                                     00003000
C     TOWER SHADOW EQUATION, ITSTYP = 1                               00003010
C                                                                     00003020
      READ(IOU5,11) TO,TP,TPO,TPS,TK                                  00003030
      TPO = TPO*RPD                                                   00003040
      TPS = TPS*RPD                                                   00003050
      GO TO 552                                                       00003060
C                                                                     00003070
  551 CONTINUE                                                        00003080
C                                                                     00003090
C     TOWER SHADOW TABLE, ITSTYP = 2                                  00003100
C                                                                     00003110
      READ(IOU5,11) AXTS,AYTS                                         00003120
```

```
      NXTS = IFIX(AXTS+0.1)                                          00003130
      NYTS = IFIX(AYTS+0.1)                                          00003140
      CALL REDTAB(TSTAB(1),NXTS,NYTS)                                00003150
C                                                                    00003160
  552 CONTINUE                                                       00003170
C                                                                    00003180
C     FLAPPING AND PITCH BLADE MOTIONS                               00003190
C                                                                    00003200
      READ(IOU5,11) AB(1,2),AB(1,1)                                  00003210
      NBH = IFIX(AB(1,2)+0.1)                                        00003220
      READ(IOU5,11) (AB(J,1), J = 2,NBH+1)                           00003230
      READ(IOU5,11) (AB(J,2), J = 2,NBH+1)                           00003240
      AB(1,1) = AB(1,1)*RPD                                          00003250
C                                                                    00003260
      DO 600   J = 2,NBH+1                                           00003270
      AB(J,1) = AB(J,1)*RPD                                          00003280
      AB(J,2) = AB(J,2)*RPD                                          00003290
  600 CONTINUE                                                       00003300
C                                                                    00003310
      READ(IOU5,11) AT(1,2),AT(1,1)                                  00003320
      NTH = IFIX(AT(1,2)+0.1)                                        00003330
      READ(IOU5,11) (AT(J,1), J = 2,NTH+1)                           00003340
      READ(IOU5,11) (AT(J,2), J = 2,NTH+1)                           00003350
      AT(1,1) = AT(1,1)*RPD                                          00003360
C                                                                    00003370
      DO 700   J = 2,NTH+1                                           00003380
      AT(J,1) = AT(J,1)*RPD                                          00003390
      AT(J,2) = AT(J,2)*RPD                                          00003400
  700 CONTINUE                                                       00003410
C                                                                    00003420
  800 CONTINUE                                                       00003430
C     ---------------------------                                    00003440
C     RECORD SET 4, AIRFOIL TABLES                                   00003450
C     ---------------------------                                    00003460
C                                                                    00003470
      CALL READAF                                                    00003480
C                                                                    00003490
      RETURN                                                         00003500
      END                                                            00003510
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT05(READAF)                                                           00000030
C                                                                              00000040
C     DOES PREPARATION FOR READING AIRFOIL TABLES AND CALLS REDTAB TO          00000050
C     READ TABLE ENTRIES                                                       00000060
C                                                                              00000070
C     ************************************************************************00000080
C                                                                              00000090
      SUBROUTINE READAF                                                        00000100
C                                                                              00000110
      CHARACTER*62 TITLE(5)                                                    00000120
C                                                                              00000130
      COMMON/ AFTABL / NAFT,   IDAFT(4),       AFTOC(4),       IAFTEX,       00000140
     1                 STP1(4),        STP2(4),        STP3(4),              00000150
     2                 STP4(4),        STP5(4),        STP6(4),              00000160
     3                 CLTAB(200,4),   NRCL(4),        NACL(4),              00000170
     4                 CDTAB(200,4),   NRCD(4),        NACD(4),              00000180
     5                 CMTAB(100,4),   NRCM(4),        NACM(4)               00000190
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,                 00000200
     1                 IOU10,  IOU11,  IOU12,  IOU13                         00000210
C                                                                              00000220
C     ************************************************************************00000230
C                                                                              00000240
C     READ NUMBER OF TABLES TO BE INPUT, TYPE OF EXTENSION TO USE              00000250
C                                                                              00000260
      READ(IOU5,11) ANAFT,AFTEX                                                00000270
   11 FORMAT(7F10.0)                                                           00000280
      NAFT   = IFIX(ANAFT+0.1)                                                 00000290
      IAFTEX = IFIX(AFTEX+0.1)                                                 00000300
C                                                                              00000310
C     LOOP TO READ TABLES                                                      00000320
C                                                                              00000330
      DO 400   J = 1,NAFT                                                      00000340
C                                                                              00000350
      READ(IOU5,13) AIDAFT, TITLE(J)                                           00000360
   13 FORMAT(F10.0,A62)                                                        00000370
      READ(IOU5,11) ANRCL,ANACL,ANRCD,ANACD,ANRCM,ANACM                        00000380
C                                                                              00000390
      IDAFT(J) = IFIX(AIDAFT+0.1)                                              00000400
      NRCL(J)  = IFIX(ANRCL+0.1)                                               00000410
      NACL(J)  = IFIX(ANACL+0.1)                                               00000420
      NRCD(J)  = IFIX(ANRCD+0.1)                                               00000430
      NACD(J)  = IFIX(ANACD+0.1)                                               00000440
      NRCM(J)  = IFIX(ANRCM+0.1)                                               00000450
      NACM(J)  = IFIX(ANACM+0.1)                                               00000460
C                                                                              00000470
      READ(IOU5,11) AFTOC(J),STP1(J),STP2(J),STP3(J),STP4(J),STP5(J),          00000480
     1              STP6(J)                                                    00000490
C                                                                              00000500
C     READ LIFT TABLE                                                          00000510
C                                                                              00000520
```

```
      CALL REDTAB(CLTAB(1,J),NRCL(J),NACL(J))                    00000530
C                                                                00000540
C     SCALE INPUT REYNOLD'S NUMBERS                              00000550
C                                                                00000560
      DO 100   JJ = 1,NRCL(J)                                    00000570
      CLTAB(JJ,J)=CLTAB(JJ,J)*1.0E+06                            00000580
  100 CONTINUE                                                   00000590
C                                                                00000600
C     READ DRAG TABLE                                            00000610
C                                                                00000620
      CALL REDTAB(CDTAB(1,J),NRCD(J),NACD(J))                    00000630
C                                                                00000640
      DO 200   JJ = 1,NRCD(J)                                    00000650
      CDTAB(JJ,J)=CDTAB(JJ,J)*1.0E+06                            00000660
  200 CONTINUE                                                   00000670
C                                                                00000680
C     READ PITCHING MOMENT TABLE                                 00000690
C                                                                00000700
      CALL REDTAB(CMTAB(1,J),NRCM(J),NACM(J))                    00000710
C                                                                00000720
      DO 300   JJ = 1,NRCM(J)                                    00000730
      CMTAB(JJ,J)=CMTAB(JJ,J)*1.0E+06                            00000740
  300 CONTINUE                                                   00000750
C                                                                00000760
  400 CONTINUE                                                   00000770
C                                                                00000780
      RETURN                                                     00000790
      END                                                        00000800
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT05(REDTAB)                                                     00000030
C                                                                        00000040
C     READS BIVARIENT TABLE ENTRIES AND ARRANGES THEM IN INTERNAL        00000050
C     STORAGE FORMAT                                                     00000060
C                                                                        00000070
C     ******************************************************************00000080
C                                                                        00000090
      SUBROUTINE REDTAB(TABLE,NCOL,NROW)                                 00000100
C                                                                        00000110
      DIMENSION TABLE(1)                                                 00000120
C                                                                        00000130
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,            00000140
     1                 IOU10,  IOU11,  IOU12,  IOU13                   00000150
C                                                                        00000160
      DATA ISIX/6/, IFIVE/5/                                             00000170
C                                                                        00000180
C     ******************************************************************00000190
C                                                                        00000200
C     READ COLUMN VALUES INTO TABLE(1->NCOL)                             00000210
C                                                                        00000220
      READ(IOU5,10) (TABLE(IS), IS = 1,NCOL)                             00000230
   10 FORMAT(10X , 6F10.0)                                               00000240
C                                                                        00000250
      DO 200   I = 1,NROW                                                00000260
C                                                                        00000270
C     ICOUNT COUNTS THE NUMBER OF CARDS CONTAINING A ROW OF TABLE VALUES00000280
C                                                                        00000290
      ICOUNT = 0                                                         00000300
C                                                                        00000310
C     ISROW IS STORAGE LOCATION FOR ROW VALUE IN 'TABLE'                 00000320
C                                                                        00000330
      ISROW = NCOL+I                                                     00000340
C                                                                        00000350
C     IMAX IS MAXIMUM SUBSCRIPT IN 'TABLE' FOR THIS ROW'S VALUES         00000360
C     ISCOL1 IS FIRST SUBSCRIPT AND ISCOL2 IS LAST SUBSCRIPT FOR         00000370
C     TABLE VALUES READ FROM EACH CARD                                   00000380
C                                                                        00000390
      ISCOL1 = NCOL+NROW+(I-1)*NCOL+1                                    00000400
      IMAX   = ISCOL1+NCOL-1                                             00000410
      ISCOL2 = MINO(IMAX,ISCOL1+IFIVE)                                   00000420
C                                                                        00000430
C     READ ROW VALUE INTO TABLE(NCOL+1->NCOL+NROW) AND TABLE VALUE INTO 00000440
C     TABLE(NCOL+NROW+1->NCOL+NROW+NCOL*NROW)                            00000450
C                                                                        00000460
      READ(IOU5,12) TABLE(ISROW),(TABLE(IS), IS = ISCOL1,ISCOL2)         00000470
   12 FORMAT(7F10.0)                                                     00000480
C                                                                        00000490
  100 CONTINUE                                                           00000500
C                                                                        00000510
      ICOUNT = ICOUNT+1                                                  00000520
```

```
C                                                                       00000530
C     IF MORE TABLE VALUES FOR THIS ROW ARE TO BE READ, THEN CONTINUE   00000540
C                                                                       00000550
      IF(NCOL.LE.ISIX*ICOUNT) GO TO 200                                 00000560
      ISCOL1 = ISCOL2+1                                                 00000570
      ISCOL2 = MIN0(IMAX,ISCOL1+IFIVE)                                  00000580
      READ(IOU5,10) (TABLE(IS), IS = ISCOL1,ISCOL2)                     00000590
      GO TO 100                                                         00000600
C                                                                       00000610
  200 CONTINUE                                                          00000620
C                                                                       00000630
      RETURN                                                            00000640
      END                                                               00000650
```

```
C     ***************************************************************** 00000010
C                                                                       00000020
C     LSWT06(OUT1)                                                      00000030
C                                                                       00000040
C     REPORTS BLADE REFERENCE GEOMETRY                                  00000050
C                                                                       00000060
C     ***************************************************************** 00000070
C                                                                       00000080
      SUBROUTINE OUT1(ITBLD)                                            00000090
C                                                                       00000100
      COMMON/ CONSTS / PI,     RPD                                      00000110
      COMMON/ PNLCRD / XS(6,24),       YS(6,24),       ZS(6,24),       00000120
     1                 XCOL(5,20),     YCOL(5,20),     ZCOL(5,20)      00000130
      COMMON/ PNLNDX / MP,             NP,             NPANEL,         00000140
     1                 MP1,            NP1,            NPNLSQ,         00000150
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),    00000160
     3                 NPS(4),         NBLDS                           00000170
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,           00000180
     1                 IOU10,  IOU11,  IOU12,  IOU13                   00000190
C                                                                       00000200
C     ***************************************************************** 00000210
C                                                                       00000220
      ICASE = 1                                                         00000230
      IF(ITBLD.GE.1) ICASE = 2                                          00000240
      CALL HEADER(ICASE,IOU6)                                           00000250
C                                                                       00000260
      IF(ITBLD.EQ.0) WRITE(IOU6,10)                                     00000270
   10 FORMAT('0',4X,'REFERENCE BLADE SURFACE PANEL COORDINATES'/        00000280
     1       ' ',4X,41('-'))                                            00000290
C                                                                       00000300
      IF(ITBLD.GT.0) WRITE(IOU6,12) ITBLD                               00000310
   12 FORMAT('0',4X,'BLADE ',I2,' SURFACE PANEL COORDINATES'/           00000320
     1       ' ',4X,37('-'))                                            00000330
C                                                                       00000340
      J1 = 1                                                            00000350
      J2 = NP1                                                          00000360
      IF(NP1.GT.11) J2 = 11                                             00000370
C                                                                       00000380
 1000 CONTINUE                                                          00000390
C                                                                       00000400
      IF(J2-J1.GT.10) J2 = J1+10                                        00000410
C                                                                       00000420
      WRITE(IOU6,14) (J, J = J1,J2)                                     00000430
   14 FORMAT('0',4X,'I,J',I8,10I10)                                     00000440
C                                                                       00000450
      DO 1100   I = 1,MP1                                               00000460
C                                                                       00000470
      WRITE(IOU6,16) I,(XS(I,J), J = J1,J2)                             00000480
   16 FORMAT('0',4X,I2,1X,'X',11F10.6)                                  00000490
C                                                                       00000500
      WRITE(IOU6,18)   (YS(I,J), J = J1,J2)                             00000510
   18 FORMAT(' ',7X,'Y',11F10.6)                                        00000520
```

```
C                                                                       00000530
      WRITE(IOU6,20)   (ZS(I,J), J = J1,J2)                             00000540
   20 FORMAT(' ',7X,'Z',11F10.6)                                        00000550
C                                                                       00000560
 1100 CONTINUE                                                          00000570
C                                                                       00000580
      JTEMP = J2                                                        00000590
      J1    = J2+1                                                      00000600
      J2    = J1+10                                                     00000610
      IF(J2.GT.NP1) J2 = NP1                                            00000620
      IF(JTEMP.LT.NP1) GO TO 1000                                       00000630
C                                                                       00000640
C     COLLOCATION POINT COORDINATES                                     00000650
C                                                                       00000660
      CALL HEADER(ICASE,IOU6)                                           00000670
C                                                                       00000680
      IF(ITBLD.EQ.0) WRITE(IOU6,22)                                     00000690
   22 FORMAT('0',4X,'REFERENCE BLADE COLLOCATION POINT COORDINATES'/     00000700
     1       ' ',4X,45('-'))                                            00000710
C                                                                       00000720
      IF(ITBLD.GT.0) WRITE(IOU6,24) ITBLD                               00000730
   24 FORMAT('0',4X,'BLADE ',I2,' COLLOCATION POINT COORDINATES'/       00000740
     1       ' ',4X,41('-'))                                            00000750
C                                                                       00000760
      J1 = 1                                                            00000770
      J2 = NP                                                           00000780
C                                                                       00000790
 1200 CONTINUE                                                          00000800
C                                                                       00000810
      IF(J2-J1.GT.9) J2 = J1+9                                          00000820
C                                                                       00000830
      WRITE(IOU6,26) (J, J = J1,J2)                                     00000840
   26 FORMAT('0',4X,'I,J',I8,9I10)                                      00000850
C                                                                       00000860
      DO 1300   I = 1,MP                                                00000870
C                                                                       00000880
      WRITE(IOU6,28) I,(XCOL(I,J), J=J1,J2)                             00000890
   28 FORMAT('0',4X,I2,1X,'X',10F10.6)                                  00000900
C                                                                       00000910
      WRITE(IOU6,30)   (YCOL(I,J), J=J1,J2)                             00000920
   30 FORMAT(' ',7X,'Y',10F10.6)                                        00000930
C                                                                       00000940
      WRITE(IOU6,32)   (ZCOL(I,J), J=J1,J2)                             00000950
   32 FORMAT(' ',7X,'Z',10F10.6)                                        00000960
C                                                                       00000970
 1300 CONTINUE                                                          00000980
C                                                                       00000990
      JTEMP = J2                                                        00001000
      J1 = J2+1                                                         00001010
      J2 = J1+9                                                         00001020
      IF(J2.GT.NP) J2 = NP                                              00001030
      IF(JTEMP.LT.NP) GO TO 1200                                        00001040
```

```
C                                                                00001050
      RETURN                                                     00001060
      END                                                        00001070
```

Source File: **LSWT06.FOR** Program Unit: **OUT2**

```
C     ***************************************************************00000010
C                                                                     00000020
C     LSWT06(OUT2)                                                    00000030
C                                                                     00000040
C     REPORTS WAKE COORDINATES                                        00000050
C                                                                     00000060
C     ***************************************************************00000070
C                                                                     00000080
      SUBROUTINE OUT2(ITBLD,PSIR)                                     00000090
C                                                                     00000100
      DIMENSION PSI(133),RW(133)                                      00000110
C                                                                     00000120
      COMMON/ CONSTS / PI,     RPD                                    00000130
      COMMON/ PNLNDX / MP,             NP,             NPANEL,      00000140
     1                 MP1,            NP1,            NPNLSQ,      00000150
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2), 00000160
     3                 NPS(4),         NBLDS                        00000170
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,        00000180
     1                 IOU10,  IOU11,  IOU12,  IOU13                00000190
      COMMON/ WAKCRD / XW(133,24),     YW(133,24),     ZW(133,24)   00000200
      COMMON/ WAKNDX / REVS,           NWIPR,          NWI,         00000210
     1                 KMAX(24),       IFWAK,          JS(3,2),     00000220
     2                 PSIMR,          PSIMT,          IROLL        00000230
C     ***************************************************************00000240
C                                                                     00000250
C     LOAD WAKE COORDINATES FOR THIS BLADE INTO BUFFER                00000260
C                                                                     00000270
      DO 100  J = 1,NP1                                               00000280
C                                                                     00000290
C     LOAD THE BUFFER                                                 00000300
C                                                                     00000310
      IREC = (ITBLD-1)*NP1+J                                          00000320
      READ(IOU13, REC=IREC) (XW(K,J),YW(K,J),ZW(K,J), K = 1,KMAX(J))  00000330
C                                                                     00000340
  100 CONTINUE                                                        00000350
C                                                                     00000360
      CALL HEADER(2,IOU6)                                             00000370
C                                                                     00000380
      WRITE(IOU6,10) ITBLD                                            00000390
   10 FORMAT('0',4X,'BLADE ',I2,' WAKE FILAMENT COORDINATES'/         00000400
     1       ' ',4X,34('-'))                                          00000410
C                                                                     00000420
       SITB  = PSIR - FLOAT(ITBLD-1)*(2.0*PI/FLOAT(NBLDS))            00000430
      PSIRD  = PSIR/RPD                                               00000440
      PSITBD = PSITB/RPD                                              00000450
C                                                                     00000460
C     SWEEP WAKE FILAMENTS                                            00000470
C                                                                     00000480
      DO 400   J = 1,NP1                                              00000490
C                                                                     00000500
C     CALCULATE CYLINDRICAL COORDINATES                               00000510
C                                                                     00000520
```

```
      PSIM1 = 0.0                                                       00000530
C                                                                       00000540
      DO 200  K=1,KMAX(J)                                               00000550
C                                                                       00000560
C     FIRST REFERENCE TO TARGET BLADE                                   00000570
C                                                                       00000580
      XTW   = XW(K,J)                                                   00000590
      YTW   = YW(K,J)                                                   00000600
      PSITW = -PSITB                                                    00000610
      CALL ROTATE(XTW,YTW,PSITW)                                        00000620
      RW(K)  = SQRT(XW(K,J)**2+YW(K,J)**2)                              00000630
      PSITWD = ATAN2(-XTW,YTW)/RPD                                      00000640
C                                                                       00000650
C     PUT IN 0 TO -360 DEG RANGE                                        00000660
C                                                                       00000670
      IF(PSITWD.GT.0.0) PSITWD = PSITWD-360.0                           00000680
C                                                                       00000690
C     ADD IN EARLIER REVS                                               00000700
C                                                                       00000710
      IREVS  = IFIX(ABS(PSIM1/360.0))                                   00000720
      PSITWD = PSITWD+IREVS*(-360.0)                                    00000730
      IF(PSITWD.GT.PSIM1) PSITWD = PSITWD - 360.0                       00000740
      PSIM1  = PSITWD                                                   00000750
C                                                                       00000760
C     REFERENCE BACK TO ROTOR AZIMUTH                                   00000770
C                                                                       00000780
      PSI(K) = PSITWD + PSITBD                                          00000790
C                                                                       00000800
  200 CONTINUE                                                          00000810
C                                                                       00000820
C     REPORT OUT THIS FILAMENT                                          00000830
C                                                                       00000840
      WRITE(IOU6,11) J                                                  00000850
   11 FORMAT('0',7X,'FILAMENT NUMBER ',I2,)                             00000860
C                                                                       00000870
      K1 = 1                                                            00000880
      K2 = KMAX(J)                                                      00000890
      IF(K2-K1.GT.10) K2 = K1+10                                        00000900
C                                                                       00000910
  300 CONTINUE                                                          00000920
C                                                                       00000930
      WRITE(IOU6,12) (K, K = K1,K2)                                     00000940
   12 FORMAT('0',7X,'K',11(5X,I2,3X))                                   00000950
C                                                                       00000960
      WRITE(IOU6,13) (PSI(K), K = K1,K2)                                00000970
   13 FORMAT(' ',5X,'PSI',11F10.3)                                      00000980
C                                                                       00000990
      WRITE(IOU6,14) (RW(K), K = K1,K2)                                 00001000
   14 FORMAT(' ',7X,'R',11F10.6)                                        00001010
C                                                                       00001020
      WRITE(IOU6,15) (XW(K,J), K = K1,K2)                               00001030
   15 FORMAT(' ',7X,'X',11F10.6)                                        00001040
```

Source File: **LSWT06.FOR** Program Unit: **OUT2**

```
C                                                                       00001050
      WRITE(IOU6,16) (YW(K,J), K = K1,K2)                               00001060
   16 FORMAT(' ',7X,'Y',11F10.6)                                        00001070
C                                                                       00001080
      WRITE(IOU6,17) (ZW(K,J), K = K1,K2)                               00001090
   17 FORMAT(' ',7X,'Z',11F10.6)                                        00001100
C                                                                       00001110
      WRITE(IOU6,18)                                                    00001120
   18 FORMAT('0')                                                       00001130
C                                                                       00001140
C     RESET AND MAKE ANOTHER PASS IF REQUIRED                           00001150
C                                                                       00001160
      KTEMP = K2                                                        00001170
      K1    = K2+1                                                      00001180
      K2    = K1+10                                                     00001190
      IF(K2.GT.KMAX(J)) K2 = KMAX(J)                                    00001200
      IF(KTEMP.LT.KMAX(J)) GO TO 300                                    00001210
C                                                                       00001220
  400 CONTINUE                                                          00001230
C                                                                       00001240
      RETURN                                                            00001250
      END                                                               00001260
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT06(OUT3)                                                       00000030
C                                                                        00000040
C     REPORTS BLADE ELEMENT AERODYNAMIC CHARACTERISTICS                  00000050
C                                                                        00000060
C     ******************************************************************00000070
C                                                                        00000080
      SUBROUTINE OUT3(ITBLD,IOUTO)                                       00000090
C                                                                        00000100
      COMMON/ ALSLP  / ALS(20),        ALSNEW(20),     ALSOLD(20)        00000110
      COMMON/ BELOAD / DFX(20),        DFXI(20),       DFXP(20),         00000120
     1                 DFZ(20),        DFZI(20),       DFZP(20),         00000130
     2                 DQ(20),         DQI(20),        DQP(20),          00000140
     3                 DPM(20)                                           00000150
      COMMON/ BLDELE / XCLE(20),       YCG(20),        RBE(20),          00000160
     1                 DBES(20),       CLAMLE(20),     CLAMQC(20),       00000170
     2                 CHDCGL(20),     BETAL(20),      AFTWF(20),        00000180
     3                 JTAB(20,2),     TOC(20),        RE(20),           00000190
     4                 CLT(20),        CDT(20),        CMT(20),          00000200
     5                 CDS(20)                                           00000210
      COMMON/ CALPHA / ALPHAG(20),     ALPHAE(20),     ALPHAW(20),       00000220
     1                 ALPHAN(20),     ALPHAI(20),     AZLLC(20),        00000230
     2                 TWSTCG(20)                                        00000240
      COMMON/ CCIRC  / CIRC(100),      DCIRC(100),     ACIRC(100),       00000250
     1                 CIRCR(100),     BCIRC(20),      GO(20),           00000260
     2                 TECF,           AKM(6),         XKM(5)            00000270
      COMMON/ CONSTS / PI,     RPD                                       00000280
      COMMON/ CVLCTY / VFS1(5,20),     VFS2(5,20),     VFS3(5,20),       00000290
     1                 VFS1M(20),      VFS2M(20),      VFS3M(20),        00000300
     2                 VI1(5,20),      VI2(5,20),      VI3(5,20),        00000310
     3                 VI1M(20),       VI2M(20),       VI3M(20),         00000320
     4                 VREL(20),       VIND(20),       QREL(20)          00000330
      COMMON/ PARMS  / RADIUS, OMEGA,  OMEGAR, RHO,    AMU               00000340
      COMMON/ PNLNDX / MP,             NP,             NPANEL,           00000350
     1                 MP1,            NP1,            NPNLSQ,           00000360
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),      00000370
     3                 NPS(4),         NBLDS                             00000380
C                                                                        00000390
C     ******************************************************************00000400
C                                                                        00000410
C     CHANGE DIMENSIONS FOR OUTPUT REPORT                                00000420
C                                                                        00000430
      DO 100   J = 1,NP                                                  00000440
      ALPHAG(J) = ALPHAG(J)/RPD                                          00000450
      ALPHAE(J) = ALPHAE(J)/RPD                                          00000460
      ALPHAW(J) = ALPHAW(J)/RPD                                          00000470
      ALPHAN(J) = ALPHAN(J)/RPD                                          00000480
      ALPHAI(J) = ALPHAI(J)/RPD                                          00000490
      AZLLC(J)  = AZLLC(J)/RPD                                           00000500
      CHDCGL(J) = CHDCGL(J)*RADIUS                                       00000510
      DBES(J)   = DBES(J)*RADIUS                                         00000520
```

```
      CLAMQC(J) = ACOS(CLAMQC(J))/RPD                                   00000530
      CLAMLE(J) = ACOS(CLAMLE(J))/RPD                                   00000540
  100 CONTINUE                                                          00000550
C                                                                       00000560
C     BLADE ELEMENT AERODYNAMIC CHARACTERISTIC REPORT                   00000570
C                                                                       00000580
      J1 = 1                                                            00000590
      J2 = NP                                                           00000600
C                                                                       00000610
  200 CONTINUE                                                          00000620
C                                                                       00000630
      IF(J2-J1.GT.7) J2 = J1+7                                          00000640
C                                                                       00000650
      CALL HEADER(2,IOUTO)                                              00000660
C                                                                       00000670
      WRITE(IOUTO,1000) ITBLD                                           00000680
 1000 FORMAT('0',4X,'BLADE ',I2,' ELEMENT CHARACTERISTICS'/             00000690
     1       ' ',4X,32('-'))                                            00000700
C                                                                       00000710
C     ELEMENT GEOMETRY                                                  00000720
C                                                                       00000730
      WRITE(IOUTO,2000)                                                 00000740
 2000 FORMAT('0',4X,'GEOMETRY')                                         00000750
C                                                                       00000760
      WRITE(IOUTO,2001) (J, J = J1,J2)                                  00000770
 2001 FORMAT('0',4X,'ELEMENT NUMBER',16X,8I11)                          00000780
C                                                                       00000790
      WRITE(IOUTO,2002) (RBE(J), J = J1,J2)                             00000800
 2002 FORMAT(' ',4X,'ELE CENTER STATION',16X,1P8E11.3)                  00000810
C                                                                       00000820
      WRITE(IOUTO,2003) (CHDCGL(J), J = J1,J2)                          00000830
 2003 FORMAT(' ',4X,'CHORD',20X,'FT',7X,1P8E11.3)                       00000840
C                                                                       00000850
      WRITE(IOUTO,2004) (DBES(J), J = J1,J2)                            00000860
 2004 FORMAT(' ',4X,'ELEMENT SPAN',13X,'FT',7X,1P8E11.3)                00000870
C                                                                       00000880
      WRITE(IOUTO,2005) (CLAMLE(J), J = J1,J2)                          00000890
 2005 FORMAT(' ',4X,'LEADING EDGE SWEEP',7X,'DEG',6X,1P8E11.3)          00000900
C                                                                       00000910
      WRITE(IOUTO,2006) (CLAMQC(J), J = J1,J2)                          00000920
 2006 FORMAT(' ',4X,'AERODYNAMIC SWEEP',8X,'DEG',6X,1P8E11.3)          00000930
C                                                                       00000940
C     ANGLES                                                            00000950
C                                                                       00000960
      WRITE(IOUTO,3000)                                                 00000970
 3000 FORMAT('0',4X,'ANGLES OF ATTACK')                                 00000980
C                                                                       00000990
      WRITE(IOUTO,3001) (ALPHAG(J), J = J1,J2)                          00001000
 3001 FORMAT('0',4X,'GEOMETRIC PITCH',10X,'DEG',6X,1P8E11.3)            00001010
C                                                                       00001020
      WRITE(IOUTO,3002) (AZLLC(J), J = J1,J2)                           00001030
 3002 FORMAT(' ',4X,'ZERO LIFT LINE',11X,'DEG',6X,1P8E11.3)             00001040
```

```
C                                                                       00001050
      WRITE(IOUT0,3004) (ALPHAE(J), J = J1,J2)                          00001060
 3004 FORMAT(' ',4X,'EFFECTIVE ANGLE',10X,'DEG',6X,1P8E11.3)            00001070
C                                                                       00001080
      WRITE(IOUT0,3005) (ALPHAW(J), J = J1,J2)                          00001090
 3005 FORMAT(' ',4X,'WIND ANGLE',15X,'DEG',6X,1P8E11.3)                 00001100
C                                                                       00001110
      WRITE(IOUT0,3006) (ALPHAN(J), J = J1,J2)                          00001120
 3006 FORMAT(' ',4X,'INFLOW ANGLE',13X,'DEG',6X,1P8E11.3)               00001130
C                                                                       00001140
      WRITE(IOUT0,3007) (ALPHAI(J), J = J1,J2)                          00001150
 3007 FORMAT(' ',4X,'INDUCED ANGLE',12X,'DEG',6X,1P8E11.3)              00001160
C                                                                       00001170
C     VELOCITIES                                                        00001180
C                                                                       00001190
      WRITE(IOUT0,4000)                                                 00001200
 4000 FORMAT('0',4X,'VELOCITIES')                                       00001210
C                                                                       00001220
      WRITE(IOUT0,4001) (VIND(J), J = J1,J2)                            00001230
 4001 FORMAT('0',4X,'INDUCED VELOCITY',9X,'FT/SEC',3X,1P8E11.3)         00001240
C                                                                       00001250
      WRITE(IOUT0,4002) (VREL(J), J = J1,J2)                            00001260
 4002 FORMAT(' ',4X,'RELATIVE VELOCITY',8X,'FT/SEC',3X,1P8E11.3)        00001270
C                                                                       00001280
      WRITE(IOUT0,4003) (RE(J), J = J1,J2)                              00001290
 4003 FORMAT(' ',4X,'REYNOLDS NUMBER',19X,1P8E11.3)                     00001300
C                                                                       00001310
      WRITE(IOUT0,4004) (QREL(J), J = J1,J2)                            00001320
 4004 FORMAT(' ',4X,'RELATIVE Q',15X,'PSF',6X,1P8E11.3)                 00001330
C                                                                       00001340
C     LIFT, DRAG AND MOMENT COEFFICIENTS                                00001350
C                                                                       00001360
      WRITE(IOUT0,5000)                                                 00001370
 5000 FORMAT('0',4X,'AERODYNAMIC COEFFICIENTS')                         00001380
C                                                                       00001390
      WRITE(IOUT0,5001) (CLT(J), J = J1,J2)                             00001400
 5001 FORMAT('0',4X,'ELE LIFT COEF',21X,1P8E11.3)                       00001410
C                                                                       00001420
      WRITE(IOUT0,5002) (CDT(J), J = J1,J2)                             00001430
 5002 FORMAT(' ',4X,'ELE DRAG COEF',21X,1P8E11.3)                       00001440
C                                                                       00001450
      WRITE(IOUT0,5003) (CMT(J), J = J1,J2)                             00001460
 5003 FORMAT(' ',4X,'ELE MOMENT COEF',19X,1P8E11.3)                     00001470
C                                                                       00001480
C     ELEMENT FORCE LOADINGS                                            00001490
C                                                                       00001500
      WRITE(IOUT0,6000)                                                 00001510
 6000 FORMAT('0',4X,'FORCE LOADING')                                    00001520
C                                                                       00001530
      WRITE(IOUT0,6001) (DFX(J), J = J1,J2)                             00001540
 6001 FORMAT(' ',4X,'ELE X FORCE',14X,'LBS/FT',3X,1P8E11.3)             00001550
C                                                                       00001560
```

```
      WRITE(IOUT0,6002) (DFXI(J), J = J1,J2)                            00001570
 6002 FORMAT(' ',4X,'ELE IND X FORCE',10X,'LBS/FT',3X,1P8E11.3)         00001580
C                                                                       00001590
      WRITE(IOUT0,6003) (DFXP(J), J = J1,J2)                            00001600
 6003 FORMAT(' ',4X,'ELE PRO X FORCE',10X,'LBS/FT',3X,1P8E11.3)         00001610
C                                                                       00001620
      WRITE(IOUT0,6004) (DFZ(J), J = J1,J2)                             00001630
 6004 FORMAT(' ',4X,'ELE Z FORCE',14X,'LBS/FT',3X,1P8E11.3)             00001640
C                                                                       00001650
      WRITE(IOUT0,6005) (DFZI(J), J = J1,J2)                            00001660
 6005 FORMAT(' ',4X,'ELE IND Z FORCE',10X,'LBS/FT',3X,1P8E11.3)         00001670
C                                                                       00001680
      WRITE(IOUT0,6006) (DFZP(J), J = J1,J2)                            00001690
 6006 FORMAT(' ',4X,'ELE PRO Z FORCE',10X,'LBS/FT',3X,1P8E11.3)         00001700
C                                                                       00001710
C     ELEMENT TORQUE LOADINGS                                           00001720
C                                                                       00001730
      WRITE(IOUT0,7000)                                                 00001740
 7000 FORMAT('0',4X,'TORQUE LOADING')                                   00001750
C                                                                       00001760
      WRITE(IOUT0,7001) (DQP(J), J = J1,J2)                             00001770
 7001 FORMAT('0',4X,'ELE PRO TORQUE',11X,'FT-LBS/FT',1P8E11.3)          00001780
C                                                                       00001790
      WRITE(IOUT0,7002) (DQI(J), J = J1,J2)                             00001800
 7002 FORMAT(' ',4X,'ELE IND TORQUE',11X,'FT-LBS/FT',1P8E11.3)          00001810
C                                                                       00001820
      WRITE(IOUT0,7003) (DQ(J), J = J1,J2)                              00001830
 7003 FORMAT(' ',4X,'ELE TORQUE',15X,'FT-LBS/FT',1P8E11.3)              00001840
C                                                                       00001850
C     PITCHING MOMENT LOADING (2D)                                      00001860
C                                                                       00001870
      WRITE(IOUT0,8000)                                                 00001880
 8000 FORMAT('0',4X,'PITCHING MOMENT LOADING (2D)')                     00001890
C                                                                       00001900
      WRITE(IOUT0,8001) (DPM(J), J = J1,J2)                             00001910
 8001 FORMAT('0',4X,'ELE PITCH MOMENT',9X,'FT-LBS/FT',1P8E11.3)         00001920
C                                                                       00001930
C     LIFT CURVE SLOPES                                                 00001940
C                                                                       00001950
      WRITE(IOUT0,9000)                                                 00001960
 9000 FORMAT('0',4X,'LIFT SLOPE CONVERGENCE')                           00001970
C                                                                       00001980
      WRITE(IOUT0,9001) (ALSOLD(J), J = J1,J2)                          00001990
 9001 FORMAT('0',4X,'INPUT LIFT SLOPE',9X,'/RAD',5X,1P8E11.3)           00002000
C                                                                       00002010
      WRITE(IOUT0,9002) (ALSNEW(J), J = J1,J2)                          00002020
 9002 FORMAT(' ',4X,'CL/ALPHAE',16X,'/RAD',5X,1P8E11.3)                 00002030
C                                                                       00002040
C     CIRCULATION                                                       00002050
C                                                                       00002060
      WRITE(IOUT0,10000)                                                00002070
10000 FORMAT('0',4X,'CIRCULATION PARAMETERS')                           00002080
```

```
C                                                                       00002090
      WRITE(IOUTO,10001) (GO(J), J = J1,J2)                             00002100
10001 FORMAT('0',4X,'CIRC SHAPE PARM',19X,1P8E11.3)                     00002110
C                                                                       00002120
      WRITE(IOUTO,10002) (BCIRC(J), J = J1,J2)                          00002130
10002 FORMAT(' ',4X,'BOUND CIRCULATION',8X,'FT**2/SEC',1P8E11.3)        00002140
C                                                                       00002150
      IF(J2.GE.NP) GO TO 300                                            00002160
C                                                                       00002170
      J1 = J2+1                                                         00002180
      J2 = J1+7                                                         00002190
      IF(J2.GT.NP) J2 = NP                                              00002200
      GO TO 200                                                         00002210
C                                                                       00002220
  300 CONTINUE                                                          00002230
C                                                                       00002240
C     RETURN TO WORKING DIMENSIONS                                      00002250
C                                                                       00002260
      DO 400   J = 1,NP                                                 00002270
      ALPHAG(J) = ALPHAG(J)*RPD                                         00002280
      ALPHAE(J) = ALPHAE(J)*RPD                                         00002290
      ALPHAW(J) = ALPHAW(J)*RPD                                         00002300
      ALPHAN(J) = ALPHAN(J)*RPD                                         00002310
      ALPHAI(J) = ALPHAI(J)*RPD                                         00002320
      AZLLC(J)  = AZLLC(J)*RPD                                          00002330
      CHDCGL(J) = CHDCGL(J)/RADIUS                                      00002340
      DBES(J)   = DBES(J)/RADIUS                                        00002350
      CLAMQC(J) = COS(CLAMQC(J)*RPD)                                    00002360
      CLAMLE(J) = COS(CLAMLE(J)*RPD)                                    00002370
  400 CONTINUE                                                          00002380
C                                                                       00002390
      RETURN                                                            00002400
      END                                                               00002410
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT06(OUT4)                                                             00000030
C                                                                              00000040
C     REPORTS BLADE PERFORMANCE CHARACTERISTICS                                00000050
C                                                                              00000060
C     ************************************************************************00000070
C                                                                              00000080
      SUBROUTINE OUT4(ITBLD,IOUTO)                                             00000090
C                                                                              00000100
      COMMON/ BLLOAD / CTRB,   CQRB,   CTWB,   CPWB,   BTHRST, BTORQ,         00000110
     1                 BTORQI, BTORQP, BPWR,   BPWRP,  BPWRI,  BPMOMT        00000120
      COMMON/ CONSTS / PI,     RPD                                             00000130
C                                                                              00000140
C     ************************************************************************00000150
C                                                                              00000160
C     BLADE PERFORMANCE SUMMARY                                                00000170
C                                                                              00000180
      CALL HEADER(2,IOUTO)                                                     00000190
C                                                                              00000200
      WRITE(IOUTO,1100) ITBLD                                                  00000210
 1100 FORMAT('0',4X,'BLADE ',I2,' PERFORMANCE'/' ',4X,20('-'))                 00000220
C                                                                              00000230
      WRITE(IOUTO,1101) BTHRST,CTRB,CTWB                                       00000240
 1101 FORMAT('0',4X,'THRUST',20X,'LBS',8X,1PE12.4/                             00000250
     1       ' ',4X,'CT ROTOR',29X,1PE12.4/                                   00000260
     2       ' ',4X,'CT WT',32X,1PE12.4)                                      00000270
C                                                                              00000280
      WRITE(IOUTO,1102) BTORQ,CQRB,CPWB                                        00000290
 1102 FORMAT('0',4X,'TORQUE',20X,'FT-LBS',5X,1PE12.4/                          00000300
     1       ' ',4X,'CQ ROTOR',29X,1PE12.4/                                   00000310
     2       ' ',4X,'CP WT',32X,1PE12.4)                                      00000320
C                                                                              00000330
      WRITE(IOUTO,1103) BPWR,BPWRP,BPWRI                                       00000340
 1103 FORMAT('0',4X,'POWER (BLADE)  ',11X,'KW',9X,1PE12.4/                     00000350
     1       ' ',4X,'POWER (PROFILE)',11X,'KW',9X,1PE12.4/                    00000360
     2       ' ',4X,'POWER (INFLOW) ',11X,'KW',9X,1PE12.4)                    00000370
C                                                                              00000380
      WRITE(IOUTO,1104) BPMOMT                                                 00000390
 1104 FORMAT('0',4X,'PITCH MOM (2D)',12X,'FT-LB',6X,1PE12.4)                   00000400
C                                                                              00000410
      RETURN                                                                   00000420
      END                                                                      00000430
```

```
C     ************************************************************************00000010
C                                                                               00000020
C     LSWT06(OUT5)                                                              00000030
C                                                                               00000040
C     REPORTS ROTOR PERFORMANCE CHARACTERISTICS                                 00000050
C                                                                               00000060
C     ************************************************************************00000070
C                                                                               00000080
      SUBROUTINE OUT5                                                           00000090
C                                                                               00000100
      COMMON/ CONSTS / PI,     RPD                                              00000110
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                           00000120
      COMMON/ RTLOAD / CTRR,   CQRR,   CTWR,   CPWR,   RTHRST, RTORQ,           00000130
     1                 RTORQP, RTORQI, RPWR,   RPWRP,  RPWRI,  CTR,            00000140
     2                 CQR,    CTW,    CPW,    THRST,  TORQ,   TORQP,          00000150
     3                 TORQI,  PWR,    PWRP,   PWRI,   RPMOMT, PMOMT           00000160
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,                    00000170
     1                 IOU10,  IOU11,  IOU12,  IOU13                           00000180
C                                                                               00000190
C     ************************************************************************00000200
C                                                                               00000210
C     ROTOR PERFORMANCE SUMMARY                                                 00000220
C                                                                               00000230
      CALL HEADER(2,IOU6)                                                       00000240
C                                                                               00000250
      WRITE(IOU6,1200)                                                          00000260
 1200 FORMAT('0',4X,'ROTOR PERFORMANCE'/                                        00000270
     1       ' ',4X,17('-'))                                                    00000280
C                                                                               00000290
      WRITE(IOU6,1201) RTHRST,CTRR,CTWR                                         00000300
 1201 FORMAT('0',4X,'THRUST',20X,'LBS',8X,1PE12.4/                              00000310
     1       ' ',4X,'CT ROTOR',29X,1PE12.4/                                     00000320
     2       ' ',4X,'CT WT',32X,1PE12.4)                                        00000330
C                                                                               00000340
      WRITE(IOU6,1202) RTORQ,CQRR,CPWR                                          00000350
 1202 FORMAT('0',4X,'TORQUE',20X,'FT-LBS',5X,1PE12.4/                           00000360
     1       ' ',4X,'CQ ROTOR',29X,1PE12.4/                                     00000370
     2       ' ',4X,'CP WT',32X,1PE12.4)                                        00000380
C                                                                               00000390
      WRITE(IOU6,1203) RPWR,RPWRP,RPWRI                                         00000400
 1203 FORMAT('0',4X,'POWER (ROTOR)  ',11X,'KW',9X,1PE12.4/                      00000410
     1       ' ',4X,'POWER (PROFILE)',11X,'KW',9X,1PE12.4/                      00000420
     2       ' ',4X,'POWER (INFLOW) ',11X,'KW',9X,1PE12.4)                      00000430
C                                                                               00000440
      IF(ISTDY.EQ.0) GO TO 1400                                                 00000450
C                                                                               00000460
 1250 CONTINUE                                                                  00000470
C                                                                               00000480
      WRITE(IOU6,1300)                                                          00000490
 1300 FORMAT('0',4X,'DISK AVERAGE PERFORMANCE'/                                 00000500
     1       ' ',4X,24('-'))                                                    00000510
C                                                                               00000520
```

```
      WRITE(IOU6,1301) THRST,CTR,CTW                                    00000530
 1301 FORMAT('0',4X,'THRUST',20X,'LBS',8X,1PE12.4/                      00000540
     1       ' ',4X,'CT ROTOR',29X,1PE12.4/                             00000550
     2       ' ',4X,'CT WT',32X,1PE12.4)                                00000560
C                                                                       00000570
      WRITE(IOU6,1302) TORQ,CQR,CPW                                     00000580
 1302 FORMAT('0',4X,'TORQUE',20X,'FT-LBS',5X,1PE12.4/                   00000590
     1       ' ',4X,'CQ ROTOR',29X,1PE12.4/                             00000600
     2       ' ',4X,'CP WT',32X,1PE12.4)                                00000610
C                                                                       00000620
      WRITE(IOU6,1303) PWR,PWRP,PWRI                                    00000630
 1303 FORMAT('0',4X,'POWER (ROTOR)',13X,'KW',9X,1PE12.4/                00000640
     1       ' ',4X,'POWER (PRO)  ',13X,'KW',9X,1PE12.4/                00000650
     2       ' ',4X,'POWER (IND)  ',13X,'KW',9X,1PE12.4)                00000660
C                                                                       00000670
      WRITE(IOU6,1304) PMOMT                                            00000680
 1304 FORMAT('0',4X,'PITCH MOM (2D)',12X,'FT-LB',6X,1PE12.4)            00000690
C                                                                       00000700
 1400 CONTINUE                                                          00000710
C                                                                       00000720
      RETURN                                                            00000730
      END                                                               00000740
```

```
C     ***************************************************************** 00000010
C                                                                       00000020
C     LSWT06(OUT6)                                                      00000030
C                                                                       00000040
C     REPORTS WAKE PARAMETERS AND WORK STATE                            00000050
C                                                                       00000060
C     ***************************************************************** 00000070
C                                                                       00000080
      SUBROUTINE OUT6                                                   00000090
C                                                                       00000100
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,           00000110
     1                 IOU10,  IOU11,  IOU12,  IOU13                    00000120
      COMMON/ WRATES / AKZW,   AKZI,   AKZ,    AKR,    A,      AKB,     00000130
     1                 CTRW,   AKZ0,   ALAM0,  AKR0,   VAXB,   VNUB     00000140
C                                                                       00000150
C     ***************************************************************** 00000160
C                                                                       00000170
      CALL HEADER(2,IOU6)                                               00000180
C                                                                       00000190
      WRITE(IOU6,10)                                                    00000200
   10 FORMAT('0',4X,'WORKING STATE AND WAKE RATE PARAMETERS'/           00000210
     1       ' ',4X,38('-'))                                            00000220
C                                                                       00000230
C     CHECK FOR WORKING STATE                                           00000240
C                                                                       00000250
      IF(VAXB.GE.2.0) GO TO 100                                         00000260
      IF(VAXB.GE.1.5) GO TO 200                                         00000270
      IF(VAXB.GE.0.0) GO TO 300                                         00000280
      GO TO 400                                                         00000290
C                                                                       00000300
  100 CONTINUE                                                          00000310
      WRITE(IOU6,101)                                                   00000320
  101 FORMAT('0',4X,'WINDMILL BRAKE STATE')                             00000330
      GO TO 500                                                         00000340
C                                                                       00000350
  200 CONTINUE                                                          00000360
      WRITE(IOU6,201)                                                   00000370
  201 FORMAT('0',4X,'VORTEX RING STATE, PAST REGION OF ROUGHNESS')      00000380
      GO TO 500                                                         00000390
C                                                                       00000400
  300 CONTINUE                                                          00000410
      WRITE(IOU6,301)                                                   00000420
  301 FORMAT('0',4X,'VORTEX RING STATE, THROUGH REGION OF ROUGHNESS')   00000430
      GO TO 500                                                         00000440
C                                                                       00000450
  400 CONTINUE                                                          00000460
      WRITE(IOU6,401)                                                   00000470
  401 FORMAT('0',4X,'NORMAL WORKING STATE')                             00000480
C                                                                       00000490
  500 CONTINUE                                                          00000500
C                                                                       00000510
      WRITE(IOU6,601) VAXB,VNUB                                         00000520
```

```
  601 FORMAT('0',6X,'REFERRED VELOCITIES,'/                          00000530
     1       ' ',8X,'AXIAL ONSET',1PE14.5/                          00000540
     2       ' ',8X,'INDUCED    ',1PE14.5)                          00000550
C                                                                   00000560
      WRITE(IOU6,602) CTRW,AKZO,ALAMO,AKRO                          00000570
  602 FORMAT('0',6X,'REFERENCE WAKE PARAMETERS,'/                   00000580
     1       ' ',8X,'CTRW       ',1PE14.5/                          00000590
     2       ' ',8X,'AKZO       ',1PE14.5/                          00000600
     3       ' ',8X,'ALAMO      ',1PE14.5/                          00000610
     4       ' ',8X,'AKRO       ',1PE14.5)                          00000620
C                                                                   00000630
      WRITE(IOU6,603) AKZW,AKZI,AKZ,AKR,A,AKB                       00000640
  603 FORMAT('0',6X,'MODIFIED WAKE PARAMETERS,'/                    00000650
     1       ' ',8X,'AKZW       ',1PE14.5/                          00000660
     2       ' ',8X,'AKZI       ',1PE14.5/                          00000670
     3       ' ',8X,'AKZ        ',1PE14.5/                          00000680
     4       ' ',8X,'AKR        ',1PE14.5/                          00000690
     5       ' ',8X,'A          ',1PE14.5/                          00000700
     6       ' ',8X,'AKB        ',1PE14.5)                          00000710
C                                                                   00000720
      RETURN                                                        00000730
      END                                                           00000740
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT06(OUT8)                                                             00000030
C                                                                              00000040
C     REPORTS RECORD IMAGE OF INPUT FILE                                       00000050
C                                                                              00000060
C     ************************************************************************00000070
C                                                                              00000080
      SUBROUTINE OUT8                                                          00000090
C                                                                              00000100
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,                  00000110
     1                 IOU10,  IOU11,  IOU12,  IOU13                         00000120
C                                                                              00000130
C     ************************************************************************00000140
C                                                                              00000150
      CALL HEADER(0,IOU6)                                                      00000160
C                                                                              00000170
      WRITE(IOU6,10)                                                           00000180
   10 FORMAT('0',4X,'RECORD IMAGE OF INPUT FILE'/                              00000190
     1       ' ',4X,26('-')//)                                                 00000200
C                                                                              00000210
      CALL APPEND(IOU5,IOU6,80,5)                                              00000220
C                                                                              00000230
      RETURN                                                                   00000240
      END                                                                      00000250
```

```
C     ***************************************************************00000010
C                                                                     00000020
C     LSWT06(HEADER)                                                  00000030
C                                                                     00000040
C     PLACES BANNER AND CASE INFORMATION ON REPORTS                   00000050
C                                                                     00000060
C       ICASE = 0  BANNER ONLY                                        00000070
C       ICASE = 1  BANNER AND CASE ID                                 00000080
C       ICASE = 2  BANNER, CASE ID, AND POINT INFORMATION             00000090
C                                                                     00000100
C     ***************************************************************00000110
C                                                                     00000120
      SUBROUTINE HEADER(ICASE,IOUTO)                                  00000130
C                                                                     00000140
      CHARACTER TM     *36                                            00000150
      CHARACTER SPEC   *35                                            00000160
      CHARACTER STATUS *15                                            00000170
      CHARACTER CASEID *72                                            00000180
      CHARACTER DIM(4) *7                                             00000190
C                                                                     00000200
      COMMON/ CASE   / IPOINT, ALPHAD, VWOD,   IVDIM,  VWFAC,  PSIRD, 00000210
     1                 CASEID                                         00000220
C                                                                     00000230
      DATA TM     /'COMPUTATIONAL METHODOLOGY ASSOCIATES'/            00000240
      DATA SPEC   /'LSWT VERSION 1.00 RELEASED MAY 1986'/             00000250
      DATA STATUS /'SERI IL-5-05105'/                                 00000260
      DATA DIM    /'(FT/SEC',' (M/SEC','   (MPH','   (TSR'/          00000270
C                                                                     00000280
C     ***************************************************************00000290
C                                                                     00000300
      WRITE(IOUTO,10) TM,SPEC,STATUS                                  00000310
   10 FORMAT('1',4X,A36,' *** ',A35,' *** ',A15,/' ',4X,122('-'))     00000320
C                                                                     00000330
      IF(ICASE.NE.1) GO TO 100                                        00000340
C                                                                     00000350
      WRITE(IOUTO,20) CASEID                                          00000360
   20 FORMAT('0',4X,A72)                                              00000370
      GO TO 200                                                       00000380
C                                                                     00000390
  100 CONTINUE                                                        00000400
C                                                                     00000410
      IF(ICASE.NE.2) GO TO 200                                        00000420
C                                                                     00000430
      WRITE(IOUTO,30) IPOINT,CASEID,ALPHAD,DIM(IVDIM+1),VWOD,PSIRD    00000440
   30 FORMAT('0',4X,'POINT ',I2,': ',A72/                             00000450
     1       ' ',4X,'ROTOR PITCH      (DEG) ',F10.4,/                 00000460
     2       ' ',4X,'WIND SPEED    ' ,A7,') ',F10.4,/                 00000470
     3       ' ',4X,'ROTOR AZIMUTH    (DEG) ',F10.4)                 00000480
C                                                                     00000490
  200 CONTINUE                                                        00000500
C                                                                     00000510
      RETURN                                                          00000520
```

```
      END                                                          00000530
```

Source File: **LSWT06.FOR** Program Unit: **APPEND**

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT06(APPEND)                                                           00000030
C     COPIES THE FILE ASSOCIATED WITH UNIT IOUFRM TO THE FILE ON UNIT          00000040
C     IOUTO AT ITS CURRENT POINTER POSITION.  BOTH FILES MUST BE               00000050
C     FORMATTED, SEQUENTIAL FILES.  'MRECL' IS THE MAXIMUM RECORD LENGTH       00000060
C     OF THE IOUFRM FILE.  TRAILING BLANKS ARE TRIMMED FROM THE RECORD         00000070
C     TO CONSERVE SPACE.  IF LPAD > 0 THEN THE RECORD IS PADDED WITH           00000080
C     LPAD LEADING BLANKS TO ACCOMODATE FORMAT CONTROL ON OUTPUT.              00000090
C     (MRECL+LPAD) MUST BE LE 132.                                             00000100
C                                                                              00000110
C     ************************************************************************00000120
C                                                                              00000130
      SUBROUTINE APPEND(IOUFRM, IOUTO, MRECL,LPAD)                             00000140
C                                                                              00000150
      CHARACTER IOBUFR(132) *1                                                 00000160
C                                                                              00000170
C     ************************************************************************00000180
C                                                                              00000190
C     RESTRICT VALUES FOR MAXIMUM RECORD LENGTH                                00000200
C                                                                              00000210
      IF(MRECL+LPAD .GT. 132) GO TO 600                                        00000220
C                                                                              00000230
C     POSITION RECORD POINTER TO BEGINNING OF 'FROM' FILE                      00000240
C                                                                              00000250
      REWIND IOUFRM                                                            00000260
C                                                                              00000270
C     READ IOUFRM AND WRITE IOUTO UNTIL END OF FILE                            00000280
C                                                                              00000290
  100 CONTINUE                                                                 00000300
C                                                                              00000310
      READ  (IOUFRM,10,END=600) (IOBUFR(I), I=1,MRECL)                         00000320
   10 FORMAT(132A1)                                                            00000330
C                                                                              00000340
C     GET NET LENGTH BY FINDING FIRST NON-BLANK CHARACTER FROM END             00000350
C                                                                              00000360
      IRECL = MRECL                                                            00000370
C                                                                              00000380
      DO 200  I = 1, MRECL                                                     00000390
      II = MRECL - I + 1                                                       00000400
      IASCII = ICHAR(IOBUFR(II))                                               00000410
      IF(IASCII .EQ. 32) GO TO 200                                             00000420
      IRECL = II                                                               00000430
      GO TO 300                                                                00000440
  200 CONTINUE                                                                 00000450
C                                                                              00000460
  300 CONTINUE                                                                 00000470
C                                                                              00000480
C     PAD WITH LEADING BLANK IF REQUESTED, LPAD > 0                            00000490
C                                                                              00000500
      IF(LPAD.EQ.0) GO TO 500                                                  00000510
      DO 400 I = 1, IRECL                                                      00000520
```

```
      II = IRECL - I + 1                                          00000530
      IOBUFR(II+LPAD) = IOBUFR(II)                                00000540
  400 CONTINUE                                                    00000550
C                                                                 00000560
      DO 410 I=1, LPAD                                            00000570
      IOBUFR(I) = ' '                                             00000580
  410 CONTINUE                                                    00000590
      IRECL = IRECL + LPAD                                        00000600
C                                                                 00000610
  500 CONTINUE                                                    00000620
C                                                                 00000630
C     APPEND RECORD TO 'TO' FILE                                  00000640
C                                                                 00000650
      WRITE (IOUTO,10) (IOBUFR(I), I=1,IRECL)                     00000660
C                                                                 00000670
C     REPEAT FOR NEXT RECORD                                      00000680
C                                                                 00000690
      GO TO 100                                                   00000700
C                                                                 00000710
  600 CONTINUE                                                    00000720
C                                                                 00000730
      RETURN                                                      00000740
      END                                                         00000750
```

```
C     ***************************************************************00000010
C                                                                     00000020
C     LSWT07(IOINIT)                                                  00000030
C                                                                     00000040
C     OPENS DISK FILES FOR FOR I/O.  FILENAMES ARE PROMPTED FROM THE  00000050
C     CONSOLE.                                                        00000060
C                                                                     00000070
C     ***************************************************************00000080
C                                                                     00000090
      SUBROUTINE IOINIT                                               00000100
C                                                                     00000110
      CHARACTER*14 IPFILE,OPFILE,MSF1,MSF2,MSF3,MSF4                  00000120
C                                                                     00000130
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,          00000140
     1                 IOU10,  IOU11,  IOU12,  IOU13                  00000150
C                                                                     00000160
      DATA MSF1,      MSF2,      MSF3,      MSF4                      00000170
     1  / 'MSF1.DAT','MSF2.DAT','MSF3.DAT','MSF4.DAT'/                00000180
C                                                                     00000190
C     ***************************************************************00000200
C                                                                     00000210
C     ASSIGN DEFAULT VALUES TO I/O UNIT POINTERS                      00000220
C                                                                     00000230
      IOU1  = 0                                                       00000240
      IOU5  = 5                                                       00000250
      IOU6  = 6                                                       00000260
      IOU7  = IOU1                                                    00000270
      IOU8  = 8                                                       00000280
      IOU10 = 10                                                      00000290
      IOU11 = 11                                                      00000300
      IOU12 = 12                                                      00000310
      IOU13 = 13                                                      00000320
C                                                                     00000330
C     CLEAR THE DISPLAY                                               00000340
C                                                                     00000350
      CALL CLRSCN                                                     00000360
C                                                                     00000370
C     PLACE CURSOR AT ROW 10 COLUMN 1                                 00000380
C                                                                     00000390
      CALL LOCATE(10,1)                                               00000400
C                                                                     00000410
C     PROMPT FOR I/O FILES AND READ USER RESPONSE                     00000420
C                                                                     00000430
      WRITE(IOU1,10)                                                  00000440
   10 FORMAT('ENTER INPUT FILENAME  ===> ' \)                         00000450
      READ(IOU1,11) IPFILE                                            00000460
   11 FORMAT(A)                                                       00000470
      WRITE(IOU1,12)                                                  00000480
   12 FORMAT(' ENTER OUTPUT FILENAME ===> ' \)                        00000490
      READ(IOU1,11) OPFILE                                            00000500
C                                                                     00000510
C     REDIRECT OUTPUT FILE IF REQUESTED                               00000520
```

```
C                                                                       00000530
      IF(OPFILE.EQ.'CON') IOU6 = IOU1                                   00000540
C                                                                       00000550
C     OPEN STANDARD I/O FILES                                           00000560
C                                                                       00000570
C       IOU5  STANDARD INPUT                                            00000580
C       IOU6  STANDARD OUTPUT                                           00000590
C       IOU7  TRACE FILE ASSIGNED TO CONSOLE OR STANDARD OUTPUT         00000600
C       IOU8  TEMPORARY OUTPUT BUFFER FILE                              00000610
C                                                                       00000620
                  OPEN(IOU5, FILE = IPFILE, STATUS = 'OLD')             00000630
      IF(IOU6.EQ.6) OPEN(IOU6, FILE = OPFILE, STATUS = 'NEW')           00000640
                  OPEN(IOU8, FILE = 'IOBUFFER.TMP', STATUS = 'NEW')     00000650
C                                                                       00000660
C     OPEN MASS STORAGE FILES                                           00000670
C                                                                       00000680
C       NAME      USE                 SIZE(ELEMENTS)                  00000690
C       MSF1.DAT  SURFACE AIC'S       2*(100*100)*NBLADES             00000700
C       MSF2.DAT  WAKE AIC'S          2*(100*20 )*NBLADES             00000710
C       MSF3.DAT  COMBINED AIC ARRAY  2*(100*100)                     00000720
C       MSF4.DAT  WAKE COORDINATES    (24 *133)*NBLADES               00000730
C                                                                       00000740
      OPEN(IOU10, FILE=MSF1, STATUS='NEW', ACCESS='DIRECT', RECL = 400 )00000750
      OPEN(IOU11, FILE=MSF2, STATUS='NEW', ACCESS='DIRECT', RECL = 80  )00000760
      OPEN(IOU12, FILE=MSF3, STATUS='NEW', ACCESS='DIRECT', RECL = 400 )00000770
      OPEN(IOU13, FILE=MSF4, STATUS='NEW', ACCESS='DIRECT', RECL = 1596)00000780
C                                                                       00000790
C     CLEAR THE DISPLAY SCREEN AND HOME THE CURSOR                      00000800
C                                                                       00000810
      CALL CLRSCN                                                       00000820
C                                                                       00000830
      RETURN                                                            00000840
      END                                                               00000850
```

Source File: **LSWT07.FOR** Program Unit: **IOFNSH**

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT07(IOFNSH)                                                           00000030
C                                                                              00000040
C     CLOSES FILES OPENED FOR DISK I/O                                         00000050
C                                                                              00000060
C     ************************************************************************00000070
C                                                                              00000080
      SUBROUTINE IOFNSH                                                        00000090
C                                                                              00000100
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,                  00000110
     1                 IOU10,  IOU11,  IOU12,  IOU13                         00000120
C                                                                              00000130
C     ************************************************************************00000140
C                                                                              00000150
C     KEEP STANDARD I/O FILES                                                  00000160
C                                                                              00000170
      CLOSE(IOU5, STATUS = 'KEEP')                                             00000180
      CLOSE(IOU6, STATUS = 'KEEP')                                             00000190
C                                                                              00000200
C     DELETE IOBUFFER AND MASS STORAGE FILES                                   00000210
C                                                                              00000220
      CLOSE(IOU8 , STATUS = 'DELETE')                                          00000230
      CLOSE(IOU10, STATUS = 'DELETE')                                          00000240
      CLOSE(IOU11, STATUS = 'DELETE')                                          00000250
      CLOSE(IOU12, STATUS = 'DELETE')                                          00000260
      CLOSE(IOU13, STATUS = 'DELETE')                                          00000270
C                                                                              00000280
      RETURN                                                                   00000290
      END                                                                      00000300
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT07(TRACE)                                                            00000030
C                                                                              00000040
C     PLACES A MARKER AND TIMING INFORMATION IN THE OUTPUT STREAM TO           00000050
C     IOU7                                                                     00000060
C                                                                              00000070
C     ************************************************************************00000080
C                                                                              00000090
      SUBROUTINE TRACE(MARKER)                                                 00000100
C                                                                              00000110
      CHARACTER*6 MARKER                                                       00000120
C                                                                              00000130
      COMMON/ CIPRT  / IPRT1,  IPRT2,  IPRT3,  IPRT4,  IPRT5,  IPRT6,          00000140
     1                 IPRT7,  IPRT8                                           00000150
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,                   00000160
     1                 IOU10,  IOU11,  IOU12,  IOU13                           00000170
C                                                                              00000180
C     ************************************************************************00000190
C                                                                              00000200
      WRITE(IOU7,10) MARKER                                                    00000210
   10 FORMAT('0','TRACE: ',A6,/)                                               00000220
C                                                                              00000230
C     DISPLAY STEP TIME                                                        00000240
C                                                                              00000250
      CALL TIMER(4)                                                            00000260
C                                                                              00000270
C     DISPLAY TOTAL TIME                                                       00000280
C                                                                              00000290
      CALL TIMER(2)                                                            00000300
C                                                                              00000310
C     INITIALIZE STEP TIME                                                     00000320
C                                                                              00000330
      CALL TIMER(3)                                                            00000340
C                                                                              00000350
      RETURN                                                                   00000360
      END                                                                      00000370
```

```
C     ************************************************************************00000010
C                                                                               00000020
C     LSWT07(TIMER)                                                             00000030
C                                                                               00000040
C     DISPLAYS PROGRAM TIMING INFORMATION TO IOU7.  SYSTEM DEPENDENT            00000050
C     SUBROUTINE SYSTIM IS CALLED TO READ THE SYSTEM CLOCK FOR THE              00000060
C     CURRENT TIME.                                                             00000070
C                                                                               00000080
C          OPTION    ACTION                                                     00000090
C            1       INITIALIZE START TIME IN H0,M0,S0,D0; NO DISPLAY           00000100
C            2       DISPLAY TOTAL TIME T-T0                                    00000110
C            3       INITIALIZE STEP TIME IN H1,M1,S1,D1; NO DISPLAY            00000120
C            4       DISPLAY STEP TIME, T-T1                                    00000130
C                                                                               00000140
C     ************************************************************************00000150
C                                                                               00000160
      SUBROUTINE TIMER(OPTION)                                                  00000170
C                                                                               00000180
      IMPLICIT INTEGER (A-Z)                                                    00000190
C                                                                               00000200
      CHARACTER*49 FMT                                                          00000210
      CHARACTER*1  FMTE(49)                                                     00000220
      EQUIVALENCE  (FMT,FMTE)                                                   00000230
C                                                                               00000240
      CHARACTER*10 TITLE(2)                                                     00000250
C                                                                               00000260
      COMMON/ CTIMER / H0,     M0,     S0,     D0,     H1,     M1,      00000270
     1                 S1,     D1                                               00000280
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,            00000290
     1                 IOU10,  IOU11,  IOU12,  IOU13                    00000300
C                                                                               00000310
      DATA FMT/'('' '',A10,'' (H:M:S.D) '',IX,'':'',IX,'':'',IX,''.'',I200000320
     1.2)'/                                                                     00000330
C                                                                               00000340
      DATA TITLE(1)/'TOTAL TIME'/                                               00000350
      DATA TITLE(2)/'STEP TIME '/                                               00000360
C                                                                               00000370
C     ************************************************************************00000380
C                                                                               00000390
      CALL SYSTIM(H,M,S,D)                                                      00000400
C                                                                               00000410
      GO TO (100,200,300,400),OPTION                                            00000420
C                                                                               00000430
  100 CONTINUE                                                                  00000440
C                                                                               00000450
C     INITIALIZE START TIME                                                     00000460
C                                                                               00000470
      H0 = H                                                                    00000480
      M0 = M                                                                    00000490
      S0 = S                                                                    00000500
      D0 = D                                                                    00000510
C                                                                               00000520
```

```
      GO TO 900                                                    00000530
C                                                                  00000540
  200 CONTINUE                                                     00000550
C                                                                  00000560
C                                                                  00000570
C     DISPLAY TOTAL TIME                                           00000580
C                                                                  00000590
      H = H-H0                                                     00000600
      M = M-M0                                                     00000610
      S = S-S0                                                     00000620
      D = D-D0                                                     00000630
C                                                                  00000640
      ITITLE = 1                                                   00000650
      GO TO 500                                                    00000660
C                                                                  00000670
  300 CONTINUE                                                     00000680
C                                                                  00000690
C     INITIALIZE STEP TIME                                         00000700
C                                                                  00000710
      H1 = H                                                       00000720
      M1 = M                                                       00000730
      S1 = S                                                       00000740
      D1 = D                                                       00000750
C                                                                  00000760
      GO TO 900                                                    00000770
C                                                                  00000780
  400 CONTINUE                                                     00000790
C                                                                  00000800
C     DISPLAY STEP TIME                                            00000810
C                                                                  00000820
      H = H-H1                                                     00000830
      M = M-M1                                                     00000840
      S = S-S1                                                     00000850
      D = D-D1                                                     00000860
C                                                                  00000870
      ITITLE = 2                                                   00000880
      GO TO 500                                                    00000890
C                                                                  00000900
  500 CONTINUE                                                     00000910
C                                                                  00000920
C     SCALE TIME COMPONENTS FOR DISPLAY                            00000930
C                                                                  00000940
      IF(D.GE.0) GO TO 600                                         00000950
      D = D+100                                                    00000960
      S = S-1                                                      00000970
C                                                                  00000980
  600 CONTINUE                                                     00000990
C                                                                  00001000
      IF(S.GE.0) GO TO 700                                         00001010
      S = S+60                                                     00001020
      M = M-1                                                      00001030
C                                                                  00001040
```

```
  700 CONTINUE                                                          00001050
C                                                                       00001060
      IF(M.GE.0) GO TO 800                                              00001070
      M = M+60                                                          00001080
      H = H-1                                                           00001090
C                                                                       00001100
  800 CONTINUE                                                          00001110
C                                                                       00001120
C     ADJUST FORMAT FOR SIZE OF TIME COMPONENTS                         00001130
C                                                                       00001140
      FMTE(25) = '2'                                                    00001150
      IF(H.LT.10) FMTE(25) = '1'                                        00001160
C                                                                       00001170
      FMTE(32) = '2'                                                    00001180
      IF(M.LT.10) FMTE(32) = '1'                                        00001190
C                                                                       00001200
      FMTE(39) = '2'                                                    00001210
      IF(S.LT.10) FMTE(39) = '1'                                        00001220
C                                                                       00001230
C     REPORT IT                                                         00001240
C                                                                       00001250
      WRITE(IOU7,FMT) TITLE(ITITLE),H,M,S,D                             00001260
C                                                                       00001270
  900 CONTINUE                                                          00001280
C                                                                       00001290
      RETURN                                                            00001300
      END                                                               00001310
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT07(LOCATE)                                                           00000030
C                                                                              00000040
C     POSITIONS THE CONSOLE DISPLAY CURSOR BY WRITING ANSI TERMINAL            00000050
C     CONTROL SEQUENCES TO UNIT IOU1.                                          00000060
C                                                                              00000070
C     ************************************************************************00000080
C                                                                              00000090
      SUBROUTINE LOCATE(IROW,ICOL)                                             00000100
C                                                                              00000110
      CHARACTER*8 CUP                                                          00000120
      CHARACTER*1 ECUP(8)                                                      00000130
      EQUIVALENCE (CUP,ECUP(1))                                                00000140
C                                                                              00000150
      CHARACTER*10 FMT                                                         00000160
      CHARACTER*1  EFMT(10)                                                    00000170
      EQUIVALENCE  (FMT,EFMT(1))                                               00000180
C                                                                              00000190
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,                   00000200
     1                 IOU10,  IOU11,  IOU12,  IOU13                         00000210
C                                                                              00000220
      DATA FMT     / '('' '',A? \)' /                                          00000230
C                                                                              00000240
C     ************************************************************************00000250
C                                                                              00000260
C     ANSI CONTROL SEQUENCE: CUP = ESC['ROW';'COLUMN'H                         00000270
C                                                                              00000280
      IR1 = IROW/10                                                            00000290
      IR2 = IROW-IR1*10                                                        00000300
      IC1 = ICOL/10                                                            00000310
      IC2 = ICOL-IC1*10                                                        00000320
C                                                                              00000330
      ECUP(1) = CHAR(27)                                                       00000340
      ECUP(2) = CHAR(91)                                                       00000350
      IPOS = 3                                                                 00000360
C                                                                              00000370
      IF(IR1.EQ.0) GO TO 100                                                   00000380
      ECUP(IPOS) = CHAR(IR1+48)                                                00000390
      IPOS = IPOS + 1                                                          00000400
  100 CONTINUE                                                                 00000410
C                                                                              00000420
      ECUP(IPOS) = CHAR(IR2+48)                                                00000430
      IPOS = IPOS + 1                                                          00000440
C                                                                              00000450
      ECUP(IPOS) = CHAR(59)                                                    00000460
      IPOS = IPOS + 1                                                          00000470
C                                                                              00000480
      IF(IC1.EQ.0) GO TO 200                                                   00000490
      ECUP(IPOS) = CHAR(IC1+48)                                                00000500
      IPOS = IPOS + 1                                                          00000510
  200 CONTINUE                                                                 00000520
```

```
C                                                                    00000530
      ECUP(IPOS) = CHAR(IC2+48)                                      00000540
      IPOS = IPOS + 1                                                00000550
C                                                                    00000560
      ECUP(IPOS) = CHAR(72)                                          00000570
C                                                                    00000580
      EFMT(7) = CHAR(IPOS+48)                                        00000590
      WRITE (IOU1,FMT) CUP                                           00000600
C                                                                    00000610
      RETURN                                                         00000620
      END                                                            00000630
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT07(CLRSCN)                                                           00000030
C                                                                              00000040
C     CLEARS THE CONSOLE DISPLAY AND HOMES THE CURSOR BY WRITING ANSI          00000050
C     TERMINAL CONTROL SEQUENCES TO UNIT IOU1.                                 00000060
C                                                                              00000070
C     ************************************************************************00000080
C                                                                              00000090
      SUBROUTINE CLRSCN                                                        00000100
C                                                                              00000110
      CHARACTER*4  ED                                                          00000120
      CHARACTER*1  EED(4)                                                      00000130
      EQUIVALENCE  (ED,EED(1))                                                 00000140
      CHARACTER*10 FMT                                                         00000150
C                                                                              00000160
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,                   00000170
     1                 IOU10,  IOU11,  IOU12,  IOU13                         00000180
C                                                                              00000190
      DATA FMT     / '('' '',A4 \)' /                                          00000200
C                                                                              00000210
C     ************************************************************************00000220
C                                                                              00000230
C     ANSI CONTROL SEQUENCE: ED = ESC[2J                                       00000240
C                                                                              00000250
      EED(1) = CHAR(27)                                                        00000260
      EED(2) = CHAR(91)                                                        00000270
      EED(3) = CHAR(50)                                                        00000280
      EED(4) = CHAR(74)                                                        00000290
C                                                                              00000300
      WRITE (IOU1,FMT) ED                                                      00000310
C                                                                              00000320
      RETURN                                                                   00000330
      END                                                                      00000340
```

```
C     ***************************************************************0000010
C                                                                     00000020
C     LSWT08(WNDPRO)                                                  00000030
C                                                                     00000040
C     DETERMINES THE ONSET WIND PROFILE DUE TO THE ATMOSPHERIC BOUNDARY 00000050
C     LAYER AND TOWER SHADOW. IF ITRAN = 0 THE AXIS SYSTEM IS WIND AXIS.00000060
C     OTHERWISE IT IS SHAFT AXIS AND THE INPUT COORDINATES ARE        00000070
C     TRANSFORMED TO WIND AXIS FOR DETERMINATION OF THE PROFILE.  THE 00000080
C     WIND VECTOR IS THEN RETURNED IN THE SAME AXIS SYSTEM AS INDICATED 00000090
C     BY 'ITRAN'.                                                     00000100
C                                                                     00000110
C     ***************************************************************00000120
C                                                                     00000130
      SUBROUTINE WNDPRO(ITRAN,X,Y,Z,VW1,VW2,VW3,AKZW)                 00000140
C                                                                     00000150
      COMMON/ CONSTS / PI,     RPD                                    00000160
      COMMON/ CWIND  / ALPS1,  ALPS2,  H0,     VW0,    E,            00000170
     1                 ITSTYP, TSTAB(100),     NXTS,   NYTS,         00000180
     2                 T0,     TP,     TP0,    TPS,    TK,           00000190
     3                 AB(5,2),        AT(5,2)                       00000200
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                 00000210
      COMMON/ PARMS  / RADIUS, OMEGA,  OMEGAR, RHO,    AMU            00000220
C                                                                     00000230
C     ***************************************************************00000240
C                                                                     00000250
      VW1  = 0.0                                                      00000260
      VW2  = 0.0                                                      00000270
      VW3  = VW0                                                      00000280
      AKZW = VW3/OMEGAR                                               00000290
C                                                                     00000300
      IF(ISTDY.EQ.0) GO TO 200                                        00000310
      IF(ITRAN.EQ.0) GO TO 100                                        00000320
C                                                                     00000330
C     TRANSFORM (X,Y,Z) FROM SHAFT TO WIND AXIS                       00000340
C                                                                     00000350
      CALL ROTATE(Z,X,ALPS2)                                          00000360
      CALL ROTATE(Y,Z,ALPS1)                                          00000370
C                                                                     00000380
  100 CONTINUE                                                        00000390
C                                                                     00000400
C     HEIGHT ABOVE GROUND (POSITIVE Y POINTS DOWN)                    00000410
C                                                                     00000420
      H = H0-Y                                                        00000430
C                                                                     00000440
C     WIND PROFILE                                                    00000450
C                                                                     00000460
      VW1 = 0.0                                                       00000470
      VW2 = 0.0                                                       00000480
      VW3 = VW0*(H/H0)**E                                             00000490
C                                                                     00000500
C     ADD TOWER SHADOW (TS IS VELOCITY DEFICIENCY FRACTION)           00000510
C                                                                     00000520
```

```
      GO TO (110,120,130), ITSTYP+1                                    00000530
C                                                                      00000540
  110 CONTINUE                                                         00000550
C                                                                      00000560
C     NO TOWER SHADOW INCLUDED IN WIND PROFILE                         00000570
C                                                                      00000580
      TS = 0.0                                                         00000590
      GO TO 140                                                        00000600
C                                                                      00000610
  120 CONTINUE                                                         00000620
C                                                                      00000630
C     TOWER SHADOW EQUATION                                            00000640
C                                                                      00000650
      TS = 0.0                                                         00000660
      PSI = ATAN2(-X,Y)                                                00000670
      IF( (PSI.LT.(TPS-TPO)) .OR. ((TPS+TPO).LT.PSI) ) GO TO 130       00000680
      TS = TO + TP * COS((PI*TK/TPO)*(PSI-TPS))                        00000690
      GO TO 140                                                        00000700
C                                                                      00000710
  130 CONTINUE                                                         00000720
C                                                                      00000730
C     TOWER SHADOW TABLE                                               00000740
C                                                                      00000750
      CALL BVTINT(X,TS,Y,NXTS,NYTS,TSTAB,INOREX)                       00000760
      IF(INOREX.NE.0) TS = 0.0                                         00000770
C                                                                      00000780
  140 CONTINUE                                                         00000790
C                                                                      00000800
      VW3  = VW3 * (1.0-TS)                                            00000810
      AKZW = VW3 / OMEGAR                                              00000820
C                                                                      00000830
      IF(ITRAN.EQ.0) GO TO 200                                         00000840
C                                                                      00000850
C     RESOLVE WIND VECTOR TO SHAFT AXIS                                00000860
C                                                                      00000870
      CALL ROTATE(VW2,VW3,-ALPS1)                                      00000880
      CALL ROTATE(VW3,VW1,-ALPS2)                                      00000890
C                                                                      00000900
  200 CONTINUE                                                         00000910
      RETURN                                                           00000920
      END                                                              00000930
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT08(FLPVEL)                                                           00000030
C                                                                              00000040
C     CALCULATES THE ONSET VELOCITY DUE TO BLADE FLAPPING MOTION.  THE         00000050
C     FLAPPING VELOCITY IS RESOLVED IN SHAFT AXIS.                             00000060
C                                                                              00000070
C     ************************************************************************00000080
C                                                                              00000090
      SUBROUTINE FLPVEL(PSIT,X,Y,Z,VF1,VF2,VF3)                                00000100
C                                                                              00000110
      COMMON/ CWIND  / ALPS1,  ALPS2,  HO,     VWO,    E,                    00000120
     1                 ITSTYP, TSTAB(100),     NXTS,   NYTS,                 00000130
     2                 TO,     TP,     TPO,    TPS,    TK,                   00000140
     3                 AB(5,2),        AT(5,2)                               00000150
      COMMON/ PARMS  / RADIUS, OMEGA,  OMEGAR, RHO,    AMU                   00000160
C                                                                              00000170
      DATA ZERO / 1.0E-06 /                                                    00000180
C                                                                              00000190
C     ************************************************************************00000200
C                                                                              00000210
C     DETERMINE AZIMUTH AND RADIUS OF COORDINATES                              00000220
C                                                                              00000230
      PSIP = 0.0                                                               00000240
      IF(ABS(X).GT.ZERO.AND.ABS(Y).GT.ZERO) PSIP = ATAN2(-X,Y)                 00000250
      R = SQRT(X**2+Y**2+Z**2)                                                 00000260
      R = R*COS(PSIP-PSIT)                                                     00000270
C                                                                              00000280
C     FLAPPING ANGULAR DISPLACEMENT AND VELOCITY                               00000290
C                                                                              00000300
      BETA  = AB(1,1)                                                          00000310
      BETAD = 0.0                                                              00000320
      NBH   = IFIX(AB(1,2)+0.1)                                                00000330
C                                                                              00000340
      DO 100   N = 1,NBH                                                       00000350
      BETA  = BETA+AB(N+1,1)*COS(N*PSIT)+AB(N+1,2)*SIN(N*PSIT)                 00000360
      BETAD = BETAD-AB(N+1,1)*SIN(N*PSIT)*N+AB(N+1,2)*COS(N*PSIT)*N            00000370
  100 CONTINUE                                                                 00000380
C                                                                              00000390
      BETAD = BETAD*OMEGA                                                      00000400
C                                                                              00000410
C     VELOCITY COMPONENTS IN SHAFT AXIS AT (X,Y,Z)                             00000420
C                                                                              00000430
      VF1 = 0.0                                                                00000440
      VF2 = 0.0                                                                00000450
      VF3 = R*BETAD                                                            00000460
      CALL ROTATE(VF3,VF2,BETA)                                                00000470
      CALL ROTATE(VF1,VF2,PSIT)                                                00000480
C                                                                              00000490
      RETURN                                                                   00000500
      END                                                                      00000510
```

```
C     ***************************************************************** 00000010
C                                                                       00000020
C     LSWT08(NRMLBC)                                                    00000030
C                                                                       00000040
C     CALCULATES THE NORMALWASH BOUNDARY CONDITION FROM SURFACE NORMAL  00000050
C     VECTORS AND ONSET VELOCITY                                        00000060
C                                                                       00000070
C     ***************************************************************** 00000080
C                                                                       00000090
      SUBROUTINE NRMLBC(PSIT)                                           00000100
C                                                                       00000110
      REAL NRMWSH                                                       00000120
C                                                                       00000130
      COMMON/ CCIRC  / CIRC(100),      DCIRC(100),     ACIRC(100),      00000140
     1                 CIRCR(100),     BCIRC(20),      GO(20),          00000150
     2                 TECF,           AKM(6),         XKM(5)           00000160
      COMMON/ CVLCTY / VFS1(5,20),     VFS2(5,20),     VFS3(5,20),      00000170
     1                 VFS1M(20),      VFS2M(20),      VFS3M(20),       00000180
     2                 VI1(5,20),      VI2(5,20),      VI3(5,20),       00000190
     3                 VI1M(20),       VI2M(20),       VI3M(20),        00000200
     4                 VREL(20),       VIND(20),       QREL(20)         00000210
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                   00000220
      COMMON/ NMWSH  / NRMWSH(100)                                      00000230
      COMMON/ PARMS  / RADIUS, OMEGA,  OMEGAR, RHO,    AMU              00000240
      COMMON/ PNLCRD / XS(6,24),       YS(6,24),       ZS(6,24),        00000250
     1                 XCOL(5,20),     YCOL(5,20),     ZCOL(5,20)       00000260
      COMMON/ PNLNDX / MP,             NP,             NPANEL,          00000270
     1                 MP1,            NP1,            NPNLSQ,          00000280
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),     00000290
     3                 NPS(4),         NBLDS                            00000300
      COMMON/ PNLVEC / AN1(5,20),      AN2(5,20),      AN3(5,20),       00000310
     1                 AT1(5,20),      AT2(5,20),      AT3(5,20),       00000320
     2                 AQC1(20),       AQC2(20),       AQC3(20)         00000330
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,           00000340
     1                 IOU10,  IOU11,  IOU12,  IOU13                    00000350
C                                                                       00000360
C     ***************************************************************** 00000370
C                                                                       00000380
      DO 300   N = 1,NP                                                 00000390
C                                                                       00000400
      IF(ISTDY.EQ.1) GO TO 100                                          00000410
C                                                                       00000420
      CALL WNDPRO(0,0.0,0.0,0.0,VW1,VW2,VW3,AKZW)                       00000430
C                                                                       00000440
      VF1 = 0.0                                                         00000450
      VF2 = 0.0                                                         00000460
      VF3 = 0.0                                                         00000470
C                                                                       00000480
  100 CONTINUE                                                          00000490
C                                                                       00000500
      DO 300   M = 1,MP                                                 00000510
C                                                                       00000520
```

```
      LP = (M-1)*NP+N                                                   00000530
C                                                                       00000540
C     BUILD FREESTREAM VECTOR FROM WIND PROFILE,                        00000550
C     FLAPPING, AND ROTATIONAL VELOCITIES                               00000560
C                                                                       00000570
C                                                                       00000580
      IF(ISTDY.EQ.0) GO TO 200                                          00000590
C                                                                       00000600
      CALL WNDPRO(1,XCOL(M,N),YCOL(M,N),ZCOL(M,N),VW1,VW2,VW3,AKZW)     00000610
C                                                                       00000620
      CALL FLPVEL(PSIT,XCOL(M,N),YCOL(M,N),ZCOL(M,N),VF1,VF2,VF3)       00000630
C                                                                       00000640
  200 CONTINUE                                                          00000650
C                                                                       00000660
      VFS1(M,N) = VW1+VF1+( OMEGAR*YCOL(M,N))                           00000670
      VFS2(M,N) = VW2+VF2+(-OMEGAR*XCOL(M,N))                           00000680
      VFS3(M,N) = VW3+VF3                                               00000690
C                                                                       00000700
C     NORMALWASH BOUNDARY CONDITION                                     00000710
C                                                                       00000720
      NRMWSH(LP) = -( AN1(M,N)*VFS1(M,N)                                00000730
     1               +AN2(M,N)*VFS2(M,N)                                00000740
     2               +AN3(M,N)*VFS3(M,N) ) / OMEGAR                     00000750
C                                                                       00000760
  300 CONTINUE                                                          00000770
C                                                                       00000780
      RETURN                                                            00000790
      END                                                               00000800
```

```
C     ************************************************************************00000010
C                                                                              00000020
C     LSWT08(CIRPRM)                                                           00000030
C                                                                              00000040
C     CALCULATES PARAMETERS DERIVED FROM THE DISTRIBUTED CIRCULATION           00000050
C     SOLUTION                                                                 00000060
C                                                                              00000070
C     ************************************************************************00000080
C                                                                              00000090
      SUBROUTINE CIRPRM                                                        00000100
C                                                                              00000110
      COMMON/ CCIRC  / CIRC(100),      DCIRC(100),     ACIRC(100),             00000120
     1                 CIRCR(100),     BCIRC(20),      GO(20),                 00000130
     2                 TECF,           AKM(6),         XKM(5)                  00000140
      COMMON/ PNLNDX / MP,             NP,             NPANEL,                 00000150
     1                 MP1,            NP1,            NPNLSQ,                 00000160
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),            00000170
     3                 NPS(4),         NBLDS                                   00000180
C                                                                              00000190
C     ************************************************************************00000200
C                                                                              00000210
      DO 100  J = 1,NP                                                         00000220
C                                                                              00000230
      JP = (MP-1)*NP+J                                                         00000240
C                                                                              00000250
C     BOUND (TRAILING EDGE) CIRCULATION                                        00000260
C                                                                              00000270
      BCIRC(J) = CIRC(JP)*TECF                                                 00000280
C                                                                              00000290
C     LEADING EDGE SUCTION PARAMETER                                           00000300
C                                                                              00000310
      GO(J) = 1.0                                                              00000320
      IF(MP.EQ.1) GO TO 100                                                    00000330
      GXKM1 = CIRC(J)/BCIRC(J)/AKM(1)                                          00000340
      GXKM2 = CIRC(J+NP)/BCIRC(J)/AKM(2)                                       00000350
      GO(J) = (GXKM2-GXKM1)/(XKM(2)-XKM(1))*(-XKM(1))+GXKM1                    00000360
C                                                                              00000370
  100 CONTINUE                                                                 00000380
C                                                                              00000390
      RETURN                                                                   00000400
      END                                                                      00000410
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT08(BEVEL)                                                      00000030
C                                                                        00000040
C     CALCULATES THE BLADE ELEMENT VELOCITIES                            00000050
C                                                                        00000060
C     ******************************************************************00000070
C                                                                        00000080
      SUBROUTINE BEVEL(PSIT)                                             00000090
C                                                                        00000100
      DIMENSION DSWT(100)                                                00000110
C                                                                        00000120
      COMMON/ ALSLP  / ALS(20),       ALSNEW(20),    ALSOLD(20)          00000130
      COMMON/ BLDELE / XCLE(20),      YCG(20),       RBE(20),            00000140
     1                 DBES(20),      CLAMLE(20),    CLAMQC(20),         00000150
     2                 CHDCGL(20),    BETAL(20),     AFTWF(20),          00000160
     3                 JTAB(20,2),    TOC(20),       RE(20),             00000170
     4                 CLT(20),       CDT(20),       CMT(20),            00000180
     5                 CDS(20)                                           00000190
      COMMON/ CCIRC  / CIRC(100),     DCIRC(100),    ACIRC(100),         00000200
     1                 CIRCR(100),    BCIRC(20),     GO(20),             00000210
     2                 TECF,          AKM(6),        XKM(5)              00000220
      COMMON/ CDLS   / DLS(25)                                           00000230
      COMMON/ CONSTS / PI,     RPD                                       00000240
      COMMON/ CVLCTY / VFS1(5,20),    VFS2(5,20),    VFS3(5,20),         00000250
     1                 VFS1M(20),     VFS2M(20),     VFS3M(20),          00000260
     2                 VI1(5,20),     VI2(5,20),     VI3(5,20),          00000270
     3                 VI1M(20),      VI2M(20),      VI3M(20),           00000280
     4                 VREL(20),      VIND(20),      QREL(20)            00000290
      COMMON/ PARMS  / RADIUS, OMEGA, OMEGAR, RHO,   AMU                 00000300
      COMMON/ PNLNDX / MP,            NP,            NPANEL,             00000310
     1                 MP1,           NP1,           NPNLSQ,             00000320
     2                 NSGMNT,        JGLIM(4,2),    JCGLIM(4,2),        00000330
     3                 NPS(4),        NBLDS                              00000340
      COMMON/ PNLVEC / AN1(5,20),     AN2(5,20),     AN3(5,20),          00000350
     1                 AT1(5,20),     AT2(5,20),     AT3(5,20),          00000360
     2                 AQC1(20),      AQC2(20),      AQC3(20)            00000370
      COMMON/ UNITS  / IOU1,   IOU5,  IOU6,   IOU7,  IOU8,               00000380
     1                 IOU10,  IOU11, IOU12,  IOU13                      00000390
C                                                                        00000400
C     ******************************************************************00000410
C                                                                        00000420
      DO 100   N = 1,NP                                                  00000430
C                                                                        00000440
C                                                                        00000450
      VFS1M(N) = 0.0                                                     00000460
      VFS2M(N) = 0.0                                                     00000470
      VFS3M(N) = 0.0                                                     00000480
C                                                                        00000490
      VI1M(N) = 0.0                                                      00000500
      VI2M(N) = 0.0                                                      00000510
      VI3M(N) = 0.0                                                      00000520
```

```
C                                                                       00000530
      DO 200   M = 1,MP                                                 00000540
C                                                                       00000550
C     NORMAL INDUCED VELOCITY                                           00000560
C                                                                       00000570
      VSIN = 0.0                                                        00000580
C                                                                       00000590
      DO 300   I = 1,MP                                                 00000600
      KP   = (I-1)*NP+N                                                 00000610
      ISTR = (I-1)*MP+M                                                 00000620
      VSIN = VSIN + DLS(ISTR)/CHDCGL(N)*CIRC(KP)                        00000630
  300 CONTINUE                                                          00000640
C                                                                       00000650
      VSIN = VSIN/RADIUS*2.0*PI/ALS(N)                                  00000660
      VFSN = VFS1(M,N)*AN1(M,N)                                         00000670
     1     + VFS2(M,N)*AN2(M,N)                                         00000680
     2     + VFS3(M,N)*AN3(M,N)                                         00000690
      VN   = -VFSN-VSIN                                                 00000700
C                                                                       00000710
C     TANGENTIAL INDUCED VELOCITY                                       00000720
C                                                                       00000730
      LP = (M-1)*NP+N                                                   00000740
      READ(IOU12, REC = NPANEL+LP) (DSWT(KP), KP = 1,NPANEL)            00000750
C                                                                       00000760
      VT = 0.0                                                          00000770
C                                                                       00000780
      DO 400   KP = 1,NPANEL                                            00000790
      VT = VT+DSWT(KP)*CIRC(KP)                                         00000800
  400 CONTINUE                                                          00000810
C                                                                       00000820
      VT = VT/RADIUS                                                    00000830
C                                                                       00000840
C     RESOLVE TO COMPONENTS IN FIXED REFERENCE SYSTEM                   00000850
C                                                                       00000860
      VI1(M,N) = VN*AN1(M,N) + VT*AT1(M,N)                              00000870
      VI2(M,N) = VN*AN2(M,N) + VT*AT2(M,N)                              00000880
      VI3(M,N) = VN*AN3(M,N) + VT*AT3(M,N)                              00000890
C                                                                       00000900
C     TRANSFORM VELOCITIES TO BLADE ELEMENT COORDINATE SYSTEM           00000910
C                                                                       00000920
      ANGLE = -PSIT                                                     00000930
      CALL ROTATE(VI1(M,N),VI2(M,N),ANGLE)                              00000940
      CALL ROTATE(VFS1(M,N),VFS2(M,N),ANGLE)                            00000950
      ANGLE = 0.0                                                       00000960
      DY    = -AN2(M,N)                                                 00000970
      DX    =  AN3(M,N)                                                 00000980
      IF(ABS(DY).GT.1.0E-06) ANGLE = -ATAN2(DY,DX)                      00000990
      CALL ROTATE(VI2(M,N),VI3(M,N),ANGLE)                              00001000
      CALL ROTATE(VFS2(M,N),VFS3(M,N),ANGLE)                            00001010
C                                                                       00001020
  200 CONTINUE                                                          00001030
C                                                                       00001040
```

```
C     GET CHORDWISE AVERAGE                                              00001050
C                                                                        00001060
      CALL CWAVG ( VFS1(1,N), VFS1M(N) )                                 00001070
      CALL CWAVG ( VFS2(1,N), VFS2M(N) )                                 00001080
      CALL CWAVG ( VFS3(1,N), VFS3M(N) )                                 00001090
C                                                                        00001100
      CALL CWAVG ( VI1(1,N), VI1M(N) )                                   00001110
      CALL CWAVG ( VI2(1,N), VI2M(N) )                                   00001120
      CALL CWAVG ( VI3(1,N), VI3M(N) )                                   00001130
C                                                                        00001140
C     ELEMENT INDUCED VELOCITY                                           00001150
C                                                                        00001160
      VIND(N) = VI1M(N)                                                  00001170
C                                                                        00001180
C     ELEMENT RELATIVE VELOCITY AND DYNAMIC PRESSURE                     00001190
C                                                                        00001200
      VREL1   = VFS1M(N) + VI1M(N)                                       00001210
      VREL2   = VFS2M(N) + VI2M(N)                                       00001220
      VREL3   = VFS3M(N) + VI3M(N)                                       00001230
      VREL(N) = SQRT( VREL1**2 + VREL2**2 + VREL3**2 )                   00001240
      QREL(N) = 0.5*RHO*VREL(N)**2                                       00001250
C                                                                        00001260
C     COSINE OF AERODYNAMIC SWEEP ANGLE FROM VECTOR PRODUCT OF           00001270
C     VELOCITY AND CIRCULATION (CIRCULATION ASSUMED TO BE ALONG          00001280
C     QUARTER CHORD FOR THIS CALCULATION) -- NOTE THAT COSINE OF SWEEP   00001290
C     IS THE SINE OF INCLUDED ANGLE                                      00001300
C                                                                        00001310
      CALL VPANG(AQC1(N),AQC2(N),AQC3(N),VREL1,VREL2,VREL3,CLAMQC(N))    00001320
C                                                                        00001330
  100 CONTINUE                                                           00001340
C                                                                        00001350
      RETURN                                                             00001360
      END                                                                00001370
```

```
C     ***************************************************************00000010
C                                                                     00000020
C     LSWT08(CWAVG)                                                   00000030
C                                                                     00000040
C     CALCULATES THE CHORDWISE AVERAGE 'YM' OF THE 'MP' POINTS PASSED 00000050
C     THROUGH THE DUMMY ARRAY 'Y'                                     00000060
C                                                                     00000070
C     ***************************************************************00000080
C                                                                     00000090
      SUBROUTINE CWAVG(Y,YM)                                          00000100
C                                                                     00000110
      COMMON/ CGRID  / NGRID(4),       XG(6),  YG(24), XCG(5)         00000120
      COMMON/ PNLNDX / MP,             NP,             NPANEL,        00000130
     1                 MP1,            NP1,            NPNLSQ,        00000140
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),   00000150
     3                 NPS(4),         NBLDS                          00000160
C                                                                     00000170
      DIMENSION Y(1)                                                  00000180
C                                                                     00000190
C     ***************************************************************00000200
C                                                                     00000210
      YM = Y(1)                                                       00000220
      IF(MP.EQ.1) GO TO 200                                           00000230
C                                                                     00000240
      YLE = (Y(2)-Y(1))/(XCG(1)-XCG(2))*(-XCG(1))+Y(1)                00000250
      YTE = (Y(MP)-Y(MP-1))/(XCG(MP)-XCG(MP-1))*(1.0-XCG(MP))+Y(MP)   00000260
      YM  = (YLE+Y(1))/2.0*XCG(1) + (Y(MP)+YTE)/2.0*(1.0-XCG(MP))     00000270
C                                                                     00000280
      DO 100  I=1,MP-1                                                00000290
      YM = YM + (Y(I+1)+Y(I))/2.0*(XCG(I+1)-XCG(I))                   00000300
  100 CONTINUE                                                        00000310
C                                                                     00000320
  200 CONTINUE                                                        00000330
C                                                                     00000340
      RETURN                                                          00000350
      END                                                             00000360
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT08(BEALPH)                                                     00000030
C                                                                        00000040
C     CALCULATES THE BLADE ELEMENT ANGLES OF ATTACK                      00000050
C                                                                        00000060
C     ******************************************************************00000070
C                                                                        00000080
      SUBROUTINE BEALPH                                                  00000090
C                                                                        00000100
      COMMON/ ALSLP  / ALS(20),        ALSNEW(20),     ALSOLD(20)        00000110
      COMMON/ BLDELE / XCLE(20),       YCG(20),        RBE(20),          00000120
     1                 DBES(20),       CLAMLE(20),     CLAMQC(20),       00000130
     2                 CHDCGL(20),     BETAL(20),      AFTWF(20),        00000140
     3                 JTAB(20,2),     TOC(20),        RE(20),           00000150
     4                 CLT(20),        CDT(20),        CMT(20),          00000160
     5                 CDS(20)                                           00000170
      COMMON/ CALPHA / ALPHAG(20),     ALPHAE(20),     ALPHAW(20),       00000180
     1                 ALPHAN(20),     ALPHAI(20),     AZLLC(20),        00000190
     2                 TWSTCG(20)                                        00000200
      COMMON/ CCIRC  / CIRC(100),      DCIRC(100),     ACIRC(100),       00000210
     1                 CIRCR(100),     BCIRC(20),      GO(20),           00000220
     2                 TECF,           AKM(6),         XKM(5)            00000230
      COMMON/ CONSTS / PI,     RPD                                       00000240
      COMMON/ CONTRL / TOL1,   TOL2,   TOL3,   ICYL1,  ICYL2,  ICYL3,    00000250
     1                 ICYL4                                             00000260
      COMMON/ CVLCTY / VFS1(5,20),     VFS2(5,20),     VFS3(5,20),       00000270
     1                 VFS1M(20),      VFS2M(20),      VFS3M(20),        00000280
     2                 VI1(5,20),      VI2(5,20),      VI3(5,20),        00000290
     3                 VI1M(20),       VI2M(20),       VI3M(20),         00000300
     4                 VREL(20),       VIND(20),       QREL(20)          00000310
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                    00000320
      COMMON/ PARMS  / RADIUS, OMEGA,  OMEGAR, RHO,    AMU               00000330
      COMMON/ PNLNDX / MP,             NP,             NPANEL,           00000340
     1                 MP1,            NP1,            NPNLSQ,           00000350
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),      00000360
     3                 NPS(4),         NBLDS                             00000370
C                                                                        00000380
      DATA ZERO /1.0E-06/                                                00000390
C                                                                        00000400
C     ******************************************************************00000410
C                                                                        00000420
C     RESET LIFT SLOPE CONVERGENCE FLAG                                  00000430
C                                                                        00000440
      LSFLAG = 0                                                         00000450
C                                                                        00000460
      DO 100   J = 1,NP                                                  00000470
C                                                                        00000480
      JP = (MP-1)*NP+J                                                   00000490
C                                                                        00000500
C     ONSET VELOCITY ANGLE OF ATTACK                                     00000510
C                                                                        00000520
```

```
      ALPHAW(J) = 0.0                                                   00000530
      IF(ABS(VFS3M(J)).GT.ZERO) ALPHAW(J) = ATAN2(VFS3M(J),VFS1M(J))    00000540
C                                                                       00000550
C     EFFECTIVE ANGLE OF ATTACK                                         00000560
C                                                                       00000570
      RE(J)     = RHO*VREL(J)*CHDCGL(J)*RADIUS/AMU                      00000580
      CLO       = 2.0*BCIRC(J)/VREL(J)/CHDCGL(J)/RADIUS                 00000590
      CDS(J)    = -(CLO**2/(2.0*PI))/CLAMLE(J) * (GO(J)**2-1.0)         00000600
      ALPHAE(J) = ASIN(CLO/ALS(J))/CLAMQC(J)                            00000610
C                                                                       00000620
C     ELEMENT AIRFOIL CHARACTERISTICS WITH SWEEP CORRECTIONS            00000630
C                                                                       00000640
      ALTAB = (ALPHAE(J)+AZLLC(J))/RPD                                  00000650
      CALL AFCOEF(J,ALTAB,RE(J),CLT(J),CDT(J),CMT(J),INOREX)            00000660
C                                                                       00000670
      CLT(J) = CLT(J)*CLAMQC(J)**2                                      00000680
C                                                                       00000690
C     'CDF' IS PORTION OF PROFILE DRAG COEFFICIENT ATTRIBUTABLE TO      00000700
C     FRICTION.  CDT-CDF IS THEN PRESSURE DRAG AND MUST BE CORRECTED    00000710
C     FOR SWEEP                                                         00000720
C                                                                       00000730
      CDF    = 0.006                                                    00000740
      CDP    = CDT(J) - CDF                                             00000750
      CDT(J) = CDF + CDP*CLAMQC(J)**3                                   00000760
C                                                                       00000770
C     RESET SUCTION FORCE INCREMENT IF STALLED                          00000780
C                                                                       00000790
      IF(INOREX.NE.0) CDS(J) = 0.0                                      00000800
C                                                                       00000810
C     CALCULATE NEW LIFT CURVE SLOPE AND CHECK CONVERGENCE              00000820
C                                                                       00000830
      ALSNEW(J) = CLT(J)/SIN(ALPHAE(J))                                 00000840
C                                                                       00000850
      TOLMAX = ABS(1.0/ALSNEW(J)**2)                                    00000860
      IF(TOLMAX.LT.0.01) TOLMAX = 0.01                                  00000870
      IF(TOL2.GT.0.0) TOLMAX = TOL2                                     00000880
      TOL = ABS((ALSNEW(J)-ALS(J))/ALSNEW(J))                           00000890
      IF(TOL.GT.TOLMAX) LSFLAG = 1                                      00000900
C                                                                       00000910
      ALSOLD(J) = ALS(J)                                                00000920
      ALS(J)    = ALSNEW(J)                                             00000930
C                                                                       00000940
C     INFLOW 'N' AND INDUCED 'I' ANGLES OF ATTACK                       00000950
C       USE ANGLE RESOLUTION BELOW STALL, VELOCITY RESOLUTION ABOVE     00000960
C       STALL                                                           00000970
C                                                                       00000980
      IF(INOREX.NE.0) GOTO 110                                          00000990
      ALPHAN(J) = ALPHAE(J)-ALPHAG(J)+AZLLC(J)                          00001000
      ALPHAI(J) = ALPHAN(J)-ALPHAW(J)                                   00001010
      GOTO 100                                                          00001020
  110 CONTINUE                                                          00001030
      ALPHAN(J) = ATAN2(VFS3M(J)+VI3M(J),VFS1M(J)+VI1M(J))              00001040
```

```
      ALPHAI(J) = ATAN2(VI3M(J),VFS1M(J)+VI1M(J))                    00001050
C                                                                    00001060
  100 CONTINUE                                                       00001070
C                                                                    00001080
      RETURN                                                         00001090
      END                                                            00001100
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT08(AFCOEF)                                                     00000030
C                                                                        00000040
C     CALLS TABLE LOOKUPS, ADDS ANALYTICAL EXTENSIONS,  AND PERFORMS     00000050
C     AVERAGING TO GET CL,CD, AND CM AT BLADE ELEMENT 'J'.               00000060
C                                                                        00000070
C     ******************************************************************00000080
C                                                                        00000090
      SUBROUTINE AFCOEF(J,ALTAB,REN,CL,CD,CM,INOREX)                     00000100
C                                                                        00000110
      COMMON/ AFTABL / NAFT,   IDAFT(4),       AFTOC(4),       IAFTEX,   00000120
     1                 STP1(4),        STP2(4),        STP3(4),          00000130
     2                 STP4(4),        STP5(4),        STP6(4),          00000140
     3                 CLTAB(200,4),   NRCL(4),        NACL(4),          00000150
     4                 CDTAB(200,4),   NRCD(4),        NACD(4),          00000160
     5                 CMTAB(100,4),   NRCM(4),        NACM(4)           00000170
      COMMON/ BLDELE / XCLE(20),       YCG(20),        RBE(20),          00000180
     1                 DBES(20),       CLAMLE(20),     CLAMQC(20),       00000190
     2                 CHDCGL(20),     BETAL(20),      AFTWF(20),        00000200
     3                 JTAB(20,2),     TOC(20),        RE(20),           00000210
     4                 CLT(20),        CDT(20),        CMT(20),          00000220
     5                 CDS(20)                                           00000230
      COMMON/ CCIRC  / CIRC(100),      DCIRC(100),     ACIRC(100),       00000240
     1                 CIRCR(100),     BCIRC(20),      GO(20),           00000250
     2                 TECF,           AKM(6),         XKM(5)            00000260
      COMMON/ CONSTS / PI,     RPD                                       00000270
C                                                                        00000280
C     ******************************************************************00000290
C                                                                        00000300
      JTAB1 = JTAB(J,1)                                                  00000310
      JTAB2 = JTAB(J,2)                                                  00000320
      IPASS = 1                                                          00000330
      JTABP = JTAB1                                                      00000340
C                                                                        00000350
      NRCLP = NRCL(JTABP)                                                00000360
      NACLP = NACL(JTABP)                                                00000370
      NRCDP = NRCD(JTABP)                                                00000380
      NACDP = NACD(JTABP)                                                00000390
      NRCMP = NRCM(JTABP)                                                00000400
      NACMP = NACM(JTABP)                                                00000410
C                                                                        00000420
  100 CONTINUE                                                           00000430
C                                                                        00000440
      CALL BVTINT(REN,CLP,ALTAB,NRCLP,NACLP,CLTAB(1,JTABP),INEXCL)       00000450
      CALL BVTINT(REN,CDP,ALTAB,NRCDP,NACDP,CDTAB(1,JTABP),INEXCD)       00000460
      CALL BVTINT(REN,CMP,ALTAB,NRCMP,NACMP,CMTAB(1,JTABP),INEXCM)       00000470
C                                                                        00000480
C     IF OUT OF TABLE RANGE THEN USE ANALYTICAL MODEL IF REQUESTED,      00000490
C     OTHERWISE KEEP TABLE EXTRAPOLATIONS                                00000500
C                                                                        00000510
      IF(INEXCL.EQ.0.AND.INEXCD.EQ.0.AND.INEXCM.EQ.0) GO TO 110          00000520
```

```
      IF(IAFTEX.EQ.0) GO TO 110                                          00000530
C                                                                        00000540
C     GET CL,CD, AND CM AT STALL (ASSUMED TO BE SAME AS TABLE LIMIT)     00000550
C                                                                        00000560
      ITABL = NRCLP+NACLP                                                00000570
      ITABD = NRCDP+NACDP                                                00000580
      ITABM = NRCMP+NACMP                                                00000590
C                                                                        00000600
      ALPSL = CLTAB(ITABL,JTABP)                                         00000610
      ALPSD = CDTAB(ITABD,JTABP)                                         00000620
      ALPSM = CMTAB(ITABM,JTABP)                                         00000630
C                                                                        00000640
      CALL BVTINT(REN,CLS,ALPSL,NRCLP,NACLP,CLTAB(1,JTABP),INOREX)       00000650
      CALL BVTINT(REN,CDS,ALPSD,NRCDP,NACDP,CDTAB(1,JTABP),INOREX)       00000660
      CALL BVTINT(REN,CMS,ALPSM,NRCMP,NACMP,CMTAB(1,JTABP),INOREX)       00000670
C                                                                        00000680
C     EXTEND TABLE ANALYTICALLY                                          00000690
C                                                                        00000700
      CALL AFTEXT(JTABP,ALTAB,ALPSL,ALPSD,CLS,CDS,CLEX,CDEX)             00000710
C                                                                        00000720
      IF(INEXCL.NE.0) CLP = CLEX                                         00000730
      IF(INEXCD.NE.0) CDP = CDEX                                         00000740
      IF(INEXCM.NE.0) CMP = CMS                                          00000750
      INOREX = 0                                                         00000760
      IF(INEXCL.NE.0) INOREX = 1                                         00000770
C                                                                        00000780
      IF(IPASS.EQ.2) GO TO 120                                           00000790
C                                                                        00000800
  110 CONTINUE                                                           00000810
C                                                                        00000820
      CL = CLP                                                           00000830
      CD = CDP                                                           00000840
      CM = CMP                                                           00000850
C                                                                        00000860
C     REPEAT FOR SECOND TABLE IF AVERAGING USED AT THIS STATION          00000870
C                                                                        00000880
      IF(JTAB1.EQ.JTAB2) GO TO 120                                       00000890
C                                                                        00000900
      IPASS = 2                                                          00000910
      JTABP = JTAB2                                                      00000920
C                                                                        00000930
      NRCLP = NRCL(JTABP)                                                00000940
      NACLP = NACL(JTABP)                                                00000950
      NRCDP = NRCD(JTABP)                                                00000960
      NACDP = NACD(JTABP)                                                00000970
      NRCMP = NRCM(JTABP)                                                00000980
      NACMP = NACM(JTABP)                                                00000990
C                                                                        00001000
      GO TO 100                                                          00001010
C                                                                        00001020
  120 CONTINUE                                                           00001030
C                                                                        00001040
```

```
      CL = CLP*AFTWF(J)+CL*(1.0-AFTWF(J))                              00001050
      CD = CDP*AFTWF(J)+CD*(1.0-AFTWF(J))                              00001060
      CM = CMP*AFTWF(J)+CM*(1.0-AFTWF(J))                              00001070
C                                                                      00001080
      RETURN                                                           00001090
      END                                                              00001100
```

```
C     ********************************************************************00000010
C                                                                          00000020
C     LSWT08(AFTEXT)                                                       00000030
C                                                                          00000040
C     EXTENDS AIRFOIL TABLES WITH ANALYTICAL METHODS.                      00000050
C                                                                          00000060
C     ********************************************************************00000070
C                                                                          00000080
      SUBROUTINE AFTEXT(JTAB,ALTAB,ALPSL,ALPSD,CLS,CDS,CL,CD)              00000090
C                                                                          00000100
      COMMON/ AFTABL / NAFT,   IDAFT(4),       AFTOC(4),       IAFTEX,     00000110
     1                 STP1(4),        STP2(4),        STP3(4),           00000120
     2                 STP4(4),        STP5(4),        STP6(4),           00000130
     3                 CLTAB(200,4),   NRCL(4),        NACL(4),           00000140
     4                 CDTAB(200,4),   NRCD(4),        NACD(4),           00000150
     5                 CMTAB(100,4),   NRCM(4),        NACM(4)            00000160
      COMMON/ CALPHA / ALPHAG(20),     ALPHAE(20),     ALPHAW(20),         00000170
     1                 ALPHAN(20),     ALPHAI(20),     AZLLC(20),         00000180
     2                 TWSTCG(20)                                         00000190
      COMMON/ CONSTS / PI,     RPD                                         00000200
C                                                                          00000210
C     ********************************************************************00000220
C                                                                          00000230
      ALP    = ALTAB * RPD                                                00000240
      ALPSL  = ALPSL * RPD                                                00000250
      ALPSD  = ALPSD * RPD                                                00000260
      ABSALP = ABS(ALP)                                                   00000270
C                                                                          00000280
      SA   = SIN(ALP)                                                     00000290
      CA   = COS(ALP)                                                     00000300
      SASL = SIN(ALPSL)                                                   00000310
      SASD = SIN(ALPSD)                                                   00000320
      CASL = COS(ALPSL)                                                   00000330
      CASD = COS(ALPSD)                                                   00000340
C                                                                          00000350
      IF(IAFTEX.GT.1) GO TO 200                                           00000360
C                                                                          00000370
C     ------------------------------------------------------               00000380
C     IAFTEX = 1  AEROVIRONMENT METHOD                                     00000390
C     FLAT PLATE NORMAL FORCE COEFFICIENT WITH MODIFICATIONS FOR           00000400
C     EFFECTIVE ASPECT RATIO BASED ON PRANDTL TIP LOSS FACTOR              00000410
C     ------------------------------------------------------               00000420
C                                                                          00000430
C     APPROXIMATE 'PRANDTL LOSS FUNCTION' 3D/2D ALPHA                      00000440
C                                                                          00000450
      F = ABS(ALPHAE(J)/(ALPHAW(J)+ALPHAG(J)-AZLLC(J)))                   00000460
      CN = 1.98                                                           00000470
      IF(F.GE.0.99999) GO TO 100                                          00000480
      AR = 2.0                                                            00000490
      IF(F.GT.0.5) AR = 2.0 * F/(1-F)                                     00000500
      CN = 1.98 - 0.81 * TANH(12.22/AR)                                   00000510
  100 CN=AMIN1( 1.0 / ( 0.222 + 0.283 / SIN(ABSALP) ),CN )                00000520
```

```
      IF(ALP.LT.0.0) CN = -CN                                          00000530
C                                                                      00000540
C     LIFT AND DRAG COEFFICIENTS                                       00000550
C                                                                      00000560
      CL = CN * CA                                                     00000570
      CD = CN * SA                                                     00000580
C                                                                      00000590
      GO TO 1000                                                       00000600
C                                                                      00000610
  200 CONTINUE                                                         00000620
      IF(IAFTEX.GT.2) GO TO 300                                        00000630
C                                                                      00000640
C     ------------------------------------------------                 00000650
C     IAFTEX = 2  VITERNA'S METHOD                                     00000660
C     ------------------------------------------------                 00000670
C                                                                      00000680
      AR    = STP1(JTAB)                                               00000690
      CDMAX = 1.11+0.018*AR                                            00000700
C                                                                      00000710
      B1 = CDMAX                                                       00000720
      B2 = (CDS-B1*SASD**2)/CASD                                       00000730
C                                                                      00000740
      A1 = B1/2.0                                                      00000750
      A2 = (CLS-CDMAX*SASL*CASL)*SASL/CASL**2                          00000760
C                                                                      00000770
C     LIFT AND DRAG COEFFICIENTS                                       00000780
C                                                                      00000790
      CL = A1*2.0*SA*CA + A2*CA**2/SA                                  00000800
      CD = B1*SA**2 + B2*CA                                            00000810
C                                                                      00000820
      GO TO 1000                                                       00000830
C                                                                      00000840
  300 CONTINUE                                                         00000850
      IF(IAFTEX.GT.3) GO TO 1000                                       00000860
C                                                                      00000870
C     ------------------------------------------------                 00000880
C     IAFTEX = 3  CMA METHOD                                           00000890
C     ------------------------------------------------                 00000900
C                                                                      00000910
      ALPR = STP1(JTAB)*RPD                                            00000920
      CL45 = STP2(JTAB)                                                00000930
      CD45 = STP3(JTAB)                                                00000940
      CL90 = STP4(JTAB)                                                00000950
      CD90 = STP5(JTAB)                                                00000960
      BPR  = STP6(JTAB)                                                00000970
C                                                                      00000980
      IF(ALP.GT.ALPR) GOTO 310                                         00000990
C                                                                      00001000
C     REGION 2 -- TRANSITION FROM STALL TO RECOVERY                    00001010
C                 ALPS < ALP < ALPR                                    00001020
C                                                                      00001030
      SAR = SIN(ALPR)                                                  00001040
```

```
      CAR = COS(ALPR)                                                   00001050
      CLR = (2.0*CL45*SAR*CAR)                                          00001060
      CDR = (2.0*CD45*SAR**2 )                                          00001070
C                                                                       00001080
      A1 = (CLR*CASL**2*SAR-CLS*CAR**2*SASL) /                          00001090
     1     (2.0*CASL*CAR*(SAR**2*CASL-SASL**2*CAR))                     00001100
      A2 = (CLS-2.0*A1*SASL*CASL)*SASL/CASL**2                          00001110
      B1 = (CDS*CAR-CDR*CASD)/(SASD**3*CAR-SAR**3*CASD)                 00001120
      B2 = (CDR-B1*SAR**3)/CAR                                          00001130
      CL = A1*2.0*SA*CA + A2*CA**2/SA                                   00001140
      CD = B1*SA**3     + B2*CA                                         00001150
C                                                                       00001160
      GOTO 1000                                                         00001170
C                                                                       00001180
  310 CONTINUE                                                          00001190
      IF(ALP.GT.PI/4.0) GOTO 320                                        00001200
C                                                                       00001210
C     REGION 3 -- RECOVERY TO 45 DEG                                    00001220
C                                                                       00001230
      A1 = 2.0*CL45*BPR                                                 00001240
      A2 = (CLR-2.0*CL45*BPR*SAR*CAR)/(1.0-2.0*SAR**2)                  00001250
      B1 = (CDR-SQRT(2.0)*CD45*BPR*CAR)/(SAR**2-SQRT(2.0)/2.0*CAR)      00001260
      B2 = (CD45*BPR-B1/2.0)*SQRT(2.0)                                  00001270
      CL = A1*SA*CA+A2*(1.0-2.0*SA**2)                                  00001280
      CD = B1*SA**2+B2*CA                                               00001290
C                                                                       00001300
      GOTO 1000                                                         00001310
C                                                                       00001320
  320 CONTINUE                                                          00001330
C                                                                       00001340
C     REGION 4 -- 45 DEG TO 90 DEG                                      00001350
C                                                                       00001360
      CL = (2.0*CL45*SA*CA - CL90*(1-2.0*SA**2))       * BPR            00001370
      CD = (CD90*SA**2 + (2.0*CD45-CD90)/SQRT(2.0)*CA) * BPR            00001380
C                                                                       00001390
 1000 CONTINUE                                                          00001400
C                                                                       00001410
      RETURN                                                            00001420
      END                                                               00001430
```

```
C     ******************************************************************00000010
C                                                                        00000020
C     LSWT08(AEROPF)                                                     00000030
C                                                                        00000040
C     CALCULATES ELEMENT, BLADE, AND ROTOR PERFORMANCE                   00000050
C                                                                        00000060
C     ******************************************************************00000070
C                                                                        00000080
      SUBROUTINE AEROPF(ITBLD,IPSIR,ISCYL)                               00000090
C                                                                        00000100
      COMMON/ BELOAD / DFX(20),        DFXI(20),       DFXP(20),         00000110
     1                 DFZ(20),        DFZI(20),       DFZP(20),         00000120
     2                 DQ(20),         DQI(20),        DQP(20),          00000130
     3                 DPM(20)                                           00000140
      COMMON/ BLDELE / XCLE(20),       YCG(20),        RBE(20),          00000150
     1                 DBES(20),       CLAMLE(20),     CLAMQC(20),       00000160
     2                 CHDCGL(20),     BETAL(20),      AFTWF(20),        00000170
     3                 JTAB(20,2),     TOC(20),        RE(20),           00000180
     4                 CLT(20),        CDT(20),        CMT(20),          00000190
     5                 CDS(20)                                           00000200
      COMMON/ BLLOAD / CTRB,   CQRB,   CTWB,   CPWB,   BTHRST, BTORQ,    00000210
     1                 BTORQI, BTORQP, BPWR,   BPWRP,  BPWRI,  BPMOMT    00000220
      COMMON/ CALPHA / ALPHAG(20),     ALPHAE(20),     ALPHAW(20),       00000230
     1                 ALPHAN(20),     ALPHAI(20),     AZLLC(20),        00000240
     2                 TWSTCG(20)                                        00000250
      COMMON/ CONSTS / PI,     RPD                                       00000260
      COMMON/ CTCON  / CTRIN,  CTROUT, CTRUPD                            00000270
      COMMON/ CVLCTY / VFS1(5,20),     VFS2(5,20),     VFS3(5,20),       00000280
     1                 VFS1M(20),      VFS2M(20),      VFS3M(20),        00000290
     2                 VI1(5,20),      VI2(5,20),      VI3(5,20),        00000300
     3                 VI1M(20),       VI2M(20),       VI3M(20),         00000310
     4                 VREL(20),       VIND(20),       QREL(20)          00000320
      COMMON/ CWIND  / ALPS1,  ALPS2,  HO,     VWO,    E,                00000330
     1                 ITSTYP, TSTAB(100),     NXTS,   NYTS,           00000340
     2                 TO,     TP,     TPO,    TPS,    TK,             00000350
     3                 AB(5,2),        AT(5,2)                           00000360
      COMMON/ IFLAGS / ISTDY,  IWFLAG, LSFLAG, IRFLAG                    00000370
      COMMON/ PARMS  / RADIUS, OMEGA,  OMEGAR, RHO,    AMU               00000380
      COMMON/ PNLNDX / MP,             NP,             NPANEL,           00000390
     1                 MP1,            NP1,            NPNLSQ,           00000400
     2                 NSGMNT,         JGLIM(4,2),     JCGLIM(4,2),      00000410
     3                 NPS(4),         NBLDS                             00000420
      COMMON/ RTLOAD / CTRR,   CQRR,   CTWR,   CPWR,   RTHRST, RTORQ,    00000430
     1                 RTORQP, RTORQI, RPWR,   RPWRP,  RPWRI,  CTR,     00000440
     2                 CQR,    CTW,    CPW,    THRST,  TORQ,   TORQP,   00000450
     3                 TORQI,  PWR,    PWRP,   PWRI,   RPMOMT, PMOMT    00000460
      COMMON/ UNITS  / IOU1,   IOU5,   IOU6,   IOU7,   IOU8,             00000470
     1                 IOU10,  IOU11,  IOU12,  IOU13                     00000480
C                                                                        00000490
C     ******************************************************************00000500
C                                                                        00000510
      IF(ISTDY.EQ.0) GO TO 20                                            00000520
```

```
      IF(ISCYL.EQ.1) GO TO 20                                          00000530
C                                                                      00000540
C     RESET IF ENTRY FOR SAME BLADE AS PREVIOUS ENTRY                  00000550
C                                                                      00000560
      IF(ITBLD.NE.NBLDS) GO TO 10                                      00000570
C                                                                      00000580
      IM1 = IPSIR - 1                                                  00000590
      IF(IM1.EQ.0) IM1 = 1                                             00000600
C                                                                      00000610
      THRST = ( THRST * IPSIR - RTHRST ) / IM1                         00000620
      TORQ  = ( TORQ  * IPSIR - RTORQ  ) / IM1                         00000630
      TORQP = ( TOPQP * IPSIR - RTORQP ) / IM1                         00000640
      TORQI = ( TORQI * IPSIR - RTORQI ) / IM1                         00000650
C                                                                      00000660
      PWR   = ( PWR  * IPSIR - RPWR  ) / IM1                           00000670
      PWRP  = ( PWRP * IPSIR - RPWRP ) / IM1                           00000680
      PWRI  = ( PWRI * IPSIR - RPWRI ) / IM1                           00000690
C                                                                      00000700
      PMOMT = ( PMOMT * IPSIR - RPMOMT ) / IM1                         00000710
C                                                                      00000720
      CTR   = ( CTR * IPSIR - CTRR ) / IM1                             00000730
      CQR   = ( CQR * IPSIR - CQRR ) / IM1                             00000740
      CTW   = ( CTW * IPSIR - CTWR ) / IM1                             00000750
      CPW   = ( CPW * IPSIR - CPWR ) / IM1                             00000760
C                                                                      00000770
   10 CONTINUE                                                         00000780
C                                                                      00000790
      RTHRST = RTHRST - BTHRST                                         00000800
      RTORQ  = RTORQ  - BTORQ                                          00000810
      RTORQP = RTORQP - BTORQP                                         00000820
      RTORQI = RTORQI - BTORQI                                         00000830
C                                                                      00000840
      RPWR  = RPWR  - BPWR                                             00000850
      RPWRP = RPWRP - BPWRP                                            00000860
      RPWRI = RPWRI - BPWRI                                            00000870
C                                                                      00000880
      RPMOMT = RPMOMT - BPMOMT                                         00000890
C                                                                      00000900
      CTRR = CTRR - CTRB                                               00000910
      CQRR = CQRR - CQRB                                               00000920
      CTWR = CTWR - CTWB                                               00000930
      CPWR = CPWR - CPWB                                               00000940
C                                                                      00000950
   20 CONTINUE                                                         00000960
C                                                                      00000970
C     INITIALIZE BLADE PERFORMANCE FOR SUMMING                         00000980
C                                                                      00000990
      BTHRST = 0.0                                                     00001000
      BTORQ  = 0.0                                                     00001010
      BTORQP = 0.0                                                     00001020
      BTORQI = 0.0                                                     00001030
      BPMOMT = 0.0                                                     00001040
```

```
C                                                                       00001050
C     ----------------------------                                      00001060
C     LOOP 100 SWEEPS BLADE ELEMENTS                                    00001070
C     ----------------------------                                      00001080
C                                                                       00001090
      DO 100   J = 1,NP                                                 00001100
C                                                                       00001110
      QS      = QREL(J)*CHDCGL(J)*DBES(J)*RADIUS**2                     00001120
      QSC     = QS*CHDCGL(J)*RADIUS                                     00001130
C                                                                       00001140
C     ELEMENT FORCES (IN ELEMENT AXIS SYSTEM)                           00001150
C                                                                       00001160
      DFXI(J) = (-CLT(J) * SIN(ALPHAN(J))                               00001170
     1        +   CDS(J) * COS(ALPHAG(J)-AZLLC(J))) * QS                00001180
      DFXP(J) =   CDT(J) * COS(ALPHAN(J)) * QS                          00001190
      DFX(J)  = DFXP(J) + DFXI(J)                                       00001200
C                                                                       00001210
      DFZI(J) = (CLT(J) * COS(ALPHAN(J))                                00001220
     1        -  CDS(J) * SIN(ALPHAG(J)-AZLLC(J))) * QS                 00001230
      DFZI(J) = DFZI(J) * COS(BETAL(J))                                 00001240
      DFZP(J) =  CDT(J) * SIN(ALPHAN(J)) * QS                           00001250
      DFZP(J) = DFZP(J) * COS(BETAL(J))                                 00001260
      DFZ(J)  = DFZP(J) + DFZI(J)                                       00001270
C                                                                       00001280
C     PITCHING MOMENT DUE TO 2D AIRFOIL COEFFICIENT                     00001290
C                                                                       00001300
      DPM(J)  =  CMT(J) * QSC                                           00001310
C                                                                       00001320
C     ELEMENT TORQUE - 'RBE' IS RADIUS OF ELEMENT WITH CONING AND STEADY00001330
C     FLAPPING, THUS TORQUE IS TIP PATH PLANE TORQUE.  ACTUAL SHAFT     00001340
C     TORQUE DEPENDS ON TYPE OF JOINT BETWEEN ROTOR AND SHAFT.          00001350
C                                                                       00001360
      DQP(J) = DFXP(J) * RBE(J) * RADIUS                                00001370
      DQI(J) = DFXI(J) * RBE(J) * RADIUS                                00001380
      DQ(J)  = DQP(J)  + DQI(J)                                         00001390
C                                                                       00001400
C     BLADE FORCES AND TORQUES                                          00001410
C                                                                       00001420
      BTHRST = BTHRST + DFZ(J)                                          00001430
      BTORQ  = BTORQ  + DQ(J)                                           00001440
      BTORQP = BTORQP + DQP(J)                                          00001450
      BTORQI = BTORQI + DQI(J)                                          00001460
      BPMOMT = BPMOMT + DPM(J)                                          00001470
C                                                                       00001480
C     CHANGE ELEMENT FORCES AND TORQUES TO LOADINGS                     00001490
C                                                                       00001500
      FAC     = DBES(J) / RADIUS                                        00001510
      DFX(J)  = DFX(J)  / FAC                                           00001520
      DFXI(J) = DFXI(J) / FAC                                           00001530
      DFXP(J) = DFXP(J) / FAC                                           00001540
      DFZ(J)  = DFZ(J)  / FAC                                           00001550
      DFZI(J) = DFZI(J) / FAC                                           00001560
```

```
      DFZP(J) = DFZP(J) / FAC                                                  00001570
      DQP(J)  = DQP(J)  / FAC                                                  00001580
      DQI(J)  = DQI(J)  / FAC                                                  00001590
      DQ(J)   = DQ(J)   / FAC                                                  00001600
      DPM(J)  = DPM(J)  / FAC                                                  00001610
C                                                                              00001620
  100 CONTINUE                                                                 00001630
C                                                                              00001640
C     --------------------------------                                         00001650
C     BLADE FORCES, TORQUES, AND POWERS                                        00001660
C     --------------------------------                                         00001670
C                                                                              00001680
C     BLADE COEFFICIENTS                                                       00001690
C                                                                              00001700
      CTRB = BTHRST / (RHO     * PI * RADIUS**2 * OMEGAR**2)                   00001710
      CQRB = BTORQ  / (RHO     * PI * RADIUS**3 * OMEGAR**2)                   00001720
      CTWB = BTHRST / (RHO/2.0 * PI * RADIUS**2 * VWO**2   )                   00001730
      CPWB = BTORQ  / (RHO/2.0 * PI * RADIUS**2 * VWO**3   ) * OMEGA           00001740
C                                                                              00001750
C     BLADE POWER IN KW                                                        00001760
C                                                                              00001770
      FAC   = OMEGA  / 737.562                                                 00001780
      BPWR  = BTORQ  * FAC                                                     00001790
      BPWRP = BTORQP * FAC                                                     00001800
      BPWRI = BTORQI * FAC                                                     00001810
C                                                                              00001820
C     --------------------------------                                         00001830
C     ROTOR FORCES, TORQUES, AND POWERS                                        00001840
C     --------------------------------                                         00001850
C                                                                              00001860
      IF(ITBLD.GT.1) GO TO 200                                                 00001870
C                                                                              00001880
C     INITIALIZE ROTOR TOTALS FOR THIS AZIMUTH AT ENTRY FOR                    00001890
C     FIRST BLADE                                                              00001900
C                                                                              00001910
      RTHRST = 0.0                                                             00001920
      RTORQ  = 0.0                                                             00001930
      RTORQP = 0.0                                                             00001940
      RTORQI = 0.0                                                             00001950
C                                                                              00001960
      RPWR  = 0.0                                                              00001970
      RPWRP = 0.0                                                              00001980
      RPWRI = 0.0                                                              00001990
C                                                                              00002000
      RPMOMT = 0.0                                                             00002010
C                                                                              00002020
      CTRR = 0.0                                                               00002030
      CQRR = 0.0                                                               00002040
      CTWR = 0.0                                                               00002050
      CPWR = 0.0                                                               00002060
C                                                                              00002070
      IF(IPSIR.GT.1) GO TO 200                                                 00002080
```

```
C                                                                       00002090
C     IF FIRST AZIMUTH THEN INITIALIZE DISK AVERAGES                    00002100
C                                                                       00002110
      THRST = 0.0                                                       00002120
      TORQ  = 0.0                                                       00002130
      TORQP = 0.0                                                       00002140
      TORQI = 0.0                                                       00002150
C                                                                       00002160
      PMOMT = 0.0                                                       00002170
C                                                                       00002180
      PWR  = 0.0                                                        00002190
      PWRP = 0.0                                                        00002200
      PWRI = 0.0                                                        00002210
C                                                                       00002220
      CTR = 0.0                                                         00002230
      CQR = 0.0                                                         00002240
      CTW = 0.0                                                         00002250
      CPW = 0.0                                                         00002260
C                                                                       00002270
  200 CONTINUE                                                          00002280
C                                                                       00002290
C     SUM THIS BLADES CONTIBUTION TO TOTALS FOR THIS AZIMUTH            00002300
C                                                                       00002310
      RTHRST = RTHRST + BTHRST                                          00002320
      RTORQ  = RTORQ  + BTORQ                                           00002330
      RTORQP = RTORQP + BTORQP                                          00002340
      RTORQI = RTORQI + BTORQI                                          00002350
C                                                                       00002360
      RPWR  = RPWR  + BPWR                                              00002370
      RPWRP = RPWRP + BPWRP                                             00002380
      RPWRI = RPWRI + BPWRI                                             00002390
C                                                                       00002400
      RPMOMT = RPMOMT + BPMOMT                                          00002410
C                                                                       00002420
      CTRR = CTRR + CTRB                                                00002430
      CQRR = CQRR + CQRB                                                00002440
      CTWR = CTWR + CTWB                                                00002450
      CPWR = CPWR + CPWB                                                00002460
C                                                                       00002470
      IF(ISTDY.NE.0) GO TO 300                                          00002480
C                                                                       00002490
C     DISK TOTALS FOR STEADY CASE                                       00002500
C                                                                       00002510
      RTHRST = RTHRST * NBLDS                                           00002520
      RTORQ  = RTORQ  * NBLDS                                           00002530
      RTORQP = RTORQP * NBLDS                                           00002540
      RTORQI = RTORQI * NBLDS                                           00002550
C                                                                       00002560
      RPWR  = RPWR  * NBLDS                                             00002570
      RPWRP = RPWRP * NBLDS                                             00002580
      RPWRI = RPWRI * NBLDS                                             00002590
C                                                                       00002600
```

```
      PMOMT = PMOMT * NBLDS                                              00002610
C                                                                        00002620
      CTRR = CTRR * NBLDS                                                00002630
      CQRR = CQRR * NBLDS                                                00002640
      CTWR = CTWR * NBLDS                                                00002650
      CPWR = CPWR * NBLDS                                                00002660
C                                                                        00002670
      GO TO 400                                                          00002680
C                                                                        00002690
  300 CONTINUE                                                           00002700
C                                                                        00002710
C     IF TOTALS AVAILABLE FOR THIS AZIMUTH THEN UPDATE                   00002720
C     DISK AVERAGES                                                      00002730
C                                                                        00002740
      IF(ITBLD.NE.NBLDS) GO TO 400                                       00002750
C                                                                        00002760
      IM1 = IPSIR - 1                                                    00002770
C                                                                        00002780
      THRST = ( THRST * IM1 + RTHRST ) / IPSIR                           00002790
      TORQ  = ( TORQ  * IM1 + RTORQ  ) / IPSIR                           00002800
      TORQP = ( TOPQP * IM1 + RTORQP ) / IPSIR                           00002810
      TORQI = ( TORQI * IM1 + RTORQI ) / IPSIR                           00002820
C                                                                        00002830
      PWR   = ( PWR  * IM1 + RPWR  ) / IPSIR                             00002840
      PWRP  = ( PWRP * IM1 + RPWRP ) / IPSIR                             00002850
      PWRI  = ( PWRI * IM1 + RPWRI ) / IPSIR                             00002860
C                                                                        00002870
      PMOMT = ( PMOMT * IM1 + RPMOMT ) / IPSIR                           00002880
C                                                                        00002890
      CTR   = ( CTR * IM1 + CTRR ) / IPSIR                               00002900
      CQR   = ( CQR * IM1 + CQRR ) / IPSIR                               00002910
      CTW   = ( CTW * IM1 + CTWR ) / IPSIR                               00002920
      CPW   = ( CPW * IM1 + CPWR ) / IPSIR                               00002930
                                                                         00002940
  400 CONTINUE                                                           00002950
C                                                                        00002960
C     UPDATE FOR WAKE PARAMETER CALCULATION                              00002970
C                                                                        00002980
      IF(ITBLD.EQ.NBLDS) CTROUT = CTR                                    00002990
      IF(ISTDY.EQ.0) CTROUT = CTRR                                       00003000
C                                                                        00003010
      RETURN                                                             00003020
      END                                                                00003030
```

```
;     ********************************************************************
;     SUBROUTINE SYSTIM
;
;     ASSEMBLER INTERFACE TO SYSTEM CLOCK FOR MS FORTRAN77, VER.3.2
;     UNDER MS-DOS 2.X
;
;     READS THE SYSTEM CLOCK AND RETURNS HOURS,
;     MINUTES, SECONDS, AND HUNDRETHS OF SECONDS
;
;     USAGE: CALL SYSTIM(H,M,S,D)
;
;     ARGUMENTS ARE ALL INTEGER*4
;     H = HOUR          RANGE 0-59
;     M = MINUTE              0-59
;     S = SECOND              0-59
;     D = 1/100 SECOND        0-99
;
;     ********************************************************************
;
      FRAME   STRUC
      SAVEBP  DW      ?
      SAVERET DD      ?
      D       DD      ?
      S       DD      ?
      M       DD      ?
      H       DD      ?
      FRAME   ENDS
;
      DATA    SEGMENT PUBLIC 'DATA'
      DATA    ENDS
;
      CODE    SEGMENT 'CODE'
      DGROUP  GROUP   DATA
              ASSUME  CS:CODE,DS:DGROUP,ES:DGROUP,SS:DGROUP
;
SYSTIM  PROC    FAR
        PUBLIC  SYSTIM
;
        PUSH    BP          ;SAVE FRAMEPOINTER ON STACK
        MOV     BP,SP
;
        MOV     AH,2CH      ;DOS SERVICE TO GET TIME
        INT     21H
;
        LES     BX,[BP]+H   ;HOURS
        MOV     AH,0
        MOV     AL,CH
        MOV     ES:[BX],AX
        MOV     WORD PTR ES:[BX+2],0
;
        LES     BX,[BP]+M   ;MINUTES
        MOV     AL,CL
```

```
        MOV     ES:[BX],AX
        MOV     WORD PTR ES:[BX+2],0
;
        LES     BX,[BP]+S    ;SECONDS
        MOV     AL,DH
        MOV     ES:[BX],AX
        MOV     WORD PTR ES:[BX+2],0
;
        LES     BX,[BP]+D    ;HUNDRETHS
        MOV     AL,DL
        MOV     ES:[BX],AX
        MOV     WORD PTR ES:[BX+2],0
;
        MOV     SP,BP
        POP     BP           ;RESTORE THE FRAME POINTER
        RET     16
;
SYSTIM  ENDP
;
CODE    ENDS
;
END
```

APPENDIX D

SAMPLE INPUT AND OUTPUT FILE LISTINGS

RECORD IMAGE OF INPUT FILE

```
MOD-0 (AILERON) *** CMA STALL MODEL *** 05
3.0         0.0         2.0         0.0         2.0         2.0         0.0
1.0
0.0         0.0         0.0
0.0         0.0         0.0         0.0
0.0         20.60       1.0         1.0
10.0        1.0         1.0         1.0
0.0         1.0         1.0         4000.0
2.0         2.0         4.0         63.9592
2.0         12.0        0.0         180.0       30.0        1.0
0.0         0.0         1.0         16.0        17.0        19.0
3.0         3.0         0.0         3.3333      13.3332
-.9170      0.0         0.0         3.0         0.0         0.0
2.0
3.3333      13.3332
1.8340      5.0
2.0
0.0         13.3332
0.0         0.0
2.0
0.0         13.3332
0.0         0.0
1.0
110.0       0.0         13.3332
3.0         1.0         0.0         13.3332     26.0430
-.9170      0.0         0.0         3.0         0.0         0.0
2.0
13.3332     26.0430
5.0         5.0
2.0
13.3332     26.0430
0.0         0.0
2.0
13.3332     26.0430
0.0         0.0
1.0
110.0       13.3332     26.0430
8.0         4.0         0.0         26.0430     62.4172
-.9170      0.0         0.0         3.0         0.0         0.0
5.0
26.0430     40.0815     42.9588     42.9982     62.4172
5.0         4.1667      3.9173      3.9402      2.1883
2.0
26.0430     62.4172
0.0         0.0
2.0
26.0430     62.4172
0.0         0.0
1.0
110.0       26.0430     62.4172
1.0         1.0         0.0         62.4172     63.9592
-.9170      0.0         0.0         3.0         0.0         0.0
2.0
62.4172     63.9592
2.1883      1.2254
2.0
62.4172     63.9592
0.0         0.0
2.0
62.4172     63.9592
0.0         0.3043
1.0
110.0       62.4172     63.9592
1.0         3.0
```

```
110.0     NACA 23024 *** ABBOTT & VON DOENHOFF *** CMA STALL MODEL
1.0       13.0      1.0       13.0      1.0       2.0
0.24      32.0      1.0       1.0       0.0       2.0       0.5960
          3.0000
-4.0      -.3000
-2.0      -.1100
0.0       0.0950
2.0       0.2800
4.0       0.4400
6.0       0.6250
8.0       0.8100
9.0       0.8900
10.0      0.9750
11.0      1.0500
12.0      1.1250
13.0      1.1800
14.0      1.1950
          3.0000
-4.0      0.0084
-2.0      0.0082
0.0       0.0084
2.0       0.0088
4.0       0.0096
6.0       0.0106
8.0       0.0121
9.0       0.0134
10.0      0.0153
11.0      0.0161
12.0      0.0163
13.0      0.0183
14.0      0.0250
          0.0000
-180.0    0.0
180.0     0.0
```

COMPUTATIONAL METHODOLOGY ASSOCIATES *** LSWT VERSION 1.00 RELEASED MAY 1986 *** SERI IL-5-05105

MOD-0 (AILERON) *** CMA STALL MODEL *** 05

REFERENCE BLADE SURFACE PANEL COORDINATES

I,J		1	2	3	4	5	6	7	8	9	10	11
1	X	-.014337	-.014337	-.014337	-.014337	-.014337	-.014337	-.014337	-.014337	-.014337	-.014337	-.014337
	Y	.052045	.072963	.130112	.208178	.208178	.274327	.340475	.406623	.406623	.517421	.623961
	Z	.002728	.003824	.006819	.010910	.010910	.014377	.017844	.021310	.021310	.027117	.032700
2	X	-.005940	-.003998	.001308	.008557	.008557	.008557	.008557	.008557	.008557	.006628	.004773
	Y	.052052	.072971	.130125	.208198	.208198	.274346	.340494	.406643	.406643	.517439	.623977
	Z	.002592	.003657	.006566	.010540	.010540	.014007	.017473	.020940	.020940	.026778	.032391
3	X	.014334	.020964	.039080	.063827	.063827	.063827	.063827	.063827	.063827	.057242	.050911
	Y	.052069	.072992	.130157	.208245	.208245	.274393	.340541	.406690	.406690	.517482	.624016
	Z	.002264	.003253	.005955	.009646	.009646	.013113	.016580	.020046	.020046	.025959	.031645

I,J		12	13	14	15	16	17	18	19
1	X	-.014337	-.014337	-.014337	-.014337	-.014337	-.014337	-.014337	-.009580
	Y	.722148	.808210	.878840	.931322	.963641	.974553	.974553	.998634
	Z	.037846	.042357	.046058	.048809	.050502	.051074	.051074	.052259
2	X	.002360	.000083	-.001785	-.003174	-.004029	-.004318	-.004318	-.003969
	Y	.722162	.808223	.878851	.931332	.963649	.974562	.974562	.998638
	Z	.037576	.042123	.045855	.048628	.050336	.050912	.050912	.052168
3	X	.042671	.034898	.028518	.023777	.020858	.019872	.019872	.009576
	Y	.722197	.808252	.878876	.931355	.963671	.974582	.974582	.998650
	Z	.036924	.041560	.045365	.048192	.049933	.050521	.050521	.051949

MOD-0 (AILERON) *** CMA STALL MODEL *** 05

REFERENCE BLADE COLLOCATION POINT COORDINATES

I,J		1	2	3	4	5	6	7	8	9	10
1	X	-.011090	-.009834	-.007659	-.006402	-.006402	-.006402	-.006737	-.007392	-.008100	-.008945
	Y	.062506	.101541	.169151	.241259	.307408	.373556	.462029	.570697	.673060	.765184
	Z	.003223	.005249	.008757	.012515	.015982	.019449	.024091	.029796	.035172	.040014
2	X	.004098	.011229	.023581	.030712	.030712	.030712	.028814	.025092	.021075	.016279
	Y	.062519	.101559	.169177	.241291	.307439	.373587	.462059	.570724	.673085	.765205
	Z	.002978	.004908	.008251	.011915	.015382	.018848	.023516	.029271	.034701	.039606

I,J		11	12	13	14	15
1	X	-.009663	-.010228	-.010616	-.010815	-.009250
	Y	.843529	.905085	.947485	.969100	.986596
	Z	.044132	.047367	.049595	.050731	.051623
2	X	.012200	.008996	.006788	.005663	.003420
	Y	.843548	.905101	.947499	.969114	.986607
	Z	.043778	.047056	.049314	.050465	.051418

POINT 8: MOD-0 (AILERON) *** CMA STALL MODEL *** 05
ROTOR PITCH (DEG) .0000
WIND SPEED (M/SEC) 10.0000
ROTOR AZIMUTH (DEG) .0000

WORKING STATE AND WAKE RATE PARAMETERS

WINDMILL BRAKE STATE

REFERRED VELOCITIES,

AXIAL ONSET	4.05452E+00
INDUCED	-2.63803E-01

REFERENCE WAKE PARAMETERS,

CTRW	6.87899E-03
AKZ0	-8.29397E-02
ALAM0	3.31759E-01
AKR0	-4.00000E+00

MODIFIED WAKE PARAMETERS,

AKZW	2.37786E-01
AKZI	-1.26566E-02
AKZ	2.25129E-01
AKR	1.47364E+00
A	1.22000E+00
AKB	2.71438E+00

POINT 8: MOD-0 (AILERON) *** CMA STALL MODEL *** 05
ROTOR PITCH (DEG) .0000
WIND SPEED (M/SEC) 10.0000
ROTOR AZIMUTH (DEG) .0000

BLADE 1 ELEMENT CHARACTERISTICS

		1	2	3	4	5	6	7	8
GEOMETRY									
ELEMENT NUMBER									
ELE CENTER STATION		6.250E-02	1.015E-01	1.691E-01	2.413E-01	3.074E-01	3.735E-01	4.620E-01	5.707E-01
CHORD	FT	2.046E+00	2.838E+00	4.209E+00	5.000E+00	5.000E+00	5.000E+00	4.789E+00	4.376E+00
ELEMENT SPAN	FT	1.340E+00	3.660E+00	5.000E+00	4.237E+00	4.237E+00	4.237E+00	7.096E+00	6.824E+00
LEADING EDGE SWEEP	DEG	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
AERODYNAMIC SWEEP	DEG	3.554E+00	2.603E+00	1.269E+00	2.179E+00	1.913E+00	1.679E+00	2.003E+00	1.531E+00
ANGLES OF ATTACK									
GEOMETRIC PITCH	DEG	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
ZERO LIFT LINE	DEG	-9.277E-01	-9.277E-01	-9.277E-01	-9.277E-01	-9.277E-01	-9.277E-01	-9.277E-01	-9.277E-01
EFFECTIVE ANGLE	DEG	6.586E+01	6.082E+01	5.101E+01	4.199E+01	3.516E+01	3.034E+01	2.557E+01	2.122E+01
WIND ANGLE	DEG	7.526E+01	6.688E+01	5.465E+01	4.470E+01	3.784E+01	3.259E+01	2.732E+01	2.268E+01
INFLOW ANGLE	DEG	7.447E+01	6.679E+01	5.461E+01	4.434E+01	3.682E+01	3.159E+01	2.643E+01	2.178E+01
INDUCED ANGLE	DEG	7.318E-01	4.129E+00	1.929E+00	3.002E-01	-7.850E-01	-7.830E-01	-7.275E-01	-7.892E-01
VELOCITIES									
INDUCED VELOCITY	FT/SEC	5.129E-01	5.107E-01	6.062E-01	6.092E-01	7.966E-01	8.713E-01	8.550E-01	8.621E-01
RELATIVE VELOCITY	FT/SEC	3.417E+01	3.686E+01	4.136E+01	4.743E+01	5.402E+01	6.156E+01	7.217E+01	8.574E+01
REYNOLDS NUMBER		4.471E+05	6.688E+05	1.113E+06	1.516E+06	1.727E+06	1.968E+06	2.210E+06	2.399E+06
RELATIVE Q	PSF	1.388E+00	1.615E+00	2.034E+00	2.675E+00	3.469E+00	4.506E+00	6.192E+00	8.740E+00
AERODYNAMIC COEFFICIENTS									
ELE LIFT COEF		4.557E-01	5.162E-01	5.864E-01	7.029E-01	8.576E-01	9.125E-01	9.476E-01	1.004E+00
ELE DRAG COEF		9.725E-01	8.893E-01	7.006E-01	5.854E-01	5.671E-01	4.402E-01	2.572E-01	1.349E-01
ELE MOMENT COEF		.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
FORCE LOADING									
ELE X FORCE	LBS/FT	-1.786E+03	-2.324E+03	-2.531E+03	-3.968E+03	-4.259E+03	-9.490E+03	-2.323E+04	-3.871E+04
ELE IND X FORCE	LBS/FT	-4.811E+03	-8.896E+03	-1.674E+04	-2.688E+04	-3.647E+04	-4.405E+04	-5.117E+04	-5.831E+04
ELE PRO X FORCE	LBS/FT	3.025E+03	6.571E+03	1.421E+04	2.291E+04	3.221E+04	3.456E+04	2.794E+04	1.960E+04
ELE Z FORCE	LBS/FT	1.228E+04	1.911E+04	3.185E+04	4.982E+04	7.273E+04	9.277E+04	1.167E+05	1.535E+05
ELE IND Z FORCE	LBS/FT	1.411E+03	3.809E+03	1.188E+04	2.747E+04	4.864E+04	7.154E+04	1.028E+05	1.457E+05
ELE PRO Z FORCE	LBS/FT	1.087E+04	1.530E+04	1.997E+04	2.236E+04	2.408E+04	2.122E+04	1.387E+04	7.824E+03
TORQUE LOADING									
ELE PRO TORQUE	FT-LBS/FT	1.209E+04	4.267E+04	1.537E+05	3.535E+05	6.333E+05	8.258E+05	8.257E+05	7.155E+05
ELE IND TORQUE	FT-LBS/FT	-1.923E+04	-5.777E+04	-1.811E+05	-4.147E+05	-7.170E+05	-1.052E+06	-1.512E+06	-2.128E+06
ELE TORQUE	FT-LBS/FT	-7.141E+03	-1.510E+04	-2.738E+04	-6.122E+04	-8.373E+04	-2.267E+05	-6.865E+05	-1.413E+06
PITCHING MOMENT LOADING (2D)									
ELE PITCH MOMENT	FT-LBS/FT	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
LIFT SLOPE CONVERGENCE									
INPUT LIFT SLOPE	/RAD	4.992E-01	5.911E-01	7.538E-01	1.056E+00	1.490E+00	1.803E+00	2.194E+00	2.775E+00
CL/ALPHAE	/RAD	4.993E-01	5.912E-01	7.545E-01	1.051E+00	1.489E+00	1.806E+00	2.196E+00	2.774E+00
CIRCULATION PARAMETERS									
CIRC SHAPE PARM		8.260E-01	8.243E-01	8.284E-01	8.383E-01	8.532E-01	8.623E-01	8.743E-01	8.926E-01
BOUND CIRCULATION	FT**2/SEC	1.591E+01	2.697E+01	5.098E+01	8.375E+01	1.158E+02	1.401E+02	1.635E+02	1.884E+02

POINT 8: MOD-0 (AILERON) *** CMA STALL MODEL *** 05
ROTOR PITCH (DEG) .0000
WIND SPEED (M/SEC) 10.0000
ROTOR AZIMUTH (DEG) .0000

BLADE 1 ELEMENT CHARACTERISTICS

GEOMETRY

		9	10	11	12	13	14	15
ELEMENT NUMBER								
ELE CENTER STATION		6.731E-01	7.652E-01	8.475E-01	9.051E-01	9.479E-01	9.691E-01	9.866E-01
CHORD	FT	3.930E+00	3.398E+00	2.945E+00	2.590E+00	2.345E+00	2.220E+00	1.707E+00
ELEMENT SPAN	FT	6.289E+00	5.512E+00	4.524E+00	3.361E+00	2.070E+00	6.989E-01	1.542E+00
LEADING EDGE SWEEP	DEG	.000E+00	.000E+00	.000E+00	1.978E-02	.000E+00	.000E+00	1.116E+01
AERODYNAMIC SWEEP	DEG	1.496E+00	1.256E+00	1.029E+00	8.767E-01	7.841E-01	7.420E-01	2.924E+00

ANGLES OF ATTACK

GEOMETRIC PITCH	DEG	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
ZERO LIFT LINE	DEG	-9.277E-01	-9.277E-01	-9.277E-01	-9.277E-01	-9.277E-01	-9.277E-01	-9.277E-01
EFFECTIVE ANGLE	DEG	1.814E+01	1.592E+01	1.448E+01	1.344E+01	1.230E+01	1.081E+01	1.075E+01
WIND ANGLE	DEG	1.950E+01	1.722E+01	1.575E+01	1.472E+01	1.408E+01	1.378E+01	1.354E+01
INFLOW ANGLE	DEG	1.851E+01	1.624E+01	1.463E+01	1.352E+01	1.230E+01	1.072E+01	1.061E+01
INDUCED ANGLE	DEG	-9.135E-01	-9.885E-01	-1.068E+00	-1.158E+00	-1.760E+00	-5.096E+00	-2.941E+00

VELOCITIES

INDUCED VELOCITY	FT/SEC	9.143E-01	9.372E-01	9.687E-01	9.928E-01	1.063E+00	1.004E+00	1.133E+00
RELATIVE VELOCITY	FT/SEC	9.820E+01	1.109E+02	1.215E+02	1.295E+02	1.349E+02	1.377E+02	1.397E+02
REYNOLDS NUMBER		2.485E+06	2.410E+06	2.284E+06	2.144E+06	2.022E+06	1.946E+06	1.524E+06
RELATIVE Q	PSF	1.165E+01	1.463E+01	1.769E+01	1.993E+01	2.164E+01	2.255E+01	2.319E+01

AERODYNAMIC COEFFICIENTS

ELE LIFT COEF		1.073E+00	1.144E+00	1.188E+00	1.153E+00	1.078E+00	9.652E-01	9.553E-01
ELE DRAG COEF		7.185E-02	5.859E-02	2.200E-02	1.731E-02	1.617E-02	1.508E-02	1.488E-02
ELE MOMENT COEF		.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00

FORCE LOADING

ELE X FORCE	LBS/FT	-5.094E+04	-5.766E+04	-5.877E+04	-5.334E+04	-4.438E+04	-3.343E+04	-2.612E+04
ELE IND X FORCE	LBS/FT	-4.368E+04	-4.520E+04	-4.325E+04	-3.629E+04	-4.766E+04	-2.644E+04	-2.840E+04
ELE PRO X FORCE	LBS/FT	1.274E+04	7.536E+03	4.486E+03	2.554E+03	2.279E+03	2.008E+03	2.368E+03
ELE Z FORCE	LBS/FT	1.943E+05	2.258E+05	2.431E+05	2.372E+05	2.189E+05	1.928E+05	1.625E+05
ELE IND Z FORCE	LBS/FT	1.900E+05	2.236E+05	2.412E+05	2.363E+05	2.182E+05	1.922E+05	1.618E+05
ELE PRO Z FORCE	LBS/FT	4.259E+03	2.192E+03	1.170E+03	8.534E+02	7.142E+02	5.486E+02	4.432E+02

TORQUE LOADING

ELE PRO TORQUE	FT-LBS/FT	5.484E+05	5.488E+05	3.420E+05	2.057E+05	1.987E+05	1.864E+05	1.424E+05
ELE IND TORQUE	FT-LBS/FT	-2.741E+06	-3.191E+06	-3.413E+06	-3.243E+06	-2.888E+06	-2.259E+06	-1.729E+06
ELE TORQUE	FT-LBS/FT	-2.193E+06	-2.822E+06	-3.171E+06	-3.038E+06	-2.690E+06	-2.072E+06	-1.648E+06

PITCHING MOMENT LOADING (2D)

ELE PITCH MOMENT	FT-LBS/FT	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00

LIFT SLOPE CONVERGENCE

INPUT LIFT SLOPE	/RAD	3.470E+00	4.181E+00	4.739E+00	4.938E+00	5.052E+00	5.144E+00	5.113E+00
CL/ALPHAE	/RAD	3.447E+00	4.141E+00	4.751E+00	4.941E+00	5.052E+00	5.144E+00	5.113E+00

CIRCULATION PARAMETERS

CIRC SHAPE PARM		9.157E-01	9.341E-01	9.549E-01	9.626E-01	9.711E-01	9.858E-01	9.211E-01
BOUND CIRCULATION	FT**2/SEC	2.099E+02	2.171E+02	2.114E+02	1.931E+02	1.704E+02	1.429E+02	1.157E+02

POINT 8: MOD-0 (AILERON) *** CMA STALL MODEL *** 05

ROTOR PITCH (DEG)		.0000
WIND SPEED (M/SEC)		10.0000
ROTOR AZIMUTH (DEG)		.0000

ROTOR PERFORMANCE

THRUST	LBS	4.0183E+03
CT ROTOR		6.9068E-03
CT WT		2.4431E-01
TORQUE	FT-LBS	-3.9070E+04
CQ ROTOR		-1.0500E-03
CP WT		-1.5619E-01
POWER (ROTOR)	KW	-1.1427E+02
POWER (PROFILE)	KW	3.9184E+01
POWER (INFLOW)	KW	-1.5346E+02

COMPUTATIONAL METHODOLOGY ASSOCIATES *** LSWT VERSION 1.00 RELEASED MAY 1986 *** SERI IL-5-05105

RECORD IMAGE OF INPUT FILE

```
ESI-54 *** CMA STALL MODEL *** 05
3.0       0.0       2.0       0.0       2.0       2.0       0.0
1.0
0.0       0.0       0.0
0.0       0.0       0.0       0.0
0.0       77.0      1.0       1.0
5.0       1.0       18.0      1.0
0.0       0.0       1.0       600.0
2.0       2.0       2.0       27.0
2.0       12.0      0.0       180.0     30.0      1.0
0.0       0.0       1.0       13.0      14.0      17.0
4.0       1.0       0.25      2.70      8.10
0.0       0.0       0.0       5.0       0.0       0.0
2.0
0.0       8.10
1.15      2.05
2.0
0.0       27.0
-7.5      2.5
2.0
0.0       27.0
0.0       0.0
1.0
120.0     0.0       27.0
11.0      4.0       0.25      8.10      27.0
0.0       0.0       0.0       5.0       0.0       0.0
2.0
8.10      27.0
2.05      1.0
2.0
0.0       27.0
-7.5      2.5
2.0
0.0       27.0
0.0       0.0
1.0
120.0     0.0       27.0
1.0       3.0
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120.0     NACA 23012 *** VDT1167 TR586 *** CMA STALL MODEL
8.0       14.0       8.0        14.0       1.0        2.0
0.12      32.0       1.0        1.0        0.0        2.0        0.5960
          0.0424     0.0842     0.1700     0.3350     0.6650     1.2860
          2.3000     3.0900
-2.0      -0.030     -0.030     -0.080     -0.080     -0.080     -0.080
          -0.080     -0.080
0.0       0.1600     0.1400     0.1300     0.1300     0.1300     0.1300
          0.1300     0.1300
2.0       0.4000     0.4000     0.3800     0.3300     0.3300     0.3300
          0.3300     0.3300
4.0       0.5800     0.5800     0.5400     0.5400     0.5400     0.5400
          0.5400     0.5400
6.0       0.7400     0.7400     0.7200     0.7200     0.7200     0.7200
          0.7200     0.7200
8.0       0.8600     0.9000     0.9000     0.9000     0.9300     0.9300
          0.9300     0.9300
9.0       0.9250     0.9800     0.9600     0.9800     1.0500     1.0600
          1.0600     1.0600
10.0      0.9000     1.0200     1.0600     1.0800     1.1100     1.1500
          1.1500     1.1500
11.0      0.8600     1.0800     1.0900     1.1500     1.1900     1.2300
          1.2400     1.2400
12.0      0.8400     0.9900     1.1000     1.1800     1.2500     1.3000
          1.3100     1.3200
13.0      0.8200     0.9400     1.1000     1.2000     1.3000     1.3800
          1.3900     1.4100
14.0      0.8000     0.9000     1.0300     1.1900     1.3000     1.4000
          1.4700     1.4900
15.0      0.7900     0.8800     0.9750     1.1200     1.2700     1.4200
          1.5400     1.5700
16.0      0.7800     0.8600     0.9400     1.0800     1.2200     1.2700
          1.5600     1.6000
          0.0424     0.0842     0.1700     0.3350     0.6650     1.2860
          2.3000     3.0900
-2.0      0.0265     0.0258     0.0125     0.0120     0.0120     0.0100
          0.0100     0.0090
0.0       0.0220     0.0215     0.0125     0.0115     0.0115     0.0100
          0.0100     0.0085
2.0       0.0225     0.0210     0.0125     0.0115     0.0115     0.0100
          0.0100     0.0080
4.0       0.0230     0.0215     0.0135     0.0120     0.0200     0.0100
          0.0100     0.0085
6.0       0.0270     0.0250     0.0170     0.0140     0.0140     0.0120
          0.0120     0.0105
8.0       0.0335     0.0313     0.0200     0.0170     0.0165     0.0135
          0.0135     0.0120
9.0       0.0424     0.0350     0.0225     0.0190     0.0180     0.0150
          0.0155     0.0140
10.0      0.0539     0.0400     0.0280     0.0230     0.0195     0.0175
          0.0170     0.0155
11.0      0.0666     0.0500     0.0400     0.0290     0.0240     0.0210
          0.0185     0.0175
12.0      0.0804     0.0643     0.0530     0.0350     0.0290     0.0240
          0.0215     0.0215
13.0      0.0954     0.0797     0.0688     0.0480     0.0400     0.0385
          0.0245     0.0235
14.0      0.1114     0.0963     0.0858     0.0657     0.0579     0.0335
          0.0295     0.0275
15.0      0.1286     0.1140     0.1039     0.0845     0.0771     0.0500
          0.0400     0.0333
16.0      0.1468     0.1326     0.1231     0.1046     0.0975     0.0715
          0.0619     0.0500
          0.0
-180.0    0.0
180.0     0.0
```

ESI-54 *** CMA STALL MODEL *** 05

REFERENCE BLADE SURFACE PANEL COORDINATES

I,J		1	2	3	4	5	6	7	8	9	10	11
1	X	-.013369	-.014764	-.016159	-.017555	-.018951	-.018951	-.017584	-.016238	-.014942	-.013725	-.012611
	Y	.099727	.149536	.199344	.249149	.298953	.298953	.398160	.495353	.588550	.675856	.755491
	Z	.007489	.011848	.016232	.020639	.025071	.025071	.034136	.042971	.051399	.059255	.066389
2	X	.002294	.002533	.002772	.003012	.003251	.003251	.003017	.002786	.002564	.002355	.002164
	Y	.099601	.149411	.199221	.249031	.298842	.298842	.398089	.495315	.588541	.675869	.755521
	Z	.008926	.013284	.017637	.021986	.026331	.026331	.034948	.043397	.051507	.059109	.066049
3	X	.040108	.044291	.048477	.052664	.056852	.056852	.052752	.048715	.044827	.041174	.037834
	Y	.099298	.149108	.198924	.248747	.298576	.298576	.397918	.495225	.588518	.675900	.755593
	Z	.012395	.016749	.021030	.025238	.029374	.029374	.036908	.044427	.051767	.058756	.065229

I,J		12	13	14	15	16	17
1	X	-.011627	-.010791	-.010123	-.009636	-.009339	-.009240
	Y	.825834	.885452	.933130	.967897	.989045	.996142
	Z	.072664	.077964	.082190	.085264	.087131	.087757
2	X	.001995	.001851	.001737	.001653	.001602	.001585
	Y	.825876	.885502	.933186	.967956	.989106	.996204
	Z	.072184	.077386	.081549	.084585	.086432	.087053
3	X	.034880	.032374	.030369	.028907	.028017	.027719
	Y	.825978	.885624	.933321	.968100	.989253	.996353
	Z	.071024	.075991	.080001	.082946	.084746	.085352

ESI-54 *** CMA STALL MODEL *** 05

REFERENCE BLADE COLLOCATION POINT COORDINATES

I,J		1	2	3	4	5	6	7	8	9	10
1	X	-.008355	-.009183	-.010012	-.010841	-.010850	-.010045	-.009260	-.008514	-.007821	-.007198
	Y	.124588	.174397	.224205	.274012	.348525	.446737	.541943	.632203	.715681	.790675
	Z	.010165	.014530	.018911	.023305	.029966	.038772	.047281	.055323	.062740	.069386
2	X	.018362	.020182	.022004	.023826	.023847	.022076	.020352	.018711	.017189	.015820
	Y	.124384	.174195	.224009	.273826	.348379	.446651	.541906	.632207	.715716	.790734
	Z	.012499	.016839	.021147	.025424	.031635	.039765	.047704	.055283	.062339	.068716

I,J		11	12	13	14	15
1	X	-.006658	-.006211	-.005868	-.005635	-.005517
	Y	.855659	.909309	.950534	.978492	.992615
	Z	.075132	.079866	.083498	.085959	.087201
2	X	.014632	.013650	.012896	.012384	.012126
	Y	.855734	.909396	.950627	.978589	.992714
	Z	.074270	.078876	.082427	.084842	.086064

POINT 8: ESI-54 *** CMA STALL MODEL *** 05
ROTOR PITCH (DEG) .0000
WIND SPEED (M/SEC) 12.0000
ROTOR AZIMUTH (DEG) .0000

WORKING STATE AND WAKE RATE PARAMETERS

WINDMILL BRAKE STATE

REFERRED VELOCITIES,

AXIAL ONSET	3.07276E+00
INDUCED	-3.69991E-01

REFERENCE WAKE PARAMETERS,

CTRW	6.92691E-03
AKZO	-8.32280E-02
ALAMO	3.32912E-01
AKRO	-4.00000E+00

MODIFIED WAKE PARAMETERS,

AKZW	1.80835E-01
AKZI	-1.75745E-02
AKZ	1.63261E-01
AKR	2.03914E+00
A	1.22000E+00
AKB	1.96161E+00

POINT 8: ESI-54 *** CMA STALL MODEL *** 05
ROTOR PITCH (DEG) .0000
WIND SPEED (M/SEC) 12.0000
ROTOR AZIMUTH (DEG) .0000

BLADE 1 ELEMENT CHARACTERISTICS

		1	2	3	4	5	6	7	8
GEOMETRY									
ELEMENT NUMBER		1	2	3	4	5	6	7	8
ELE CENTER STATION		1.245E-01	1.743E-01	2.241E-01	2.740E-01	3.485E-01	4.467E-01	5.419E-01	6.322E-01
CHORD	FT	1.525E+00	1.675E+00	1.825E+00	1.975E+00	1.975E+00	1.827E+00	1.684E+00	1.548E+00
ELEMENT SPAN	FT	1.350E+00	1.350E+00	1.350E+00	1.350E+00	2.690E+00	2.635E+00	2.527E+00	2.367E+00
LEADING EDGE SWEEP	DEG	1.591E+00	1.591E+00	1.591E+00	1.591E+00	7.957E-01	7.957E-01	7.955E-01	7.960E-01
AERODYNAMIC SWEEP	DEG	3.000E-01	6.256E-02	3.375E-01	5.439E-01	4.601E-01	2.121E-01	3.956E-02	7.913E-02
ANGLES OF ATTACK									
GEOMETRIC PITCH	DEG	-6.250E+00	-5.750E+00	-5.250E+00	-4.750E+00	-4.002E+00	-3.016E+00	-2.060E+00	-1.154E+00
ZERO LIFT LINE	DEG	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00
EFFECTIVE ANGLE	DEG	4.678E+01	3.889E+01	3.247E+01	2.797E+01	2.254E+01	1.695E+01	1.473E+01	1.366E+01
WIND ANGLE	DEG	5.556E+01	4.618E+01	3.904E+01	3.358E+01	2.756E+01	2.213E+01	1.852E+01	1.601E+01
INFLOW ANGLE	DEG	5.564E+01	4.633E+01	3.881E+01	3.343E+01	2.689E+01	1.999E+01	1.668E+01	1.462E+01
INDUCED ANGLE	DEG	1.421E+00	1.373E+00	4.997E-01	4.740E-01	-3.677E-01	-2.055E+00	-1.759E+00	-1.320E+00
VELOCITIES									
INDUCED VELOCITY	FT/SEC	3.796E-01	6.908E-01	9.374E-01	1.088E+00	1.229E+00	1.723E+00	1.667E+00	1.497E+00
RELATIVE VELOCITY	FT/SEC	4.867E+01	5.593E+01	6.380E+01	7.275E+01	8.643E+01	1.053E+02	1.249E+02	1.438E+02
REYNOLDS NUMBER		4.746E+05	5.990E+05	7.445E+05	9.187E+05	1.092E+06	1.231E+06	1.345E+06	1.423E+06
RELATIVE Q	PSF	2.817E+00	3.719E+00	4.840E+00	6.293E+00	8.881E+00	1.319E+01	1.855E+01	2.458E+01
AERODYNAMIC COEFFICIENTS									
ELE LIFT COEF		5.959E-01	7.866E-01	9.061E-01	9.594E-01	1.065E+00	1.307E+00	1.392E+00	1.335E+00
ELE DRAG COEF		6.072E-01	5.777E-01	5.271E-01	3.468E-01	1.814E-01	6.757E-02	3.551E-02	2.908E-02
ELE MOMENT COEF		.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
FORCE LOADING									
ELE X FORCE	LBS/FT	-2.190E+02	-7.721E+02	-1.012E+03	-2.167E+03	-4.090E+03	-6.732E+03	-8.325E+03	-8.568E+03
ELE IND X FORCE	LBS/FT	-1.292E+03	-2.584E+03	-3.657E+03	-4.789E+03	-6.159E+03	-7.848E+03	-9.100E+03	-9.348E+03
ELE PRO X FORCE	LBS/FT	1.073E+03	1.812E+03	2.645E+03	2.622E+03	2.070E+03	1.116E+03	7.746E+02	7.806E+02
ELE Z FORCE	LBS/FT	2.634E+03	4.348E+03	6.648E+03	8.951E+03	1.315E+04	2.189E+04	3.048E+04	3.590E+04
ELE IND Z FORCE	LBS/FT	1.071E+03	2.457E+03	4.529E+03	7.226E+03	1.210E+04	2.149E+04	3.025E+04	3.570E+04
ELE PRO Z FORCE	LBS/FT	1.564E+03	1.890E+03	2.119E+03	1.725E+03	1.046E+03	4.043E+02	2.312E+02	2.029E+02
TORQUE LOADING									
ELE PRO TORQUE	FT-LBS/FT	3.607E+03	8.527E+03	1.601E+04	1.939E+04	1.947E+04	1.345E+04	1.133E+04	1.332E+04
ELE IND TORQUE	FT-LBS/FT	-4.344E+03	-1.216E+04	-2.213E+04	-3.543E+04	-5.795E+04	-9.465E+04	-1.332E+05	-1.596E+05
ELE TORQUE	FT-LBS/FT	-7.365E+02	-3.634E+03	-6.125E+03	-1.603E+04	-3.848E+04	-8.120E+04	-1.218E+05	-1.462E+05
PITCHING MOMENT LOADING (2D)									
ELE PITCH MOMENT	FT-LBS/FT	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
LIFT SLOPE CONVERGENCE									
INPUT LIFT SLOPE	/RAD	8.174E-01	1.254E+00	1.682E+00	2.027E+00	2.794E+00	4.648E+00	5.460E+00	5.653E+00
CL/ALPHAE	/RAD	8.177E-01	1.253E+00	1.688E+00	2.046E+00	2.778E+00	4.483E+00	5.475E+00	5.654E+00
CIRCULATION PARAMETERS									
CIRC SHAPE PARM		8.304E-01	8.400E-01	8.524E-01	8.594E-01	8.844E-01	9.478E-01	9.721E-01	9.771E-01
BOUND CIRCULATION	FT**2/SEC	2.210E+01	3.687E+01	5.256E+01	6.829E+01	9.143E+01	1.304E+02	1.460E+02	1.486E+02

POINT 8: ESI-54 *** CMA STALL MODEL *** 05
ROTOR PITCH (DEG) .0000
WIND SPEED (M/SEC) 12.0000
ROTOR AZIMUTH (DEG) .0000

BLADE 1 ELEMENT CHARACTERISTICS

		9	10	11	12	13	14	15
GEOMETRY								
ELEMENT NUMBER								
ELE CENTER STATION		7.157E-01	7.907E-01	8.557E-01	9.093E-01	9.506E-01	9.785E-01	9.926E-01
CHORD	FT	1.422E+00	1.309E+00	1.212E+00	1.131E+00	1.069E+00	1.027E+00	1.005E+00
ELEMENT SPAN	FT	2.159E+00	1.907E+00	1.616E+00	1.292E+00	9.424E-01	5.732E-01	1.924E-01
LEADING EDGE SWEEP	DEG	7.955E-01	7.957E-01	7.955E-01	7.955E-01	7.957E-01	7.957E-01	7.957E-01
AERODYNAMIC SWEEP	DEG	1.631E-01	2.247E-01	2.705E-01	3.033E-01	3.275E-01	3.443E-01	3.561E-01
ANGLES OF ATTACK								
GEOMETRIC PITCH	DEG	-3.157E-01	4.371E-01	1.090E+00	1.628E+00	2.042E+00	2.323E+00	2.464E+00
ZERO LIFT LINE	DEG	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00
EFFECTIVE ANGLE	DEG	1.297E+01	1.247E+01	1.206E+01	1.153E+01	1.056E+01	8.926E+00	5.676E+00
WIND ANGLE	DEG	1.422E+01	1.291E+01	1.195E+01	1.126E+01	1.078E+01	1.048E+01	1.033E+01
INFLOW ANGLE	DEG	1.305E+01	1.176E+01	1.067E+01	9.562E+00	8.111E+00	6.096E+00	2.504E+00
INDUCED ANGLE	DEG	-1.113E+00	-1.103E+00	-1.252E+00	-1.679E+00	-2.682E+00	-4.453E+00	-7.962E+00
VELOCITIES								
INDUCED VELOCITY	FT/SEC	1.384E+00	1.341E+00	1.346E+00	1.360E+00	1.198E+00	3.384E-01	-1.497E+00
RELATIVE VELOCITY	FT/SEC	1.614E+02	1.772E+02	1.909E+02	2.022E+02	2.103E+02	2.146E+02	2.148E+02
REYNOLDS NUMBER		1.468E+06	1.484E+06	1.479E+06	1.462E+06	1.437E+06	1.409E+06	1.381E+06
RELATIVE Q	PSF	3.096E+01	3.734E+01	4.335E+01	4.859E+01	5.257E+01	5.476E+01	5.488E+01
AERODYNAMIC COEFFICIENTS								
ELE LIFT COEF		1.283E+00	1.248E+00	1.217E+00	1.174E+00	1.089E+00	8.972E-01	5.794E-01
ELE DRAG COEF		2.275E-02	2.122E-02	1.997E-02	1.834E-02	1.583E-02	1.327E-02	1.044E-02
ELE MOMENT COEF		.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
FORCE LOADING								
ELE X FORCE	LBS/FT	-8.587E+03	-8.329E+03	-7.877E+03	-7.088E+03	-5.650E+03	-3.364E+03	-5.985E+02
ELE IND X FORCE	LBS/FT	-9.299E+03	-9.070E+03	-8.628E+03	-7.812E+03	-6.291E+03	-3.905E+03	-1.018E+03
ELE PRO X FORCE	LBS/FT	7.116E+02	7.405E+02	7.516E+02	7.245E+02	6.417E+02	5.406E+02	4.194E+02
ELE Z FORCE	LBS/FT	4.014E+04	4.355E+04	4.578E+04	4.632E+04	4.407E+04	3.648E+04	2.321E+04
ELE IND Z FORCE	LBS/FT	3.998E+04	4.340E+04	4.564E+04	4.620E+04	4.398E+04	3.642E+04	2.319E+04
ELE PRO Z FORCE	LBS/FT	1.643E+02	1.536E+02	1.410E+02	1.216E+02	9.111E+01	5.751E+01	1.827E+01
TORQUE LOADING								
ELE PRO TORQUE	FT-LBS/FT	1.375E+04	1.581E+04	1.736E+04	1.779E+04	1.647E+04	1.428E+04	1.124E+04
ELE IND TORQUE	FT-LBS/FT	-1.797E+05	-1.936E+05	-1.993E+05	-1.918E+05	-1.615E+05	-1.032E+05	-2.728E+04
ELE TORQUE	FT-LBS/FT	-1.659E+05	-1.778E+05	-1.820E+05	-1.740E+05	-1.450E+05	-8.888E+04	-1.604E+04
PITCHING MOMENT LOADING (2D)								
ELE PITCH MOMENT	FT-LBS/FT	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
LIFT SLOPE CONVERGENCE								
INPUT LIFT SLOPE	/RAD	5.716E+00	5.779E+00	5.826E+00	5.872E+00	5.941E+00	5.782E+00	5.858E+00
CL/ALPHAE	/RAD	5.716E+00	5.780E+00	5.826E+00	5.872E+00	5.942E+00	5.782E+00	5.858E+00
CIRCULATION PARAMETERS								
CIRC SHAPE PARM		9.793E-01	9.823E-01	9.854E-01	9.907E-01	1.005E+00	1.039E+00	1.161E+00
BOUND CIRCULATION	FT**2/SEC	1.472E+02	1.448E+02	1.408E+02	1.342E+02	1.223E+02	9.883E+01	6.257E+01

COMPUTATIONAL METHODOLOGY ASSOCIATES *** LSWT VERSION 1.00 RELEASED MAY 1986 *** SERI IL-5-05105

POINT 8: ESI-54 *** CMA STALL MODEL *** 05

ROTOR PITCH	(DEG)	.0000
WIND SPEED	(M/SEC)	12.0000
ROTOR AZIMUTH	(DEG)	.0000

ROTOR PERFORMANCE

THRUST	LBS	1.7996E+03
CT ROTOR		6.9716E-03
CT WT		4.2638E-01
TORQUE	FT-LBS	-6.6231E+03
CQ ROTOR		-9.5026E-04
CP WT		-3.2138E-01
POWER (ROTOR)	KW	-7.2407E+01
POWER (PROFILE)	KW	1.0465E+01
POWER (INFLOW)	KW	-8.2873E+01

RECORD IMAGE OF INPUT FILE

```
CARTER 25 *** CMA STALL MODEL *** 05
3.0         0.0         2.0         0.0         2.0         2.0         0.0
1.0
0.0         0.0         0.0
0.0         0.0         0.0         0.0
0.0         124.0       1.0         1.0
5.0         1.0         18.0        1.0
0.0         1.0         1.0         300.0
2.0         2.0         2.0         16.0
2.0         12.0        0.0         180.0       30.0        1.0
0.0         0.0         1.0         14.0        15.0        17.0
9.0         3.0         0.25        1.280       10.40
0.0         0.0         0.0         6.0         0.0         0.0
8.0
0.0         0.80        2.40        4.00        5.60        7.20        8.80
10.40
3.6480      3.6480      3.0080      2.400       1.9040      1.4400      1.1520
1.0880
8.0
0.0         0.80        2.40        4.00        5.60        7.20        8.80
10.40
-41.00      - 34.00     -20.00      -11.00      -5.00       -1.200      0.60
1.00
2.0
0.0         16.0
0.0         0.0
1.0
120.0       0.0         16.0
6.0         4.0         0.25        10.40       16.0
0.0         0.0         0.0         6.0         0.0         0.0
2.0
10.40       16.0
1.0880      1.0880
2.0
10.40       16.0
1.00        1.00
2.0
0.0         16.0
0.0         0.0
1.0
120.0       0.0         16.0
1.0         3.0
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120.0     NACA 23012 *** VDT1167 TR586 *** CMA STALL MODEL
8.0       14.0       8.0        14.0       1.0        2.0
0.12      32.0       1.0        1.0        0.0        2.0        0.5960
          0.0424     0.0842     0.1700     0.3350     0.6650     1.2860
                     2.3000     3.0900
-2.0      -0.030     -0.030     -0.080     -0.080     -0.080     -0.080
          -0.080     -0.080
0.0       0.1600     0.1400     0.1300     0.1300     0.1300     0.1300
          0.1300     0.1300
2.0       0.4000     0.4000     0.3800     0.3300     0.3300     0.3300
          0.3300     0.3300
4.0       0.5800     0.5800     0.5400     0.5400     0.5400     0.5400
          0.5400     0.5400
6.0       0.7400     0.7400     0.7200     0.7200     0.7200     0.7200
          0.7200     0.7200
8.0       0.8600     0.9000     0.9000     0.9000     0.9300     0.9300
          0.9300     0.9300
9.0       0.9250     0.9800     0.9600     0.9800     1.0500     1.0600
          1.0600     1.0600
10.0      0.9000     1.0200     1.0600     1.0800     1.1100     1.1500
          1.1500     1.1500
11.0      0.8600     1.0800     1.0900     1.1500     1.1900     1.2300
          1.2400     1.2400
12.0      0.8400     0.9900     1.1000     1.1800     1.2500     1.3000
          1.3100     1.3200
13.0      0.8200     0.9400     1.1000     1.2000     1.3000     1.3800
          1.3900     1.4100
14.0      0.8000     0.9000     1.0300     1.1900     1.3000     1.4000
          1.4700     1.4900
15.0      0.7900     0.8800     0.9750     1.1200     1.2700     1.4200
          1.5400     1.5700
16.0      0.7800     0.8600     0.9400     1.0800     1.2200     1.2700
          1.5600     1.6000
          0.0424     0.0842     0.1700     0.3350     0.6650     1.2860
                     2.3000     3.0900
-2.0      0.0265     0.0258     0.0125     0.0120     0.0120     0.0100
          0.0100     0.0090
0.0       0.0220     0.0215     0.0125     0.0115     0.0115     0.0100
          0.0100     0.0085
2.0       0.0225     0.0210     0.0125     0.0115     0.0115     0.0100
          0.0100     0.0080
4.0       0.0230     0.0215     0.0135     0.0120     0.0200     0.0100
          0.0100     0.0085
6.0       0.0270     0.0250     0.0170     0.0140     0.0140     0.0120
          0.0120     0.0105
8.0       0.0335     0.0313     0.0200     0.0170     0.0165     0.0135
          0.0135     0.0120
9.0       0.0424     0.0350     0.0225     0.0190     0.0180     0.0150
          0.0155     0.0140
10.0      0.0539     0.0400     0.0280     0.0230     0.0195     0.0175
          0.0170     0.0155
11.0      0.0666     0.0500     0.0400     0.0290     0.0240     0.0210
          0.0185     0.0175
12.0      0.0804     0.0643     0.0530     0.0350     0.0290     0.0240
          0.0215     0.0215
13.0      0.0954     0.0797     0.0688     0.0480     0.0400     0.0385
          0.0245     0.0235
14.0      0.1114     0.0963     0.0858     0.0657     0.0579     0.0335
          0.0295     0.0275
15.0      0.1286     0.1140     0.1039     0.0845     0.0771     0.0500
          0.0400     0.0333
16.0      0.1468     0.1326     0.1231     0.1046     0.0975     0.0715
          0.0619     0.0500
                     0.0
-180.0    0.0
180.0     0.0
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COMPUTATIONAL METHODOLOGY ASSOCIATES *** LSWT VERSION 1.00 RELEASED MAY 1986 *** SERI IL-5-05105

CARTER 25 *** CMA STALL MODEL *** 05

REFERENCE BLADE SURFACE PANEL COORDINATES

I,J		1	2	3	4	5	6	7	8	9	10	11
1	X	-.047428	-.047195	-.046281	-.044077	-.039921	-.034577	-.028618	-.022273	-.017980	-.016987	-.016987
	Y	.082260	.090725	.115877	.157023	.213154	.282549	.363167	.452551	.547942	.646370	.646370
	Z	-.017314	-.015009	-.008296	.001942	.013092	.024969	.036566	.047615	.058173	.068604	.068604
2	X	.008137	.008097	.007941	.007562	.006849	.005932	.004910	.003821	.003085	.002915	.002915
	Y	.079099	.087736	.113383	.155249	.212020	.281973	.362972	.452557	.548012	.646451	.646451
	Z	.012768	.013433	.015430	.018816	.023882	.030448	.038425	.047557	.057499	.067830	.067830
3	X	.142285	.141584	.138842	.132231	.119764	.103730	.085854	.066818	.053941	.050961	.050961
	Y	.071466	.080519	.107363	.150968	.209282	.280583	.362500	.452571	.548183	.646647	.646647
	Z	.085391	.082098	.072710	.059553	.049931	.043676	.042914	.047416	.055872	.065963	.065963

I,J		12	13	14	15	16	17
1	X	-.016987	-.016987	-.016987	-.016987	-.016987	-.016987
	Y	.736460	.820411	.892501	.947818	.982592	.994453
	Z	.078073	.086896	.094473	.100287	.103942	.105189
2	X	.002915	.002915	.002915	.002915	.002915	.002915
	Y	.736542	.820492	.892583	.947900	.982673	.994534
	Z	.077299	.086123	.093700	.099514	.103169	.104415
3	X	.050961	.050961	.050961	.050961	.050961	.050961
	Y	.736738	.820689	.892779	.948096	.982869	.994730
	Z	.075431	.084255	.091832	.097646	.101301	.102548

CARTER 25 *** CMA STALL MODEL *** 05

REFERENCE BLADE COLLOCATION POINT COORDINATES

I,J		1	2	3	4	5	6	7	8	9	10
1	X	-.028103	-.027784	-.026907	-.024990	-.022026	-.018772	-.015080	-.011944	-.010384	-.010089
	Y	.085427	.102350	.135698	.184578	.247523	.322711	.407819	.500257	.597182	.691443
	Z	-.006018	-.002597	.003980	.012373	.022151	.032166	.042472	.052787	.063138	.073070
2	X	.061765	.061062	.059134	.054921	.048407	.041256	.033143	.026251	.022823	.022174
	Y	.080441	.097910	.132280	.182242	.246239	.322129	.407689	.500326	.597306	.691575
	Z	.041415	.039641	.036502	.034598	.034374	.037708	.043711	.052129	.061962	.071816

I,J		11	12	13	14	15
1	X	-.010089	-.010089	-.010089	-.010089	-.010089
	Y	.778464	.856484	.920188	.965233	.988550
	Z	.082216	.090417	.097112	.101847	.104297
2	X	.022174	.022174	.022174	.022174	.022174
	Y	.778596	.856616	.920320	.965365	.988682
	Z	.080962	.089163	.095858	.100593	.103043

POINT 8: CARTER 25 *** CMA STALL MODEL *** 05
ROTOR PITCH (DEG) .0000
WIND SPEED (M/SEC) 12.0000
ROTOR AZIMUTH (DEG) .0000

WORKING STATE AND WAKE RATE PARAMETERS

WINDMILL BRAKE STATE

REFERRED VELOCITIES,

AXIAL ONSET	2.73829E+00
INDUCED	-4.33967E-01

REFERENCE WAKE PARAMETERS,

CTRW	9.57775E-03
AKZ0	-9.78660E-02
ALAMO	3.91464E-01
AKR0	-4.00000E+00

MODIFIED WAKE PARAMETERS,

AKZW	1.89494E-01
AKZI	-2.39673E-02
AKZ	1.65527E-01
AKR	2.36496E+00
A	1.22000E+00
AKB	1.69136E+00

COMPUTATIONAL METHODOLOGY ASSOCIATES *** LSWT VERSION 1.00 RELEASED MAY 1986 *** SERI IL-5-05105

POINT 8: CARTER 25 *** CMA STALL MODEL *** 05
ROTOR PITCH (DEG) .0000
WIND SPEED (M/SEC) 12.0000
ROTOR AZIMUTH (DEG) .0000

BLADE 1 ELEMENT CHARACTERISTICS

GEOMETRY									
ELEMENT NUMBER		1	2	3	4	5	6	7	8
ELE CENTER STATION		8.387E-02	1.010E-01	1.346E-01	1.838E-01	2.471E-01	3.225E-01	4.078E-01	5.003E-01
CHORD	FT	3.428E+00	3.318E+00	3.102E+00	2.796E+00	2.409E+00	2.031E+00	1.625E+00	1.287E+00
ELEMENT SPAN	FT	1.386E-01	4.114E-01	6.718E-01	9.118E-01	1.124E+00	1.302E+00	1.441E+00	1.536E+00
LEADING EDGE SWEEP	DEG	5.662E+00	5.663E+00	5.608E+00	5.409E+00	4.914E+00	4.368E+00	4.056E+00	2.555E+00
AERODYNAMIC SWEEP	DEG	9.369E+00	8.591E+00	7.220E+00	5.088E+00	3.358E+00	1.970E+00	8.185E-01	1.065E-01
ANGLES OF ATTACK									
GEOMETRIC PITCH	DEG	-2.919E+01	-2.679E+01	-2.205E+01	-1.686E+01	-1.114E+01	-6.542E+00	-2.719E+00	-2.454E-01
ZERO LIFT LINE	DEG	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00
EFFECTIVE ANGLE	DEG	6.913E+00	1.090E+01	1.465E+01	2.449E+01	2.342E+01	2.006E+01	2.006E+01	1.976E+01
WIND ANGLE	DEG	6.726E+01	6.302E+01	5.553E+01	4.660E+01	3.800E+01	3.078E+01	2.513E+01	2.086E+01
INFLOW ANGLE	DEG	3.554E+01	3.747E+01	3.670E+01	4.182E+01	3.495E+01	2.679E+01	2.297E+01	2.017E+01
INDUCED ANGLE	DEG	-3.224E+01	-2.749E+01	-2.091E+01	-4.342E+00	-2.419E+00	-3.858E+00	-1.935E+00	-4.413E-01
VELOCITIES									
INDUCED VELOCITY	FT/SEC	1.305E+01	1.078E+01	8.059E+00	3.384E+00	2.765E+00	2.707E+00	2.112E+00	1.671E+00
RELATIVE VELOCITY	FT/SEC	3.725E+01	3.982E+01	4.481E+01	5.566E+01	6.595E+01	7.807E+01	9.430E+01	1.125E+02
REYNOLDS NUMBER		8.166E+05	8.449E+05	8.886E+05	9.951E+05	1.016E+06	1.014E+06	9.802E+05	9.261E+05
RELATIVE Q	PSF	1.650E+00	1.885E+00	2.387E+00	3.684E+00	5.171E+00	7.248E+00	1.057E+01	1.505E+01
AERODYNAMIC COEFFICIENTS									
ELE LIFT COEF		6.724E-01	1.074E+00	1.311E+00	1.010E+00	1.038E+00	1.131E+00	1.131E+00	1.138E+00
ELE DRAG COEF		1.385E-02	1.791E-02	4.257E-02	2.326E-01	2.050E-01	1.299E-01	1.314E-01	1.278E-01
ELE MOMENT COEF		.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
FORCE LOADING									
ELE X FORCE	LBS/FT	-4.390E+02	-1.024E+03	-1.420E+03	-1.319E+03	-1.360E+03	-1.485E+03	-1.409E+03	-1.351E+03
ELE IND X FORCE	LBS/FT	-4.553E+02	-1.047E+03	-1.485E+03	-1.776E+03	-1.896E+03	-1.922E+03	-1.941E+03	-1.946E+03
ELE PRO X FORCE	LBS/FT	1.632E+01	2.277E+01	6.470E+01	4.570E+02	5.358E+02	4.371E+02	5.323E+02	5.950E+02
ELE Z FORCE	LBS/FT	8.581E+02	1.375E+03	2.029E+03	2.381E+03	3.070E+03	4.005E+03	4.779E+03	5.486E+03
ELE IND Z FORCE	LBS/FT	8.465E+02	1.358E+03	1.981E+03	1.974E+03	2.698E+03	3.786E+03	4.555E+03	5.269E+03
ELE PRO Z FORCE	LBS/FT	1.159E+01	1.736E+01	4.796E+01	4.067E+02	3.724E+02	2.195E+02	2.243E+02	2.173E+02
TORQUE LOADING									
ELE PRO TORQUE	FT-LBS/FT	2.189E+01	3.678E+01	1.394E+02	1.344E+03	2.119E+03	2.256E+03	3.473E+03	4.762E+03
ELE IND TORQUE	FT-LBS/FT	-6.109E+02	-1.691E+03	-3.198E+03	-5.225E+03	-7.495E+03	-9.920E+03	-1.267E+04	-1.558E+04
ELE TORQUE	FT-LBS/FT	-5.890E+02	-1.654E+03	-3.059E+03	-3.881E+03	-5.377E+03	-7.664E+03	-9.192E+03	-1.081E+04
PITCHING MOMENT LOADING (2D)									
ELE PITCH MOMENT	FT-LBS/FT	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
LIFT SLOPE CONVERGENCE									
INPUT LIFT SLOPE	/RAD	5.568E+00	5.627E+00	5.038E+00	2.630E+00	2.745E+00	3.445E+00	3.411E+00	3.466E+00
CL/ALPHAE	/RAD	5.587E+00	5.678E+00	5.182E+00	2.437E+00	2.610E+00	3.299E+00	3.296E+00	3.366E+00
CIRCULATION PARAMETERS									
CIRC SHAPE PARM		1.196E+00	1.147E+00	1.049E+00	8.703E-01	8.722E-01	9.044E-01	9.035E-01	9.029E-01
BOUND CIRCULATION	FT**2/SEC	4.223E+01	6.955E+01	8.786E+01	8.450E+01	8.656E+01	9.365E+01	8.966E+01	8.485E+01

POINT 8: CARTER 25 *** CMA STALL MODEL *** 05
ROTOR PITCH (DEG) .0000
WIND SPEED (M/SEC) 12.0000
ROTOR AZIMUTH (DEG) .0000

BLADE 1 ELEMENT CHARACTERISTICS

GEOMETRY

		9	10	11	12	13	14	15
ELEMENT NUMBER								
ELE CENTER STATION		5.972E-01	6.915E-01	7.785E-01	8.565E-01	9.202E-01	9.653E-01	9.886E-01
CHORD	FT	1.120E+00	1.088E+00	1.088E+00	1.088E+00	1.088E+00	1.088E+00	1.088E+00
ELEMENT SPAN	FT	1.584E+00	1.449E+00	1.351E+00	1.160E+00	8.899E-01	5.594E-01	1.908E-01
LEADING EDGE SWEEP	DEG	5.730E-01	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
AERODYNAMIC SWEEP	DEG	1.558E-01	1.758E-01	1.595E-01	1.440E-01	1.356E-01	1.297E-01	1.282E-01

ANGLES OF ATTACK

GEOMETRIC PITCH	DEG	8.020E-01	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
ZERO LIFT LINE	DEG	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00	-1.238E+00
EFFECTIVE ANGLE	DEG	1.699E+01	1.449E+01	1.285E+01	1.132E+01	9.783E+00	7.860E+00	4.768E+00
WIND ANGLE	DEG	1.768E+01	1.539E+01	1.374E+01	1.253E+01	1.168E+01	1.115E+01	1.090E+01
INFLOW ANGLE	DEG	1.621E+01	1.336E+01	1.160E+01	9.960E+00	8.314E+00	6.266E+00	2.977E+00
INDUCED ANGLE	DEG	-1.356E+00	-1.968E+00	-2.092E+00	-2.544E+00	-3.378E+00	-4.945E+00	-8.014E+00

VELOCITIES

INDUCED VELOCITY	FT/SEC	1.721E+00	1.789E+00	1.761E+00	1.713E+00	1.508E+00	8.322E-01	-3.257E-01
RELATIVE VELOCITY	FT/SEC	1.310E+02	1.495E+02	1.669E+02	1.824E+02	1.948E+02	2.026E+02	2.054E+02
REYNOLDS NUMBER		9.381E+05	1.040E+06	1.161E+06	1.269E+06	1.355E+06	1.410E+06	1.429E+06
RELATIVE Q	PSF	2.041E+01	2.658E+01	3.313E+01	3.957E+01	4.510E+01	4.881E+01	5.014E+01

AERODYNAMIC COEFFICIENTS

ELE LIFT COEF		1.265E+00	1.351E+00	1.264E+00	1.155E+00	1.001E+00	7.852E-01	4.906E-01
ELE DRAG COEF		8.088E-02	4.011E-02	2.368E-02	1.784E-02	1.434E-02	1.247E-02	1.000E-02
ELE MOMENT COEF		.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00

FORCE LOADING

ELE X FORCE	LBS/FT	-1.612E+03	-2.022E+03	-2.130E+03	-2.009E+03	-1.640E+03	-9.967E+02	-2.163E+02
ELE IND X FORCE	LBS/FT	-2.066E+03	-2.311E+03	-2.345E+03	-2.203E+03	-1.818E+03	-1.165E+03	-3.558E+02
ELE PRO X FORCE	LBS/FT	4.544E+02	2.889E+02	2.141E+02	1.937E+02	1.782E+02	1.685E+02	1.395E+02
ELE Z FORCE	LBS/FT	7.201E+03	9.749E+03	1.140E+04	1.251E+04	1.240E+04	1.057E+04	6.812E+03
ELE IND Z FORCE	LBS/FT	7.070E+03	9.680E+03	1.136E+04	1.247E+04	1.237E+04	1.055E+04	6.805E+03
ELE PRO Z FORCE	LBS/FT	1.314E+02	6.823E+01	4.370E+01	3.383E+01	2.590E+01	1.840E+01	7.213E+00

TORQUE LOADING

ELE PRO TORQUE	FT-LBS/FT	4.342E+03	3.197E+03	2.667E+03	2.655E+03	2.624E+03	2.602E+03	2.206E+03
ELE IND TORQUE	FT-LBS/FT	-1.975E+04	-2.557E+04	-2.920E+04	-3.019E+04	-2.677E+04	-1.800E+04	-5.628E+03
ELE TORQUE	FT-LBS/FT	-1.540E+04	-2.237E+04	-2.654E+04	-2.753E+04	-2.414E+04	-1.539E+04	-3.421E+03

PITCHING MOMENT LOADING (2D)

ELE PITCH MOMENT	FT-LBS/FT	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00

LIFT SLOPE CONVERGENCE

INPUT LIFT SLOPE	/RAD	4.522E+00	5.388E+00	5.683E+00	5.888E+00	5.913E+00	5.743E+00	5.902E+00
CL/ALPHAE	/RAD	4.330E+00	5.401E+00	5.681E+00	5.886E+00	5.890E+00	5.742E+00	5.902E+00

CIRCULATION PARAMETERS

CIRC SHAPE PARM		9.405E-01	9.701E-01	9.799E-01	9.906E-01	1.004E+00	1.042E+00	1.167E+00
BOUND CIRCULATION	FT**2/SEC	9.692E+01	1.097E+02	1.148E+02	1.147E+02	1.065E+02	8.655E+01	5.480E+01

POINT 8: CARTER 25 *** CMA STALL MODEL *** 05

ROTOR PITCH	(DEG)	.0000
WIND SPEED	(M/SEC)	12.0000
ROTOR AZIMUTH	(DEG)	.0000

ROTOR PERFORMANCE

THRUST	LBS	7.9598E+02
CT ROTOR		9.6418E-03
CT WT		5.3703E-01
TORQUE	FT-LBS	-1.6217E+03
CQ ROTOR		-1.2277E-03
CP WT		-3.6086E-01
POWER (ROTOR)	KW	-2.8551E+01
POWER (PROFILE)	KW	5.6907E+00
POWER (INFLOW)	KW	-3.4241E+01

COMPUTATIONAL METHODOLOGY ASSOCIATES *** LSWT VERSION 1.00 RELEASED MAY 1986 *** SERI IL-5-05105

RECORD IMAGE OF INPUT FILE

```
ENERTECH 1500 *** CMA STALL MODEL *** 05
3.0         0.0         2.0         0.0         2.0         2.0         0.0
1.0
0.0         0.0         0.0
0.0         0.0         0.0         0.0
0.0         170.0       1.0         1.0
4.0         1.0         15.0        1.0
0.0         0.0         1.0         400.0
3.0         2.0         2.0         6.560
1.3333      12.0        0.0         180.0       30.0        1.0
0.0         0.0         1.0         14.0        15.0        17.0
10.0        1.0         0.25        0.840       5.057760
0.0         0.0         0.0         0.0         0.0         0.0
2.0
0.0         5.057760
0.58333     0.58333
2.0
0.0         6.560
-5.7294     0.0
2.0
0.0         6.560
0.0         0.0
1.0
130.0       0.0         6.560
5.0         4.0         0.25        5.057760    6.560
0.0         0.0         0.0         0.0         0.0         0.0
2.0
5.057760    6.560
0.58333     0.541667
2.0
0.0         6.560
-5.7294     0.0
2.0
0.0         6.560
0.0         0.0
1.0
130.0       0.0         6.560
1.0         3.0
```

```
130.0     NACA 4415 *** VDT 1163  TR 586 *** CMA STALL MODEL
5.0       15.0      5.0       14.0      1.0       2.0
0.15      32.0      1.0       1.0       0.0       2.0       0.5960
          0.0417    0.0830    0.1630    0.3340    0.6540
-6.0      -0.375    -0.175    -0.175    -0.200    -0.200
-4.0      -0.120    0.0100    0.0100    0.0100    0.0100
-2.0      0.1100    0.2100    0.2100    0.2100    0.2100
0.0       0.3300    0.4000    0.4000    0.4000    0.4000
2.0       0.5750    0.6000    0.6000    0.6000    0.6000
4.0       0.7500    0.7800    0.8100    0.8100    0.8100
6.0       0.9100    0.9400    0.9800    1.0000    1.0000
8.0       1.0800    1.0800    1.0800    1.1400    1.1400
9.0       1.1250    1.1250    1.1250    1.1750    1.1900
10.0      1.1900    1.1900    1.2000    1.2000    1.2500
11.0      1.2200    1.2200    1.2200    1.2500    1.3000
12.0      1.2450    1.2450    1.2450    1.2900    1.3400
13.0      1.1850    1.2500    1.2500    1.3050    1.3750
14.0      1.0950    1.2350    1.2600    1.3200    1.3800
15.0      1.0150    1.1900    1.2600    1.3200    1.3900
          0.0417    0.0830    0.1630    0.3340    0.6540
-6.0      0.0460    0.0330    0.0215    0.0160    0.0145
-4.0      0.0380    0.0265    0.0170    0.0130    0.0120
-2.0      0.0340    0.0250    0.0160    0.0125    0.0120
0.0       0.0320    0.0230    0.0150    0.0125    0.0115
2.0       0.0305    0.0230    0.0155    0.0135    0.0115
4.0       0.0305    0.0240    0.0180    0.0155    0.0140
6.0       0.0320    0.0275    0.0220    0.0190    0.0165
8.0       0.0375    0.0335    0.0270    0.0230    0.0210
9.0       0.0415    0.0375    0.0315    0.0255    0.0240
10.0      0.0495    0.0445    0.0390    0.0270    0.0275
11.0      0.0575    0.0520    0.0425    0.0330    0.0355
12.0      0.0716    0.0662    0.0490    0.0475    0.0475
13.0      0.0868    0.0816    0.0650    0.0650    0.0640
14.0      0.1031    0.0981    0.0821    0.0821    0.0811
          0.0
-180.0    0.0
180.0     0.0
```

ENERTECH 1500 *** CMA STALL MODEL *** 05

REFERENCE BLADE SURFACE PANEL COORDINATES

I,J		1	2	3	4	5	6	7	8	9	10	11
1	X	-.022226	-.022230	-.022230	-.022230	-.022229	-.022227	-.022225	-.022221	-.022216	-.022211	-.022204
	Y	.128049	.192344	.256639	.320934	.385229	.449524	.513820	.578115	.642410	.706705	.771000
	Z	-.000453	-.000202	-.000059	.000084	.000227	.000369	.000511	.000653	.000796	.000938	.001080
2	X	.003813	.003814	.003814	.003814	.003814	.003814	.003813	.003813	.003812	.003811	.003810
	Y	.128049	.192344	.256639	.320934	.385229	.449524	.513820	.578115	.642410	.706705	.771000
	Z	.000078	.000035	.000010	-.000014	-.000039	-.000063	-.000088	-.000112	-.000136	-.000161	-.000185
3	X	.066678	.066689	.066691	.066691	.066688	.066682	.066674	.066663	.066649	.066632	.066613
	Y	.128049	.192344	.256639	.320934	.385229	.449524	.513820	.578115	.642410	.706705	.771000
	Z	.001359	.000605	.000176	-.000252	-.000681	-.001108	-.001534	-.001960	-.002387	-.002813	-.003239

I,J		12	13	14	15	16	17
1	X	-.022204	-.021706	-.021256	-.020899	-.020669	-.020590
	Y	.771000	.841765	.905603	.956265	.988792	1.000000
	Z	.001080	.001209	.001321	.001405	.001457	.001474
2	X	.003810	.003724	.003647	.003586	.003546	.003533
	Y	.771000	.841765	.905603	.956265	.988792	1.000000
	Z	-.000185	-.000208	-.000227	-.000241	-.000250	-.000253
3	X	.066613	.065119	.063769	.062697	.062008	.061770
	Y	.771000	.841765	.905603	.956265	.988792	1.000000
	Z	-.003239	-.003628	-.003962	-.004214	-.004370	-.004423

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ENERTECH 1500 *** CMA STALL MODEL *** 05

REFERENCE BLADE COLLOCATION POINT COORDINATES

I,J		1	2	3	4	5	6	7	8	9	10
1	X	-.013203	-.013204	-.013204	-.013203	-.013203	-.013201	-.013199	-.013197	-.013194	-.013190
	Y	.160196	.224491	.288787	.353082	.417377	.481672	.545967	.610262	.674557	.738852
	Z	-.000162	-.000077	.000008	.000092	.000177	.000261	.000346	.000430	.000514	.000599
2	X	.029017	.029018	.029019	.029018	.029016	.029013	.029009	.029003	.028997	.028989
	Y	.160196	.224491	.288787	.353082	.417377	.481672	.545967	.610262	.674557	.738852
	Z	.000357	.000170	-.000017	-.000203	-.000389	-.000574	-.000760	-.000945	-.001131	-.001316

I,J		11	12	13	14	15
1	X	-.013040	-.012759	-.012519	-.012345	-.012253
	Y	.806382	.873684	.930934	.972528	.994396
	Z	.000680	.000752	.000810	.000850	.000870
2	X	.028660	.028041	.027514	.027131	.026929
	Y	.806382	.873684	.930934	.972528	.994396
	Z	-.001495	-.001652	-.001779	-.001868	-.001913

POINT 7: ENERTECH 1500 *** CMA STALL MODEL *** 05
ROTOR PITCH (DEG) .0000
WIND SPEED (M/SEC) 10.0000
ROTOR AZIMUTH (DEG) .0000

WORKING STATE AND WAKE RATE PARAMETERS

WINDMILL BRAKE STATE

REFERRED VELOCITIES,

AXIAL ONSET	2.90268E+00
INDUCED	-3.99491E-01

REFERENCE WAKE PARAMETERS,

CTRW	1.87344E-02
AKZO	-1.36874E-01
ALAMO	5.47495E-01
AKRO	-4.00000E+00

MODIFIED WAKE PARAMETERS,

AKZW	2.80934E-01
AKZI	-3.10553E-02
AKZ	2.49878E-01
AKR	2.19105E+00
A	1.22000E+00
AKB	1.82561E+00

POINT 7: ENERTECH 1500 *** CMA STALL MODEL *** 05
ROTOR PITCH (DEG) .0000
WIND SPEED (M/SEC) 10.0000
ROTOR AZIMUTH (DEG) .0000

BLADE 1 ELEMENT CHARACTERISTICS

GEOMETRY

ELEMENT NUMBER		1	2	3	4	5	6	7	8
ELE CENTER STATION		1.602E-01	2.245E-01	2.888E-01	3.531E-01	4.174E-01	4.817E-01	5.460E-01	6.103E-01
CHORD	FT	5.833E-01	5.833E-01	5.833E-01	5.833E-01	5.833E-01	5.833E-01	5.833E-01	5.833E-01
ELEMENT SPAN	FT	4.218E-01	4.218E-01	4.218E-01	4.218E-01	4.218E-01	4.218E-01	4.218E-01	4.218E-01
LEADING EDGE SWEEP	DEG	.000E+00	.000E+00	1.978E-02	.000E+00	.000E+00	1.978E-02	.000E+00	.000E+00
AERODYNAMIC SWEEP	DEG	4.120E+00	3.600E+00	3.251E+00	2.904E+00	2.603E+00	2.348E+00	2.140E+00	1.960E+00
ANGLES OF ATTACK									
GEOMETRIC PITCH	DEG	-4.812E+00	-4.443E+00	-4.075E+00	-3.706E+00	-3.338E+00	-2.970E+00	-2.601E+00	-2.233E+00
ZERO LIFT LINE	DEG	-4.107E+00	-4.107E+00	-4.107E+00	-4.105E+00	-4.104E+00	-4.102E+00	-4.100E+00	-4.098E+00
EFFECTIVE ANGLE	DEG	5.284E+01	4.649E+01	3.983E+01	3.501E+01	3.132E+01	2.832E+01	2.536E+01	2.288E+01
WIND ANGLE	DEG	6.031E+01	5.137E+01	4.421E+01	3.851E+01	3.394E+01	3.025E+01	2.723E+01	2.472E+01
INFLOW ANGLE	DEG	5.856E+01	5.071E+01	4.288E+01	3.721E+01	3.282E+01	2.921E+01	2.568E+01	2.267E+01
INDUCED ANGLE	DEG	-2.321E+00	9.238E-01	-6.884E-01	-7.851E-01	-6.653E-01	-6.378E-01	-1.291E+00	-1.878E+00
VELOCITIES									
INDUCED VELOCITY	FT/SEC	8.619E-01	9.886E-01	1.150E+00	1.205E+00	1.225E+00	1.283E+00	1.414E+00	1.570E+00
RELATIVE VELOCITY	FT/SEC	3.762E+01	4.304E+01	4.767E+01	5.336E+01	5.952E+01	6.597E+01	7.237E+01	7.898E+01
REYNOLDS NUMBER		1.403E+05	1.606E+05	1.778E+05	1.990E+05	2.220E+05	2.461E+05	2.699E+05	2.946E+05
RELATIVE Q	PSF	1.683E+00	2.203E+00	2.702E+00	3.385E+00	4.212E+00	5.175E+00	6.227E+00	7.417E+00
AERODYNAMIC COEFFICIENTS									
ELE LIFT COEF		5.879E-01	6.664E-01	8.259E-01	9.068E-01	9.487E-01	9.952E-01	1.059E+00	1.135E+00
ELE DRAG COEF		6.683E-01	5.865E-01	5.696E-01	5.123E-01	3.710E-01	2.765E-01	2.009E-01	1.501E-01
ELE MOMENT COEF		.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
FORCE LOADING									
ELE X FORCE	LBS/FT	-3.000E+00	-7.981E+00	-9.814E+00	-1.193E+01	-2.141E+01	-3.174E+01	-4.344E+01	-5.569E+01
ELE IND X FORCE	LBS/FT	-1.772E+01	-2.852E+01	-3.812E+01	-4.660E+01	-5.437E+01	-6.309E+01	-7.174E+01	-8.148E+01
ELE PRO X FORCE	LBS/FT	1.472E+01	2.054E+01	2.831E+01	3.467E+01	3.297E+01	3.135E+01	2.830E+01	2.578E+01
ELE Z FORCE	LBS/FT	3.708E+01	4.844E+01	6.734E+01	8.769E+01	1.056E+02	1.304E+02	1.628E+02	2.059E+02
ELE IND Z FORCE	LBS/FT	1.299E+01	2.334E+01	4.105E+01	6.137E+01	8.430E+01	1.128E+02	1.492E+02	1.951E+02
ELE PRO Z FORCE	LBS/FT	2.409E+01	2.510E+01	2.629E+01	2.633E+01	2.126E+01	1.753E+01	1.361E+01	1.077E+01
TORQUE LOADING									
ELE PRO TORQUE	FT-LBS/FT	1.547E+01	3.025E+01	5.363E+01	8.030E+01	9.026E+01	9.906E+01	1.013E+02	1.032E+02
ELE IND TORQUE	FT-LBS/FT	-1.862E+01	-4.200E+01	-7.222E+01	-1.079E+02	-1.489E+02	-1.993E+02	-2.569E+02	-3.262E+02
ELE TORQUE	FT-LBS/FT	-3.152E+00	-1.175E+01	-1.859E+01	-2.764E+01	-5.861E+01	-1.003E+02	-1.556E+02	-2.230E+02
PITCHING MOMENT LOADING (2D)									
ELE PITCH MOMENT	FT-LBS/FT	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
LIFT SLOPE CONVERGENCE									
INPUT LIFT SLOPE	/RAD	7.349E-01	9.375E-01	1.301E+00	1.579E+00	1.828E+00	2.117E+00	2.570E+00	3.083E+00
CL/ALPHAE	/RAD	7.377E-01	9.189E-01	1.289E+00	1.580E+00	1.825E+00	2.098E+00	2.472E+00	2.921E+00
CIRCULATION PARAMETERS									
CIRC SHAPE PARM		8.377E-01	8.357E-01	8.490E-01	8.568E-01	8.632E-01	8.707E-01	8.859E-01	9.028E-01
BOUND CIRCULATION	FT**2/SEC	6.415E+00	8.524E+00	1.157E+01	1.409E+01	1.648E+01	1.931E+01	2.322E+01	2.760E+01

POINT 7: ENERTECH 1500 *** CMA STALL MODEL *** 05
ROTOR PITCH (DEG) .0000
WIND SPEED (M/SEC) 10.0000
ROTOR AZIMUTH (DEG) .0000

BLADE 1 ELEMENT CHARACTERISTICS

GEOMETRY

ELEMENT NUMBER		9	10	11	12	13	14	15
ELE CENTER STATION		6.746E-01	7.389E-01	8.064E-01	8.737E-01	9.309E-01	9.725E-01	9.944E-01
CHORD	FT	5.833E-01	5.833E-01	5.769E-01	5.646E-01	5.542E-01	5.467E-01	5.427E-01
ELEMENT SPAN	FT	4.218E-01	4.218E-01	4.642E-01	4.188E-01	3.323E-01	2.134E-01	7.352E-02
LEADING EDGE SWEEP	DEG	1.978E-02	.000E+00	3.976E-01	3.971E-01	3.971E-01	3.971E-01	3.976E-01
AERODYNAMIC SWEEP	DEG	1.809E+00	1.674E+00	1.534E+00	1.400E+00	1.309E+00	1.261E+00	1.247E+00

ANGLES OF ATTACK

GEOMETRIC PITCH	DEG	-1.865E+00	-1.496E+00	-1.109E+00	-7.237E-01	-3.957E-01	-1.574E-01	-3.211E-02
ZERO LIFT LINE	DEG	-4.096E+00	-4.096E+00	-4.096E+00	-4.096E+00	-4.096E+00	-4.096E+00	-4.096E+00
EFFECTIVE ANGLE	DEG	2.051E+01	1.874E+01	1.736E+01	1.580E+01	1.346E+01	1.007E+01	6.336E+00
WIND ANGLE	DEG	2.261E+01	2.082E+01	1.921E+01	1.783E+01	1.679E+01	1.611E+01	1.578E+01
INFLOW ANGLE	DEG	1.979E+01	1.614E+01	1.437E+01	1.243E+01	9.756E+00	6.130E+00	2.272E+00
INDUCED ANGLE	DEG	-2.734E+00	-4.678E+00	-4.834E+00	-5.399E+00	-7.036E+00	-9.983E+00	-1.350E+01

VELOCITIES

INDUCED VELOCITY	FT/SEC	1.715E+00	1.808E+00	1.846E+00	1.812E+00	1.497E+00	4.092E-01	-1.043E+00
RELATIVE VELOCITY	FT/SEC	8.559E+01	9.243E+01	9.976E+01	1.069E+02	1.122E+02	1.149E+02	1.153E+02
REYNOLDS NUMBER		3.192E+05	3.447E+05	3.680E+05	3.859E+05	3.978E+05	4.015E+05	4.000E+05
RELATIVE Q	PSF	8.710E+00	1.016E+01	1.183E+01	1.358E+01	1.498E+01	1.569E+01	1.580E+01

AERODYNAMIC COEFFICIENTS

ELE LIFT COEF		1.238E+00	1.321E+00	1.315E+00	1.285E+00	1.189E+00	9.969E-01	6.249E-01
ELE DRAG COEF		1.118E-01	8.905E-02	6.935E-02	4.327E-02	2.587E-02	1.842E-02	1.334E-02
ELE MOMENT COEF		.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00

FORCE LOADING

ELE X FORCE	LBS/FT	-6.863E+01	-6.356E+01	-6.840E+01	-7.164E+01	-6.351E+01	-4.381E+01	-1.497E+01
ELE IND X FORCE	LBS/FT	-9.163E+01	-8.537E+01	-8.813E+01	-8.559E+01	-7.262E+01	-5.057E+01	-1.989E+01
ELE PRO X FORCE	LBS/FT	2.300E+01	2.181E+01	1.974E+01	1.395E+01	9.109E+00	6.759E+00	4.915E+00
ELE Z FORCE	LBS/FT	2.629E+02	3.295E+02	3.789E+02	4.171E+02	4.202E+02	3.673E+02	2.313E+02
ELE IND Z FORCE	LBS/FT	2.546E+02	3.232E+02	3.739E+02	4.140E+02	4.186E+02	3.666E+02	2.311E+02
ELE PRO Z FORCE	LBS/FT	8.277E+00	6.312E+00	5.058E+00	3.074E+00	1.566E+00	7.258E-01	1.950E-01

TORQUE LOADING

ELE PRO TORQUE	FT-LBS/FT	1.018E+02	1.057E+02	1.044E+02	7.995E+01	5.563E+01	4.312E+01	3.206E+01
ELE IND TORQUE	FT-LBS/FT	-4.055E+02	-4.138E+02	-4.662E+02	-4.906E+02	-4.435E+02	-3.226E+02	-1.297E+02
ELE TORQUE	FT-LBS/FT	-3.037E+02	-3.081E+02	-3.618E+02	-4.106E+02	-3.878E+02	-2.795E+02	-9.767E+01

PITCHING MOMENT LOADING (2D)

ELE PITCH MOMENT	FT-LBS/FT	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00

LIFT SLOPE CONVERGENCE

INPUT LIFT SLOPE	/RAD	3.685E+00	4.143E+00	4.441E+00	4.731E+00	5.166E+00	5.687E+00	5.670E+00
CL/ALPHAE	/RAD	3.532E+00	4.112E+00	4.408E+00	4.722E+00	5.109E+00	5.702E+00	5.663E+00

CIRCULATION PARAMETERS

CIRC SHAPE PARM		9.245E-01	9.406E-01	9.513E-01	9.666E-01	1.004E+00	1.093E+00	1.212E+00
BOUND CIRCULATION	FT**2/SEC	3.222E+01	3.587E+01	3.812E+01	3.886E+01	3.738E+01	3.121E+01	1.957E+01

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POINT 7: ENERTECH 1500 *** CMA STALL MODEL *** 05
ROTOR PITCH (DEG) .0000
WIND SPEED (M/SEC) 10.0000
ROTOR AZIMUTH (DEG) .0000

ROTOR PERFORMANCE

THRUST	LBS	8.3094E+01
CT ROTOR		1.8951E-02
CT WT		4.8024E-01
TORQUE	FT-LBS	-7.2929E+01
CQ ROTOR		-2.5355E-03
CP WT		-2.2871E-01
POWER (ROTOR)	KW	-1.7603E+00
POWER (PROFILE)	KW	7.4273E-01
POWER (INFLOW)	KW	-2.5030E+00

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15. Supplementary Notes

Technical Monitor: James Tangler

16. Abstract (Limit: 200 words) This report describes how numerical lifting-surface theory is applied to the calculation of a horizontal-axis wind turbine's aerodynamic characteristics and performance. The report also describes how such an application is implemented as a computer program. The method evolved from rotary-wing and helicopter applications and features a detailed, prescribed wake. The wake model extends from a hovering-rotor experimental generalization to include the effect of the windmill brake state on the radial and axial displacement rates of the trailing vortex system. Performance calculations are made by coupling the lifting-surface circulation solution to a blade-element analysis that incorporates two-dimensional airfoil characteristics as functions of angle of attack and Reynolds number. Several analytical stall models are also provided to extend the airfoil characteristics beyond the limits of available data. Although this work focuses on the steady-performance problem, the method includes ways to investigate the effects of wind-shear profile, tower shadow, and off-axis shaft alignment. Correlating the method to measured wind-turbine performance, and comparing it to blade-element momentum theory calculations, validate and highlight the extreme sensitivity of predictions to the quality of early post-stall airfoil bahavior.

17. Document Analysis

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