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THEORETICAL PERFORMANCE OF CROSS-WIND AXIS TURBINES WITH RESULTS FOR A CATENARY VERTICAL AXIS CONFIGURATION

By

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## THEORETICAL PERFORMANCE OF CROSS-WIND AXIS TURBINES WITH RESULTS FOR A CATENARY VERTICAL AXIS CONFIGURATION

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Ralph J. Muraca Maria V. Stephens J. Ray Dagenhart

#### SUMMARY

A general analysis capable of predicting performance characteristics of vertical axis windmills (VAW) has been developed. This analysis includes the effects of airfoil geometry, support struts, blade aspect ratio, windmill solidity, blade interference and curved flow. The results from the analysis are compared with available wind tunnel results for a catenary blade shape. A theoretical performance curve for an aerodynamically efficient straight blade configuration is also presented. In addition, a linearized analytical solution applicable for straight blade configurations is developed. This analysis is useful for parameter studies when the aerodynamic characteristics of the airfoil can be assumed to behave linearly with angle of attack. The errors introduced by this assumption are demonstrated by comparing numerical with analytical results. A listing of the computer program developed for numerical solutions of the general performance equations is included in the appendix.

## SYMBOLS

AR	aspect ratio
A <sub>s</sub>	swept or projected area in vertical plane
a	lift curve slope for two dimensional airfoil
C <sub>D</sub>	drag coefficient
c <sub>L</sub>	lift coefficient
с <sub>м</sub>	moment coefficient
с <sub>ма</sub>	coefficient of the average moment produced during one revolution of the windmill
С <sub>Р</sub>	power coefficient
C p	pressure coefficient
с <sub>р</sub>	pressure coefficient - lower surface
с <sub>р</sub>	pressure coefficient - upper surface
с <sub>т</sub>	thrust coefficient
c	chord length
D	drag
Ġ	chordwise distance from airfoil leading edge to center of pressure
h	height of windmill
ĸ	lift curve slope including aspect ratio and downwash corrections
L	lift
1	length
м	moment

## SYMBOLS CONTINUED

N	normal force
n	number of blades
P	power
P <sub>t</sub>	total wind stream power
q	dynamic pressure
R	tip speed to wind speed ratio
Rey	Reynolds number
r	distance from axis of rotation to half chord point of blade element
r'	distance from axis of rotation to any particular point along blade chord line
8	spanwise distance
т <sub>h</sub>	thrust
<b>V</b> .	wind speed at windmill
V <sub>r</sub>	wind speed relative to blades
V <sub>∞</sub>	wind speed in free stream
x	chordwise distance from leading edge
У	vertical distance
α	angle of actack
β	local blade slope angle
ε	angle in plane of rotation between r and r' directions
Θ	angle of rotation from wind direction
ξ	chordwise distance from half chord point forward
ρ <sub>∞</sub>	air density
ω	rotational speed

•

## SYMBOLS CONTINUED

## Subscripts:

8	average
n, nax	maximum
r	relative
T	total
0	reference
8	free stream

## Superscripts:

 nondimensional
1.4

• time derivative

#### INTRODUCTION

As a consequence of the current shortages of fossil fuels interest is being revived in alternate sources of energy. One means for converting solar energy to a more useful form is through the use of windmills. Windmills may take many forms from drag devices to those which utilize the efficiency of airfoil shapes. An interesting survey of various types of windmills is given in reference 1. The most common windmill using airfoil shapes is the conventional multibladed horizontal axis type. These range from two blades to as high as twenty-seven blades depending on application, and the blades may range from propeller type to flexible sails. Analyses of horizontal axis windmills are well documented.

Another category of windmill is the vertical axis (VAW) or Darrieus windmill. The primary attraction of a VAW is the simplicity of manufacture compared to a HAW, and the manner in which the loads developed during operation are resisted by the structure. These differences indicate that if the efficiency of a VAW is equal to or not much less than a conventional windmill, use of a VAW might result in a more economical energy conversion system.

In recent years a small body of data has been published on the vertical axis windmill. Some of these reports present the results from tests of the vertical axis concept, ref. 2 and 3, while others present various analyses, structural, aerodynamic,

and economic, of vertical axis windmills, references 4 through 7.

This report presents a general analysis of vertical axis windmills. Airfoil theory is used to determine the torque generated by the blades about the axis of rotation, and momentum theory is used to determine the effective wind velocity at the blades. These yield a set of integral equations which require an iterative approach for their solution. The nonlinear characteristics of the blades airfoils are accounted for in the general analysis. A more simplified analysis assuming linear aerodynamics and applicable to straight blade configuration is also presented.

The results of this analysis in addition to being in **good** agreement with available test data on one VAW concept indicate that the VAW can be designed such that their efficiency is comparable to the best horizontal axis designs.

This report presents the details of the general nonlinear analysis and the linearized analytical solutions for the straight blade concept. The result produced from the general analysis are compared with existing test data. The results from a parameter study of VAW's using the general analysis and the linearized solutions are compared and limitation of the linear analysis are identified. One straight blade configuration having significantly improved aerodynamic performance while maintaining the same structural capability of the tested configuration is also analyzed and the results are presented. Also included in the Appendix of this report is a listing, of a computer program for general analyses of vertical axis windmills along with input and results for a sample case.

#### GENERAL THEORY

In this section, general nondimensional equations for aerodynamic torque and average windmill thrust are developed by use of actuator disk theory and blade element aerodynamics. Real effects such as aspect ratio, downwash and flow curvature are accounted for. An average nondimensional power coefficient is defined and its relation to wind speed and average windmill torque is given.

#### Defining Equations

The basic elements of the vertical axis windmill are shown on figure 1. It is composed of an arbitrary number of blades (the figures are shown with two) attached to a rotating shaft which is nominally perpendicular to free stream velocity vector. The blades shown in the figure are straight; however, this is not a requirement. The blade cross section must be such that when subjected to an angle of attack a lift force is generated. The performance of the windmill is directly related to the ratio of this lift force to the blade drag. Since the angle of attack which the blades experience is cyclic the blade cross sections are restricted to symmetric shapes.

The coordinate system used in this analysis is shown in figure 2. The origin is located at the midpoint of the rotor with the y axis corresponding to the spin axis. The wind velocity is arbitrarily assumed to be directed along the x-axis. The rotor position as given by the angle  $\Theta$  is measured from the x-axis. The local radius is measured

from the y-axis and the local slope,  $\beta$  , is measured with respect to the radius vector.

The determination of local lift and drag characteristics of a blade element represents an unsteady flow problem. However, it has been assumed that the static aerodynamic data for the subject airfoil section is applicable.

Consider an arbitrary blade section as shown in figure 3. For a blade element the incremental forces acting in radial and tangential directions are derived as follows. The total velocity at any location on a blade is,

$$v_r^2 = (r\omega - V \sin \theta)^2 + (V \cos \theta)^2$$
(1)

The angle of attack is given by

$$\tan \alpha = \frac{V \cos \Theta \sin \beta}{r\omega - V \sin \Theta}$$
(2)

The incremental forces developed as a consequence of the angle of attack are defined as, dL, in the direction normal to the relative velocity vector, and dD, in the direction of the relative velocity. These forces act to produce a moment about the axis of rotation given by  $dM = (dL \sin \alpha - dD \cos \alpha) r + (dL \cos \alpha + dD \sin \alpha) \sin \beta(\frac{c}{2} - d)$  (3)

#### The elemental lift and drag force can be written as

$$dL = C_{L} q cds \tag{4a}$$

and

$$dD = C_{D} q cds$$
 (4b)

where the element length, ds, is given by ds = dy/sin 
$$\beta$$
.  
Substituting eq. (4) into eq. (3) yields  

$$dM = (C_L q c(dy/sin \beta)sin \alpha - C_D q c(dy/sin \beta) cos \alpha)r$$

$$+ (C_L q c(dy/sin \beta)cos \alpha + C_D q c(dy/sin \beta) sin \alpha) sin \beta (\frac{c}{2} - d), (5)$$
where  $q = \frac{1}{2} \rho_{\infty} V_r^2$ .  
Integrating over y yields the total moment due to the blade as a  
function of the angle  $\Theta$ .  

$$M(\Theta) = \int (C_L sin \alpha - C_D cos \alpha) \frac{rqc dy}{sin \beta}$$

$$-h/2$$

$$h/2$$

$$+ \int (C_L cos \alpha + C_D sin \alpha) qc (\frac{c}{2} - d) dy \qquad (6)$$

The following nondimensionalization scheme is used; all velocities are nondimensionalized using the free stream velocity,  $V_{\infty}$ , and all lengths are nondimensionalized using the maximum radius of the windmill blades  $r_{max}$ . The nondimensional variables are denoted by a bar, i.e.  $\bar{V} = V/V_{\infty}$ . With this notation equation (6) becomes,

$$M(\Theta) = \frac{1}{2} \rho_{\infty} V_{\infty}^{2} (r_{\max})^{3} \int_{-\overline{h}/2}^{h/2} (C_{L} \sin \alpha - C_{D} \cos \alpha) \frac{\overline{r} \overline{c} \overline{v}_{r}^{2} d\overline{y}}{\sin \beta}$$

$$+\frac{1}{2}\rho_{\infty}^{\prime}v_{\infty}^{2}(r_{\max})^{3}\int_{0}^{\overline{h}/2}(c_{L}\cos\alpha+c_{D}\sin\alpha)\overline{v}_{r}^{2}\overline{c}(\frac{\overline{c}}{2}-\overline{d})d\overline{y}$$
(7)  
$$-\overline{h}/2$$

If a moment coefficient,  $C_{M}$ , is defined as

$$C_{M} \equiv \frac{M}{\frac{1}{2} \rho_{\infty} \nabla_{\infty}^{2} r_{max}^{3} \bar{A}_{s}}$$
(8)

where  $\bar{A}_{s}$  is the area swept out by the windmill then eq. (7) becomes

$$C_{\mathbf{M}}(\theta) = \frac{1}{\bar{\mathbf{A}}} \int_{\mathbf{S}} [(C_{\mathbf{L}} \sin \alpha - C_{\mathbf{D}} \cos \alpha) \frac{\bar{\mathbf{r}}}{\sin \beta}]$$

+ (
$$C_{L} \cos \alpha + C_{D} \sin \alpha$$
) ( $\frac{\overline{c}}{2} - \overline{d}$ )]  $\overline{c} \overline{v}_{r}^{2} d\overline{y}$ 

This can be rewritten as

$$C_{M}(\theta) = \frac{2}{\bar{A}} \int_{S}^{\bar{h}/2} \frac{\bar{c} \ \bar{r} \ \bar{v}_{r}^{2}}{\sin \beta} [(C_{L} \sin \alpha - C_{D} \cos \alpha) + \frac{\bar{c}}{\bar{r}}(\frac{1}{2} - \frac{\bar{d}}{\bar{c}}) \sin \beta (C_{L} \cos \alpha + C_{D} \sin \alpha)] d\bar{y}$$
(9)

.

Equation (9) holds for one blade, if there are n blades in the configuration the contribution for each blade can be obtained by replacing  $\Theta$  in equations (1) and (2) by  $\Theta$  + (1 - 1)  $\Delta\Theta$  and re-evaluating equation (9).

Doing this the total moment coefficient can be written

$$C_{M_{T}}(\Theta) = \sum_{i=1}^{i=n} C_{M_{i}}(\Theta + (i-1) \Delta \Theta)$$
(10)

where  $\Delta \Theta = \frac{2 \pi}{n}$ .

The integral of the total moment through one revolution of the windmill is given by

$$\begin{array}{c} 2\pi/n \\ C_{M_{N}} = n \int C_{M_{T}} (\Theta) \ d\Theta \end{array}$$
(11)

The average moment is then given by

$$C_{M_{a}} = \frac{C_{M_{N}}}{2\pi} = \frac{n}{2\pi} \int C_{M_{T}} (\Theta) d\Theta$$
(12)

The average power developed by the windmill is given by

$$P = \frac{\omega n}{2\pi} \int M_{T} (\Theta) d\Theta$$
(13)

Defining a power coefficient  $C_p$  as

$$C_p = \frac{P}{P_t}$$

where

$$P_{t} = \frac{1}{2} \stackrel{*}{m} V_{\infty}^{2} = \frac{1}{2} \rho_{\infty} A_{s} V_{\infty}^{3}$$

represents the total kinetic energy available per unit time in the stream tube. Using the definition of eq. (3), eq. (13) can be written in terms of the average moment coefficient as

$$\mathbf{p} = \frac{1}{2} \rho_{\omega} \left( \mathbf{v}_{\omega}^{2} \right) \mathbf{A}_{\mathbf{g}} \mathbf{C}_{\mathbf{H}_{\mathbf{g}}} \left( \mathbf{r}_{\mathbf{w}}^{\omega} \right)$$
(14)

chereby giving

$$C_p = (\frac{r_{max}}{V_{\infty}}) C_{Max}$$

or

$$C_p \approx R C_{M_a}$$
 (15)

where

$$\mathbf{R} \equiv (\frac{\mathbf{r}_{\max}\omega}{\mathbf{v}_{\infty}})$$

In nondimensional form equations (1) and (2) become

$$\bar{v}_{r}^{2} = (R \bar{r} - \bar{V} \sin \theta)^{2} + \bar{V}^{2} \cos^{2} \theta \qquad (16)$$

and

$$\tan \alpha = \frac{\bar{\mathbf{v}}\cos\Theta\sin\beta}{\bar{\mathbf{r}}\,\mathbf{R} - \bar{\mathbf{v}}\sin\Theta} \tag{17}$$

#### Momentum Loss and Windmill Thrust

The thrust acting on any device extracting energy from the wind is directly related to the change in momentum which occurs in the wind stream. Using momentum theory, reference 8 gives

$$\mathbf{T}_{\mathbf{h}} = 2 \rho_{\infty} \, \overline{\mathbf{v}} \, (1 - \overline{\mathbf{v}}) \, \mathbf{A}_{\mathbf{s}} \, \mathbf{v}_{\infty}^{2} \tag{18}$$

.

or

$$C_{T_a} = 4 \, \overline{v} \, (1 - \overline{v})$$

where  $C_{T}$  is an average thrust coefficient and is defined as

$$C_{T_{a}} \equiv \frac{T_{h}}{\frac{1}{2} \rho_{\infty} V_{\infty}^{2} A_{s}}$$
(19)

In terms of the elemental forces acting on a blade section the average thrust coefficient can be written

$$C_{T_{a}} = \frac{n}{2\pi} \int \frac{2\overline{c}}{A_{s}} \frac{\sqrt{r}}{-\overline{h}/2} \int \frac{\overline{v}}{r} \frac{2}{(C_{L} \cos \alpha + C_{D} \sin \alpha)} \cos \theta \sin \beta$$

+ 
$$(C_1 \sin \alpha - C_n \cos \alpha) \sin \theta ]d\bar{y} d\theta$$
 (20)

The determination of  $C_T$  and  $\overline{V}$  for specified values of  $V_\infty$  requires an iterative procedure.

#### Real Effects

Although determining the flow field around a rotating windmill airfoil constitutes a 3 dimensional unsteady flow problem, the assumption has been made in this analysis that the flow is steady and that a two dimensional analysis can be used. However, a number of other effects including aspect ratio, downwash and curved flow can influence the rotor performance and some attempt has been made to evaluate these.

Aspect Ratio. - During a rotation through 360 degrees a blade section will experience large angles of attack as the ratio of  $r\omega/V_{\infty}$  becomes small. When this occurs blade stall will result and to account for stall effects, it is necessary to use experimental data on section lift, drag and moment coefficients. These data are generally presented for infinite aspect ratio wings with appropriate aspect ratio correction being required. From reference 9 using Prandtl's lifting line theory, aspect ratio correction can be written as

$$C_{L} = C_{L_{o}} / (1 + \frac{a_{o}}{\pi AR})$$
 (21a)

and

$$C_{\rm D} = C_{\rm D_{\rm O}} + \frac{C_{\rm L}^2}{\pi AR}$$
 (21b)

where  $C_{L_0} & C_{D_0}$  represents the lift and drag coefficient for an infinite aspect ratio wing, and AR = h/c.

<u>Downwash</u>. - For a multibladed configuration each blade is in the downwash from the preceding blade thus the angle of attack is reduced by

this downwash angle. Again using the approach outlined in reference 9 the effect of downwash can be accounted for by using an aspect ratio correction. This yields

$$C_{\rm L} = C_{\rm L_o} \qquad \left[ \frac{1 - a_0 / \pi \, AR}{1 + a_0 / \pi \, AR} \right] \,. \tag{22}$$

<u>Flow Curvature</u>. - Since the airfoil is traveling in a circular arc the angle of attack varies along the length of the chord. The effect of flow curvature is a function of the spin rate and the chord to radius ratio. This effect can be evaluated by considering the flow over a flat plate. The force distribution on a plate of unit width in a uniform stream of velocity  $V_{\infty}$ , is given by

$$\frac{dN}{dx} = q \left( C_{p_{L}} - C_{p_{U}} \right)$$
(23)

For a flat plate the velocity ratio at angle of attack is given by reference 10 as

$$\frac{V}{V_{\infty}} = \cos \alpha \pm \sin \alpha \ (\frac{c - x}{x}), \qquad (24)$$

where the (+) and (-) signs refer to the upper and lower surfaces, respectively. Now the relation between  $V/V_{\infty}$  and  $C_{\rm p}$  is

$$C_{\rm p} = 1 - (V/V_{\infty})^2$$
 (25)

Substituting yields

$$\frac{dN}{dx} = 4 q \cos \alpha \sin \alpha \left(\frac{c - x}{x}\right)$$
(26)

Since the blade is actually moving along a curved path, the local angle of attack will vary. Referring to figure 4 the local angle of attack can be written as

$$\cot \alpha = \frac{\mathbf{r}^{\prime} \mathbf{\omega} \cos \varepsilon - \mathbf{V}_{\mathbf{\omega}} \sin \theta}{\mathbf{V}_{\mathbf{\omega}} \cos \theta - \mathbf{r}^{\prime} \mathbf{\omega} \sin \varepsilon}$$

or

$$\cot \alpha = \frac{r\omega - V_{\infty} \sin \theta}{V_{\infty} \cos \theta - \xi \omega}$$

or

$$\cot \alpha = \frac{R - \sin \theta}{\cos \theta - \xi R}$$
(27)

where  $R = r\omega/V_{\infty}$ .

In terms of the coordinate  $\hat{\mathbf{x}}$  measured from the leading edge of the plate this becomes

$$\cot \alpha = \frac{R - \sin \theta}{\cos \theta + R(\bar{x} - \bar{c}/2)}.$$
 (28)

In terms of the lift distribution on the plate eq. (26) becomes

$$\frac{dL}{d\bar{x}} = 4 q \cos^2 \alpha \sin \alpha \left(\frac{\bar{c} - \bar{x}}{\bar{x}}\right).$$
(29)

In the limiting case  $\bar{c} \rightarrow o$  and the expression for angle of attack becomes

$$\cot \alpha_{o} = \frac{R - \sin \Theta}{\cos \Theta}$$
.

Defining a reference lift distribution as

.

$$\left(\frac{dL}{d\bar{x}}\right)_{0} = 4 q \cos^{2} \alpha_{0} \sin \alpha_{0} \left(\frac{\bar{c} - \bar{x}}{\bar{x}}\right)$$

the effect of curvature can be displayed as a function of the ratio of lift distributions, with and without curvature effects. That is

$$\frac{(dL/d\bar{x})}{(dL/d\bar{x})} = \frac{\cos^2 \alpha \sin \alpha}{\cos^2 \alpha \sin \alpha}$$
(30)

The ratio of lift with and without curvature effects can be written

$$\frac{L}{L_{o}} = \frac{\int_{0}^{\overline{c}} \cos^{2} \alpha \sin \alpha d \overline{x}}{\int_{0}^{\overline{c}} \cos^{2} \alpha \sin \alpha d \overline{x}} = \frac{\int_{0}^{\overline{c}} \cos^{2} \alpha \sin \alpha d \overline{x}}{\cos^{2} \alpha \sin \alpha \sqrt{c}}$$
(31)

The numerator can be integrated giving

$$\frac{L}{L_{o}} = \frac{\frac{R - \sin \theta}{R} (\cos \alpha_{1} - \cos \alpha_{2})}{\cos^{2} \alpha_{o} \sin \alpha_{o} \vec{c}}$$
(32)

where

$$\alpha_{0} = \tan^{-1} \quad \left(\frac{\cos \theta}{R - \sin \theta}\right)$$

$$\alpha_{1} = \tan^{-1} \quad \left(\frac{\cos \theta - \frac{R \bar{c}}{2}}{R - \sin \theta}\right)$$

$$\alpha_{2} = \tan^{-1} \quad \left(\frac{\cos \theta + \frac{R \bar{c}}{2}}{R - \sin \theta}\right)$$

This correction term has been applied to account for flow curvature effects. For most typical configurations the correction is less than one percent. However, if  $\bar{c}$  becomes large this effect would become more important. i.

#### VERIFICATION OF GENERAL THEORY

In this section, the difficulties of modeling windmill \_ performance using airfoil data with corrections for three dimensional flow effects are discussed. Theoretical results are compared to test data.

Reynolds Number, Roughness and Crossflow

As indicated in reference 11 the NACA 0012 airfoil falls into the category which experiences either leading edge or trailing edge stall depending on Reynolds Number.

Furthermore, the section characteristics are very dependent on surface roughness. When these effects are combined with the three dimensional nature of the flow over the windmill blades it becomes apparent that using two dimensional data at a fixed Reynolds Number represents a significant approximation.

Fortunately, use of two dimensional data yields a good approximation to the actual performance of a windmill; however, differences between measured and computed performance can easily be explained within the framework of these aerodynamics uncertainties. The data used in this analysis come from reference 12, however, some cases are presented in which these data have been modified to simulate leading edge stall and surface roughness.

#### Comparison with Test Data

The results predicted by the analysis for a two blade configuration (n = 2) were compared with test data from references

3 and 4. The blade shape is a catenary with maximum radius of 2.13 m (7 ft) and a height of 4.27 m (14 ft). The shape of the upper half of a blade is represented by the curve shown on figure 5. The test Reynolds number was about 0.3 x  $10^6$  consequently low Reynolds number data were used for the NACA 0012 airfoil. The airfoil data were obtained from reference 12, and a tabulation of lift and drag coefficient and center of pressure versus angle of attack is presented in table 1. These data are for a Reynolds Number of 0.5 x  $10^6$ .

From the theoretical curve it is seen that the catenary VAW does not begin to produce sufficient power to overcome the drag due to stall until a velocity ratio of about 2.5 is reached. At this point the power coefficient increases with spin rate until a peak value of about .37 is reached. The power coefficient then decreases until at a velocity ratio of R  $\sim$  10 it reaches zero. This determines the no load spin rate at which the windmill would operate.

The test data follows the same trends; however, there are differences between these results. The test data see to indicate that stall occurred at a higher velocity ratio and more abruptly than predicted, possibly indicating leading edge stall. Also, the no load velocity ratio reached in the tests was slightly greater than 8 indicating the zero lift drag was greater than predicted by smooth airfoil data. To demonstrate the effect of these variations on the predicted performance curve a computation was made using a zero lift drag coefficient representative of a rough surface.

Increasing  $C_{D_{a}}$  reduces the peak efficiency somewhat and causes the

no load tip speed ratio to drop to a value of about 8.5. To demonstrate the effect of leading edge stall at low Reynolds number the lift and drag coefficient data were modified to reflect a sudden stall at an angle of attack of 10 degrees. These changes cause the peak value of power coefficient to be reduced slightly, and to occur at a higher tip speed ratio. Also, the no load point drops to about 8.6. For the catenary configuration the angle of attack variation along the blade is shown on figure 7 for R = 4and R = 5, and at one angular location  $\theta = 0$ . As can be seen the angle of attack is almost constant over the majority of the blade and doesn't increase appreciable until the last 15 percent of the blade is reached. However, the contribution of this part of the blade to the total power production is small. Shown on figure 8 is the variation of peak angle of attack with R at the maximum radius. From this it can be seen that at values of R  $\leq 4.5$  the peak angle of attack exceeds 10° consequently stall begins to set in. Since the angle of attack is essentially constant over the major part of the blade the whole blade stalls at about the same time thus causing the rapid reduction in the power coefficient curve as shown in figure 6.

If a system could be built with no losses other than aerodynamic its starting characteristics would consist of an initial rotation caused by the differential drag on the two blades. However, the angles of attack experienced would be higher than the stall angle and limiting spin rate would be reached where the moment generated by the lift force

would just balance that generated by the drag force. To get the windmill over this point some energy must be added to the system. Once the spin rate attains a value high enough such that the net torque due to lift is greater than that due to drag the system will spin up to the velocity ratio corresponding to no load condition.

The computed results for the case n = 2 are also snown plotted on figure 9 versus the induced velocity at the blades  $\tilde{V}$ . Included on this figure is a plot of the theoretical maximum curve obtained by setting the drag coefficient of the airfoil to zero.

As indicated previously no power is available until R reaches a value of about 2.5. As the spin rate increases the power curve follows the trend of the theoretical maximum curve although it is displaced somewhat. As the spin rate increases to values greater than about 6 the drag losses become more important since the angles of attack are decreasing and the contribution of the lift forces to the turning moment become of the same order as the retarding effects of the drag forces. Consequently the actual curve departs from the theoretical maximum by a large amount.

#### LINEAR THEORY FOR STRAIGHT BLADE CONFIGURATIONS

By restricting the possible windmill configurations to those with straight blades and by assuming that the blade aerodynamic coefficients vary linearly with angle of attack, closed form analytical expressions for windmill performance parameters are obtained. These expressions are used to study the effects on windmill performance of variations in aspect ratio and solidity.

#### Reduction to Analytical Form

Consider the special case of a straight blade configuration where  $\bar{r} = 1.0$  and  $\beta = 90^{\circ}$ , both constant with respect to  $\bar{y}$ . From figure 3 we have

$$\bar{\mathbf{v}}_{\mathbf{r}} \sin \alpha = \bar{\mathbf{v}} \cos \Theta \tag{33a}$$

and

$$\overline{\mathbf{v}}_{\mathbf{r}} \cos \alpha = \mathbf{R} - \overline{\mathbf{v}} \sin \Theta$$
 (33b)

Also, if only small angles of attack are considered

$$C_{L} = K_{1} \sin \alpha \qquad (34a)$$

$$c_{\rm D} \stackrel{\sim}{\sim} c_{\rm D}$$
 (34b)

With these approximations the trust coefficient for one blade becomes

$$C_{T}(\Theta) = \frac{\bar{c}}{2} \{ [K_{1} \sin \alpha \cos \alpha \cos \Theta + K_{1} \sin^{2} \alpha \sin \Theta] + C_{D_{0}} [\sin \alpha \cos \Theta - \cos \alpha \sin \Theta] \} \bar{v}_{r}^{2}$$
(35)

Substituting for  $\bar{V}^{\phantom{\dagger}}_{\mathbf{r}}$  yields

$$C_{T}(\Theta) = \frac{\bar{c}}{2} \{ K_{1} [ \bar{V} (R - \bar{V} \sin \Theta) \cos^{2} \Theta + \bar{V}^{2} \cos^{2} \Theta \sin \Theta ] + \bar{V}_{T} C_{D_{0}} [ \bar{V} - R \sin \Theta ] \}$$
(36)

and integrating over  $\Theta$  an average thrust coefficient  $C_{T}_{a}$  for n blades is obtained,

$$C_{T_{a}} = \frac{n\bar{c}}{4} K_{i} \bar{V}R + \frac{n\bar{c}}{4\pi} \int [(R - \bar{V} \sin \Theta)^{2} \\ \Theta \\ + (\bar{V} \cos \Theta)^{2}]^{\frac{1}{2}} (\bar{V} - R \sin \Theta) C_{D_{o}} d\Theta$$
(37)

Simplifying by assuming (R -  $\overline{V} \sin \Theta$ )>>  $\overline{V} \cos \Theta$  this becomes

$$C_{T_{a}} \approx \frac{n\overline{c} K_{1} \overline{V}R}{4} + \frac{n\overline{c} C_{D}}{4\pi} \int (R - \overline{V} \sin \Theta) (\overline{V} - R \sin \Theta) d\Theta$$

or

$$C_{T_{a}} = \frac{n\bar{c}}{4} R K_{1} \bar{v} + 3 \frac{n\bar{c}}{4} \bar{v} R C_{D_{o}}$$
 (38)

From momentum theory we have

$$C_{T_a} = 4 \overline{V} (1 - \overline{V})$$

therefore, equating these yields an expression for  $\bar{V},$  the nondimensional velocity at the blade

$$\overline{v} = 1 - \frac{n\overline{c}}{10} \frac{\kappa}{1} + 3 C_{D_o}$$
(39)

Using eq. (9) with  $\bar{r} = 1$  and  $\beta = 90^{\circ}$ , the moment coefficient  $C_{H}(\theta)$  can be written as

$$C_{M}(\Theta) = \frac{2 \bar{Y}_{m}}{\bar{A}_{s}} \bar{c} \bar{V}_{r}^{2} [(C_{L} \sin \alpha - C_{D} \cos \alpha) + \bar{c}(.5 - \bar{d}/\bar{c}) (C_{L} \cos \alpha + C_{D} \sin \alpha)]$$
(40)

but for a straight blade configuration  $\bar{A}_{g} = 2 \bar{h}$ Using the relationships between  $\bar{V}_{r} \in \bar{V}$  in equation (33)

yields

$$C_{M}(\theta) = \frac{\overline{c} K_{1}}{2} \left[ \overline{v}^{2} \cos^{2} \theta + \overline{c} (.5 - \overline{d}/\overline{c}) \overline{v} \cos \theta (R - \overline{v} \sin \theta) \right]$$

.

$$+ \frac{\bar{c}}{2} (R - \bar{V} \sin \theta)^{2} + \bar{V}^{2} \cos^{2} \theta [\bar{c} (.5 - \bar{d}/\bar{c}) C_{D_{0}} \bar{V} \cos \theta$$
$$- C_{D_{0}} (R - \bar{V} \sin \theta)]$$
(41)

Restricting this analysis to cases in which  $R - \overline{V} \sin \theta \gg \overline{V} \cos \theta$ equation 41 can be integrated over  $\Theta$  to yield the average moment

$$C_{M_{a}}^{as} = \frac{n\bar{c} K_{1}}{4} \bar{v}^{2} - \frac{n\bar{c} C_{D}}{4} (2R^{2} + \bar{v}^{2})$$
 (42)

The power coefficient  $C_p$  is given by  $C_p = R C_{M_a}$ , substituting yields

$$C_{p} = R \frac{n\bar{c} K_{1}}{4} \left(1 - \frac{n\bar{c} R}{16} (K_{1} + 3 C_{D_{0}})\right)^{2} - \frac{n\bar{c} C_{D}}{4} \left[2R^{2} + (1 - \frac{n\bar{c} R}{16} (K_{1} + 3 C_{D_{0}}))^{2}\right]$$
(43)

where

$$K_{1} = a_{0} \frac{1 - a_{0}/\pi AR}{1 + a_{0}/\pi AR}$$

Now for a straight blade

$$AR = \frac{h}{c} = \bar{h}/\bar{c}$$
(44)

therefore,

$$K_{1} = a_{0} \frac{1 - a_{0} \bar{c} / \pi \bar{h}}{1 - a_{0} \bar{c} / \pi \bar{h}}$$
(45)

Equation (43) can be used to evaluate the effects of  $n\bar{c}$ ,  $\bar{h}$ , and  $C_{D_O}$  on performance of windmills. For the case where  $C_{D_O} = 0$ the windmills performance reaches the theoretical maximum. This case along with a case using a representative value of  $C_{D_O}$  are

shown in figure 10. Both  $C_p$  and R are shown as a function of velocity ratio  $\overline{V}$ . Also shown on this figure are the results of the numerical analysis using nonlinear aerodynamics. As would be expected the linear and nonlinear results are in fairly good agreement at the higher spin rates; however, comparing these with the limiting value given by the  $C_{D_c} = 0$  curve indicates that

significant improvements in performance could be realized if the airfoil drag could be reduced. For low spin rates the analytical and numerical results are in poor agreement due to the stall effects. The use of linear aerodynamics in the analytical solution causes the drag term to appear erroneously small so that the analytical results approach the theoretical maximum for low spin rates. This is due to the fact that the airfoil experiences high angles of attack and the contribution of the lift force is orders of magnitude greater than the retarding effect of the zero lift drag force.

#### Parameter Study

The analytical solutions can be used to evaluate the effects of solidity, and windmill aspect ratio on power coefficient. For small values of solidity, which is proportional to nc, and for high tip speed ratios these results are adequate to identify trends; however, at low tip speed ratios the effects of nonlinear airfoil characteristics become dominant and the analytical results are inaccurate. Figure 11 shows the analytical results as a function of solidity at a fixed aspect ratio. Power coefficient is plotted versus tip speed ratio and as indicated on the figure peak efficiency increases as solidity increases; however, the peak value occurs at a lower tip speed ratio and the range of tip speed ratios at which power can be supplied by the windmill varies inversely with solidity. Figure 12 shows the variation of power coefficient with  $\bar{h}$  as tip speed ratio varies. As can be seen  $\bar{h}$ does not have a major effect on windmill performance for the range

of values cited. In general as  $\tilde{h}$  increases the aspect ratio of each blade increases consequently its performance improves. However, due to structural considerations it is desirable to design a windmill with as small a value of  $\tilde{h}$  as possible without drastically and impairing performance.

When a numerical analysis based on the general theory is used to determine the effect of solidity on performance a major difference occurs for small values of tip speed ratio. These results are shown on figure 13. Since in this analysis the occurrence of airfoil stall is not dependent on solidity the minimum speed ratio at which power is produced is essentially the same for all configurations. Using the aerodynamic data for the NACA 0012 airfoil this value of tip speed ratio is about 2.5. The efficiency increases rapidly as tip speed ratio increases from this minimum value. However, for some values of solidity the peak efficiency would occur at tip speed ratios less than this minimum value were it not for stall effects. Consequently, with stall effects included, these peak values are never achieved. If a windmill could be designed using a blade which did not stall or stalled at a higher angle of attack it might be possible to achieved the higher performance indicated by the analytical solution. However, it remains questionable if one would want a design which responded so radically to changes in wind velocity.

#### LINFIGURATION EFFECTS ON AERODYNAMIC EFFICIENCY

Considering only aerodynamic efficiency the optimum VAW design as depicted in figure 14a would consist of straight blades attached to the center shaft by low drag struts. The windmill aspect ratio must be large enough to minimize losses due to blade aspect ratio. Unfortunately such a design leads to severe structural limitations due to the high bending loads which develop in the blade. It is for this reason that curved blades have been selected for designs currently in operation. With a curved blade the bending loads are greatly reduced and the centrifugal loads are reacted as almost pure tension loads in the blades. However, it is possible to design a straight bladed VAW which has the same structural capability as  $\varepsilon$  curved blade VAW. This can be accomplished by supporting the blade at appropriate intervals as shown in figure 14c. Secondly, by placing the support struts at an angle other than 90 degrees from the axis of rotation they will produce enough lift force such that their lift induced torque is greater than the drag induced torque and they in effect contribute to the performance of the windmill.

The results of such a design are shown in figure 15 along with a comparison of the catenary VAW performance. For this configuration the support struts and the primary blade are an NACA 0012 airfoil. The strut to blade chord ratio is 1/2. As the data indicates the peak power coefficient for the chevron design is about .43 compared to the value of .37 for the catenary. However, the catenary can produce power over a wider range of spin ratios than the chevron.

No attempt has been made to optimize the chevron design and one would expect that for higher values of h/r some improvement in performance could be expected. Also, the higher the angle of the support struts the greater will be their contribution. It is also possible to select a support strut angle such that the angle of attack at some point on the strut is the same as the angle of attack at the blade.

#### CONCLUSIONS

The results from the analysis presented herein indicate that a numerical solution using non-linear aerodynamic data and assuming a uniform induced velocity over the complete volume swept by the windmill can be used to predict performance of vertical axis windmills. The major parameters affecting windmill performance are the blade shape, blade aspect ratio and downwash effects. The effects of curved flow are insignificant providing the ratio of blade chord to diameter is small. The use of linear aerodynamics allows the defining torque equation to be integrated; however, these analytic solutions are incorrect at lower values of spin parameter where the aerodynamics are nonlinear. They are useful for assessing trends at higher spin parameter values. The performance of a VAW can be improved by using straight rather than curved blades provided the blade is supported in the proper manner. However, optimization of any VAW design will ultimately be based on the costs per installed unit of power consequently not only aerodynamic but also structural considerations must be taken into account.

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#### APPENDIX

#### WINDMILL PERFORMANCE PREDICTION COMPUTER PROGRAM

#### Order of Input

1. Header Card, Columns 1 through 80.

2. Namelist \$NAM1 including:

Fortran Symbol	Engineering Symbol	Definition
AR	AR	Aspect ratio of blade
ARS	AR s	Aspect ratio of lifting struts
AZ	a 2	Section lift curve slope
BETA(I)	β	Array of local slope of blade for each YBAR(I)
BETS	β <sub>s</sub>	Angle of lifting struts
CBAR	Ē	Nondimensional blade chord
CBARS	с <sub>в</sub>	Chord of lifting and n <b>onlifting</b> struts
CD(I)	с <sub>р</sub>	Array of Section drag coefficient of blade and struts for each GAM(I)
CD1	°D1	Zero lift drag coefficient of nonlifting struts
CK1	CK1	Number of nonlifting struts
CL(I)	с <sub>г</sub>	Array of Section lift coefficient of blade and struts for each GAM(I)
CMC4(I)	с <sub>м</sub> с/4	Quarter chord pitching moment coefficient
UY YU	DY	Increment used to calculate y coordinate array for blade, from YMIN to YMAX.
DYS	DY s	Increment used to calculate Y coordinate array for struts from YSMIN to YSMAX.
GAM(I)	γ	Array of angle of attack, where I = 1, NGAM.

Fortran Symbol	Engineering Symbol	Definition
ITHPRNT		Total number of THPRNT values, maximum is 10.
N	n	Number of blades
NGAM		Total number of GAM values, maximum is 100.
NS	n s	Number of lifting struts, if none set = 0.
NTHETA		Total number in THETA array, maximum is 200.
NVR		Ťotal number in VRRY array, maximum is 10.
NY		Total number in YBAR array, maximum is 50.
RBAR(I)	ī	Array of windmill blade radius for each YBAR(I).
TC	τ	Blade airfoil thickness ratio.
THETA(I)	θ	Array of windmill angular coordinate, degrees, where I = 1, NTHETA.
THPRNT(1)		Array of THETA values at which the lift, drag and moment values can be printed, where I = 1, ITHPRNT.
VRRY(I)	R	Array of specified velocity ratios at which the windmill is to be analyzed, where I = 1, NVR.
YBAR(I)	ÿ	Array of coordinates along the axis of rotation of the windmill, where I = 1, NY.
YMAX	<b>Ÿ</b> max	Maximum Y coordinate of blade.
YMIN	Ϋ́mín	Minimum Y coordinate of blade.
YSMAX	<b>Y</b> smax	Maximum y coordinate of lifting struts
YSMIN	<b>Ÿ</b> smin	Minimum y coordinate of lifting struts

# Output Parameters

Output Symbol	Engineering Symbol	Definition
BARCT	С <sub>Та</sub>	Windmill thrust coefficient averaged over a revolution
CD	с <sub>р</sub>	Airfoil section drag coefficient
CL	с <sub>L</sub>	Airfoil section lift coefficient
CM(THETA)	с <sub>М</sub> (Ө)	Blade moment coefficient for angular docation $\Theta$
CMA	с <sub>ма</sub>	Average windmill moment coefficient
CMAS	C <sub>M</sub> as	Average moment coefficient due to struts
CMC4	C <sub>M</sub> c/4	Airfoil section quarter chord moment coefficient
CMS (THETA)	С <sub>М</sub> (Ө)	Strut moment coefficient for angular location $\Theta$
CMT	с <sub>мт</sub> (ө)	Total moment coefficient for n blades at angular location $\Theta$
CMTS	с <sub>мт</sub> (Ө) г	Total moment coefficient for all struts at angular location $\Theta$
CPA	°°°°a	Power coefficient due to lifting blades and struts
CPL	° <sub>P1</sub>	Power coefficient loss due to nonlifting struts
CPN	° <sub>Pn</sub>	Net power coefficient
D/C	d/c	Location of center of pressure measured chordwise from the airfoil leading edge in fractions of the chord length

Output Symbol	Engineering Symbol	Definition
DEL CM	∆c <sub>M</sub>	Incremental moment coefficient due to a blade element
GAMMA	Ŷ	Local blade angle of attack
OMEGA	ω	Windmill rotational speed
RMAX	r max	Maximum windmill radius
SBAR	s	Nondimensional windmill projected area in a vertical plane
THETA	Θ	Angle of windmill rotation measured from the free wind direction
VINF	v <sub>∞</sub>	Wind stream speed at a large distance from the windmill
VR	v	Wind stream speed at the windmill









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J	NTHETA - TOTAL NUMBER IN THETA ARRAY, MAXIMUM IS 200
J	NVR TOTAL NUMBER IN VERY ARRAY, MAXIMUM IS 10
J	NY - TOTAL NUMBER IN YBAR ARRAY, MAXIMUM IS 50
<u>ں</u>	RBAR - WINDMILL BLADE KACEUS FOR EACH YEAR
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J	VALUES CAN BE PRINTED
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000054	7 HC(1) = 0.25
000056	60 TO 5
000057	6 HC(I) = 0.25 - CMC4(I)/CN
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Call FTLUP(GAMM , TCL,1,NGAM,GAM,CL)Call FTLUP(GAMM , TCD,1,NGAM,GAM,CD)Call FTLUP(GAMM , THC,1,NGAM,GAM,CD)FIA Call FTLUP(GAMM , THC,1,NGAM,GAM,HC)IF(AGAMS.LT.0.)TCL=-TCL	C DOWNWASH AND ASPECT RATIO CGRRECTION C TCL=TCL/(1.+AZ/(3.14159*ARS))*(1AZ/(3.14159*ARS))	C CURVED FLOW CORRECTION TCL=TCL*CLCLO(CAPR,CBAR,TH) TCD=TCD+TCL**2/(3,14159*ARS)	C TORQUE DUE TO STRUTS	<pre>1 C CM(K)=2.*CBARS*RS(K)/SBAR*EQ* (CBARS/RS(K)*(.5-THC)*(EQ1*TCL+EQ2* 1TCD)+1./SIN(BETSR)*(EQ2*TCL-EQ1*TCD))</pre>	0 60 T0 57 . 0 55 CM(K) =0. 2 57 IF(NPRNT.EQ.1)WRITE(6,101)YS(K),GAMDEG.TCL.TCD.THC.CM(K)	Call TRAP(CM,YS,KS,SUM,O.)	5 58 CONTINUE 5 IF (NPRNT.EQ.1)WRITE(6,117) 3 DO 50 J=1,IT 0	C COMPUTE BLADE LIFT AND DRAG	CALL FTLUP(YR(J), BET, 1, NY, YBAR, RBETA) CALL GAMMA(AGAM, EQ2, EQ1, EQ, TH, BET, VR, RR(J)) GAMDEG=AGAM/RADIANS	5 GAMM = ABS(AGAM)/RADIANS 7 CALL FTLUP(GAMM , TCL,1,NGAM,GAM,CL) 3 CALL FTLUP(GAMM , TCD,1,NGAM,GAM,CD)	7 CALL FILUP (GAMM , THC,1,NGAM,GAM,HC) 3 IF(AGAM.LT.O.)TCL=-TCL C DOWNAAA AND ACPECT PATIO CERFECTION	C       TCL=TCL/(1.+AZ/(3.14159*AR))*(1AZ/(3.14159*AR))         6       TCL=TCL/(1.+AZ/(3.14159*AR))*(1AZ/(3.14159*AR))         7       C         7       TCL=TCL*CLCL0(CAPR, CBAR, TH)	
00072 00073 00073 00073	00074	00076	00076	17000	00102	00104 00104	00105		00100	001100	001112	00112	

		.5-THC)*(Eq1	)) Ton Ture CH1 11							ICIENT CPA						PB				<b>JO</b> 1			ED		N)			CPL	SBAR*VVR**3)								· ·
TCD=TCD+TCL**2/(3.14159+4R)	C TORQUE DUE TO BLADE	C CM(J)=2.*CBAR*RR(J)/SBAR*EQ* (CBAR/RR(J)*(	T*TCL+EQ2*TCD)+1。/SIN(BET)*(EQ2*TCL-EQ1*TCD	IF (NPKN1. EQ. 19WK] (E10+101/1K101 + 64MUEV+1CL	50 CUNIINUE FALL TRADICM.YR IT.SHM.D.1	SUMCM(I)=SUM(I7)	IF (NPRNT. EQ.1)WPITE(6,102)THETA (J. SUMCM(I	90 CONTINUE	WRITE(6,103)(THETA(1), SUMCM(1), SUMCMS(1),	C CCMPUTE TOTAL AVERAGE TORQUE AND PUWER COEFF	NN=NTHETA/N	00 80 I=1,NN		03 60 J=1.N	NJ=(J-1)*NN	00 60 1=1,NN	CT(1) = CT(1) + SUMCM(1+NJ)	C1S(I)=C1S(I)+NS#SUMCMS(I+NJ)	60 CUNIINUE	CALL TRAP(CTS.THETA.NN. SUMS.O.)	00 65 1=1,NN	SUM(I)=N*SUM(I)/360.	SUMS(I)=N#SUMS(I)/360.	65 CONTINUE	WRITE(5,108)N, (THETA(I), CT(I), CTS(I), I=1, N	WRITE(6,111) SUM(NN), SUMS(NN)	CPA=(SUM(NN)+SUMS(NN))/VVR	CCOMPUTE POWER LOSS DUE TO NCNLIFTING STRUTS,	CPL=[CK1*CBARS*CD1)*(1.+(VR/CAPR)**2)/(4.*	CPN=CPA-CPL	WKITELON4407744077440774						-
001143		001147		001176	001217	001225	001230	001241	001244		001262	001265	107100	001274	001275	001300	001302	001306	001312	001323	001327	_001331	001334	101337	001341	001361	001371		 001374	001405	001/21	001424	+ 3 + 300		•	a na antara ana amin'ny faritr'o amin'ny faritr'o amin'ny faritr'o amin'ny faritr'o amin'ny faritr'o amin'ny fa	

					ND SUPPORTING STR	<pre>CE 20 • 11 1</pre>		A ANALY SI ST / LLA		SWEPT AREA SBAR=			MT *1 2X*CMTS*		12.4//)	IKUI LUSSES, LYA=* +cic 1/		=*F15.7/* AVFRAGE		5.7/* VR =+E15.7/		K	CD+13X+CMC++13X+D	6X*YSDAR*,8X	IN	/7X*YBAR*BX*GAMMA	00	RI	GINPOC	L Q	GE		92			2013年1月1日,1月1日,1月1日,1月1日(1月1日)),1月1日(1月1日))。1月1日):1月1日(1月1日))、1月1日(1月1日))(1月1日))(1月1日))(1月1日))(1月1日))
	re energy of the second of the second device devices and the second device of the second of the second device of t	#TFETA =#F12.2) F.S. 0 EF1E 31	+ F±U• <+ >= 12• (1	X(:: F5] +) : + E) 57)	0X*MOMENT COEFFICIENT FOR ONE BLADE A	A#5X#CMLFELAJ#0X#CMSLEELAJ#/LF10.024		DX*PROGRAM 44426 - WINUMILL EFFILIENU		DX*DUTPUT*//* NONDIMENSIONAL WINDMILL		P = #E15.7)	X*NUMBER OF BLACES =*13/5X+THETA*8X*C	(1)	3H VELOCITY RATIO RMAX*OMFGA/VINF =+F	DWER CUEFFICIEN! WITHUUT NUNLIFIING S S. OCT SUL TO NOW ITITUC STOUTS COL-	K LUNI VVE TU NUMLIFIING NIKULNI OFEF Correitient rom-teis 71	VERAGE READE MOMENT COFFEEDENT. CMA	T COEFFICIENT • CMAS =#E15.7)	INDMILL THRUST COEFFICIENT BARCT =#E1	=+15)	=+E15.7)	0X*INPUT TABLES*//6X*6AMMA*7X*CL*14X*	ELS.()) WINDMILL STRUT LIFT.DRAG AND MOMENT*/	L*13X*CD*12X*D/C*10X*DEL CMS*)	*WINDMILL BLADE LIFT,DRAG AND MOMENT*	UC#124*U/C*104,*UEL UM*1						:			
υ	CFDRMATS	100 FORMAT(//5X,*	TOT FURMALIETS .	102 FURMAT (/1 X*C)	103 FORMAT(1H1,1)		104 FURMAT(BAIO)	105 FORMAT (IHI , I(	18410)	106 FORMAT (1H1,20	1*E15.7)	107 FORMAT(//* CI	108 FORMAT(1H1,5)	1/(F10.2,2515	109 FORMAT (1H1 ,3	IIO FORMAT(//* P		V #//JHVWGUJ III	STRUT MOMEN	113 FORMAT(//* W	1 * I TERATIONS	114 FDRMAT(* CTS	115 FORMAT(1H1,20	116 FORMAT (//5X#1	1 *64MMA*1 0X*CI	117 FURMAT (//+5X	L*LOX*CL*L3X7(					, and then the state of the sta		and the second se		م. محمد المحمد المحم وقد المحمد ال
		001424	001424	001424	001424		001424	001424		001424	A COMPANY AND A COMPANY AND A COMPANY	001424	001424		001424	001424		001626	17110	061474		001424	001424	001424	; ; ; ;	001424	001424						· · · · · · · · · · · · · · · · · · ·			

	APPENDIX -	COULTINUED	
41) (X(NP)-X(N))/2.			
SUBROUTINETRAP(Y, X, NL, SUM, SUM DIMENSION Y(NL), X(NL), SUM(NL) SUM(1) = SUM1 NLM=NL-1 NLM=NL-1 DOIN=1, NLM NP=N+1 SUM(NP) = SUM(N) : (Y(NP) + Y(N)) *( RETURN END			
000010 000010 000011 000012 000015 000034 000035			

(.TH.BET.VR.RR) MMA(I.E. ALPHA), AND THE				PENDIX	INPED ORIGIN	IAL P OR QI	AGE IS		
C CALCULATE THE CAMMA(GAM, SCAM, CGAM, VBAR2 C CALCULATE THE COCAL ANGLE OF ATTACK GAL	000013 CCMMDN/GAMSUB/CAPR	000013 PARTI=RR*CAPR-VR*SIN(TH) 000024 PART2=VR*COS(TH)*SIN(BET) 000042 GAM=ATAN2(PART2,PARTI) 000051 DENC=SQRT(PART1**2+PART2**2) 000055 SAM=0AT2(PART1**2+PART2**2)	000062 CGAM= PART1/DENO 000064 VBAR2=PART1/DENO 000074 RETURN 000075 END						

UNCTION CLCLO(CAPR,CBAR,TH) ICTION CLCLO CORRECTS LIFT COEFFICIENT FOR FLOW CURVATURE EFFECTS FAL NUM DSTH=COS(TH)	INTH= SIN(TH) =CAPR*CBAR/2. DHAD=ATEN2(CPSTH.CAPR-SINTH)	LPHA1=ATAN2 (COSTH-A, CAPR-SINTH)	LPHAZ = A LANZ LOUS (H + A , CAZK - SIN H) UM= (CAPR-SINTH) * (COS(ALPHAI) - COS(ALPHA2))/CAPR.	15NCM= (CGS(ALPHAU))**2*SIN(ALPHAO)*CBAR 1 CLO=NUM/DENOM	E TURN		PEN										
000006 C FUN 000006 C C C C C C C C C C C C C C C C C	000015 A	000026	000037 A	000063 000075 0	000077		-							an anna an ann an anna anna anna anna		nn e n a suiteachtainn ann ann ann ann ann ann ann ann ann	

F1L U0010	FTLU0020	FTLU0030	FTLU0040	FTLU0050	FTLU0060	FTLU0070	FTLU0080	FT LU0090	FTLU0100	FTLU0110	FTLU0120	FTLU0130	FTLU0140	FTLU0150	FTLU0160	FTLU0170	FTLU0180	FTLUOI90	FTLU0 200	FTLU0210	FTLU0220					FTLU0250		6TLU0270 E	FTLU0280	FTLU0290	FTLU0300	ETLU0310 HB	ETLU0320	FTLU0330		FTLU0350 D.H				
SUBROUTINE FTLUP(X+Y+M+VARI+VARD)	DIMENSION VARI(1), VARD(1), V(3), YY(2)	IF (M.EQ.O.AND.17.EQ.0) CO TO 1	IF (M.EQ.O.AND.N. VE. U) GO TC 97	IF(N+LE.IABS(M)) GO TO 57	IF(M.GT.0)GO TO 31	C M.LT.O	D0 44 IYY=1,N		1F (VART (1)-X)800.119.44	44 CONTINUE		C IF X.LT.XIN), EXTRAPCLATE	IF (M.EQ1)GD TO 801	GO TO 802	C IF X.GT.X(1), EXTRAPOLATE	BJO IF [].EQ.1.AND.M.EQ1)GO TO 801	IF(I.EQ.1.AND.M.EQ2)G0 TO 802	IF(M.NE1)G0 T0 622	C #=-1		801 IF(VARI(I).LE.VARI(I+1))GC TO 97		C M=-2	622 1F(1.NE.N/6U IU 1022 1=N-2		C COMPARE WITH NEXT	I622 IF (VARI(I+1)-X)803,97,97	803 I=I-I	IF(I.EQ.1)60 TO 802	C SEE WHICH THREE	IF{(VAR!(I-1)-X).LT.(X-VAR!(I+2)))I=I-1	802 IF (VARI(I).LE.VARI(I+1).OR.VARI(I+1).LE.VARI(I+2))G0 T0 97		M.GT.O	31 00 4 IYY=1 +N		IF (X-VARI(I))700,119,4	4 CONTINUE	C IF X.GT.X(N), EXTRAPULATE	
	00011	11000	00016	00024	00026		00031	00032	00033	00036	0041		00042	00044		00044	00054	00063	F	00065	00066	00072		2/000	00075		00076	10100	00103		00104	00112	00125	1	00125	00127	00130	EE100	00136	

FTLU0400 FTLU0410 FTLU0420 FTLU0430 FTLU0430	FTLU0450 FTLU0460 FTLU0470	FTLU0480 FTLU0490	))/(VARI(1+1)-VARI(1)F1LU0500 F7LU0510 F7LU0520	FTLU0530	FTLU0540	FTLU0570			FTLU0530 FTLU0530	FTLU0650 FTLU0660	+1)-VARI(K)) FTLU0570 FTLU0680 FTLU0690	FTLU0700 FTLU0710	FTLU0720 FTLU0730	FTLU0740 FTLU0750	FTLU0760	FTLU0780	
IF(M.EQ.1)(0 T0 701 GD T0 702 IF X.LT.X(1),EXTRAPOLATE IF(1.EQ.1.AND.M.EQ.1)GO T0 701 TE(1.EQ.1.AND.M.EQ.1)GO T0 701	IF(M.NE.1)GO TO 222 M=1 T=t-1	IF {VARI(I+1).LE.VARI(I))GG TO 97 LINEAR	Y=(VARD(I)*(VARI(I+1)-X)-VARD(I+1)*(VARI(I)-X C) RETURN	M=2 IF(I.NE.N)GO TO 1222 I=N-2 GO TO 702	COMPARE WITH NEXT IF (X-VARI(I+1))703,97,97	TF([.60.1)60 TC 702 See Juich Three	JF((X-VARI(I-1)).LT.(VARI(I+2)-X))]=I-1 TE(VADI(I+1).LT.(VARI(I+2)-X))]=I-1	SECOND ORDER	V(2)=VARI(1+1)-X V(3)=VARI(1+2)-X	K=I DO 704 J=1,2	YY{J)={VARD(K]*V(J+1)-VARD(K+1)*V(J))/(VARI{K K=K+1 V={vv{1}}*v{3}-vv{2}*v{1})/{vART{1+2}-vART{1}}	RETURN ZFRO ORDER(Y=Y(1))	Y = VARD(1) RETURN	Y=VARD(1)	RETURN	ERPOR PRINT Print 103	
000137 000141 000141 000141 000150	000155 C	20016C 70	000164 170	000200 C 22 000202 22 000203	000204 122 000204 122	000211	000212 70	000233 C	000235	000241	000257 70 000257 70	000273	000274 000275	000276 C	000300	000301 C	

	APPENDIX - CONTINUED
FTLU0800 FTLU0810 FTLU0820 FTLU0830 FTLU0850 FTLU0850 FTLU0850 FTLU0850	ORIGINAL PAGE IS OF POOR QUALITY
FTLUP) .8)	
DUNTERED IN 15.5X,2HX=E2	
RRDR HAS ENC * X M=15,5X,2HL	
RMAT( /314 E INT 1103.M.N RNAT( 1X.24 (N.EQ.0) STOP (M.EQ.0) STOP INT 1104 INT 1104 C RMAT( 194 TA	
103 F0 1103 F0 1104 F0 1104 F0 70 870 870 870	
000341 000322 000322 000341 000343	

AR = 0.285+C2,	
ASS = 1,	
A2 = 0.573E+01.	
BETA = 0.9E+02, 0.888E+02, 0.863E+02, 0.828E+02, 0.7925E+02, 0.76E+02,	
0.725E+02, 0.696E+02, 0.664E+C2, 0.634E+U2, 0.600E+02, 0.582E+02, 0.554E+02, 0.526E+02, 0.5E+02, 0.475E+02, 0.449E+02,	
0.425E+C2, 0.4E+C2, 0.377E+C2, 0.355E+C2, 0.355E+C2, 0.335E+C2, 0.315E+C2, 0.295E+C2, 0.279E+C2, 0.264E+C2, 0.25E+C2, 0.25E+C2, 1, 1, 1, 1,	
I. I	
BETS = I	
CBAR = 0.7142E-01,	
CBARS = 0.0.	Anno anno anno an Anno Anno
CD = 0.65E-02, 0.8E-02, 0.1E-01, 0.12E-01, 0.14E-01, 0.45E-01,	<b>APE</b>
0.1E+00, 0.175E+00, 0.21E+00, 0.24E+00, 0.245E+00, 0.59E+00, 0.101E+01, 0.101E+01, 0.12E+01, 0.160E+01, 0.160E+01	END
0.1945+01, 0.1895+01, 0.1785+01, 0.1575+01, 0.1325+01, 0.1945+01, 0.1895+01, 0.1785+01, 0.1575+01, 0.1325+01,	
0.995400, 0.65400, 0.425400, 0.285400, 0.235400, 0.195400, 0.125400, 0.85-01, 0.25-01, [, [, [, [, [, [, [, [, [, [, [, [, [,	co
I, I	
CD1 = 0.0,	
CK1 = 0.0,	ORI
CL = 0.0, 0.21E+00, 0.695E+00, 0.855E+00, 0.56E+00, 0.1015E+01,	PO
0.8E+00, 0.67E+00, 0.63E+00, 0.63E+00, 0.655E+00, 0.575E+00, 0.113F+01, 0.1139E+01, 0.105E+01, 0.959E+00, 0.7E+00, 0.41E+00,	JAI
0.8E-01, -0.22E+00, -0.533E+00, -0.79E+00, -0.96E+00, -0.1075E+01, -0.1075E+01, -0.1075E+01, -0.1075E+01, -0.1015E+01, -0.1015E+01, -0.1015E+00, -0.1005E+00, -0.	P
-0.78E+00, -0.1E-01, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	AG JAI
Image:	
CMC4 = 0.0, 0.25-02; 0.65-02; 0.15-01; 0.26-01; -0.355-01; -0.655-01;	
-0.27E+00; -0.32E+00; -0.39E+00; -0.43E+00; -0.48E+00; -0.52E+00; -0.57E+00; -0.32E+00; -0.39E+00; -0.43E+00; -0.48E+00; -0.52E+00; -0.57E+00; -0.59E+00; -0.59E+00; -0.58E+00; -0.57E+00; -0.47E+00;	

		APPERDIX - CONTIN	JIIID	
-0.75E-01.       1.	GAM       = 0.0, 0.2E+01, 0.6E+01, 0.8E+01, 0.1E+02, 0.12E+02, 0.127E+02, 0.14E+02, 0.14E+02, 0.16E+02, 0.16E+02, 0.2E+02, 0.3E+02, 0.4E+02, 0.4E+02, 0.4E+02, 0.4E+02, 0.42E+02, 0.5E+02, 0.6E+02, 0.6E+02, 0.6E+02, 0.6E+02, 0.6E+02, 0.15E+03, 0.17E+03, 0.17	ITHPRNT = 1. N = 2. NGAM = 32. NS = 0. NTHETA = 73. NVR = 1.	NY       = 28;         RBAR       = 0.1E+01;       0.9956E+00;       0.9933E+00;       0.9889E+00;       0.98822E+00;         0.9732E+00;       0.9598E+00;       0.9933E+00;       0.93308E+00;       0.913E+00;         0.9732E+00;       0.9598E+00;       0.9464E+00;       0.93308E+00;       0.913E+00;         0.872E+00;       0.8706E+00;       0.9464E+00;       0.93308E+00;       0.913E+00;         0.7545E+00;       0.7138E+00;       0.6786E+00;       0.63652E+00;       0.789E+00;         0.75402E+00;       0.4822E+00;       0.63661E+00;       0.7871E+00;         0.255E+00;       0.1875E+00;       0.1071E+00;       1; <th>THETA       0.00       0.5E+01       0.1E+02       0.15E+02       0.2E+02       0.2E+02       0.3E+02       0.05E+02       0.6E+02       0.6E+03       0.115E+03       0.115E+03       0.115E+03       0.115E+03       0.115E+03       0.216+03&lt;</th>	THETA       0.00       0.5E+01       0.1E+02       0.15E+02       0.2E+02       0.2E+02       0.3E+02       0.05E+02       0.6E+02       0.6E+03       0.115E+03       0.115E+03       0.115E+03       0.115E+03       0.115E+03       0.216+03<

	APPER	DIX - CONTINUED ORIGINAL PAGE IS OF POOR QUALITY
IE+03,       0.27E+03,         IE+03,       0.3E+03,         IE+03,       0.32E+03,         I.       I.       I.         I.       I.       I.       I.         I.       I.       I.       I.       I.         I.       I.       I.       I.       I.       I.         I.       I.       I.       I.       I.       I.       I.         I.       I.       I.       I.       I.       I.       I.       I.         I.       I.       I.       I.       I.       I.       I.       I.       I.         I.       I.       I.       I.       I.       I.       I.       I.       I.	0.5E+01, 11E+02, I, I, I, I, 0.357E+00, 0.5355E+00, 0.714E+00, 0.8925E+00, 0.8925E+00, 1, I, I, I, I, I, I,	
0.266403, 0.26 0.266403, 0.26 0.526403, 0.29 0.356403, 0.329 0.356403, 0.329 0.356403, 0.329 0.326403, 0.329 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	4 E + 01, 0.45 E + 01, E + 01, 0.1 E + 02, ( 071 E + 00, 0.1428 E + 00, 0.3213 E + 00, + 00, 0.4598 E + 00, + 00, 0.6783 E + 00, + 1, 1, 1, 1, 1, 1, 1	
не на	1, 0.35E+01, 0.9 1, 0.8E+01, 0.9 0.714E-01, 0.9 285E+00, 0.2856E 285E+00, 0.4641E 069E+00, 0.6426E 854E+00, 0.8211E 854E+00, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,	
0.245E+C3.       0.25         0.275E+C3.       0.28         0.235E+C3.       0.31         0.335E+C3.       0.31         0.335E+C3.       0.31         1.1       1.1         1.1       1.1         1.1       1.1         1.1       1.1         1.1       1.1         1.1       1.1         1.1       1.1         1.1       1.1         1.1       1.1         1.1       1.1         1.1       1.1         1.1       1.1         1.1       1.1         1.1       1.1         1.1       1.1	<pre>= 0.6E+01, 0.3E+0 = 0.6E+01, 0.3E+0 1, 1, 1, 1, 1, = 0.0, 0.357E-01, = 0.0, 0.357E-01, 0.2142E+00, 0.4 0.3927E+00, 0.4 0.5712E+00, 0.4 0.5712E+00, 0.4 0.5712E+00, 0.4 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1</pre>	
THPRNT	VRRY Ybar	YMAX YMIN YSMAX YSMIN \$END

INPUT TABLES

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ним дивертивно наставляется области и на промитие назволяется на политие и и толяхование политие на ставляется п	energy and a second	میں میں ایک اور ایک	و مواقعه من جود و مواقعه ومواقعه ومواقعه ومنه ومنها ومنها ومنها ومنها ولو والمناصلة والمناصلة ومناصر ومناورو من والمناور والم	1999年,1999年,1997年,1997年,1997年,1997年,1997年,1997年,1997年,1997年,1997年,1997年,1997年,1997年,1997年,1997年,1997年			and a second	en an e a de la companya de la compa		A management of the same data with the same state of the same state of the same and the same of the same same same same same same same sam									PP	EN	DI			CO	NT	IN	JE	D											And And A A A AND AND AND AND AND AND AND AND A	enneme o mar de mer	Annahar	化化学学家 化化学学家 化化学学家 化化学学家 化化学学家 化化学学家 化化学学家 化化学学 化分子子 化分子子 化分子子 化分子子 化合金化合金 化合金化合金 化分子分子
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THETA         0.00         MOMENT         CD         0/C         DEL           VINDMIT         64.00         MOMENT         0/C         DEL         DEL           1:0000005         7.11         6.060485         0.1.6449145         DEL         DEL           1:0000005         7.11         6.060486         1.6449145         DEL         DEL         DEL           1:0000005         7.11         6.08045         DEL	THETA =       0.00         VBAR       CL       CD       DC         VBAR       T.11       6.8646994E-01       1.6453737E-02       2.3957835E-01         1.0000006E-02       7.12       6.97545416E-01       1.6459131E-02       2.3957835E-01         3.0000006E-02       7.12       6.9861446E-01       1.6459131E-02       2.3955841E-01       1.6531657E-02         3.0000006E-02       7.14       6.8861446E-01       1.6531657E-02       2.39556417E-01       1.6531657E-02         4.0000006E-02       7.14       6.8873266E-01       1.6531657E-02       2.39556418F-01       1.6531657E-02         7.0000000E-02       7.14       6.8873246E-01       1.65523189E-02       2.39555167E-01       1.65022946E-01         7.0000000E-02       7.14       6.9873546E-01       1.65523189E-02       2.3955167E-01       1.65022947E-01         1.0000000E-02       7.14       6.98775957E-01       1.65502597E-02       2.395516976-01       1.1         1.1000000E-02       7.12       6.88773957E-01       1.65502597E-02       2.3956497E-01       1.1         1.1000000E-01       7.12       6.88773957E-01       1.65502797E-02       2.395610976-01       1.1         1.1.0000000E-01       7.12       6.877995276-01       1.65502797E-02	XIQN364V 1.53261666-01 1.53261666-01 1.52839256-01 1.52839256-01 1.52839256-01 1.52839256-01 1.52831376-01 1.52831376-01 1.51890816-01 1.51890816-01 1.51837376-01 1.51137936-01
THE TA         0.00           VINOMIL         0.00           0.         0.00           0.         0.00           0.0000067-02         1.10           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000067-02         1.11           0.00000	THE TA0.00 $V \ ME \ M$ $V \ ME \ M$ $V \ ME \ M$ $O \ ME \ M$	XIQN3646 1.53261656-01 1.53261656-01 1.53052756-01 1.52839256-01 1.52839256-01 1.52839256-01 1.52839256-01 1.52271376-01 1.52271376-01 1.52290976-01 1.52290976-01 1.51137936-01 1.51137936-01 1.51137936-01 1.51137936-01 1.51137936-01 1.51137936-01 1.51137936-01 1.51137936-01 1.51137936-01 1.51137936-01 1.51137936-01 1.51137936-01 1.51137936-01 1.51137936-01 1.51137936-01 1.51137936-01 1.511379376-01 1.511379376-01 1.511379376-01 1.511379376-01 1.511379376-01 1.511379376-01 1.511379376-01 1.511379376-01 1.5113793776-01 1.5115777777777777777777777777777777777
WINNILL BLAR         NOT         OL	WINDWILL       BLADE       LIFT.DRAG       AND       MOMENT       CO       D/C         0.       YBAR       CL       CL       CO       D/C       D/C       D/C         1.       0.       YBAR       CAMMA       CL       D/C       D/C       D/C         1.       0.       7.11       6.88469915-01       1.646991316-02       2.39579836-01       1         1.       0.0000006F-02       7.112       6.8955446F-01       1.6557917F-02       2.3955947F-01       1         5.00000006F-02       7.14       6.8873566F-01       1.65527917F-02       2.3955567F-01       1         5.0000006F-02       7.14       6.8873567F-01       1.655327917F-02       2.3955907F-01       1         5.0000006F-02       7.14       6.8873567F-01       1.65532595F-02       2.3955907F-01       1         1.       0.000000F-02       7.14       6.8874567E-01       1.65532595F-02       2.3955907F-01       1         1.       0.000000F-02       7.11       6.8874567E-01       1.65528457E-02       2.3955918F-01       1         1.       0.000000F-02       7.11       6.8874567E-01       1.65528457E-02       2.3955918F-01       1         1.       0.000000F       7.11	DEL CM 1.5326166E-01 1.5326166E-01 1.5305275E-01 1.5283925E-01 1.5283925E-01 1.5283925E-01 1.5283925E-01 1.5227137E-01 1.5227137E-01 1.5229097E-01 1.5113793E-01 1.5113793E-01
Withowit         Bit         B	WINDWILL6LADELIFT, DRAGANDMOMENTCC $D/C$ 7.116.8846994E-011.64463737E-022.39957987-011.70000006E-027.126.88765414E-011.6449313E-022.39957987-012.00000006E-027.146.887646E-011.6518141E-022.3995591E-011.0000006E-027.146.8876476E-011.65237917E-022.3995591E-011.0000000E-027.146.8876476E-011.65532505E-022.3995593E-011.0000000E-027.146.8876476E-011.65532505E-022.3995593E-011.0000000E-027.146.8876476E-011.65524425E-0111.0000000E-027.146.8875456E-011.65524455E-022.3995593E-011.10000000E-027.146.8875456E-011.65524455E-022.3995593E-011.1000000E-027.116.8875456E-011.65524455E-022.3995593E-011.1000000E-017.136.8875456E-011.65524425E-0111.1000000E-017.136.8875456E-011.655244556-022.39954056-011.1000000E-017.116.8875456E-011.655244556-0111.1000000E-017.116.8875466E-011.655244556-0111.1000000E-017.116.8875755976-022.399540569E-0111.1000000E-017.116.887575527956-011.644517456-022.39656956-011.1000000E-017.006.8875756-011.644517456-022.39656956-011.1000000E-017.006.8877572796-011.644517456-022.39656956-01<	DEL CM 1.5326166E-01 1.5326166E-01 1.5305275E-01 1.5283925E-01 1.5283925E-01 1.5283925E-01 1.5283956-01 1.5227137E-01 1.5227137E-01 1.5229097E-01 1.5113793E-01 1.5113793E-01
WINDHILL BLADE   F1+DRAG AND HOMENT         CO         D/C         <	WINDMILL         BLAC         CL         CO         D/C           YBAR         GAMMA         CO         D/C         D/C           YBAR         GAMMA         CO         D/C         D/C           YBAR         GAMMA         CO         D/C         D/C           2.07000006F02         7.12         6.8755414E-01         1.6459131E-02         2.39556717E-01           2.07000006F02         7.14         6.8872506E-01         1.65531657E-02         2.39556717E-01           4.07000006F02         7.14         6.8877456F01         1.65531657E-02         2.3955506F01         1           5.0000006F02         7.14         6.887745F-01         1.65531657E-02         2.3955506F01         1           6.000006F02         7.14         6.8877456F01         1.65531657E-02         2.3955506F01         1           1.0000006F02         7.14         6.8877456F01         1.6553240F-02         2.3955607E-01         1           1.10000006F01         7.12         6.8877456F01         1.6553240F-02         2.3955716F-01         1           1.10000006F01         7.12         6.887456F01         1.65502596F02         2.39557166F01         1           1.10000006F01         7.12         6.887456F01         1.6550259	DEL CM 1.5326165E-01 1.5305275E-01 1.5283925E-01 1.5283925E-01 1.5283925E-01 1.5283925E-01 1.5283925E-01 1.5227137E-01 1.5227137E-01 1.5229097E-01 1.5113793E-01 1.5113793E-01
VBAR         GANIA         CL         D/C         D/C <thd <="" c<="" td=""><td>VBAR         CL         CO         D/C           0.         7.11         6.8864994F-01         1.6446137F-02         2.3956518F-01           2.0000000E-02         7.12         6.8706998F-01         1.649131E-02         2.395558F-01           2.0000000E-02         7.13         6.8861646E-01         1.6552717F-01         1           4.000000E-02         7.14         6.8861646E-01         1.65527917F-02         2.3955568F-01           7.000000E-02         7.14         6.8874266E-01         1.65523405F-02         2.3955566F-01           7.000000E-02         7.14         6.8877456F-01         1.6553260F-02         2.3955506F-01           7.0000000E-02         7.14         6.8874266F-01         1.6553260F-02         2.3955506F-01           7.0000000E-02         7.14         6.8874266F-01         1.6553260F-02         2.3955501E-01           1.10000000E-01         7.12         6.8874266F-01         1.6552294E-02         2.39556767E-01           1.20000000F-01         7.12         6.8874266F-01         1.6552294E-02         2.3956418F-01           1.2000000F-01         7.12         6.877597F-01         1.6552294E-02         2.39566186F-01           1.2000000F-01         7.12         6.877597F-01         1.6445146702         2.39566169701<td>DEL CM 1.5326166E-01 1.5305275E-01 1.5283925E-01 1.5262121E-01 1.5263137E-01 1.5227137E-01 1.5227137E-01 1.5227137E-01 1.5189081E-01 1.5113793E-01 1.5113793E-01</td></td></thd>	VBAR         CL         CO         D/C           0.         7.11         6.8864994F-01         1.6446137F-02         2.3956518F-01           2.0000000E-02         7.12         6.8706998F-01         1.649131E-02         2.395558F-01           2.0000000E-02         7.13         6.8861646E-01         1.6552717F-01         1           4.000000E-02         7.14         6.8861646E-01         1.65527917F-02         2.3955568F-01           7.000000E-02         7.14         6.8874266E-01         1.65523405F-02         2.3955566F-01           7.000000E-02         7.14         6.8877456F-01         1.6553260F-02         2.3955506F-01           7.0000000E-02         7.14         6.8874266F-01         1.6553260F-02         2.3955506F-01           7.0000000E-02         7.14         6.8874266F-01         1.6553260F-02         2.3955501E-01           1.10000000E-01         7.12         6.8874266F-01         1.6552294E-02         2.39556767E-01           1.20000000F-01         7.12         6.8874266F-01         1.6552294E-02         2.3956418F-01           1.2000000F-01         7.12         6.877597F-01         1.6552294E-02         2.39566186F-01           1.2000000F-01         7.12         6.877597F-01         1.6445146702         2.39566169701 <td>DEL CM 1.5326166E-01 1.5305275E-01 1.5283925E-01 1.5262121E-01 1.5263137E-01 1.5227137E-01 1.5227137E-01 1.5227137E-01 1.5189081E-01 1.5113793E-01 1.5113793E-01</td>	DEL CM 1.5326166E-01 1.5305275E-01 1.5283925E-01 1.5262121E-01 1.5263137E-01 1.5227137E-01 1.5227137E-01 1.5227137E-01 1.5189081E-01 1.5113793E-01 1.5113793E-01
0.       0. <td< td=""><td><math display="block">\begin{array}{c c c c c c c c c c c c c c c c c c c </math></td><td>1.53261666-01         1.53261666-01         1.53052756-01         1.52839256-01         1.52631216-01         1.52631376-01         1.52271376-01         1.51890816-01         1.51137936-01         1.51137936-01</td></td<>	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	1.53261666-01         1.53261666-01         1.53052756-01         1.52839256-01         1.52631216-01         1.52631376-01         1.52271376-01         1.51890816-01         1.51137936-01         1.51137936-01
1.0000000E-07       7.11       0.8666999E-01       1.649913EE-02       2.395798EF-01       1.526212E-01         2.0000000E-07       7.11       0.8801646E-01       1.6521041E-02       2.395596EF-01       1.5262137E-01         4.0000000E-02       7.14       0.8801646E-01       1.652108F-02       2.3955964E-01       1.552137E-01         4.000000E-02       7.14       0.8801646E-01       1.652108F-02       2.3955961E-01       1.552137E-01         5.000000E-02       7.14       0.887257E-01       1.6522506E-02       2.3955961E-01       1.55263137F-01         5.000000E-02       7.14       0.8876426F-01       1.6522506E-02       2.395540E-01       1.5526312F-01         5.000000E-02       7.14       0.8876426F-01       1.65225456F-02       2.395540F-01       1.555230F-01         5.000000E-01       7.11       0.8876456F-01       1.6552366F-02       2.395540FF-01       1.488106F-01         1.1000000E-01       7.11       0.8875456F-01       1.6572366F-01       1.4641746F-01       1.4478116-01         1.2000000E-01       7.11       0.8875466F-01       1.6572366F-01       1.4641746F-01       1.447811746F-01         1.20000000E-01       7.11       0.8875467F-01       1.6572366F-02       2.3955401FF-01       1.44781746F-01	0. $-239060991F - 01$ $1.649816.7E - 02$ $2.39957983F - 01$ $1.712$ $6.8755414E - 01$ $1.648316.7E - 02$ $2.39557983F - 01$ $1.712$ $6.87554146E - 01$ $1.6523167F - 02$ $2.3955563E - 01$ $1.712$ $6.98764746E - 01$ $1.65231657E - 02$ $2.3955563E - 01$ $1.712$ $6.9876476 + 01$ $1.65321657E - 02$ $2.3955563E - 01$ $1.712$ $6.9876476 + 01$ $1.653231687E - 02$ $2.3955563E - 01$ $1.712$ $6.9876476 + 01$ $1.653231687E - 02$ $2.3955563E - 01$ $1.712$ $1.712$ $6.887732467E - 01$ $1.653231687E - 02$ $2.3955506E - 01$ $1.712$ $1.712$ $6.88732546F - 01$ $1.653231687E - 02$ $2.39557447F - 01$ $1.712$ $1.712$ $6.88732344E - 01$ $1.653231687E - 02$ $2.39557447F - 01$ $1.712$ $1.712$ $6.88732344E - 01$ $1.65221667E - 01$ $1.65221667E - 01$ $1.712$ $1.712$ $6.88732344E - 01$ $1.65221667E - 01$ $1.712$ $1.712$ $6.8873371267 - 01$ $1.65221667E - 01$ $1.712$ $1.712$ $6.887336676 - 01$ $1.65221667 - 01$ $1.712$ $1.800000000$ $1.7102$ $1.8000000000000000000000000000000000000$	x1048647555-01 1.53052755-01 1.52839255-01 1.52831955-01 1.52831955-01 1.52831955-01 1.52831975-01 1.51890815-01 1.51890815-01 1.51137936-01
1.0000006F-02       7.12       6.9164914-01       1.6531311E-01       1.5283356110       1.528335610         3.0000006F-02       7.11       6.98164916       1.6531414-02       2.3955416-01       1.528313756-01         3.0000006F-02       7.14       6.98174166       1.6531416-02       2.3955446       1.52831376-01         5.0000006F-02       7.14       6.98175400       1.6531316F-02       2.3955446       1.52831376-01         5.0000006F-02       7.14       6.98175406F       1.65323406F-02       2.3955446F       1.528313776-01         5.0000006F-02       7.14       6.98175476F       1.65323406F       2.3955446F       1.51843776-01         1.0000006F-02       7.14       6.98175476F       1.6552346F       2.3955416F       1.4731476F       1.4731476F         1.00000006F-01       7.11       6.9835715F       1.65523475F       1.65523475F       1.65523475F       1.6450576F       1.4731476F       0.144736176F       0.144736176F       1.4731476F       0.144736176F       0.14474617       0.144736176F       0.144736176F       0.14476176       0.14476176       0.144736176F	$\begin{array}{c} 1.0000000 f = 02 \\ 2.0990000 f = 02 \\ 7.12 \\ 6.89755414 = 01 \\ 1.6516141 = 02 \\ 2.39556177 = 01 \\ 1.6516141 = 02 \\ 2.3955637 = 01 \\ 1.65000000 f = 02 \\ 7.14 \\ 6.8861646 = 01 \\ 1.65231657 = 02 \\ 2.3955564 = 01 \\ 1.65231657 = 02 \\ 2.3955504 = 01 \\ 1.65231657 = 02 \\ 2.3955504 = 01 \\ 1.65231657 = 02 \\ 7.14 \\ 6.887757 = 01 \\ 1.65231657 = 02 \\ 7.14 \\ 5.887757 = 01 \\ 1.65231657 = 02 \\ 7.14 \\ 5.887757 = 01 \\ 1.65231657 = 02 \\ 7.12 \\ 5.887757 = 01 \\ 1.65231657 = 02 \\ 7.12 \\ 5.8877597 = 01 \\ 1.65231657 = 02 \\ 7.12 \\ 5.8877597 = 01 \\ 1.65231657 = 02 \\ 7.12 \\ 5.880237157 = 01 \\ 1.65231657 = 02 \\ 7.12 \\ 5.8955506 = 02 \\ 7.14 \\ 5.880237157 = 01 \\ 1.65231657 = 02 \\ 2.3955106 = 01 \\ 7.12 \\ 5.8734567 = 01 \\ 1.65231657 = 02 \\ 2.3957166 = 01 \\ 1.6600006 = 01 \\ 7.11 \\ 5.86473265 = 01 \\ 1.6418555 = 02 \\ 2.39561695 = 01 \\ 1.64000006 = 01 \\ 7.01 \\ 5.84750667 = 01 \\ 1.6418555 = 02 \\ 2.39561696 = 01 \\ 1.6418555 = 02 \\ 2.39561696 = 01 \\ 1.6418555 = 02 \\ 2.39561696 = 01 \\ 1.6418555 = 02 \\ 2.39561696 = 01 \\ 1.6418555 = 02 \\ 2.39561696 = 01 \\ 1.6418555 = 02 \\ 2.39561696 = 01 \\ 1.6418555 = 02 \\ 2.39561696 = 01 \\ 1.6418555 = 02 \\ 2.39561696 = 01 \\ 1.6418555 = 02 \\ 2.39561696 = 01 \\ 1.6418555 = 02 \\ 2.39561696 = 01 \\ 1.6418555 = 02 \\ 2.39561696 = 01 \\ 1.6525556 = 02 \\ 2.39561696 = 01 \\ 1.6525556 = 02 \\ 2.39561696 = 01 \\ 1.652555 = 02 \\ 2.39561696 = 01 \\ 1.652555 = 02 \\ 2.39561696 = 01 \\ 1.652555 = 02 \\ 2.39561693 = 01 \\ 1.652555 = 01 \\ 1.652555 = 01 \\ 1.652555 = 01 \\ 1.652555 = 01 \\ 1.652555 = 01 \\ 1.652555 = 01 \\ 1.652555 = 01 \\ 1.652555 = 01 \\ 1.652555 = 02 \\ 2.39561693 = 01 \\ 1.652955 = 02 \\ 1.652555 = 01 \\ 1.6525555 = 02 \\ 1.652555 = 01 \\ 1.652555 = 02 \\ 1.652555 = 01 \\ 1.652555 = 02 \\ 1.652555 = 02 \\ 1.652555 = 01 \\ 1.652555 = 02 \\ 1.652555 = 01 \\ 1.652555 = 02 \\ 1.652555 = 01 \\ 1.652555 = 02 \\ 1.652555 = 01 \\ 1.652555 = 01 \\ 1.652555 = 02 \\ 1.652555 = 01 \\ 1.652555 = 02 \\ 1.652555 = 02 \\ 1.652555 = 02 \\ 1.652555 = 02 \\ 1.652555 = 02 \\ 1.652555 = 02 \\ 2.3956569 = 01 \\ 1.652555 = 02 \\ 1.652555 = 02 \\ 1.6525555 = 02 \\ 1.652555 = 02 $	1. 5305275E-01 1. 5283925E-01 1. 5283925E-01 1. 5283925E-01 1. 5227137E-01 1. 5229097E-01 1. 5209097E-01 1. 5189081E-01 1. 5154327E-01 1. 5113793E-01
Z.0000006=02       7.12       6.9355446=01       1.655164610       1.55212151=01         4.000006=02       7.14       6.987256610       1.65516717=02       2.3955611=01       1.52231777=01         5.0000006=02       7.14       6.98736456=01       1.65525656=02       2.3955616=01       1.5523177=01         7.0000006=02       7.14       6.98736456=01       1.65525656=02       2.39555016=01       1.55231776=01         7.0000006=02       7.14       6.9873456=01       1.65525056=02       2.39555016=01       1.51137936         7.0000006=01       7.14       6.9873456=01       1.655225465=01       1.655225465=01       1.655225465=01       1.655225465=01         1.10000006=01       7.11       6.98734565       1.65520566=02       2.39559156=01       1.4817466=01         1.11       6.987355566=01       1.65520566=02       2.39551516=01       1.4817466=01         1.11       5.9000006=01       7.11       6.987355566=01       1.6572046=01       1.4817466=01         1.120000006=01       7.10       6.98725566=01       1.6572046=01       1.4817466=01       1.4817466=01         1.120000006=01       7.10       6.98725566=01       1.64505766=01       1.44517456=01       1.44517466=01         1.200000006=01       7.10       6.	Z.0000006-02       7.12       6.8822866-01       1.655161717E-02       2.395543E-01         J.0000006-02       7.14       6.8819260E-01       1.6552191F-02       2.3955449E-01         J.0000006-02       7.14       6.8879260E-01       1.65521657E-02       2.3955563E-01         J.0000006-02       7.14       6.8879260E-01       1.65521657E-02       2.3955506E-01         J.0000006-02       7.14       6.8879260E-01       1.65526456-02       2.3955506E-01         J.0000006-02       7.14       6.8879575-01       1.65526456       1.1         J.0000006-02       7.14       6.8875456E-01       1.65526456       1.1         J.10000006-01       7.12       6.88754565-01       1.655284566       1.1         J.10000006-01       7.12       6.88754565       1.65528456       1.1         J.120000006-01       7.12       6.88754565       1.65528456       1.1         J.120000006-01       7.12       6.88754565       1.65528456       1.1         J.120000006-01       7.12       6.88754565       1.656284565       1.1         J.120000006-01       7.12       6.88754565       1.656284567       1.1         J.120000006-01       7.12       6.86734566       1.656284567       2.395646567 <td>1.52839256-01         1.5262121E-01         1.52621217-01         1.52271376-01         1.52209097E-01         1.5189081E-01         1.5113793E-01</td>	1.52839256-01         1.5262121E-01         1.52621217-01         1.52271376-01         1.52209097E-01         1.5189081E-01         1.5113793E-01
3.000000000000000000000000000000000000	3,0000005-02       7.13       6.8822865-01       1.653161415-02       2.395564175-01         5,0000005-02       7.14       6.88732665-01       1.6531655-02       2.39556456-01         5,0000005-02       7.14       6.88732665-01       1.65325055-02       2.39556475-01       1         6,0000005-02       7.14       6.88732665-01       1.6532505505       2.3955647570-01       1         7,0000005-02       7.14       6.88759266-01       1.655245505       2.3955667126-01       1         10,0000005-01       7.12       6.88759324501       1.65501916-02       2.39559125-01       1         11,0000006-01       7.12       6.887595715-01       1.65501916-02       2.395561076701       1         11,20000006-01       7.12       6.877599276-01       1.6550294502       2.3957456501       1         11,20000005-01       7.12       6.877599276-01       1.6570294502       2.39564696701       1         11,20000005-01       1.6570294502       2.395646956-01       1       1         11,70000005-01       1.64730265-02       2.395646956-01       1       1         11,70000005-01       1.64730265-02       2.395646956-01       1       1         11,70000005-01       1.6485052766-01       1.6473026502 <td>1.5262121E-01         1.5263121E-01         1.5227137E-01         1.5227137E-01         1.5189081E-01         1.5187081E-01         1.5113793E-01</td>	1.5262121E-01         1.5263121E-01         1.5227137E-01         1.5227137E-01         1.5189081E-01         1.5187081E-01         1.5113793E-01
4,0000000E-02       7.14       6.0001446E-01       1.6521657E-02       2.395564E-01       1.5237137E-01         5,0000000E-02       7.14       6.0001446E-01       1.6521657E-02       2.3955501E-01       1.511379E-01         7,0000000E-02       7.14       6.00014501       1.6522346E-01       1.6522346E-01       1.6522346E-01       1.6522346E-01       1.6522346E-01       1.6522346E-01       1.6522346E-01       1.552346E-01       1.552346E-01       1.552346E-01       1.552346E-01       1.552346E-01       1.552346E-01       1.552346E-01       1.552350EE-02       2.3955501E-01       1.511379E-01         9,0000000E-01       7.112       6.007232E-01       1.65220131E-02       2.3955616E-01       1.4914992E-01         11,000000E-01       7.112       6.007232E-01       1.6520131E-02       2.39561616-01       1.491746E-01         11,2000000E-01       7.11       6.007236E-01       1.6520131E-02       2.39561657E-01       1.491746E-01         11,2000000E-01       7.11       6.007236E-01       1.641757E-02       2.39561657E-01       1.491746E-01         11,2000000E-01       7.10       6.007236E-01       1.6418747E-02       2.3956057E-01       1.491746E-01         11,2000000E-01       7.10       6.007236E-01       1.6418774E-02       2.3956057E-01       1.941746E-01 <td>5.0000000E-02       7.14       5.9851240EF-01       1.6531657F-02       2.3955563F-01         7.0000000E-02       7.14       5.9874146F-01       1.6531657F-02       2.3955563F-01         7.0000000F-02       7.14       5.9875426F-01       1.6531657F-02       2.3955563F-01         7.0000000F-02       7.14       5.9875426F-01       1.6532340F-02       2.3955560F-01         7.0000000F-02       7.14       5.9875426F-01       1.6532340F-02       2.3955516F-01         8.0000000F-02       7.114       5.8875926F-01       1.6520158F-02       2.3955916F-01         1.000000E-01       7.12       6.8875957F-01       1.6520158F-02       2.39559160F-01         1.2000000F-01       7.12       6.8875952F-01       1.6520158F-02       2.3957160F-01         1.2000000F-01       7.12       6.8875952F-01       1.6473026F-02       2.3957160F-01         1.2000000F-01       7.12       6.887595254FF-01       1.6489909F-02       2.395160F-01         1.600000F-01       7.11       6.860236FF-01       1.6451755276-02       2.3956468F9-01         1.6000000F-01       7.12       6.840328FF-01       1.64517552776-02       2.3956476F-01         1.6000000F-01       7.00       6.840236FF-01       1.64517552776-02       2.395646767F-01      &lt;</td> <td>1.52271376-01         1.52271376-01         1.52271376-01         1.522090976-01         1.5189081E-01         1.51543276-01         1.51137936-01</td>	5.0000000E-02       7.14       5.9851240EF-01       1.6531657F-02       2.3955563F-01         7.0000000E-02       7.14       5.9874146F-01       1.6531657F-02       2.3955563F-01         7.0000000F-02       7.14       5.9875426F-01       1.6531657F-02       2.3955563F-01         7.0000000F-02       7.14       5.9875426F-01       1.6532340F-02       2.3955560F-01         7.0000000F-02       7.14       5.9875426F-01       1.6532340F-02       2.3955516F-01         8.0000000F-02       7.114       5.8875926F-01       1.6520158F-02       2.3955916F-01         1.000000E-01       7.12       6.8875957F-01       1.6520158F-02       2.39559160F-01         1.2000000F-01       7.12       6.8875952F-01       1.6520158F-02       2.3957160F-01         1.2000000F-01       7.12       6.8875952F-01       1.6473026F-02       2.3957160F-01         1.2000000F-01       7.12       6.887595254FF-01       1.6489909F-02       2.395160F-01         1.600000F-01       7.11       6.860236FF-01       1.6451755276-02       2.3956468F9-01         1.6000000F-01       7.12       6.840328FF-01       1.64517552776-02       2.3956476F-01         1.6000000F-01       7.00       6.840236FF-01       1.64517552776-02       2.395646767F-01      <	1.52271376-01         1.52271376-01         1.52271376-01         1.522090976-01         1.5189081E-01         1.51543276-01         1.51137936-01
$ \begin{array}{c} 4,0000000 = 02 \\ 7,14 \\ 6,887547 = 01 \\ 1,65323567 = 02 \\ 2,3955545 = 01 \\ 1,527375 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51737 = 01 \\ 1,51777 = 01 \\ 1,51$	4,0300000000000000000000000000000000000	1.5243195E-01         1.5227137E-01         1.5227137E-01         1.52209097E-01         1.5189081E-01         1.5154327E-01         1.5113793E-01
5,0000006-02       7,14       5,8879266F-01       1.6532308F-02       2.3955545F-01       1.5227137F-01         8,0000006-02       7,14       6,8879246F-01       1.6552346F-02       2.3955501F-01       1.511793F-01         8,0000006-02       7,14       6,887542F-01       1.6552842FF-02       2.3955501F-01       1.5119792F-01         8,0000006-01       7,13       6,887542F-01       1.6552842FF-02       2.39554418F-01       1.511793FF-01         1,0000006-01       7,13       6,887594FF-01       1.6550194FF-02       2.39554418F-01       1.511793FF-01         1,20000006-01       7,11       6,8875942F-01       1.6550194FF-02       2.3956444F-01       1.6475926F         1,20000006-01       7,11       6,887394F-01       1.6473026F-02       2.3956469F       1.4485997         1,20000006-01       7,11       6,887394F-01       1.6473026F-02       2.39561697       1.4487897         1,50000006-01       7,11       6,887394F-01       1.6473026F-02       2.39561697       1.4487897         1,6000006-01       7,11       6,8860376F-01       1.6473036F-01       1.4477817FE-01       1.4477817FE-01         1,80000006-01       7,01       6,886037FF-01       1.6477307FF-01       1.4477817FE-01       1.4477817FE-01         1,80000006-01 <td>5.0000006-02       7.14       5.887446F-01       1.6531657F-02       2.3955563F-01       1         7.0000006-02       7.14       6.88776501       1.6533188F-02       2.3955566F-01       1         7.0000006-02       7.14       6.88764266F-01       1.6532456F-02       2.39555126-01       1         9.0000006-01       7.14       6.88754266F-01       1.6520158F-02       2.3955418F-01       1         1.2000006F-01       7.12       6.8875456F-01       1.6520158F-02       2.39557160F-01       1         1.2000006F-01       7.12       6.88734569F-01       1.6520158F-02       2.3955126F-01       1         1.2000006F-01       7.12       6.887345696F-01       1.6570191E-02       2.3957140E-01       1         1.2000006F-01       7.12       6.887345696F-01       1.64773026F-02       2.39567676F-01       1         1.50000006F-01       7.11       6.887345696F-01       1.64773026F-02       2.3956767F-01       1         1.60000006F-01       7.10       6.887345696F-01       1.64773026F-02       2.3956767F-01       1         1.70000006F-01       7.10       6.887345697F-01       1.6473026F-02       2.3966767F-01       1         1.70000006F-01       7.09       6.88525547FF-01       1.647357F-02       2</td> <td>1       1.52271376-01         1       52090976-01         1       52090916-01         1       51890816-01         1       51543276-01         1       51137936-01</td>	5.0000006-02       7.14       5.887446F-01       1.6531657F-02       2.3955563F-01       1         7.0000006-02       7.14       6.88776501       1.6533188F-02       2.3955566F-01       1         7.0000006-02       7.14       6.88764266F-01       1.6532456F-02       2.39555126-01       1         9.0000006-01       7.14       6.88754266F-01       1.6520158F-02       2.3955418F-01       1         1.2000006F-01       7.12       6.8875456F-01       1.6520158F-02       2.39557160F-01       1         1.2000006F-01       7.12       6.88734569F-01       1.6520158F-02       2.3955126F-01       1         1.2000006F-01       7.12       6.887345696F-01       1.6570191E-02       2.3957140E-01       1         1.2000006F-01       7.12       6.887345696F-01       1.64773026F-02       2.39567676F-01       1         1.50000006F-01       7.11       6.887345696F-01       1.64773026F-02       2.3956767F-01       1         1.60000006F-01       7.10       6.887345696F-01       1.64773026F-02       2.3956767F-01       1         1.70000006F-01       7.10       6.887345697F-01       1.6473026F-02       2.3966767F-01       1         1.70000006F-01       7.09       6.88525547FF-01       1.647357F-02       2	1       1.52271376-01         1       52090976-01         1       52090916-01         1       51890816-01         1       51543276-01         1       51137936-01
0,0000005-02       7.14       6.08792607-01       1.65335055-02       2.39555070-01       1.51137935-01         9,0000005-02       7.14       6.0876475-01       1.65325055-02       2.39555052-01       1.51137935-01         9,0000005-01       7.14       6.08754575-01       1.65525475-01       1.65127415-01       1.51137935-01         9,0000005-01       7.112       6.08754576-01       1.655224456-02       2.39559035-01       1.45137457-01         11,0000005-01       7.112       6.8735956-01       1.65522946-02       2.39559476-01       1.49549926-01         11,0000005-01       7.111       6.87345925-01       1.645502746-01       1.64553946-01       1.448519446-01         11,0000005-01       7.111       6.8734650-01       1.645502745-02       2.39559475-01       1.4455946-01         11,5000005-01       7.111       6.8672466-01       1.645502745-02       2.39551645-01       1.44559546-01         11,5000005-01       7.107       6.8672466-01       1.645502746-01       1.64559346-01       1.44559546-01         11,50000005-01       7.07       6.8457067670       1.64550276-02       2.395645276-01       1.475555476-01         11,50000005-01       7.07       6.84527696-01       1.645557476-01       1.445555546-01         11,50000005-0	6.000000000000000000000000000000000000	1.5209076-01         1.51890816-01         1.51843276-01         1.51137936-01
7.000000000000000000000000000000000000	7.00000006-02       7.14       6.8876476-01       1.653250560       2.39555006-01         8.0000006-02       7.14       6.8876426E-01       1.65528425E-02       2.39555056-01         9.0000006-01       7.12       6.88753756-01       1.655284256-02       2.39555056-01         1.10000006-01       7.13       6.887345656-01       1.655201586-02       2.39555056-01         1.10000006-01       7.12       6.887345656-01       1.65201586-02       2.39557476-01         1.20000006-01       7.12       6.87345656-01       1.65201586-02       2.3955766-01         1.20000006-01       7.12       6.873456567-01       1.644730266-02       2.3955766-01         1.20000006-01       7.10       6.87456676-01       1.644730266-02       2.395676676-01         1.50000006-01       7.10       6.86776676-01       1.644730266-02       2.395676676-01         1.6000006-01       7.10       6.86403286-01       1.644730266-02       2.395676676-01         1.6000006-01       7.10       6.86403769676-01       1.644730266-02       2.39564696901         1.70000006-01       7.00       6.8640576901       1.644730266-02       2.39646256-01       1.22000006-01         1.70000006-01       7.00       6.844965766701       1.64435576702       2.39669696	1.5189081E-01 1.5154327E-01 1.5113793E-01
7.000000000000000000000000000000000000	7.0000006-027.14 $6.8876977F-01$ $1.65532340E-02$ $2.3955512E-01$ 9.0000006-017.13 $6.887592F-01$ $1.65520158E-02$ $2.3955803E-01$ 1.0000006-017.13 $6.8802397E-01$ $1.65520158E-02$ $2.3955803E-01$ 1.0000006-017.13 $6.8802397E-01$ $1.65502294E-02$ $2.3955803E-01$ 1.2000006-017.12 $6.875925E-01$ $1.65502294E-02$ $2.3955803E-01$ 1.2000006-017.12 $6.8734565F-01$ $1.65502294E-02$ $2.3957147E-01$ 1.2000006-017.12 $6.8734565F-01$ $1.65502294E-02$ $2.395669E-01$ 1.5000006-017.10 $6.8640328E-01$ $1.6473026E-02$ $2.3956669E-01$ 1.5000006-017.10 $6.8660769E-01$ $1.6473026E-02$ $2.3966603E-01$ 1.7000006-017.09 $6.8467069E-01$ $1.6473026E-02$ $2.3966609E-01$ 1.80000006-017.09 $6.8457069E-01$ $1.6473026E-02$ $2.3966609E-01$ 1.90000006-017.09 $6.8467069E-01$ $1.6425531E-02$ $2.3966609E-01$ 2.0000006-017.09 $6.826577E-01$ $1.63259247E-02$ $2.3966969E-01$ 2.0000006-017.09 $6.826577E-01$ $1.632592826E-02$ $2.3966969E-01$ 2.0000006-017.09 $6.826577E-01$ $1.632592826E-02$ $2.3966969E-01$ 2.0000006-017.09 $6.82756F-01$ $1.63253276F-02$ $2.39669696E-01$ 2.0000006-017.00 $6.827596F-01$ $1.63253926E-02$ $2.3966963E-01$ 2.0000006-017.02 $6.8273576-01$ $1.632596$	1.51890815-01 1.1.51543275-01 1.51137936-01
8.0000006-02       7.14       6.8876.26E-01       1.652346E-02       2.395593E-01       1.5513795E-01         1.0000006-01       7.13       6.8835715F-01       1.65520158E-02       2.3957160E-01       1.5513795E-01         1.0000006-01       7.13       6.8835715F-01       1.65520158E-02       2.3957160E-01       1.5018074F-01         1.1000006-01       7.12       6.8875952E-01       1.6550158E-02       2.39550569E-01       1.4954957E-01         1.1000006-01       7.11       6.867908F-01       1.6550256F-02       2.39550569E-01       1.498106F-01         1.5000006-01       7.11       6.867058E-01       1.6473026F-02       2.395505691       1.455304F-01         1.5000006-01       7.10       6.860769F-01       1.6450527F-02       2.3961603F-01       1.475817F-01         1.5000006F-01       7.09       6.860769F-01       1.6450527F-02       2.3961603F-01       1.475817F-01         1.50000006F-01       7.09       6.862765F-01       1.6450527F-02       2.396496491       1.4753104F-01         1.50000006F-01       7.09       6.8225954F-01       1.6450527F-01       1.447281F-01       1.447281F-01         2.50000006F-01       7.07       5.845056F-01       1.447281F-01       1.447281F-01       1.447281F-01         2.10000006F-	8.0000000E-02       7.14       6.8876426E-01       1.6528425E-02       2.3955512E-01         1.000000E-01       7.12       6.985344E-01       1.6528425E-02       2.3957160E-01         1.1000000E-01       7.12       6.985344E-01       1.6520158E-02       2.3957160E-01         1.2000000E-01       7.12       6.9875957E-01       1.65502544E-02       2.395747E-01         1.2000000E-01       7.12       6.8734569E-01       1.65502294E-02       2.3957926-01         1.2000000E-01       7.11       6.86734569E-01       1.6570224E-02       2.3957926-01         1.5000000E-01       7.11       6.8673696E-01       1.6542026E-02       2.39560767E-01         1.4000000E-01       7.10       6.8640328E-01       1.6443695277E-02       2.39667677E-01         1.4000000E-01       7.09       6.8640328E-01       1.6443695277E-02       2.39667677E-01         1.8000000E-01       7.09       6.84966767E-01       1.64436957E-02       2.39667667E-01         1.8000000E-01       7.09       6.8252547E-01       1.64436957E-02       2.396676627E-01       1.         1.8000000E-01       7.09       6.8252547E-01       1.64436957E-02       2.396676627E-01       1.         2.0000000E-01       7.07       6.82796767E-01       1.64436957E-02	L 1.5154327E-01
9,000000E-02 77.14 6.9843344E-01 1.6526425E-0? 2.39554168E-01 1.5013793E-01 1.2000000E-01 77.12 6.8802397E-01 1.65720191E-02 2.3957147E-01 1.4817446E-01 1.200000E-01 77.12 6.8734565E-01 1.65720191E-02 2.39591605E-01 1.48184166E-01 1.200000E-01 77.11 6.8673028E-01 1.64489099E-02 2.395916057E-01 1.4818416E-01 1.700000E-01 77.11 6.8673028E-01 1.64489591E-02 2.395916037E-01 1.481841E-01 1.700000E-01 77.09 6.852547E-01 1.64489555E-02 2.396516637E-01 1.472817E-01 1.800000E-01 77.09 6.852547E-01 1.64488555E-02 2.396516637E-01 1.472817E-01 1.800000E-01 77.09 6.852547E-01 1.64488555E-02 2.396516637E-01 1.472817E-01 1.800000E-01 77.09 6.8327956E-01 1.642851E-02 2.396516677E-01 1.472817E-01 2.000000E-01 77.09 6.8327956E-01 1.652547E-02 2.3965965E-01 1.472817E-01 2.2000000E-01 77.09 6.8327956E-01 1.652547E-02 2.39658058E-01 1.3753588E-01 2.2000000E-01 77.09 6.8376577E-01 1.65358247E-02 2.39658058E-01 1.3753586E-01 2.2000000E-01 77.09 6.8376577E-01 1.65358264E-02 2.39658058E-01 1.3753548E-01 2.2000000E-01 77.09 6.8376577E-01 1.65358264E-02 2.39658195E-01 1.37536491E-01 2.2000000E-01 77.09 6.87165701 1.6525981E-02 2.397545626-01 1.37536491E-01 2.4000000E-01 1.652598664E-01 1.652598266E-02 2.39712059E-01 1.325100366E-01 2.4000000E-01 6.99 6.7737186F-01 1.6225981E-02 2.39712059E-01 1.325100366E-01 2.000000E-01 6.99 6.7737186F-01 1.6225981E-02 2.3981056-01 1.322454E-02 2.30910505E-01 1.6225981E-02 2.39911056-01 1.2202545E-01 2.000000E-01 6.99 6.7737186F-01 1.6225981E-02 2.3981056E-01 1.22025545E-01 2.000000E-01 6.99 6.7737186F-01 1.62210674E-02 2.3981056E-01 1.2202564E-01 2.000000E-01 6.99 6.7737186F-01 1.6221674E-02 2.3981056E-01 1.2210546E-01 2.000000E-01 6.99 6.7737186F-01 1.62216428128E-02 2.3981056E-01 1.2210546E-01 2.000000E-01 6.99 6.7737186F-01 1.6221674E-02 2.3981056E-01 1.2210546E-01 2.000000E-01 6.99 6.7737186F-01 1.6221677E-02 2.3981056E-01 1.2210546E-01 2.000000E-01 6.99 6.7757186F-01 1.62216776440E-02 2.3981056E-01 1.221056E-01 2.2000000E-01 6.99 6.7757186F-01 1.66259347E-02 2.39891056E-01 1.2210566E-01 2.2000000E	9.000000E-02       7.14       6.9853344E-01       1.6520458E-02       2.3955803E-01         1.2000000E-01       7.13       6.9875992E-01       1.6520158E-02       2.3957147E-01         1.2000000E-01       7.13       6.873456901       1.6520158E-02       2.3957147E-01         1.2000000E-01       7.13       6.875992E-01       1.6502294E-02       2.3957147E-01         1.2000000E-01       7.12       6.8734569701       1.6502294E-02       2.3956169701         1.2000000E-01       7.11       6.8678084E-01       1.6473026E-02       2.3956160971         1.4000000E-01       7.10       6.8677696E-01       1.6447359276F-02       2.396676776F-01         1.7000000E-01       7.10       6.86403268E-01       1.6447355716-02       2.39667676F-01         1.7000000E-01       7.09       6.864037696F-01       1.6447355716-02       2.39667676F-01         1.7000000E-01       7.07       6.8253766F-01       1.64535716F-02       2.396666256F-01         2.0000000E-01       7.07       6.827306F-01       1.64535706F-02       2.39666956F-01         2.1000000E-01       7.07       6.827306F-01       1.64535706F-02       2.39666956F-01       1.23000006F-02         2.1000000E-01       7.07       6.827306F-01       1.6535966676F-02       2.39	1.5113793E-01
1.0000000E-01       7.12       6.9892397E-01       1.651031E-02       2.3957160E-01       1.6518074E-01         1.1000000E-01       7.12       6.9862397E-01       1.651031E-02       2.3957160E-01       1.4954952-01         1.1000000E-01       7.12       6.9873565E-01       1.651031E-02       2.3957160E-01       1.4951495E-01         1.1000000E-01       7.11       6.98673696E-01       1.6480294E-02       2.395677E-01       1.495495991E-01         1.500000E-01       7.11       6.9867369E-01       1.6473026E-02       2.395677E-01       1.4956994E-01         1.500000E-01       7.09       6.952547E-01       1.64730257E-02       2.3966777E-01       1.447381E-01         1.7000000E-01       7.09       6.98470567E-01       1.6418556-02       2.396607567E-01       1.4473817E-01         1.9000000E-01       7.09       6.98470567E-01       1.64355276-02       2.39663767E-01       1.4473817E-01         1.9000000E-01       7.07       6.98470567E-01       1.644188556-02       2.396632766-01       1.4473817E-01         2.1000000E-01       7.07       6.9847676-01       1.644188556-02       2.3966326606-01       1.4473817E-01         2.1000000E-01       7.07       6.9847676-01       1.644188556-02       2.39663669096-01       1.4473817E-01	0.0000000E-01 $7.12$ $6.88023715F-01$ $1.65502594E-02$ $2.3955418F-01$ $1.1000000E-01$ $7.12$ $6.8875992F-01$ $1.65502294E-02$ $2.39554747E-01$ $1.2000000E-01$ $7.12$ $6.8775992F-01$ $1.65502294E-02$ $2.3956469E-01$ $1.2000000E-01$ $7.12$ $6.8775992F-01$ $1.65702294E-02$ $2.3958669E-01$ $1.5000000E-01$ $7.12$ $6.8734569F-01$ $1.6473026E-02$ $2.3958669F-01$ $1.5000000E-01$ $7.10$ $6.8640328E-01$ $1.6473026E-02$ $2.39561603F-01$ $1.7000000E-01$ $7.10$ $6.8640328E-01$ $1.6473026F-02$ $2.3964767F-01$ $1.7000000E-01$ $7.10$ $6.8649256+01$ $1.6473026F-02$ $2.3964767F-01$ $1.7000000E-01$ $7.09$ $6.8496678F-01$ $1.6435531E-02$ $2.3964767F-01$ $1.8000000E-01$ $7.09$ $6.8496078F-01$ $1.6435531F-02$ $2.3964623F-01$ $1.9000000E-01$ $7.09$ $6.822790F-01$ $1.635527F-02$ $2.396496928F-01$ $2.2000000E-01$ $7.00$ $6.82235577F-01$ $1.6355247F-02$ $2.39649528F-01$ $2.2000000E-01$ $7.00$ $6.82230577F-01$ $1.6355247F-02$ $2.39649528F-01$ $2.3000000E-01$ $7.00$ $6.82306577F-01$ $1.6355247F-02$ $2.39649528F-01$ $2.3000000E-01$ $7.00$ $6.8278577F-01$ $1.6355247F-02$ $2.3964955F-01$ $2.3000000E-01$ $7.00$ $6.8278577F-01$ $1.6355247F-02$ $2.39649565F-01$ $2.4000000E-01$ $7.00$ $6.8230567F-01$ $1.63725396F-02$ $2.39772$	
1.0000000E-01       7.13       6.887337E-01       1.6550138E-02       2.3956418E-01       1.5008074E-01         1.1000000E-01       7.12       6.8874567E-01       1.65501391E-02       2.3957447E-01       1.4817445E-01         1.2000000E-01       7.11       6.8774567E-01       1.65501391E-02       2.39595467E-01       1.4817445E-01         1.2000000E-01       7.11       6.8774567E-01       1.6473026E-02       2.39595467-01       1.4818466-01         1.4000000E-01       7.10       6.8602769E-01       1.64730261-02       2.3961603E-01       1.4472817E-01         1.4000000E-01       7.10       6.8602769F-01       1.64730261-02       2.3961603E-01       1.4472817E-01         1.4000000E-01       7.09       6.8622796F-01       1.64188551-02       2.3964925E-01       1.4472817E-01         1.8000000E-01       7.09       6.8825647E-01       1.64188551-02       2.3964926101       1.4472817E-01         1.8000000E-01       7.09       6.822790F-01       1.64339276101       1.4472817E-01       1.4472817E-01         2.2000000E-01       7.07       5.8223067701       1.64339276101       1.4472817E-01       1.4472817E-01         2.2000000E-01       7.07       5.8223067701       1.64339376760       1.44728176-01       2.236489276701       2.3564969267	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	
1.1000006-01       7.13       6.8802397E-01       1.6510191E-02       2.3957147E-01       1.50180745-01         1.2000006-01       7.12       6.877592E-01       1.65502294E-02       2.39559577E-01       1.4954992E-01         1.2000006-01       7.11       6.877592E-01       1.64573026E-02       2.39559927E-01       1.495496E-01         1.4000006-01       7.11       6.877592E-01       1.64575702       2.395606767-01       1.4472817E-01         1.4000006-01       7.01       6.852547E-01       1.6450527E-02       2.3956053E-01       1.4472817E-01         1.4000006-01       7.09       6.852547E-01       1.6445020226-01       1.645057E-01       1.4472817E-01         1.4000006-01       7.09       6.852547E-01       1.645057E-02       2.395650576-01       1.4472817E-01         1.4000006-01       7.09       6.822596E-01       1.6450577E-02       2.396693559-01       1.4472817E-01         2.40000006-01       7.07       5.822796E-01       1.64516276-02       2.399656575-01       1.447281056-01         2.40000006-01       7.07       5.822796E-01       1.6451676-02       2.3965955556-01       1.44728106-01         2.40000006-01       7.07       5.822796E-01       1.6537876E-02       2.396596926-01       1.447281076-01         2	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	[ ].5069444E-01
1.2000000E-01       7.12       6.877592E-01       1.6485909E-02       2.39597447E-01       1.4954992E-01         1.200000E-01       7.11       6.86786967E-01       1.6461745E-02       2.3956057E-01       1.4954992E-01         1.5000006E-01       7.11       6.867294E-02       2.3956076F-01       1.4954992E-01         1.6000006E-01       7.10       6.8660738E-01       1.6461745E-02       2.3950747E-01       1.4954992E-01         1.5000006E-01       7.10       6.8660758E-01       1.64557F-02       2.395076603E-01       1.447281F-01         1.5000006E-01       7.09       6.862766F-01       1.647281E-02       2.396492F-01       1.447281F-01         1.5000006E-01       7.09       6.847605F-01       1.6453531E-02       2.396492F-01       1.447281F-01         1.9000006E-01       7.09       6.84560F-01       1.6435956F-02       2.396492F-01       1.447281F-01         2.0000006E-01       7.07       6.84260F-01       1.6535876F-02       2.396492F-01       1.447281F-01         2.0000006E-01       7.07       6.821567F-01       1.6535876F-02       2.39549576F-01       1.4255104F-01         2.0000006E-01       7.07       6.821567F-01       1.6535876F-02       2.39549876-01       1.4255104F-01         2.0000006F-01       7.07	1.2000000E-01       7.12       6.8775992E-01       1.6502294E-02       2.3957747E-01         1.3000000E-01       7.12       6.875992E-01       1.6472026E-02       2.3956669E-01         1.5000000E-01       7.11       6.8678084E-01       1.6472026E-02       2.3956767E-01         1.5000000E-01       7.11       6.8678084E-01       1.6472026E-02       2.3966767E-01         1.5000000E-01       7.10       6.86478028E-01       1.64481745E-02       2.3966767E-01         1.5000000E-01       7.10       6.86470528E-01       1.644885527F-02       2.3966767E-01         1.7000000E-01       7.09       6.8552547E-01       1.6443855E-02       2.3966767E-01         1.7000000E-01       7.09       6.8525647E-01       1.6443855E-02       2.3966765E-01         1.9000000E-01       7.07       6.8277967E-01       1.6443855E-02       2.3966965E-01         2.1000000E-01       7.07       6.8316907F-01       1.6539646E-02       2.3966965E-01         2.1000000E-01       7.07       6.8277867-01       1.653953674F-02       2.3966965E-01         2.3000000E-01       7.05       6.8278577E-01       1.653953674F-02       2.396692366-01       1.         2.4000000E-01       7.05       6.8278577E-01       1.653953674F-02       2.396692366F-01	1.501R074F-01
$ \begin{array}{c} 1.5000000E-01 & 7.12 & 6.87345694E-01 & 1.6486992294E-02 & 2.3956169E-01 & 1.4881964E-01 \\ 1.5000000E-01 & 7.11 & 6.86490328E-01 & 1.64450527E-02 & 2.39561603E-01 & 1.4653994E-01 \\ 1.665390000E-01 & 7.10 & 6.865769E-01 & 1.64450527E-02 & 2.39661603E-01 & 1.4653964E-01 \\ 1.700000E-01 & 7.09 & 6.8879667E-01 & 1.64436551E-02 & 2.39650610 & 1.4472817E-01 \\ 1.700000E-01 & 7.09 & 6.887667E-01 & 1.6435551E-02 & 2.396509E-01 & 1.4472817E-01 \\ 1.7000000E-01 & 7.09 & 6.887667E-01 & 1.6435551E-02 & 2.396506697E-01 & 1.4472817E-01 \\ 2.20000000E-01 & 7.09 & 6.8872676-01 & 1.64365316E-02 & 2.39650657E-01 & 1.4472817E-01 \\ 2.2000000E-01 & 7.07 & 6.8316907E-01 & 1.63552826E-02 & 2.39650657E-01 & 1.4255164E-01 \\ 2.2000000E-01 & 7.07 & 6.8376577E-01 & 1.6355326E-02 & 2.396596596-01 & 1.472510526-01 \\ 2.2000000E-01 & 7.06 & 6.8316907E-01 & 1.6355326E-02 & 2.39659699819E-01 & 1.38744895-01 \\ 2.2000000E-01 & 7.06 & 6.8378577E-01 & 1.63253856E-02 & 2.396596596-01 & 1.3553866-01 \\ 2.2000000E-01 & 7.06 & 6.8378577E-01 & 1.6535326E-02 & 2.397565757-01 & 1.35753869-01 \\ 2.4000000E-01 & 7.09 & 6.8778577E-01 & 1.6525598E-02 & 2.3971205701 & 1.3634223E-01 \\ 2.4000000E-01 & 7.09 & 6.8778677E-01 & 1.6527598E-02 & 2.3971205701 & 1.35753869-01 \\ 2.4000000E-01 & 7.09 & 6.877180F-01 & 1.65279444E-02 & 2.3971391E-01 & 1.36745801 \\ 2.4000000E-01 & 6.99 & 6.7777180F-01 & 1.6527938E-02 & 2.3971491E-01 & 1.2757431E-01 \\ 2.0000000E-01 & 6.99 & 6.7777180F-01 & 1.6210574E-02 & 2.3981149F-01 & 1.2757431E-01 \\ 2.000000E-01 & 6.99 & 6.7797180F-01 & 1.66120578E-02 & 2.3981149F-01 & 1.2757431E-01 \\ 2.000000E-01 & 6.99 & 6.7797180F-01 & 1.66127588E-02 & 2.3981149F-01 & 1.2757431E-01 \\ 2.000000E-01 & 6.99 & 6.7797180F-01 & 1.66127588E-02 & 2.3981149F-01 & 1.2757431E-01 \\ 2.000000E-01 & 6.99 & 6.7797180F-01 & 1.66162788E-02 & 2.3981149F-01 & 1.2757431E-01 \\ 2.398400E-01 & 6.99 & 6.7797180F-01 & 1.66182788E-02 & 2.3981149F-01 & 1.2757431E-01 \\ 2.3984000E-01 & 6.99 & 6.7797180F-01 & 1.66189218E-02 & 2.3981149F-01 & 1.2757431E-01 \\ 2.9984000E-01 & 6.99 & 6$	1.2000000E-01       7.12       0.87345697E-01       1.64730265-02       2.39586697E-01       1         1.40000005-01       7.11       6.867303285-01       1.64730265-02       2.395696767E-01       1         1.50000005-01       7.11       6.86403286-01       1.64730265277E-02       2.39667677E-01       1         1.5000005-01       7.10       6.86403286-01       1.644505277E-02       2.396616035E-01       1         1.50000005-01       7.09       6.85525475-01       1.64435551E-02       2.39659645E-01       1         1.70000005-01       7.09       6.85525477E-01       1.645355777-02       2.3965965601       1         1.90000005-01       7.09       6.8547069761       1.65379204502       2.3965969576-01       1         2.10000005-01       7.07       6.831690775-01       1.65379204602       2.396692356-01       1         2.10000005-01       7.07       6.831690775-01       1.65379204602       2.396698196-01       1         2.30000005-01       7.07       6.82785775-01       1.65379204602       2.396698196-01       1         2.30000005-01       7.07       6.82385775-01       1.65379265-02       2.396598866650       1       1         2.50000005-01       7.05       6.82385776-01       1.653	
1.3000000E-01       7.12       6.8734565F-01       1.6486909F-02       2.3958057F-01       1.4888106F-01         1.4000000E-01       7.11       6.8607769F-01       1.6473026F-02       2.3959577F-01       1.46538181F-01         1.5000000F-01       7.10       6.8607769F-01       1.6475027F-02       2.39561057F-01       1.4472817F-01         1.5000007F-01       7.09       6.8552547F-01       1.6450527F-02       2.3965057F-01       1.4472817F-01         1.7000007F-01       7.09       6.8552547F-01       1.6450557F-02       2.3965056601       1.4472817F-01         1.7000007F-01       7.09       6.852547F-01       1.643855F-02       2.3965056601       1.4472817F-01         1.80000007F-01       7.09       6.852547F-01       1.6437926602       2.3965027F-01       1.4472817F-01         2.0000007F-01       7.07       6.823756F-01       1.6535326F-02       2.3965923F-01       1.4472817F-01         2.10000007F-01       7.07       6.823756F-01       1.6535326F-02       2.3965923F-01       1.447897556F-01         2.10000007F-01       7.07       6.823756F-01       1.6535326F-02       2.39659256F-01       1.447897556F-01         2.40000007F-01       7.07       6.823756F-01       1.6535326F-02       2.3965938F-01       1.39752657F-01	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	
1.400000E-01       7.11       6.8640328E-01       1.6473026E-02       2.3955927E-01       1.4817466E-01         1.600000E-01       7.10       6.8602546F-01       1.6455531E-02       2.3961603E-01       1.47586534E-01         1.600000E-01       7.09       6.8640328E-01       1.6435531E-02       2.39615031       1.4455817E-01         1.800000E-01       7.09       6.8496578E-01       1.64188551E-02       2.3965364E-01       1.4472817E-01         1.800000E-01       7.09       6.8496578E-01       1.64188551E-02       2.39653656-01       1.4472817E-01         1.900000E-01       7.09       6.8440567E-01       1.64188551E-02       2.39653656-01       1.4472817E-01         2.000000E-01       7.07       6.8279677E-01       1.6535246F-02       2.396560556-01       1.44728176-01         2.1000000E-01       7.07       6.8316977E-01       1.65352476F-02       2.396560566-01       1.447281756-01         2.1000000E-01       7.07       6.83178576F-01       1.65352476F-02       2.396596976F-01       1.3755386F-01         2.4000000E-01       7.06       6.83178576F-01       1.65352476F-02       2.39649326F-01       1.367448976-01         2.4000000E-01       7.06       6.817135157F-01       1.6525986F-02       2.3974381F-01       1.35754316-01	1.400000E-017.116.8678084E-011.6473026E-022.3959927E-0111.5000000E-017.106.8640328E-011.6461745E-022.3961603E-0111.600000E-017.106.8602769E-011.64455531E-022.3961603E-0111.7000000E-017.096.8552547E-011.64435531E-022.3961603E-0111.8000000E-017.096.8552547E-011.64435531E-022.3965064E-0111.9000000E-017.096.8572547E-011.6418855E-022.3965095E-0112.0000000E-017.085.84570697-011.65410021F-022.3965956976-0112.1000000E-017.076.8316907E-011.65379204E-022.3965956976-0112.1000000E-017.056.8278577E-011.65379204E-022.39658969676-0112.2000000E-017.056.8278577E-011.653538266-022.39658988E-0112.4000000E-017.056.8278577E-011.653538266-022.39658988E-0112.5000000E-017.056.8278577E-011.653258266-022.396588886666-0112.600000E-017.056.81713516-011.652793956-022.39769388196-0112.6000000E-017.026.80286666E-011.65279446E-022.397693956-0112.6000000E-017.026.80286666E-011.65279446E-022.397639265-0112.8000000E-017.026.80286666E-011.65279444E-022.397639265-0112.8000000E-017.016.90286666E-011.652794446-02	1.4888106E-01
1.5000000E-01       7.11       6.8640328E-01       1.6445F45E-02       2.3961603E-01       1.473818E-01         1.700000E-01       7.10       6.8640328E-01       1.6435531E-02       2.3961603E-01       1.4556634E-01         1.700000E-01       7.09       6.884765F-01       1.643555E-02       2.3965669E-01       1.4556634E-01         1.8000000E-01       7.09       6.8847665F-01       1.6418055F-02       2.39656667E-01       1.475817F-01         1.8000000E-01       7.09       6.8847065F-01       1.6418055F-02       2.396566627       2.39656667E-01       1.475817F-01         2.0000000E-01       7.07       6.8316907F-01       1.6535826F-02       2.396569596F-01       1.473516-01       1.473516-01         2.20000006F-01       7.07       6.8316907F-01       1.6535826F-02       2.39659566-01       1.473516-01       1.33755386-01         2.20000006F-01       7.06       6.8213065F-01       1.65358266F-02       2.39659898F-01       1.33755388F-01         2.20000006F-01       7.07       6.8213065F-01       1.6535987F-02       2.3976398F-01       1.3544997E-01         2.40000006F-01       7.05       6.8213065F-01       1.6527944F-02       2.3976398F-01       1.3644598F-01         2.40000006F-01       7.05       6.8171357F-01       1.6227944F-02	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	
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$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	
1.7000000E-01       7.09       6.8552547E-01       1.643555E-02       2.3962721E-01       1.4566634E-01         1.8000000E-01       7.09       6.8496678E-01       1.641855E-02       2.39656025E-01       1.4472817E-01         1.9000000E-01       7.09       6.842790F-01       1.66379701E-02       2.39656025E-01       1.4472817E-01         2.0000000E-01       7.07       6.842790F-01       1.6537971E-02       2.3965625E-01       1.4472817E-01         2.000000E-01       7.07       6.827957E-01       1.6537971E-02       2.3965625E-01       1.4472817E-01         2.000000E-01       7.07       6.827957E-01       1.6537971E-02       2.39656565E-01       1.411553E-01         2.2000000E-01       7.05       6.8278577E-01       1.65378576E-02       2.39656565E-01       1.35755386-01         2.4000000E-01       7.05       6.8278577E-01       1.65378576E-02       2.39679656E-01       1.35755386E-01         2.4000000E-01       7.05       6.817135156F-01       1.653239766E-02       2.39769565E-01       1.35484895E-01         2.4000000E-01       7.05       6.817135156F-01       1.653239567E-02       2.3976956561       1.3494395E-01         2.4000000E-01       7.05       6.817135157E-01       1.65275986F-02       2.39769356561       1.3494382E-01 <td><math display="block"> \begin{array}{c ccccccccccccccccccccccccccccccccccc</math></td> <td>L 1.4653904E-01</td>	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	L 1.4653904E-01
1.8000000E-017.096.8496678E-011.6418855E-022.3964622E-011.4472817E-012.0000000E-017.076.8457069E-011.6418855E-022.39656096E-011.4472817E-012.1000000E-017.076.822790F-011.653953264E-022.39656095E-011.4235104E-012.1000000E-017.076.8316907F-011.6535328264E-022.39656556E-011.4235104E-012.2000000E-017.076.8316907F-011.6535328264E-022.39656556E-011.33753885E-012.300000E-017.056.83171351F-011.6535328266-022.39658819E-011.337534895E-012.4000000E-017.056.82300655E-011.6535328265-022.39743815-011.335534895E-012.5000000E-017.056.82300655E-011.653539765-022.39743815-011.35534895E-012.6000000E-017.026.80286426-011.65275986-022.39743815-011.35534895E-012.6000000E-017.026.80286426-011.65275986-022.39743815-011.35634226-012.9000000E-017.016.79383125-011.65275986-022.39743815-011.32624815-012.9000000E-017.026.80286426-011.65275986-022.39743815-011.32624815-012.9000000E-017.016.7938125-011.65275986-022.39743815-011.32624815-012.9000000E-016.996.77246025-011.65255986-022.39743815-011.2574315-013.000000E-016.996.76407595-011.61642735-022.39840006-011.26026546-013.2000000E-016.92	1.8000000E-017.096.8496678E-011.6418855E-022.3963964E-011.9000000E-017.086.8467069E-011.64100216-022.3965609E-012.0000000E-017.076.8227905-011.65304812E-022.3965609E-012.1000000E-017.076.8316907E-011.65379204E-022.3965695E-012.1000000E-017.066.8316907E-011.65353826E-022.3965898E-012.3000000E-017.056.8278577E-011.65353826E-022.3965898E-012.4000000E-017.056.8270055E-011.65353826E-022.39568819E-012.4000000E-017.056.8171351E-011.65353826E-022.3971205E-012.6000000E-017.026.8028664E-011.6527944E-022.3972653E-012.6000000E-017.026.8028664E-011.6527944E-022.3974381E-012.8000000E-017.016.7938312E-011.6527944E-022.3974381E-01	1.4566634E-01
1.9000000E-01       7.08       6.8457065E-01       1.65410021F-02       2.3564525E-01       1.4725104E-01         2.0000000E-01       7.07       6.825790F-01       1.65359646-02       2.3966923E-01       1.411523E-01         2.0000000E-01       7.07       6.8316907E-01       1.65359247E-02       2.3966923E-01       1.4111523E-01         2.0000000E-01       7.06       6.8316907E-01       1.63552826E-02       2.3966923E-01       1.4111523E-01         2.000000E-01       7.05       6.83106907E-01       1.63553826E-02       2.3966923E-01       1.4111523E-01         2.3000000E-01       7.06       6.8371351E-01       1.63553826E-02       2.3966938E-01       1.3874489E-01         2.4000000E-01       7.05       6.8171351E-01       1.65353956E-02       2.39743819E-01       1.3634238E-01         2.4000000E-01       7.06       6.8171351E-01       1.65353956E-02       2.3974381E-01       1.3634238E-01         2.4000000E-01       7.01       6.8171351E-01       1.6525598E-02       2.3974381E-01       1.3634238E-01         2.494998E-01       1.6221997E-02       2.3974381E-01       1.35349498E-01       1.35349489E-01         2.49000000E-01       7.02       6.8171351E-01       1.622199726-02       2.3974381E-01       1.354494982E-01	1.000000000000000000000000000000000000	1 46730175-01
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2.100000007.076.8316907F-011.6379204F-022.3966923F-011.4111523F-012.2000000E-017.076.8316907F-011.6355247F-022.3965965F-011.3874489F-012.3000000E-017.056.8278577F-011.6355826F-022.39669898E-011.3874489F-012.4000000E-017.056.8230065F-011.6535826F-022.39658998E-011.3874489F-012.5000000F-017.056.8230065F-011.6535826F-022.3971205F-011.3634223F-012.6000000F-017.036.8171351F-011.653536F-022.3971205F-011.3634223F-012.6000000F-017.036.8171351F-011.6579444F-022.39745659F-011.3553869F-012.7000000F-017.016.7938212F-011.6579444F-022.39745659F-011.3553569F-012.9000000F-017.026.8028664E-011.6252598F-022.397653F-011.3557481F-012.9000000F-016.996.7797180F-011.62226911F-022.397653F-011.3510036F-013.000000E-016.996.7797180F-011.6210674F-022.397633F-011.2910724F-013.1000000E-016.966.7724602F-011.6164273F-022.3983015F-011.2510254F-013.2000000E-016.966.7556505F-011.6164273F-022.3983015F-011.2602654F-01	<b>2.</b> 1000000E-01 7.07 6.8369776E-01 1.6379204E-02 2.3966923E-01 1 <b>2.</b> 2000000E-01 7.06 6.8316977E-01 1.6365247E-02 2.3967965E-01 1 <b>2.</b> 4000000E-01 7.05 6.8278577E-01 1.6355826E-02 2.3968819E-01 1 <b>2.</b> 4000000E-01 7.05 6.8230065E-01 1.6339376E-02 2.39771205E-01 1 <b>2.</b> 6000000E-01 7.04 6.8171351E-01 1.65339376E-02 2.39771205E-01 1 <b>2.</b> 6000000E-01 7.03 6.8136309E-01 1.6527944E-02 2.39772653E-01 1 <b>2.</b> 6000000E-01 7.02 6.8028664E-01 1.627944E-02 2.3977653E-01 1 <b>2.</b> 7000000E-01 7.01 6.7938312E-01 1.627944E-02 2.39776392E-01 1 <b>2.</b> 8000000E-01 7.01 6.7938312E-01 1.627944E-02 2.39776392E-01 1	1.42351045-01
2.1000000E-017.006.8316907E-011.03179704E-022.39605952F-011.3874489E-012.2000000E-017.056.8230577E-011.6335336E-022.396586819E-011.3874489E-012.4000000E-017.056.82305055E-011.6335376E-022.39769657E-011.36342232012.4000000E-017.056.8173577E-011.65329266E-022.3974381E-011.36342326012.4000000E-017.056.81713515-011.65329566E-022.3974381E-011.36342326012.5000000E-017.026.8028664E-011.65225985-022.3974381E-011.3535695-012.6000000E-017.016.996.79383125-011.65226911E-022.3974381E-011.33535695-012.9000000E-017.016.996.77971805-011.62228911E-022.3974381E-011.3365461-013.000000E-016.976.77246025-011.62106745-022.3974381E-011.2757431E-013.1000000E-016.956.755565-011.61891385-022.39830155-011.26026545-013.2000000E-016.966.75556505-011.61642735-022.39840000E-011.26026545-01	2.1000000E-01       7.01       0.835576E-01       1.03579204E-02       2.3966955E-01       1         2.2000000E-01       7.05       6.8316907E-01       1.6355826E-02       2.3967865E-01       1         2.3000000E-01       7.05       6.8278577E-01       1.6355826E-02       2.3966819E-01       1         2.4000000E-01       7.05       6.8278577E-01       1.6355826E-02       2.3966819E-01       1         2.4000000E-01       7.05       6.82706551E-01       1.6333976E-02       2.39712055-01       1         2.5000000E-01       7.03       6.8171351E-01       1.652218955E-02       2.39712055-01       1         2.6000000E-01       7.02       6.8028664E-01       1.65279444E-02       2.3974381E-01       1         2.8000000E-01       7.01       6.7938212E-01       1.6557986-02       2.3974381E-01       1	
2.2000000E-017.066.8316907E-011.6365247E-022.3967565E-011.3991650E-012.300000E-017.056.8278577E-011.6352826E-022.3968819E-011.3874489E-012.4000000E-017.056.8230065E-011.6532826E-022.3968819E-011.3874489E-012.4000000E-017.056.8171351E-011.6532826E-022.3971205E-011.3634223E-012.5000000E-017.076.8171351E-011.65223956-022.3974381E-011.3634223E-012.6000000E-017.026.81053095-011.65205396E-022.3974381E-011.36342369E-012.7000000E-017.026.8028664E-011.6279444E-022.3974381E-011.3210036E-012.900000E-017.016.996.7797180F-011.6228911E-022.3976392E-011.3210036E-012.0000000E-016.996.7797180F-011.6228911E-022.3976392E-011.2210074E-013.000000E-016.976.7797180F-011.6210674E-022.3976392E-011.2757431E-013.1000000E-016.966.77640759E-011.6164273E-022.3983015E-011.2602654E-013.3000000E-016.966.756505F-011.6164273E-022.39840000E-011.2602654E-01	<b>2.2000006-01 7.06 6.8316907E-01 1.6365247E-02 2.3967965E-01 1 2.300000E-01 7.05 6.8278577E-01 1.6352826E-02 2.3968819E-01 1 2.4000000E-01 7.05 6.8230065E-01 1.65339376E-02 2.3965898E-01 1 2.6000000E-01 7.05 6.8171351E-01 1.652218955-02 2.3971205E-01 1 2.6000000E-01 7.02 6.8171351E-01 1.652739E-02 2.3971205E-01 1 2.6000000E-01 7.02 6.8028664E-01 1.627944E-02 2.3972653E-01 1 2.8000000E-01 7.01 6.7938312E-01 1.627944E-02 2.3977653E-01 1 2.8000000E-01 7.01 6.7938312E-01 1.627944E-02 2.397639E-01 1 2.8000000E-01 1.627944E-02 2.397653E-01 1 2.8000000E-01 1.627944E-02 2.397653E-01 1 2.8000000E-01 1.627944E-02 2.397653E-01 1 1.627944E-02 2.397653E-01 1 1.627944E-02 2.3976392E-01 1 1.627944E-02 2.3976392E-01 1 2.800000E-01 1.627944E-02 2.3976392E-01 1 1.627944E-02 2.3976392E-01 1.628</b>	L.4.11523E-01
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2.5000000000000000000000000000000000000	2.40000005-01 7.05 6.82300655-01 1.63353765-02 2.3969895-01 1 2.40000005-01 7.05 6.82300655-01 1.63353765-02 2.39712055-01 1 2.60000005-01 7.03 6.81713515-01 1.630253955-02 2.39712055-01 1 2.40000005-01 7.02 6.80286645-01 1.62794445-02 2.39743815-01 1 2.80000005-01 7.01 6.79383125-01 1.62525985-02 2.39763925-01 1	1 3074605-01
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45.00 6.578	4310E-02	•			
50.00 5.069	19422E-02	•			
55.00 3.621	7730E-02	•			
60.00 2.279	12385-02	•			
65.00 1.086	6548E-02	•			
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145.00 9.933	9351E-02	•			
150.00 1.121	2209E-01	•			
155.00 1.232	72145-01	•			
160.00 1.318	22516-01	•			
145.00 1.384	3510E-01	•			
170.00 1.432	22265-01	••	•		and a second
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 1					

Table I. Aerodynamic Characteristic of the NACA 0012 Airfoil at Reynolds Numbers of .5 x 10<sup>6</sup> and 1.8 x 10<sup>6</sup>

Rey		-		.5 × 10 <sup>6</sup>						Ann ar ann a dù Manara ann an Ann				1.8 × 10°																	
с. 	2.500000E-01	2.4133246E-01	2, 3821240E-01	2.28699546-01	2.84924016-01	3.31005745-01	3.5109260E-01	3.56518936-01	3.6287190E-01	3.6440116E-01	3.94816276-01	4.2455810E-01	4.2736741E-01		4.6007494E-01	4.7269860E-01	4.5464500E-01	5.1804124E-01	5.5008067E-01	5.6806794E-01	5.89097066-01	6.0620961E-01	6.4044907E-01	6.8541787E-01	7.3085367E-01	6.5840155E-01	6.5550001E-01	6.9650059E-01	7.53735585-01	7.9240805E-01	7.74999596 +00
с. <sub>м</sub> с./4	0. 2.0000000E_03	6.00000006-03	1.000000E-02	2.000000E-02	-3.500000E-02	-6.5C00000E-02	-7.00C0000E-02	-7.2C00000E-02	-7.60000005-02	-8. C000000E-02	-1.65000005-01	-2.6C00000E-01	-2.7C00000E-01	-3.3000000E-01	-3.900000E-01	-4.300000E-01	-4. 8C00000E-01	-5.20000005-01	-5.7C00000E-01	-5-900000E-01	-5.950000E-01	-5.80000005-01	-5.7000006-01	-4.7000005-01	-4.0000000E-01	-3.4000000E-01	-3.2000000E-01	-3.500000E-01	-3.90000009-01	-4.2500000E-01	-7.5000006-02
°,	6.5000000E-03	3. UUUUUUUE-U3 1. 00000000E-02	1.2000000E-02	1.400000E-02	4.500000E-C2	1.0000000E-01	1.7503000E-01	2.100000E-01	2.40000006-01	2.4500000E-01	5.900000UE-01	9.700000E-01	1.0100000E+00	1.30000 DE+CO	1.59000U.E+00	1.8000000E+00	1.9200000E+00	1.94000006+00	1.9900000E+00	1.7800005+00	1.570J000E+00	1.3200000E+00	9.9000000E-01	6.0000000E-01	4.2030000E-01	2. 3003000E-01	2.3000000E-01	1.9000000E-01	1.2000000E-01	8.00000005-02	2.00000005-02
с <sup>г</sup>			8.5500000E-01	9.6000000E-01	1.0150000E+00	8.UJ00000E-01	6.7000000F-01	<pre>"6.3000000E-01</pre>	6.30CC000E-01	6.5500000E-01	9.7500000E-01	1.1300000E+00	1.1350000F+00		9.5900000E-01	7. CO00000E-01	4.1000000F-01	8. COGOOOOE-02	-2.2300000E-01	-5.33000005-01	-7.93C0000E-01	-9.60000005-01	-1.0750000E+00	-9.00000005-01	-7.2200005-01	-7.03C0000E-01	-7.5500000E-01	-7.6100000F-01	-7.6500000E-01	-7.3COCJOOE-01	-1.0303000E-02
α, degrees	00000.0	2.0000	8.0000	10.0000	12.0000	12.7000	14.0000	16.0000	16.0000	20.0000	30.0000	40.0000		. 0000 • 0 1	60.000	70.0000	80.0000	2000 • 05	100.000	. 0000 • 0 1 1	120.0000	130.0000	140.0000	150.0000	155.0000	160.0000	. 164.0000	169.0000	170.0000	172.0000	180.0000

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FIGURE 2 - Coordinate System.



Figure 3. - Velocity and force vector components.



FIGURE 4. - Local Coordinates for Flow Curvature Analysis.



Figure 5. - Side View of the Upper Half of a Blade.



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FIGURE 6. - Comparison of Analysis with Test Data for a Two Blade Catenary VAW Using the NACA 0012 Airfoil.



FIGURE 7 - Variation of Angle of Attack Along the Blade - Catenary VAW.



FIGURE 8 - Maximum Angle of Attack Envelope for the Catenary VAW as a Function of R.



FIGURE 9 - Performance Characteristics of the Catenary Windmill.



FIGURE 10 - Performance Characteristics of a Straight Blade VAW.



FIGURE 11 - Effect of Solidity on the Performance of a Straight Blade VAW - Analytical Solution.



FIGURE (2 - ) of Windmill Aspect Ratio II on rformance for a Straight Blade Design -Analytical Results.



FIGURE 13 - Effect of Solidity on Performance for a Straight Blade Configuration -Numerical Results.



a) STRAIGHT BLADE CONFIGURATION.



b) TYPICAL LOADING FOR STRAIGHT AND CURVED BLADE VAW.



c) CHEVRON STRAIGHT BLADE VAW CONCEPT.

FIGURE 14 - Straight and Curved Blade VAW Designs.



FIGURE 15 - Performance Characteristics of a Chevron Type Straight Blade VAW.