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Method for Calculating Induced Rolling Moments for Cruciform Canard Missiles at Angles of Attack up to 20 Deg.

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for the
Aircraft Systems Department

MAY 1975

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R. G. Freeman, III, RAdm., USN . . . . . Commander

G. L. Hollingsworth . . . . . Technical Director

FOREWORD

This report documents an effort to develop engineering methods to predict the aerodynamic induced rolling moment characteristics of canard controlled missile airframes.

The work was performed by Nielsen Engineering & Research, Inc., Mountain View, Calif., during the period from November 1973 to April 1975 under Contract N00123-74-C-0829 with the Naval Weapons Center (NWC). Funds were provided under Task Area No. F3234401, Work Unit No. 151931. This report has been reviewed for technical content by R. E. Meeker, NWC technical coordinator for the contract, and J. R. Marshall.

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(U) An engineering predictive method has been developed for calculating the induced roll characteristics of canard-cruciform missiles at subsonic, transonic, and supersonic speeds. The use of pitch control and yaw control of the canard fins is included but the use of roll control is not. The steps in the predictive method are outlined. Sample calculative cases are carried out in detail for both transonic and supersonic speeds. The four computer programs used in the analysis are described and listed, and sample input and output are given. Good agreement between predictions and experiment is shown for angles of attack up to 20 deg.

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NOMENCLATURE

A_L	Left afterbody vortex
A_R	Right afterbody vortex
AR	Aspect ratio
a	Body radius
a_e	Value of elliptic component of span loading at the fin-body junction
a_L	Value of linear component of span loading at the fin-body junction
C_{ℓ_C}	Rolling-moment coefficient of canard section; rolling moment/$q_\infty S_R \ell_r$; positive clockwise looking upstream
C_{ℓ_T}	Rolling-moment coefficient of tail section; rolling moment/$q_\infty S_R \ell_r$; positive clockwise looking upstream
CN	Fin normal-force coefficient; fin normal force/$q_\infty S_R$
CNC1,CNC2, etc.	Normal-force coefficients associated with C1, C2, etc.
CNi	Fin normal-force coefficient for fin i
C_{N_T}	Normal-force coefficient of "tail alone" formed by joining two opposing tail fins
CNT1,CNT2, etc.	Normal-force coefficients associated with T1, T2, etc.
C_{N_W}	Normal-force coefficient of "wing alone" formed by joining two opposing canard fins
$C_{N_{W(B)}}$	Normal-force coefficient of two opposing canard fins in the presence of a body
CRMC1,CRMC2, etc.	Rolling-moment coefficients associated with C1, C2, etc.
CRMT1,CRMT2, etc.	Rolling-moment coefficients associated with T1, T2, etc.
C1,C2, etc.	Canard fins; also, vortices associated with canard fins
C_6	Large-aspect-ratio canard fins used in NWC-MICOM test; see Ref. 5
C_7	Low-aspect-ratio canard fins used in NWC-MICOM test; see Ref. 5
c_{d_c}	Crossflow drag coefficient
g_1, g_2, etc.	Axial distances used in correlating multiple body-vortex data; see Fig. 15

$h_{cen.}$	See step 3 on page 8
K_W	Wing-body interference factor for fin normal force; ratio of normal force on fins C2 and C4 at $\alpha = \alpha_c$, $\phi = 0$, $\delta_2 = \delta_4 = 0$ to that on the wing alone formed by C2 and C4 at $\alpha = \alpha_c$
$(K_{\alpha\beta})_{H,i}$	Wing-body interference factor for horizontal fin i associated with $\alpha\beta$ coupling
$(K_{\alpha\beta})_{V,i}$	Wing-body interference factor for vertical fin i associated with $\alpha\beta$ coupling
$(K_{\alpha\delta_V})_{H,i}$	Wing-body interference factor for horizontal fin i associated with $\alpha\delta_V$ coupling
$(K_{\alpha\delta_V})_{V,i}$	Wing-body interference factor for vertical fin i associated with $\alpha\delta_V$ coupling
$(K_{\beta\delta_H})_{H,i}$	Wing-body interference factor for horizontal fin i associated with $\beta\delta_H$ coupling
$(K_{\beta\delta_H})_{V,i}$	Wing-body interference factor for vertical fin i associated with $\beta\delta_H$ coupling
k_w	Wing-body interference factor for fin deflection; ratio of normal force on fins C2 and C4 for $\alpha = \beta = 0$ and $\delta_2 = \delta_4 \neq 0$ to that on the wing alone formed by C2 and C4 at $\alpha = \delta_2 = \delta_4$
ℓ_r	Reference length, body diameter; 0.75 inch for calculative examples
M_c	Crossflow Mach number, $M_\infty \sin \alpha_c$
M_∞	Free-stream Mach number
N_L	Left body nose vortex
N_R	Right body nose vortex
q_∞	Free-stream dynamic pressure
R_{nc}	Crossflow Reynolds number
r	Local radius of missile nose
r_n	Radius of nose tip at juncture with rest of nose
r_v	$\sqrt{y_v^2 + z_v^2}$
S	Strouhal number
S_C	Crossflow area in front of canard fins
S_R	Reference area

s_m	Fin maximum semispan measured from body centerline
V_∞	Free-stream velocity
x,y,z	Missile body axes; x measured positive downstream along body rotational axis, y measured positive to right in the plane of C4, and z measured positive upward in the plane of C1
$x_{cen.}$	x-coordinate of area centroid of canard fin planform
$x_{\ell.e.}$	x-coordinate of leading edge of canard root chord
x_s	x-coordinate of separation position for body nose vortices
x_o,y_o,z_o	Special set of x,y,z axes for $\phi = 0$
y_v,z_v	Position of vortex in crossflow plane in unrolled body coordinates
$\bar{y}$ or $\bar{z}$	Lateral distance from x axis to fin center of pressure
α	Angle of attack, $\alpha_c \cos \phi$
α_c	Included angle of attack, angle between x axis and free-stream velocity
α_{cr}	Resultant angle of crossflow at body centerline due to free-stream flow and external canard vortices
$\bar{\alpha}_{cr}$	Average value of α_{cr} between two axial stations
α_{eq}	Equivalent angle of attack; that angle of attack of the wing alone for which its normal force is twice that of the fin; the wing alone is formed by joining two opposing fins together
$(\Delta\alpha_{eq})_v$	Change in α_{eq} due to a collection of external vortices and their images
β	Angle of sideslip, $\alpha_c \sin \phi$
Γ	Strength of vortex, positive counterclockwise
Γ_N	Strength of body nose vortex for symmetrical vortex shedding
δ_1,δ_2, etc.	Incidence angles associated with fins C1, C2, etc.; for $\phi = 0$, δ_1 and δ_3 are positive for trailing edges to the right viewed from the rear, and δ_2 and δ_4 are positive for trailing edges down
δ_H	Incidence angle for pitch associated with the horizontal fins C2 and C4
δ_V	Incidence angle for yaw associated with the vertical fins C1 and C3

ϵ Ratio of the nose tip radius to the nose base radius

η Half angle of body nose for pointed body; also, angle between tangent to nose at juncture of spherical nose cap and rest of nose and the body axis; see Fig. 2

$\bar{\eta}$ $(\bar{y} - a)/(s_m - a)$

θ Direction of resultant crossflow velocity at body centerline due to free-stream flow and external canard vortices; measured counterclockwise from positive y_o axis

λ Ratio of fin tip chord to root chord

ν Kinematic viscosity

ξ Angle between asymptotic trajectory of a torn body vortex and the body axis

ϕ Roll angle, angle between z axis and z_o axis; positive measured clockwise viewed from rear

METHOD FOR CALCULATING INDUCED ROLLING MOMENTS FOR CRUCIFORM CANARD MISSILES AT ANGLES OF ATTACK UP TO 20°

INTRODUCTION

In 1973, Nielsen Engineering & Research, Inc. (NEAR) under the sponsorship of the Naval Weapons Center, China Lake, CA, carried out an investigation to determine the state of the art concerning existing theory and experiment for the induced-roll characteristics of cruciform canard missiles. References 1 to 3 represent progress reports on this investigation, and Ref. 4 is the final report. Under Contract No. N00123-74-C-0829 to the Naval Weapons Center, NEAR was funded to carry out additional experiments and analysis necessary to improve the state of the art with respect to predicting the induced-roll characteristics of cruciform canard missiles. References 5 and 6 report on the experimental work performed, and Refs. 7 and 8 report on the analytical work accomplished. The present report is a final report summarizing the work of Refs. 5 to 8.

The primary purpose of this report is to summarize the prediction method developed by NEAR for predicting the induced-roll characteristics of cruciform canard missiles undergoing pitch or yaw control with the canard fins at subsonic or supersonic speeds for a range of angles of attack up to 20°. The necessary information to apply the method to calculations for practical configurations is contained in this report. For instance, the details of how to utilize several computer programs used in the method are contained in the appendices to this report. For illustrative purposes, the method is applied to two example cases for the AIM-9L missile, one at subsonic speed and one at supersonic speed.

The computer program reported in Appendix A is an extended version of a cruciform wing-body lifting-surface program developed during the first year of an Office of Naval Research contract* and reported in Ref. 9. The program of Appendix A was developed under an extension of the above contract.** NEAR wishes to thank the Office of Naval Research for permission

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**Technical Monitor: Mr. T. L. Wilson.

to publish the operating details of the extended program prior to the detailed ONR technical report on the subject.

PRELIMINARY CONSIDERATIONS

Consider the canard missile configuration shown in Fig. 1. The experimental work on this configuration completed during this investigation and reported in Refs. 5 and 6 has shown that the following sources of static induced rolling moments can be important for included angles of attack in the range $0 \leq \alpha_c \leq 20^\circ$:

1. Panel-Panel Interference: This source of induced roll is due to nonlinear lift effects on a cruciform set of fins at combined angles of attack and sideslip.

2. Nose-Canard Interference: At sufficiently high angles of attack, separated flow will develop on the missile nose. Although, for the α_c's of interest here, the separated flow will be symmetrical about the plane containing the wind and body axes, a canard fin configuration at nonzero bank and/or fin deflection angles will produce a net rolling moment due to the nose vorticity. This component of induced rolling moment is usually small for $\alpha_c \leq 20^\circ$ except for long noses.

3. Canard-Tail Interference: The trailing vorticity from a canard fin configuration with nonzero bank and/or fin deflection will interact with the tail fins to produce a net rolling moment.

4. Afterbody-Tail Interference: Separated flow (body vortices) from the afterbody section of the missile at angle of attack will interact with the tail fins to produce a net rolling moment.

The lifting-surface computer program of Appendix A is used for the calculation of panel-panel interference. The program, which is applied to induced rolling-moment calculations in Refs. 7 and 8, solves the linear wave equation using elementary constant u-velocity panels to approximate the body and the fins. A nonlinear pressure coefficient is then used to account for effects of sideslip. Similar computer programs for subsonic and transonic speeds have not yet been developed. Hence, for these Mach numbers, the method uses modified slender-body theory (Ref. 10) to account for panel-panel interference.

To account for nonlinear lift effects on fins at the high angles of attack resulting from missile incidence and fin deflection, a correlation method based on the concept of an "equivalent angle of attack" has been developed. The equivalent angle of attack, α_{eq}, is defined to be the angle of attack at which the normal force generated by a wing-alone formed by two opposing fins is equal to the normal force actually generated by the fins in the presence of the body. It is calculated from slender-body theory for subsonic and transonic speeds (and from the lifting-surface computer program for supersonic speeds) using the wing-body interference factors presented in Ref. 7. The equivalent angle-of-attack method was previously utilized in Ref. 11 for symmetrical missile configurations. The wing-alone correlations based on the α_{eq} concept are used to correct loads calculated by the slender-body and lifting-surface methods.

Separated flows from the nose and afterbody sections are modeled as two potential line vortices. The missile station at which separation begins; that is, the station at which the vorticity is rolled up, is determined from an empirical correlation. The vortex positions on the nose are also obtained from an empirical correlation. The strength of the nose vortices at the leading edge of the canards is then calculated using the vortex impulse theorem (Ref. 10) and the crossflow drag coefficient correlations given by Fidler and Bateman in Ref. 12. The positions of all vortices downstream of the canard leading edge are calculated using slender-body theory. The afterbody vortices are assumed to grow unsymmetrically under the influence of the canard and nose vortices. The strengths of the afterbody vortices downstream of the canard trailing edge are assumed to be given by the vortex impulse theorem and the crossflow drag coefficient correlations of Fidler.

Vortex-fin interactions are handled by reverse-flow methods using modified slender-body theory for span loadings. Although the lifting-surface program could be used for this purpose for supersonic speeds, its greater cost and complexity is not usually justified on the grounds of accuracy as is shown in Ref. 8.

CALCULATION OF ROLLING MOMENTS DUE TO INTERACTION OF NOSE VORTICES WITH CANARD FINS

For the angles of attack of interest here, the nose vortices of most canard configured missiles will be too weak to cause significant rolling moments when they interact with the canard fins. However, missiles with long forebodies such as "finners" (no forward lifting surfaces) usually experience significant rolling moments due to body vortex-fin interaction. The method presented below for handling nose-fin interactions is applicable to both configurations. The steps involved in the method are as follows:

1. Calculate the axial starting positions of the nose vortices.

2. Determine the nose vortex positions in the crossflow plane at the leading edge of the canard fin root chord.

3. Estimate the nose vortex strengths at the positions given by step 2.

4. Track the nose vortices over the canards to the crossflow plane containing fin area centroid.

5. Using reverse-flow methods, calculate the rolling moments due to nose vortex-fin interaction.

The first four steps are described in detail in the following subsections. Step 5 is described in the section on vortex-fin interference.

AXIAL STARTING POSITIONS OF NOSE VORTICES

As the angle of attack of a body of revolution increases, flow separation occurs on the leeward side. Separation first occurs at the aft end. As the angle of attack is increased, the separated region extends forward until it finally covers most, if not all, of the body length. For the angles of attack and nose lengths of interest in this report, the separated flow on the nose has been observed to consist of a pair of symmetrical concentrated vortices (e.g., see Refs. 10 and 13). The approximate starting positions of these vortices must be determined if correlations of their positions downstream are to be developed. Although there is some uncertainty associated with the experimental correlation of the origin of separation, the correlation should be used in conjunction with the correlations for downstream vortex positions for consistency. It is assumed in all that follows that the nose is a body of revolution.

The following rules were devised to guide the user in applying the method in a consistent manner (see Fig. 2):

1. If the angle of attack is less than 4°, assume that no body vortices appear anywhere on the missile.

2. If the nose is pointed and the nose half-angle, η, is greater than 30°, treat the nose as if it were blunt.

3. If the nose is pointed and the angle of attack is greater than η, the nose vortices begin at the nose tip.

4. If the nose is pointed and $4^{\circ} < \alpha_c \leq \eta$, then the origin of the nose vortices is given by

$$\frac{x_s}{a} = 32\left[1 - \sqrt{\frac{\alpha_c - 4^{\circ}}{\eta - 4^{\circ}}}\right] \tag{1}$$

5. If the nose is blunt, determine the ratio of the nose tip radius to the nose base radius. If the ratio is 0.2 or less, treat the nose as pointed and use the angle between the body axis and the tangent at the interface of the nose tip and the nose afterbody to obtain an effective η.

6. If the nose is blunt and the ratio of the nose tip radius to the nose base radius is greater than 0.2, then the origin of the nose vortices is given by

$$\frac{x_s}{a} = 2 + \frac{10^{\circ}}{\alpha_c - 4^{\circ}} \tag{2}$$

The rules given above are presented in flow chart form in Fig. 3. If x_s is greater than the distance to the leading edge of the tail fins, there will be no body vortices according to the method. If x_s is greater than the distance to the leading edge of the canards, there will be no nose vortices.

NOSE VORTEX POSITIONS AT CANARD LEADING EDGES

If nose vortices are present, their positions in the crossflow plane at the leading edge of the canard root chord can be estimated from correlations given in Ref. 14 and reproduced in Fig. 4. The data are shown as functions of distance along the body from the origin of separation given

by equations (1) and (2). Note that the axial distance along the body is normalized by the body radius at the base of the nose and that the positions are normalized by the local body radius.

The lateral vortex positions in Fig. 4(a) appear to be a function of Mach number and have been resolved into two faired curves. The two recommended curves are shown for Mach numbers less than and greater than one. The vertical vortex positions in Fig. 4(b) have been resolved into one faired curve. The data did not seem to have strong Reynolds number dependency as long as the free-stream Reynolds number based on diameter was at least 10^5.

NOSE VORTEX STRENGTHS AT CANARD LEADING EDGES

If the quantity $[(x_{\ell.e.} - x_s)\sin\alpha_c/a]$ is greater than or equal to 4, the correlation curves of Ref. 14 which are given in Fig. 5 should be used to calculate the nose vortex strengths. Note that the axial distance along the body is normalized by the body radius at the base of the nose and that the strength data are also normalized by the base radius. Also note that two faired curves have been drawn, one each for subsonic and supersonic flows.

If the quantity $[(x_{\ell.e.} - x_s)\sin\alpha_c/a]$ is less than 4, use the following procedure based on the vortex impulse theorem (Refs. 8 and 10):

1. Calculate the body planform area, S_c, between x_s and the leading edge of the canard fin root chord.

2. Calculate the crossflow Reynolds number; that is,

$$R_{nc} = V_\infty \sin\alpha_c \left(\frac{a}{\nu}\right) \tag{3}$$

3. Calculate the crossflow Mach number; that is,

$$M_c = M_\infty \sin\alpha_c \tag{4}$$

4. Use the correlations developed by Fidler and Bateman in Ref. 12 and reproduced in Fig. 6 to get c_{d_c}. If the flow conditions present indicate that the body boundary layer is turbulent at the point of separation, then use the "turbulent" curves in Fig. 6 even if $R_{nc} < 10^5$.

5. Calculate the nondimensional nose vortex strength from the following equation

$$\frac{\Gamma_N}{2\pi V_\infty r} = \frac{1}{8\pi} (c_{d_c}) (S_c) \frac{\sin^2\alpha_c}{r^2 \left(\frac{y_v}{r}\right)\left(1 - \frac{r^2}{r_v^2}\right)} \tag{5}$$

In summary, if $\left[(x_{\ell\ e.} - x_s) \sin \alpha_c / a\right] \geq 4$, use Fig. 5; otherwise, use equation (5).

TRACKING NOSE VORTICES PAST CANARD SECTION

Fins Not Deflected

The method for tracking the nose vortices past the canard section assumes that the crossflow plane or slender-body approach is valid. The necessary equations are given in Appendix A of Ref. 8. The computer program which carries out the calculations is called CRUTRJ and is described in Appendix B. If a vortex appears to be "captured" by its own image vortex, it should be eliminated from the calculation of vortex loads. By "capturing" we mean that a vortex has moved so close to the body (or fin) surface that its image vortex dominates its movement. See Ref. 8, pages 16-17 for further discussion. Run the calculations to the axial location of the fin area centroid, $x_{cen.}$. The method assumes that the vortex locations in the crossflow plane at $x_{cen.}$ will give the most accurate loads.

Fins Deflected

The computer program CRUTRJ cannot handle the case when the canard fins are deflected. However, a simple approximation described in Ref. 8, page 18, is adequate. The approximation consists of using CRUTRJ with the fins undeflected and then moving the nose vortices normal to the fin a fraction of the chord to account for the turning of the flow due to the fin deflection. To use the method do the following:

1. Run CRUTRJ with fins undeflected to the axial station corresponding to fin planform centroid.

2. Determine if a deflected fin is in the sector about the positive z_o axis bounded by $-45^o \leq \phi \leq 45^o$. If so, continue to step 3. Otherwise, use results of step 1 for vortex loads calculation.

3. Calculate the amount $h_{cen.} = (x_{cen.} - x_{\ell.e.})\sin\delta$ where δ is the deflection angle of the fin in the sector $-45^o \leq \phi \leq 45^o$.

4. Move each nose vortex from its position given by CRUTRJ the distance $h_{cen.}$ in the direction normal to the fin from suction side to pressure side.

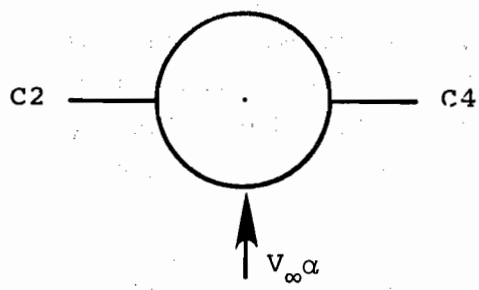
EQUIVALENT ANGLE-OF-ATTACK CONCEPT FOR CRUCIFORM WING-BODY COMBINATIONS

The accurate calculation of induced rolling moments due to panel-panel interference and to vortex-fin interactions for the angles of attack of interest here requires accounting for nonlinear fin normal force and center-of-pressure position in the method. To account for such nonlinearities, we have extended the concept of an equivalent angle of attack utilized earlier in Ref. 11 (see also Refs. 7, 8, and 10). The α_{eq} concept not only introduces nonlinearities into the method but also provides a means of correlating panel force and moment data taken on a cruciform wing-body combination and extending the results to other conditions and configurations for which data are not available. Although the equivalent angle of attack will be defined in terms of fin normal force, it will also be used to correlate fin center-of-pressure data.

The effects of body (Beskin) upwash and fin deflection are discussed first with respect to a planar wing-body combination for simplicity. Second, we show how to apply those results to a banked cruciform wing-body combination at angle of attack. Third, the additional effects of sideslip are considered. We show how to calculate the increments for each fin of the equivalent angle of attack from the lifting-surface program of Ref. 9. Then we show how to obtain similar results from slender-body theory.

PLANAR WING-BODY COMBINATION AT ANGLE OF ATTACK WITH NO FIN DEFLECTION; NO BANK

Consider a planar wing-body combination at angle of attack and zero bank angle with the fins at zero deflection as shown in the sketch below.



The effective angle of attack on the fins is higher than α because of the flow around the body. To account for this effect, we define the interference factor K_W <u>for the linear range</u> such that twice the normal force on each fin is K_W times that of the wing-alone at the same angle of attack, α. Thus, <u>in the linear range</u>, the fins are generating as much force as the wing-alone develops at angle of attack $K_W\alpha$. Hence, we are led to extend the concept to the nonlinear range by assuming the following relationship

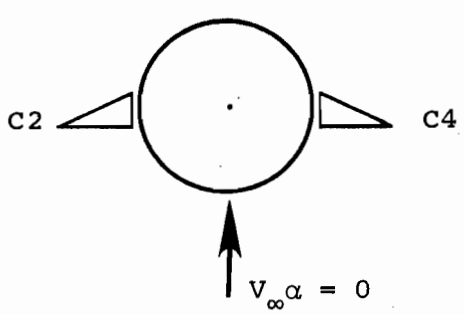
$$C_{N_{W(B)}}(\alpha,\ \delta_H = 0) = C_{N_W}(K_W\alpha) \tag{6}$$

Thus, the equivalent angle of attack, α_{eq}, for the fins for the body upwash effect is just $K_W\alpha$.

Table 1 gives values of K_W for various a/s_m ratios based on slender-body theory. These values can be used at subsonic and supersonic speeds.

PLANAR WING-BODY COMBINATION WITH FIN DEFLECTION AT ZERO ANGLE OF ATTACK; NO BANK

Now consider the body at <u>zero</u> angle of attack and the horizontal panels deflected at angle δ_H as shown in the sketch below.



The fins now have slightly less normal force than they would have if they were acting at the same incidence as a wing-alone because of the "imperfect" reflection plane of the body. As before with K_W, we define the interference factor k_w and assume the following relationship holds for the nonlinear range.

$$C_{N_{W(B)}}(\alpha = 0,\ \delta_H) = C_{N_W}(k_w \delta_H) \tag{7}$$

Slender-body values of k_w are given in Table 1.

PLANAR WING-BODY COMBINATION WITH FIN DEFLECTION AT ANGLE OF ATTACK; NO BANK

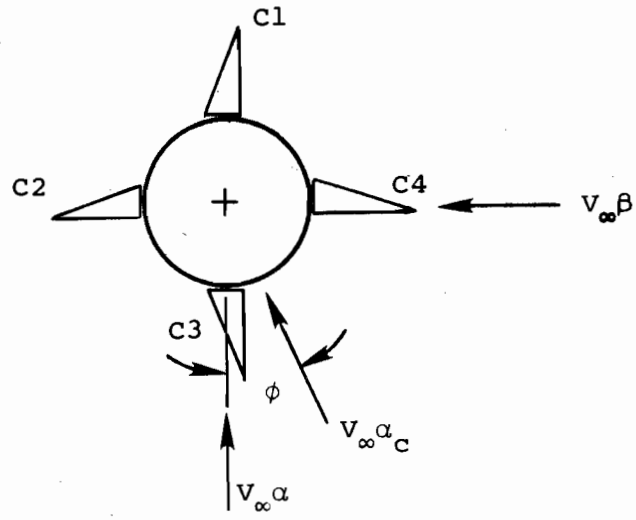
To apply K_W and k_w to combined conditions of angle of attack and fin deflection, we assume that the following relationship holds

$$C_{N_{W(B)}}(\alpha,\ \delta_H) = C_{N_W}(K_W \alpha + k_w \delta_H) \tag{8}$$

The usefulness of equation (8) is illustrated in Fig. 4 of Ref. 7 for two wings of aspect ratio 4 with slightly different planforms for three Mach numbers. The wings had a/s_m ratios of 0.226 (AIM-9L test model) and 0.400 (MICOM test model).

BODY UPWASH AND REFLECTION PLANE EFFECTS FOR BANKED CRUCIFORM WING-BODY COMBINATION

When a cruciform wing-body combination is rolled ϕ degrees and is at an included angle of attack, α_c, it is convenient to consider the flow with components normal and parallel to each set of opposing fins as shown below.



where $\alpha = \alpha_c \cos \phi$

$\beta = \alpha_c \sin \phi$

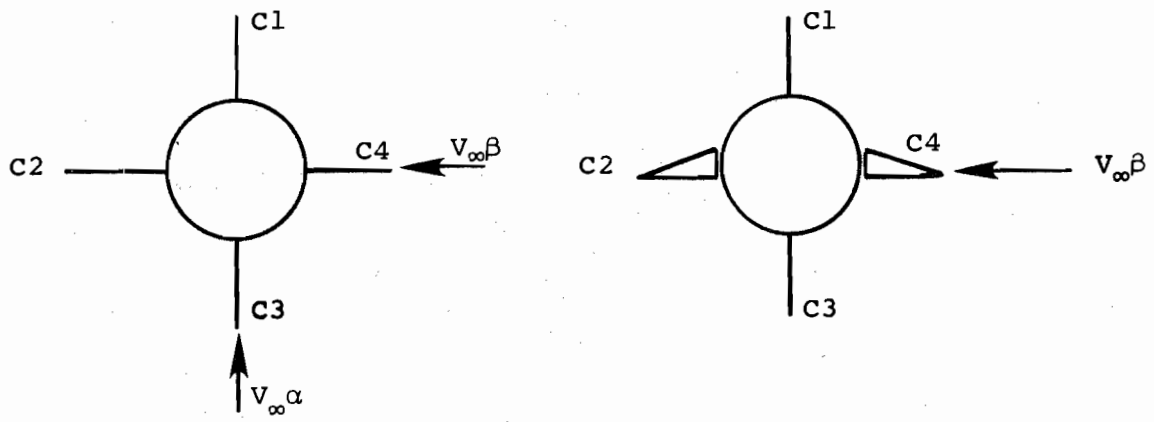
The equivalent angles of attack for each fin due to the effects of body upwash and the so-called "imperfect" body reflection plane are simply

$$\alpha_{eq} = K_W \alpha_c \cos \phi + k_w \delta_H, \text{ horizontal fins} \tag{9}$$

$$\alpha_{eq} = K_W \alpha_c \sin \phi + k_w \delta_V, \text{ vertical fins} \tag{10}$$

INCREMENTS IN EQUIVALENT ANGLE OF ATTACK DUE TO SIDESLIP ON FINS

When a cruciform wing-body combination is at an included angle, α_c, and is banked ϕ degrees as shown in the previous sketch, each fin has a different normal force and equivalent angle of attack because of variations in local flow conditions. The effects of sideslip on α_{eq} are separately considered as shown below, the left sketch representing sideslip due to bank with no fin deflection and the right sketch representing sideslip (no bank) with fin deflection.



$\phi \neq 0,\ \delta_V = \delta_H = 0$ $\qquad$ $\phi = 90^\circ,\ \alpha = \delta_V = 0$

$\alpha \neq 0,\ \beta \neq 0$ $\qquad$ $\delta_H \neq 0,\ \beta \neq 0$

SIDESLIP WITH NO FIN DEFLECTION

Definitions of Interference Factors

The interference factors for the case of $\phi \neq 0$ with no fin deflection are defined in Ref. 7 so that the increment in α_{eq} due to sideslip is given by

$$\alpha_{eq} = \pm K_{\alpha\beta} \left(\frac{4}{AR}\right) \alpha\beta \tag{11}$$

In Ref. 7 we assigned the effects of sideslip to each fin of an opposing set equally. Further work with the lifting-surface program has indicated that the K factors due to sideslip can be assigned to each fin separately. Except for one case described below, we will use the newer approach.

It follows from equation (11) that $K_{\alpha\beta}$ for each horizontal fin is

$$(K_{\alpha\beta})_{H,i} = \frac{|CNi(\alpha,\beta) - CNi(\alpha,\ \beta = 0)|}{\frac{1}{2} C_{N_W}(\alpha)} \left(\frac{AR}{4\beta}\right) \tag{12}$$

and for each vertical fin

$$(K_{\alpha\beta})_{V,i} = \frac{|CNi(\alpha,\beta) - CNi(\alpha = 0, \beta)|}{\frac{1}{2} C_{N_W}(\beta)} \left(\frac{AR}{4\alpha}\right) \tag{13}$$

Calculation of $K_{\alpha\beta}$ Interference Factors from Lifting-Surface Programs

If a lifting-surface program, such as that of Appendix A, which is capable of handling the effects of sideslip on fin normal force is available, the $K_{\alpha\beta}$ factors can be obtained directly from equations (12) and (13) and computer runs for the following cases ($\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$)

1. $\phi \neq 0$, $\alpha_c \neq 0$
2. $\phi = 0$, $\alpha_c = \alpha$
3. $\phi = 90^\circ$, $\alpha_c = \beta$

The quantities $C_{N_W}(\alpha)$ and $C_{N_W}(\beta)$ may be obtained from the program for a wing-alone, or, more simply from linear theory.*

Since fin normal-force behavior is nonlinear, the $K_{\alpha\beta}$ factors are not exactly constant. However, since the increment in α_{eq} due to $K_{\alpha\beta}$ is relatively small compared to the increments due to K_W or k_w, it is usually accurate enough to assume that the $K_{\alpha\beta}$'s are constants. For example, if the user is calculating the induced rolling moments for a range of α_c's at a given bank angle, he may calculate $K_{\alpha\beta}$ at an α_c in the middle of the angle-of-attack range and use that value for all α_c's.

Calculation of $K_{\alpha\beta}$ Interference Factors from Slender-Body Theory

Slender-body theory (Ref. 10) predicts that $K_{\alpha\beta}$ will be the same for all four fins provided that they have identical planforms. The results for triangular planforms are presented in Table 1. Those values may also be used to estimate $K_{\alpha\beta}$ for other planforms provided the correct aspect ratio is used in equation (11).

*The program should include the effects of leading-edge and side-edge suction if the fin planform is such that those effects create a significant portion of the normal force.

SIDESLIP WITH FIN DEFLECTION AND NO BANK

Definition of Interference Factors

The interference factors for the case of $\phi = 0$ and horizontal fin deflection (see right side of previous sketch) are defined in Ref. 7 so that the increment in α_{eq} due to sideslip is given by

$$\alpha_{eq} = \pm K_{\beta\delta_H} \left(\frac{4}{AR} \right) \beta\delta_H \tag{14}$$

Using the newer approach outlined above, we find that equation (14) gives the following $K_{\beta\delta_H}$ for each horizontal fin ($\delta_V = 0$)

$$(K_{\beta\delta_H})_{H,i} = \frac{|CNi(\alpha = 0, \beta, \delta_H) - CNi(\alpha = 0, \beta = 0, \delta_H)|}{\frac{1}{2} C_{N_W}(\delta_H)} \left(\frac{AR}{4\beta} \right) \tag{15}$$

By symmetry, we can also write ($\delta_H = 0$)

$$(K_{\alpha\delta_V})_{V,i} = \frac{|CNi(\alpha, \beta = 0, \delta_V) - CNi(\alpha = 0, \beta = 0, \delta_V)|}{\frac{1}{2} C_{N_W}(\delta_V)} \left(\frac{AR}{4\alpha} \right) \tag{16}$$

Equations (15) and (16) give the K factors for the deflected fins which are the primary source of induced roll. The undeflected fins produce induced roll of an opposite sign to that of the deflected fins. The K factors for the undeflected vertical fins when $\delta_H \neq 0$ are:

$$(K_{\beta\delta_H})_{V,i} = \frac{|CNi(\alpha = 0, \beta, \delta_H) - CNi(\alpha = 0, \beta, \delta_H = 0)|}{\frac{1}{2} C_{N_W}(\delta_H)} \left(\frac{AR}{4\beta} \right) \tag{17}$$

and, similarly, for the undeflected horizontal fins when $\delta_V \neq 0$ are:

$$(K_{\alpha\delta_V})_{H,i} = \frac{|CNi(\alpha, \beta = 0, \delta_V) - CNi(\alpha, \beta = 0, \delta_V = 0)|}{\frac{1}{2} C_{N_W}(\delta_V)} \left(\frac{AR}{4\alpha} \right) \tag{18}$$

The induced roll produced by the undeflected fins is small, however, and

to avoid an extra computer run we can safely assign the sideslip effect equally to each fin. Hence, for our purposes, equations (17) and (18) can be averaged to get

$$(K_{\beta\delta_H})_V = \frac{|CN1(\alpha = 0,\beta,\delta_H) - CN3(\alpha = 0,\beta,\delta_H)|}{C_{N_W}(\delta_H)} \left(\frac{AR}{4\beta}\right) \tag{19}$$

$$(K_{\alpha\delta_V})_H = \frac{|CN2(\alpha,\beta = 0,\delta_V) - CN4(\alpha,\beta = 0,\delta_V)|}{C_{N_W}(\delta_V)} \left(\frac{AR}{4\alpha}\right) \tag{20}$$

Note that the following equalities follow from symmetry:

$$\begin{aligned}
(K_{\beta\delta_H})_{V,1} &= (K_{\alpha\delta_V})_{H,2} \\
(K_{\beta\delta_H})_{H,2} &= (K_{\alpha\delta_V})_{V,1} \\
(K_{\beta\delta_H})_{V,3} &= (K_{\alpha\delta_V})_{H,4} \\
(K_{\beta\delta_H})_{H,4} &= (K_{\alpha\delta_V})_{V,3}
\end{aligned} \tag{21}$$

Hence, either the $\beta\delta_H$ or the $\alpha\delta_V$ case may be used to find the interference factors.

Calculation of $K_{\alpha\delta_V}$ and $K_{\beta\delta_H}$ Interference Factors from Lifting-Surface Program

If a lifting-surface program capable of handling the effect of sideslip on fin normal force is available, the $K_{\alpha\delta_V}$ and $K_{\beta\delta_H}$ factors can be obtained directly from equations (15), (19), and (21) and computer runs for the following cases.

1. $\alpha = 0$, β, δ_H, $\delta_V = 0$.

2. $\alpha = 0$, $\beta = 0$, δ_H, $\delta_V = 0$.

Note that by using equation (19) rather than equation (17) we have avoided a third computer run.

Calculation of $K_{\alpha\delta_V}$ and $K_{\beta\delta_H}$ Interference Factors from Slender-Body Theory

Slender-body theory predicts that the $K_{\alpha\delta_V}$ and $K_{\beta\delta_H}$ interference factors will be equal for opposing fins. Hence, equations (21) can be written:

$$
\begin{aligned}
(K_{\alpha\delta_V})_V &= (K_{\beta\delta_H})_H \\
(K_{\alpha\delta_V})_H &= (K_{\beta\delta_H})_V
\end{aligned}
\tag{22}
$$

The results are presented in Table 1 for triangular planforms. The values given may be used for other planforms provided the correct aspect ratio is used in equation (14). This method is used at subsonic speeds.

EQUIVALENT ANGLES OF ATTACK FOR THE GENERAL CASE FOR CANARD FINS

For the general case shown in the sketch on page 11 with bank and fin deflection, the following equations give the equivalent angle of attack* for each canard fin:

$$
\begin{aligned}
\text{C1:}\quad \alpha_{eq} = {} & K_W\alpha_c \sin\phi + k_w\delta_V + \frac{4}{AR}\Big[-(K_{\alpha\beta})_{V,1}\alpha_c^2 \sin\phi\cos\phi \\
& -(K_{\alpha\delta_V})_{V,1}\delta_V\alpha_c\cos\phi - (K_{\beta\delta_H})_{V,1}\delta_H\alpha_c\sin\phi\Big]
\end{aligned}
\tag{23}
$$

$$
\begin{aligned}
\text{C2:}\quad \alpha_{eq} = {} & K_W\alpha_c \cos\phi + k_w\delta_H + \frac{4}{AR}\Big[-(K_{\alpha\beta})_{H,2}\alpha_c^2 \sin\phi\cos\phi \\
& -(K_{\beta\delta_H})_{H,2}\delta_H\alpha_c\sin\phi - (K_{\alpha\delta_V})_{H,2}\delta_V\alpha_c\cos\phi\Big]
\end{aligned}
\tag{24}
$$

$$
\begin{aligned}
\text{C3:}\quad \alpha_{eq} = {} & K_W\alpha_c \sin\phi + k_w\delta_V + \frac{4}{AR}\Big[(K_{\alpha\beta})_{V,3}\alpha_c^2 \sin\phi\cos\phi \\
& + (K_{\alpha\delta_V})_{V,3}\delta_V\alpha_c\cos\phi + (K_{\beta\delta_H})_{V,3}\delta_H\alpha_c\sin\phi\Big]
\end{aligned}
\tag{25}
$$

*All angles are in radians in equations (23) to (30).

$$\text{C4:} \quad \alpha_{eq} = K_W \alpha_c \cos\phi + k_w \delta_H + \frac{4}{AR}\Big[(K_{\alpha\beta})_{H,4}\, \alpha_c^2 \sin\phi \cos\phi + (K_{\beta\delta_H})_{H,4}\, \delta_H \alpha_c \sin\phi + (K_{\alpha\delta_V})_{H,4}\, \delta_V \alpha_c \cos\phi\Big] \tag{26}$$

EQUIVALENT ANGLES OF ATTACK FOR THE GENERAL CASE FOR TAIL FINS

Since the tail fins are never deflected and since they are numbered in clockwise order, equations (23) to (26) yield:

$$\text{T1:} \quad \alpha_{eq} = K_W \alpha_c \sin\phi - (K_{\alpha\beta})_{V,1} \left(\frac{4}{AR}\right) \alpha_c^2 \sin\phi \cos\phi \tag{27}$$

$$\text{T2:} \quad \alpha_{eq} = K_W \alpha_c \cos\phi + (K_{\alpha\beta})_{H,2} \left(\frac{4}{AR}\right) \alpha_c^2 \sin\phi \cos\phi \tag{28}$$

$$\text{T3:} \quad \alpha_{eq} = K_W \alpha_c \sin\phi + (K_{\alpha\beta})_{V,3} \left(\frac{4}{AR}\right) \alpha_c^2 \sin\phi \cos\phi \tag{29}$$

$$\text{T4:} \quad \alpha_{eq} = K_W \alpha_c \cos\phi - (K_{\alpha\beta})_{V,4} \left(\frac{4}{AR}\right) \alpha_c^2 \sin\phi \cos\phi \tag{30}$$

INDUCED ROLL DUE TO PANEL-PANEL INTERFERENCE

For the angles of attack of interest here, the induced rolling moments due to panel-panel interference are usually small compared to those generated by vortex-tail interaction. This was found to be true for the configurations investigated under this contract (AIM-9L, Ref. 15 and NWC-MICOM test model, $BN_3C_6T_2$, Ref. 5). In any case, the methods given below should be used for a few flight conditions to determine if the induced rolling moments due to panel-panel interference are indeed small.

For reasons of simplicity and lower cost, the method uses the equivalent angle-of-attack concept to predict induced rolling moments due to panel-panel interference. For considerably greater expense, the lifting-surface program may be used for supersonic speeds. If the lifting-surface program is used, simply read the induced rolling moment for each fin from the computer output listed under the heading for the Bernoulli pressure coefficient. If the α_{eq} method is to be used, do the following (see Fig. 7 for sign conventions):

1. If none of the fins is deflected, neglect induced roll. Previous test experience with the AIM-9L and MICOM-NWC configurations (Refs. 5, 7, and 15) indicates this to be a reasonable assumption. Hence, panel-panel interference for the tail section may be ignored.

2. If $M_\infty > 1$ and the fin leading edges are subsonic, neglect induced roll.

3. Calculate α_{eq} for each fin using equations (23) to (26) or (27) to (30).

4. Determine the normal-force coefficient and center of pressure for each fin using appropriate wing-alone data or correlations.

5. Calculate the rolling moment generated by each fin from the following equation:

$$\text{CRMCi} = \text{CNCi}\ \frac{\bar{y}}{\ell_r} \cos \delta_i\ ;\quad i = 1,2,3,4 \tag{31}$$

6. Add the fin rolling moments to get the total induced rolling moment for the canard section due to panel-panel interference

$$C_{\ell_C} = -\ \text{CRMC1} + \text{CRMC2} + \text{CRMC3} - \text{CRMC4} \tag{32}$$

VORTEX DEVELOPMENT OVER AFTERBODY

In this section the method for calculating the trajectories of the canard and afterbody vortices from the canard trailing edge to the tail-fin centroid is presented. The calculation of the canard fin trailing-vortex strengths and initial positions is discussed first. Second, we discuss the method for calculating the starting positions of the afterbody vortices. Finally, we discuss the tracking of the vortices to the tail fin area centroid.

CALCULATION OF CANARD FIN TRAILING-VORTEX STRENGTHS AND INITIAL POSITIONS

The vorticity shed from the trailing edges of the canard fins is assumed to roll up as a single vortex per fin immediately behind the trailing edge. Furthermore, the fin span loading is assumed to be a linear

combination of elliptical span loading and linear span loading. It is shown in Ref. 8, pages 18-19, how to obtain the vortex strength and position for each fin. The method consists of the following steps for each fin:

1. If loading results from the lifting-surface program are to be used, go to step 2. Otherwise, calculate α_{eq}.

2. Determine CN and $\bar{y}$.

3. Calculate $\bar{\eta}$

$$\bar{\eta} = \frac{\bar{y} - a}{s_m - a} \tag{33}$$

4. Calculate a_e/a_L

$$\frac{a_e}{a_L} = \frac{\frac{1}{2}\bar{\eta} - \frac{1}{6}}{\frac{1}{3} - \frac{\pi}{4}\bar{\eta}} \tag{34}$$

5. Calculate a_L

$$a_L = \frac{(CN)(S_R)}{(s_m - a)\left[\frac{1}{2} + \frac{\pi}{4}\left(\frac{a_e}{a_L}\right)\right]} \tag{35}$$

6. Calculate the vortex strength

$$\frac{\Gamma}{2\pi V_\infty a} = \frac{1}{4\pi a} a_L \left(1 + \frac{a_e}{a_L}\right) \tag{36}$$

7. Calculate the fraction of the span that the vortex is outboard of the fin root

$$\frac{y_v - a}{s_m - a} = \frac{\frac{1}{2} + \frac{\pi}{4}\left(\frac{a_e}{a_L}\right)}{1 + \frac{a_e}{a_L}} \tag{37}$$

8. Start the vortex on the fin trailing edge at the distance outboard given by step 7.

CALCULATION OF INITIAL POSITIONS OF AFTERBODY VORTICES

For cruciform canard missiles with noses having typical fineness ratios of about 3 to 4, nose vortices play no significant part in the region aft of the canard trailing edge up to angles of attack of 20°. Consequently, we will ignore nose vortices in the afterbody region.

Starting Positions in the Axial Direction of the Afterbody Vortices

Depending upon the geometry of a missile and its fin deflections at any time, the trailing vortices generated by the canard fins may dominate the crossflow over the afterbody. If this is true, special care must be taken in applying the method. To estimate the effect of the canard fin trailing vortices, the user should run the vortex tracking program VCHASE with no body vortices present with output generated at roughly one-diameter intervals.

The program VCHASE calculates the velocity at the body centerline due to all the free vortices as if the body were not present. This velocity is added vectorially to the crossflow component of the free-stream velocity and is used to estimate the crossflow drag coefficient at that station. The direction of that velocity vector measured counterclockwise from the positive y_o-axis is output as THETA.* The magnitude of that velocity is output as a crossflow angle in degrees. It is called FLOANG.** The quantities FLOANG and THETA tell the user the influence of the canard fin trailing vortices on the crossflow at a given axial station. Depending on the values of α_{cr} and θ found from running VCHASE with canard vortices only, two different methods must be used to estimate the axial starting positions of the afterbody vortices. The following procedure is recommended:

1. If nose vortices are present, $\alpha_{cr} > 4^{\circ}$ and θ is not more than 90° from the direction of the <u>free-stream</u> crossflow velocity vector, start the afterbody vortices at the canard trailing edge.

2. If any of the three criteria in step 1 are not met, then it is assumed that the body boundary layer begins again and a certain body length is needed for the layer to separate. It is recommended that the body length after the canard trailing edge which is required for separation be

---

*We will refer to THETA later in the text as θ.
**We will refer to FLOANG later in the text as α_{cr}.

estimated from equation (2) using α_{cr} averaged over the length for α_c. This step may require some iteration if $\bar{\alpha}_{cr}$ is a strong function of x_s.

For some missiles, the distance between the canard trailing edge and the tail leading edge may be large enough at α_c's of interest in this report to form a third and even a fourth afterbody vortex. The method for determining the starting positions of these vortices is given in the section on vortex tracking.

Starting Positions of the Afterbody Vortices in the Crossflow Plane

In Ref. 8, we gave a method for finding the initial locations of the afterbody vortices in the crossflow plane based on a procedure for calculating the position of the velocity maxima on the body surface. Since the publication of that report, we have developed a simpler method which appears to give positions close to those of Ref. 8. The direction of the velocity vector in the crossflow plane, measured from the positive y_o-axis, which is due to the free-stream velocity and to the external canard vortices (excluding images) is called θ. The left and right afterbody vortices are assumed to start at some given distance r_v from the body axis and at $\theta \pm 50^o$, respectively. This method gives results more suitable for VCHASE when the canard fin vortices are strongly influencing the flow. The VCHASE program will use this method if suitable control values are input as described in Appendix C. It is recommended that the user try a value of $r_v/a = 1.2$ to start with. This is the value we have found satisfactory for all cases tried so far.

VORTEX TRACKING OVER AFTERBODY

The canard and afterbody vortices are tracked by the slender-body theory described in Refs. 4, 8, and 10. The afterbody vortices are allowed to grow unsymmetrically under the influence of the canard vortices. As described in Ref. 8, pages 6 to 11, the method uses the vortex impulse theorem and empirical correlations of the crossflow drag coefficient to estimate the increase in strengths of the afterbody vortices at each time step. The crossflow drag coefficient is assumed to vary with crossflow Mach number along the length of the body.

There are four possible stages of vortex development over the afterbody between the canard trailing edge and the area centroid of the tail fin.

The possible development stages are:

1. Canard vortices only
2. Afterbody vortices growing in strength
3. Tearing of one or more afterbody vortices and the subsequent formation of new afterbody vortices
4. Free vortex movement over the tail section.

Canard Vortices Only

If afterbody vortices do not start immediately after the canard trailing edge, the canard vortices will be tracked as free vortices ($c_{d_c} = 0$) until x_s or the leading edge of the tail fin root chord, whichever comes first. Since VCHASE was run with no body vortices present in the previous section, this part of the method already has been completed.

Afterbody Vortices Present

To track the afterbody and canard vortices together, start (restart) VCHASE at x_s allowing the program to select the initial afterbody vortex positions or using independently obtained positions. Note that the program assumes that the first and second vortices listed are the afterbody vortices. Track the vortices until the starting position of a third afterbody vortex, if present, or until the leading edge of the tail fin root chord, whichever comes first. The initial strengths of the afterbody vortices should always be zero.

Tracking When an Afterbody Vortex has Torn

If the missile afterbody is long enough, for a given α_c it is possible that multiple afterbody vortices may form. This phenomenon is described for round bodies in Ref. 16. We will assume for the purposes of this report that the data and correlations of Ref. 16 can be applied to afterbodies as well. Since this portion of the method is being presented for the first time, it is illustrated in the calculated-example sections for clarity. We will simply state here that once a vortex has torn, it should be treated as a free vortex (constant strength) and a new afterbody vortex started to replace it. To do this, VCHASE should be restarted at the axial station where tearing occurs. The torn vortex should be added to the list of free vortices and a new zero-strength afterbody vortex started in its place.

This process can be repeated as often as necessary until the vortices have been tracked to the leading edge of the tail fin root chord.

Vortex Movement Over the Tail Section

When the computer program CRUTRJ is used to track vortex movement over a cruciform tail section, large motions are calculated for a vortex near the surface of the body or a fin. This result can be attributed to the influence of the vortex's image. The vapor-screen films taken during the test of Ref. 5 do not show such large motions. Indeed, numerical experiments with CRUTRJ indicate that a concentrated vortex has a larger calculated motion than if it had been spread out into a number of discrete vortices with the same center of vorticity. At this time we recommend that the user restart VCHASE at the leading edge of the tail root chord and run the vortices at constant strength ($c_{d_c} = 0$) back to the axial station corresponding to the area centroid of the tail fin, thereby avoiding the large motion due to the tail fins.

INDUCED ROLL DUE TO VORTEX-FIN INTERFERENCE

Reverse-flow methods are used for the calculation of induced rolling moments due to vortex-fin interference both for the canard section and for the tail section. Although the lifting-surface program of Ref. 9 can be used, the results presented in Ref. 8 indicate that the substantial increase in computing costs required are not generally warranted unless detailed loadings are desired. The program to be used here has been previously described in Refs. 14 and 17. It assumes each vortex to be infinite in length and that its centroid has the same crossflow location for all axial stations. Since the vortices do actually move over the tail section, we must choose an appropriate axial location which will best "average" the vortex effects. We have chosen to use the axial station at the fin area centroid. To use the method, do the following:

1. Obtain the vortex positions at the axial station corresponding to the centroid of the fin planform area.

2. Calculate the α_{eq} for each fin without the vortices present.

3. Determine the normal-force coefficient for the tail-alone* for each fin equivalent angle of attack without vortices present using the appropriate wing-alone correlation.

4. Run the reverse-flow program called REVFLO.

5. Add the α_{eq} obtained from REVFLO to the α_{eq} from step 2.

6. Determine the normal-force coefficient for the tail-alone for each fin equivalent angle of attack with vortices present using the appropriate tail-alone curve.

7. Calculate the normal-force increment for each fin due to the vortices by subtracting the results of step 3 from the results of step 6.

8. Obtain the induced rolling moment for each fin by multiplying the center of pressure for the vortex loading from REVFLO times one-half the results of step 7.**

9. Add the results of step 8 to get the total induced rolling moment for the tail section due to the presence of the vortices.

FIRST CALCULATIVE EXAMPLE

As the first calculative example, we will consider the AIM-9L configuration at $M_\infty = 1.75$ and $\phi = 0$ with 20° of yaw control. The AIM-9L as shown in Fig. 8 has a long slender afterbody between the canards and tail fins. This is the principal difference between AIM-9L and the missile previously tested and analyzed in Refs. 5-8. The longer afterbody can generate more than two vortices even for angles of attack less than 16°.

In carrying out the following calculative example, we are trying to predict the rolling-moment characteristics of the AIM-9L missile for wind-tunnel conditions so that comparison between experiment and theory can be made. The tests were performed at crossflow Reynolds numbers which reached about 10^5 at $\alpha_c = 20^\circ$. We will nevertheless assume the crossflow is supercritical over the afterbody on the supposition that the canard fin shocks for 20° of yaw control will trip the body boundary layer. We do not

*This procedure, although written for the empennage, applies equally to the canard section.

**Recall that the tail-alone normal-force curve is developed for two opposing fins placed together. Hence, the need for a factor of one-half.

possess vapor-screen pictures to guide us in setting up the afterbody vortex model, as was the case for the missile described in Ref. 5.

The sample calculation is described below under the headings:

1. Geometric and Aerodynamic Characteristics
2. Canard Panel-Panel Interference
3. Canard Vortex Strengths and Positions
4. Body Vortices
5. Multiple Afterbody Vortices
6. Vortex Trajectories and Empennage Rolling Moment
7. Summary of Results

Detailed calculations will be made below for (b)(3). Final results for other angles of attack will also be presented.

GEOMETRIC AND AERODYNAMIC CHARACTERISTICS

The overall dimensions of the static force model of AIM-9L are shown in Fig. 8 including the detailed dimensions of the canard and tail fins. The fins have the following properties:

Parameter	Canard Fins	Tail Fins
Fin Area Aspect Ratio Taper Ratio a/s_m	(b)(3) (b)(3)	(b)(3) (b)(3)

Based on the foregoing values of a/s_m, the following interference factors based on slender-body theory are obtained from Table 1:

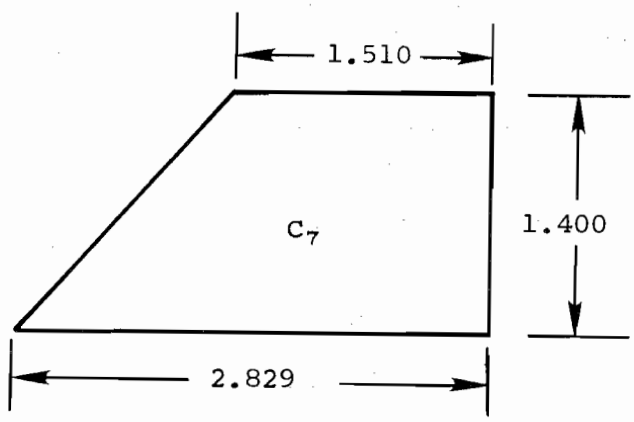
Canard Fins: (b)(3) (b)(3) (b)(3)

Tail Fins: (b)(3) (b)(3)

We need the normal-force and lateral center-of-pressure curves for the wing formed by joining the canard fins together. We have data on the normal force developed by an opposing pair of canard fins obtained during the tests of the configuration shown in Fig. 8 as reported in Ref. 15.

These data have been converted to "wing-alone" data by plotting the measured normal-force coefficient versus the equivalent angle of attack using slender-body theory values of K_W and k_w. The results were presented as Fig. 28 of Ref. 4. The figure is reproduced here for S_R = planform area as shown in Fig. 9. However, no measurements were made of the lateral center of pressure of the AIM-9L canard fins. Since the AIM-9L canard fins are close in planform to that for the canards tested and reported in Ref. 5, we will use the data for the lateral center of pressure for the corresponding wing-alone given in Fig. 5 of Ref. 7 for M_∞ = 0.8, 1.3 and 1.75 included here as Fig. 10. For comparison, the normal-force curve for the wing-alone of Ref. 7 is presented in Fig. 11.

We will need the normal-force curve of the "tail-alone" formed by joining two opposing tail fins. Since no such data are available, the wing-alone curve was approximated in the following manner. Data at M_∞ = 1.75 are available for canard fins of the following planform in Ref. 5.



Fin Area: 6.12 in^2

Aspect Ratio: 1.30

Taper Ratio: 0.533

The data for the tail-alone based on this canard fin were "corrected" to the aspect ratio and taper ratio for the AIM-9L tail fin with the help of the lifting-surface computer program of Ref. 14. This lifting-surface computer program computes the potential lift using methods similar to those utilized in CRFWBD, but in addition it computes the vortex lift associated with leading-edge and side-edge suction. The ratio of the normal force between the two tail fins was determined with the following results:

α	Theoretical C_{N_T}*		Ratio
	AIM-9L	C_7	
5°	0.158	0.1929	0.817
15°	0.537	0.6169	0.870
25°	1.002	1.0092	0.917

*Based on fin planform area.

The data for the C_7 tail-alone were scaled down by the foregoing ratio and referred to the body cross-sectional area of AIM-9L to obtain Fig. 12 for the tail-alone normal-force curve for the AIM-9L missile. Since the above ratios do not represent large corrections, it is felt the resulting normal-force curve is fairly accurate. This procedure is not considered part of the general method, but illustrates an approximate method for obtaining a C_{N_T} curve in the absence of data.

CANARD PANEL-PANEL INTERFERENCE

The program CRFWBD has been run to determine the canard panel normal-force and rolling-moment coefficients for $M_\infty = 1.75$ using the Bernoulli pressure equation. The program cannot handle arbitrary nose configurations. Hence, the ellipsoidal nose shown in Fig. 13 was used to represent the AIM-9L nose. The following results were obtained for $M = 1.75$, $\phi = 0^\circ$, $\delta_1 = \delta_3 = 20^\circ$ and $\delta_2 = \delta_4 = 0^\circ$:

α_c	CNC1	CNC2	CNC3	CNC4	CRMC1	CRMC2	CRMC3	CRMC4
0°	1.1094	0	1.1094	0	1.3000	0	1.3000	0
8°	1.0449	0.81933	1.1818	0.85912	1.2224	0.94571	1.3761	0.98793
15°	0.99115	1.5032	1.2538	1.5681	1.1487	1.7289	1.4445	1.7980
20°	0.95169	1.9477	1.3101	2.0218	1.0900	2.2301	1.4950	2.3088

The resulting induced rolling-moment coefficients are:

α_c	C_{ℓ_C}
0°	0
8°	0.1115
15°	0.2268
20°	0.3263

Relatively small induced rolling moments for the canard fins are produced by panel-panel interference.

CANARD VORTEX STRENGTHS AND POSITIONS

The first step in determining the canard vortex strengths and positions at the trailing edges is to obtain the fin normal forces and centers of pressure. To do this we must first find the equivalent angles of attack for the canard fins for each α_c. For this case equations (23) to (26) become

$$\text{C1:} \quad \alpha_{eq} = k_w\delta_V - (K_{\alpha\delta_V})_{V,1}\delta_V\alpha_c \tag{38}$$

$$\text{C2:} \quad \alpha_{eq} = K_W\alpha_c - (K_{\alpha\delta_V})_{H,2}\delta_V\alpha_c \tag{39}$$

$$\text{C3:} \quad \alpha_{eq} = k_w\delta_V + (K_{\alpha\delta_V})_{V,3}\delta_V\alpha_c \tag{40}$$

$$\text{C4:} \quad \alpha_{eq} = K_W\alpha_c + (K_{\alpha\delta_V})_{H,4}\delta_V\alpha_c \tag{41}$$

where $\delta_V = 20^\circ$. We will use the tabulated results of the lifting-surface program CRFWBD given on page 27 for $\alpha_c = 0^\circ$ and 15° and substitute those results into equations (16) and (20) to get the $K_{\alpha\delta_V}$ factors.

First, we must get the wing-alone normal force at $\delta_V = 20^\circ$ based on linear theory. For supersonic edges, we have

$$C_{N_W} = \frac{4}{\sqrt{M^2 - 1}} \times \frac{20^\circ}{57.3^\circ} = 0.972$$

based on the wing planform area. Since planform area/πa^2 = 3.54 for the AIM-9L canard fins, C_{N_W} = 3.44 based on πa^2. For C1, equation (16) gives

$$(K_{\alpha\delta_V})_{V,1} = \frac{|0.99115 - 1.1094|}{\frac{1}{2}(3.44)}\left(\frac{4.2}{4}\right)\left(\frac{57.3^\circ}{15^\circ}\right) = 0.276$$

For C2 and C4, equation (20) gives

$$(K_{\alpha\delta_V})_{H,2} = (K_{\alpha\delta_V})_{H,4} = \frac{|1.5032 - 1.5681|}{3.44}\left(\frac{4.2}{4}\right)\left(\frac{57.3^\circ}{15^\circ}\right) = 0.076$$

For C3, equation (16) gives

$$(K_{\alpha\delta_V})_{V,3} = \frac{|1.2538 - 1.1094|}{\frac{1}{2}(3.44)}\left(\frac{4.2}{4}\right)\left(\frac{57.3^\circ}{15^\circ}\right) = 0.337$$

The canard fin α_{eq}'s for $\alpha_c = 16^\circ$ were obtained from equations (38) to (41) using the above $K_{\alpha\delta_V}$ factors and are listed below. The corresponding normal-force coefficients and centers of pressure from Figs. 9 and 10 are also given.

$\alpha_c = 16^\circ$, $\phi = 0^\circ$			
Fin	α_{eq}	CNCi*	$\bar{\eta} = \frac{\bar{y} - a}{s_m - a}$
C1	17.4°	0.66	0.375
C2	18.6°	0.70	0.375
C3	20.6°	0.77	0.375
C4	19.5°	0.73	0.375

*CNCi is based on planform area of one fin only.

Let us first find the positions of the vortices at the fin trailing edges. From equation (34) we have

$$\frac{a_e}{a_L} = \frac{\left(\frac{1}{2}\right)(0.375) - \frac{1}{6}}{\left(\frac{1}{3}\right) - \left(\frac{\pi}{4}\right)(0.375)}$$

$$= 0.5368$$

Then equation (37) gives

$$\frac{y_v - a}{s_m - a} = \frac{\left(\frac{1}{2}\right) + \left(\frac{\pi}{4}\right)(0.5368)}{1.5368}$$

$$= 0.600$$

We also have

$$\frac{y_v}{a} = \left(\frac{y_v - a}{s_m - a}\right)\left(\frac{s_m - a}{a}\right) + 1$$

$$= (0.600)\left(\frac{1.280}{0.375}\right) + 1$$

$$= 3.05 \tag{42}$$

Hence, the positions of the C2 and C4 vortices are given by $y_v/a = \pm 3.05$ and $z_v/a = 0$. For the C1 and C3 fins, the above value is actually z_v/a. However, the deflection of the yaw panels by 20° moves the trailing edges to the right by the following amount

$$\left(\frac{y_v}{a}\right)_{C1,C3} = \left(\frac{2.767 - 2.225}{0.375}\right)\sin 20^\circ$$

$$= 0.493$$

Using equations (34) to (36) and the previously tabulated values of CNCi and $\overline{\eta}$, we can calculate the trailing-vortex strengths. The results together with the vortex positions are listed below:

$\alpha_c = 16^o, \phi = 0^o$			
Fin	$\frac{\Gamma}{2\pi V_\infty a}$	$\frac{y_v}{a}$	$\frac{z_v}{a}$
C1	0.143	0.493	3.05
C2	-0.152	-3.05	0
C3	-0.167	0.493	-3.05
C4	0.158	3.05	0

BODY VORTICES

The AIM-9L configuration for the angles of attack of interest in this report has weak nose vortices which play an insignificant role in the generation of induced rolling moments. Hence, we will not calculate nose vortex-canard fin interactions in this example. (An illustration of such a calculation is provided by an example case in Ref. 8.) As a first step we need to determine the axial station for body vortex separation for starting the afterbody vortices. The nose tip radius is 0.225 inches. Hence, the ratio of the nose tip radius to the nose base radius, ϵ, is greater than 0.2 and equation (2) should be used to get x_s. Since the nose fineness ratio is 2, equation (2) states that nose vortices will be present for $\alpha_c \geq 9^o$.

The afterbody vortex system for the AIM-9L missile possesses interesting aspects because the large canard fins drastically influence the resultant crossflow angle, α_{cr}, and direction, θ, over the afterbody for the present case. For several angles of attack, α_{cr} is plotted versus x/a in Fig. 14. Recall that the resultant crossflow angle is the result of the free-stream velocity component normal to the body axis and the induced velocities of the canard vortices at the body axis. At the axial position $x/a = 7.39$ the resultant crossflow velocity would be horizontal for $\alpha_c = 0$ since it would be due entirely to yaw panel deflection. The arrows on the figure show the resultant direction of the crossflow velocity in the crossflow plane as viewed from the rear. This information was obtained by running VCHASE with no afterbody vortices.

As an example of the method for determining the axial starting position of the afterbody vortices, consider the case when $\alpha_c = 4^o$. We

follow step 2 on pages 20 and 21 since equation (2) showed that no nose vortices are present for $\alpha_c = 4^\circ$. The average value of α_{cr}, which is an equivalent α_c, is approximately 6.4°. So equation (2) gives $x_s/a = 6.2$. Since the canard fin root chord is 3.39 radii long, we have

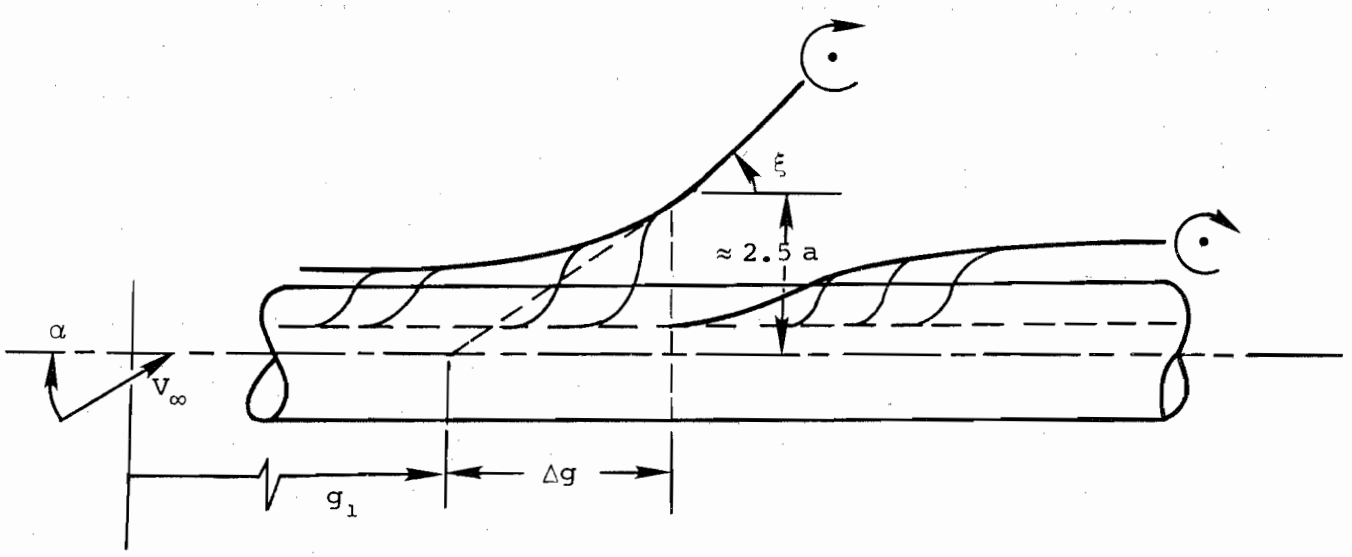
$$\left(\frac{x_s}{a}\right)_{\substack{\text{Afterbody vortices} \\ \text{for } \alpha_c = 4^\circ}} = 6.2 + 3.4$$

$$= 9.6$$

For $\alpha_c \geq 9^\circ$, the afterbody vortices start at the canard trailing edge since θ is within 90° of the vertical direction.

MULTIPLE AFTERBODY VORTICES

At $\alpha_c = 20^\circ$, based on the data correlations of Thomson (Ref. 16), it appears that multiple afterbody vortices are possible. For purposes of estimating when the third vortex appears on the afterbody, consider first the following sketch. At some distance from their point of origin either



the left or right afterbody vortex will tear away from the body depending on which is higher. Assume for discussion purposes that the left vortex tears first. We now designate this vortex A_{L1} and the vortex which starts under it A_{L2}. A_{L1} is now a free vortex and moves away from the body at angle ξ which is approximately streamwise. To proceed further we need a means of estimating the axial position at which A_{L1} becomes a

free vortex. Thomson's data correlations (Ref. 16), which are reproduced here as Fig. 15, provide a means of making that estimate. The so-called "starting positions," g_i, of the torn vortices shown in Fig. 15 are actually the intercepts of these free trajectories extrapolated linearly to the body axis. While g_1 can be used as an approximate location of the vortex tearing position, we feel that the position is better given by adding an increment Δg to g_1. Hence, assuming ξ can be approximated by α_c, we will estimate Δg in the following way:

$$\frac{\Delta g}{a} \approx \frac{2.5}{\tan \alpha_c} \tag{43}$$

Equation (43) simply says that we have estimated that when A_{L1} has essentially turned streamwise, it is approximately 2.5 radii from the body.

From Fig. 15 we obtain the following values of g_1:

α_c	M_c	$\frac{g_1}{2a} S \tan \alpha_c$
16°	0.483	0.44
20°	0.600	0.50

The Strouhal number, S, is given by Thomson as 0.2 and is recommended for all Reynolds numbers. It would appear that Thomson implies the use of his data for supercritical speeds, recommending that $S = 0.2$ be used for this case. Since the data correlation is for subcritical crossflow Reynolds numbers, its use in the present case, which has been assumed supercritical, is open to some risk.

Using $S = 0.2$, the tabulated values for g_1 and equation (43), we get

$$\alpha_c = 16^\circ: \quad \frac{g_1}{a} + \frac{\Delta g}{a} = \frac{(2)(0.44)}{(0.2)\tan 16^\circ} + \frac{2.5}{\tan 16^\circ}$$

$$= 24.1$$

$$\alpha_c = 20^\circ: \quad \frac{g_1}{a} + \frac{\Delta g}{a} = \frac{(2)(0.50)}{(0.2)\tan 20^\circ} + \frac{2.5}{\tan 20^\circ}$$

$$= 20.6$$

Since for $\alpha_c = 16^\circ$, 20°, the afterbody vortices started at the canard trailing edge, the axial tearing positions are:

$$\alpha_c = 16^\circ: \quad \left(\frac{x}{a}\right)_{\substack{\text{First}\\ \text{tear}}} = \left(\frac{x}{a}\right)_{\substack{\text{Canard}\\ \text{trailing}\\ \text{edge}}} + \frac{g_\perp}{a} + \frac{\Delta g}{a}$$

$$= 7.4 + 24.1$$

$$= 31.5$$

$$\alpha_c = 20^\circ: \quad \left(\frac{x}{a}\right)_{\substack{\text{First}\\ \text{tear}}} = 7.4 + 20.6$$

$$= 28.0$$

Since the tail section starts at $x/a = 34.3$, we will neglect the third vortex for $\alpha_c = 16^\circ$. For $\alpha_c = 20^\circ$, however, we have included the third vortex. This is done simply by letting the higher of the vortices A_R and A_L tear at $x/a = 28.0$ and by treating it as a constant strength vortex thereafter. A new afterbody vortex is started and the VCHASE program continued.

VORTEX TRAJECTORIES AND EMPENNAGE ROLLING MOMENT

Vortex trajectories and tail rolling moments for $\alpha_c = 16^\circ$ will be discussed in this section. The program VCHASE was started at $x/a = 7.4$ with the canard trailing-vortex strengths and positions calculated previously. The program automatically calculated the initial positions of the afterbody vortices using $r_v/a = 1.2$. The vortices were tracked until the leading edge of the tail fin root chord, $x/a = 34.3$. As outlined in the method previously, VCHASE was stopped and then restarted with the vortex strengths constant. The trajectories were calculated until $x/a = 40.3$ which is the axial position of the tail fin area centroid. The vortex trajectories over the afterbody are presented in Fig. 16.

At $x/a = 40.3$, the vortex strengths and positions are:

$\alpha_c = 16^\circ$, $\phi = 0^\circ$			
Fin	$\frac{\Gamma}{2\pi V_\infty a}$	$\frac{y_v}{a}$	$\frac{z_v}{a}$
C1	0.143	1.337	8.902
C2	-0.152	-0.5261	7.273
C3	-0.167	0.7469	3.251
C4	0.158	3.856	8.942
A_R	0.412	1.584	3.432
A_L	-0.492	-0.8161	2.945

Note that the afterbody vortices are about three times as strong as the canard vortices and are nearer the tail fins. Vortices C3 and A_R are close to each other as the final position is approached. Trajectories for other angles of attack show that A_L is almost in line with tail fin T1 at $\alpha_c = 12^\circ$.

To obtain the empennage rolling moment we first note that it possesses no rolling moment due to panel-panel interference, and its total rolling moment is due to vortex interference. To determine this latter component of interference, the foregoing information on vortex strengths and positions was introduced into REVFLO to obtain the changes in equivalent angles of attack associated with each fin and the center-of-pressure location of the vortex loading. The following results were obtained.

$\alpha_c = 16^\circ$, $\phi = 0^\circ$		
Fin	$(\Delta\alpha_{eq})_v$	$\frac{\bar{y}}{\ell_r}$ or $\frac{\bar{z}}{\ell_r}$
T1	6.48°	0.0806
T2	-3.51°	0.518
T3	1.02°	0.544
T4	-2.23°	0.303

Note that the above values are not the actual fin values but include any reverse-roll effects induced on the other fins by the fin in question.

In converting the quantities $(\Delta\alpha_{eq})_v$ into fin-associated normal forces, we find α_{eq} for the tail fins without vortices and with vortices. The difference in normal-force coefficients between these two conditions represents the normal-force coefficient due to the vortices. Using the results tabulated above and Fig. 12, we can obtain the rolling moments, due to the vortices, associated with each fin. The results are listed below.

$\alpha_c = 16^\circ$, $\phi = 0^\circ$						
Fin	No Vortices		With Vortices			
	α_{eq}	CNTi*	α_{eq}	CNTi*	$(\Delta CNTi)_v$*	$(\Delta CRMTi)_v$**
T1	0	0	6.5°	0.180	0.180	0.141
T2	18.9°	0.538	15.4°	0.440	-0.098	-0.494
T3	0	0	1.0°	0.032	0.032	0.169
T4	18.9°	0.538	16.7°	0.478	-0.060	-0.177
C_{ℓ_T} = -0.141 + 0.494 + 0.169 - 0.177 = 0.345						

*S_R = Fin planform area.

**$S_R = \pi a^2$.

SUMMARY OF RESULTS

We present tabulated results for the following quantities:

1. C_{ℓ_C} = Rolling moment of canard fins due to panel-panel interference (see table on page 28)
2. $(C_{\ell_T})_0$ = Rolling-moment coefficient of tail with no body vortices
3. $(C_{\ell_T})_2$ = Rolling-moment coefficient of tail with two afterbody vortices
4. $(C_{\ell_T})_3$ = Rolling-moment coefficient of tail with three afterbody vortices ($\alpha = 20^\circ$ only)

	(1)	(2)	(3)	(4)	(1)+(3)	(1)+(4)
α_c	C_{ℓ_C}	$(C_{\ell_T})_0$	$(C_{\ell_T})_2$	$(C_{\ell_T})_3$		
0°	0	0	0	----	----	----
4°	0.06	1.61	1.47	----	1.53	----
8°	0.11	1.15	1.34	----	1.45	----
12°	0.18	0.20	1.91	----	2.09	----
16°	0.24	-0.33	0.35	----	0.59	----
20°	0.33	-0.38	-0.69	0.11	-0.36	0.44

The total configuration rolling moment based on (1)+(3) and (1)+(4) is compared with the data for the present example in Fig. 17. The general nonlinear shape of the data and theory curves are in fair agreement. The first maximum is predicted fairly well but at a slightly high angle of attack. The first minimum is not well predicted. However, it is interesting that the second rise for $\alpha > 16^o$ is predicted by including the third afterbody vortex.

SECOND CALCULATIVE EXAMPLE

As a second calculative example we will consider the AIM-9L missile as tested at transonic speeds at angle of roll with large pitch and yaw fin deflections. This case will be completely general in the absence of applied roll control and will serve to illustrate the method fully. While in Ref. 8 fair agreement was found at $M_\infty = 0.8$ in applying the present method to the case of an unrolled missile with yaw control, no representation is made here that a general method applicable at transonic speeds has been developed. Only application of the method to a large number of transonic examples can determine the limitation of the present method or indicate the areas requiring more attention. For instance the method does not account for effects of fin thickness, which may conceivably be important in some instances. We will discuss the calculative example under the following headings:

1. Canard and Tail Aerodynamic Characteristics
2. Canard Panel-Panel Interference

3. Canard Vortex Strengths and Positions
4. Afterbody Vortices
5. Multiple Afterbody Vortices
6. Tail Rolling-Moment Coefficient

CANARD AND TAIL AERODYNAMIC CHARACTERISTICS

We are concerned with the "wing-alone" normal-force curves for the canard fins and tail fins for $M_\infty = 0.8$ as well as the variation of lateral center of pressure with angle of attack. As in the case of the preceding calculative example, we have the wing-alone normal-force curve for the canard fins reconstructed from AIM-9L aerodynamic tests. This curve is presented in Fig. 9. The lateral center-of-pressure curve will be taken from Fig. 10 as in the previous calculative example.

The tail-alone normal-force curve is not available from experiment, and we must construct the curve from the best available information. For this purpose the data of Ref. 18 were used as a guide. Emerson tested a systematic series of clipped delta wings on a transonic bump in a wind tunnel. The normal-force curve for the AIM-9L tail fins has been estimated from these data. Emerson's data for a systematic series of wings of aspect ratio 1.33 were compared over a taper ratio range of 0.2 to 0.5 together with a corresponding set of aspect ratio 1 with taper ratio varying from 0.3 to 0.5. For the two series of wings, no significant effect of taper ratio on the measured lift coefficients could be found. This is consistent with the results of slender-body theory. In addition to the two low-aspect-ratio series described above, a single wing of aspect ratio 0.86 and taper ratio 0.4 was tested. We will use the latter set of data as an approximation to those for the AIM-9L tail-alone for which the aspect ratio is 0.87 and the taper ratio 0.64.

The "tail-alone" normal-force curve is given in Fig. 18 by the solid line as calculated from the lift and drag data of Ref. 18. A theoretical determination of the normal-force curve of the AIM-9L tail-alone has also been made using the computer program of Ref. 14 which includes the effect of leading-edge and side-edge suction in its prediction. The calculated points as shown in Fig. 18 are in good agreement with the data up to angles of attack above 20°. The figure indicates that the theoretical tail-alone

normal-force curve can be fitted closely by the following formula for a range of angle of attack up to 20°:

$$C_N = \left(\frac{dC_N}{d\alpha}\right)_o \sin\alpha + K_V \sin^2\alpha$$

with

$$\left(\frac{dC_N}{d\alpha}\right)_o = 1.37 \; ; \quad K_V = 3.05$$

The calculations indicate that at $\alpha_c = 20°$, 57 percent of the normal force is associated with potential flow, 15 percent with leading-edge vortex lift, and 28 percent with side-edge vortex lift.

CANARD PANEL-PANEL INTERFERENCE

The present calculative example illustrates the most complicated kind of panel-panel interference in the absence of roll control. The equivalent angles of attack for the four canard fins given by equations (23) to (26) each contains five terms, three of which are coupling terms. For a value of a/s_m of 0.227, we find the following values for the interference parameter from Table 1:

$$K_W = 1.19$$

$$k_w = 0.942$$

$$K_{\alpha\beta} = 0.495$$

$$(K_{\alpha\delta_V})_V = (K_{\beta\delta_H})_H = 0.452$$

$$(K_{\alpha\delta_V})_H = (K_{\beta\delta_H})_V = 0.142$$

Allowing the term $4/AR$ to be unity, we have the following results for the equivalent angles of attack for $\alpha_c = 12°$, $\phi = 22.5°$ (all angles in degrees):

Fin C1

$$\alpha_{eq} = 1.19\ \beta + 0.94\ \delta_V + \frac{1}{57.3}\left[-0.495\ \alpha\beta - 0.452\ \alpha\delta_V - 0.142\ \beta\delta_H\right]$$

$$\alpha_{eq} = 21.9^\circ$$

Fin C2

$$\alpha_{eq} = 1.19\ \alpha + 0.94\ \delta_H + \frac{1}{57.3}\left[-0.495\ \alpha\beta - 0.142\ \alpha\delta_V - 0.452\ \beta\delta_H\right]$$

$$\alpha_{eq} = 30.3^\circ$$

Fin C3

$$\alpha_{eq} = 1.19\ \beta + 0.94\ \delta_V + \frac{1}{57.3}\left[0.495\ \alpha\beta + 0.452\ \alpha\delta_V + 0.142\ \beta\delta_H\right]$$

$$\alpha_{eq} = 26.7^\circ$$

Fin C4

$$\alpha_{eq} = 1.19\ \alpha + 0.94\ \delta_H + \frac{1}{57.3}\left[0.495\ \alpha\beta + 0.142\ \alpha\delta_V + 0.452\ \beta\delta_H\right]$$

$$\alpha_{eq} = 33.8^\circ$$

The foregoing values of α_{eq} yield the following information from Figs. 9 and 10:

$\alpha_c = 12^\circ,\ \phi = 22.5^\circ$			
Fin	α_{eq}	C_{N_W}	$\bar{\eta} = \frac{\bar{y} - a}{s_m - a}$
C1	21.9°	0.88	0.333
C2	30.3°	0.88	0.333
C3	26.7°	0.88	0.333
C4	33.8°	0.93	0.333

The net rolling moment due to canard panel-panel interference is due to an unbalance of loading between fins C2 and C4. With the following values:

$$s_m - a = 1.28 \text{ ins.} \qquad a = 0.375 \text{ in.} \qquad \ell_r = 0.75 \text{ in.}$$

we have

$$\frac{\bar{y}}{\ell_r} = \frac{0.375 + (1.28)(0.333)}{0.75} = 1.068$$

Thus, the rolling-moment coefficient due to C2 and C4 is

$$C_{\ell_C} = -\frac{(3.30 - 3.15)}{2}(1.078) = -0.080$$

This small rolling-moment coefficient is associated with the fact that the fins have equivalent angles of attack in the range of the flat top of the normal-force curve in Fig. 9. The magnitude is insignificant compared to the tail-generated induced rolling moments.

CANARD VORTEX STRENGTHS AND POSITIONS

We calculate the vortex strengths and positions in the same manner as in the previous example except that we must transfer the results to unrolled body axes. Because the hinge line is in front of the canard fin trailing edge, the trailing edges for all four fins are displaced an amount laterally for deflections of 20° given by

$$\frac{\Delta y}{a} = \left(\frac{2.767 - 2.225}{0.375}\right)(\sin 20^\circ) = 0.493$$

In rolled body coordinates we have the following results:

$\alpha_c = 12^\circ$, $\phi = 22.5^\circ$			
Fin	$\frac{\Gamma}{2\pi V_\infty a}$	$\frac{y_v'}{a}$	$\frac{z_v'}{a}$
C1	0.228	0.493	2.71
C2	-0.228	-2.71	-0.493
C3	-0.228	0.493	-2.71
C4	0.241	2.71	-0.493

The transformation to unrolled body coordinates is made by

$$\frac{y}{a} = \frac{y'}{a} \cos \phi + \frac{z'}{a} \sin \phi$$

$$\frac{z}{a} = - \frac{y'}{a} \sin \phi + \frac{z'}{a} \cos \phi$$

with the following results:

$\alpha_c = 12^\circ$, $\phi = 22.5^\circ$		
Fin	$\frac{y_v}{a}$	$\frac{z_v}{a}$
C1	1.49	2.31
C2	-2.69	0.58
C3	-0.58	-2.69
C4	2.31	-1.49

AFTERBODY VORTICES

The vortex system generated by the afterbody depends on the crossflow to which it is subjected. The magnitude of the crossflow angle, α_{cr}, and the inclination of the crossflow, θ, have been calculated using VCHASE with the four canard vortices present but without any afterbody vortices. The resulting values are shown in Fig. 19. Note that the crossflow angle is small at the canard trailing edge and the flow is directed almost horizontally from left to right. At the tail section the flow has become vertical. Note in Fig. 19 that direction of the resultant crossflow velocity is more than 90° from the vertical. Hence, following the procedure outlined on pages 20 and 21, we will entirely neglect the nose vortices and assume that the afterbody is a blunt body developing its own vortex system starting at the trailing edge of the canard fins. Thus, x_s is to be measured behind the canard trailing edges.

To determine the distance behind the trailing edge to the start of the first afterbody vortex pair, we start with a trial value of $\overline{\alpha}_{cr} = 5.5^\circ$ for a short distance behind the canard trailing edge. From the blunt nose formula

$$\frac{x_s}{a} = \frac{10^\circ}{\alpha_c - 4^\circ} + 2$$

we find

$$\frac{x_s}{a} = \frac{10^\circ}{1.5} + 2 = 8.67$$

This gives for the position of the first afterbody vortex pair:

$$\frac{x}{a} = 7.39 + 8.67 \approx 16$$

Since the average value of α_{cr} over the range $7.39 \leq x/a \leq 16$ is about 5.5°, we need not perform another iteration.

We now start the first afterbody vortex pair at $x/a = 16$ with their starting points disposed at 40° from the diameter normal to the crossflow direction. The canard vortex positions are taken as those given by VCHASE up to $x/a = 16$. The initial vortex positions are given in the table below.

$\alpha_c = 12^\circ$, $\phi = 22.5^\circ$		
Vortex	$\frac{y_v}{a}$	$\frac{z_v}{a}$
C1	1.55	3.33
C2	-2.288	1.946
C3	0.275	-1.917
C4	2.792	-0.417
A_R	0.573	1.055
A_L	-0.939	-0.747
$\alpha_{cr} = 6.5^\circ$		$\theta = 11.51^\circ$

The VCHASE program is now restarted with the foregoing initial conditions and run to the tail centroid. The resulting strengths of the afterbody vortices are plotted in Fig. 20 for $\alpha_c = 12^\circ$. Note that both the right-hand and left-hand vortices tend to decrease in strength approaching the tail which starts at $x/a = 34.3$. It is not physically permissible for vortex strength to decrease in this fashion, but the effect is

insignificant in this case because the strengths of the afterbody vortices are about 10 percent of those for the canard vortices. The calculations show that vortex C3 passes between the body and the afterbody vortices, cutting their feeding sheets and giving them severe kicks as shown in Fig. 21. We have no data to show what subsequently happens in a case like this. We can speculate that there could be vortex combinations, or the two afterbody vortices could become free with new afterbody vortices forming beneath them. These possibilities can be handled by VCHASE.

MULTIPLE AFTERBODY VORTICES

The cutting of the afterbody vortex feeding sheets by vortex C3 invalidates a direct application of the data of Thomson for predicting the onset of a third afterbody vortex. If we nevertheless apply the data of Thomson, it turns out that the predictions indicate no third afterbody vortex forms. We will carry out the prediction in full as part of the example calculation.

Before making this determination, consider the following table showing the variation of α_{cr} and θ along the afterbody for no afterbody vortices and two afterbody vortices:

VCHASE RESULTS

$\alpha_c = 12^\circ$, $M_\infty = 0.8$, $\delta_1 = \delta_2 = \delta_3 = \delta_4 = 20^\circ$

	NO AFTERBODY VORTICES		TWO AFTERBODY VORTICES	
x/a	α_{cr}*	θ*	α_{cr}*	θ*
7.38	4.94	- 6.11	----	-----
8.00	4.93	- 5.67	----	-----
16.00	6.50	11.51	6.51	11.58
20.00	9.15	25.17	9.07	24.75
24.00	13.64	54.26	13.36	52.11
28.00	15.34	90.20	15.66	86.16
32.00	14.31	104.27	14.81	105.01
34.33	13.72	107.58	14.17	110.15
40.28	12.53	109.31	----	-----

*All angles are in degrees.

Note that the crossflow velocity due to C1, C2, C3 and C4 is not changed significantly by the addition of A_L and A_R so that we can use Fig. 19 to estimate the starting position of the third afterbody vortex.

We must first estimate g_1 which is measured from the initial separation point of the first afterbody vortex pair. The value of g_1 is obtained from the value of $g_1 S \tan \alpha/2a$ as given by Thomson (Ref. 16) as a function of crossflow Mach number. The calculation is a trial-and-error one made by assuming various values of α_{cr}. From Fig. 15 we obtain the following g_1 values:

α_{cr}	$\tan \alpha_{cr}$	M_c	$\frac{g_1 S \tan \alpha_{cr}}{2a}$	$\frac{g_1}{a}$
8°	0.1405	0.112	0.206	14.6
10°	0.1763	0.141	0.2205	12.5
12°	0.2126	0.170	0.235	11.0
14°	0.2493	0.200	0.250	10.0

From Fig. 19 we make the following approximate evaluations of the average value of α_{cr} between certain values of x/a.

x/a	$\Delta x/a$	$\bar{\alpha}_{cr}$
16-21	5	8°
16-25	9	10°
16-32	16	12°

By plotting g_1/a and $\Delta x/a$ versus α_{cr}, we find the condition where g_1/a and $\Delta x/a$ are the same. This gives

$$\frac{g_1}{a} = \frac{\Delta x}{a} = 11.5 ; \quad \bar{\alpha}_{cr} = 11^\circ$$

As in the first example, we must add a Δg onto g_1 to obtain the point where the feeding sheet tears as given approximately by

$$\frac{\Delta g}{a} = \frac{2.5}{\tan \alpha_{cr}} = 12.9$$

The point g_1/a corresponds to x/a of

$$\left(\frac{x}{a}\right)_{g_1} = 16 + 11.5 = 27.5$$

This quantity added to $\Delta g/a$ yields that the A_L feeding sheet tears near $x/a = 40.4$. This point is beyond the start of the tail fins and the third afterbody vortex is not predicted to appear. It should appear at a slightly higher angle. Note that g_1/a tends to be less at subsonic speeds than at supersonic speeds so that multiple vortex shedding should occur at smaller angles of attack for comparable conditions. In this case multiple vortex shedding would be predicted at slightly higher included angles than $\alpha_c = 12^\circ$.

TAIL ROLLING-MOMENT COEFFICIENT

Having determined that the canard fins produced no appreciable rolling moment, we will attribute the total configuration rolling moment to the tail fins. Consider first the tail rolling moments <u>with no afterbody vortices</u>. The program VCHASE has been continued to $x/a = 40.3$ at the tail centroid with the vortices constant at their strengths at the beginning of the tail section on the assumption that the tail fins will cut off any feeding sheets. At $x/a = 40.38$, we then have the following results:

$\alpha_c = 12^\circ$, $\phi = 22.5^\circ$			
Vortex	$\frac{\Gamma}{2\pi V_\infty a}$	$\frac{y_v}{a}$	$\frac{z_v}{a}$
C1	0.2280	1.848	5.710
C2	-0.2280	-1.014	5.167
C3	-0.2280	1.108	1.791
C4	0.2410	4.134	2.767

The corresponding changes in equivalent angles of attack due to the vortices and the corresponding lateral locations of the centers of pressure for the tail fins were found from REVFLO as follows:

Fin	$(\Delta\alpha_{eq})_v$	$\frac{\bar{y}}{\ell_r}$
T1	-3.992°	1.260
T2	-4.896°	0.5237
T3	2.299°	0.5024
T4	0.627°	0.6341

Using the results tabulated above, we can obtain the rolling moments, due to the vortices, associated with each fin. The α_{eq} for no vortices present are given by equations (27) to (30) and the slender-body theory K factors on page 25. The results are tabulated below:

$\alpha_c = 12°$, $\phi = 22.5°$, No Body Vortices						
Fin	No Vortices		With Vortices			
	α_{eq}	CNTi*	α_{eq}	CNTi*	$(\Delta CNTi)_v$*	$(\Delta CRMTi)_v$**
T1	3.40°	0.090	-0.52°	-0.014	-0.104	-1.27
T2	15.10°	0.600	10.20°	0.355	-0.245	-1.25
T3	7.44°	0.240	9.74°	0.335	0.095	0.47
T4	11.06°	0.400	11.67°	0.427	0.027	0.16
$C_{\ell_T} = 1.27 + 1.25 + 0.47 + 0.16 = 3.05$						

*S_R = Fin planform area.
**$S_R = \pi a^2$.

The rolling moment found above is compared with experiment in Fig. 22. We will next consider the change in rolling moment <u>with the afterbody vortices present</u>.

The afterbody vortex strengths are less than 10 percent of the strengths of the canard vortices. Even though the C3 vortex cuts the afterbody vortex feeding sheets, we have carried out the formal calculation with afterbody vortices for illustrative purposes. Actually, it is probable that vortex C3 would combine with at least one afterbody vortex and a new crossflow vortex formed. The effect of the afterbody vortices would still be small.

In the VCHASE calculation all vortices were frozen in strength at their values at the beginning of the tail section, x/a = 34.3, and then VCHASE was continued to the centroid of the tail section at x/a = 40.3. The following values were obtained:

$\alpha_c = 12^\circ$, $\phi = 22.5^\circ$			
Vortex	$\frac{\Gamma}{2\pi V_\infty a}$	$\frac{y_v}{a}$	$\frac{z_v}{a}$
C1	0.228	1.822	5.708
C2	-0.228	-0.9773	5.125
C3	-0.228	0.784	1.739
C4	0.241	4.08	2.821
A_L	0.01937	-0.02039	1.764
A_R	0.02037	4.736	0.1903

The corresponding data from REVFLO is

Fin	$(\Delta\alpha_{eq})_v$	$\frac{\bar{y}}{\ell_r}$
T1	-1.801°	0.8091
T2	-7.368°	0.5211
T3	3.190°	0.4955
T4	1.671°	0.5431

The rest of the calculation is completed as previously. The results are tabulated below.

$\alpha_c = 12^\circ$, $\phi = 22.5^\circ$, Afterbody Vortices Present						
Fin	No Vortices		With Vortices			
	α_{eq}	CNTi*	α_{eq}	CNTi*	$(\Delta CNTi)_v$*	$(\Delta CRMTi)_v$**
T1	3.40°	0.090	1.80°	0.040	-0.050	-0.39
T2	15.10°	0.600	7.73°	0.250	-0.350	-1.78
T3	7.44°	0.240	10.63°	0.385	0.045	0.70
T4	11.06°	0.400	12.23°	0.480	0.080	0.42
$C_{\ell_C} = 0.39 + 1.78 + 0.70 + 0.42 = 3.29$						

*S_R = Fin planform area. **$S_R = \pi a^2$.

The rolling-moment coefficient of 3.29 with afterbody vortices compared to the value of 3.05 without them simply indicates that the effect of afterbody vortices is small for $\alpha_c = 12^o$. The above result is compared with experiment in Fig. 22.

CONCLUDING REMARKS

The method of predicting induced rolling moments presented herein is broad in scope and its limitations have not been fully established. The scope of the method is broader than might be readily apparent. Consider first the range over which the method can be applied by virtue of its nature and without regard for its limitations. It is designed to apply over the Mach number range from low subsonic speeds to high supersonic speeds. It has been used considering only pitch and yaw control of the canard fins. At the present time the method could be applied as it is to roll control at supersonic speeds, and with a little more work at subsonic speed. While it was conceived initially to apply up to $\alpha_c = 20^o$, this angle presents no inherent limitation. The equivalent angle-of-attack concept certainly applies to such high angles, and can be pushed to even higher angles by using proper addition theorems for equivalent angle of attack. The method was designed primarily for cruciform canard configurations, but a body-lift missile with cruciform tail fins is a special subcase to which it is applicable. It is also applicable to a midwing configuration with two wing panels. In determining the induced rolling moment, it has been necessary to advance an aerodynamic model which is also capable of yielding all forces and moments on the missile airframe, not only induced rolling moments. The determination of the additional missile forces and moments and their component quantities from the aerodynamic model is not difficult and would be worth pursuing.

The thoughts of the authors concerning the limitations of the method should be of interest to potential users of the method. The method is limited to the extent that the aerodynamic model properly represents the real aerodynamic behavior of missiles and to the extent that certain empirical correlations of vortex data which are used in the method are general. We have applied the method in determining the induced rolling moments of the AIM-9L missile and the MICOM missiles (Ref. 5) at both transonic and supersonic speeds with fair success. These applications are

not nearly extensive enough to determine the limitations of the method. However, they have shown a number of specialized phenomena with which the method must cope. One of the interesting effects observed both theoretically and experimentally is that in certain cases a canard vortex can tend to go into the body boundary layer. In certain instances, vortices tend to pass close to each other, in which case they can be combined in VCHASE. Another phenomenon that we have not yet observed experimentally is the cutting of afterbody vortex feeding sheets by a canard vortex. While we can speculate concerning how to handle this case using our computer program, it is important to verify any chosen method by experiment. Another phenomenon which falls in the same category is the possibility of formation of afterbody vortices on the windward surface of the afterbody because of the high downwash induced over the afterbody by the canard fins. Whether such vortices could be stable if formed is not clear. Also, other phenomenon such as special nonlinear transonic effects may appear in future applications of the method. We have cited the above phenomena as vortex phenomena which may occur for canard cruciform missiles although some have not been experimentally investigated. Thus, we cannot delineate completely the limitations of the present method until more data are available.

In order that the limitations of the present method be determined with some degree of certainty, it is necessary that much more comparison be made between experiment and theory. A fair amount of data exist which can be used for this comparison. The unanalyzed vapor-screen data of Ref. 5 should be most valuable in this connection. MICOM and others possess quantities of force and moment data on canard cruciform missiles including component data. However, existing data are not sufficient to determine completely the limitations of the method. There is not enough very high angle-of-attack data available including component measurements for this purpose. Other required data include flow visualization data on the formation of multiple afterbody vortices including the effects of canard fins and the nose shape. These latter data are needed for supercritical crossflow Reynolds numbers.

It is now possible to put together a composite computer program to calculate the characteristics of canard cruciform missiles, but much more comparison between experiment and prediction is needed to determine its generality and shortcomings.

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TABLE 1. Slender-Body Theory Interference Factors for a Cruciform Wing-Body Combination

a/s_m	K_W	k_w	$K_{\alpha\beta}$	$(K_{\beta\delta_H})_V^*$	$(K_{\beta\delta_H})_H^{**}$
0.0	1.000	1.000	0.382	0.250	0.500
0.1	1.077	0.963	0.447	0.201	0.477
0.2	1.162	0.944	0.490	0.153	0.457
0.3	1.253	0.936	0.508	0.112	0.426
0.4	1.349	0.935	0.502	0.079	0.385
0.5	1.450	0.940	0.471	0.052	0.332
0.6	1.555	0.948	0.417	0.031	0.273
0.7	1.663	0.958	0.342	0.017	0.206
0.8	1.774	0.971	0.244	0.007	0.137
0.9	1.887	0.985	0.127	0.002	0.068
1.0	2.000	1.000	0.0	0.0	0.0

*Undeflected panels.

**Deflected panels.

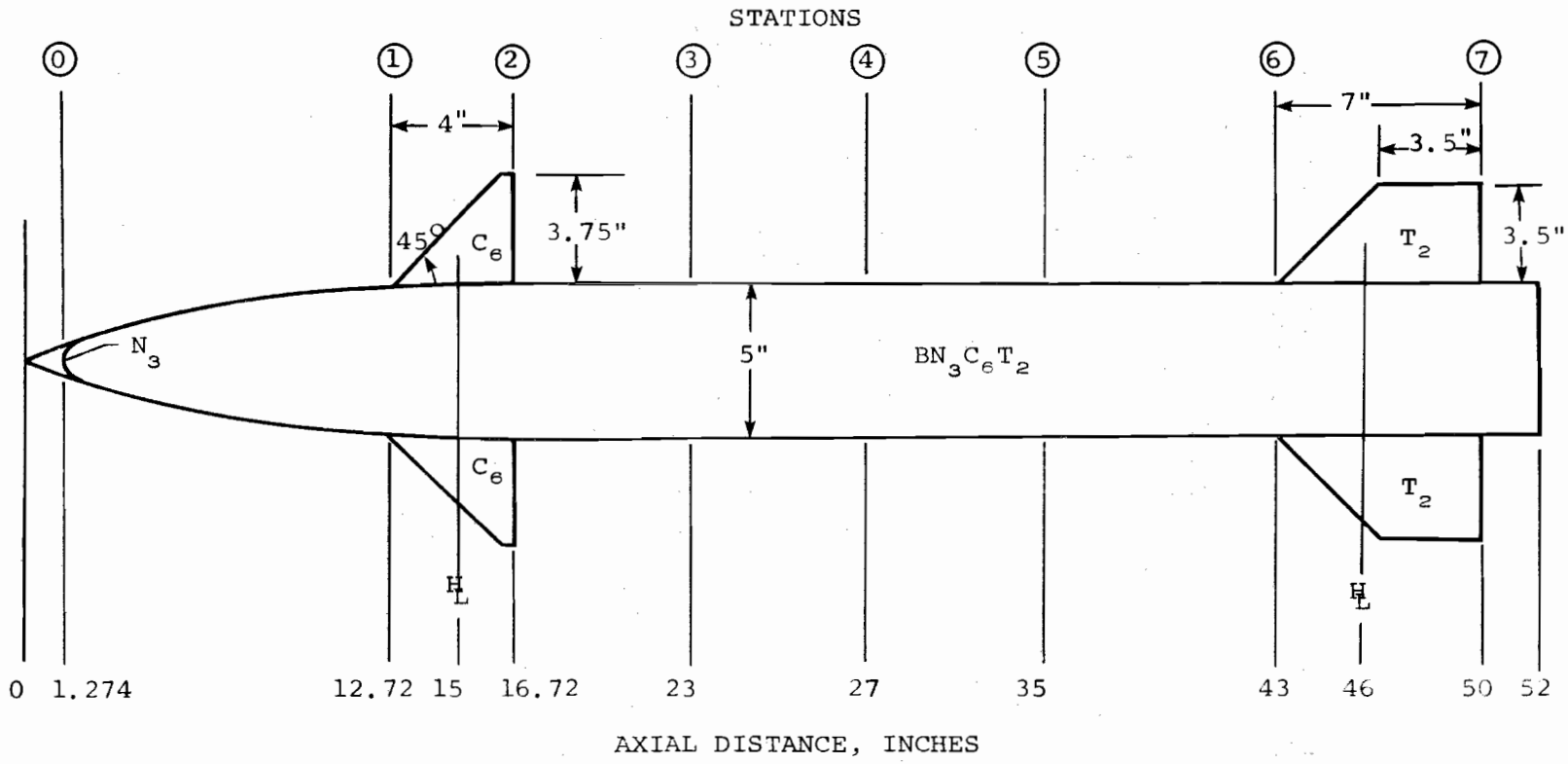
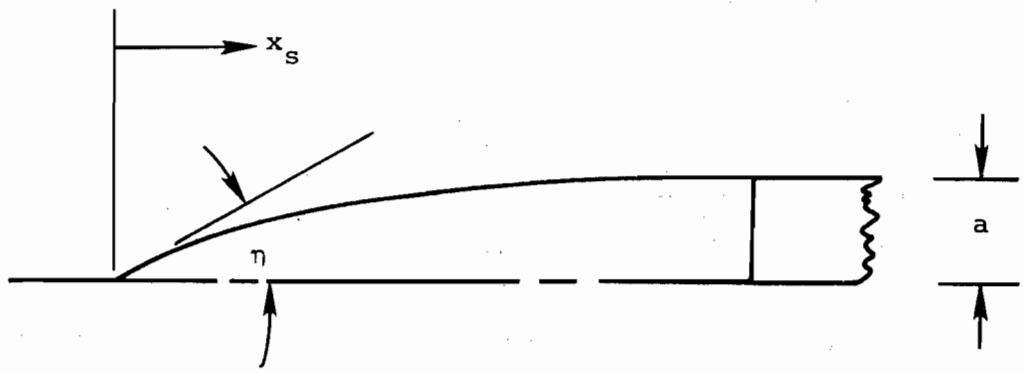
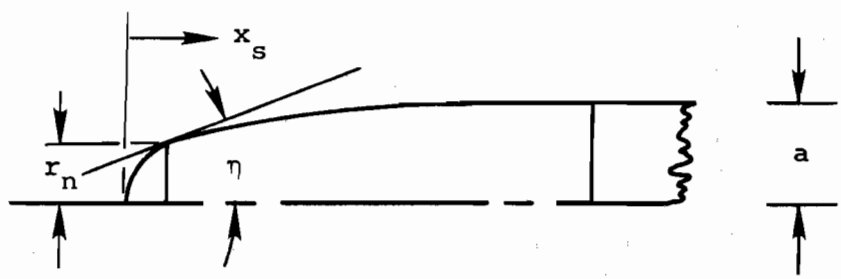


FIG. 1. Dimensions and Stations of Canard Cruciform Missile Used in Test Program.



(a) Pointed nose.



(b) Blunt nose.

FIG. 2. Typical Nose Configurations.

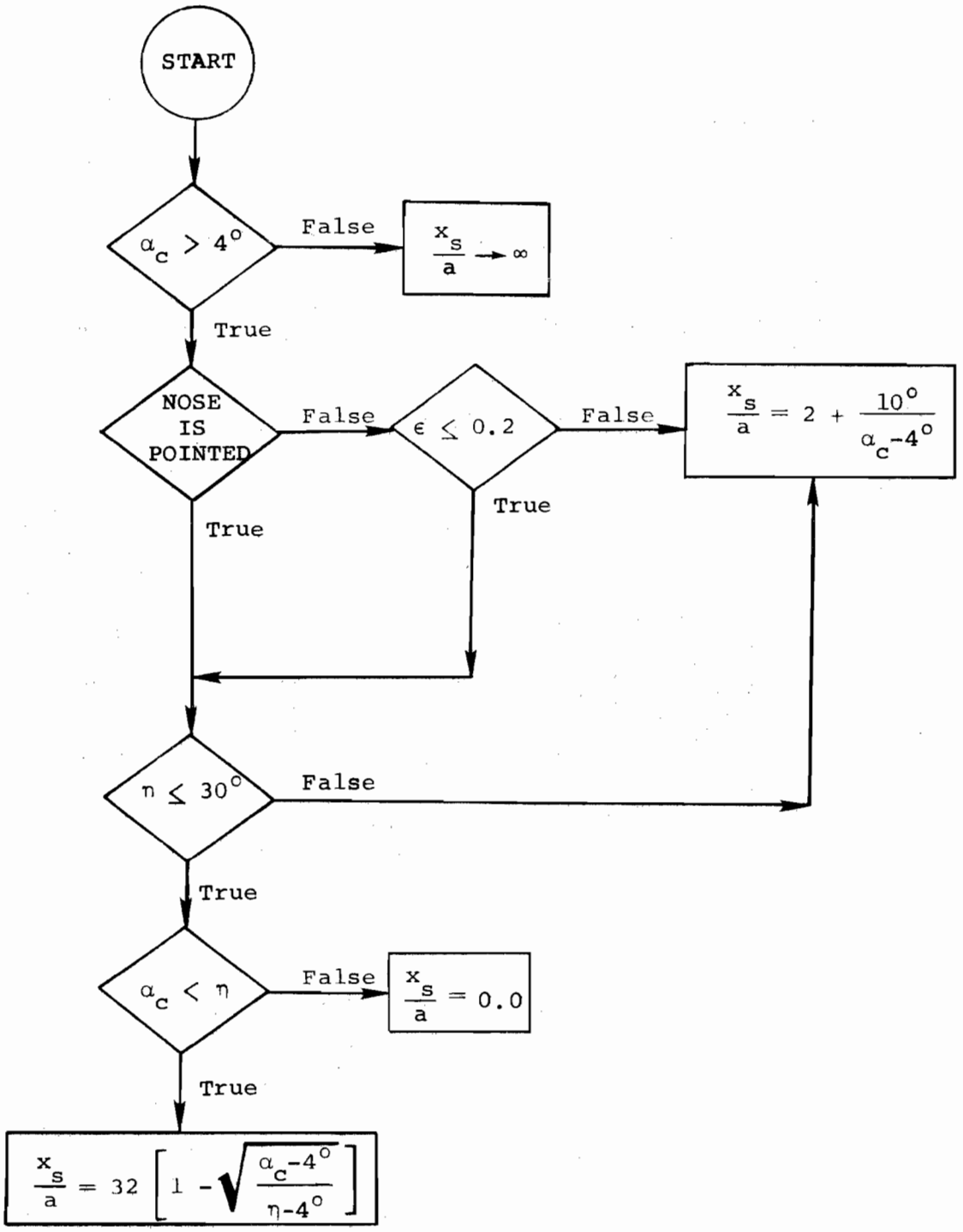
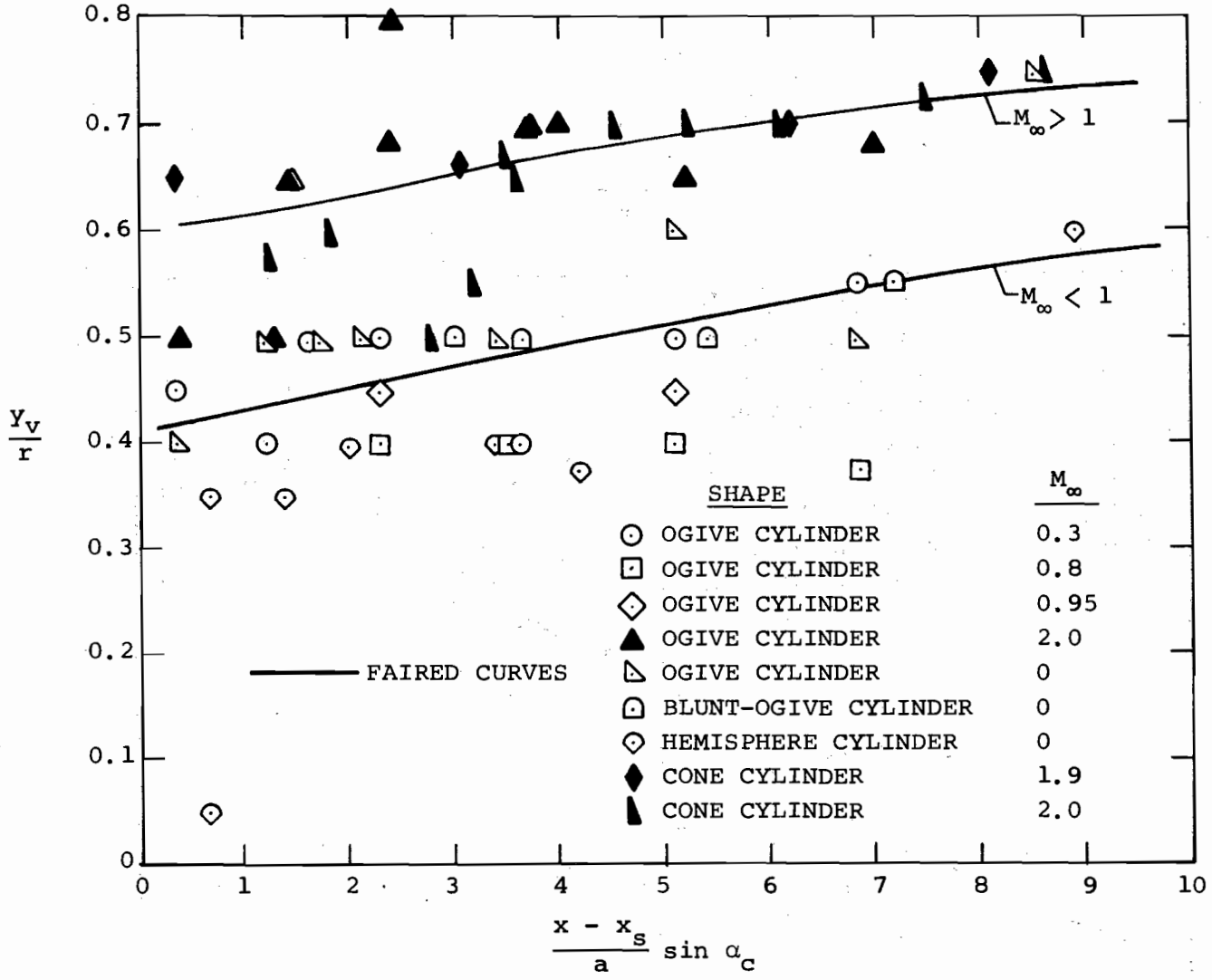
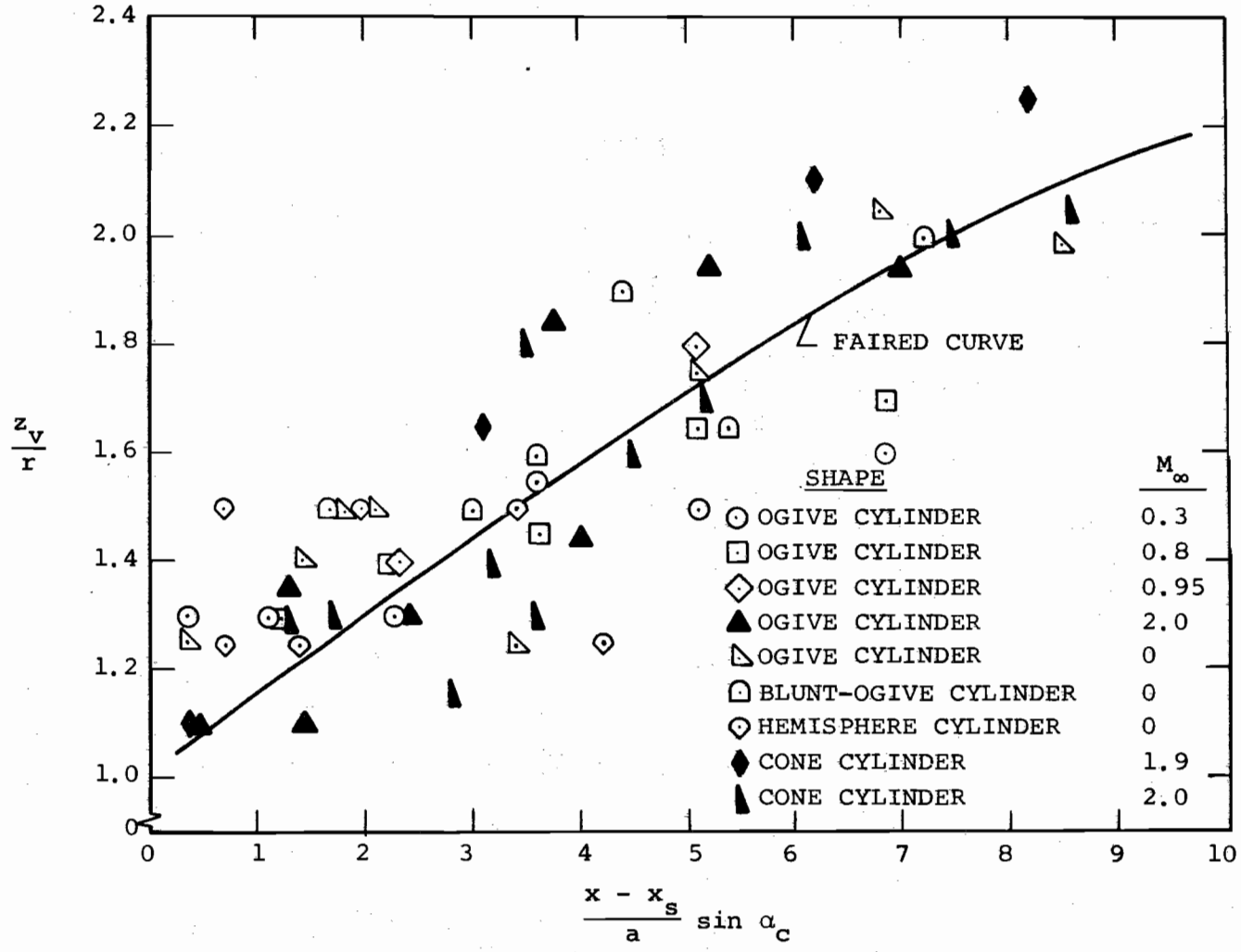


FIG. 3. Procedure for Estimating Axial Starting Positions of Nose Vortices.



(a) Horizontal vortex position.

FIG. 4. Correlation of Positions of Nose Vortices in Crossflow Plane.



(b) Vertical vortex position.

FIG. 4. Concluded.

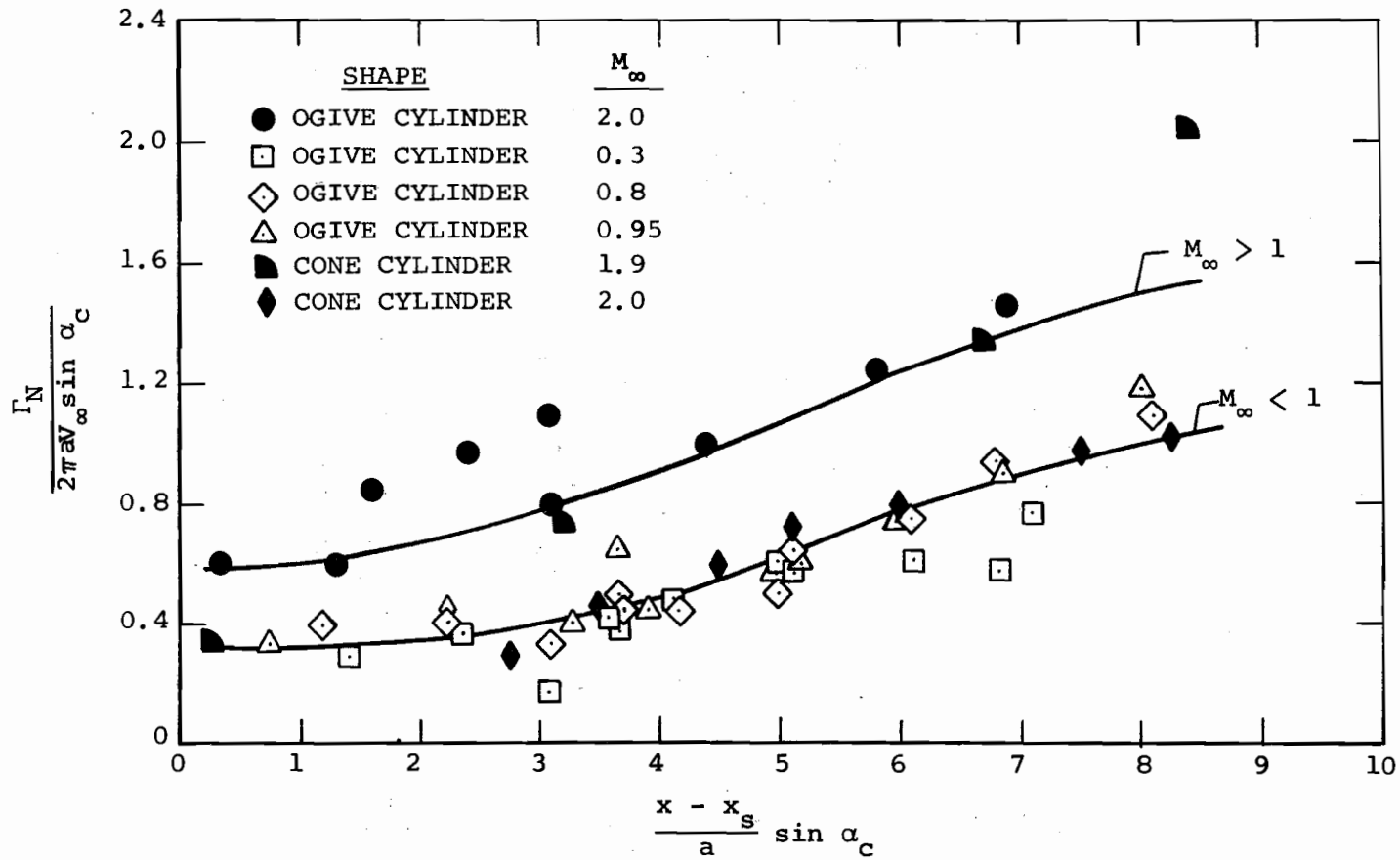


FIG. 5. Nose Vortex Strength Correlation.

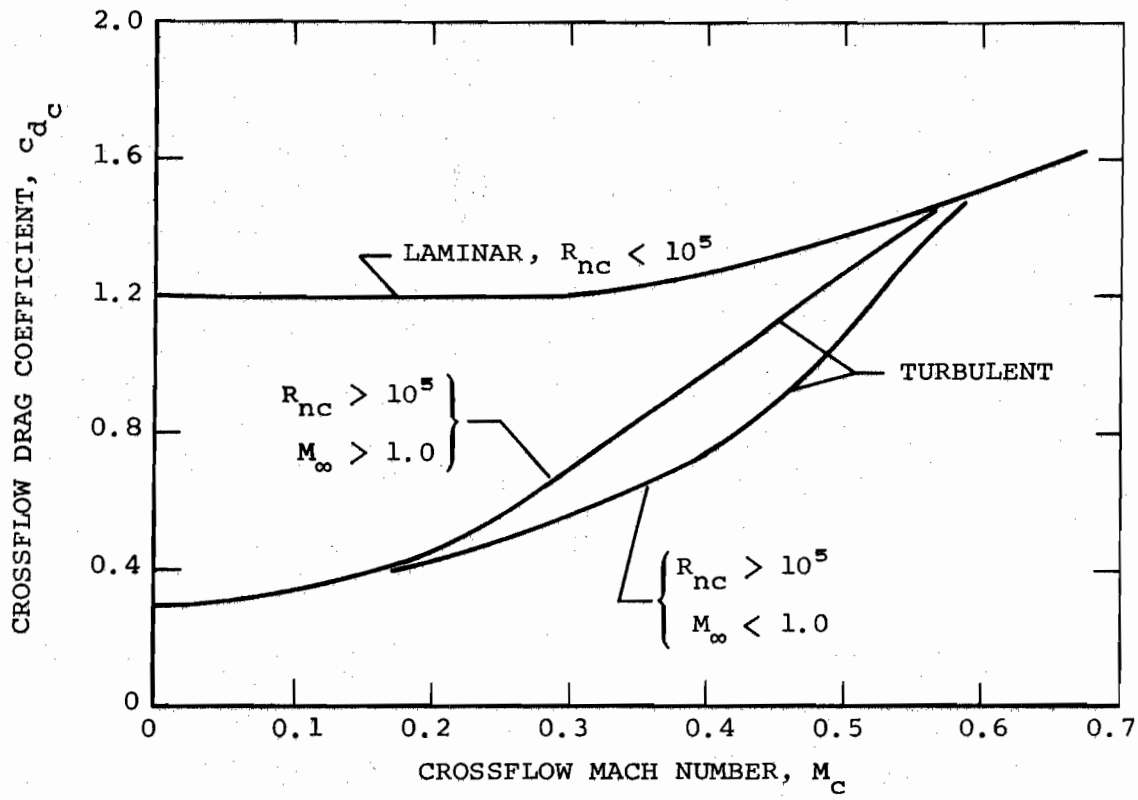


FIG. 6. Correlations for Predicting Crossflow Drag Coefficient.

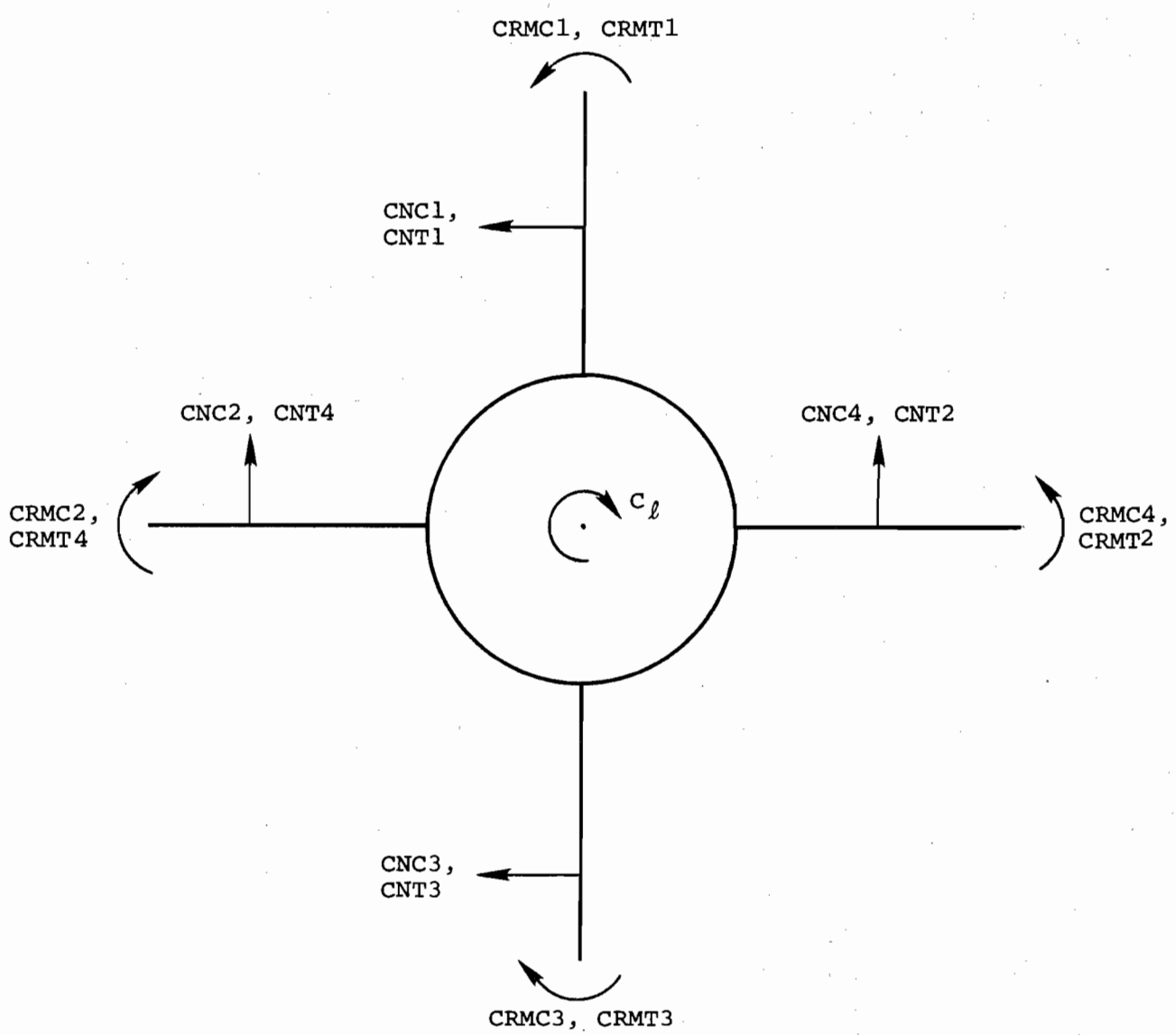


FIG. 7. Sign Convention for Fin Normal Force and Rolling-Moment Coefficients.

(b)(3)

(b)(3)

(b)(3)

(b)(3)

FIG. 8. AIM-9L Wind Tunnel Model.

(b)(3)

(b)(3)

FIG. 9. Wing-Alone Normal-Force Coefficient for Two AIM-9L Canard Fins Put Together.

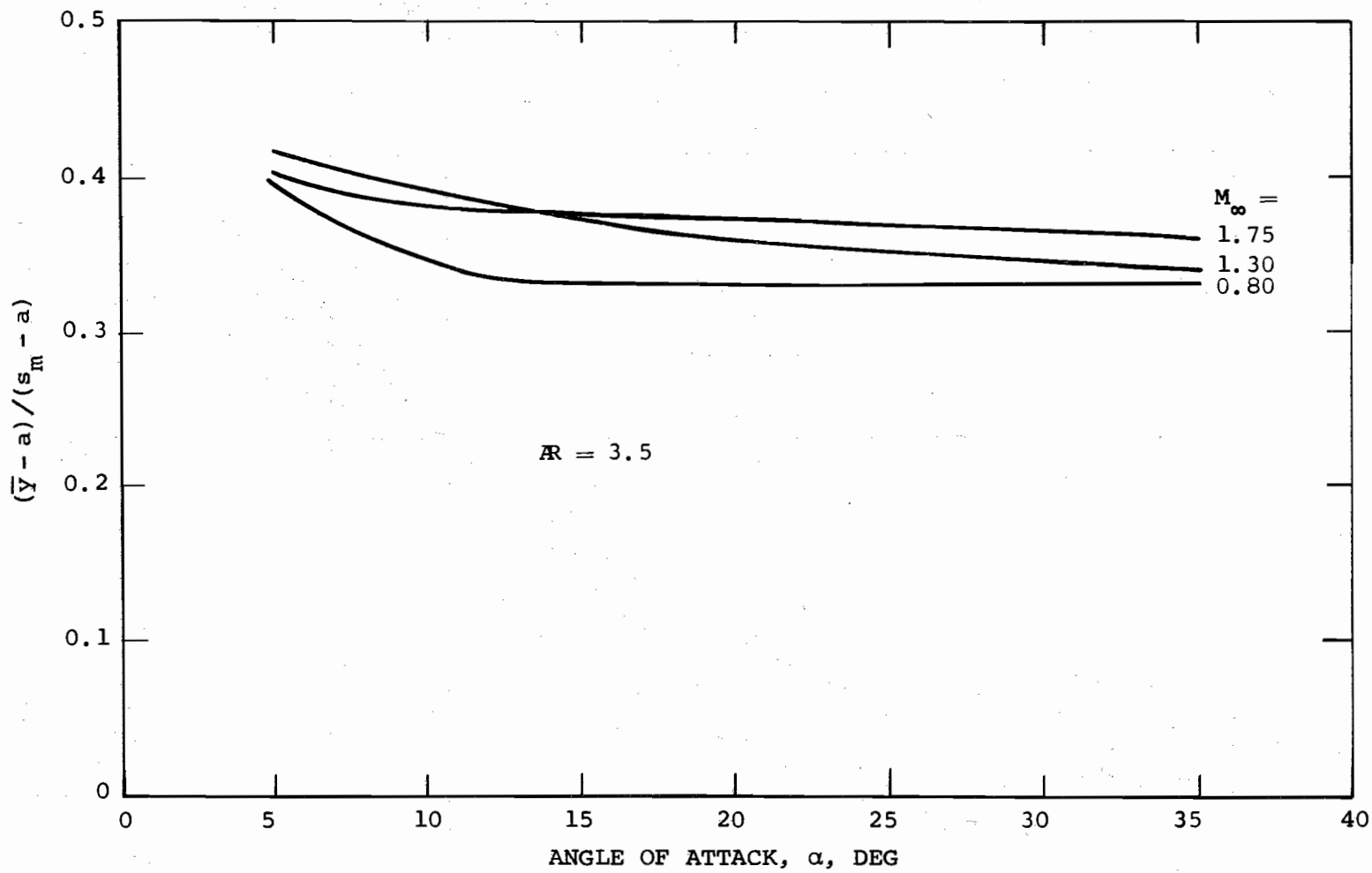


FIG. 10. Center-of-Pressure Location for NWC-MICOM C_6 Fins.

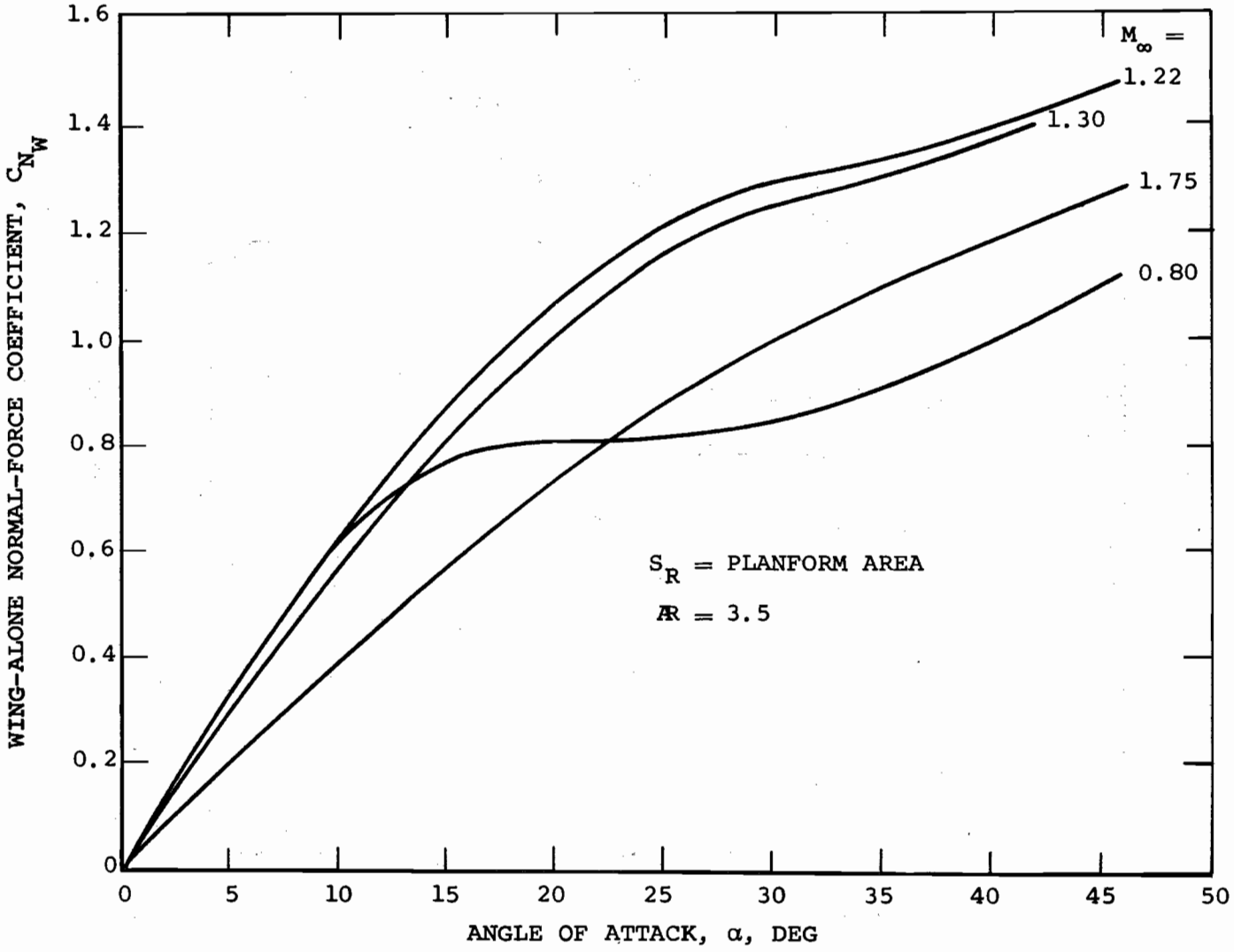


FIG. 11. Wing-Alone Normal-Force Coefficient for Two NWC-MICOM C_6 Canard Fins Put Together.

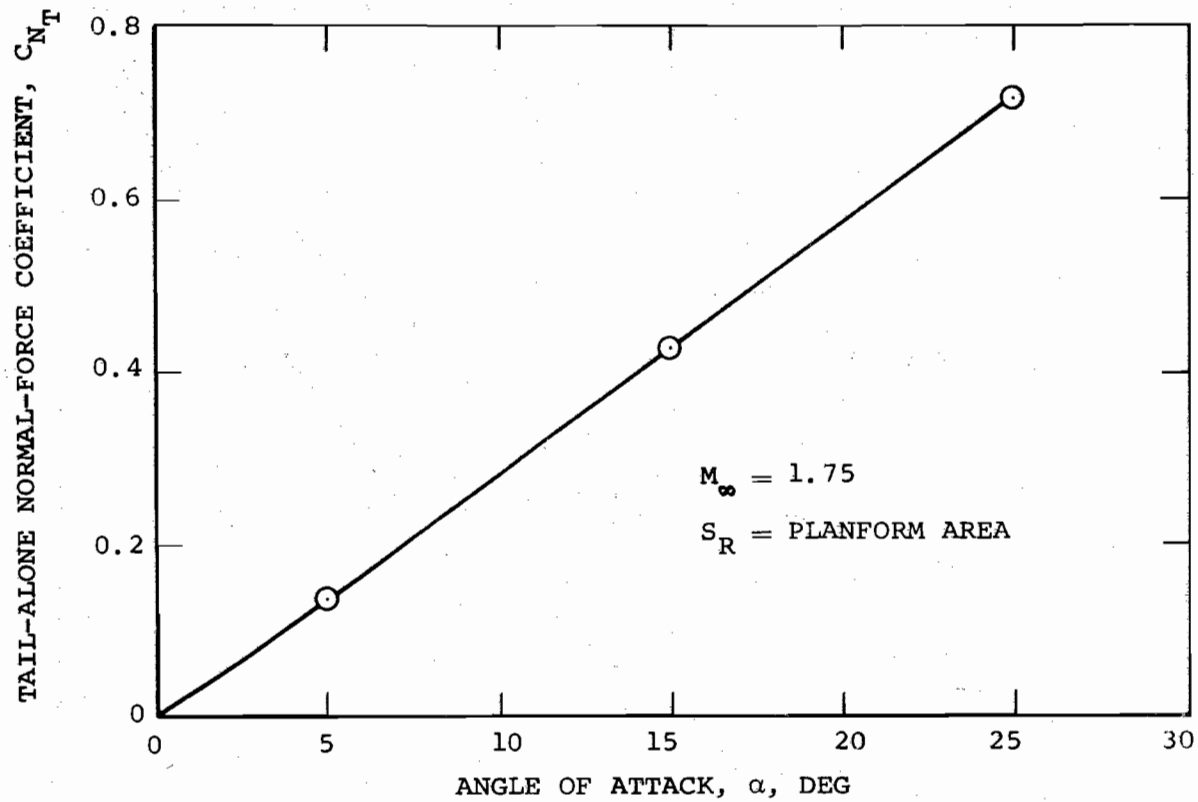


FIG. 12. Calculated C_{N_W} for Two AIM-9L Tail Fins Put Together.

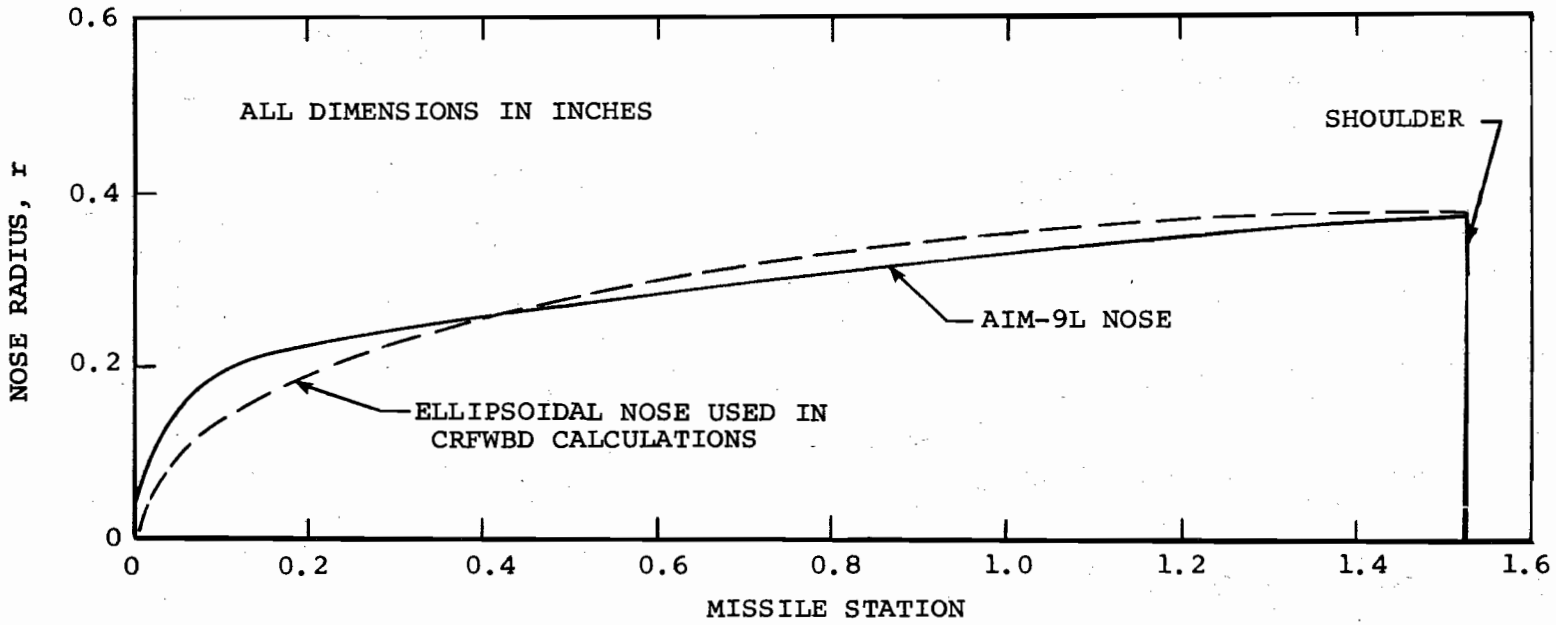


FIG. 13. AIM-9L Nose Configuration.

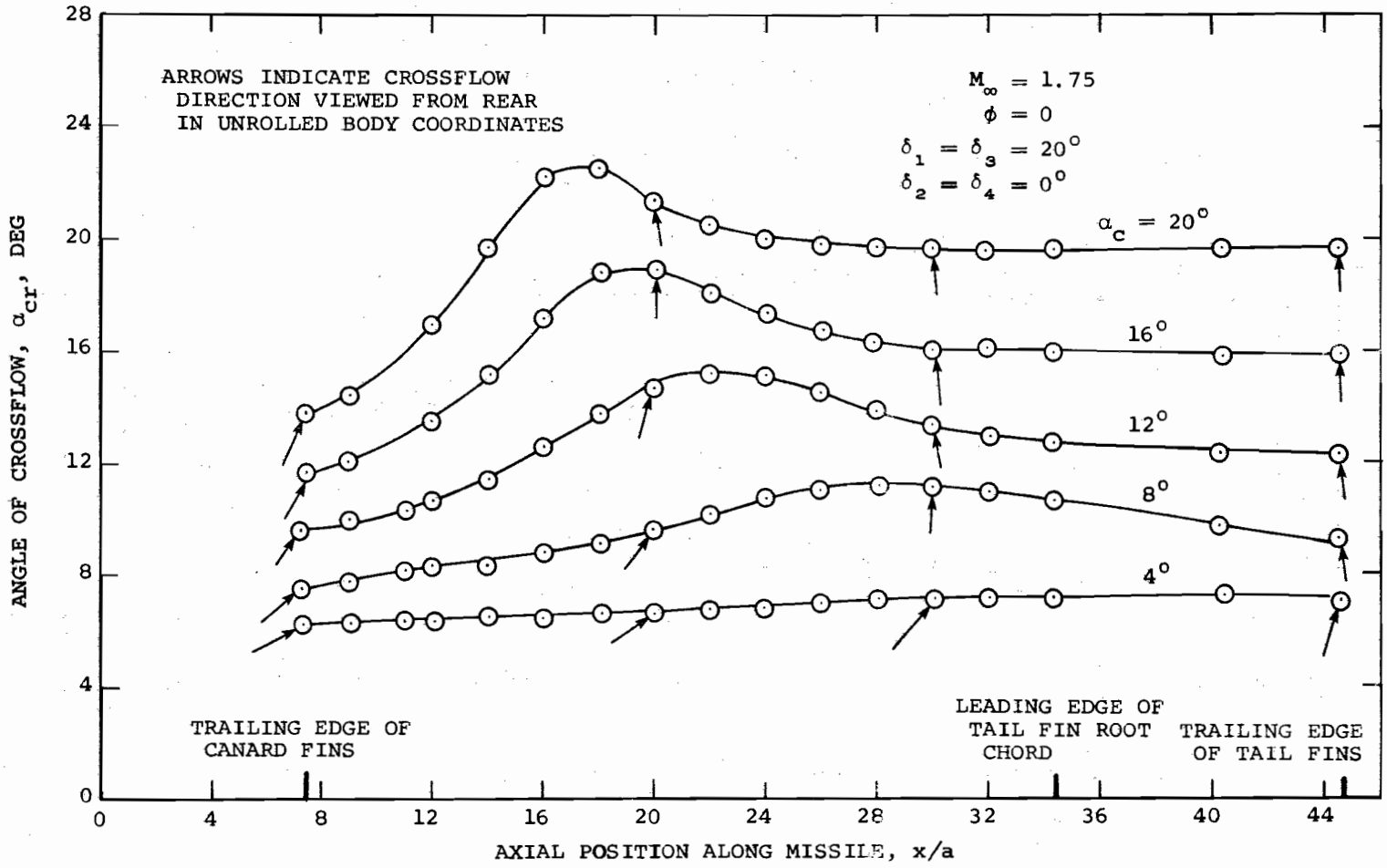


FIG. 14. Angle of Crossflow and Direction of Crossflow Behind Canards of AIM-9L Missile; No Body Vortices Present.

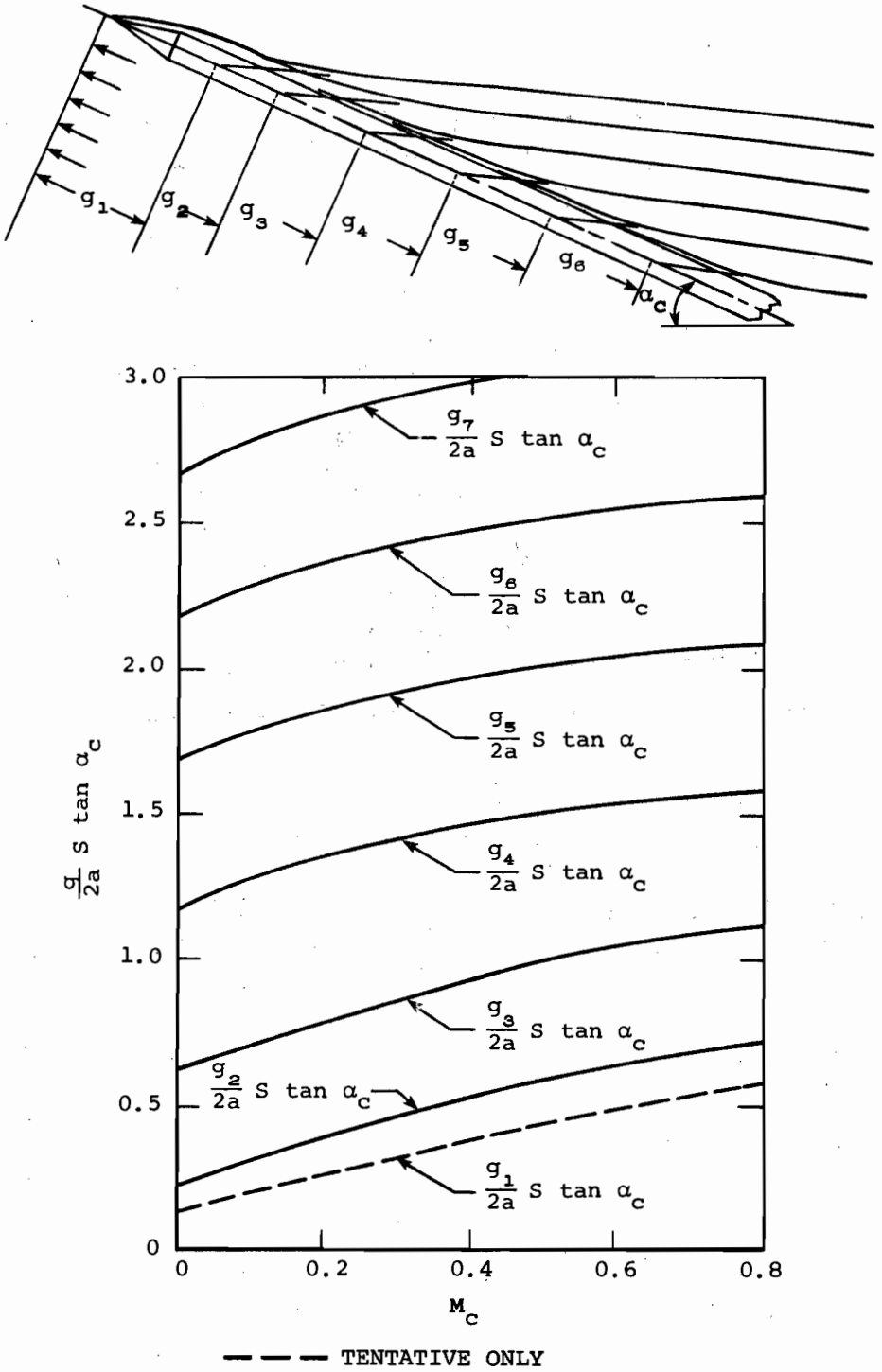


FIG. 15. Starting Positions of All the Vortices in Wake of Slender Cone-Cylinder at Incidence.

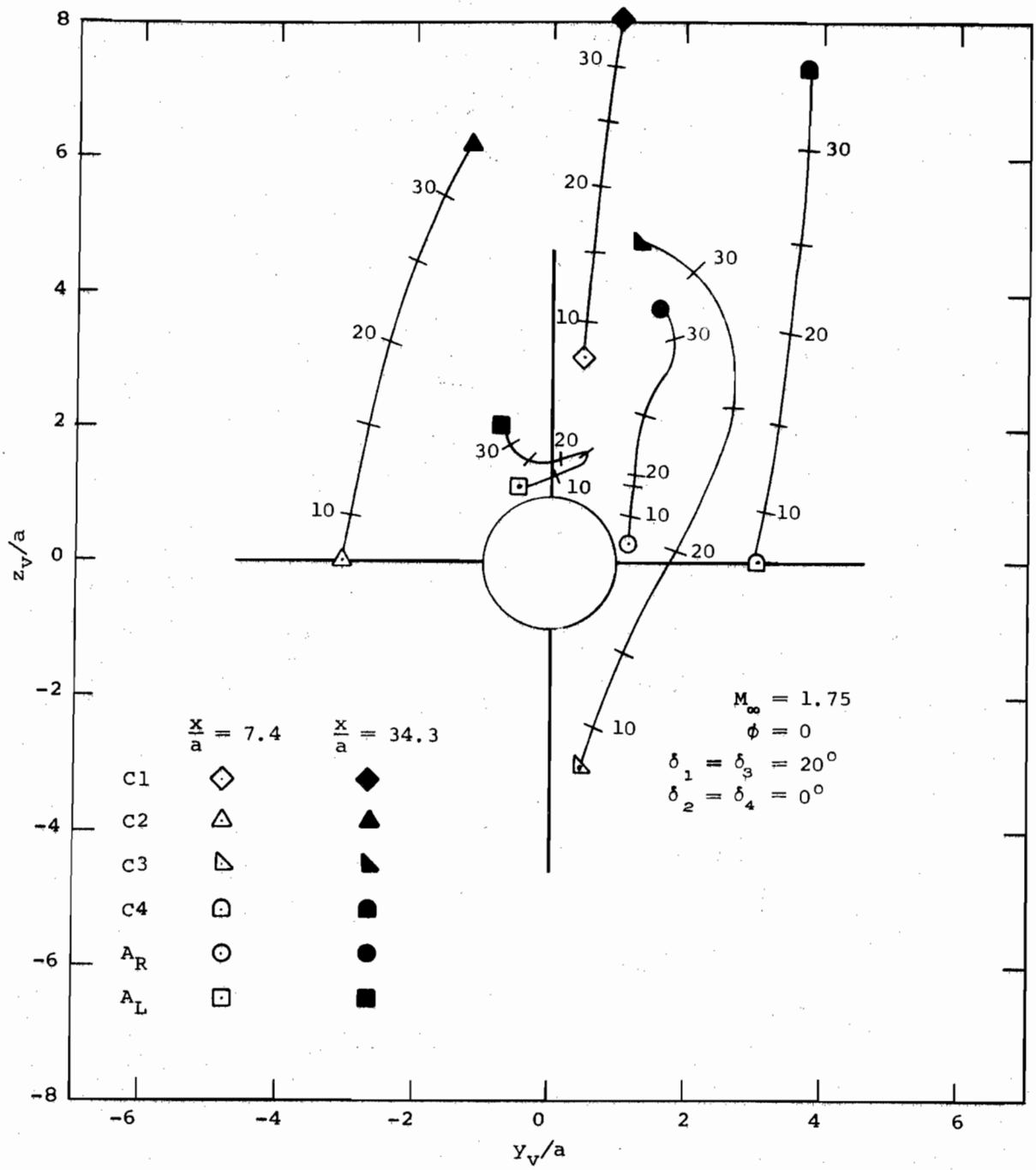


FIG. 16. Predicted AIM-9L Vortex Trajectories for $\alpha_c = 16^\circ$; First Example Case.

(b)(3)

(b)(3)

FIG. 17. Comparison of Experiment and Theory for First Example Case.

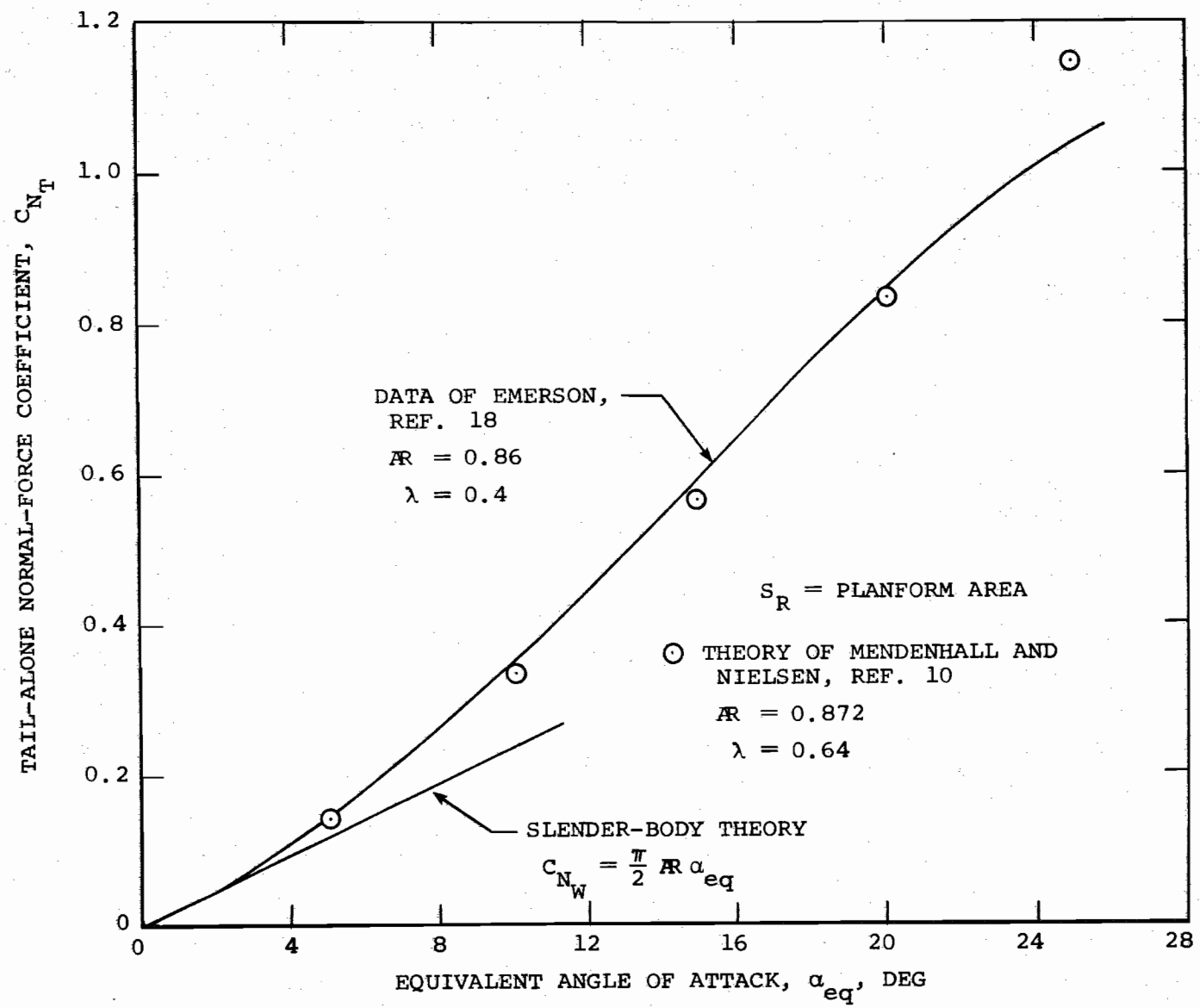


FIG. 18. Normal-Force Curve of "Tail Alone," AIM-9L, $M_\infty = 0.8$.

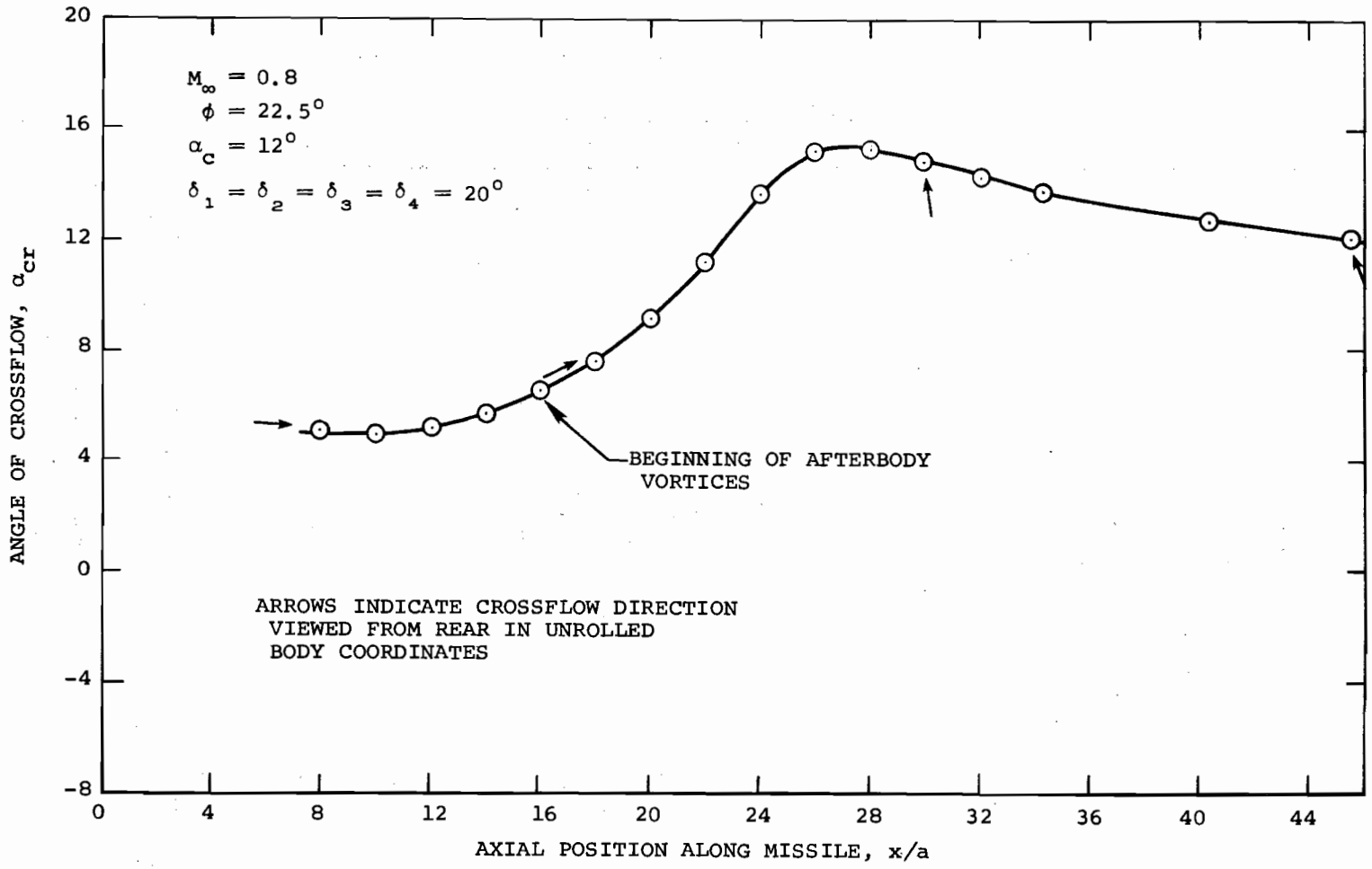


FIG. 19. Angle of Crossflow and Direction of Crossflow over AIM-9L Afterbody for $M_\infty = 0.8$ With No Afterbody Vortices.

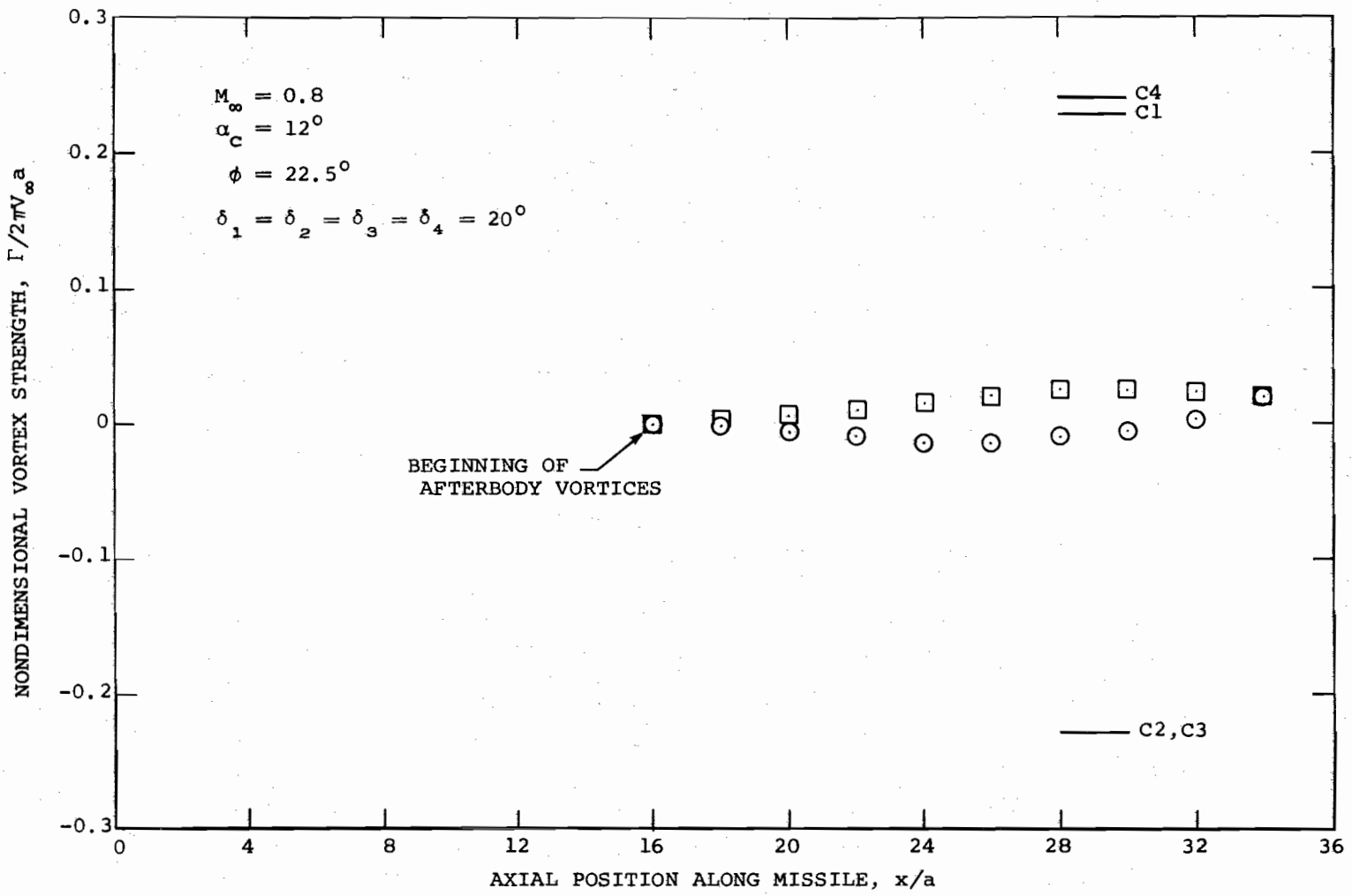


FIG. 20. Afterbody Vortex Strength History for Second Example.

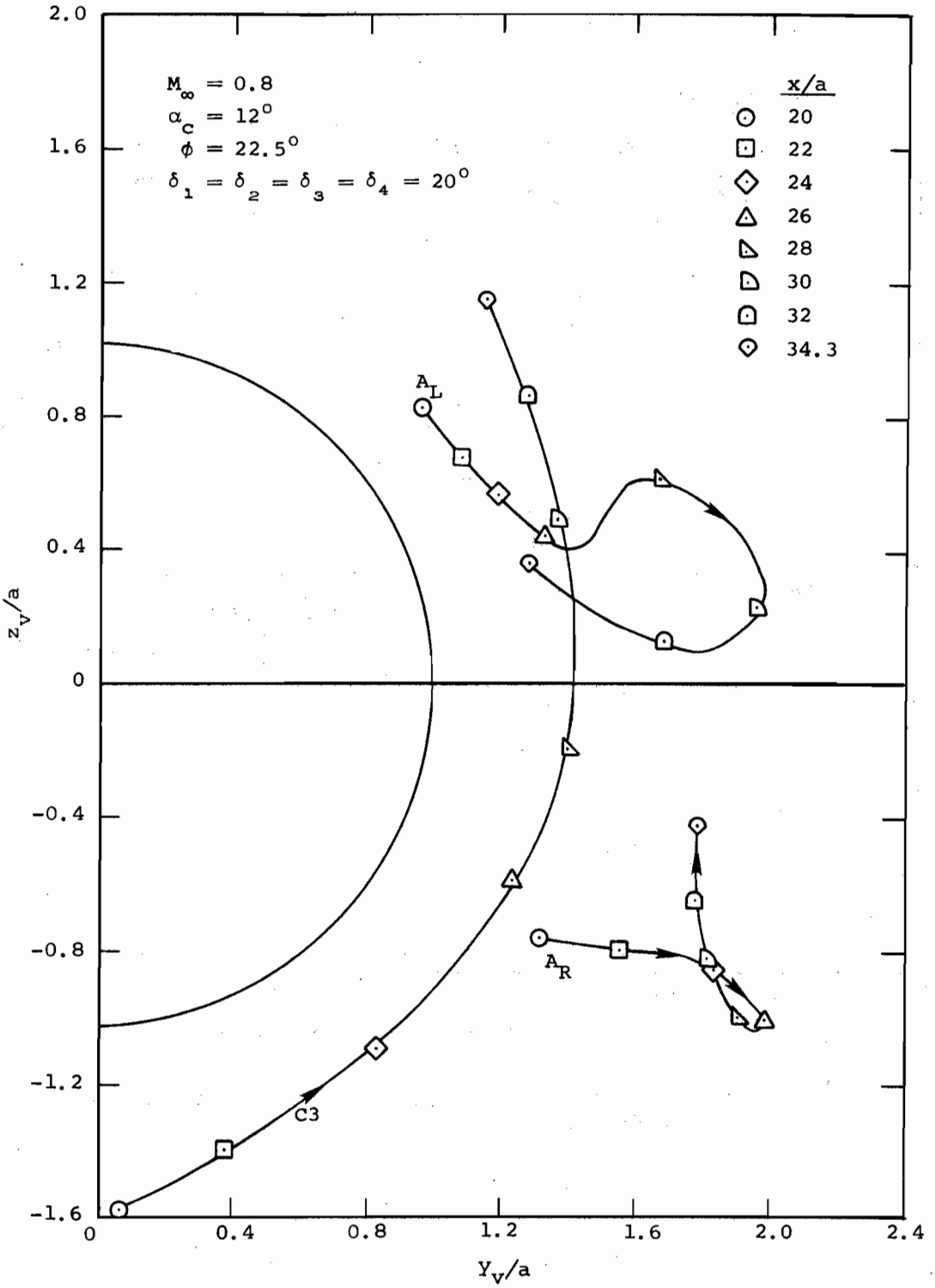


FIG. 21. Cutting of Afterbody Vortex Feeding Sheets by C3 Vortex.

(b)(3)

(b)(3)

FIG. 22. Comparison of Experiment and Theory for Second Example Case.

Appendix A

CRFWBD, A COMPUTER PROGRAM FOR CALCULATING AERODYNAMIC CHARACTERISTICS OF CRUCIFORM WING-BODY COMBINATIONS IN SUPERSONIC FLOW

INTRODUCTION

The purpose of this appendix is to describe the cruciform wing-body program CRFWBD in sufficient detail to permit understanding and use of the program. This program computes overall loading, rolling moment and span loading for each fin of a cruciform wing-body combination. In addition, it can calculate leading-edge suction force. Pressure distributions on the body are calculated. The program can also treat a planar wing or cruciform wing alone.

Configuration parameters taken into consideration by the program are listed in detail in the section concerned with the theoretical analysis of the wings and the body in Ref. A-1.

This computer program is an extended version of the cruciform wing-body lifting-surface program developed for the Office of Naval Research* and reported in Ref. A-1. The extended version of this program was developed under an extension of the original ONR contract. NEAR wishes to thank the Office of Naval Research for permission to publish the operating details of this program prior to the detailed ONR technical report on the subject.

PROGRAM DESCRIPTION

Fundamentally, the program is based on representing the wings by constant u—velocity panels and the body by a distribution of sources and doublets along its centerline. The body source and doublet strengths are determined explicitly from the flow tangency condition at points on the body surface. The strengths of the constant u-velocity panels associated with the wings and those laid out on the body surface to account for interference are obtained from a set of simultaneous equations provided by the flow tangency condition applied at a finite set of control points distributed over the wings and body. Thus, wing-to-wing and wing-to-body mutual

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interference is fully accounted for in the calculation of the constant u-velocity panel strengths.

A sample case described at the end of this appendix illustrates the input and output of the program.

Calculation Procedure

The computer program proceeds through various stages as follows. After reading in the run identification, namelist INPUT is read in. It contains wing geometry data, body radius, flow conditions and constant u-velocity panel distribution specifications for wing and body. The panel layout on the wings is specified in terms of the chordwise and spanwise numbers of panels for each wing surface. As an option, the user can specify the distances along the wing semispan from the plane of symmetry to the outboard panel edges. This input allows unequal spanwise spacing and breaks in sweep and is read in separately for each wing surface.

For the planar wing or cruciform wing in pitch and sideslip, the program proceeds to construct a geometrically asymmetric panel layout. The panel side edges are streamwise but not necessarily parallel to the wing root chord. If these configurations are pitched only, then the panel layout is arranged symmetrically with respect to the vertical or (x_w, z_w) plane which contains the wing root chord, and the panel side edges lie parallel to the root chord. The wing surfaces of a cruciform wing-body combination are always covered with a panel layout with the panel side edges parallel to the individual wing root chords which in turn are made to be parallel to the body centerline, see Fig. A-3. For all wing or cruciform wings without sideslip and for cruciform wing-body combinations, the wing leading and trailing edges may have breaks in sweep. The actual construction of the constant u- velocity panel geometric characteristics, centroid and control point coordinates is performed in subroutine LAYOUT.

Next, the geometric characteristics of the body interference panels are also determined in subroutine LAYOUT if the configuration of interest is a wing-body combination. The panel side edges lie parallel to the body centerline for both pitch and sideslip conditions.

After printing the geometrical characteristics, the program proceeds to read in the second namelist BODY which contains body geometry data and

a control index. The strengths of the sources and doublets employed to flow model the body are then computed and printed in subroutine BDYGEN for the flow conditions read in by means of namelist INPUT. Perturbation velocities induced by the body at the wing control points are calculated in subroutine VELCAL.

If the effects of external vortices are considered, their strengths and locations are read in next and the program proceeds to compute vortex-induced velocities in subroutine VRTVEL. The expressions for the velocities are given by equations (16) and (17) in Ref. A-2. The program then prints the wing control point coordinates together with the body and vortex-induced perturbation velocities.

The aerodynamic influence coefficients associated with all the constant u-velocity panel interactions are then determined. In this process, subroutine VELNOR actually calculates the components which are required by the influence matrix defined by the left-hand side of equations (41), (42), and (43), Ref. A-1. The next step is to build up the array defined by the right-hand side of these equations. Subroutine LINEQS together with subroutine SOLVE solve the set of simultaneous equations by a Gaussian elimination method to obtain the unknown constant u-velocity panel strengths multiplied by a constant, $4\pi u$, where u is the axial perturbation velocity component divided by the free-stream velocity V_∞.

After the constant u-velocity panel strengths are known, the program calls on subroutine SPECPR to calculate the nonlinear pressure loadings in accordance with the expressions given by equations (C-2) through (C-5), Ref. A-2. In this process, the vortex-induced velocity component parallel to the wing surfaces can be excluded as an option. Linear pressure loadings are directly related to the u-velocity through equation (C-1) of Ref. A-2.

Normal force, lift, induced drag, rolling moment and spanwise load distribution are then calculated in subroutine LOADS for each lifting surface on the basis of the linear and Bernoulli pressure loadings. Body and external vortex effects, if present, are included in the loading determinations. The calculations are based on equations (44) through (48) of Ref. A-1 for aerodynamic forces acting on the wing surfaces. Spanwise loadings are calculated for the planar and cruciform wing cases only for zero sideslip. The spanwise loadings are always computed for the fins of a cruciform wing-body combination.

The remainder of the program arranges for the optional output of loading characteristics for all the constant u—velocity panels. Loading coefficients are printed for each wing surface. Spanwise loadings are also printed for cases for which they are calculated.

The program is arranged to read in consecutively as many sets of wing-body configuration data as the user desires.

Program Operation

The cruciform wing-body computer program is written in the FORTRAN IV language (026 punch) and has been run on the CDC 6600 machine belonging to Boeing Computer Services. The main program is arranged so that a total of 250 constant u—velocity panels are available to cover the wing surfaces and to be used as body interference panels. A total of 100 sources and 100 doublets can be used to model the body. If the program is to be run on a different computer with smaller core memory, dimension statements need to be changed to permit operation on that machine.

No tapes are required other than the standard input and output. The program employs a system-supplied subroutine REQFL which computes the actual dimension requirement for the aerodynamic coefficient matrix FVN. This subroutine makes use of special machine-dependent parameters. Certain machine systems may have a similar subroutine available. If no such subroutine is available, the dimension of array FVN should be set to 62,500 and the three calls to REQFL marked in the main program removed.

For a configuration employing 192 constant u-velocity panels and 22 sources and doublets, the running time on the CDC 6600 is approximately 50 seconds for one set of flow conditions.

Program Limitations and Precautions

There are some problems that could arise in the use of the cruciform wing-body program. The first is concerned with the input for a configuration which includes unswept wing surfaces or fins. For this case, the sweep should be set equal to 0.0001 in the namelist INPUT.

Problems can arise when an attempt is made to run a wing alone with forward sweep at zero sideslip. In order to save running time, the program makes use of loading symmetry for unswept or sweptback wings with zero sideslip. In these cases, only one-half of the wing is covered with

constant u—velocity panels. The aerodynamic interference coefficients are determined accounting for the fact that every panel on one-half wing has its mirror image on the other half. Presently, wings with forward sweep at zero sideslip cannot be handled this way. However, the program can still treat such a wing by covering both wing halves with the same panel layout and solving this system without the computer time-saving benefits of loading symmetry. It should be noted that subroutines LOADS, VRTVEL, and TRBIPW contain entry points. The first does not employ an argument list and should not cause any problems. However, the entry points in the second and third may need to have the appropriate subroutine argument list attached to them if other computer machines are used.

The last warning is concerned with the use of system subroutine REQFL already mentioned above under program operation. If this subroutine is not available, an equivalent subroutine can be called or the calls to REQFL can be removed and the dimension on FVN set to 62,500.

DESCRIPTION OF INPUT

This section describes the input for the cruciform wing-body computer program. In the following discussion, the content of all input cards is specified. All possible input variables are listed at the end of this section in the order of appearance in the input deck, except for the first four variables which do not appear in the input deck but are needed for program input preparation. The input format for all cards is shown in Fig. A-1 and the item numbers also refer to that figure. A sample input is described in a later section concerned with the sample case.

Item 1

The first card serves as identification and may contain any alphanumeric information desired. This information is printed on the first page of the output.

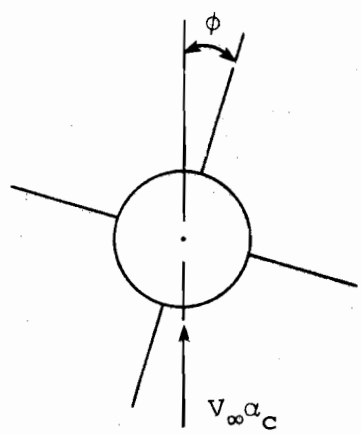
Item 2

The second and following cards form the namelist INPUT which specifies the geometrical parameters of the wing surfaces specified in their planform plane. These parameters are the leading-edge and trailing-edge sweeps, semispan and root chord. For a wing or cruciform alone, the root chord is

the wing centerline or the cruciform wing junction. In the case of a cruciform wing-body combination, the root chord is the line formed by the junction of the wing surface and the body. The semispan is measured from the root chord in any case.

This namelist also contains the deflection angles and the number of chordwise and spanwise constant $u-$velocity panels for each wing surface or fin. The spanwise number may differ from one fin to another but the chordwise number NCW is the same for all. Body radius RB and the number of body interference panels NBDCR on the circumference are also included in this namelist. The specification of the latter also determines whether or not a body is present. The number of body interference panels in the axial direction is specified by NCWB. The body should be cylindrical in cross section over the length spanned by the wings. The input value RB is the radius of this cylindrical portion.

The included angle of attack ALFAC is the angle between the free stream and the body/wing centerline (x_B-axis). Angle of roll PHI is indicated by ϕ in the sketch below. The program computes pitch and



sideslip angles in accordance with the pitch-roll transformation described fully in Ref. A-3.

In addition, control indices, free-stream Mach number and reference quantities are read in. Breaks in leading-edge and/or trailing-edge sweeps are only allowed if the configuration is a wing or cruciform wing alone at zero sideslip or if the configuration consists of a cruciform wing-body. This option is governed by control index LVSWP. Angles SWLEP, SWTEP, SWLEV, and SWTEV need not be specified if LVSWP $\neq$ 0.

Item 3

This optional input is required when there are breaks in the wing sweep or if the constant u—velocity panel side edges are to be laid out with user-determined unequal spanwise spacings. This input pertains only to a wing or cruciform wing alone at zero sideslip. Variable YR is the distance from the root chord to the outboard panel side edges. Therefore, the first value for YR is zero. The last value for YR must equal wing semispan, B2, specified in the namelist INPUT. In effect, this specification positions the panel outboard side edges on the right wing. The sweep angles are positive for wings with sweptback leading and trailing edges.

Item 4

The optional input of this item is associated with a planar or cruciform wing-body combination with breaks in leading-edge and/or trailing-edge sweeps. Also, this input should be used for this configuration if the constant u-velocity panel side edges are to be laid out with user-determined unequal spacings. Variable YRT is the distance from the body centerline to the outboard constant u—velocity panel edges on the right wing or fin. The first value should equal the radius of the cylindrical part of the body, RB, and the last value for YRT must be the same as the semispan, B2, specified in the namelist INPUT. The sweep angles are positive for right wings or fins with sweptback leading and trailing edges.

Item 5

This optional output accompanies Item 4 and is associated with the left wing or fin. Variable YLT is the distance from the body centerline to the outboard constant u—velocity panel edges on the left wing or fin. The first value should equal the negative of the radius of the cylindrical part of the body, -RB, and the last value for YLT must equal negative semispan, -B2. The sweep angles are negative for left wings or fins with sweptback leading and trailing edges.

Item 6

The information in this optional item accompanies Items 4 and 5 if the configuration is a cruciform wing-body combination. Again, this input

should only be used if there are breaks in the wing or fin sweeps or if the panel side edges are to be laid out with user-determined unequal spacings. Variable ZUT is the distance from the body centerline to the outboard constant u— velocity panel edges on the upper wing or fin. The first value should equal the radius of the cylindrical part of the body, RB, and the last must be the same as the semispan, B2V, specified in the namelist INPUT. The sweep angles are positive for upper wings or fins with swept-back leading and trailing edges.

Item 7

This optional information is the last of four inputs associated with a cruciform wing-body combination if there are breaks in sweep or if the constant u-velocity panel side edges are to be laid out with user-determined spacings, see Items 4 through 6. Variable ZDT is the distance from the body centerline to the outboard constant u-velocity panel edges on the lower wing or fin. The first value should equal the negative of the radius of the cylindrical part of the body, -RB, and the last value for ZDT must equal negative semispan, -B2V. The sweep angles are negative for lower wings or fins with sweptback leading and trailing edges.

Item 8

The input cards for this item form the namelist BODY which is required only when a body is part of the configuration under consideration. If the integer NBDCR in namelist INPUT under Item 2 is specified to be nonzero, a body is present. The information in this input includes specification of body geometry parameters and is input in subroutine BODY. The length of the nose LNOSE determines the body length over which the the radius is changing as a function of the body axial coordinate. The actual nose configuration is governed by control index BCODE, which selects pre-programmed forebody shapes described in section 2.2.1 of Ref. A-1.

Normally, the body length LBODY should at least equal the axial distance from the body nose to the trailing edges of the wings or fins.

The minimum number of body modeling singularities NXBODY should be determined as follows. Let the density (sources and doublets/unit body length) be determined by the number of constant u-velocity panels in the chordwise direction on the wing divided by the root chord (or length of

wing-body junction). Then number NXBODY equals the density times body length.

The pressure coefficient distributions are calculated along the body meridians (i.e., in longitudinal planes) at $\theta = 0^{\circ}$ (top of body), 45°, 90°, 135°, and 180°. The expression used is governed by control index PCODE which selects one from the set given by equations (48b) through (48d) of Ref. A-1.

Item 9

This input is required only when variable NVRTX specified in namelist INPUT, Item 2, is nonzero. In fact, NVRTX is the number of external vortices whose influences are to be included in the loading calculations. Each vortex is assumed to be infinite in length and parallel to the wing surfaces. Therefore, with each vortex there is associated a nondimensional strength GAMMA, and nondimensional crossflow plane coordinates YVRTX, ZVRTX. These quantities are input in subroutine VRTVEL.

Item 10

This card ends the process of reading in data. It should only be put at the end of all data cards for the case(s) to be run. The computer program stops the search for more data and the run is finished.

PROGRAM VARIABLE	ALGEBRAIC SYMBOL (IF APPLICABLE)	COMMENTS
MSWRP		(Number of chordwise rows on right wing) + 1; MSWRP = MSWR + 1.
MSWLP		(Number of chordwise rows on left wing) + 1; MSWLP = MSWL + 1.
MSWUP		(Number of chordwise rows on upper wing) + 1; MSWUP = MSWU + 1.
MSWDP		(Number of chordwise rows on lower wing) + 1; MSWDP = MSWD + 1.
Item 1		Any alphanumeric information may be put on this card for identification of the calculation.

PROGRAM VARIABLE	ALGEBRAIC SYMBOL (IF APPLICABLE)	COMMENTS
Item 2		Namelist INPUT.
CRP	$c_{r,H}$	Horizontal wing root chord, dimensional.
SWLEP	$\Lambda_{LE,H}$	Horizontal wing leading-edge sweep angle measured in wing planform, positive for sweep back, degrees. Omit if LVSWP $\neq$ 0.
SWTEP	$\Lambda_{TE,H}$	Horizontal wing trailing-edge sweep angle measured in wing planform, positive for sweep back, degrees. Omit if LVSWP $\neq$ 0.
NCW		Number of chordwise constant u-velocity panels on the wing.
MSWR		Number of spanwise constant u-velocity panels on right wing. $1 \leq$ MSWR ≤ 19.
MSWL		Number of spanwise constant u-velocity panels on left wing. $1 \leq$ MSWL ≤ 19, default is 0.
MSWU		Number of spanwise constant u-velocity panels on the upper wing. $1 \leq$ MSWU ≤ 19, default is 0.
MSWD		Number of spanwise constant u-velocity panels on the lower wing. $1 \leq$ MSWD ≤ 19, default is 0.
SWLEV	$\Lambda_{LE,V}$	Vertical wing leading-edge sweep angle measured in wing planform positive for sweep back, degrees. Omit if LVSWP $\neq$ 0.
SWTEV	$\Lambda_{TE,V}$	Vertical wing trailing-edge sweep angle measured in wing planform, positive for sweep back, degrees. Omit if LVSWP $\neq$ 0.
CRPV	$c_{r,V}$	Vertical wing root chord, dimensional.
B2	$b_H/2$	Horizontal wing semispan, dimensional.
B2V	$b_V/2$	Vertical wing semispan, dimensional.
RB	a	Radius of cylindrical portion of body.
DELR	$\delta_{H,R}$	Deflection angle of horizontal right wing, same sense as α, degrees, default is 0.0 (also see Fig. 5 in Ref. A-1).

PROGRAM VARIABLE	ALGEBRAIC SYMBOL (IF APPLICABLE)	COMMENTS
DELL	$\delta_{H,L}$	Deflection angle of horizontal left wing, same sense as α, degrees, default is 0.0.
DELU	$\delta_{V,U}$	Deflection angle of vertical upper wing, same sense as β, degrees, default is 0.0 (also see Fig. 5 in Ref. A-1).
DELD	$\delta_{V,D}$	Deflection angle of vertical lower wing, same sense as β, degrees, default is 0.0.
ALFAC	α_c	Angle of incidence, measured between free-stream velocity vector and body/wing centerline.
PHI	ϕ	Angle of roll, measured from the plane containing the free-stream velocity vector and the body/wing centerline to the upper wing surface, positive right wing down, default is 0.0.
FMACH	M_∞	Free-stream Mach number.
LVSWP		LVSWP = 0 No breaks in wing leading or or trailing edges, default value. LVSWP $\neq$ 0 Up to 19 breaks in wing leading or trailing edges.
NVRTX		Number of external vortices present, NVRTX $\leq$ 10 (see Item 9).
NCRX		NCRX = 0 Horizontal wing only present, default value. NCRX = 1 Vertical wing surfaces in addition to horizontal wing surfaces present.
NBDCR		Number of constant u-velocity panels on the circumference of the body. NBDCR = 0 No body present, default value. NBDCR > 0 Body present (see Item 8).
NCWB		Number of constant u-velocity panels in the longitudinal direction on the surface of the body.
SREF	S_R	Reference area used in load calculations.
REFL	ℓ_r	Reference length used in rolling-moment calculations.

PROGRAM VARIABLE	ALGEBRAIC SYMBOL (IF APPLICABLE)	COMMENTS
NFVNPR		NFVNPR $\neq$ 0 Print influence coefficient matrix FVN for debugging, default is 0.
NOLINP		NOLINP = 0 Loadings calculated on the basis of linear pressures only. NOLINP = 1 Loadings calculated on the basis of linear and Bernoulli pressures, default is 0.
NOUT		NOUT $\neq$ 0 Print large amount of output for debugging, default is 0.
NPR		Same as NOUT, default is 0.
NDRAG		NDRAG = 0 Omit calculation of induced drag, default is 1.
Item 3		Optional input for planar or cruciform wing alone at zero sideslip.
YR(KJ)	$y_{W,R}(KJ)$	Distance from wing root chord to the constant pressure panel outboard side edge on right wing. $1 \leq KJ \leq MSWRP$, $(MSWRP \leq 20)$, YR(1) = 0.0, YR(MSWRP) = B2.
VSWLER(KJ)	$\Lambda_{LE,R}(KJ)$	Leading-edge sweep of wing between YR(KJ-1) and YR(KJ), positive for sweep back, degrees. $1 \leq KJ \leq MSWRP$, $(MSWRP \leq 20)$, VSWLER(1) = 0.0.
Item 4		Optional input for wing-body combination.
YRT(KJ)	$y_{W,R}(KJ)$	Distance from body centerline to the constant u-velocity panel outboard side edge on right wing. $1 \leq KJ \leq MSWRP$, $(MSWRP \leq 20)$, YRT(1) = RB, YRT(MSWRP) = B2.
VSWLER(KJ)	$\Lambda_{LE,R}(KJ)$	Leading-edge sweep of wing between (YRT(KJ-1) and YRT(KJ), positive for sweep back, degrees. $1 \leq KJ \leq MSWRP$, $(MSWRP \leq 20)$, VSWLER(1) = 0.0.
VSWTER(KJ)	$\Lambda_{TE,R}(KJ)$	Trailing-edge sweep of wing between (YRT(KJ-1) and YRT(KJ), positive for sweep back, degrees. $1 \leq KJ \leq MSWRP$, $(MSWRP \leq 20)$, VSWTER(1) = 0.0.
Item 5		Optional input for wing-body combination.
YLT(KJ)	$y_{W,L}(KJ)$	Distance from body centerline to the constant u-velocity panel outboard side edge on left wing. $1 \leq KJ \leq MSWLP$, $(MSWLP \leq 20)$, YLT(1) = -RB, YLT(MSWLP) = -B2.

PROGRAM VARIABLE	ALGEBRAIC SYMBOL (IF APPLICABLE)	COMMENTS
VSWLEL(KJ)	$\Lambda_{LE,L}(KJ)$	Leading-edge sweep of wing between YLT(KJ-1) and YLT(KJ), negative for sweep back, degrees. $1 \leq KJ \leq MSWLP$, $(MSWLP \leq 20)$, VSWLEL(1) = 0.0.
VSWTEL(KJ)	$\Lambda_{TE,L}(KJ)$	Trailing-edge sweep of wing between YLT(KJ-1) and YLT(KJ), negative for sweep back, degrees. $1 \leq KJ \leq MSWLP$, $(MSWLP \leq 20)$, VSWTEL(1) = 0.0.
Item 6		Optional input for cruciform wing-body combination.
ZUT(KJ)	$Z_{W,U}(KJ)$	Distance from body centerline to the constant u-velocity panel outboard side edge on upper wing. $1 \leq KJ \leq MSWUP$, $(MSWUP \leq 20)$, ZUT(1) = RB, ZUT(MSWUP) = B2V.
VSWLEU(KJ)	$\Lambda_{LE,U}(KJ)$	Leading-edge sweep of wing between ZUT(KJ-1) and ZU(KJ), positive for sweep back, degrees. $1 \leq KJ \leq MSWUP$, $(MSWUP \leq 20)$, VSWLEU(1) = 0.0.
VSWTEU(KJ)	$\Lambda_{TE,U}(KJ)$	Trailing-edge sweep of wing between ZUT(KJ-1) and ZUT(KJ), positive for sweep back, degrees. $1 \leq KJ \leq MSWUP$, $(MSWUP \leq 20)$, VSWTEU(1) = 0.0.
Item 7		Optional input for cruciform wing-body combination.
ZDT(KJ)	$Z_{W,D}(KJ)$	Distance from body centerline to the constant u-velocity panel outboard side edge on lower wing. $1 \leq KJ \leq MSWDP$, $(MSWDP \leq 20)$, ZDT(1) = -RB, ZDT(MSWDP) = -B2V.
VSWLED(KJ)	$\Lambda_{LE,D}(KJ)$	Leading-edge sweep of wing between ZDT(KJ-1) and ZDT(KJ), negative for sweep back, degrees. $1 \leq KJ \leq MSWDP$, $(MSWDP \leq 20)$, VSWLED(1) = 0.0.
VSWTED(KJ)	$\Lambda_{TE,D}(KJ)$	Trailing-edge sweep of wing between ZDT(KJ-1) and ZDT(KJ), negative for sweep back, degrees. $1 \leq KJ \leq MSWDP$, $(MSWDP \leq 20)$, VSWTED(1) = 0.0.
Item 8		
NXBODY		Number of source or doublet singularities distributed along body centerline.
LNOSE		Length of nose part of body measured from nose tip, dimensional (real variable).

PROGRAM VARIABLE	ALGEBRAIC SYMBOL (IF APPLICABLE)	COMMENTS
LBODY		Length of body, dimensional (real variable).
RNOSE		RNOSE = 0.0.
XNOSE		XNOSE = 0.0.
BCODE		Control index (integer) for specifying forebody shape. BCODE = 0 Parabolic. = 1 Sears-Haack. = 2 Tangent ogive. = 3 Ellipsoidal. = 4 Conical.
PCODE		Control index (integer) for specifying the expression for calculating the pressure coefficient distribution along the body meridians. PCODE = 0 No pressures calculated on the body meridians. = 1 Planar, equation (48d), Ref. A-1. = 2 Slender body, equation (48c), Ref. A-1. = 3 Second order, equation (48b), Ref. A-1.
XWLE		Distance from body nose tip to leading edge of wing-body junction.
Item 9		Optional input when the effects of external vortices are considered.
GAMMA(I)	$\frac{\Gamma}{2\pi V_\infty a}$ (I)	Nondimensional vortex strengths, $1 \leq I \leq$ NVRTX.
YVRTX(I)	$\frac{y(I)}{a}$	Nondimensional y-coordinate, $1 \leq I \leq$ NVRTX.
ZVRTX(I)	$\frac{z(I)}{a}$	Nondimensional z-coordinate, $1 \leq I \leq$ NVRTX.
Item 10		
ZZZZ		This card causes the program to stop searching for more data and the run is stopped.

DESCRIPTION OF OUTPUT

This section describes the minimum output for the cruciform wing-body computer program. This output occurs when NOUT = 0 in namelist INPUT. In the following, all items of output are specified and the contents briefly described. A sample output is referred to in a later section concerned with the sample case.

The first page identifies the run. The second and possibly the third show the namelist INPUT. All length dimensions in the output are the same as in input.

On the next page, the wing geometry and flow conditions are listed. The quantities ALFA and BETA correspond to angle of pitch α, and sideslip β, respectively, calculated by the program from the angle of incidence ALFAC and angle of roll PHI specified in namelist INPUT.

The next page shows the namelist BODY. It is followed by the program-computed body definition point coordinates in the body coordinate system and source T(I) and doublet TC(I) strengths. The body coordinate system is shown in Fig. A-2. Quantity TX is the origin of each line singularity. Presently, the strengths of the very last source and doublet are arbitrarily set to zero. Body-induced perturbation velocities computed by the program at the body definition points are then displayed separately for the sources and doublets. Quantity ALFAC is the angle of incidence α_c expressed in degrees. Quantities V, VT, and VN refer to the radial, tangential and normal-to-the-body-surface components. Pressure coefficient distributions along the indicated body meridians are shown next if PCODE $\neq$ 0 in namelist BODY. The quantities marked x are the control point axial coordinates in the body coordinate system (x_B, y_B, z_B).

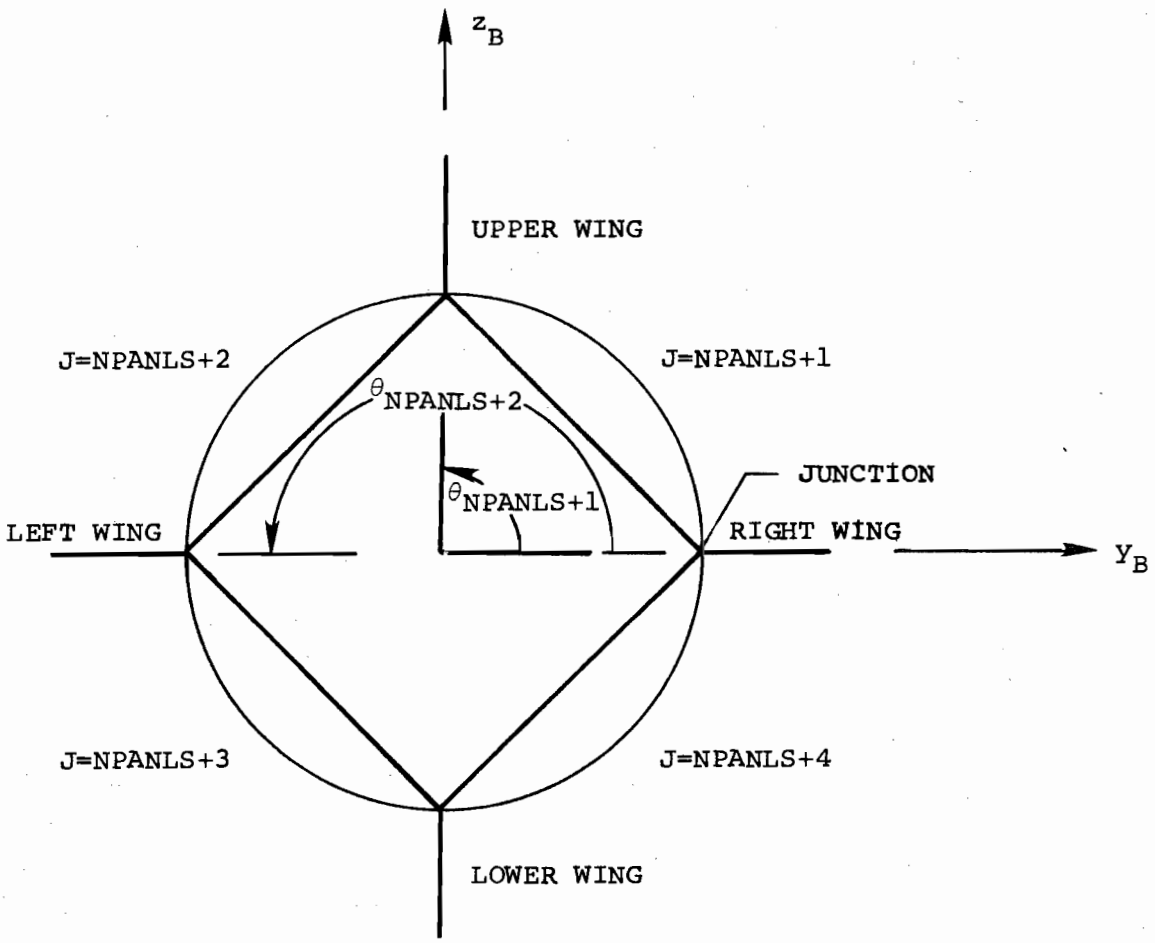
The next page in the output lists the calculated control point coordinates in the wing coordinate system shown in Figs. A-2 and A-3, for the constant u-velocity panels distributed on the wing surfaces or fins. Perturbation velocities, in the wing coordinate system, induced by the body and external vortices (if present) at the wing control points are also shown. The quantities BU, BV, BW and VV, WV, are due to body and vortices, respectively. Coordinates of the control points associated with the body interference panels are given on the next page. They are expressed in the wing coordinate system.

Wing and body interference constant u-velocity panel properties appear on the next pages. Wing panel properties only appear if NOUT $\neq$ 0 in namelist INPUT. The panel numbering sequence for this output is described first. Quantities NHP, NPANLS, etc., which appear in the following are explained in section 2.3 of Ref. A-1 and in the input description. J = 1 corresponds to the constant u-velocity panel on the right wing surface or fin adjacent to the wing root chord or wing-body junction and at the wing leading edge. This starts the first chordwise row. The sequence proceeds towards the trailing edge (J=NCW) and then back up to the leading edge (J=NCW+1) for the next chordwise row. This process continues along the semispan for each chordwise row until the wing surface tip is reached. There, the aft panel of the last chordwise row is located adjacent to the wing tip and next to the trailing edge. This panel is the last panel on the right wing.

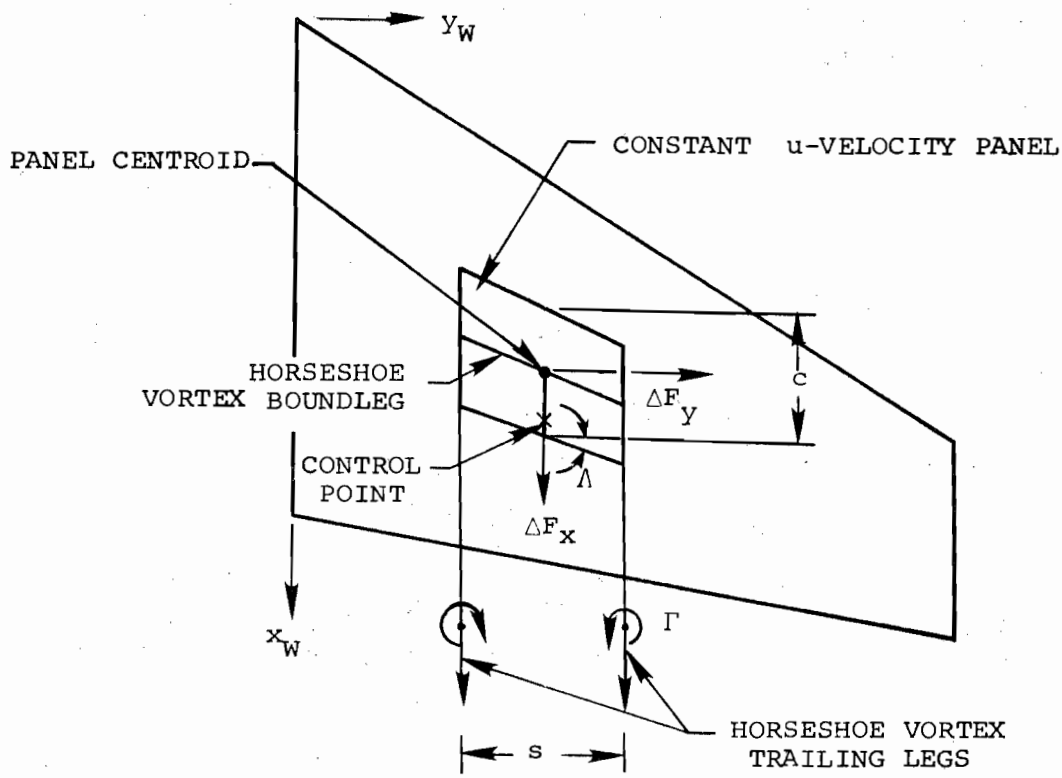
The sequence continues on to the left wing surface with the constant u-velocity panel closest to the root chord or wing-body junction and nearest the leading edge. The same process along the semispan for each chordwise row is then followed out to the left wing tip. The last panel on the left wing corresponds to J=NHP. The upper wing follows in the same manner starting from the root chord or wing-body junction and continuing out to its tip. This numbering scheme is continued on the lower wing, so that the last wing constant u-velocity panel is located adjacent to the lower wing tip and next to its trailing edge.

If a body is present, the panel numbering sequence continues with the most forward panel next to and above the right wing-body junction. The first body interference panel corresponds to J=NPANLS+1. The numbering sequence continues on the body circumference in the counterclockwise direction up to the most forward panel next to but underneath the right wing-body junction. This panel corresponds to J=NPANLS+NBDCR where NBDCR is the number of interference panels on the body circumference. This concludes the first circumferential row. The process is repeated for the next circumferential row, etc. There are NCWB such rows. The very last constant u-velocity panel for a wing-body combination lies next to and underneath the right wing-body junction closest to the wing trailing edge. It corresponds to J=NWBP. Quantity THETA under the heading BODY INFLUENCE PROPERTIES is the angle θ measured between the positive y_B-axis and the radial line to the panel left side as shown in the sketch on the next page.

Also shown are four body interference panels; they are numbered for the first circumferential row.



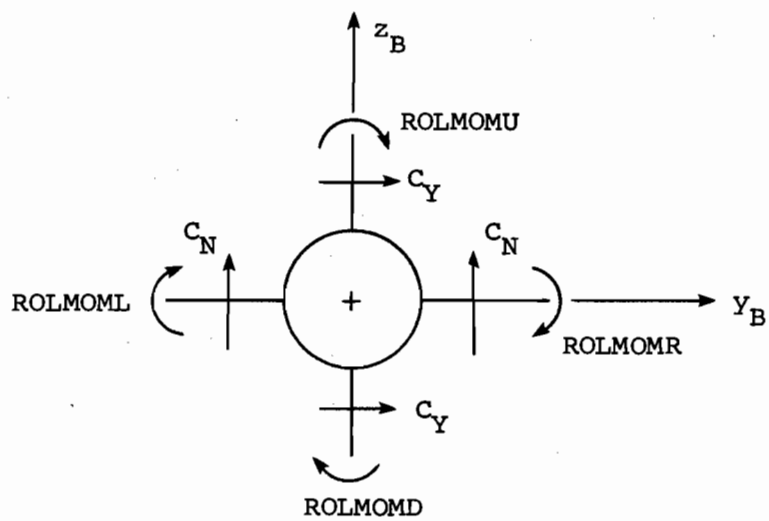
The quantities displayed under the panel properties heading will now be described briefly. Quantity YCPT is the y_W-coordinate of the panel control point. The next three are self evident and are illustrated in the sketch below. Note that the midchord sweep for panels on the left and



lower wings are negative for sweptback wings. For the panels on the wing, and if NOUT $\neq$ 0 in namelist INPUT, pressure loadings and the equivalent vortex strengths are listed. They are related through equation (46), Ref. A-1. Quantity VNOR/V is the perturbation velocity normal to the surface and is necessary to compute the in-plane forces FX, FY for the horizontal wings and FX,FZ for the vertical wings. They correspond to ΔC_{F_x} and ΔC_{F_y} given by equation (47), Ref. A-1, multiplied by the reference area S_R. Similar expressions can be written for the vertical wing by interchanging pertinent quantities such as β for α, v_W for w_W and z for y. The normal-force FN corresponds to ΔC_N given by equation (44), Ref. A-1, multiplied by S_R. The normal forces are also listed for all the body interference panels. Forces FY, FZ acting on the body interference panels are the components of FN in the y_B and z_B direction. In-plane forces are not calculated. The quantity designated DELTA-CP is in fact the u-velocity multiplied by 4π, which is the strength of the constant u-velocity panel.

The next pages of the output contain overall normal, side, thrust, lift, and induced-drag force coefficients computed for each wing surface

or fin. Thrust and induced drag are computed only when NDRAG = 1 in namelist INPUT. The pertinent equations appear in Ref. A-1, section 2.4.1. The sums of these wing forces are also shown. Contributions from the body interference panels to the total normal force and side force are listed as CN-BIP and CY-BIP, respectively. Flow conditions and reference area S_R and length ℓ_r are indicated in the heading. Rolling moment for the right, left, upper and lower wing surfaces or fins appear as ROLMOMR, ROLMOML, ROLMOMU, and ROLMOMD. The positive directions of the normal forces and rolling moments are shown below.



Positive moments correspond to clockwise rotation when viewing forward. They are calculated in accordance with equation (45) of Ref. A-1. Spanwise load distributions follow and are shown for each wing surface. Note that the dimensionless quantity Y/(B/2) is zero at the body centerline. Quantity (B/2) is the wing semispan and (B*2) is four times the semispan and c is the local chord. The spanwise distributions are given in terms of section normal force and section thrust force. Quantity ROLLING MOMENT represents the overall rolling moment.

It should be noted that for the yawed and cruciform wing cases, the force coefficients in the output pertain to the wing surface parts to the right and left, top and bottom of the x_W-axis shown in the sketches of section 3.1.3, Ref. A-1. However, the printed rolling moments are computed relative to the wing or cruciform centerline. All loading information is first calculated on the basis of linear pressures related directly to the constant u-velocity panel strengths. This is indicated by the line U/VINF TYPE LOADING PRESSURE.

The next pages in the output contain nonlinear loading pressures calculated at the wing control points and expressed in terms of ΔC_P. These pressures are designated and computed in accordance with the indicated equations in Ref. A-2, pages 65 through 67.

1. DELTP,LIN = $\Delta C_{P,LIN}$; ΔC_P given by equation (C-1)

2. DELTP,UBAR = $\Delta C_{P,UBAR}$; ΔC_P given by equation (C-2)

3. DELTP,1STORD = $\Delta C_{P,SLENDER\ BODY}$; ΔC_P given by equation (C-4)

4. DELTP,2NDORD = $\Delta C_{P,2NDORD}$; ΔC_P given by equation (C-3)

5. DELTP,EXACT = $\Delta C_{P,BERNOULLI}$; ΔC_P given by equation (C-5)

If the effects of external vortices are accounted for, all pressures listed above, except the linear, are first calculated without and then with the vortex-induced velocity component parallel to the wing surface under consideration.

The following page contains the loading results described above calculated with the Bernoulli loading pressures.

SAMPLE CASE

In this section a sample case is described to illustrate the use of the computer program presented in this appendix. The case involves a cruciform-canard body combination at angle of attack and with yaw control.

The configuration is shown in Fig. A-4 and is based on the AIM-9L static force model used in Ref. A-4. Input for this calculation is listed in Fig. A-5. Namelist INPUT specifies angle of attack as 20° and the vertical fins are deflected 20°. Mach number is 1.75. On each fin, a layout of 4 chordwise by 9 spanwise constant u-velocity panels is specified. On the body surface spanned by the fins, 12 interference panels on the circumference and 4 in the longitudinal direction are to be distributed. In addition, 22 source and 22 doublet singularities are distributed along the body centerline in namelist BODY. Note that the specified body length LBODY extends just past the cruciform-canard trailing edges in order to account for wing-body interference. The nose shape is assumed to be ellipsoidal. It should be noted here that the present program does not model blunt nose shapes properly because the first source

singularity always generates a conical nose tip. The length affected by this approximation is Mach number dependent and becomes longer as the Mach number increases. In between the two namelists, the optional spanwise layout of the constant u-velocity panels side edges and the leading-edge and trailing-edge sweep angles are specified for all fins. This input is necessary because of the break in leading-edge sweep.

The output for this case is shown in Fig. A-6. Note that the first input list also displays the defaulted variables (i.e., the variables which are initialized prior to reading in the namelist INPUT). The effect of the body is to generate upwash and sidewash at the control points of the fins. The effects on the horizontal fins are the same at corresponding control points on the right and left fins because the roll angle PHI is zero. The fin loadings appear under the heading THRUST, LIFT, AND SIDE-FORCE INFORMATION. These results are first calculated on the basis of linear loading pressures. Nonlinear loading pressures are listed next and the loading is recalculated on the basis of Bernoulli loading pressures. In the first instance, the left and right fin loadings are the same. When the nonlinear Bernoulli pressures are used, the left and right fin loadings differ. Similar behavior is observed for the deflected vertical panels. Thus, a net overall rolling moment results from the second calculation.

PROGRAM LISTING

The cruciform wing-body program is written in FORTRAN IV computer language (026 punch) for the CDC 6600 computer. The program consists of a main program, CRFWBD, and sixteen subroutines. Each source deck is identified in columns 73 through 80 by a four-character identification and a three-digit number sequencing the cards within that deck. The program listing is given on the following pages. The table below will act as a table of contents for the listing.

PROGRAM	IDENTIFICATION	PAGE NO.
CRFWBD	WB01	105
LAYOUT	WB02	109
LOADS (multiple entries)	WB03	110
VELNOR	WB04	113

PROGRAM	IDENTIFICATION	PAGE NO.
VELO	WB05	116
TRBIPW (multiple entries)	WB06	117
LINEQS	WB07	118
SOLVE	WB08	118
BDYGEN	WB09	118
VELCAL	WB10	120
CP	WB11	121
DOUBLET	WB12	121
BODYR	WB13	121
SOURCE	WB14	122
SPECPR	WB15	122
VRTVEL (multiple entries)	WB16	124
NOUT	WB17	125

```
      PROGRAM CRFWBD(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C     VERSION FOR NWC,FEBR. 1975.
C
C     PLANAR OR CRUCIFORM WING-BODY PROGRAM, SUPERSONIC FLOW
C     SET UP GEOMETRY, COORDINATES, AERODYNAMIC INFLUENCE COEFFICIENT
C     MATRIX
C
      DIMENSION YR(20),YRT(20),YLT(20),HEAD(20)
      DIMENSION YLC(250),YRC(250),RHB(250)
      DIMENSION XLF(250),XLB(250),XRF(250),XRB(250),ZLF(250),ZRF(250),
     1ZLB(250),ZRB(250),XBAR(250),ZBAR(250),SWPPLE(250),SWPPTE(250),
     2XCPT(250),YCPT(250),PNLC(250),DELTP(250),ZCPT(250)
      DIMENSION VNOR(250)
      DIMENSION CIRC(250)
      DIMENSION          ZUT(20),ZDT(20)
      DIMENSION BDU(250),BDV(250),BDW(250)
C
      LOGICAL ASYM,BODY  ,DELTA
C
      COMMON /THRUST/CN,XBAR,ZBAR,YCPT,              VNOR,CIRC,PNLC,
     1  NCW,MSWR,MSWL,MSWU,MSWD,NRP,NWP,N3P,B2,B2V,XCPT,ZCPT
      COMMON /VWNOR/SWPPLE,SWPPTE,ZLF,ZRF,ZLB,ZRB,ASYM,UCHK,VCHK,WCHK,
     1   II,IF,CONST,BETAR,SINBET,COSBET
      COMMON FVN(1)
      COMMON /VELARG/X,Y,Z,U,V,W,A,EM,BETA,SLOPE,TLRNC,TIPV
      COMMON /PRESS/DELTP,XRF,XRB,XLF,XLB,YLC,YRC,COSALF,NPANLS,
     1 ARWING,FMACH,ALFA,FN(250),SINALF,DELTA
      COMMON /IPR/NPR,I,J
      COMMON/SWEEPB/VBWLER(20),VSWTER(20),VSWLEL(20),VSWTEL(20),
     1  VBWLEU(20),VBWTEU(20),VBWLED(20),VSWTED(20),LVSWP,LEFT,FAC,NCWB,
     2ARPNL(250),WIDTH(250)
      COMMON /TRANS/WBIP,RB,DX,WBIP,XFBIP(100),SNT(125),CST(125),
     1  SNT2(125),CST2(125)
      COMMON /TILT/ANGLR,ANGLL,ANGLU,ANGLD,DELR,DELL,DELU,DELD
      COMMON /BVEL/BDU,BDV,BDW
      COMMON/WBTR/XWLE
      COMMON/REF/SREF,REFL
      COMMON/CRUX/NCRX
      COMMON/NONLIN/NWBP,NOLINP,TOTLR,BODY,ALFR,NOUT,NPRESS,NOCPT,NDRAG
      COMMON/SPSANG/SINALC,COSALC,SINPHI,COSPHI
      COMMON/VRTXV/VVRTX(250),WVRTX(250),NVRTPL,NVRTX
C
      EQUIVALENCE (RHB(1),DELTP(1)),(HEAD(1),VVRTX(1)),(YLT(1),VVRTX(21)
     1),(YR(1),VVRTX(41)),(YRT(1),VVRTX(61)),(ZDT(1),VVRTX(81)),(ZUT(1),
     2VVRTX(101))
C
      DATA PI/3.14159265358979/
      DATA QUIT/6HZZZZ/
C
      NAMELIST /INPUT/CRP,SWLEP,SWTEP,NCW,MSWR,MSWL,ALFAC,PHI,B2,FMACH,
     1LVSWP,      FAC,       NFVNPR,       TOLFAC,MSWU,MSWD,SWLEV,SWTEV,
     1  CRPV,B2V,NCRX,RB,NBDCR,DELR,DELL,DELU,DELD,SREF,REFL,NOLINP,
     1NOUT,NPR,NDRAG,NVRTX,NPRESS,VRTMAX ,NCWB
C
C
    1 FORMAT (20A4)
    2 FORMAT (1H1,20A4)
  701 FORMAT(1H1,20X'  WWING GEOMETRY///
     1 9X,21HLEADING EDGE SWEEP = ,F10.5,2X,7HDEGREES//
     2 8X,22HTRAILING EDGE SWEEP = ,F10.5,2X,7HDEGREES//
     3 18X,12HTIP CHORD = ,F10.5//
     4 17X,13HROOT CHORD = ,F10.5//
     9 14X,16HWING SEMISPAN = ,F10.5//)
  702 FORMAT (//20X,15HFLOW CONDITIONS//5X,7HMACH = ,F10.5,4X,8HALPHAC=
     1 ,F10.5,4X,7HPHI  = ,F10.5,4X,7HALFA = ,F10.5,4X,7HBETA = ,F10.5/)
  703 FORMAT(1H1,18X,52H              PANEL CORNER COORDINATES FOR WING PA
     1NELS)
  704 FORMAT (1H1,10X,30HCONTROL POINT COORDINATES FOR ,I2,14H CHORDWISE
     1 BY I2,36H SPANWISE PANELS ON RIGHT WING PART,2X,I2,1X,
     126HSPANWISE ON LEFT WING PART/53X,3HAND,I2,36H SPANWISE PANELS ON
     1UPPER WING PART,1X,,I2,28H SPANWISE ON LOWER WING PART//
     1                          5X,1HJ,6X,4HX(J),8X,4HY(J),8X,4HZ(J),
     X  7X,5HBU(J),9X,5HBV(J),9X,5HBW(J),10X,5HVV(J),10X,5HWV(J)/)
  705 FORMAT (1X,I5,2X,F10.5,2X,F10.5,2X,F10.5)
  706 FORMAT(3X,I3,3X,F9.4,1X,F9.4,1X,F9.4,1H*,F9.4,1X,F9.4,1X,F9.4,
     1  1H*,F9.4,1X,F9.4,1X,F9.4,1H*,F9.4,1X,F9.4,1X,F9.4)
  707 FORMAT(1H1,30X,20HINFLUENCE MATRIX FVN//)
  708 FORMAT(/1X,56(1H-),17HRIGHT WING PANELS,57(1H-)/)
  709 FORMAT(/1X,57(1H-),16HLEFT WING PANELS,57(1H-)/)
  710 FORMAT(/1X,56(1H-),17HUPPER WING PANELS,57(1H-)/)
  711 FORMAT(/1X,56(1H-),17HLOWER WING PANELS,57(1H-)/)
  713 FORMAT(3F10.5)
  715 FORMAT(//  30X,15HPARAMETERS USED//
     1  12X,7HASYM = ,L3/12X,8HTLRNC = ,E12.5/12X,7HLEFT = ,L3///)
  717 FORMAT(1H1,30X,21HSLOPES OF PANEL EDGES//6X,1HJ,5X,10HL.E. SLOPE,
     1  5X,10HT.E. SLOPE/)
  718 FORMAT(5X,I3,5X,F10.5,5X,F10.5)
  722 FORMAT (//10X,23HRIGHT WING PART SPAN = ,F10.5/
     110X,  23H LEFT WING PART SPAN = ,F10.5/
     2 10X,23HUPPER WING PART SPAN = ,F10.5/
     3 10X,23HLOWER WING PART SPAN = ,F10.5//)
  723 FORMAT(//10X,7HCRPT = ,F10.5/9X,8HCRPTV = ,F10.5//)
  724 FORMAT(1H1,20X,22HVERTICAL WING GEOMETRY///
     1 9X,21HLEADING EDGE SWEEP = ,F10.5,2X,7HDEGREES//
     2 8X,22HTRAILING EDGE SWEEP = ,F10.5,2X,7HDEGREES//
     3 18X,12HTIP CHORD = ,F10.5//
     4 17X,13HROOT CHORD = ,F10.5//
     9 14X,16HWING SEMISPAN = ,F10.5//)
  725 FORMAT(1H1,30X,48HCONTROL POINT COORDINATES FOR BIP*S (WING FRAME)
     1//5X,1HJ,6X,4HX(J),8X,4HY(J),8X,4HZ(J)//)
  726 FORMAT(///25X,35HBIP CORNER COORDINATES IN BIP FRAME)
  727 FORMAT(9X,F9.4,11(1X,F9.4))
  728 FORMAT(1H1,30X,22HRIGHT HAND SIDE VECTOR//4X,1HJ,3X,6HRHB(J)//)
  729 FORMAT(2X,I3,2X,E12.5)
  731 FORMAT(1H1,30X,19HPRESSURE ON PANEL J//4X,1HJ,4X,4HP(J)//)
 7030 FORMAT (                                  //5X,1HJ,15X,2HLF,15X,
     1  1H*,12X,2HLB,15X,1H*,12X,2HRF,15X,1H*,12X,2HRB/12X,1HX,9X,1HY,
     2  9X,1HZ,5X,1H*,3X,1HX,9X,1HY,9X,1HZ,5X,1H*,3X, 1HX,9X,1HY,9X,1HZ,
     3  5X,1H*,3X,1HX,9X,1HY,9X,1HZ/38X,1H*,29X,1H*,29X,1H*/130(1H-)/
     4  38X,1H*,29X,1H*,29X,1H*)
 7051 FORMAT(1X,I5,2X,F10.5,2X,F10.5,2X,F10.5,2X,E12.5,2X,E12.5,
     1  2X,E12.5,2X,E12.5,2X,E12.5)
C
C
C
C
C     DEFAULT VALUES FOR NAMELIST INPUT
C
      ASYM=.FALSE.
      BODY=.FALSE.
      FAC=0.95
      LVSWP=0
      TOLFAC=1.0
      NPR=0
      NFVNPR=0
      NOLINP=0
      NOUT=0
      NVRTX=0
      NPRESS=0
      PHI=0.0
      MSWL=0
      SWLEP=0.0
      SWTEP=0.0
      SWLEV=0.0
      SWTEV=0.0
      CRPV=0.0
      B2V=0.0
      MSWD=0
      MSWU=0
      NCRX=0
      NBDCR=0
      RB=0.0
      DELR=0.0
      DELL=0.0
      DELU=0.0
      DELD=0.0
      VRTMAX=0.35
      NDRAG=1
      DTOR=PI/180.0
C*****************************************************************
C     SET CORE REQUIREMENT BASED ON FVN(1)
      LFL=0
      CALL REQFL(LFL)
```

```
C                                                                       *WB01 155
C***********************************************************************WB01 156
C                                                                       WB01 157
C     WING GEOMETRY SPECIFIED IN PLANFORM,                              WB01 158
C     GEOMETRICALLY SYMMETRIC WINGS ONLY                                WB01 159
C                                                                       WB01 160
C                                                                       WB01 161
C     READ HEADER CARD                                                  WB01 162
C                                                                       WB01 163
  999 READ(5,1) HEAD                                                    WB01 164
      IF(HEAD(1).EQ.QUIT) STOP                                          WB01 165
C                                                                       WB01 166
C     READ NAMELIST INPUT                                               WB01 167
C                                                                       WB01 168
      READ (5,INPUT)                                                    WB01 169
C                                                                       WB01 170
      TIPY=B2                                                           WB01 171
      NRP=NCW*MSWR                                                      WB01 172
      NRP1=NRP+1                                                        WB01 173
      NHP=NCW*(MSWR+MSWL)                                               WB01 174
      NHP1=NHP+1                                                        WB01 175
      N3P=NCW*(MSWL+MSWR+MSWU)                                          WB01 176
      N3P1=N3P+1                                                        WB01 177
      NPANLS=NCW*(MSWR+MSWL+MSWU+MSWD)                                  WB01 178
      NPANLP=NPANLS+1                                                   WB01 179
      NBIP=NCWB*NBDCR                                                   WB01 180
      NWBP=NPANLS+NBIP                                                  WB01 181
C                                                                       WB01 182
C     ANGLE OF ATTACK AND SIDESLIP ARE CALCULATED IN ACCORDANCE WITH    WB01 183
C     PITCH-ROLL TRANSFORMATION, SEE NIELSEN PAGE 5,                    WB01 184
C                                                                       WB01 185
      ALFACR=ALFAC*DTOR                                                 WB01 186
      SINALC=SIN(ALFACR)                                                WB01 187
      COSALC=COS(ALFACR)                                                WB01 188
      PHIR=PHI*DTOR                                                     WB01 189
      SINPHI=SIN(PHIR)                                                  WB01 190
      COSPHI=COS(PHIR)                                                  WB01 191
      SINALF=SINALC*COSPHI                                              WB01 192
      ALFR=ASIN(SINALF)                                                 WB01 193
      COSALF=COS(ALFR)                                                  WB01 194
      SINBET=SINALC*SINPHI                                              WB01 195
      BETAR=ASIN(SINBET)                                                WB01 196
      COSBET=COS(BETAR)                                                 WB01 197
      BETAY=BETAR/DTOR                                                  WB01 198
      ALFA=ALFR/DTOR                                                    WB01 199
C                                                                       WB01 200
      SLPWLE=TAN(SWLEP*DTOR)                                            WB01 201
      SLPWTE=TAN(SWTEP*DTOR)                                            WB01 202
      ASYM=(BETAY.NE.0.0).AND.(NBDCR.EQ.0)                              WB01 203
      BODY=NBDCR.NE.0                                                   WB01 204
      DELTA=DELR.NE.0..OR.DELL.NE.0..OR.DELU.NE.0..OR.DELD.NE.0.        WB01 205
C                                                                       WB01 206
      WRITE (6,2) HEAD                                                  WB01 207
C                                                                       WB01 208
      RDELR=DELR*DTOR                                                   WB01 209
      ANGLR=RDELR + ALFR                                                WB01 210
      RDELL=DELL*DTOR                                                   WB01 211
      ANGLL=ALFR+RDELL                                                  WB01 212
      RDELU=DELU*DTOR                                                   WB01 213
      ANGLU=BETAR+RDELU                                                 WB01 214
      RDELD=DELD*DTOR                                                   WB01 215
      ANGLD=BETAR+RDELD                                                 WB01 216
      BETA=SQRT(ABS(FMACH*FMACH-1.) )                                   WB01 217
      TLRNC=(B2*15.E-5)**2*TOLFAC                                       WB01 218
      TOTLR=2.0*TLRNC                                                   WB01 219
      CONST= 4.0*PI                                                     WB01 220
C                                                                       WB01 221
C                                                                       WB01 222
      WRITE(6,INPUT)                                                    WB01 223
C                                                                       WB01 224
C                                                                       WB01 225
C     UP TO STATEMENT 69 IS FOR WING ALONE CASE                         WB01 226
C                                                                       WB01 227
      IF(ASYM.OR.BODY.OR.NCRX.NE.0) GO TO 69                            WB01 228
      MSWRP=MSWR+1                                                      WB01 229
      IF(LVSWP.EQ.0) GO TO 25                                           WB01 230
      READ(5,713) (YR(KJ),VSWLER(KJ),VSWTER(KJ),KJ=1,MSWRP)             WB01 231
C                                                                       WB01 232
C     LAY OUT THE SPANWISE LOCATION OF PANEL RHS, YR(I)IN THE PLANFORM  WB01 233
C     PLANE                                                             WB01 234
C     IF THEY WERE NOT READ IN ALREADY                                  WB01 235
C                                                                       WB01 236
   25 YR(1)=0.0                                                         WB01 237
      YR(MSWRP)=B2                                                      WB01 238
      DY=B2/MSWR                                                        WB01 239
      DO 110 I=2,MSWR                                                   WB01 240
      AI=I-1                                                            WB01 241
  110 YR(I)= YR(1)+DY*AI                                                WB01 242
      SPANR=B2                                                          WB01 243
      CRPT=CRP                                                          WB01 244
      GO TO 68                                                          WB01 245
C                                                                       WB01 246
C     IF WITH SIDESLIP AND WITHOUT BODY,                                WB01 247
C     YAWED WING GEOMETRY LAID OUT RELATIVE TO LINE FORMED BY           WB01 248
C     INTERSECTION OF STREAMWISE PLANE THROUGH WING ROOT CHORD LE AND   WB01 249
C     WING PLANFORM PLANE (A STREAMWISE LINE)                           WB01 250
C                                                                       WB01 251
   69 CONTINUE                                                          WB01 252
      MSWRP=MSWR+1                                                      WB01 253
      MSWLP=MSWL+1                                                      WB01 254
      MSWUP=MSWU+1                                                      WB01 255
      MSWDP=MSWD+1                                                      WB01 256
      IF(BODY) GO TO 74                                                 WB01 257
      IF (.NOT.ASYM) GO TO 74                                           WB01 258
      IF (LVSWP.NE.0) GO TO 60                                          WB01 259
      SWPLER=SWLEP*BETAY                                                WB01 260
      SWPTER=SWTEP*BETAY                                                WB01 261
      SWPLEL=SWLEP*BETAY                                                WB01 262
      SWPTEL=SWTEP*BETAY                                                WB01 263
      CRPT= CRP*(COSBET+SINBET*TAN(SWPTEL*DTOR))                        WB01 264
      SPANR= (B2/COS(SWLEP*DTOR))*COS(SWPLER*DTOR)+CTP*SINBET           WB01 265
      SPANL= (B2/COS(SWLEP*DTOR))*COS(SWPLEL*DTOR)                      WB01 266
      GO TO 76                                                          WB01 267
C                                                                       WB01 268
C     SET UP SYMMETRIC GEOMETRIC LAYOUT FOR USE LATER WITH NON SYMMETRICWB01 269
C                                                                       WB01 270
   74 SWPLER=SWLEP                                                      WB01 271
      SWPTER=SWTEP                                                      WB01 272
      SWPLEL=SWLEP                                                      WB01 273
      SWPTEL=SWTEP                                                      WB01 274
      CRPT=CRP                                                          WB01 275
      SPANR=B2                                                          WB01 276
      SPANL=B2                                                          WB01 277
   76 CONTINUE                                                          WB01 278
      IF(NCRX.EQ.0) GO TO 77                                            WB01 279
C                                                                       WB01 280
C     CASE FOR VERTICAL WING PANELS                                     WB01 281
C                                                                       WB01 282
      IF(BODY) GO TO 75                                                 WB01 283
      IF (.NOT.ASYM) GO TO 75                                           WB01 284
      SWPLEU=SWLEV+ALFA                                                 WB01 285
      SWPTEU=SWTEV+ALFA                                                 WB01 286
      SWPLED=SWLEV+ALFA                                                 WB01 287
      SWPTED=SWTEV+ALFA                                                 WB01 288
      CRPTV=CRPV+(COSALF+SINALF*TAN(SWPTEU*DTOR))                       WB01 289
      SPANU=(B2V/COS(SWLEV*DTOR))*COS(SWPLEU*DTOR)                      WB01 290
      SPAND=(B2V/COS(SWLEV*DTOR))*COS(SWPLED*DTOR)+CTPV*SINALF          WB01 291
      GO TO 77                                                          WB01 292
   75 SWPLEU=SWLEV                                                      WB01 293
      SWPTEU=SWTEV                                                      WB01 294
      SWPLED=SWLEV                                                      WB01 295
      SWPTED=SWTEV                                                      WB01 296
      CRPTV=CRPV                                                        WB01 297
      SPANU=B2V                                                         WB01 298
      SPAND=B2V                                                         WB01 299
   77 CONTINUE                                                          WB01 300
C                                                                       WB01 301
C                                                                       WB01 302
      SLPWLR= TAN(SWPLER*DTOR)                                          WB01 303
      SLPWTR= TAN(SWPTER*DTOR)                                          WB01 304
      SLPWLL= TAN(SWPLEL*DTOR)                                          WB01 305
      SLPWTL= TAN(SWPTEL*DTOR)                                          WB01 306
      IF(NCRX.EQ.0) GO TO 64                                            WB01 307
      SLPWLU=TAN(SWPLEU*DTOR)                                           WB01 308
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      SLPWLD=TAN(SWPLED*DTOR)                                           WB01 309
      SLPWTU=TAN(SWPTEU*DTOR)                                           WB01 310
      SLPWTD=TAN(SWPTED*DTOR)                                           WB01 311
   64 IF(LVSWP.NE.0) GO TO 60                                           WB01 312
      GO TO 65                                                          WB01 313
   60 READ (5,713) (YRT(KJ),VSWLER(KJ),VSWTER(KJ),KJ=1,MSWRP)           WB01 314
      SPANR=YRT(MSWRP)                                                  WB01 315
      READ (5,713) (YLT(KJ),VSWLEL(KJ),VSWTEL(KJ),KJ=1,MSWLP)           WB01 316
      SPANL=YLT(MSWLP)                                                  WB01 317
      IF(NCRX.EQ.0) GO TO 68                                            WB01 318
      READ(5,713) (ZUT(KJ),VSWLEU(KJ),VSWTEU(KJ),KJ=1,MSWUP)            WB01 319
      SPANU=ZUT(MSWUP)                                                  WB01 320
      READ(5,713)  (ZDT(KJ),VSWLED(KJ),VSWTED(KJ),KJ=1,MSWDP)           WB01 321
      SPAND=ZDT(MSWDP)                                                  WB01 322
      GO TO 68                                                          WB01 323
   65 CONTINUE                                                          WB01 324
      YRT(1)=RB                                                         WB01 325
      YRT(MSWRP)=SPANR+RB                                               WB01 326
      DYR=SPANR/MSWR                                                    WB01 327
      DO 51 I=2,MSWR                                                    WB01 328
      AI=I-1                                                            WB01 329
   51 YRT(I)=DYR*AI+RB                                                  WB01 330
C                                                                       WB01 331
      YLT(1)=-RB                                                        WB01 332
      YLT(MSWLP)=-SPANL-RB                                              WB01 333
      DYL=SPANL/MSWL                                                    WB01 334
      DO 52 I=2,MSWL                                                    WB01 335
      AI=I-1                                                            WB01 336
   52 YLT(I)=-DYL*AI-RB                                                 WB01 337
      IF(NCRX.EQ.0) GO TO 68                                            WB01 338
C                                                                       WB01 339
C     PANELS IN VERTICAL PLANE                                          WB01 340
C                                                                       WB01 341
      ZUT(1)=RB                                                         WB01 342
      ZUT(MSWUP)=SPANU+RB                                               WB01 343
      DZU=SPANU/MSWU                                                    WB01 344
      DO 54 I=2,MSWU                                                    WB01 345
      AI=I-1                                                            WB01 346
   54 ZUT(I)=DZU*AI+RB                                                  WB01 347
C                                                                       WB01 348
      ZDT(1)=-RB                                                        WB01 349
      ZDT(MSWDP)=-SPAND-RB                                              WB01 350
      DZD=SPAND/MSWD                                                    WB01 351
      DO 55 I=2,MSWD                                                    WB01 352
      AI=I-1                                                            WB01 353
   55 ZDT(I)=-DZD*AI-RB                                                 WB01 354
   68 CONTINUE                                                          WB01 355
C                                                                       WB01 356
C                                                                       WB01 357
C     LAY-OUT ELEMENTAL PANELS ON WING                                  WB01 358
C                                                                       WB01 359
      IF(ASYM.OR.BODY.OR.NCRX.NE.0) GO TO 50                            WB01 360
      CALL LAYOUT(SLPWLE,SLPWTE,YR,MSWRP,CRP,0,CTP)                     WB01 361
      IF (NOUT.EQ.1) WRITE (6,715) ASYM,TLRNC,LEFT                      WB01 362
      GO TO 53                                                          WB01 363
   50 CALL LAYOUT(SLPWLR,SLPWTR,YRT,MSWRP,CRPT,0,CTP)                   WB01 364
      IF (NOUT.EQ.1) WRITE (6,715) ASYM,TLRNC,LEFT                      WB01 365
      CALL LAYOUT(SLPWLL,SLPWTL,YLT,MSWLP,CRPT,1,CTP)                   WB01 366
      IF (NOUT.EQ.1) WRITE (6,715) ASYM,TLRNC,LEFT                      WB01 367
      IF(NCRX.EQ.0) GO TO 62                                            WB01 368
      CALL LAYOUT(SLPWLU,SLPWTU,ZUT,MSWUP,CRPTV,2,CTPV)                 WB01 369
      IF (NOUT.EQ.1) WRITE (6,715) ASYM,TLRNC,LEFT                      WB01 370
      CALL LAYOUT(SLPWLD,SLPWTD,ZDT,MSWDP,CRPTV,3,CTPV)                 WB01 371
      IF (NOUT.EQ.1) WRITE (6,715) ASYM,TLRNC,LEFT                      WB01 372
C                                                                       WB01 373
C     LAY-OUT BODY INTERFERENCE PANELS                                  WB01 374
C                                                                       WB01 375
   62 IF(NBDCR.EQ.0) GO TO 53                                           WB01 376
      CALL LAYOUT(SLPWLE,SLPWTE,DUMMY,NBDCR,CRP,4,0,0)                  WB01 377
      IF (NOUT.EQ.1) WRITE (6,715) ASYM,TLRNC,LEFT                      WB01 378
   53 CONTINUE                                                          WB01 379
C                                                                       WB01 380
C                                                                       WB01 381
      WRITE(6,701)  SWLEP,SWTEP,CTP,CRP,R2                              WB01 382
      IF(NCRX.NE.0) WRITE(6,724) SWLEV,SWTEV,CTPV,CRPV,B2V              WB01 383
      WRITE (6,702) FMACH,ALFAC,PHI,ALFA,BETAY                          WB01 384
      WRITE(6,722) SPANR,SPANL,SPANU,SPAND                              WB01 385
      WRITE(6,723) CRPT,CRPTV                                           WB01 386
      IF (NOUT.NE.1) GO TO 7813                                         WB01 387
      WRITE(6,703)                                                      WB01 388
      WRITE(6,7030)                                                     WB01 389
      WRITE(6,708)                                                      WB01 390
      WRITE(6,706) (J,XLF(J),YLC(J),ZLF(J),XLB(J),YLC(J),ZLB(J),XRF(J), WB01 391
     1  YRC(J),ZRF(J),XRB(J),YRC(J),ZRB(J),J=1,NRP)                     WB01 392
      IF(.NOT.(ASYM,          OR.BODY).AND.NCRX.EQ.0) GO TO 73          WB01 393
      WRITE(6,709)                                                      WB01 394
      WRITE(6,706) (J,XLF(J),YLC(J),ZLF(J),XLB(J),YLC(J),ZLB(J),XRF(J), WB01 395
     I  YRC(J),ZRF(J),XRB(J),YRC(J),ZRB(J),J=NRP1,NWP)                  WB01 396
   73 IF(NCRX.EQ.0) GO TO 71                                            WB01 397
      WRITE(6,710)                                                      WB01 398
      WRITE(6,706) (J,XLF(J),YLC(J),ZLF(J),XLB(J),YLC(J),ZLB(J),XRF(J), WB01 399
     1  YRC(J),ZRF(J),XRB(J),YRC(J),ZRB(J),J=NWP1,N3P)                  WB01 400
      WRITE(6,711)                                                      WB01 401
      WRITE(6,706) (J,XLF(J),YLC(J),ZLF(J),XLB(J),YLC(J),ZLB(J),XRF(J), WB01 402
     1  YRC(J),ZRF(J),XRB(J),YRC(J),ZRB(J),J=N3P1,NPANLS)               WB01 403
   71 IF(NBDCR.EQ.0) GO TO 72                                           WB01 404
      WRITE(6,726)                                                      WB01 405
      WRITE(6,7030)                                                     WB01 406
      WRITE(6,727) XLF(NPANLP),YLC(NPANLP),ZLF(NPANLP),XLB(NPANLP),     WB01 407
     1  YLC(NPANLP),ZLB(NPANLP),XRF(NPANLP),YRC(NPANLP),ZRF(NPANLP),    WB01 408
     1  XRB(NPANLP),YRC(NPANLP),ZRB(NPANLP)                             WB01 409
      WRITE (6,717)                                                     WB01 410
      WRITE (6,718) (J,SWPPLE(J),SWPPTE(J),J=1,NWBP)                    WB01 411
      GO TO 7813                                                        WB01 412
   72 WRITE(6,717)                                                      WB01 413
      WRITE(6,718) (J,SWPPLE(J),SWPPTE(J),J=1,NPANLS)                   WB01 414
 7813 CONTINUE                                                          WB01 415
C                                                                       WB01 416
      DO 10 KM=1,NWBP                                                   WB01 417
      VVRTX(KM)=0.0                                                     WB01 418
      WVRTX(KM)=0.0                                                     WB01 419
      BDU(KM)=0.0                                                       WB01 420
      BDV(KM)=0.0                                                       WB01 421
   10 BDW(KM)=0.0                                                       WB01 422
C                                                                       WB01 423
C                                                                       WB01 424
C     GENERATE BODY SOURCE AND DOUBLET DISTRIBUTION AND CALCULATE       WB01 425
C     INDUCED VELOCITIES DUE TO THEM AT THE WING CONTROL POINTS         WB01 426
C     ( BDU(K), BDV(K), BDW(K) )                                        WB01 427
C                                                                       WB01 428
C     NOTE: SUBROUTINE BODY READS IN NAMELIST BODY                      WB01 429
C                                                                       WB01 430
      IF (.NOT.BODY) GO TO 7811                                         WB01 431
      CALL BDYGEN(ALFR,BETAR)                                           WB01 432
      NSTART=1                                                          WB01 433
      CALL VELCAL(NPANLS,ALFR,BETAR,NSTART)                             WB01 434
 7811 CONTINUE                                                          WB01 435
C                                                                       WB01 436
C                                                                       WB01 437
C     SUBROUTINE VRTVEL READS IN VORTEX STRENGHTS AND Y,Z LOCATIONS     WB01 438
C     ONLY IF NVRTX NE. 0                                               WB01 439
C     THERE ARE NVRTX VORTICES                                          WB01 440
C     COMPUTE EXTERNAL VORTICES INDUCED VELOCITIES AT THE WING CONTROL  WB01 441
C     POINTS                                                            WB01 442
C                                                                       WB01 443
      NSTART=1                                                          WB01 444
      N=NPANLS                                                          WB01 445
      IF (NVRTX.NE.0) CALL VRTVEL(NSTART,N)                             WB01 446
C                                                                       WB01 447
      WRITE(6,704) NCH,MSWR,MSWL,MSWU,MSWD                              WB01 448
      WRITE(6,7051) (J,XCPT(J),YCPT(J),ZCPT(J),BDU(J),BDV(J),BDW(J),    WB01 449
     1VVRTX(J),WVRTX(J),J=1,NPANLS)                                     WB01 450
      IF(.NOT.BODY) GO TO 78                                            WB01 451
      WRITE(6,725)                                                      WB01 452
      WRITE(6,705) (K,XCPT(K),YCPT(K),ZCPT(K),K=NPANLP,NWBP)            WB01 453
   78 CONTINUE                                                          WB01 454
C                                                                       WB01 455
C                                                                       WB01 456
C*********************************************************************WB01 457
C                                                                      *WB01 458
C     SPECIAL PURPOSE CORE MEMORY ECONOMY SECTION FOR BCS 6600         *WB01 459
C     BET CORE REQUIREMENT BASED ON LFL PLUS FVN(NWBP,NWBP)            *WB01 460
C                                                                      *WB01 461
      MFLTOT=LFL+NWBP*NWBP-1                                            WB01 462
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```
      CALL REQFL(MFLTOT)
C
C*****************************************************************
C
C     SET UP INFLUENCE COEFFICIENT MATRIX
C
C     CALCULATE THE INFLUENCE OF EACH PANEL ON EACH CONTROL POINT
C     II AND IF ARE THE LIMITS FOR SUMMATION OF THE INFLUENCE FUNCTION
C     IN SUBROUTINE VELNOR
C     IF II = IF, THE INFLUENCE OF A SINGLE PANEL AT A POINT RESULTS
C     AS IN THE COMPUTATION OF THE ARRAY FVN,  IF II=1 AND IF=NPANLS,
C     THE INFLUENCES ARE SUMMED OVER ALL PANELS, AS IN THE COMPUTATION O
C     RESULTANT VELOCITIES BELOW....
C
C     *** I IS THE INDEX OF THE INFLUENCING PANEL
C
C
      JJ=0
      NOCPT=0
      DO 450 I=1,NWBP
      II=I
      IF=I
C
C     J IS THE INDEX OF THE INFLUENCED PANEL
C
      DO 425 J=1,NWBP
      JS=J+NPANLS
      CALL VELNOR(XCPT(J),YCPT(J),ZCPT(J))
      JJ=JJ+1
      IF(J.LE.NPANLS) GO TO 417
C
C     INFLUENCED PANEL IS A BIP,  RESOLVE WING-FRAME VELOCITIES INTO
C     BIP FRAME
C
      CALL ROTWB (VCHK,WCHK,VV,WW,JS)
      GO TO 418
  417 VV=VCHK
      WW=WCHK
  418 IF(J.GT.NHP.AND.J.LE.NPANLS) GO TO 426
      FVN(JJ)=WW
      GO TO 425
  426 FVN(JJ)=VV
  425 CONTINUE
      IF (ABS(FVN(JJ)).LT.1.0E-10) FVN(JJ)=0.0
  450 CONTINUE
C
C     DEBUG DUMP OF THE FVN ARRAY
C
      IF(NFVNPR.EQ.0) GO TO 618
      WRITE (6,707)
      CALL OUT(FVN,NWBP)
  618 CONTINUE
      CALL LINEQS(NWBP,FVN)
C
C     SET UP SINGLE COLUMN MATRIX RHS FOR RIGHT HAND SIDE
C     IT REPRESENTS THE EXTERNALLY INDUCED VELOCITIES AND ANGLE OF
C     ATTACK
C
C     CASE FOR WING PANEL ALL AT SAME ANGLE AS BODY
C
      IF(DELTA) GO TO 627
      DO 620 I=1,NWBP
      IF (I.LE.NHP.AND.ABS(WVRTX(I)).GT.VRTMAX) GO TO 631
      WADVRT=WVRTX(I)
      GO TO 632
  631 IF (WVRTX(I).LT.0.0) WADVRT=-VRTMAX
      IF (WVRTX(I).GT.0.0) WADVRT= VRTMAX
      GO TO 633
  632 IF (I.GT.NHP.AND.I.LE.NPANLS.AND.ABS(VVRTX(I)).GT.VRTMAX) GO TO634
      VADVRT=VVRTX(I)
      GO TO 633
  634 IF (VVRTX(I).LT.0.0) VADVRT=-VRTMAX
      IF (VVRTX(I).GT.0.0) VADVRT= VRTMAX
  633 CONTINUE
      IF(I.LE.NHP) GO TO 602
      IF(I.LE.NPANLS) GO TO 604
      RHS(I)=0.0
      GO TO 620
  602 RHS(I)=-ALFR-BDW(I)-WADVRT
      GO TO 620
  604 RHS(I)=BETAR-BDV(I)-VADVRT
  620 CONTINUE
      GO TO 646
C
C     RIGHT HAND SIDE FOR PANELS TILTED WITH RESPECT TO BODY
C
  627 CONTINUE
      DO 645 K=1,NWBP
      IF (K.LE.NHP.AND.ABS(WVRTX(K)).GT.VRTMAX) GO TO 649
      WADVRT=WVRTX(K)
      GO TO 651
  649 IF (WVRTX(K).LT.0.0) WADVRT=-VRTMAX
      IF (WVRTX(K).GT.0.0) WADVRT= VRTMAX
      GO TO 653
  651 IF (K.GT.NHP.AND.K.LE.NPANLS.AND.ABS(VVRTX(K)).GT.VRTMAX) GO TO
     X652
      VADVRT=VVRTX(K)
      GO TO 653
  652 IF (VVRTX(K).LT.0.0) VADVRT=-VRTMAX
      IF (VVRTX(K).GT.0.0) VADVRT= VRTMAX
  653 CONTINUE
      IF(K.LE.NRP) GO TO 641
      IF(K.LE.NHP) GO TO 642
      IF(K.LE.N3P) GO TO 643
      IF(K.LE.NPANLS) GO TO 644
      RHS(K)=0.0
      GO TO 645
  641 RHS(K)=-ANGLR-BDW(K)-WADVRT
      GO TO 645
  642 RHS(K)=-ANGLL-BDW(K)-WADVRT
      GO TO 645
  643 RHS(K)=ANGLU-BDV(K)-VADVRT
      GO TO 645
  644 RHS(K)=ANGLD-BDV(K)-VADVRT
  645 CONTINUE
      IF (NOUT.EQ.0) GO TO 648
  646 CONTINUE
      IF (NOUT.NE.0) WRITE (6,728)
      WRITE(6,729) (K,RHS(K),K=1,NWBP)
  648 CONTINUE
      CALL SOLVE(RHS,FVN,NWBP)
      IF (NOUT.NE.0) WRITE(6,731)
      DO 630 I=1,NWBP
      DEMONP=RHS(I)*CONST
      DELTP(I)=DEMONP
      IF (ABS(DELTP(I)).LT.1.0E-10) DELTP(I)=0.0
      IF (NOUT.EQ.0) GO TO 630
      WRITE(6,729) I,DELTP(I)
  630 CONTINUE
C*****************************************************************
C     REDUCE REQUIRED CORE ALLOCATION BACK TO LFL SIZE
C
      CALL REQFL(LFL)
C
C*****************************************************************
C
C
C     CALCULATE LOADINGS ON THE WINGS OR FINS WITH LINEAR PRESSURE
C     LOADINGS
C
      IF (NPRESS.EQ.0) CALL LOADS
C
C
C     NON LINEAR PRESSURE LOADING CALCULATION
C     SURFACES
C     NVRTPL=0 MEANS EXCLUDE VORTEX INDUCED VELOCITIES PARALLEL TO WING
C
      IF (NOLINP.EQ.0) GO TO 200
      NVRTPL=0
      CALL SPECPR
C
C
C     REPEAT INCLUDING VORTEX VELOCITIES PARALEEL TO WING SURFACES
C
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      IF (NVRTX.EQ.0) GO TO 999                                         WB01 617
      NVRTPL=1                                                          WB01 618
      CALL SPECPR                                                       WB01 619
  200 CONTINUE                                                          WB01 620
      GO TO 999                                                         WB01 621
      END                                                               WB01 622
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      SUBROUTINE LAYOUT (SLPWLE,SLPWTE,Y,MSWP,CRP,IL,CTP)               WB02   1
C                                                                       WB02   2
C     THIS SUBROUTINE LAYS OUT ALL THE PANELS ON THE WING AND THE BODY  WB02   3
C     INTERFERENCE PANELS                                               WB02   4
C                                                                       WB02   5
      DIMENSION Y(1),CSIDE(20),DELTP(250),SWPPLE(250),SWPPTE(250),ZLF(25WB02   6
     10),ZRF(250),ZLB(250),ZRB(250),XBAR(250),ZBAR(250),YCPT(250),PNLC(2WB02   7
     250),ZCPT(250),XCPT(250),XLF(250),XLB(250),XRF(250),XRB(250),YLC(25WB02   8
     30),YRC(250)                                                       WB02   9
C                                                                       WB02  10
      LOGICAL LEFT                                                      WB02  11
C                                                                       WB02  12
      COMMON/VWNOR/SWPPLE,SWPPTE,ZLF,ZRF,ZLB,ZRB,ASYM,DUM1(9)           WB02  13
      COMMON/PRESS/DELTP,XRF,XRB,XLF,XLB,YLC,YRC,DDM,NPANLS,DUM2(255)   WB02  14
      COMMON/THRUST/CN,XBAR,ZBAR,YCPT,DUM3(500),PNLC,NCW,MSWR,MSWL,MSWU WB02  15
     1  , MSWD,NPD(3),B2,B2V,XCPT,ZCPT                                  WB02  16
      COMMON/SWEEPS/VSWLER(20),VSWTER(20),VSWLEL(20),VSWTEL(20),        WB02  17
     1  VSWLEU(20),VSWTEU(20),VSWLED(20),VSWTED(20),LVSWP,LEFT,FAC,NCWB WB02  18
     2,ARPNL(250),WIDTH(250)                                            WB02  19
      COMMON /TRANS/NBIP,RB,DX,WBIP,XFBIP(100),SNT(125),CST(125),       WB02  20
     1  SNT2(125),CST2(125)                                             WB02  21
      COMMON/CRUX/NCRX                                                  WB02  22
C                                                                       WB02  23
      DATA DTOR /0.0174533/                                             WB02  24
      DATA PI/3.14159265358979/                                         WB02  25
C                                                                       WB02  26
      TWOPI=2.0*PI                                                      WB02  27
      PI2=PI/2.0                                                        WB02  28
      IF(IL.EQ.4) GO TO 200                                             WB02  29
      LEFT=IL.EQ.1.OR.IL.EQ.3                                           WB02  30
      NS=IL+1                                                           WB02  31
      ANCW=NCW                                                          WB02  32
      SLPDIF= SLPWLE-SLPWTE                                             WB02  33
      CSIDE(1)= CRP                                                     WB02  34
C                                                                       WB02  35
C     VERTICAL WING TREATED IN THE SAME WAY AS HORIZONTAL WING          WB02  36
C     Y AND Z COORDINATES ARE INTERCHANGED FOR VERTICAL WING            WB02  37
C                                                                       WB02  38
C     LEFT STANDS FOR EITHER LEFT HORIZONTAL WING OR FOR LOWER          WB02  39
C     VERTICAL WING                                                     WB02  40
C                                                                       WB02  41
C                                                                       WB02  42
C                                                                       WB02  43
C     INDEX I RUNS SPANWISE, K CHORDWISE ALONG WING                     WB02  44
C     CALCULATE LENGTHS OF OUTBOARD PANEL SIDE,CSIDE                    WB02  45
C                                                                       WB02  46
      WLEX=0.0                                                          WB02  47
      DO 140 I=2,MSWP                                                   WB02  48
      IM=I-1                                                            WB02  49
      IF(LVSWP.EQ.0) GO TO 40                                           WB02  50
      GO TO (42,41,30,31),NS                                            WB02  51
C                                                                       WB02  52
C     CASE FOR YAWED WING, STREAMWISE PLANE PASSING THROUGH ROOTCHORD   WB02  53
C     LE INTERSECTS WING TE                                             WB02  54
C     TE SWEEPS MAY VARY AS A CONSEQUENCE                               WB02  55
C                                                                       WB02  56
C     PANELS ON RIGHT HAND WING                                         WB02  57
C                                                                       WB02  58
   42 SLPWLE= TAN (VSWLER(I)*DTOR)                                      WB02  59
      SLPWTE= TAN(VSWTER(I)*DTOR)                                       WB02  60
      GO TO 44                                                          WB02  61
C                                                                       WB02  62
C     PANELS ON LEFT HAND WING                                          WB02  63
C                                                                       WB02  64
   41 SLPWLE= TAN(-VSWLEL(I)*DTOR)                                      WB02  65
      SLPWTE= TAN(-VSWTEL(I)*DTOR)                                      WB02  66
      GO TO 44                                                          WB02  67
C                                                                       WB02  68
C     PANELS ON UPPER WING                                              WB02  69
C                                                                       WB02  70
   30 SLPWLE=TAN(VSWLEU(I)*DTOR)                                        WB02  71
      SLPWTE=TAN(VSWTEU(I)*DTOR)                                        WB02  72
      GO TO 44                                                          WB02  73
C                                                                       WB02  74
C     PANELS ON LOWER WING                                              WB02  75
C                                                                       WB02  76
   31 SLPWLE=TAN(-VSWLED(I)*DTOR)                                       WB02  77
      SLPWTE=TAN(-VSWTED(I)*DTOR)                                       WB02  78
C                                                                       WB02  79
C                                                                       WB02  80
   44 SLPDIF= SLPWLE-SLPWTE                                             WB02  81
      CSIDE(I)= CSIDE(IM)-(Y(I)-Y(IM))*SLPDIF                           WB02  82
      IF (LEFT) CSIDE(I)=CSIDE(IM)+(Y(I)-Y(IM))*SLPDIF                  WB02  83
      GO TO 43                                                          WB02  84
C                                                                       WB02  85
C     NONVARYING L.E. AND T.E. SWEEPS  CONSTANT VALUES USED             WB02  86
C                                                                       WB02  87
   40 CSIDE(I)=CRP-(Y(I)-Y(1))*SLPDIF                                   WB02  88
      IF (LEFT) CSIDE(I)= CRP+(Y(I)-Y(1))*SLPDIF                        WB02  89
   43 CONTINUE                                                          WB02  90
C                                                                       WB02  91
C     SWPPLE AND SWPPTE ARE PANEL L.E. AND T.E. SWEEPS                  WB02  92
C     CALCULATE PANEL CORNER POINT COORDINATES                          WB02  93
C                                                                       WB02  94
      IF (1.EQ.2) GO TO 45                                              WB02  95
      JLE=(I-3)*NCW+1                                                   WB02  96
      IF (NS.GT.1) JLE=JLE+NPD(NS-1)                                    WB02  97
      WLEX=XRF(JLE)                                                     WB02  98
      IF (LEFT)  WLEX=XLF(JLE)                                          WB02  99
   45 CONTINUE                                                          WB02 100
      DO 130 K=1,NCW                                                    WB02 101
      J=(I-2)*NCW+K                                                     WB02 102
      IF(NS.LE.1) GO TO 131                                             WB02 103
      J=J+NPD(NS-1)                                                     WB02 104
  131 AKM=K-1                                                           WB02 105
      AK=K                                                              WB02 106
      SWPPLE(J)=SLPWLE-AKM*SLPDIF/ANCW                                  WB02 107
      SWPPTE(J)=SLPWLE-AK*SLPDIF/ANCW                                   WB02 108
      IF (LEFT) GO TO 50                                                WB02 109
      XLF(J)=AKM*CSIDE(IM)/ANCW+WLEX                                    WB02 110
      XLB(J)=XLF(J)+CSIDE(IM)/ANCW                                      WB02 111
      XRF(J)=AKM*CSIDE(I)/ANCW+(Y(I)-Y(IM))*SLPWLE+WLEX                 WB02 112
      XRB(J)=XRF(J)+CSIDE(I)/ANCW                                       WB02 113
      YLC(J)=Y(IM)                                                      WB02 114
      YRC(J)=Y(I)                                                       WB02 115
      GO TO 51                                                          WB02 116
   50 CONTINUE                                                          WB02 117
      XLF(J)=AKM*CSIDE(I)/ANCW-(Y(I)-Y(IM))*SLPWLE+WLEX                 WB02 118
      XRF(J)=AKM*CSIDE(IM)/ANCW+WLEX                                    WB02 119
      XRB(J)= XRF(J)+CSIDE(IM)/ANCW                                     WB02 120
      XLB(J)= XLF(J)+CSIDE(I)/ANCW                                      WB02 121
      YLC(J)=Y(I)                                                       WB02 122
      YRC(J)=Y(IM)                                                      WB02 123
   51 CONTINUE                                                          WB02 124
      ZLF(J)=0.0                                                        WB02 125
      ZRF(J)=0.0                                                        WB02 126
      ZLB(J)=0.0                                                        WB02 127
      ZRB(J)=0.0                                                        WB02 128
C                                                                       WB02 129
C     FIND Y-COORDINATE OF CONTROL POINT AND PANEL CENTROID             WB02 130
C                                                                       WB02 131
      A1=XRB(J)-XRF(J)                                                  WB02 132
      A2=XLB(J)-XLF(J)                                                  WB02 133
      H=Y(I)-Y(IM)                                                      WB02 134
      YBAR=(2.0*A1+A2)*H/(3.0*(A1+A2))                                  WB02 135
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```
      IF (LEFT) YBAR=-(2.0*A2+A1)*H/(3.0*(A1+A2))                       WB02 136
      YCPT(J)=Y(IM)+YBAR                                                WB02 137
      IF (LEFT) YCPT(J)=Y(IM)-YBAR                                      WB02 138
C                                                                       WB02 139
C     FIND X-COORDINATE OF CONTROL POINT AND PANEL CENTROID             WB02 140
C                                                                       WB02 141
      XPCLE=XLF(J)+YBAR *SWPPLE(J)                                      WB02 142
      IF(LEFT) XPCLE=XRF(J)+YBAR*SWPPLE(J)                              WB02 143
      XPCTE=XLB(J)+YBAR*SWPPTE(J)                                       WB02 144
      IF (LEFT) XPCTE=XRB(J)+YBAR*SWPPTE(J)                             WB02 145
      PNLC(J)=XPCTE-XPCLE                                               WB02 146
      XCPT(J)=XPCLE+FAC *PNLC(J)                                        WB02 147
      XBAR(J)=(XPCTE+XPCLE)/2.0                                         WB02 148
C                                                                       WB02 149
C                                                                       WB02 150
      ZCPT(J)=0.0                                                       WB02 151
      ZBAR(J)=0.0                                                       WB02 152
      IF (LEFT) GO TO 60                                                WB02 153
      GO TO 129                                                         WB02 154
   60 SWPPLE(J)=-SWPPLE(J)                                              WB02 155
      SWPPTE(J)=-SWPPTE(J)                                              WB02 156
  129 IF(NB.LE.2) GO TO 128                                             WB02 157
      ZLF(J)=YLC(J)                                                     WB02 158
      ZLB(J)=YLC(J)                                                     WB02 159
      YLC(J)=0.                                                         WB02 160
      ZRF(J)=YRC(J)                                                     WB02 161
      ZRB(J)=YRC(J)                                                     WB02 162
      YRC(J)=0.                                                         WB02 163
      ZBAR(J)=YCPT(J)                                                   WB02 164
      ZCPT(J)=YCPT(J)                                                   WB02 165
      YCPT(J)=0.                                                        WB02 166
  128 CONTINUE                                                          WB02 167
      IF(J.GT.NPD(2)) GO TO 120                                         WB02 168
      GO TO 121                                                         WB02 169
  120 ARPNL(J)=0.5*(ZRF(J)-ZLF(J))*(XLB(J)-XLF(J)+XRB(J)-XRF(J))        WB02 170
      WIDTH(J)=ZRF(J)-ZLF(J)                                            WB02 171
      GO TO 130                                                         WB02 172
  121 ARPNL(J)=0.5*(YRC(J)-YLC(J))*(XLB(J)-XLF(J)+XRB(J)-XRF(J))        WB02 173
      WIDTH(J)=YRC(J)-YLC(J)                                            WB02 174
  130 CONTINUE                                                          WB02 175
  140 CONTINUE                                                          WB02 176
      CTP=CSIDE(MSWP)                                                   WB02 177
      RETURN                                                            WB02 178
C                                                                       WB02 179
C     LAY OUT BODY INTERFERENCE PANELS                                  WB02 180
C                                                                       WB02 181
  200 DX=CRP/NCWB                                                       WB02 182
C                                                                       WB02 183
C     HERE X HAS ONE VALUE FOR EACH RING OF BIP-S                       WB02 184
C     FOR EACH CIRCUMFRNTIAL RING, THE X FRONT POSITION, XFBIP(L)       WB02 185
C     IS A CONSTANT --                                                  WB02 186
C     XFBIP(L) IS IN THE WING COORDINATE SYSTEM                         WB02 187
C                                                                       WB02 188
      KX=0                                                              WB02 189
      DO 250 K=1,NBIP,MSWP                                              WB02 190
      XS=KX*DX                                                          WB02 191
      KP=K+MSWP-1                                                       WB02 192
      DO 240 L=K,KP                                                     WB02 193
  240 XFBIP(L)=XS                                                       WB02 194
      KX=KX+1                                                           WB02 195
  250 CONTINUE                                                          WB02 196
C                                                                       WB02 197
C     CALCULATE THE TRIG FUNCTIONS OF THE ANGLES ASSOCIATED WITH EACH   WB02 198
C     BIP.  THIS LOOP EXECUTES ONCE FOR EACH DIFFERENT BIP ORIENTATION, WB02 199
C     SETS THE FUNCTIONS FOR ALL BIP-S THAT ARE AT THE SAME ANGLE.      WB02 200
C                                                                       WB02 201
C     ANG IS THE ANGLE OF ROTATION OF THE BIP WITH RESPECT TO THE WING  WB02 202
C     COORDINATE SYSTEM.                                                WB02 203
C     THT IS THE POLAR ANGLE OF THE BIP WITH RESPECT TO THE WING Y-AXIS,WB02 204
C                                                                       WB02 205
      DTHT=TWOPI/MSWP                                                   WB02 206
      WSIP=2.*RB*SIN(DTHT/2.)                                           WB02 207
      CPY=0.5*WBIP                                                      WB02 208
      DO 260 I=1,MSWP                                                   WB02 209
      THT=I*DTHT                                                        WB02 210
      ANG=PI2-THT+DTHT/2.                                               WB02 211
      SN=SIN(THT)                                                       WB02 212
      CS=COS(THT)                                                       WB02 213
      SN2=SIN(ANG)                                                      WB02 214
      CS2=COS(ANG)                                                      WB02 215
      DO 255 J=I,NBIP,MSWP                                              WB02 216
      K=J+NPANLS                                                        WB02 217
      SNT(J)=SN                                                         WB02 218
      SNT2(J)=SN2                                                       WB02 219
      CST(J)=CS                                                         WB02 220
      CST2(J)=CS2                                                       WB02 221
C                                                                       WB02 222
C     TRANSFORM THE BIP CONTROL POINT Y AND Z COORDINATES INTO WING     WB02 223
C     COORDINATE SYSTEM                                                 WB02 224
C                                                                       WB02 225
      CALL TRBIPW(CPY,0.,YCPT(K),ZCPT(K),J)                             WB02 226
C                                                                       WB02 227
C     NOTE -- THE FOLLOWING CORNER-POINT COORDINATES ARE COMPUTED IN THEWB02 228
C     THE **BIP** SYSTEM..  THAT IS WHY THEY ARE ALL THE SAME.          WB02 229
C                                                                       WB02 230
      XLF(K)=0.                                                         WB02 231
      XLB(K)=DX                                                         WB02 232
      XRF(K)=0.                                                         WB02 233
      XRB(K)=DX                                                         WB02 234
      YLC(K)=0.                                                         WB02 235
      YRC(K)=WBIP                                                       WB02 236
      ZLF(K)=0.                                                         WB02 237
      ZLB(K)=0.                                                         WB02 238
      ZRF(K)=0.                                                         WB02 239
      ZRB(K)=0.                                                         WB02 240
      SWPPLE(K)=0.0                                                     WB02 241
      SWPPTE(K)=0.0                                                     WB02 242
C                                                                       WB02 243
C     CONTROL POINT X COORDINATE SYSTEM IN WING SYSTEM                  WB02 244
C                                                                       WB02 245
  255 XCPT(K)=XFBIP(J)+FAC*DX                                           WB02 246
  260 CONTINUE                                                          WB02 247
      RETURN                                                            WB02 248
      END                                                               WB02 249
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        SUBROUTINE LOADS                                                WB03   1
C                                                                       WB03   2
      DIMENSION FX(250),SLOAD(20),FY(250),FZ(250),DLTPG(250)            WB03   3
      DIMENSION BFY(100),BFZ(100)                                       WB03   4
C                                                                       WB03   5
      LOGICAL DELTA,ANY,ANYMORE                                         WB03   6
      LOGICAL ASYM                                                      WB03   7
C                                                                       WB03   8
      COMMON/SWEEPS/VSWLER(20),VSWTER(20),VSWLEL(20),VSWTEL(20),        WB03   9
     1  VSWLEU(20),VSWTEU(20),VSWLED(20),VSWTED(20),LVSWP,LEFT,FAC,NCWB WB03  10
     2,ARPNL(250),WIDTH(250)                                            WB03  11
      COMMON /PRESS/DELTP(250),XRF(250),XRB(250),XLF(250),XLB(250),     WB03  12
     1YLC(250),YRC(250),COSALF,NPANLS,ARWING,FMACH,ALFA,FN(250),SINALF  WB03  13
     1  , DELTA                                                         WB03  14
      COMMON /THRUST/CN,XBAR(250),ZBAR(250),YCPT(250),                  WB03  15
     1                  VNOR(250),CIRC(250),PNLC(250),                  WB03  16
     1  NCW,MSWR,MSWL,MSWU,MSWD,NRP,NWP,NJP,B2,B2V,XCPT(250),ZCPT(250)   WB03  17
      COMMON /VWNOR/SWPPLE(250),SWPPTE(250),ZLF(250),ZRF(250),DUM(500), WB03  18
     1ASYM,UP,VP,WP,                                                    WB03  19
     1II,IF,CONST,BETAR,SINBET,COSBET                                   WB03  20
      COMMON/IPR/NPR,I,J                                                WB03  21
      COMMON /TRANS/NBIP,RB,DX,WBIP,XFBIP(100),SNT(125),CST(125),       WB03  22
     1  SNT2(125),CST2(125)                                             WB03  23
      COMMON /TILT/ANGLR,ANGLL,ANGLU,ANGLD,DFLR,DELL,DELU,DELD          WB03  24
      COMMON/REF/SREF,REFL                                              WB03  25
      COMMON/CRUX/NCRX                                                  WB03  26
      COMMON/BVEL/BDU(250),BDV(250),BDW(250)                            WB03  27
      COMMON/NONLIN/NWBP,NOLINP,TOTLR,BODY,ALFR,NOUT,NPRESS,NOCPT,NDRAG WB03  28
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      COMMON/BPCPRS/DLTP(250),DLTP2(250),DLTP3(250),DLTP1(250)
C
      EQUIVALENCE (BFY(1),CIRC(1)),(BFZ(1),CIRC(101)),
     1                 (DLTPG(1),ZBAR(1))
C
C
  701 FORMAT(1H1,25X,21HWING PANEL PROPERTIES//2X,1HJ,5X,7HYCPT(J),3X,
     1                    10HCHORD THRU,4X,5HPANEL,3X,8HMIDCHORD,5X,
     1 6HDELTA=,6X,
     17HGAMMA/V,3X,9HVNOR/V AT,6X,2HFX, 8X,2HFY,8X,2HFZ,8X,2HFN/
     1                    18X,8HCENTROID,6X,4HSPAN,5X,9HSWEEP,DEG,
     2  5X,2HCP,16X,14HPANEL CENTROID//)
  702 FORMAT(//31X,21HSPANWISE DISTRIBUTION//)
  703 FORMAT(10X,I2,5X,F10.5,2X,F10.5,2X,F10.5)
  705 FORMAT (8X,I3,7X,F10.5,2X,F10.5,2X,F10.5,2X,F10.5,2X,F10.5,
     12X,F10.5,2X,F10.5)
  706 FORMAT (1X,I3,1X,F10.5,1X,F10.5,1X,F10.5,1X,F10.5,1X,F10.5,1X,F10.
     1 5,1X,F10.5,1X,F10.5,1X,F10.5,1X,F10.5,1X,F10.5)
  707 FORMAT(1H1,20X,31HBODY INFLUENCE PANEL PROPERTIES//2X,1HJ,5X,
     1  7HYCPT(J),3X,6HLENGTH,4X,5HWIDTH,4X,8HTHETA(J),7X,5HFY(J),7X,
     2  5HFZ(J),7X,5HFN(J),7X,8HDELTA=CP/)
  716 FORMAT(1H1,25X,35HVELOCITIES AT PANEL CENTROID POINTS//
     1  10X,1HJ,11X,7HXBAR(J),5X,7HYBAR(J),5X,7HZBAR(J),9X,1HU,11X,
     2  1HV,11X,1HW,8X,4HVNOR//)
  717 FORMAT(1H1,40HTHRUST, LIFT, AND SIDE FORCE INFORMATION//
     X  11X,14HMACH NUMBER = ,E12.5/
     1  7X,18HANGLE OF ATTACK = ,F8.3,1X,7HDEGREES/
     27X,18HSIDE SLIP ANGLE W ,F8.3,1X,7HDEGREES/
     3 13X,12HWING AREA = ,F8.3/
     4 8X,1THREFERENCE AREA = ,F8.5/
     5 6X,19HREFERENCE LENGTH = ,F8.5///)
  718 FORMAT(/29X,5HTOTAL,12X,10HRIGHT WING,9X,9HLEFT WING,8X,10HUPPER W
     1ING,8X,10HLOWER WING/
     1  6X,19HDEFL, ANGLE DEG, = ,12X,4(6X,F12.5)/
     2  20X,5HCN = ,E12.5,2(6X,E12.5)/
     4  20X,5HCY = ,E12.5,36X,2(6X,E12.5)/
     5  15X,10HCTHRUST = ,E12.5,4(6X,E12.5)/
     6  20X,5HCL = ,E12.5,4(6X,E12.5)/
     7  19X,6HCDI = ,E12.5,4(6X,E12.5)///
     8  13X,12HCDI/CL**2 = ,E12.5/
     9  16X,9HCNADDV = ,E12.5/
     X  16X,9HCYADDH = ,E12.5/
     1  15X,10HCY=BIP  = E12.5/
     2  15X,10HCN=BIP  = ,E12.5///
     315X,10HROLMOMR = ,E12.5/
     315X,10HROLMOML = ,E12.5/
     315X,10HROLMOMU = ,E12.5/
     315X,10HROLMOMD = ,E12.5)
  719 FORMAT (///5X,23HROLLING MOMENT          =,F10.5/
     15X,22HBETA                    =,F10.5,2X,8HDEGREES,/)
  721 FORMAT(/1X,20(1H=),A10,21(1H=))
  723 FORMAT(11X,1HI,8X,7HZ/(B/2),2X,10HCY*C/(2*B),2X,10HCT*C/(2*B))
  724 FORMAT(11X,1HI,8X,7HY/(B/2),2X,10HCN*C/(2*B),2X,10HCT*C/(2*B)/)
  725 FORMAT (//1X,28HU/VINF TYPE LOADING PRESSURE//)
  726 FORMAT (//1X,32HBERNOUILLI TYPE LOADING PRESSURE//)
  727 FORMAT (//1X,36HFULL 2ND ORDER TYPE LOADING PRESSURE//)
  728 FORMAT (//1X,31HUBAR/VINF TYPE LOADING PRESSURE//)
  729 FORMAT (//1X,31H1ST ORDER TYPE LOADING PRESSURE//)
C
C
      DATA ARW/10HRIGHT WING/,ALW/10H LEFT WING/,AUW/10HUPPER WING/,
     1 ADW/10HLOWER WING/
C
C
C
C     CALCULATE WING AND BODY PANEL INDUCED VELOCITIES AT THE CENTROID
C     POINTS
C
      IF (NDRAG.EQ.0) GO TO 513
      NOCPT=1
      II=1
      IF=NWBP
      NPR=0
      IF(NOUT.EQ.1) WRITE (6,716)
      DO 510 J=1,NPANLS
      CALL VELNOR(XBAR(J),YCPT(J),ZBAR(J))
      UCT=UP
      VCT=VP
      WCT=WP
      IF(J.GT.NWP) GO TO 509
      VNOR(J)=WP
      GO TO 512
  509 VNOR(J)=VP
  512 CONTINUE
      IF (NOUT.NE.1) GO TO 510
      WRITE (6,705) J,XBAR(J),YCPT(J),ZBAR(J),UCT,VCT,WCT,VNOR(J)
  510 CONTINUE
  513 CONTINUE
C
C
C     RE-ENTER HERE FOR NONLINEAR PRESSURE LOADINGS
C
      ENTRY SPECLD
C
C     INITIALIZE VARIABLES
C
      DTOR=0.0174533
      ALFAR= ALFA*DTOR
      AREA=0.0
      CY=0.0
      CN=0.0
      CNR=0.
      CNL=0.
      CYU=0.
      CYD=0.
      CYB=0.
      CNB=0.
      CTHRR=0.
      CTHRL=0.
      CTHRU=0.
      CTHRD=0.
      CNADDV=0.0
      CYADDH=0.0
      ROLMR=0.0
      ROLML=0.0
      ROLMU=0.0
      ROLMD=0.0
      ANYS=SYM.OR.NBIP.NE.0.          OR.NCRX.GT.0
      ANYMORE=(NBIP.NE.0.          OR.NCRX.GT.0).AND.(.NOT.ASYM)
      BETAY= BETAR/DTOR
C
      DO 902 I=1,NPANLS
      IF (NPRESS.EQ.0) DLTPG(I)=DELTP(I)
      IF (NPRESS.EQ.1) DLTPG(I)=DLTP(I)
      IF (NPRESS.EQ.4) DLTPG(I)=DLTP1(I)
      IF (NPRESS.EQ.2) DLTPG(I)=DLTP2(I)
      IF (NPRESS.EQ.3) DLTPG(I)=DLTP3(I)
  902 CONTINUE
C
C
C
C     CN CONTRIBUTION OF BODY INTERFERENCE PANELS,CNB AND CY CONTRIBUTIO
C     CYB
C     WRITE OUT BIP PANEL PROPERTIES
C
      IF(NBIP.EQ.0) GO TO 160
      IF (NPRESS.NE.0) GO TO 160
      AREAP=NBIP*DX
      WRITE (6,707)
      DO 140 K=1,NBIP
      I=K+NPANLS
      F=DELTP(I)*AREAP
      FN(I)=F
      CALL ROTBW(0.,F,BFY(K),BFZ(K),K)
      CNB=CNB+BFZ(K)
      THTI=ATAN2(SNT(K),CST(K))*57.2957795
      IF(THTI.LT.0.) THTI=THTI+360.
      L=I
      CYB=CYB+BFY(K)
  140 WRITE(6,706) L,YCPT(L),DX,NBIP,THTI,BFY(K),BFZ(K),FN(L),DELTP(L)
  160 CONTINUE
C
C
C     CALCULATE NORMAL FORCE, CN, AND SIDE FORCE, CY
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C     RIGHT HAND WING PANELS                                            WB03 183
C     CN CONTRIBUTION OF RIGHT HORIZONTAL WING, CNR                     WB03 184
C                                                                       WB03 185
C     CALCULATE CTHRST,CDI,AND *ADDITIONAL* TERMS OF CY AND CN          WB03 186
C     CONTRIBUTED TO CN BY THE VERTICAL WING, AND TO CY BY THE          WB03 187
C     HORIZONTAL WING, CNADDV AND CYADDH RESPECTIVELY                   WB03 188
C     FX.....THRUST FORCE IN NEG, X=DIR, IN PLANE OF WING/Q*ARWING      WB03 189
C     FY.....SIDE FORCE IN Y=DIRECTION IN PLANE OF WING/Q*ARWING        WB03 190
C     FZ.....UPWARDS FORCE IN Z=DIR, IN PLANE OF VERTICAL WING          WB03 191
C                                                                       WB03 192
C     RIGHT WING                                                        WB03 193
C                                                                       WB03 194
      IF (NDRAG.NE.0) WRITE (6,701)                                     WB03 195
      DO 300 J=1,NRP                                                    WB03 196
      AREA=AREA+ARPNL(J)                                                WB03 197
      I=J                                                               WB03 198
      F=    ARPNL(J)*DLTPG(I)                                           WB03 199
      FN(I)=F                                                           WB03 200
      YCHK= YCPT(I)*COSBET-XBAR(I)*SINBET                               WB03 201
      IF (ANYMORE  ) YCHK=YCPT(I)                                       WB03 202
      ROLMR= -FN(I)*YCHK+ROLMR                                          WB03 203
      CNR=CNR+F                                                         WB03 204
      IF (NDRAG.EQ.0) GO TO 300                                         WB03 205
      CIRC(J)=0.5*DLTPG(J)*PNLC(J)                                      WB03 206
      SLPMC=0.5*(SWPPLE(J)+SWPPTE(J))                                   WB03 207
      SWPMC=ATAN(SLPMC)*57.2957795                                      WB03 208
      FX(J)=2.*WIDTH(J)*CIRC(J)*(ANGLR+VNOR(J)+BDW(J))                  WB03 209
      FY(J)=FX(J)*SLPMC                                                 WB03 210
      CYADDH=CYADDH+FY(J)+FX(J)*BETAR                                   WB03 211
      IF (ANYMORE) CYADDH=CYADDH+FY(J)                                  WB03 212
      CTHRR=CTHRR+FX(J)-FY(J)*BETAR                                     WB03 213
      IF (ANYMORE) CTHRR=CTHRR+FX(J)                                    WB03 214
      WRITE (6,706) J,YCPT(J),PNLC(J),WIDTH(J),SWPMC,DLTPG(J),CIRC(J),  WB03 215
     1  VNOR(J),FX(J),FY(J),FZ(J),FN(J)                                 WB03 216
  300 CONTINUE                                                          WB03 217
      IF(ANY) GO TO 301                                                 WB03 218
      CNL = CNR                                                         WB03 219
      ROLML=-ROLMR                                                      WB03 220
      CTHRL=CTHRR                                                       WB03 221
      CYADDH=0.0                                                        WB03 222
      AREA=2.0*AREA                                                     WB03 223
      GO TO 311                                                         WB03 224
  301 CONTINUE                                                          WB03 225
C                                                                       WB03 226
C     LEFT WING                                                         WB03 227
C     CN CONTRIBUTION OF LEFT HORIZONTAL WING, CNL                      WB03 228
C                                                                       WB03 229
      NRP1=NRP+1                                                        WB03 230
      DO 310 J=NRP1,NHP                                                 WB03 231
      I=J                                                               WB03 232
      F=    ARPNL(J)*DLTPG(I)                                           WB03 233
      FN(I)=F                                                           WB03 234
      YCHK= YCPT(I)*COSBET-XBAR(I)*SINBET                               WB03 235
      IF (ANYMORE  ) YCHK=YCPT(I)                                       WB03 236
      ROLML= -FN(I)*YCHK+ROLML                                          WB03 237
      CNL=CNL+F                                                         WB03 238
      IF (NDRAG.EQ.0) GO TO 310                                         WB03 239
      CIRC(J)=0.5*DLTPG(J)*PNLC(J)                                      WB03 240
      SLPMC=0.5*(SWPPLE(J) +SWPPTE(J))                                  WB03 241
      SWPMC=ATAN(SLPMC)*57.2957795                                      WB03 242
      FX(J)=2.*WIDTH(J)*CIRC(J)*(ANGLL+VNOR(J)+BDW(J))                  WB03 243
      FY(J)=FX(J)*SLPMC                                                 WB03 244
      CTHRL=CTHRL+FX(J)-FY(J)*BETAR                                     WB03 245
      IF (ANYMORE) CTHRL=CTHRL+FX(J)                                    WB03 246
      CYADDH=CYADDH+FY(J)+FX(J)*BETAR                                   WB03 247
      IF (ANYMORE) CYADDH=CYADDH+FY(J)                                  WB03 248
      WRITE (6,706) J,YCPT(J),PNLC(J),WIDTH(J),SWPMC,DLTPG(J),CIRC(J),  WB03 249
     1  VNOR(J),FX(J),FY(J),FZ(J),FN(J)                                 WB03 250
  310 CONTINUE                                                          WB03 251
  311 CONTINUE                                                          WB03 252
      IF(NHP.EQ.NPANLS) GO TO 350                                       WB03 253
C                                                                       WB03 254
C     UPPER VERTICAL WING                                               WB03 255
C     CY CONTRIBUTION OF UPPER VERTICAL WING, CYU                       WB03 256
C                                                                       WB03 257
      NHP1=NHP+1                                                        WB03 258
      DO 320 J=NHP1,N3P                                                 WB03 259
      I=J                                                               WB03 260
      F=    ARPNL(J)*DLTPG(I)                                           WB03 261
      FN(I)=F                                                           WB03 262
      ZCHK= ZCPT(I)*COSALF+XBAR(I)*SINALF                               WB03 263
      IF (ANYMORE  ) ZCHK=ZCPT(I)                                       WB03 264
      ROLMU=-FN(I)*ZCHK+ROLMU                                           WB03 265
      CYU=CYU-F                                                         WB03 266
      IF (NDRAG.EQ.0) GO TO 320                                         WB03 267
      SLPMC=0.5*(SWPPLE(J)+SWPPTE(J))                                   WB03 268
      SWPMC=ATAN(SLPMC)*57.2957795                                      WB03 269
      CIRC(J)=0.5*DLTPG(J)*PNLC(J)                                      WB03 270
      FX(J)=2.*WIDTH(J)*CIRC(J)*(ANGLU-VNOR(J)-BDV(J))                  WB03 271
      FZ(J)=FX(J)*SLPMC                                                 WB03 272
      CNADDV=CNADDV+FZ(J)-FX(J)*ALFAR                                   WB03 273
      IF (ANYMORE) CNADDV= CNADDV+FZ(J)                                 WB03 274
      CTHRU=CTHRU+FX(J)+FZ(J)*ALFAR                                     WB03 275
      IF (ANYMORE) CTHRU=CTHRU+FX(J)                                    WB03 276
      WRITE (6,706) J,YCPT(J),PNLC(J),WIDTH(J),SWPMC,DLTPG(J),CIRC(J),  WB03 277
     1  VNOR(J),FX(J),FY(J),FZ(J),FN(J)                                 WB03 278
  320 CONTINUE                                                          WB03 279
      IF(ANY) GO TO 321                                                 WB03 280
      CYD=CYU                                                           WB03 281
      ROLMD=-ROLMU                                                      WB03 282
      CNADDV=0.0                                                        WB03 283
      CTHRD=CTHRU                                                       WB03 284
      GO TO 350                                                         WB03 285
  321 CONTINUE                                                          WB03 286
C                                                                       WB03 287
C     LOWER VERTICAL WING                                               WB03 288
C     CY CONTRIBUTION OF LOWER VERTICAL WING, CYD                       WB03 289
C                                                                       WB03 290
      N3P1=N3P+1                                                        WB03 291
      DO 330 J=N3P1,NPANLS                                              WB03 292
      I=J                                                               WB03 293
      F=    ARPNL(J)*DLTPG(I)                                           WB03 294
      FN(I)=F                                                           WB03 295
      ZCHK= ZCPT(I)*COSALF+XBAR(I)*SINALF                               WB03 296
      IF (ANYMORE  ) ZCHK=ZCPT(I)                                       WB03 297
      ROLMD=-FN(I)*ZCHK+ROLMD                                           WB03 298
      CYD=CYD-F                                                         WB03 299
      IF (NDRAG.EQ.0) GO TO 330                                         WB03 300
      CIRC(J)=0.5*DLTPG(J)*PNLC(J)                                      WB03 301
      SLPMC=0.5*(SWPPLE(J)+SWPPTE(J))                                   WB03 302
      SWPMC=ATAN(SLPMC)*57.2957795                                      WB03 303
      FX(J)=2.*WIDTH(J)*CIRC(J)*(ANGLD-VNOR(J)-BDV(J))                  WB03 304
      FZ(J)=FX(J)*SLPMC                                                 WB03 305
      CNADDV=CNADDV+FZ(J)-FX(J)*ALFAR                                   WB03 306
      IF (ANYMORE) CNADDV= CNADDV+FZ(J)                                 WB03 307
      CTHRD=CTHRD+FX(J)+FZ(J)*ALFAR                                     WB03 308
      IF (ANYMORE) CTHRD=CTHRD+FX(J)                                    WB03 309
      WRITE (6,706) J,YCPT(J),PNLC(J),WIDTH(J),SWPMC,DLTPG(J),CIRC(J),  WB03 310
     1  VNOR(J),FX(J),FY(J),FZ(J),FN(J)                                 WB03 311
  330 CONTINUE                                                          WB03 312
  350 CONTINUE                                                          WB03 313
C                                                                       WB03 314
C                                                                       WB03 315
      CNR=CNR/SREF                                                      WB03 316
      CNL=CNL/SREF                                                      WB03 317
      CYU=CYU/SREF                                                      WB03 318
      CYD=CYD/SREF                                                      WB03 319
      CNB=CNB/SREF                                                      WB03 320
      CYB=CYB/SREF                                                      WB03 321
      ROLMR=ROLMR/(REFL*SREF)                                           WB03 322
      ROLML=ROLML/(REFL*SREF)                                           WB03 323
      ROLMU=ROLMU/(REFL*SREF)                                           WB03 324
      ROLMD=ROLMD/(REFL*SREF)                                           WB03 325
C                                                                       WB03 326
C                                                                       WB03 327
C                                                                       WB03 328
C     CALCULATE CDI FOR EACH WING AND TOTAL CDI, CTHRST, CN, CY         WB03 329
C                                                                       WB03 330
      IF (NDRAG.EQ.0) GO TO 201                                         WB03 331
      CDIR=CNR*ANGLR-CTHRR/SREF                                         WB03 332
      CDIL=CNL*ANGLL-CTHRL/SREF                                         WB03 333
      CDID=-CYD*ANGLD-CTHRD/SREF                                        WB03 334
      CDIU=-CYU*ANGLU-CTHRU/SREF                                        WB03 335
      CDI=CDIR+CDIL+CDIU+CDID                                           WB03 336
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      CTHRST=(CTHRR+CTHRL+CTHRU+CTHRD)/SREF                             WB03 337
      CNADDV=CNADDV/SREF                                                WB03 338
      CYADDH=CYADDH/SREF                                                WB03 339
C                                                                       WB03 340
C     CALCUATE LIFT COEFFICIENT, CL FOR EACH WING                       WB03 341
C                                                                       WB03 342
      CLR=CNR+CTHRR*ANGLR/SREF                                          WB03 343
      CLL=CNL+CTHRL*ANGLL/SREF                                          WB03 344
      CLU=CTHRU*ANGLU/SREF                                              WB03 345
      CLD=CTHRD*ANGLD/SREF                                              WB03 346
      CL=CLR+CLL+CLU+CLD                                                WB03 347
      CDCLS=CDI/(CL*CL)                                                 WB03 348
  201 CONTINUE                                                          WB03 349
      CY=CYU+CYD+CYADDH                                                 WB03 350
      CN=CNR+CNL+CNADDV                                                 WB03 351
C                                                                       WB03 352
C                                                                       WB03 353
      WRITE(6,717) FMACH,ALFA,BETAY,AREA,SREF,REFL                      WB03 354
      IF (NPRESS.EQ.0) WRITE (6,725)                                    WB03 355
      IF (NPRESS.EQ.1) WRITE (6,726)                                    WB03 356
      IF (NPRESS.EQ.4) WRITE (6,729)                                    WB03 357
      IF (NPRESS.EQ.2) WRITE (6,727)                                    WB03 358
      IF (NPRESS.EQ.3) WRITE (6,728)                                    WB03 359
      CTHRR=CTHRR/SREF                                                  WB03 360
      CTHRL=CTHRL/SREF                                                  WB03 361
      CTHRU=CTHRU/SREF                                                  WB03 362
      CTHRD=CTHRD/SREF                                                  WB03 363
      WRITE (6,718) DELR,DELL,DELU,DELD,                                WB03 364
     1                          CN,CNR,CNL,CY,CYU,CYD,CTHRBT,           WB03 365
     1  CTHRR,CTHRL,CTHRU,CTHRD,CL,CLR,CLL,CLU,CLD,CDI,CDIR,CDIL,       WB03 366
     2  CDIU,CDID,CDCLS,CNADDV,CYADDH,CYB,CNB,ROLMR,ROLML,ROLMU,ROLMD   WB03 367
      NBWRP=NBWR+1                                                      WB03 368
      NBWLP=NBWL+1                                                      WB03 369
      CFC=1.0/(4.0*B2)                                                  WB03 370
      IF(ASYM) GO TO 524                                                WB03 371
C                                                                       WB03 372
C     CALCULATE SPANWISE LOAD DISTRIBUTIONS                             WB03 373
C     FOR USKEWED PANEL CASES ONLY                                      WB03 374
C                                                                       WB03 375
C     THIS LOOP TO 542 IS USED FOR LEFT AND RIGHT HORIZONTAL WINGS      WB03 376
C                                                                       WB03 377
      BTW=1./B2                                                         WB03 378
      WRITE(6,702)                                                      WB03 379
       WRITE(6,721) ARW                                                 WB03 380
      WRITE(6,724)                                                      WB03 381
      J=1                                                               WB03 382
      IL=0                                                              WB03 383
      KUL=MSWRP                                                         WB03 384
  540 CONTINUE                                                          WB03 385
      I=0                                                               WB03 386
      DO 542 K=2,KUL                                                    WB03 387
      I=I+1                                                             WB03 388
      BECFXX=0.0                                                        WB03 389
      SUM1=0.0                                                          WB03 390
      YCHK=YCPT(J)*COSBET-XBAR(J)*SINBET                                WB03 391
      YLOC=YCHK*BTW                                                     WB03 392
      DO 541 L=1,NCW                                                    WB03 393
      SUM1=SUM1+FN(J)                                                   WB03 394
      WIDI=1./WIDTH(J)                                                  WB03 395
      IF (NDRAG.EQ.0) GO TO 541                                         WB03 396
      BECFXX=BECFXX+CFC*WIDI*(FX(J)*COSBET-FY(J)*SINBET)                WB03 397
  541 J=J+1                                                             WB03 398
      BLOAD(I)=SUM1*WIDI*BTW*0.25                                       WB03 399
  542 WRITE(6,703) I,YLOC,BLOAD(I),BECFXX                               WB03 400
      IF (NBWL.EQ.0) GO TO 549                                          WB03 401
      IF(IL.NE.0) GO TO 543                                             WB03 402
C                                                                       WB03 403
C     RE-ENTER ABOVE LOOP FOR LEFT HORIZONTAL WING                      WB03 404
C                                                                       WB03 405
      IL=1                                                              WB03 406
      KUL=MSWLP                                                         WB03 407
      WRITE(6,721) ALW                                                  WB03 408
      WRITE(6,724)                                                      WB03 409
      GO TO 540                                                         WB03 410
  543 IF(MSWU.EQ.0) GO TO 549                                           WB03 411
C                                                                       WB03 412
C     THIS LOOP TO 546 USED FOR UPPER AND LOWER WINGS, IF PRESENT       WB03 413
C                                                                       WB03 414
      KU=MSWU+1                                                         WB03 415
      WRITE(6,721) AUW                                                  WB03 416
      WRITE(6,723)                                                      WB03 417
      IL=0                                                              WB03 418
  544 CONTINUE                                                          WB03 419
      I=0                                                               WB03 420
      DO 546 K=2,KU                                                     WB03 421
      I=I+1                                                             WB03 422
      BECFXX=0.0                                                        WB03 423
      SUM1=0.0                                                          WB03 424
      ZCHK=ZCPT(J)*COSALF-XBAR(J)*SINALF                                WB03 425
      IF (ANYMORE) ZCHK=ZCPT(J)                                         WB03 426
      ZLOC=ZCHK*BTW                                                     WB03 427
      DO 545 L=1,NCW                                                    WB03 428
      SUM1=SUM1+FN(J)                                                   WB03 429
      WIDI=1./WIDTH(J)                                                  WB03 430
      IF (NDRAG.EQ.0) GO TO 545                                         WB03 431
      IF (ANYMORE) GO TO 810                                            WB03 432
      BECFXX=BECFXX+CFC*WIDI*(FX(J)*COSALF+FZ(J)*SINALF)                WB03 433
      GO TO 811                                                         WB03 434
  810 BECFXX= BECFXX+CFC*WIDI*FX(J)                                     WB03 435
  811 CONTINUE                                                          WB03 436
  545 J=J+1                                                             WB03 437
      BLOAD(I)=SUM1*WIDI*BTW*0.25                                       WB03 438
  546 WRITE(6,703) I,ZLOC,BLOAD(I),BECFXX                               WB03 439
      IF(IL.NE.0) GO TO 549                                             WB03 440
C                                                                       WB03 441
C     RE-ENTER ABOVE LOOP FOR LOWER WING                                WB03 442
C                                                                       WB03 443
      IL=1                                                              WB03 444
      KU=MBWD+1                                                         WB03 445
      WRITE(6,721) ADW                                                  WB03 446
      WRITE(6,723)                                                      WB03 447
      GO TO 544                                                         WB03 448
  549 CONTINUE                                                          WB03 449
C                                                                       WB03 450
C                                                                       WB03 451
C     CLL.....ROLLING MOMENT,POSITIVE RIGHT WING DOWN                   WB03 452
C     REFERENCED TO BREF,REFL                                           WB03 453
C                                                                       WB03 454
  524 CONTINUE                                                          WB03 455
      ROLMOM=ROLMR+ROLML+ROLMU+ROLMD                                    WB03 456
      WRITE (6,719) ROLMOM,BETAY                                        WB03 457
C                                                                       WB03 458
C                                                                       WB03 459
      RETURN                                                            WB03 460
      END                                                               WB03 461
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      SUBROUTINE VELNOR(XX,YY,ZZ)                                       WB04   1
C                                                                       WB04   2
C                                                                       WB04   3
C     THIS SUBROUTINE CALCULATES PERTURBATION VELOCITIES INDUCED BY     WB04   4
C     THE WING AND BODY INTERFERENCE PANELS                             WB04   5
C     SUPERPOSITION OF 4 CORNER SOLUTIONS IS USED                       WB04   6
C     VELNOR RETURNS VELOCITIES UP,VP,WP IN WING REFERENCE FRAME...     WB04   7
C                                                                       WB04   8
      LOGICAL ASYM,ASYMI,DELTA                                          WB04   9
C                                                                       WB04  10
      COMMON /IPR/NPR,MI,MJ                                             WB04  11
      COMMON /VELARG/X,Y,Z,U,V,W,A,EM,BETA,SLOPE,TLRNC,TIPY             WB04  12
      COMMON /PRESS/DELTP(250),XRF(250),XRB(250),XLF(250),XLB(250),     WB04  13
     1YLC(250),YRC(250),COSALF,NPANLS,ARWING,FMACH,ALFA,FN(250),BINALF  WB04  14
     1  , DELTA                                                         WB04  15
      COMMON /VWNOR/SWPPLE(250),SWPPTE(250),ZLF(250),ZRF(250),ZLB(250), WB04  16
     1 ZRB(250),ASYMI,UP,VP,WP,II,IF,CONST,BETAR,SINBET,COSBET          WB04  17
      COMMON/THRUST/CN,DUM(500),YCPT(250),DUM1(756 ),NWP,DUM2(253),     WB04  18
     1ZCPT(250)                                                         WB04  19
      COMMON /TRANS/NBIP,CRD(3),XFBIP(100),GBG(500)                     WB04  20
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      COMMON/CRUX/NCRX                                                  WB04  21
      COMMON/NONLIN/NWBP,NOLINP,TOTLR,BODY,ALFR,NOUT,NPRESS,NOCPT,NDRAG WB04  22
C                                                                       WB04  23
    1 FORMAT(5X,5HPANEL,I4,6X,6HCORNER,I2,                              WB04  24
     1                    6X,4HC.P.,I5,3X,4HX = ,E12.5,3X,4HY = ,E12.5WB04  25
     1 ,3X,4HZ = E12.5/6X,4HU = ,E12.5,6X,4HV = ,E12.5,6X,4HW = ,E12.5/ WB04  26
     2  5X,5HTU = ,E12.5,5X,5HTV = ,E12.5,5X,5HTW = ,E12.5)             WB04  27
    2 FORMAT(1X,7HASYM = ,L3)                                           WB04  28
C                                                                       WB04  29
      ASYM= ASYMI.OR.NBIP.NE.0.OR.NCRX.GT.0                             WB04  30
C                                                                       WB04  31
      UP=0.                                                             WB04  32
      VP=0.                                                             WB04  33
      WP=0.                                                             WB04  34
C                                                                       WB04  35
C     I IS INDEX OF INFLUENCING PANEL                                   WB04  36
C                                                                       WB04  37
      DO 100 I=II,IF                                                    WB04  38
      MI=I                                                              WB04  39
      TU=0.                                                             WB04  40
      TV=0.                                                             WB04  41
      TW=0.                                                             WB04  42
      IF(I.LE.NPANLS) GO TO 201                                         WB04  43
C                                                                       WB04  44
C     INFLUENCER IS A BIP.  TRANSFORM C.P. COORDINATES INTO ITS REF. FRAWB04  45
C                                                                       WB04  46
      IB=I-NPANLS                                                       WB04  47
      CALL TRWBIP(YY,ZZ,YI,ZI,IB)                                       WB04  48
      XI=XX-XFBIP(IB)                                                   WB04  49
      GO TO 202                                                         WB04  50
  201 XI=XX                                                             WB04  51
      YI=YY                                                             WB04  52
      ZI=ZZ                                                             WB04  53
  202 CONTINUE                                                          WB04  54
      EM1=SWPPLE(I)                                                     WB04  55
      EM2=SWPPTE(I)                                                     WB04  56
C                                                                       WB04  57
C******************  CORNER 1  ************************************WB04  58
C                                                                       WB04  59
C                                                                       WB04  60
C     NOTE: YCPT AND ZCPT ARE USED TO CHARACTERIZE THE BODY INFL. PANELSWB04  61
C     TO SEPARATE THEM LEFT AND  RIGHT                                  WB04  62
C                                                                       WB04  63
C     SHOULD NOT USE MORE THAN  NPANLS FIELD POINTS WHEN CALCULATING    WB04  64
C     FLOWFIELD                                                         WB04  65
C                                                                       WB04  66
      IF (NOCPT.EQ.1.AND.I.LE.NPANLS) GO TO 60                          WB04  67
      IF (EM1.LT.0.0.OR.(YCPT(I).LT.0.0.AND.ZCPT(I).GT.0.0).OR.         WB04  68
     1(YCPT(I).GT.0.0.AND.ZCPT(I).LT.0.0)) GO TO 15                     WB04  69
   60 IF (EM1.LT.0.0) GO TO 15                                          WB04  70
      SLOPE=EM1                                                         WB04  71
      EM=EM1                                                            WB04  72
      X=XI-XLF(I)                                                       WB04  73
      Y=YI-YLC(I)                                                       WB04  74
      Z=ZI-ZLF(I)                                                       WB04  75
      CALL VELO                                                         WB04  76
      TU=TU+U                                                           WB04  77
      TV=TV+V                                                           WB04  78
      TW=TW+W                                                           WB04  79
      ICNR=1                                                            WB04  80
      MNJ=MJ                                                            WB04  81
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04  82
      IF(NPR.NE.0) WRITE(6,2) ASYM                                      WB04  83
      IF(ASYM) GO TO 10                                                 WB04  84
      IF(I.GT.NHP.AND.I.LE.NPANLS) GO TO 31                             WB04  85
      Y=-(YI+YLC(I) )                                                   WB04  86
      CALL VELO                                                         WB04  87
      TU=TU+U                                                           WB04  88
      TV=TV-V                                                           WB04  89
      TW=TW+W                                                           WB04  90
      GO TO 32                                                          WB04  91
   31 Z=-(ZI+ZLF(I))                                                    WB04  92
      CALL VELO                                                         WB04  93
      TU=TU+U                                                           WB04  94
      TV=TV+V                                                           WB04  95
      TW=TW-W                                                           WB04  96
   32 CONTINUE                                                          WB04  97
      MNJ=-MJ                                                           WB04  98
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04  99
      GO TO 10                                                          WB04 100
C                                                                       WB04 101
C     CORNER 1 FOR M .LT.0.0                                            WB04 102
C                                                                       WB04 103
   15 CONTINUE                                                          WB04 104
      SLOPE=-EM1                                                        WB04 105
      EM=-EM1                                                           WB04 106
      X=XI-XLF(I)                                                       WB04 107
      Y=YLC(I)-YI                                                       WB04 108
      Z=ZI-ZLF(I)                                                       WB04 109
      IF(I.GT.NHP.AND.I.LE.NPANLS) GO TO 51                             WB04 110
      CALL VELO                                                         WB04 111
      TU=TU-U                                                           WB04 112
      TV=TV+V                                                           WB04 113
      TW=TW-W                                                           WB04 114
      GO TO 52                                                          WB04 115
   51 Y=YI-YLC(I)                                                       WB04 116
      Z=-Z                                                              WB04 117
      CALL VELO                                                         WB04 118
      TU=TU-U                                                           WB04 119
      TV=TV-V                                                           WB04 120
      TW=TW+W                                                           WB04 121
   52 CONTINUE                                                          WB04 122
      ICNR=1                                                            WB04 123
      MNJ=MJ                                                            WB04 124
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 125
      IF(ASYM) GO TO 17                                                 WB04 126
      Y=YLC(I)+YI                                                       WB04 127
      CALL VELO                                                         WB04 128
      TU=TU-U                                                           WB04 129
      TV=TV-V                                                           WB04 130
      TW=TW-W                                                           WB04 131
      MNJ=-MJ                                                           WB04 132
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 133
      GO TO 17                                                          WB04 134
   10 CONTINUE                                                          WB04 135
C                                                                       WB04 136
C******************  CORNER 2  ************************************WB04 137
C                                                                       WB04 138
      X=XI-XRF(I)                                                       WB04 139
      Y=YI-YRC(I)                                                       WB04 140
      Z=ZI-ZRF(I)                                                       WB04 141
      CALL VELO                                                         WB04 142
      TU=TU-U                                                           WB04 143
      TV=TV-V                                                           WB04 144
      TW=TW-W                                                           WB04 145
      ICNR=2                                                            WB04 146
      MNJ=MJ                                                            WB04 147
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 148
      IF(ASYM) GO TO 20                                                 WB04 149
      IF(I.GT.NHP.AND.I.LE.NPANLS) GO TO 33                             WB04 150
      Y=-(YI+YRC(I))                                                    WB04 151
      CALL VELO                                                         WB04 152
      TU=TU-U                                                           WB04 153
      TV=TV+V                                                           WB04 154
      TW=TW-W                                                           WB04 155
      GO TO 34                                                          WB04 156
   33 Z=-(ZI+ZRF(I))                                                    WB04 157
      CALL VELO                                                         WB04 158
      TU=TU-U                                                           WB04 159
      TV=TV-V                                                           WB04 160
      TW=TW+W                                                           WB04 161
   34 CONTINUE                                                          WB04 162
      MNJ=-MJ                                                           WB04 163
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 164
      GO TO 20                                                          WB04 165
C                                                                       WB04 166
C     CORNER 2 FOR M .LT. 0                                             WB04 167
C                                                                       WB04 168
   17 CONTINUE                                                          WB04 169
      X=XI-XRF(I)                                                       WB04 170
      Y=YRC(I)-YI                                                       WB04 171
      Z=ZI-ZRF(I)                                                       WB04 172
      IF(I.GT.NHP.AND.I.LE.NPANLS) GO TO 53                             WB04 173
      CALL VELO                                                         WB04 174
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      TU=TU+U                                                           WB04 175
      TV=TV+V                                                           WB04 176
      TW=TW+W                                                           WB04 177
      GO TO 54                                                          WB04 178
   53 Y=YI+YRC(I)                                                       WB04 179
      Z=-Z                                                              WB04 180
      CALL VELO                                                         WB04 181
      TU=TU+U                                                           WB04 182
      TV=TV+V                                                           WB04 183
      TW=TW+W                                                           WB04 184
   54 CONTINUE                                                          WB04 185
      ICNR=2                                                            WB04 186
      MNJ=MJ                                                            WB04 187
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 188
      IF(ASYM) GO TO 20                                                 WB04 189
      Y=YRC(I)+YI                                                       WB04 190
      CALL VELO                                                         WB04 191
      TU=TU+U                                                           WB04 192
      TV=TV+V                                                           WB04 193
      TW=TW+W                                                           WB04 194
      MNJ=-MJ                                                           WB04 195
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 196
   20 CONTINUE                                                          WB04 197
C                                                                       WB04 198
C******************  CORNER 3  ************************************WB04 199
C                                                                       WB04 200
      IF (NOCPT.EQ.1.AND.I.LE.NPANLB) GO TO 61                          WB04 201
      IF (EM2.LT.0.0.OR.(YCPT(I).LT.0.0.AND.ZCPT(I).GT.0.0).OR.         WB04 202
     1(YCPT(I).GT.0.0.AND.ZCPT(I).LT.0.0)) GO TO 19                     WB04 203
   61 IF (EM2.LT.0.0) GO TO 19                                          WB04 204
      EM=EM2                                                            WB04 205
      SLOPE=EM2                                                         WB04 206
      X=XI+XLB(I)                                                       WB04 207
      Y=YI+YLC(I)                                                       WB04 208
      Z=ZI+ZLB(I)                                                       WB04 209
      CALL VELO                                                         WB04 210
      TU=TU+U                                                           WB04 211
      TV=TV+V                                                           WB04 212
      TW=TW+W                                                           WB04 213
      ICNR=3                                                            WB04 214
      MNJ=MJ                                                            WB04 215
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 216
      IF(ASYM) GO TO 30                                                 WB04 217
      IF(I.GT.NHP.AND.I.LE.NPANLB) GO TO 35                             WB04 218
      Y=-(YI+YLC(I))                                                    WB04 219
      CALL VELO                                                         WB04 220
      TU=TU+U                                                           WB04 221
      TV=TV+V                                                           WB04 222
      TW=TW+W                                                           WB04 223
      GO TO 36                                                          WB04 224
   35 Z=-(ZI+ZLB(I))                                                    WB04 225
      CALL VELO                                                         WB04 226
      TU=TU+U                                                           WB04 227
      TV=TV+V                                                           WB04 228
      TW=TW+W                                                           WB04 229
   36 CONTINUE                                                          WB04 230
      MNJ=-MJ                                                           WB04 231
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 232
      GO TO 30                                                          WB04 233
C                                                                       WB04 234
C     CORNER 3 FOR M .LT. 0                                             WB04 235
C                                                                       WB04 236
   19 CONTINUE                                                          WB04 237
      SLOPE=-EM2                                                        WB04 238
      EM=-EM2                                                           WB04 239
      X=XI+XLB(I)                                                       WB04 240
      Y=YLC(I)-YI                                                       WB04 241
      Z=ZI+ZLB(I)                                                       WB04 242
      IF(I.GT.NHP.AND.I.LE.NPANLB) GO TO 55                             WB04 243
      CALL VELO                                                         WB04 244
      TU=TU+U                                                           WB04 245
      TV=TV+V                                                           WB04 246
      TW=TW+W                                                           WB04 247
      GO TO 56                                                          WB04 248
   55 Y=YI+YLC(I)                                                       WB04 249
      Z=-Z                                                              WB04 250
      CALL VELO                                                         WB04 251
      TU=TU+U                                                           WB04 252
      TV=TV+V                                                           WB04 253
      TW=TW+W                                                           WB04 254
   56 CONTINUE                                                          WB04 255
      ICNR=3                                                            WB04 256
      MNJ=MJ                                                            WB04 257
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 258
      IF(ASYM) GO TO 21                                                 WB04 259
      Y=YLC(I)+YI                                                       WB04 260
      CALL VELO                                                         WB04 261
      TU=TU+U                                                           WB04 262
      TV=TV+V                                                           WB04 263
      TW=TW+W                                                           WB04 264
      MNJ=-MJ                                                           WB04 265
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 266
      GO TO 21                                                          WB04 267
   30 CONTINUE                                                          WB04 268
C                                                                       WB04 269
C******************  CORNER 4  ************************************WB04 270
C                                                                       WB04 271
      X=XI+XRB(I)                                                       WB04 272
      Y=YI+YRC(I)                                                       WB04 273
      Z=ZI+ZRB(I)                                                       WB04 274
      CALL VELO                                                         WB04 275
      TU=TU+U                                                           WB04 276
      TV=TV+V                                                           WB04 277
      TW=TW+W                                                           WB04 278
      ICNR=4                                                            WB04 279
      MNJ=MJ                                                            WB04 280
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 281
      IF(ASYM) GO TO 40                                                 WB04 282
      IF(I.GT.NHP.AND.I.LE.NPANLB) GO TO 37                             WB04 283
      Y=-(YI+YRC(I))                                                    WB04 284
      CALL VELO                                                         WB04 285
      TU=TU+U                                                           WB04 286
      TV=TV+V                                                           WB04 287
      TW=TW+W                                                           WB04 288
      GO TO 38                                                          WB04 289
   37 Z=-(ZI+ZRB(I))                                                    WB04 290
      CALL VELO                                                         WB04 291
      TU=TU+U                                                           WB04 292
      TV=TV+V                                                           WB04 293
      TW=TW+W                                                           WB04 294
   38 CONTINUE                                                          WB04 295
      MNJ=-MJ                                                           WB04 296
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 297
      GO TO 40                                                          WB04 298
C                                                                       WB04 299
C     CORNER 4 FOR M.LT.0                                               WB04 300
C                                                                       WB04 301
   21 CONTINUE                                                          WB04 302
      X=XI+XRB(I)                                                       WB04 303
      Y=YRC(I)-YI                                                       WB04 304
      Z=ZI+ZRB(I)                                                       WB04 305
      IF(I.GT.NHP.AND.I.LE.NPANLB) GO TO 57                             WB04 306
      CALL VELO                                                         WB04 307
      TU=TU+U                                                           WB04 308
      TV=TV+V                                                           WB04 309
      TW=TW+W                                                           WB04 310
      GO TO 58                                                          WB04 311
   57 Y=YI+YRC(I)                                                       WB04 312
      Z=-Z                                                              WB04 313
      CALL VELO                                                         WB04 314
      TU=TU+U                                                           WB04 315
      TV=TV+V                                                           WB04 316
      TW=TW+W                                                           WB04 317
   58 CONTINUE                                                          WB04 318
      ICNR=4                                                            WB04 319
      MNJ=MJ                                                            WB04 320
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 321
      IF(ASYM) GO TO 40                                                 WB04 322
      Y=YI+YRC(I)                                                       WB04 323
      CALL VELO                                                         WB04 324
      TU=TU+U                                                           WB04 325
      TV=TV+V                                                           WB04 326
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      TW=TW+W                                                           WB04 327
      MNJ=MJ                                                            WB04 328
      IF(NPR.NE.0) WRITE(6,1) MI,ICNR,MNJ,X,Y,Z,U,V,W,TU,TV,TW          WB04 329
   40 CONTINUE                                                          WB04 330
      IF(I.LE.NPANLS) GO TO 203                                         WB04 331
C                                                                       WB04 332
C     INFLUENCER IS A BIP.  RESOLVE ITS VELOCITIES INTO WING REFERENCE  WB04 333
C     FRAME BEFORE ADDING THEM IN.                                      WB04 334
C                                                                       WB04 335
      VT=TV                                                             WB04 336
      WT=TW                                                             WB04 337
      CALL ROTBW(VT,WT,TV,TW,IB)                                        WB04 338
  203 CONTINUE                                                          WB04 339
      IF(II.EQ.IF.AND.NOCPT.EQ.0) GO TO 101                             WB04 340
      UP=UP+TU*DELTP(I)                                                 WB04 341
      VP=VP+TV*DELTP(I)                                                 WB04 342
      WP=WP+TW*DELTP(I)                                                 WB04 343
  100 CONTINUE                                                          WB04 344
      UP=UP/CONST                                                       WB04 345
      VP=VP/CONST                                                       WB04 346
      WP=WP/CONST                                                       WB04 347
      RETURN                                                            WB04 348
  101 UP=TU                                                             WB04 349
      VP=TV                                                             WB04 350
      WP=TW                                                             WB04 351
      RETURN                                                            WB04 352
      END                                                               WB04 353
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      SUBROUTINE VELO                                                   WB05   1
C                                                                       WB05   2
C     THIS SUBROUTINE CALCULATES THE INFLUENCE OF THE BASIC             WB05   3
C     SEMI-INFINITE TRIANGLES WHICH ARE UNDER CONSTANT LOADING          WB05   4
C     MORE CORRECTLY, THEY ARE UNDER CONSTANT U DIFFERENCE              WB05   5
C                                                                       WB05   6
      COMMON /IPR/NPR,MI,MJ                                             WB05   7
      COMMON /THRUST/DUM(1507),NHP,DM(503)                              WB05   8
      COMMON /VELARG/X,YS,ZS,U,V,W,A,EM,BETA,SLOPE,TLRNC,TIPY           WB05   9
      COMMON /PRESS/QQQ(1751),NPANLS,RRR(255)                           WB05  10
C                                                                       WB05  11
      NAMELIST /DEBUG/X,Y,Z,F1,F2,   F4,F5,   F7,ARG,  EML,BETA,U,V,W    WB05  12
     1,TOP,BOT,ARGY,      TLRNC,YEDGE                                   WB05  13
C                                                                       WB05  14
      DATA PI/3.141592653 5/                                            WB05  15
C                                                                       WB05  16
C                                                                       WB05  17
C         STATEMENT FUNCTIONS ** U3,V3,W3 ON PAGE 26 OF BOEING REPORT   WB05  18
C   NOTE ** THESE FUNCTIONS HAVE BEEN RECAST IN TERMS OF                WB05  19
C   EML = 1 / M                                                         WB05  20
C     PLANAR FORMULATION                                                WB05  21
C                                                                       WB05  22
      F1T(X,Y,Z) = Z*SQRT(XSQ-BTSQ*(YSQ+ZSQ))                           WB05  23
      F1B(X,Y,Z) = Y*(EML*Y-X)+EML*ZSQ                                  WB05  24
      FF2(X,Y,Z) = EML*ALOG((X*EML-BTSQ*Y                               WB05  25
     1  + SQRT((X*EML-BTSQ*Y)*(X*EML-BTSQ*Y)                            WB05  26
     2  - BTSQ*((Y*EML-X)*(Y*EML-X)+ EMLSQ*ZSQ-BTSQ*ZSQ)))              WB05  27
     4  /(BETA*SQRT((Y*EML-X)*(Y*EML-X) + EMLSQ*ZSQ-BTSQ*ZSQ)))         WB05  28
     6  / SQRT(ABS(EMLSQ-BTSQ))                                         WB05  29
      FF4(X,Y,Z) = (Y/(YSQ+ZSQ))*SQRT(XSQ-BTSQ*(YSQ+ZSQ))               WB05  30
      FF5(X,Y,Z) = ALOG((X+SQRT(XSQ-BTSQ*(YSQ+ZSQ)))                    WB05  31
     1  /(BETA*SQRT(YSQ+ZSQ)))                                          WB05  32
      FFT(X,Y,Z) = (Z/(YSQ+ZSQ))*SQRT(XSQ-BTSQ*(YSQ+ZSQ))               WB05  33
      FFSON(X,Y,Z) = (SQRT(XSQ-BTSQ*(YSQ+ZSQ)))/(X-BETA*Y)              WB05  34
      FSS(X,Y,Z) = EML*ATAN2(SQRT((BTSQ-EMLSQ)*(XSQ-BTSQ*(YSQ+ZSQ))),  WB05  35
     1   X*EML-BTSQ*Y)  / SQRT(ABS(EMLSQ-BTSQ))                         WB05  36
C                                                                       WB05  37
C     MI IS INDEX OF INFLUENCING PANEL                                  WB05  38
C                                                                       WB05  39
C     FOR THE VERTICAL WING PANELS,THE TRANSFORMATION ROTATES TRIANGLE  WB05  40
C     90 DEG. IN COUNTER CLOCKWISE DIRECTION                            WB05  41
C     NOTE: PRESSURE THEN ACTS FROM RIGHT TO LEFT                       WB05  42
C                                                                       WB05  43
      IF(MI.GT.NHP.AND.MI.LE.NPANLS) GO TO 5                            WB05  44
      Y=YS                                                              WB05  45
      Z=ZS                                                              WB05  46
      GO TO 6                                                           WB05  47
    5 Y=ZS                                                              WB05  48
      Z=-YS                                                             WB05  49
    6 CONTINUE                                                          WB05  50
      TOP=0.0                                                           WB05  51
      BOT=0.0                                                           WB05  52
      EML=EM                                                            WB05  53
      XSQ=X*X                                                           WB05  54
      YSQ=Y*Y                                                           WB05  55
      ZSQ=Z*Z                                                           WB05  56
      BTSQ=BETA*BETA                                                    WB05  57
      EMLSQ=EML*EML                                                     WB05  58
      ARG4=ABS(X*X-BTSQ*(Y*Y+Z*Z))                                      WB05  59
C                                                                       WB05  60
C     CHECK FOR SUBSONIC,SONIC OR SUPERSONIC LEADING EDGE               WB05  61
C                                                                       WB05  62
      IF (X.LT.TLRNC) GO TO 50                                          WB05  63
      IF(ABS(EML).LT.TLRNC) GO TO 120                                   WB05  64
      YEDGE=X/EML                                                       WB05  65
      GO TO 121                                                         WB05  66
  120 YEDGE=TIPY                                                        WB05  67
      GO TO 20                                                          WB05  68
C                                                                       WB05  69
C     CHECK FOR SUBSONIC,SONIC, OR SUPERSONIC LEADING EDGE              WB05  70
C                                                                       WB05  71
  121 ARG=BTSQ*(1./EMLSQ)                                               WB05  72
      IF (ABS(ARG-1.0).LT.TLRNC) GO TO 25                               WB05  73
      IF(ARG.LT.1.0) GO TO 10                                           WB05  74
      RBT=SQRT(YSQ+ZSQ)*BETA                                            WB05  75
      IF(X.GT.RBT) GO TO 63                                             WB05  76
      GO TO 21                                                          WB05  77
   50 U=0.                                                              WB05  78
      V=0.                                                              WB05  79
      W=0.                                                              WB05  80
      RETURN                                                            WB05  81
C                                                                       WB05  82
C     SUPERSONIC LEADING EDGE CASE **                                   WB05  83
C                                                                       WB05  84
   20 CONTINUE                                                          WB05  85
C                                                                       WB05  86
C     CHECK IF POINT (X,Y,Z) LIES INSIDE, ON, OR OUTSIDE MACH CONE      WB05  87
C     FROM ORIGIN                                                       WB05  88
C                                                                       WB05  89
      RBT=SQRT(YSQ+ZSQ)*BETA                                            WB05  90
      IF(X.GT.RBT) GO TO 24                                             WB05  91
   21 IF(Y.LT.0.0.OR.Y.GE.YEDGE) GO TO 50                               WB05  92
C                                                                       WB05  93
C     POINT LIES OUTSIDE MACH CONE FROM ORIGIN BUT THE POINT LIES       WB05  94
C     INSIDE MACH CONE FROM LEADING EDGE AT SAME Y AS P(X,Y,Z)          WB05  95
C                                                                       WB05  96
      XLE=Y*SLOPE                                                       WB05  97
      XTRANSF=X-XLE                                                     WB05  98
      RSTB=ABS(Z)*BETA                                                  WB05  99
      IF(ABS(RSTB).LT.TLRNC.AND.X.LE.XLE) GO TO 50                      WB05 100
      IF(XTRANSF.LE.RSTB) GO TO 50                                      WB05 101
      IF(ABS(Z)     .LT.TLRNC.OR.(Z)     .GT.0.) GO TO 70               WB05 102
      GO TO 71                                                          WB05 103
   70 F1=PI                                                             WB05 104
      GO TO 74                                                          WB05 105
   71 F1=-PI                                                            WB05 106
   74 F2=-(EML*PI)/SQRT(ABS(BTSQ-EMLSQ))                                WB05 107
      IF(ABS(EML).LT.TLRNC) F2=-BETA*PI                                 WB05 108
      F4= 0.0                                                           WB05 109
      F5=0.                                                             WB05 110
      F7=0.0                                                            WB05 111
      GO TO 47                                                          WB05 112
C                                                                       WB05 113
C     POINT LIES INSIDE MACH CONE FROM ORIGIN                           WB05 114
C                                                                       WB05 115
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   24 CONTINUE                                                          WB05 116
      F2=-BETA*ATAN2(SQRT(X*X-BTSQ*(YSQ+ZSQ)),-BETA*Y)                  WB05 117
      IF(F2.GT.0.0) F2=-2.0*PI*BETA + F2                                WB05 118
      GO TO 22                                                          WB05 119
   63 F2=-FSS(X,Y,Z)                                                    WB05 120
      IF(F2.GT.0.0) F2=-2.0*PI*EML/SQRT(ABS(EMLSQ-BTSQ))+F2             WB05 121
      GO TO 22                                                          WB05 122
C                                                                       WB05 123
C     SONIC LEADING EDGE CASE--                                         WB05 124
C                                                                       WB05 125
   25 CONTINUE                                                          WB05 126
C                                                                       WB05 127
C     CHECK IF POINT(X,Y,Z) LIES ON OR OUTSIDE MACH CONE FROM ORIGIN    WB05 128
C     IF TRUE SET PERTURBATION VELOCITIES EQUAL TO ZERO                 WB05 129
C                                                                       WB05 130
      RBT=SQRT(YSQ+ZSQ)*BETA                                            WB05 131
      IF (X.LE.RBT) GO TO 50                                            WB05 132
      F2=FFSON(X,Y,Z)                                                   WB05 133
      GO TO 22                                                          WB05 134
C                                                                       WB05 135
C     SUBSONIC LEADING EDGE CASE--                                      WB05 136
C                                                                       WB05 137
   10 CONTINUE                                                          WB05 138
C                                                                       WB05 139
C     CHECK IF POINT (X,Y,Z) LIES ON OR OUTSIDE MACH CONE               WB05 140
C     IF TRUE SET PERTURBATION VELOCITIES TO ZERO                       WB05 141
C                                                                       WB05 142
      RBT=SQRT(YSQ+ZSQ)*BETA                                            WB05 143
      IF(X.LE.RBT) GO TO 50                                             WB05 144
      F2=FF2(X,Y,Z)                                                     WB05 145
   22 CONTINUE                                                          WB05 146
      IF(ABS(Y).LT.TLRNC.AND.ABS(Z)     .LT.TLRNC) GO TO 91             WB05 147
      ARGY=Y-YEDGE                                                      WB05 148
      IF(ABS(ARGY).LT.TLRNC.AND.ABS(Z)     .LT.TLRNC) GO TO 83          WB05 149
      GO TO 84                                                          WB05 150
   91 F1=PI/2.0                                                         WB05 151
      F4=0.0                                                            WB05 152
      F5=0.0                                                            WB05 153
      F7= 0.0                                                           WB05 154
      GO TO 47                                                          WB05 155
   83 F1=PI/2.0                                                         WB05 156
      IF(ARG4.LT.TLRNC) GO TO 68                                        WB05 157
      F4=FF4(X,Y,Z)                                                     WB05 158
      GO TO 69                                                          WB05 159
   68 F4=0.0                                                            WB05 160
   69 CONTINUE                                                          WB05 161
      GO TO 49                                                          WB05 162
   84 CONTINUE                                                          WB05 163
      TOP=F1T(X,Y,Z)                                                    WB05 164
      BOT=F1B(X,Y,Z)                                                    WB05 165
      IF(ABS(TOP).GE.TLRNC) GO TO 43                                    WB05 166
      IF (Y.GT.0.0.AND.Y.LT.YEDGE.AND.ABS(Z)    .LT.TLRNC) GO TO 48     WB05 167
      GO TO 44                                                          WB05 168
   48 F1=PI                                                             WB05 169
      GO TO 46                                                          WB05 170
   43 F1=ATAN2(TOP,BOT)                                                 WB05 171
      IF(ABS(F1).LT.TLRNC) F1= 0.                                       WB05 172
      GO TO 46                                                          WB05 173
   44 F1=0.0                                                            WB05 174
   46 CONTINUE                                                          WB05 175
      IF(ARG4.LT.TLRNC) GO TO 66                                        WB05 176
      F4= FF4(X,Y,Z)                                                    WB05 177
      GO TO 67                                                          WB05 178
   66 F4=0.0                                                            WB05 179
   67 CONTINUE                                                          WB05 180
   49 F5=FF5(X,Y,Z)                                                     WB05 181
      F7=FF7(X,Y,Z)                                                     WB05 182
C                                                                       WB05 183
C     CALCULATE PERTURBATION VELOCITIES U/V,V/V,W/V                     WB05 184
C                                                                       WB05 185
   47 U=F1                                                              WB05 186
      IF(ABS(EML).LT.TLRNC) GO TO 101                                   WB05 187
      V=-EML*F1+F7                                                      WB05 188
      W=       (EML*(ABS (1.0-BTSQ/EMLSQ)*F2-F5)-F4)                    WB05 189
      GO TO 102                                                         WB05 190
  101 CONTINUE                                                          WB05 191
      V= F7                                                             WB05 192
      W=-F4+F2                                                          WB05 193
  102 CONTINUE                                                          WB05 194
C                                                                       WB05 195
C     TRANSFORM VELOCITIES BACK INTO HORIZONTAL WING SYSTEM             WB05 196
C     THAT IS, THE MAIN WING COORDINATE SYSTEM                          WB05 197
C                                                                       WB05 198
      IF(MI.LE.NWP.OR.MI.GT.NPANLS) GO TO 103                           WB05 199
      TEMP=V                                                            WB05 200
      V=-W                                                              WB05 201
      W=TEMP                                                            WB05 202
  103 CONTINUE                                                          WB05 203
      IF(NPR.EQ.0) RETURN                                               WB05 204
      WRITE(6,DEBUG)                                                    WB05 205
C                                                                       WB05 206
      RETURN                                                            WB05 207
      END                                                               WB05 208
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      SUBROUTINE TRBIPW(YI,ZI,YO,ZO,I)                                  WB06   1
C                                                                       WB06   2
C     THIS SUBROUTINE TRANSFORMS COORDINATES AND VELOCITIES             WB06   3
C                                                                       WB06   4
      COMMON /TRANB/NBIP,RB,DX,WBIP,XFBIP(100),SNT(125),CST(125),       WB06   5
     1  SNT2(125),CST2(125)                                             WB06   6
C                                                                       WB06   7
C     TRANSFORM FROM BIP TO WING COORDINATES                            WB06   8
C                                                                       WB06   9
      YO=YI*CST2(I) + ZI*SNT2(I) + RB*CST(I)                            WB06  10
      ZO=ZI*CST2(I) - YI*SNT2(I) + RB*SNT(I)                            WB06  11
      RETURN                                                            WB06  12
C                                                                       WB06  13
C     TRANSFORM FROM WING TO BIP COORDINATES                            WB06  14
C                                                                       WB06  15
      ENTRY TRWBIP                                                      WB06  16
      ZC=ZI-RB*SNT(I)                                                   WB06  17
      YC=YI-RB*CST(I)                                                   WB06  18
   10 YO=YC*CST2(I) - ZC*SNT2(I)                                        WB06  19
      ZO=ZC*CST2(I) + YC*SNT2(I)                                        WB06  20
      RETURN                                                            WB06  21
C                                                                       WB06  22
C     VELOCITY TRANSFORM -- BIP TO WING                                 WB06  23
C                                                                       WB06  24
      ENTRY ROTBW                                                       WB06  25
      YO=YI*CST2(I) + ZI*SNT2(I)                                        WB06  26
      ZO=ZI*CST2(I) - YI*SNT2(I)                                        WB06  27
      RETURN                                                            WB06  28
C                                                                       WB06  29
C     WING TO BIP VELOCITY TRANSFORM                                    WB06  30
C                                                                       WB06  31
      ENTRY ROTWB                                                       WB06  32
      ZC=ZI                                                             WB06  33
      YC=YI                                                             WB06  34
      GO TO 10                                                          WB06  35
      END                                                               WB06  36
```

```
      SUBROUTINE LINEQS(N,A)                                            WB07   1
C                                                                       WB07   2
C     THIS SUBROUTINE TRIANGULATES MATRIX A(N,N)                        WB07   3
C     IP(300) REMEMBERS WHAT WAS DONE TO TRIANGULATE MATRIX A           WB07   4
C      IT IS USED IN SOLVE TO DO SAME THING TO B                        WB07   5
C                                                                       WB07   6
      DIMENSION A(N,N),IP(300)                                          WB07   7
      COMMON /LINSOL/IP                                                 WB07   8
      IP(N)=1                                                           WB07   9
      DO 6 K=1,N                                                        WB07  10
      IF(K.EQ.N)GO TO 5                                                 WB07  11
      KP1=K+1                                                           WB07  12
      M=K                                                               WB07  13
      DO 1 I=KP1,N                                                      WB07  14
    1 CONTINUE                                                          WB07  15
      IP(K)=M                                                           WB07  16
      IF(M.NE.K)IP(N)=-IP(N)                                            WB07  17
      T=A(M,K)                                                          WB07  18
      A(M,K)=A(K,K)                                                     WB07  19
      A(K,K)=T                                                          WB07  20
      IF(T.EQ.0.)GO TO 5                                                WB07  21
      DO 2 I=KP1,N                                                      WB07  22
    2 A(I,K)=-A(I,K)/T                                                  WB07  23
      DO 4 J=KP1,N                                                      WB07  24
      T=A(M,J)                                                          WB07  25
      A(M,J)=A(K,J)                                                     WB07  26
      A(K,J)=T                                                          WB07  27
      IF(T.EQ.0.)GO TO 4                                                WB07  28
      DO 3 I=KP1,N                                                      WB07  29
    3 A(I,J)=A(I,J)+A(I,K)*T                                            WB07  30
    4 CONTINUE                                                          WB07  31
    5 IF(A(K,K).EQ.0.)IP(N)=0                                           WB07  32
    6 CONTINUE                                                          WB07  33
      RETURN                                                            WB07  34
      END                                                               WB07  35
```

```
      SUBROUTINE SOLVE (B,A,N)                                          WB08   1
C                                                                       WB08   2
C     THIS SUBROUTINE TAKES IN THE TRIANGULATED MATRIX A, RIGHT HAND    WB08   3
C     SIDE VECTOR B, IT IS OPERATED ON BY IP(300)                       WB08   4
C     SOLUTION THEN PROCEEDS, ANSWER IS IN VECTOR B AGAIN               WB08   5
C                                                                       WB08   6
      DIMENSION B(1)                                                    WB08   7
      DIMENSION A(N,N)                                                  WB08   8
C                                                                       WB08   9
      COMMON /LINSOL/IP(300)                                            WB08  10
      COMMON/NONLIN/NWBP,NOLINP,TOTLR,BODY,ALFR,NOUT,NPRESS,NOCPT,NDRAG WB08  11
C                                                                       WB08  12
    1 FORMAT (3X,I3,5X,E12.5)                                           WB08  13
    2 FORMAT (1H1,4X,1HI,5X,29HB(I) AFTER DO LOOP 7 IN SOLVE//)         WB08  14
C                                                                       WB08  15
      IF(N.EQ.1)GO TO 9                                                 WB08  16
      NM1=N-1                                                           WB08  17
      DO 7 K=1,NM1                                                      WB08  18
      KP1=K+1                                                           WB08  19
      M=IP(K)                                                           WB08  20
      T=B(M)                                                            WB08  21
      B(M)=B(K)                                                         WB08  22
      B(K)=T                                                            WB08  23
      DO 7 I=KP1,N                                                      WB08  24
    7 B(I)=B(I)+A(I,K)*T                                                WB08  25
C                                                                       WB08  26
      IF (NOUT.NE.0) WRITE (6,2)                                        WB08  27
      DO 20 I=1,N                                                       WB08  28
      IF (NOUT.EQ.0) GO TO 19                                           WB08  29
      WRITE (6,1) I,B(I)                                                WB08  30
   19 IF (ABS(B(I)).LE.1.0E-10) B(I)=0.0                                WB08  31
   20 CONTINUE                                                          WB08  32
C                                                                       WB08  33
      DO 8 KB=1,NM1                                                     WB08  34
      KM1=N-KB                                                          WB08  35
      K=KM1+1                                                           WB08  36
      B(K)=B(K)/A(K,K)                                                  WB08  37
      T=-B(K)                                                           WB08  38
      DO 8 I=1,KM1                                                      WB08  39
    8 B(I)=B(I)+A(I,K)*T                                                WB08  40
    9 B(1)=B(1)/A(1,1)                                                  WB08  41
      RETURN                                                            WB08  42
      END                                                               WB08  43
```

```
      SUBROUTINE BDYGEN(AC,B)                                           WB09   1
C                                                                       WB09   2
C SUBROUTINE TO CALCULATE SUPERSONIC LINE SOURCES AND DOUBLETS TO GIVE AWB09   3
C REQUIRED BODY SHAPE AND ANGLE OF ATTACK,  METHOD IS THAT OF WOODWARD  WB09   4
C AND LARSEN (BOEING REPT, D6-1074) WITHOUT MODIFICATION,  ORIGINAL     WB09   5
C PROGRAM WAS WRITTEN BY RALPH CARMICHAEL (AMES RESEARCH CENTER),       WB09   6
C MODIFICATIONS BY M. HEMSCH -NIELSEN ENGINEERING AND RESEARCH, INC,    WB09   7
C                                 510 CLYDE AVE,                        WB09   8
C                                 MOUNTAIN VIEW, CA 94306               WB09   9
C                                 MAY 1974                              WB09  10
      COMMON /WBTR/XWLE                                                 WB09  11
      COMMON /TRANS/DMD,RB,QKC(602)                                     WB09  12
      COMMON /PRESS/GNP(1753),FMACH,CRD(253)                            WB09  13
      COMMON/BDYBLK/RNOSE,RADIUS,LNOSE,LBODY,BCODE,NXBODY,              WB09  14
     X XBODY(101),RBODY(101),RPBODY(101),DRDX(100)                      WB09  15
      COMMON/BRCE/XFIELD,RFIELD,BSQ,X2,      U,V,VT                     WB09  16
      COMMON/VEL/MACH,MACHSQ,BETASQ,BETA                                WB09  17
      COMMON/CPFN/UBS(101),VBS(101),UBD(101),VBD(101),VTBD(101),COEFF(5)WB09  18
      COMMON/BSINGS/T(100),TC(100),TX(101)                              WB09  19
      COMMON/BPSANG/SINALC,COSALC,SINPHI,COSPHI                         WB09  20
      COMMON/NONLIN/NWBP,NOLINP,TOTLR, DUM,ALFR,NOUT,NPRESS,NOCPT,NDRAG WB09  21
C                                                                       WB09  22
      REAL MACH,MACHSQ,LNOSE,LBODY                                      WB09  23
C                                                                       WB09  24
      INTEGER PCODE,BCODE                                               WB09  25
C                                                                       WB09  26
      DIMENSION CPT(  5),A(100),XF(100),RF(100)                         WB09  27
C                                                                       WB09  28
      NAMELIST/BODY/NXBODY,LNOSE,LBODY,       RNOSE,                    WB09  29
     2  XNOSE,BCODE,PCODE,XWLE                                          WB09  30
C                                                                       WB09  31
      DATA XNOSE/0./,RNOSE/0./                                          WB09  32
C                                                                       WB09  33
C                                                                       WB09  34
    6 FORMAT(I4,F9.4,10G11.4)                                           WB09  35
  227 FORMAT(1H0,62HVELOCITIES INDUCED ON BODY BY BODY LINE SINGULARITIEWB09  36
     18 AT MACH=,F7.4,5X,6HALFAC=,F7.4//20X,12HBODY SOURCES,25X,13HBODY WB09  37
     2DOUBLETS,//9X,1HX,7X,1HU,10X,1HV,11X,2HVN,9X,1HU,10X,1HV,9X,2HVT, WB09  38
     39X,2HVN)                                                          WB09  39
  301 FORMAT(1H0,54HPRESSURE COEFFICIENT ON BODY USING SLENDER BODY THEOWB09  40
     1RY,                  //,8X,1HX,5X,7HTHETA=0,6X,4HPI/4,7X,4HPI/2,5XWB09  41
     2,6H3*PI/4,9X,2HPI,//)                                             WB09  42
  302 FORMAT(1H0,50HPRESSURE COEFFICIENTS ON BODY USING LINEAR FORMULA,/WB09  43
     1/,8X,1HX,5X,7HTHETA=0,6X,4HPI/4,7X,4HPI/2,5X,6H3*PI/4,9X,2HPI,//) WB09  44
  305 FORMAT(1H0,54HPRESSURE COEFFICIENTS ON BODY USING 2ND ORDER  FORMUWB09  45
     XLA,//,8X,1HX,5X,7HTHETA=0,6X,4HPI/4,7X,4HPI/2,5X,6H3*PI/4,9X,2HPI,WB09  46
     X//)                                                               WB09  47
  306 FORMAT (//1X,42HSAME AS ABOVE CALCULATED AT CONTROL POINTS/)      WB09  48
  331 FORMAT(1H ,I4,F9.4,5G11.4)                                        WB09  49
  799 FORMAT(-1PHYSICAL DIMENSIONS OF BODY AND LINE SINGULARITY STRENGTHWB09  50
     1S REPRESENTING THE BODY AT MACH=,F7.4/                            WB09  51
     2 9X,1HX,12X,1HR,11X,5HDR/DX,12X,2HTX,10X,4HT(I),10X,5HTC(I))      WB09  52
```

```
  801 FORMAT(I4,F9.4, 6G15.5)                                          WB09  53
  802 FORMAT (1H1,48HBODY RADIUS TOO LARGE IN RELATION TO BODY LENGTH//)WB09  54
C                                                                      WB09  55
C                                                                      WB09  56
      MACH=FMACH                                                       WB09  57
      RADIUS=RB                                                        WB09  58
C                                                                      WB09  59
C     READ NAMELIST BODY                                               WB09  60
C                                                                      WB09  61
      READ(5,BODY)                                                     WB09  62
C                                                                      WB09  63
      WRITE(6,BODY)                                                    WB09  64
C                                                                      WB09  65
      IF(NXBODY.LE.0.OR.NXBODY.GT.101)NXBODY=51                        WB09  66
C                                                                      WB09  67
C                                                                      WB09  68
C     INITIALIZE DOUBLET STRENGHTS                                     WB09  69
C                                                                      WB09  70
      DO 103 I=1,NXBODY                                                WB09  71
  103 TC(I)=0.0                                                        WB09  72
C                                                                      WB09  73
C CALCULATION OF AERODYNAMIC DATA                                      WB09  74
C                                                                      WB09  75
      MACHSQ=MACH*MACH                                                 WB09  76
      BETASQ=1.  -MACHSQ                                               WB09  77
      BETA= SQRT( ABS(BETASQ))                                         WB09  78
      ALPHA=ASIN(SINALC)                                               WB09  79
      N=NXBODY-1                                                       WB09  80
      XBODY(1)=XNOSE                                                   WB09  81
      XBODY(NXBODY)=XNOSE+LBODY                                        WB09  82
C                                                                      WB09  83
      IF (BETA*RADIUS.GE.LBODY) GO TO 200                              WB09  84
      GO TO 204                                                        WB09  85
  200 WRITE (6,802)                                                    WB09  86
      STOP                                                             WB09  87
  204 CONTINUE                                                         WB09  88
C                                                                      WB09  89
C SETUP OF POINTS ON BODY AXIS BY DIVIDING BODY LENGTH INTO N  EQUAL SEGWB09  90
C                                                                      WB09  91
      DEL=LBODY/N                                                      WB09  92
      DO 33 I=2,N                                                      WB09  93
   33 XBODY(I)=XBODY(I-1)+DEL                                          WB09  94
C                                                                      WB09  95
C CALCULATION OF RADII AND RPBODY TO GO WITH THE AXIS POINTS           WB09  96
C                                                                      WB09  97
      DO 35 I=1,NXBODY                                                 WB09  98
   35 CALL BODYR(XBODY(I)-XNOSE,RBODY(I),RPBODY(I))                    WB09  99
C                                                                      WB09 100
C CALCULATION OF DRDX AT MIDPOINTS BETWEEN SETPOINTS                   WB09 101
C                                                                      WB09 102
      DO 36 I=1,N                                                      WB09 103
      XF(I)=.5*(XBODY(I+1)+XBODY(I))-XNOSE                             WB09 104
      CALL BODYR(XF(I),RF(I),DRDX(I))                                  WB09 105
   36 XF(I)=XF(I)+XNOSE                                                WB09 106
C                                                                      WB09 107
C THIS LOOP DETERMINES THE LOCATIONS OF THE ORIGINS OF THE CONICAL LINE WB09 108
C SOURCES AND DOUBLETS.  THE ORIGINS ARE LOCATED AT THE TX(I).         WB09 109
C                                                                      WB09 110
      DO 10 I=1,NXBODY                                                 WB09 111
   10 TX(I)=XBODY(I)-BETA*RBODY(I)                                     WB09 112
C                                                                      WB09 113
C ROUTINE FOR DROPPING CONTROL POINTS IF THEY ARE OUTSIDE THE MACH     WB09 114
C CONE OF THE NOSE.                                                    WB09 115
C                                                                      WB09 116
  100 IF(BETA*RF(1).LT.(XF(1)-XNOSE))GO TO 199                         WB09 117
      N=N-1                                                            WB09 118
      NXBODY=NXBODY-1                                                  WB09 119
      DO 101 I=2,NXBODY                                                WB09 120
      XBODY(I)=XBODY(I+1)                                              WB09 121
      RBODY(I)=RBODY(I+1)                                              WB09 122
      RPBODY(I)=RPBODY(I+1)                                            WB09 123
  101 TX(I)=TX(I+1)                                                    WB09 124
      DO 102 I=2,N                                                     WB09 125
      XF(I)=XF(I+1)                                                    WB09 126
      RF(I)=RF(I+1)                                                    WB09 127
  102 DRDX(I)=DRDX(I+1)                                                WB09 128
      XF(1)=.5*(XBODY(2)+XBODY(1))                                     WB09 129
      CALL BODYR(XF(1)-XNOSE,RF(1),DRDX(1))                            WB09 130
      GO TO 100                                                        WB09 131
  199 CONTINUE                                                         WB09 132
C                                                                      WB09 133
C     DETERMINATION OF SOURCE STRENGTHS AT CONTROL POINTS MIDWAY BETWEENWB09 134
C      BODY DEFINITION POINTS.                                         WB09 135
C                                                                      WB09 136
C CALCULATION OF THE FIRST SOURCE STRENGTH.                            WB09 137
C                                                                      WB09 138
      XFIELD=XF(1)                                                     WB09 139
      RFIELD=RF(1)                                                     WB09 140
      SLOPE=DRDX(1)                                                    WB09 141
      BSQ=BETASQ*RFIELD*RFIELD                                         WB09 142
      X2=XFIELD-LBODY                                                  WB09 143
      CALL SOURCE(1)                                                   WB09 144
      A(1)=V-SLOPE*U                                                   WB09 145
      T(1)=DRDX(1)/A(1)                                                WB09 146
C                                                                      WB09 147
C CALCULATION OF THE REST OF SOURCE STRENGTHS USING EQUATION (86) IN   WB09 148
C WOODWARD AND LARSEN.                                                 WB09 149
C                                                                      WB09 150
      DO 210 I=2,N                                                     WB09 151
      XFIELD=XF(I)                                                     WB09 152
      RFIELD=RF(I)                                                     WB09 153
      SLOPE=DRDX(I)                                                    WB09 154
      BSQ=BETASQ*RFIELD*RFIELD                                         WB09 155
      X2=XFIELD-LBODY                                                  WB09 156
      DO 205 J=1,I                                                     WB09 157
      CALL SOURCE(J)                                                   WB09 158
  205 A(J)=V-SLOPE*U                                                   WB09 159
      SUM=0.                                                           WB09 160
      IM1=I-1                                                          WB09 161
      DO 201 J=1,IM1                                                   WB09 162
  201 SUM=T(J)*A(  J)+SUM                                              WB09 163
  210 T(I)=(DRDX(I)-SUM)/A(I)                                          WB09 164
      T(NXBODY)=0.0                                                    WB09 165
C                                                                      WB09 166
C     DETERMINATION OF DOUBLET STRENGTHS AT CONTROL POINTS MIDWAY      WB09 167
C      BETWEEN BODY DEFINITION POINTS                                  WB09 168
C                                                                      WB09 169
C CALCULATION OF THE FIRST DOUBLET STRENGYH.                           WB09 170
C                                                                      WB09 171
      IF (ABS(ALPHA).LT.1.0E-10) GO TO 798                             WB09 172
      XFIELD=XF(1)                                                     WB09 173
      RFIELD=RF(1)                                                     WB09 174
      SLOPE=DRDX(1)                                                    WB09 175
      BSQ=BETASQ*RFIELD*RFIELD                                         WB09 176
      X2=XFIELD-LBODY                                                  WB09 177
      CALL DOUBLT(1)                                                   WB09 178
      A(1)=SLOPE*U-V                                                   WB09 179
      TC(1)=ALPHA/A(1)                                                 WB09 180
C                                                                      WB09 181
C CALCULATION OF THE REST OF THE DOUBLET STRENGTHS USING EQUATION (90) WB09 182
C IN WOODWARD AND LARSEN.                                              WB09 183
C                                                                      WB09 184
      DO 215 I=2,N                                                     WB09 185
      XFIELD=XF(I)                                                     WB09 186
      RFIELD=RF(I)                                                     WB09 187
      SLOPE=DRDX(I)                                                    WB09 188
      BSQ=BETASQ*RFIELD*RFIELD                                         WB09 189
      X2=XFIELD-LBODY                                                  WB09 190
      DO 212 J=1,I                                                     WB09 191
      CALL DOUBLT(J)                                                   WB09 192
  212 A(  J)=SLOPE*U-V                                                 WB09 193
      SUM=0.                                                           WB09 194
      IM1=I-1                                                          WB09 195
      DO 203 J=1,IM1                                                   WB09 196
  203 SUM=TC(J)*A(  J)+SUM                                             WB09 197
  215 TC(I)=(ALPHA-SUM)/A(I)                                           WB09 198
      TC(NXBODY)=0.0                                                   WB09 199
  798 CONTINUE                                                         WB09 200
C                                                                      WB09 201
C PRINT OUT OF BODY CHARACTERISTICS                                    WB09 202
C                                                                      WB09 203
      WRITE(6,799)MACH                                                 WB09 204
      DO 800 I=1,NXBODY                                                WB09 205
  800 WRITE(6,801) I,XBODY(I),RBODY(I),RPBODY(I),TX(I),T(I),TC(I)      WB09 206
```

```
C
C COMPUTATION OF VELOCITIES INDUCED ON BODY BY BODY SOURCES AND
C DOUBLETS AT BODY DEFINITION POINTS.
C
      ALFAC=ALPHA*57.2957795
      WRITE(6,227)MACH,ALFAC
      DO 225 I=1,NXBODY
      COSTH=SQRT(1./(RPBODY(I)**2+1.))
      SINTH=SQRT(1.-COSTH*COSTH)
      XFIELD=XBODY(I)
      RFIELD=RBODY(I)
      IF(RFIELD.GT.0.  )GO TO 214
C
C  IF THE FIELD POINT IS ON THE AXIS, THEN WE SHIFT OUT TO AVOID THE
C   SINGULARITY IN THE VELOCITY FUNCTION ON THE AXIS.
C
      IF(I.EQ.NXBODY)GO TO 221
      RFIELD=RBODY(I+1)/10.
      XFIELD=XFIELD+(XBODY(I+1)-XBODY(I))/10.
      GO TO 214
  221 RFIELD=RBODY(I-1)/10.
      XFIELD=XFIELD-(XBODY(I)-XBODY(I-1))/10.
  214 BSQ=BETASQ*RFIELD*RFIELD
      X2=XFIELD-LBODY
      US=0.
      VS=0.
      UD=0.
      VD=0.
      VTD=0.
      DO 218 J=1,I
      CALL SOURCE(J)
      US=US+T(J)*U
      VS=VS+T(J)*V
      CALL DOUBLT(J)
      UD=UD+U*TC(J)
      VD=VD+V*TC(J)
  218 VTD=VTD+VT*TC(J)
      IF(RPBODY(I).LT.0.)GO TO 220
      VNS=VS*COSTH-(1.+US)*SINTH
      VND=(VD+ALPHA)*COSTH-UD*SINTH
      GO TO 222
  220 VNS=VS*COSTH+(1.+US)*SINTH
      VND=(VD+ALPHA)*COSTH+US*SINTH
  222 UBS(I)=US
      VBS(I)=VS
      UBD(I)=UD
      VBD(I)=VD
      VTBD(I)=VTD
  225 WRITE(6,6) I,XBODY(I),US,VS,VNS,UD,VD,VTD,VND
C
C CALCULATION AND PRINTOUT OF THE PRESSURE COEFFICIENT FOR BODY
C DEFINITION POINTS.
C
      IF (PCODE.EQ.0) RETURN
      GO TO (300,299,304)PCODE
  299 WRITE(6,301)
      GO TO 303
  300 WRITE(6,302)
      GO TO 303
  304 WRITE(6,305)
  303 SQ2=1./SQRT(2.)
      COEFF(1)=1.
      COEFF(2)=SQ2
      COEFF(3)=0.
      COEFF(4)=-SQ2
      COEFF(5)=-1.
      DO 330 I=1,NXBODY
      DO 320 J=1,5
  320 CPT(J)=CP(PCODE,I,J)
  330 WRITE(6,331)I,XBODY(I),(CPT(J),J=1,5)
      WRITE(6,306)
C
C COMPUTATION OF VELOCITIES INDUCED ON BODY BY BODY SOURCES AND DOUBLETS
C AT CONTROL POINTS AND PRINTOUT OF PRESSURES.
C
      DO 450 I=1,N
      XFIELD=XF(I)
      RFIELD=RF(I)
      RSQ=BETASQ*RFIELD*RFIELD
      X2=XFIELD-LBODY
      US=0.
      VS=0.
      UD=0.
      VD=0.
      VTD=0.
      DO 410 J=1,I
      CALL SOURCE(J)
      US=US+T(J)*U
      VS=VS+T(J)*V
      CALL DOUBLT(J)
      UD=UD+TC(J)*U
      VD=VD+TC(J)*V
  410 VTD=VTD+TC(J)*VT
      UBB(I)=US
      VBB(I)=VS
      UBD(I)=UD
      VBD(I)=VD
  450 VTBD(I)=VTD
      DO 350 I=1,N
      XBODY(I)=XF(I)
      DO 340 J=1,5
  340 CPT(J)=CP(PCODE,I,J)
  350 WRITE(6,331)I,XBODY(I),(CPT(J),J=1,5)
      RETURN
      END
```

```
      SUBROUTINE VELCAL(NDIM,ALPHA,BETA,NSTART)
C
C SUBROUTINE TO CALCULATE THE VELOCITIES FOR THE FIELD POINTS X,Y,Z DUE
C TO THE BODY SINGULARITIES.
C
C
      DIMENSION X(250)
C
      COMMON/SRCE/XFIELD,RFIELD,BSQ,X2,      U,V,VT
      COMMON/BSINGS/T(100),TC(100),TX(101)
      COMMON/BDYBLK/RNOSE,RADIUS,XA    ,LBODY,BCODE,NXBODY, ZZ(403)
      COMMON/VEL/XB,XC,BETASQ,XD
      COMMON /BVEL/U1(250),V1(250),W1(250)
      COMMON /THRUST/DMY(501),Y(250),DMM(760),XX(250),Z(250)
      COMMON /WBTR/XWLE
C
      EQUIVALENCE (X(1),ZZ(1))
C
      REAL LBODY
C
C
C     TRANSFORM X-COORDINATES INTO THE BODY SYSTEM
C
      DO 50 K=NSTART,NDIM
   50 X(K)=XX(K)+XWLE
      N=NXBODY-1
C
C CALCULATION OF COORDINATE ROTATION ANGLE.
C
      IF (ABS(ALPHA).LT.1.0E-04) GO TO 51
      PHI=ATAN(BETA/ALPHA)
      GO TO 52
   51 PHI=0.0
   52 CONTINUE
C
C CALCULATION OF VELOCITIES.
C
      DO 100 I=NSTART,NDIM
```

```
C
C TRANSFORMATION OF FIELD POINTS INTO THE NO-SIDESLIP COORDINATE SYSTEM,
C
      XFIELD=X(I)
      RFIELD=SQRT(Y(I)**2+Z(I)**2)
      THETA=ATAN2(Y(I),Z(I))
      THPLPH=THETA+PHI
      BSQ=BETASQ*RFIELD*RFIELD
      X2=XFIELD-LBODY
C
C CALCULATION OF AXIAL, RADIAL AND TANGENTIAL PERTURBATION VELOCITIES ON
C LEEWARD LINE OF SYMMETRY,
C
      US=0.
      VS=0.
      UD=0.
      VD=0.
      VTD=0.
      DO 110 J=1,N
      CALL SOURCE(J)
      US=US+T(J)*U
      VS=VS+T(J)*V
      CALL DOUBLT(J)
      UD=UD+U*TC(J)
      VD=VD+V*TC(J)
  110 VTD=VTD+VT*TC(J)
C
C TRANSFORMATION OF VELOCITIES INTO ORIGINAL COORDINATE SYSTEM...I.E....
C U,V,W, RATHER THAN U,VR,VTHETA.
C
      COSTH=COS(THPLPH)
      U1(I)=US+UD*COSTH
      VR=VD*COSTH+VS
      VTD=VTD*SIN(THPLPH)
      SINTH=SIN(THETA)
      COSTH=COS(THETA)
      V1(I)=VR*SINTH+VTD*COSTH
      W1(I)=VR*COSTH-VTD*SINTH
      IF (ABS(U1(I)).LT.1.0E-06) U1(I)=0.0
      IF (ABS(V1(I)).LT.1.0E-06) V1(I)=0.0
      IF (ABS(W1(I)).LT.1.0E-06) W1(I)=0.0
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE DOUBLT(J)
C
C SUBROUTINE TO CALCULATE THE VELOCITIES DUE TO A LINEAR LINE DOUBLET OF
C UNIT SLOPE WITH ORIGIN AT TX(J).
C SOLUTIONS GIVEN BY WOODWARD AND LARSEN (BOING REPT. D6-10741),EQUATION
C (56) OR ANTONIO FERRI, %ELEMENTS OF AERODYNAMICS OF SUPERSONIC FLOWS,%
C EQUATION (404).
C
      COMMON/BODYBLK/RNOSE,RADIUS,XA,XB,      BCODE,NXBODY, ZZ(403)
      COMMON/BSINGS/T(100),TC(100),TX(101)
      COMMON/SRCE/XFIELD,RFIELD,BSQ,X2,     U,V,VT
      COMMON/VEL/XC,XD,      BETASQ,BETA
C
C
  100 FORMAT(1H0,59HFIELD POINT IS WITHIN TAIL MACH CONE.  U AND V SET T
     10 ZERO.)
C
C
      X1=XFIELD-TX(J)
      BR=BETA*RFIELD
      IF(X1.LE.BR    )GO TO 10
      IF(X2.LE.BR    )GO TO 21
      WRITE(6,100)
      GO TO 10
   21 XBR=X1/BR
      XX=SQRT(XBR*XBR-1.)
      U=BETA*XX
      ACOSH=ALOG(XBR+XX)
      XX=XBR*XX
      V= .5*BETASQ*(ACOSH+XX)
      VT=-.5*BETASQ*(ACOSH-XX)
      RETURN
C
C FIELD POINT IS AHEAD OF MACH CONE FROM DOUBLET ORIGIN.
C
   10 U=0.
      V=0.
      VT=0.
      RETURN
      END
```

```
      FUNCTION CP(M,I,J)
C
      COMMON/VEL/MACH,MACHSQ,BETASQ,BETA
      COMMON/CPFN/UBS(101),VBS(101),UBD(101),VBD(101),VTBD(101),COEFF(5)
C
      REAL MACH,MACHSQ
      GO TO (1,2,3)M
C
C LINEAR THEORY TO FIRST ORDER.
C
    1 CP=-2.*(UBS(I)+UBD(I)*COEFF(J))
      RETURN
C
C BLENDER BODY THEORY TO FIRST ORDER.
C
    2 CP=-2.*(UBS(I)+UBD(I)*COEFF(J))+VBS(I)**2
      RETURN
C
C LINEAR THEORY TO SECOND ORDER.
C
    3 U=UBS(I)+UBD(I)*COEFF(J)
      VR=VBS(I)+VBD(I)*COEFF(J)
      VTHSQ=VTBD(I)**2*(1.-COEFF(J)**2)
      CP=-2.*U-BETASQ*U*U-VR*VR-VTHSQ
      RETURN
      END
```

```
      SUBROUTINE BODYR(X,R,RPRIME)
C
C SUBROUTINE FOR THE CALCULATION OF BODY RADII AND SLOPE.  THE INTEGER
C VARIABLE BCODE CONTROLS THE TYPE OF NOSE DEFINITION
C     BCODE=0   PARABOLIC BODY
C     BCODE=1   BEARS-MAACK-ADAMS BODY
C     BCODE=2   TANGENT OGIVE
C     BCODE=3   ELLIPSOIDAL BODY
C     BCODE=4   CONICAL BODY
C  CODE DEVELOPED BY RALPH CARMICHAEL - AMES RESEARCH CENTER.  MODIFIED
C   BY MICHAEL HEMSCH - NEAR, INC. - MAY 1, 1974
C
      COMMON/BODYBLK/RNOSE,RADIUS,LNOSE,LBODY,BCODE,NXBODY, ZZ(403)
C
      REAL LNOSE,LBODY
      INTEGER BCODE
C
      IF(X.LE.LNOSE) GO TO 20
C
C CYLINDRICAL SECTION OF BODY
C
      R=RADIUS
      RPRIME=0.
      RETURN
C
```

```
C NOSE SECTION
C
   20 XX=(LNOSE-X)/LNOSE
      RR=RADIUS*RNOSE
      IF(BCODE.GT.0)GO TO 22
C
C PARABOLIC NOSE
C
      R=RNOSE+RR*(1.-XX*XX)
      RPRIME=RR/LNOSE*2.*XX
      RETURN
   22 GO TO(23,24,25,26),BCODE
C
C SEARS-HAACK-ADAMS FOREBODY
C
   23 IF(XX.GT.9.999E-1) GO TO 223
      XY=1.-XX*XX
      PHI=XY**.75
      R=RNOSE+RR*PHI
      RPRIME=RR/LNOSE*1.5*XX*PHI/XY
      RETURN
  223 R=RNOSE
      RPRIME=1.E9
      RETURN
C
C TANGENT OGIVE NOSE
C
   24 RL=RR/LNOSE
      RDL=.5*(1.+RL*RL)/RL
      XY=SQRT(RDL*RDL-XX*XX)
      R=RADIUS-LNOSE*(RDL-XY)
      RPRIME=XX/XY
      RETURN
C
C ELLIPSOID FOREBODY
C
   25 IF(XX.GT.9.999E-1) GO TO 223
      PHI=SQRT(1.-XX*XX)
      R=RNOSE+RR*PHI
      RPRIME=RR/LNOSE*XX/PHI
      RETURN
C
C CONE FOREBODY
C
   26 R=RNOSE+RR*(1.-XX)
      RPRIME=RR/LNOSE
      RETURN
      END
```

```
      SUBROUTINE SOURCE(J)
C
C SUBROUTINE TO CALCULATE THE VELOCITIES DUE TO A LINEAR LINE SOURCE OF
C UNIT SLOPE WITH ORIGIN AT TX(J).
C SOLUTIONS GIVEN BY WOODWARD AND LARSEN (BOING REPT. D6-10741),EQUATION
C (53) OR ANTONIO FERRI, %ELEMENTS OF AERODYNAMICS OF SUPERSONIC FLOWS,%
C EQUATION (378).
C
      COMMON/BDYBLK/RNOSE,RADIUS,XA,XB,      BCODE,NXBODY, ZZ(403)
      COMMON/BSINGS/T(100),TC(100),TX(101)
      COMMON/BRCE/XFIELD,RFIELD,BSQ,X2,      U,V,VT
      COMMON/VEL/XC,XD,      BETASQ,BETA
C
C
  100 FORMAT(1H0,59HFIELD POINT IS WITHIN TAIL MACH CONE,  U AND V SET T
     10 ZERO.)
C
      X1=XFIELD-TX(J)
      BR=BETA*RFIELD
      IF(X1.LE.BR) GO TO 10
      IF(X2.LE.BR)GO TO 11
      WRITE(6,100)
      GO TO 10
   11 XL=X1/BR
      D23= SQRT(XL*XL-1.)
      U=-ALOG(XL+D23)
      V=BETA*D23
      RETURN
C
C FIELD POINT IS AHEAD OF MACH CONE FROM SOURCE ORIGIN.
C
   10 U=0.
      V=0.
      RETURN
      END
```

```
      SUBROUTINE SPECPR
C
C     THIS SUBROUTINE COMPUTES EXACT,SECOND ORDER ,FIRST ORDER AND
C     EXTENDED LINEAR PRESSURES AT CONTROL POINTS ON THE WING SURFACES
C     EXACT MEANS BERNOULLI
C
C
      DIMENSION PRESSU(250),
     1PRESSD(250),PRESSR(250),PRESSL(250),PRESU2(250),PRESD2(250),
     2PRESR2(250),PRESL2(250),PRESU3(250),PRESD3(250),PRESR3(250),
     1PRESL3(250),PRESU1(250),PRESD1(250),PRESR1(250),PRESL1(250)
C
      LOGICAL BODY
C
      COMMON/NONLIN/NWBP,NOLINP,TOTLR,BODY,ALFR,NOUT,NPRESS,NOCPT,NDRAG
      COMMON/BVEL/BDU(250),BDV(250),BDW(250)
      COMMON/VWNDR/DUM1(1501),UCHK,VCHK,WCHK,II,IF,CONST,BETAR,DUM2(2)
      COMMON/IPR/NPR,I,K
      COMMON/PRESS/DELTP(250),DUM3(1500),COSALF,NPANLS,ARWING,FMACH,
     1DUM4(251),SINALF,DELTA
      COMMON/THRUST/CN,DUM5(500),YCPT(250),DUM6(756 ),NHP,DUM7(3),
     1XCPT(250),ZCPT(250)
      COMMON/VELARG/DUM8(8),BETA,DUM9(3)
      COMMON/CRUX/NCRX
      COMMON/SPCPRS/DLTP(250),DLTP2(250),DLTP3(250),DLTP1(250)
      COMMON/SPSANG/SINALC,COSALC,SINPHI,COSPHI
      COMMON/VRTXV/VVRTX(250),WVRTX(250),NVRTPL,NVRTX
C
      EQUIVALENCE (PRESL1(1),DUM4(2)),(PRESL2(1),DUM5(201)),(PRESL3(1),
     1DUM6(201))
C
C
  720 FORMAT (1X,I3,10(2X,E11.4))
  732 FORMAT (////15X,84HVELOCITIES AND PRESSURES AT CONTROL POINTS IMME
     1DIATELY ABOVE HORIZONTAL WING SURFACE//
     1 2X,1HJ,7X,4HX(J),8X,4HY(J),8X,4HZ(J),10X,4HUTOT,8X,4HVTOT,8X,
     24HWTOT,5X,14HCP,UPPER EXACT,2X,10HCP 2NDORD.,3X,7HCP,UBAR,6X,
     310HCP,18TORD./)
  733 FORMAT (//////,15X,84HVELOCITIES AND PRESSURES AT CONTROL POINTS IM
     1MEDIATELY BELOW HORIZONTAL WING SURFACE//
     1 2X,1HJ,7X,4HX(J),8X,4HY(J),8X,4HZ(J),10X,4HUTOT,8X,4HVTOT,8X,
     24HWTOT,5X,14HCP,LOWER EXACT,2X,10HCP 2NDORD.,3X,7HCP,UBAR,6X,
     310HCP,18TORD./)
  734 FORMAT (////15X,88HVELOCITIES AND PRESSURES AT CONTROL POINTS IMME
     1DIATELY TO RIGHT OF VERTICAL WING SURFACE//
     1 2X,1HJ,7X,4HX(J),8X,4HY(J),8X,4HZ(J),10X,4HUTOT,8X,4HVTOT,8X,
     24HWTOT,5X,14HCP,RIGHT EXACT,2X,10HCP 2NDORD.,3X,7HCP,UBAR,6X,
```

```
     310HCP,1STORD,/)
 735 FORMAT (//////,15X,87HVELOCITIES AND PRESSURES AT CONTROL POINTS I
     1MMEDIATELY TO LEFT OF VERTICAL WING SURFACE//
     1 2X,1HJ,7X,4HX(J),8X,4HY(J),8X,4HZ(J),10X,4HUTOT,8X,4HVTOT,8X,
     24HWTOT,5X,14HCP,LEFT  EXACT,2X,10HCP 2NDORD,,3X,7HCP UBAR,6X,
     310HCP,1STORD,/)
 736 FORMAT (////35HPRESSURE LOADINGS AT CONTROL POINTS//
     1 2X,1HJ,7X,4HX(J),8X,4HY(J),8X,4HZ(J),5X,10HDELTP,LIN.,5X,
     110HDELTP UBAR,3X,13HDELTP,1STORD,,1X,
     213HDELTP 2NDORD,,1X,11HDELTP,EXACT/)
 737 FORMAT (1H1,77HPRESSURE LOADINGS EXCLUDE VORTEX INDUCED COMPONENTS
     1 PARALLEL TO WING SURFACES//)
 738 FORMAT (1H1,77HPRESSURE LOADINGS INCLUDE VORTEX INDUCED COMPONENTS
     1 PARALLEL TO WING SURFACES//)
C
C
      NOCPT=1
      NHP1=NHP+1
      NPNLS1=NPANLS+1
      IF (NVRTX.NE.0.AND.NVRTPL.EQ.0) WRITE (6,737)
      IF (NVRTX.NE.0.AND.NVRTPL.EQ.1) WRITE (6,738)
C
C     TREAT POINTS IMMEDIATELY ABOVE HORIZONTAL WING SURFACE
C
      IF (NOUT.NE.0) WRITE (6,732)
C
C     BODY SOURCE AND SINK CONTRIBUTION ALREADY CALCULATED AT WING
C     SURFACE CONTROL POINTS IN PROGRAM CRFWBD
C     VORTEX VELOCITIES ALSO ALREADY CALCULATED IN PROGRAM CRFWBD
C
C
C     WING SURFACES AND BODY INTRFERENCE PANELS CONTRIBUTION
C
      BETASQ=BETA*BETA
      FACTR1=1.428571429/(FMACH*FMACH)
      FACTR2=0.2*FMACH*FMACH
C
      DO 807 K=1,NHP
      VADVRT=VVRTX(K)
      IF (NVRTX.NE.0.AND.NVRTPL.EQ.0) VADVRT=0.0
      II=K
      IF=K
      CALL VELNOR(XCPT(K),YCPT(K),ZCPT(K))
      UTOT=UCHK+BDU(K)
      VTOT=VCHK+BDV(K)+VADVRT
      WTOT=     BDW(K)+WVRTX(K)
      II=1
      IF=NHP
      CALL VELNOR(XCPT(K),YCPT(K),ZCPT(K))
      WTOT=WTOT+WCHK
      IF (NHP.EQ.NWBP) GO TO 801
      II=NHP1
      IF=NWBP
      CALL VELNOR(XCPT(K),YCPT(K),ZCPT(K))
      UTOT=UTOT+UCHK
      VTOT=VTOT+VCHK
      WTOT=WTOT+WCHK
 801  CONTINUE
      BDUSQ=UTOT*UTOT
      BDVSQ=VTOT*VTOT
      BDWSQ=WTOT*WTOT
      UBAR=UTOT  *COSALC-VTOT  *SINALC*SINPHI+WTOT  *SINALC*COSPHI
      VBAR=VTOT  *COSPHI+WTOT  *SINPHI
      WBAR=-UTOT  *SINALC-VTOT  *COSALC*SINPHI+WTOT  *COSALC*COSPHI
      ARG=1.0-FACTR2*(2.0*UBAR+BDUSQ+BDVSQ+BDWSQ)
      IF (ARG.LT.1.0E-05) GO TO 900
      GO TO 901
 900  PRESSU(K)=-FACTR1
      GO TO 902
 901  PRESSU(K)=FACTR1*(ARG**3.5-1.0)
 902  BDUSQ=UBAR*UBAR
      BDVSQ=VBAR*VBAR
      BDWSQ=WBAR*WBAR
      PRESU1(K)=-2.0*UBAR-BDVSQ-BDWSQ
      PRESU2(K)=-2.0*UBAR+BETASQ*BDUSQ-BDVSQ-BDWSQ
      PRESU3(K)=-2.0*UBAR
      IF (NOUT.EQ.0) GO TO 807
      WRITE (6,720) K,XCPT(K),YCPT(K),ZCPT(K),UTOT,VTOT,WTOT,
     1PRESSU(K),PRESU2(K),PRESU3(K),PRESU1(K)
 807  CONTINUE
C
C     TREAT POINTS IMMEDIATELY BELOW HORIZONTAL WING SURFACE
C
      IF (NOUT.NE.0) WRITE (6,733)
C
C
      DO 810 K=1,NHP
      VADVRT=VVRTX(K)
      IF (NVRTX.NE.0.AND.NVRTPL.EQ.0) VADVRT=0.0
      II=K
      IF=K
      CALL VELNOR(XCPT(K),YCPT(K),ZCPT(K))
      UTOT=-UCHK+BDU(K)
      VTOT=-VCHK+BDV(K)+VADVRT
      WTOT=     BDW(K)+WVRTX(K)
      II=1
      IF=NHP
      CALL VELNOR(XCPT(K),YCPT(K),ZCPT(K))
      WTOT=WTOT+WCHK
      IF (NHP.EQ.NWBP) GO TO 802
      II=NHP1
      IF=NWBP
      CALL VELNOR(XCPT(K),YCPT(K),ZCPT(K))
      UTOT=UTOT+UCHK
      VTOT=VTOT+VCHK
      WTOT=WTOT+WCHK
 802  CONTINUE
      BDUSQ=UTOT*UTOT
      BDVSQ=VTOT*VTOT
      BDWSQ=WTOT*WTOT
      UBAR=UTOT  *COSALC-VTOT  *SINALC*SINPHI+WTOT  *SINALC*COSPHI
      VBAR=VTOT  *COSPHI+WTOT  *SINPHI
      WBAR=-UTOT  *SINALC-VTOT  *COSALC*SINPHI+WTOT  *COSALC*COSPHI
      ARG=1.0-FACTR2*(2.0*UBAR+BDUSQ+BDVSQ+BDWSQ)
      IF (ARG.LT.1.0E-05) GO TO 910
      GO TO 911
 910  PRESSD(K)=-FACTR1
      GO TO 912
 911  PRESSD(K)=FACTR1*(ARG**3.5-1.0)
 912  BDUSQ=UBAR*UBAR
      BDVSQ=VBAR*VBAR
      BDWSQ=WBAR*WBAR
      PRESD1(K)=-2.0*UBAR-BDVSQ-BDWSQ
      PRESD2(K)=-2.0*UBAR+BETASQ*BDUSQ-BDVSQ-BDWSQ
      PRESD3(K)=-2.0*UBAR
      IF (NOUT.EQ.0) GO TO 810
      WRITE (6,720) K,XCPT(K),YCPT(K),ZCPT(K),UTOT,VTOT,WTOT,
     1PRESSD(K),PRESD2(K),PRESD3(K),PRESD1(K)
 810  CONTINUE
C
C     TREAT POINTS IMMEDIATELY TO THE RIGHT OF VERTICAL WING SURFACE
C
      IF (NCRX.EQ.0) GO TO 841
      IF (NOUT.NE.0) WRITE (6,734)
C
C
      DO 813 K=NHP1,NPANLS
      WADVRT=WVRTX(K)
      IF (NVRTX.NE.0.AND.NVRTPL.EQ.0) WADVRT=0.0
      II=K
      IF=K
      CALL VELNOR(XCPT(K),YCPT(K),ZCPT(K))
      UTOT=-UCHK+BDU(K)
      VTOT=     BDV(K)+VVRTX(K)
      WTOT=-WCHK+BDW(K)+WADVRT
      II=NHP1
      IF=NPANLS
      CALL VELNOR(XCPT(K),YCPT(K),ZCPT(K))
      VTOT=VTOT+VCHK
      IF (NPANLS.EQ.NWBP) GO TO 803
      II=NPNLS1
      IF=NWBP
      CALL VELNOR(XCPT(K),YCPT(K),ZCPT(K))
      UTOT=UTOT+UCHK
```

```
      VTOT=VTOT+VCHK                                                    WB15 202
      WTOT=WTOT+WCHK                                                    WB15 203
  803 CONTINUE                                                          WB15 204
      BDUSQ=UTOT*UTOT                                                   WB15 205
      BDVSQ=VTOT*VTOT                                                   WB15 206
      BDWSQ=WTOT*WTOT                                                   WB15 207
      UBAR=UTOT  *COSALC-VTOT  *SINALC*SINPHI+WTOT  *SINALC*COSPHI      WB15 208
      VBAR=VTOT  *COSPHI+WTOT  *SINPHI                                  WB15 209
      WBAR=-UTOT  *SINALC-VTOT  *COSALC*SINPHI+WTOT  *COSALC*COSPHI     WB15 210
      ARG=1.0-FACTR2*(2.0*UBAR+BDUSQ+BDVSQ+BDWSQ)                       WB15 211
      IF (ARG.LT.1.0E-05) GO TO 920                                     WB15 212
      GO TO 921                                                         WB15 213
  920 PRESSR(K)=-FACTR1                                                 WB15 214
      GO TO 922                                                         WB15 215
  921 PRESSR(K)=FACTR1*(ARG**3.5-1.0)                                   WB15 216
  922 BDUSQ=UBAR*UBAR                                                   WB15 217
      BDVSQ=VBAR*VBAR                                                   WB15 218
      BDWSQ=WBAR*WBAR                                                   WB15 219
      PRESR1(K)=-2.0*UBAR-BDVSQ-BDWSQ                                   WB15 220
      PRESR2(K)=-2.0*UBAR+BETASQ*BDUSQ-BDVSQ-BDWSQ                      WB15 221
      PRESR3(K)=-2.0*UBAR                                               WB15 222
      IF (NOUT.EQ.0) GO TO 813                                          WB15 223
      WRITE (6,720) K,XCPT(K),YCPT(K),ZCPT(K),UTOT,VTOT,WTOT,           WB15 224
     1PRESSR(K),PRESR2(K),PRESR3(K),PRESR1(K)                           WB15 225
  813 CONTINUE                                                          WB15 226
C                                                                       WB15 227
C     TREAT POINTS IMMEDIATELY TO THE LEFT OF VERTICAL WING SURFACE     WB15 228
C                                                                       WB15 229
      IF (NOUT.NE.0) WRITE (6,735)                                      WB15 230
C                                                                       WB15 231
C                                                                       WB15 232
      DO 816 K=NHP1,NPANLS                                              WB15 233
      WADVRT=WVRTX(K)                                                   WB15 234
      IF (NVRTX.NE.0.AND.NVRTPL.EQ.0) WADVRT=0.0                        WB15 235
      II=K                                                              WB15 236
      IF=K                                                              WB15 237
      CALL VELNOR(XCPT(K),YCPT(K),ZCPT(K))                              WB15 238
      UTOT=UCHK+BDU(K)                                                  WB15 239
      VTOT=      BDV(K)+VVRTX(K)                                        WB15 240
      WTOT=WCHK+BDW(K)+WADVRT                                           WB15 241
      IF=NPANLS                                                         WB15 242
      II=NHP1                                                           WB15 243
      CALL VELNOR(XCPT(K),YCPT(K),ZCPT(K))                              WB15 244
      VTOT=VTOT+VCHK                                                    WB15 245
      IF (NPANLS.EQ.NWBP) GO TO 804                                     WB15 246
      II=NPNLS1                                                         WB15 247
      IF=NWBP                                                           WB15 248
      CALL VELNOR(XCPT(K),YCPT(K),ZCPT(K))                              WB15 249
      UTOT=UTOT+UCHK                                                    WB15 250
      VTOT=VTOT+VCHK                                                    WB15 251
      WTOT=WTOT+WCHK                                                    WB15 252
  804 CONTINUE                                                          WB15 253
      BDUSQ=UTOT*UTOT                                                   WB15 254
      BDVSQ=VTOT*VTOT                                                   WB15 255
      BDWSQ=WTOT*WTOT                                                   WB15 256
      UBAR=UTOT  *COSALC-VTOT  *SINALC*SINPHI+WTOT  *SINALC*COSPHI      WB15 257
      VBAR=VTOT  *COSPHI+WTOT  *SINPHI                                  WB15 258
      WBAR=-UTOT  *SINALC-VTOT  *COSALC*SINPHI+WTOT  *COSALC*COSPHI     WB15 259
      ARG=1.0-FACTR2*(2.0*UBAR+BDUSQ+BDVSQ+BDWSQ)                       WB15 260
      IF (ARG.L7.1.0E-05) GO TO 930                                     WB15 261
      GO TO 931                                                         WB15 262
  930 PRESSL(K)=-FACTR1                                                 WB15 263
      GO TO 932                                                         WB15 264
  931 PRESSL(K)=FACTR1*(ARG**3.5-1.0)                                   WB15 265
  932 BDUSQ=UBAR*UBAR                                                   WB15 266
      BDVSQ=VBAR*VBAR                                                   WB15 267
      BDWSQ=WBAR*WBAR                                                   WB15 268
      PRESL1(K)=-2.0*UBAR-BDVSQ-BDWSQ                                   WB15 269
      PRESL2(K)=-2.0*UBAR+BETASQ*BDUSQ-BDVSQ-BDWSQ                      WB15 270
      PRESL3(K)=-2.0*UBAR                                               WB15 271
      IF (NOUT.EQ.0) GO TO 816                                          WB15 272
      WRITE (6,720) K,XCPT(K),YCPT(K),ZCPT(K),UTOT,VTOT,WTOT,           WB15 273
     1PRESSL(K),PRESL2(K),PRESL3(K),PRESL1(K)                           WB15 274
  816 CONTINUE                                                          WB15 275
  841 CONTINUE                                                          WB15 276
C                                                                       WB15 277
C                                                                       WB15 278
C     CALCULATE PRESSURE DIFFERENCES AT CONTROL POINTS                  WB15 279
C                                                                       WB15 280
      WRITE (6,736)                                                     WB15 281
      DO 821 K=1,NPANLS                                                 WB15 282
      IF (K.LE.NHP) GO TO 822                                           WB15 283
      GO TO  823                                                        WB15 284
  822 DLTP(K)=PRESSD(K)-PRESSU(K)                                       WB15 285
      DLTP1(K)=PRESD1(K)-PRESU1(K)                                      WB15 286
      DLTP2(K)=PRESD2(K)-PRESU2(K)                                      WB15 287
      DLTP3(K)=PRESD3(K)-PRESU3(K)                                      WB15 288
      GO TO 824                                                         WB15 289
  823 DLTP(K)=PRESSR(K)-PRESSL(K)                                       WB15 290
      DLTP1(K)=PRESR1(K)-PRESL1(K)                                      WB15 291
      DLTP2(K)=PRESR2(K)-PRESL2(K)                                      WB15 292
      DLTP3(K)=PRESR3(K)-PRESL3(K)                                      WB15 293
  824 CONTINUE                                                          WB15 294
  821 WRITE (6,720) K,XCPT(K),YCPT(K),ZCPT(K),DELTP(K),DLTP3(K),        WB15 295
     1DLTP1(K),                                          DLTP2(K),DLTP(K) WB15 296
C                                                                       WB15 297
C     CALCULATE WING LOADINGS DUE TO THE EXACT LOADING PRESSURES        WB15 298
C                                                                       WB15 299
      NPRESS=1                                                          WB15 300
      CALL SPECLD                                                       WB15 301
C                                                                       WB15 302
C                                                                       WB15 303
      RETURN                                                            WB15 304
      END                                                               WB15 305
```

```
      SUBROUTINE VRTVEL(NSTART,N)                                       WB16   1
C                                                                       WB16   2
C     THIS SUBROUTINE READS IN UP TO 10 VORTEX STRENGHTS AND THEIR      WB16   3
C     LOCATIONS  IN THE CROSSFLOW PLANE                                 WB16   4
C     Y IS TO THE RIGHT WHEN VIEWING FORWARDS, Z IS UP                  WB16   5
C     VORTEX INDUCED VELOCITIES ARE NAMED VVRTX,WVRTX                   WB16   6
C                                                                       WB16   7
      DIMENSION  GAMMA(10),YVRTX(10),ZVRTX(10)                          WB16   8
C                                                                       WB16   9
      COMMON/NONLIN/DUM(5),NOUT,DUM1(3)                                 WB16  10
      COMMON/THRUST/DUM2(501),YCPT(250),DUM3(750),NCW,DUM8(9),          WB16  11
     1XCPT(250),ZCPT(250)                                               WB16  12
      COMMON/PRESS/DUM4(1751),NPANLS,DUM5(255)                          WB16  13
      COMMON/TRANS/DUM6,RB,DUM7(602)                                    WB16  14
      COMMON/VRTXV/VVRTX(250),WVRTX(250),NVRTPL,NVRTX                   WB16  15
C                                                                       WB16  16
    1 FORMAT (8F10.5)                                                   WB16  17
    2 FORMAT (1H1,10X,73HLINE VORTEX NON-DIMENSIONAL STRENGHTS AND COORDWB16  18
     1INATES IN CROSS FLOW PLANE//15X,1HI,10X,6HGAMMA/,23X,2HY/,17X,    WB16  19
     22HZ/,,24X,23H(2.0*PI*BODY RAD,*VINF),5X,11H(BODY RAD.),8X,        WB16  20
     311H(BODY RAD.)//)                                                 WB16  21
    3 FORMAT (15X,I2,8X,F10.5,17X,F10.5,9X,F10.5)                       WB16  22
C                                                                       WB16  23
C     READ IN NON-DIMENSIONALIZED VORTEX STRENGHTS,GAMMA=GAMMA/         WB16  24
C     (2*PI*BODY RADIUS*VINF)                                           WB16  25
C     AND NON-DIMENSIONALIZED LOCATIONS,YVRTX/BODY RADIUS,              WB16  26
C     ZVRTX/BODY RADIUS                                                 WB16  27
C                                                                       WB16  28
      WRITE (6,2)                                                       WB16  29
      DO 100 I=1,NVRTX                                                  WB16  30
      READ (5,1) GAMMA(I),YVRTX(I),ZVRTX(I)                             WB16  31
      WRITE (6,3) I,GAMMA(I),YVRTX(I),ZVRTX(I)                          WB16  32
  100 CONTINUE                                                          WB16  33
C                                                                       WB16  34
C     COMPUTE VORTEX INDUCED PERTURBATION VELOCITIES AT CONTROL POINTS  WB16  35
C     OF ALL WING SURFACES                                              WB16  36
C     CONTRIBUTION DUE TO EXTERNAL VORTEX,...,VVRTXE,WVRTXE             WB16  37
C     CONTRIBUTION DUE TO IMAGE    VORTEX,...,VVRTXI,WVRTXI             WB16  38
```

```
C     CONTRIBUTION DUE TO CENTER   VORTEX,...,VVRTXC,WVRTXC
C     ENTER HERE IF VORTICES HAVE BEEN READ IN ALREADY
C
      ENTRY VORTEX
C
      DO 101 IC=NSTART,N,NCW
      Y=YCPT(IC)/RB
      YS=Y*Y
      Z=ZCPT(IC)/RB
      ZS=Z*Z
      DENOM=YS+ZS
      VVRTX(IC)=0.0
      WVRTX(IC)=0.0
      DO 102 JV=1,NVRTX
      ZVSYVS=ZVRTX(JV)*ZVRTX(JV)+YVRTX(JV)*YVRTX(JV)
      DELTY=Y-YVRTX(JV)
      DELTYB=DELTY*DELTY
      DELTZ=Z-ZVRTX(JV)
      DELTZS=DELTZ*DELTZ
      DENOM1=DELTYB+DELTZS
      VVRTXE=-GAMMA(JV)*(DELTZ/DENOM1)
      WVRTXE= GAMMA(JV)*(DELTY/DENOM1)
      DENOM2=(Y-YVRTX(JV)/ZVSYVS)**2+(Z-ZVRTX(JV)/ZVSYVS)**2
      VVRTXI=GAMMA(JV)*(Z-ZVRTX(JV)/ZVSYVS)/DENOM2
      WVRTXI=-GAMMA(JV)*(Y-YVRTX(JV)/ZVSYVS)/DENOM2
      VVRTXC=0.0
      WVRTXC=0.0
      VVRTX(IC)=VVRTX(IC)+VVRTXE+VVRTXI+VVRTXC
      WVRTX(IC)=WVRTX(IC)+WVRTXE+WVRTXI+WVRTXC
  102 CONTINUE
  101 CONTINUE
C
C     FILL UP THE ARRAY
C     NOTE: VELOCITIES ARE THE SAME FOR EACH CHORDWISE ROW
C
      NCWM1=NCW-1
      DO 103 IC=NSTART,N,NCW
      DO 103 K=1,NCWM1
      ICR=IC+K
      VVRTX(ICR)=VVRTX(IC)
      WVRTX(ICR)=WVRTX(IC)
  103 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE OUT(A,N)
      DIMENSION A(N,N)
    1 FORMAT(10(1X,E11.4))
    2 FORMAT (1H )
      DO 100 I=1,N
      WRITE (6,1) (A(I,J),J=1,N)
  100 WRITE(6,2)
      RETURN
      END
```

REFERENCES

A-1. Nielsen Engineering & Research, Inc. Supersonic Lifting-Surface Computer Program for Cruciform Wing-Body Combinations in Combined Pitch and Sideslip, by M. F. E. Dillenius and J. N. Nielsen. Mountain View, Calif., NEAR, September 1974. (NEAR TR 74.)

A-2. ———. The Induced Rolling Moments of Canard-Cruciform Missiles as Influenced by Canard and Body Vortices, by J. N. Nielsen, M. J. Hemsch, and M. F. E. Dillenius. Mountain View, Calif., NEAR, January 1975. (NEAR TR 79.)

A-3. Nielsen, J. N. Missile Aerodynamics. New York, N. Y., McGraw-Hill Book Co., 1960. p. 5.

A-4. Naval Weapons Center. AIM-9L Wind Tunnel Test Report, by E. M. Piper and A. E. Brown. China Lake, Calif., NWC, October 1972. (NWC TN 4063-233.)

Item No. 1: Format (20A4), any alphabetic or numeric information.
(1 card)

Column Number	1-80
Program Variable	HEAD
Data	

Item No. 2: Namelist INPUT, start in column 2 with any variable and its value in appropriate format.

(1)

Column Number	2 10	20	
Program Variable			
Data	$INPUT		

(2)

Column Number	2 10	20	30	40	
Program Variable	CRP	SWLEP			
Data	CRP=X.X,	SWLEP=XX.XX, etc.			

(3)

Column Number	2 10	20	
Program Variable			
Data	$END		

FIG. A-1(a). Input Formats for Cruciform Wing-Body Computer Program.

Item No. 3 (option): Format (3F10.5)

(MSWRP cards)

(1)

Column Number	10	20	30	40	50	
Program Variable	YR(1)	VSWLER(1)	VSWTER(1)			
Data	0.0	0.0	0.0			

(MSWRP)

Column Number	10	20	30	40	50	
Program Variable	YR(MSWRP)	VSWLER (MSWRP)	VSWTER (MSWRP)			
Data						

Item No. 4 (option): Format (3F10.5), decimal point required.

(MSWRP cards)

(1)

Column Number	10	20	30	40	50	
Program Variable	YRT(1)	VSWLER(1)	VSWTER(1)			
Data		0.0	0.0			

(MSWRP)

Column Number	10	20	30	40	50	
Program Variable	YRT(MSWRP)	VSWLER (MSWRP)	VSWTER (MSWRP)			
Data						

FIG. A-1(b). Continued.

Item No. 5 (option): Format (3F10.5)

(MSWLP cards) (1)

Column Number	10	20	30	40	50	
Program Variable	YLT(1)	VSWLEL (1)	VSWTEL (1)			
Data		0.0	0.0			

(MSWLP)

Column Number	10	20	30	40	50	
Program Variable	YLT (MSWLP)	VSWLEL (MSWLP)	VSWTEL (MSWLP)			
Data						

Item No. 6 (option): Format (3F10.5), decimal point required.

(MSWUP cards) (1)

Column Number	10	20	30	40	50	
Program Variable	ZUT(1)	VSWLEU(1)	VSWTEU(1)			
Data		0.0	0.0			

(MSWUP)

Column Number	10	20	30	40	50	
Program Variable	ZUT (MSWUP)	VSWLEU (MSWUP)	VSWTEU (MSWUP)			
Data						

FIG. A-1(c). Continued.

Item No. 7 (option): Format (3F10.5)

(MSWDP cards) (1)

Column Number	10	20	30	40	50	
Program Variable	ZDT(1)	VSWLED(1)	VSWTED(1)			
Data		0.0	0.0			

(MSWDP)

Column Number	10	20	30	40	50	
Program Variable	ZDT (MSWDP)	VSWLED (MSWDP)	VSWTED (MSWDP)			
Data						

FIG. A-1(d). Continued.

Item No. 8 (option): Namelist BODY, start in column 2 with any variable and its variable in appropriate format.

(1)

Column Number	2 10	20	
Program Variable			
Data	$INPUT		

(2)

Column Number	2 10	20	30	40	
Program Variable					
Data	NXBODY=xx,LNOSE=xx.xx, etc.				

(3)

Column Number	2 10	20	
Program Variable			
Data	$END		

FIG. A-1(e). Continued.

Item No. 9 (option): Format (8F 10.5)

(NVRTX cards)

(1)

Column Number	10	20	30	40	50	
Program Variable	GAMMA(1)	YVRTX(1)	ZVRTX(1)			
Data						

(NVRTX)

Column Number	10	20	30	40	50	
Program Variable	GAMMA (NVRTX)	YVRTX (NVRTX)	ZVRTX (NVRTX)			
Data						

FIG. A-1(f). Continued.

Item No. 10: Format (20A4)

(1 cards) (1)

Column No.	10	20	30	40	50	
Program Variable						
Data	ZZZZ					

FIG. A-1(g). Concluded.

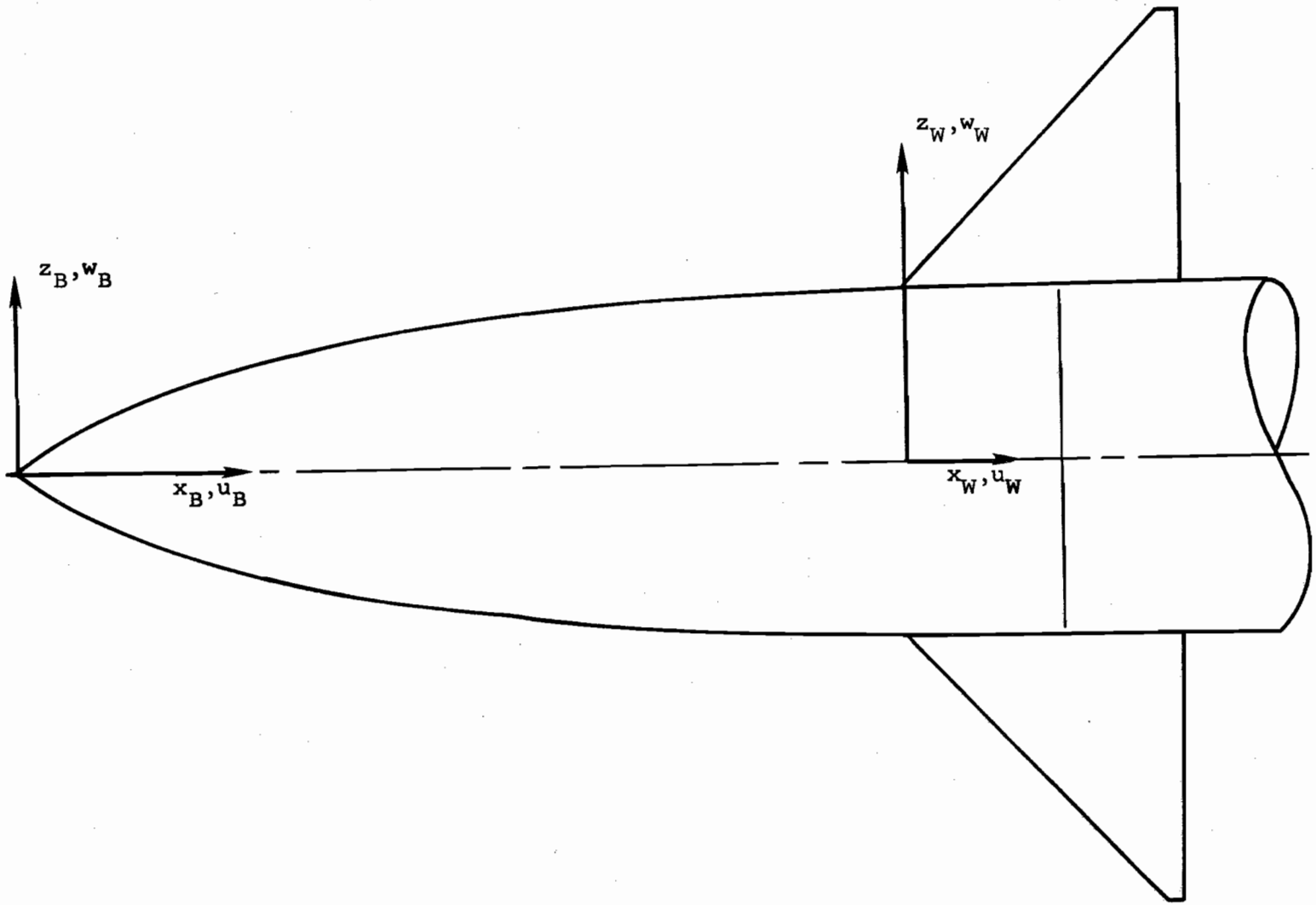

FIG. A-2. Body and Wing Coordinate Systems for a Cruciform Canard-Body Combination.

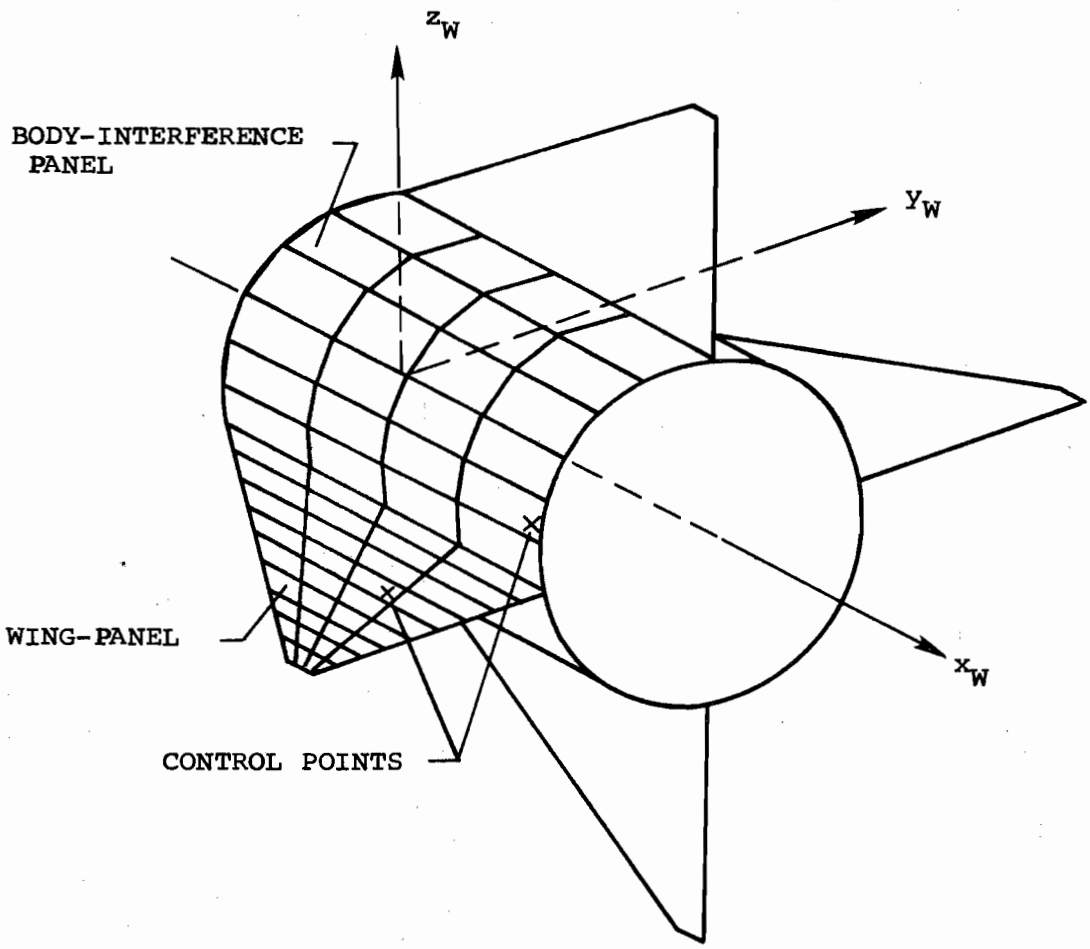

FIG. A-3. Panel Layout on Body Cruciform Wing Combination.

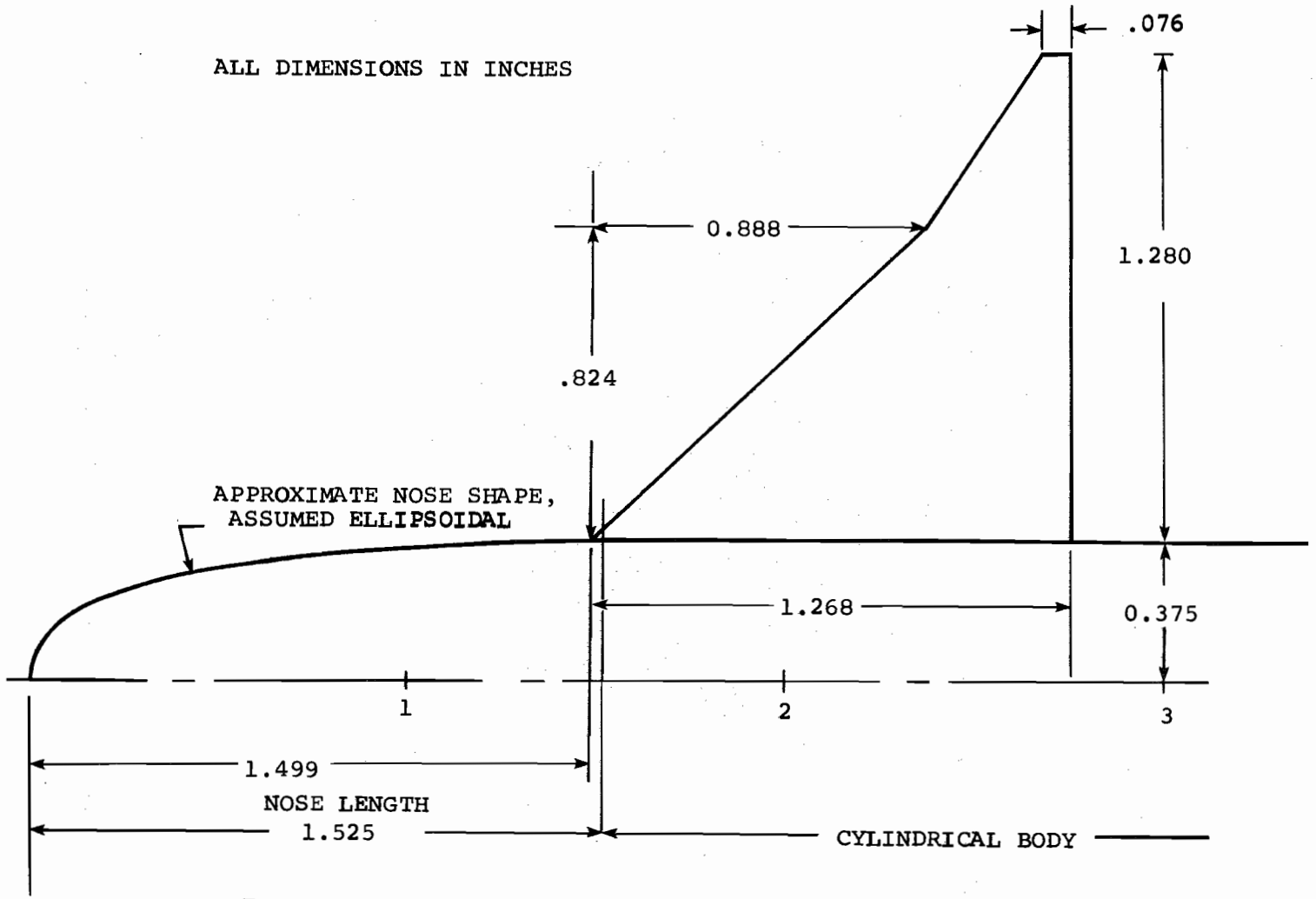

FIG. A-4. AIM-9L Static-Force Model for Sample Calculation Case.

```
AIM-9L STATIC FORCE MODEL,CRUCIFORM CANARD/ELLIPSOIDAL NOSE,CYLINDRICAL BODY
$INPUT
CRP=1.268,B2=1.28,LVSWP=1,NCRX=1,
CRPV=1.268,B2V=1.28,
RB=0.375,NCWB=4,NBDCR=12,
NCW=4,MSWR=9,MSWL=9,MSWU=9,MSWD=9,
ALFAC=20.0,FMACH=1.75,
DELU=20.0,DELD=20.0,
NOLINP=1,
NDRAG=0,
SREF=0.4418,REFL=0.75,
$END
  0.375     47.141      0.0001
  0.517     47.141      0.0001
  0.659     47.141      0.0001
  0.801     47.141      0.0001
  0.943     47.141      0.0001
  1.085     47.141      0.0001
  1.199     47.141      0.0001
  1.341     33.69       0.0001
  1.483     33.69       0.0001
  1.655     33.69       0.0001
 -0.375    -47.141      0.0001
 -0.517    -47.141      0.0001
 -0.659    -47.141      0.0001
 -0.801    -47.141      0.0001
 -0.943    -47.141      0.0001
 -1.085    -47.141      0.0001
 -1.199    -47.141      0.0001
 -1.341    -33.69       0.0001
 -1.483    -33.69       0.0001
 -1.655    -33.69       0.0001
  0.375     47.141      0.0001
  0.517     47.141      0.0001
  0.659     47.141      0.0001
  0.801     47.141      0.0001
  0.943     47.141      0.0001
  1.085     47.141      0.0001
  1.199     47.141      0.0001
  1.341     33.69       0.0001
  1.483     33.69       0.0001
  1.655     33.69       0.0001
 -0.375    -47.141      0.0001
 -0.517    -47.141      0.0001
 -0.659    -47.141      0.0001
 -0.801    -47.141      0.0001
 -0.943    -47.141      0.0001
 -1.085    -47.141      0.0001
 -1.199    -47.141      0.0001
 -1.341    -33.69       0.0001
 -1.483    -33.69       0.0001
 -1.655    -33.69       0.0001
$BODY
NXBODY=22,BCODE=3,PCODE=0,
LBODY=2.8,LNOSE=1.525,RNOSE=0.0,XNOSE=0.0,
XWLE=1.499,
$END
ZZZZZZZ
```

FIG. A-5. CRFWBD Input for Sample Case.

AIM-9L STATIC FORCE MODEL,CRUCIFORM CANARD/ELLIPSOIDAL NOSE,CYLINDRICAL BODY

```
$INPUT
CRP     = 0.1268E+01,
SWLEP   = 0.0,
SWTEP   = 0.0,
NCW     = 4,
MSWR    = 9,
MSWL    = 9,
ALFAC   = 0.2E+02,
PHI     = 0.0,
B2      = 0.128E+01,
FMACH   = 0.175E+01,
LVSWP   = 1,
FAC     = 0.95E+00,
NFVNPR  = 0,
TOLFAC  = 0.1E+01,
MSWU    = 9,
MSWD    = 9,
SWLEV   = 0.0,
SWTEV   = 0.0,
CRPV    = 0.1268E+01,
B2V     = 0.128E+01,
NCRX    = 1,
RB      = 0.375E+00,
NBDCR   = 12,
DELR    = 0.0,
DELL    = 0.0,
DELU    = 0.2E+02,
DELD    = 0.2E+02,
SREF    = 0.4418E+00,
REFL    = 0.75E+00,
NOLINP  = 1,
NOUT    = 0,
NPR     = 0,
NDRAG   = 0,
NVRTX   = 0,
NPRESS  = 0,
VRTMAX  = 0.35E+00,
NCWB    = 4,
$END
```

FIG. A-6(a). CRFWBD Output for Sample Case.

WING GEOMETRY

```
LEADING EDGE SWEEP =     .00000  DEGREES
TRAILING EDGE SWEEP =    .00000  DEGREES
          TIP CHORD =    .07599
         ROOT CHORD =   1.26800
       WING SEMISPAN =  1.28000
```

VERTICAL WING GEOMETRY

```
LEADING EDGE SWEEP =     .00000  DEGREES
TRAILING EDGE SWEEP =    .00000  DEGREES
          TIP CHORD =    .07599
         ROOT CHORD =   1.26800
       WING SEMISPAN =  1.28000
```

FLOW CONDITIONS

```
MACH =   1.75000   ALPHAC=  20.00000   PHI  =    .00000   ALFA =  20.00000   BETA =    .00000

  RIGHT WING PART SPAN =   1.65500
   LEFT WING PART SPAN =  -1.65500
  UPPER WING PART SPAN =   1.65500
  LOWER WING PART SPAN =  -1.65500

   CRPT =   1.26800
  CRPTV =   1.26800
```

FIG. A-6(b). Continued.

```
$BODY
NXBODY  =  22,
LNOSE   =  0.1525E+01,
LBODY   =  0.28E+01,
RNOSE   =  0.0,
XNOSE   =  0.0,
BCODE   =  3,
PCODE   =  0,
XWLE    =  0.1499E+01,
$END
```

PHYSICAL DIMENSIONS OF BODY AND LINE SINGULARITY STRENGTHS REPRESENTING THE BODY AT MACH= 1.7500

	X	R	DR/DX	TX	T(I)	TC(I)
1	.0000	.0	.10000E+10	.0	.34542	.30222
2	.8000	.32991	.13288	.32620	-.87778	-.81328
3	.9333	.34563	.10351	.43697	.50445	.51015
4	1.0667	.35766	.77487E-01	.55301	-.60276E-01	-.65569E-01
5	1.2000	.36639	.53637E-01	.67382	.27853E-01	.32208E-01
6	1.3333	.37203	.31153E-01	.79905	.34306E-03	-.57586E-03
7	1.4667	.37473	.94130E-02	.92851	.43905E-02	.21502E-02
8	1.6000	.37500	.0	1.0614	.29286E-01	.14978E-02
9	1.7333	.37500	.0	1.1948	.52316E-02	.38543E-02
10	1.8667	.37500	.0	1.3281	.58400E-02	.36361E-02
11	2.0000	.37500	.0	1.4614	.34386E-02	.36249E-02
12	2.1333	.37500	.0	1.5948	.25933E-02	.33788E-02
13	2.2667	.37500	.0	1.7281	.18913E-02	.30847E-02
14	2.4000	.37500	.0	1.8614	.14370E-02	.27490E-02
15	2.5333	.37500	.0	1.9948	.11053E-02	.24032E-02
16	2.6667	.37500	.0	2.1281	.86365E-03	.20629E-02
17	2.8000	.37500	.0	2.2614	.0	.0

VELOCITIES INDUCED ON BODY BY BODY LINE SINGULARITIES AT MACH= 1.7500 ALFAC=20.0000

		BODY SOURCES			BODY DOUBLETS			
	X	U	V	VN	U	V	VT	VN
1	.0000	-.3851	.6749	-.6149	.5905	-1.063	-.3685	-.5905
2	.8000	-.3851	.6749	.5880	.5905	-1.063	-.3685	-.7859
3	.9333	.1460	-.9798E-01	-.2155	-.1315	-.4825E-01	-.3730	.3128
4	1.0667	-.5605E-02	.1077	.3052E-01	.9674E-01	-.3894	-.3704	-.4768E-01
5	1.2000	.3192E-01	.4433E-01	-.1100E-01	.4314E-01	-.3283	-.3757	.1839E-01
6	1.3333	.3359E-01	.3262E-01	.4197E-03	.4625E-01	-.3488	-.3825	-.1157E-02
7	1.4667	.4356E-01	.8953E-02	-.8696E-03	.3347E-01	-.3475	-.3915	.1239E-02
8	1.6000	.5047E-01	-.1070E-01	-.1070E-01	.2219E-01	-.3488	-.4010	.2419E-03
9	1.7333	.3812E-01	-.1083E-02	-.1083E-02	.1121E-01	-.3475	-.4070	.1594E-02
10	1.8667	.3392E-01	-.1784E-02	-.1784E-02	.3469E-02	-.3476	-.4098	.1437E-02
11	2.0000	.2940E-01	-.9673E-03	-.9673E-03	-.2523E-02	-.3476	-.4102	.1461E-02
12	2.1333	.2589E-01	-.7466E-03	-.7466E-03	-.6843E-02	-.3477	-.4088	.1363E-02
13	2.2667	.2289E-01	-.5387E-03	-.5387E-03	-.9834E-02	-.3478	-.4060	.1249E-02
14	2.4000	.2035E-01	-.4093E-03	-.4093E-03	-.1174E-01	-.3479	-.4024	.1116E-02
15	2.5333	.1817E-01	-.3140E-03	-.3140E-03	-.1278E-01	-.3481	-.3982	.9780E-03
16	2.6667	.1629E-01	-.2450E-03	-.2450E-03	-.1315E-01	-.3482	-.3938	.8415E-03
17	2.8000	.1467E-01	-.1934E-03	-.1934E-03	-.1302E-01	-.3484	-.3893	.7113E-03

FIG. A-6(c). Continued.

CONTROL POINT COORDINATES FOR 4 CHORDWISE BY 9 SPANWISE PANELS ON RIGHT WING PART, 9 SPANWISE ON LEFT WING PART
AND 9 SPANWISE PANELS ON UPPER WING PART, 9 SPANWISE ON LOWER WING PART

J	X(J)	Y(J)	Z(J)	BU(J)	BV(J)	BW(J)	VV(J)	WV(J)
1	.35824	.44448	.00000	.33002E-01	-.40103E-02	.29988E+00	.0	.0
2	.65652	.44448	.00000	.24970E-01	-.29259E-02	.29905E+00	.0	.0
3	.95481	.44448	.00000	.19325E-01	-.22038E-02	.29268E+00	.0	.0
4	1.25309	.44448	.00000	.15251E-01	-.17076E-02	.28429E+00	.0	.0
5	.47474	.58626	.00000	.30898E-01	-.10286E-01	.18317E+00	.0	.0
6	.73483	.58626	.00000	.24163E-01	-.75025E-02	.18211E+00	.0	.0
7	.99491	.58626	.00000	.19217E-01	-.55713E-02	.17789E+00	.0	.0
8	1.25500	.58626	.00000	.15531E-01	-.42217E-02	.17233E+00	.0	.0
9	.59118	.72795	.00000	.33774E-01	-.20255E-01	.12579E+00	.0	.0
10	.81309	.72795	.00000	.24075E-01	-.11146E-01	.12530E+00	.0	.0
11	1.03500	.72795	.00000	.19670E-01	-.85733E-02	.12270E+00	.0	.0
12	1.25691	.72795	.00000	.16520E-01	-.70294E-02	.11907E+00	.0	.0
13	.70752	.86953	.00000	.26675E-01	-.14133E-01	.92908E-01	.0	.0
14	.89128	.86953	.00000	.24360E-01	-.14218E-01	.92986E-01	.0	.0
15	1.07505	.86953	.00000	.21350E-01	-.12630E-01	.91622E-01	.0	.0
16	1.25881	.86953	.00000	.17497E-01	-.93673E-02	.89423E-01	.0	.0
17	.82367	1.01087	.00000	.20622E-01	-.86321E-02	.72065E-01	.0	.0
18	.96935	1.01087	.00000	.26769E-01	-.19522E-01	.72456E-01	.0	.0
19	1.11503	1.01087	.00000	.22004E-01	-.14741E-01	.72022E-01	.0	.0
20	1.26072	1.01087	.00000	.19672E-01	-.13095E-01	.70925E-01	.0	.0
21	.92924	1.13936	.00000	.15181E-01	-.32170E-02	.58912E-01	.0	.0
22	1.04031	1.13936	.00000	.20781E-01	-.12364E-01	.59405E-01	.0	.0
23	1.15138	1.13936	.00000	.24881E-01	-.19565E-01	.59473E-01	.0	.0
24	1.26245	1.13936	.00000	.21172E-01	-.15579E-01	.59148E-01	.0	.0
25	1.01263	1.26663	.00000	.10646E-01	.14073E-02	.49170E-01	.0	.0
26	1.09636	1.26663	.00000	.13421E-01	-.31194E-02	.49623E-01	.0	.0
27	1.18009	1.26663	.00000	.17399E-01	-.94836E-02	.49946E-01	.0	.0
28	1.26382	1.26663	.00000	.20887E-01	-.15263E-01	.50053E-01	.0	.0
29	1.08414	1.40729	.00000	-.28142E-02	.18914E-01	.40937E-01	.0	.0
30	1.14442	1.40729	.00000	.63094E-02	.56654E-02	.41427E-01	.0	.0
31	1.20470	1.40729	.00000	.10084E-01	-.47184E-04	.41586E-01	.0	.0
32	1.26499	1.40729	.00000	.11128E-01	-.18556E-02	.41823E-01	.0	.0
33	1.16007	1.55667	.00000	.48618E-01	-.56423E-01	.35357E-01	.0	.0
34	1.19546	1.55667	.00000	.12688E-01	-.52954E-02	.34201E-01	.0	.0
35	1.23085	1.55667	.00000	-.13559E-02	.14778E-01	.34204E-01	.0	.0
36	1.26623	1.55667	.00000	-.63697E-02	.21981E-01	.34550E-01	.0	.0
37	.35824	-.44448	.00000	.33002E-01	.40103E-02	.29988E+00	.0	.0
38	.65652	-.44448	.00000	.24970E-01	.29259E-02	.29905E+00	.0	.0
39	.95481	-.44448	.00000	.19325E-01	.22038E-02	.29268E+00	.0	.0
40	1.25309	-.44448	.00000	.15251E-01	.17076E-02	.28429E+00	.0	.0
41	.47474	-.58626	.00000	.30898E-01	.10286E-01	.18317E+00	.0	.0
42	.73483	-.58626	.00000	.24163E-01	.75025E-02	.18211E+00	.0	.0
43	.99491	-.58626	.00000	.19217E-01	.55713E-02	.17789E+00	.0	.0
44	1.25500	-.58626	.00000	.15531E-01	.42217E-02	.17233E+00	.0	.0
45	.59118	-.72795	.00000	.33774E-01	.20255E-01	.12579E+00	.0	.0
46	.81309	-.72795	.00000	.24075E-01	.11146E-01	.12530E+00	.0	.0
47	1.03500	-.72795	.00000	.19670E-01	.85733E-02	.12270E+00	.0	.0
48	1.25690	-.72795	.00000	.16520E-01	.70294E-02	.11907E+00	.0	.0
49	.70752	-.86953	.00000	.26675E-01	.14133E-01	.92908E-01	.0	.0
50	.89128	-.86953	.00000	.24360E-01	.14218E-01	.92986E-01	.0	.0
51	1.07505	-.86953	.00000	.21350E-01	.12630E-01	.91622E-01	.0	.0
52	1.25881	-.86953	.00000	.17497E-01	.93674E-02	.89423E-01	.0	.0
53	.82366	-1.01087	.00000	.20622E-01	.86321E-02	.72065E-01	.0	.0

FIG. A-6(d). Continued.

54	.96935	-1.01087	.00000	.26769E-01	.19522E-01	.72456E-01	.0	.0
55	1.11503	-1.01087	.00000	.22004E-01	.14741E-01	.72022E-01	.0	.0
56	1.26071	-1.01087	.00000	.19672E-01	.13095E-01	.70925E-01	.0	.0
57	.92924	-1.13936	.00000	.15181E-01	.32169E-02	.58912E-01	.0	.0
58	1.04031	-1.13936	.00000	.20781E-01	.12363E-01	.59405E-01	.0	.0
59	1.15138	-1.13936	.00000	.24881E-01	.19565E-01	.59473E-01	.0	.0
60	1.26245	-1.13936	.00000	.21172E-01	.15579E-01	.59148E-01	.0	.0
61	1.01263	-1.26663	.00000	.10646E-01	-.14073E-02	.49170E-01	.0	.0
62	1.09636	-1.26663	.00000	.13421E-01	.31193E-02	.49623E-01	.0	.0
63	1.18009	-1.26663	.00000	.17399E-01	.94835E-02	.49946E-01	.0	.0
64	1.26381	-1.26663	.00000	.20887E-01	.15263E-01	.50053E-01	.0	.0
65	1.08413	-1.40729	.00000	-.28144E-02	-.18915E-01	.40937E-01	.0	.0
66	1.14442	-1.40729	.00000	.63092E-02	-.56657E-02	.41427E-01	.0	.0
67	1.20470	-1.40729	.00000	.10084E-01	.47346E-04	.41586E-01	.0	.0
68	1.26498	-1.40729	.00000	.11128E-01	.18554E-02	.41822E-01	.0	.0
69	1.16007	-1.55667	.00000	.48617E-01	.56422E-01	.35357E-01	.0	.0
70	1.19546	-1.55667	.00000	.12689E-01	.52970E-02	.34201E-01	.0	.0
71	1.23084	-1.55667	.00000	-.13554E-02	-.14777E-01	.34204E-01	.0	.0
72	1.26623	-1.55667	.00000	-.63694E-02	-.21981E-01	.34550E-01	.0	.0
73	.35824	.00000	.44448	.38518E-01	.0	-.25078E+00	.0	.0
74	.65652	.00000	.44448	.18757E-01	.0	-.24644E+00	.0	.0
75	.95481	.00000	.44448	.76711E-02	.0	-.24423E+00	.0	.0
76	1.25309	.00000	.44448	.21911E-02	.0	-.24351E+00	.0	.0
77	.47474	.00000	.58626	.34104E-01	.0	-.15125E+00	.0	.0
78	.73483	.00000	.58626	.17599E-01	.0	-.14177E+00	.0	.0
79	.99491	.00000	.58626	.78640E-02	.0	-.13680E+00	.0	.0
80	1.25500	.00000	.58626	.26656E-02	.0	-.13477E+00	.0	.0
81	.59118	.00000	.72795	.37039E-01	.0	-.11312E+00	.0	.0
82	.81309	.00000	.72795	.18487E-01	.0	-.95746E-01	.0	.0
83	1.03500	.00000	.72795	.91980E-02	.0	-.88702E-01	.0	.0
84	1.25691	.00000	.72795	.33919E-02	.0	-.84564E-01	.0	.0
85	.70752	.00000	.86953	.31129E-01	.0	-.82280E-01	.0	.0
86	.89128	.00000	.86953	.20821E-01	.0	-.73787E-01	.0	.0
87	1.07505	.00000	.86953	.12113E-01	.0	-.65830E-01	.0	.0
88	1.25881	.00000	.86953	.59535E-02	.0	-.60276E-01	.0	.0
89	.82367	.00000	1.01087	.26392E-01	.0	-.62616E-01	.0	.0
90	.96935	.00000	1.01087	.26573E-01	.0	-.66864E-01	.0	.0
91	1.11503	.00000	1.01087	.16207E-01	.0	-.55406E-01	.0	.0
92	1.26072	.00000	1.01087	.10183E-01	.0	-.49337E-01	.0	.0
93	.92924	.00000	1.13936	.22481E-01	.0	-.49664E-01	.0	.0
94	1.04031	.00000	1.13936	.23471E-01	.0	-.53489E-01	.0	.0
95	1.15138	.00000	1.13936	.23553E-01	.0	-.55954E-01	.0	.0
96	1.26245	.00000	1.13936	.15940E-01	.0	-.47136E-01	.0	.0
97	1.01263	.00000	1.26663	.17024E-01	.0	-.36611E-01	.0	.0
98	1.09636	.00000	1.26663	.19720E-01	.0	-.41900E-01	.0	.0
99	1.18009	.00000	1.26663	.20687E-01	.0	-.44730E-01	.0	.0
100	1.26382	.00000	1.26663	.21114E-01	.0	-.46774E-01	.0	.0
101	1.08414	.00000	1.40729	.14962E-01	.0	-.29572E-01	.0	.0
102	1.14442	.00000	1.40729	.13202E-01	.0	-.27819E-01	.0	.0
103	1.20470	.00000	1.40729	.14273E-01	.0	-.30105E-01	.0	.0
104	1.26499	.00000	1.40729	.16821E-01	.0	-.34559E-01	.0	.0
105	1.16007	.00000	1.55667	-.20140E-01	.0	.23405E-01	.0	.0
106	1.19546	.00000	1.55667	-.81900E-03	.0	-.44222E-02	.0	.0
107	1.23085	.00000	1.55667	.83968E-02	.0	-.17934E-01	.0	.0
108	1.26623	.00000	1.55667	.13234E-01	.0	-.25230E-01	.0	.0
109	.35824	.00000	-.44448	.27486E-01	.0	-.24276E+00	.0	.0
110	.65652	.00000	-.44448	.31183E-01	.0	-.24059E+00	.0	.0
111	.95481	.00000	-.44448	.30978E-01	.0	-.23982E+00	.0	.0

FIG. A-6(e). Continued.

112	1.25309	.00000	-.44448	.28312E-01	.0	-.24009E+00	.0	.0
113	.47474	.00000	-.58626	.27692E-01	.0	-.13068E+00	.0	.0
114	.73483	.00000	-.58626	.30727E-01	.0	-.12677E+00	.0	.0
115	.99491	.00000	-.58626	.30570E-01	.0	-.12565E+00	.0	.0
116	1.25500	.00000	-.58626	.28397E-01	.0	-.12633E+00	.0	.0
117	.59118	.00000	-.72795	.30508E-01	.0	-.72609E-01	.0	.0
118	.81309	.00000	-.72795	.29663E-01	.0	-.73455E-01	.0	.0
119	1.03500	.00000	-.72795	.30143E-01	.0	-.71556E-01	.0	.0
120	1.25690	.00000	-.72795	.29649E-01	.0	-.70505E-01	.0	.0
121	.70752	.00000	-.86953	.22221E-01	.0	-.54013E-01	.0	.0
122	.89128	.00000	-.86953	.27899E-01	.0	-.45352E-01	.0	.0
123	1.07505	.00000	-.86953	.30587E-01	.0	-.40569E-01	.0	.0
124	1.25881	.00000	-.86953	.29041E-01	.0	-.41541E-01	.0	.0
125	.82366	.00000	-1.01087	.14851E-01	.0	-.45352E-01	.0	.0
126	.96935	.00000	-1.01087	.26964E-01	.0	-.27820E-01	.0	.0
127	1.11503	.00000	-1.01087	.27802E-01	.0	-.25924E-01	.0	.0
128	1.26071	.00000	-1.01087	.29162E-01	.0	-.23147E-01	.0	.0
129	.92924	.00000	-1.13936	.78817E-02	.0	-.43230E-01	.0	.0
130	1.04031	.00000	-1.13936	.18092E-01	.0	-.28762E-01	.0	.0
131	1.15138	.00000	-1.13936	.26209E-01	.0	-.16824E-01	.0	.0
132	1.26245	.00000	-1.13936	.26403E-01	.0	-.15978E-01	.0	.0
133	1.01263	.00000	-1.26663	.42684E-02	.0	-.39425E-01	.0	.0
134	1.09636	.00000	-1.26663	.71221E-02	.0	-.35662E-01	.0	.0
135	1.18009	.00000	-1.26663	.14112E-01	.0	-.25763E-01	.0	.0
136	1.26381	.00000	-1.26663	.20661E-01	.0	-.16248E-01	.0	.0
137	1.08413	.00000	-1.40729	-.20591E-01	.0	-.67401E-01	.0	.0
138	1.14442	.00000	-1.40729	-.58368E-03	.0	-.39151E-01	.0	.0
139	1.20470	.00000	-1.40729	.58952E-02	.0	-.30010E-01	.0	.0
140	1.26498	.00000	-1.40729	.54349E-02	.0	-.30848E-01	.0	.0
141	1.16007	.00000	-1.55667	.11737E+00	.0	.13625E+00	.0	.0
142	1.19546	.00000	-1.55667	.26198E-01	.0	.61726E-02	.0	.0
143	1.23084	.00000	-1.55667	-.11107E-01	.0	-.47488E-01	.0	.0
144	1.26623	.00000	-1.55667	-.25973E-01	.0	-.69190E-01	.0	.0

FIG. A-6(f). Continued.

CONTROL POINT COORDINATES FOR BIP*S (WING FRAME)

J	X(J)	Y(J)	Z(J)
145	.30115	.34988	.09375
146	.30115	.25613	.25613
147	.30115	.09375	.34988
148	.30115	-.09375	.34988
149	.30115	-.25613	.25613
150	.30115	-.34988	.09375
151	.30115	-.34988	-.09375
152	.30115	-.25613	-.25613
153	.30115	-.09375	-.34988
154	.30115	.09375	-.34988
155	.30115	.25613	-.25613
156	.30115	.34988	-.09375
157	.61815	.34988	.09375
158	.61815	.25613	.25613
159	.61815	.09375	.34988
160	.61815	-.09375	.34988
161	.61815	-.25613	.25613
162	.61815	-.34988	.09375
163	.61815	-.34988	-.09375
164	.61815	-.25613	-.25613
165	.61815	-.09375	-.34988
166	.61815	.09375	-.34988
167	.61815	.25613	-.25613
168	.61815	.34988	-.09375
169	.93515	.34988	.09375
170	.93515	.25613	.25613
171	.93515	.09375	.34988
172	.93515	-.09375	.34988
173	.93515	-.25613	.25613
174	.93515	-.34988	.09375
175	.93515	-.34988	-.09375
176	.93515	-.25613	-.25613
177	.93515	-.09375	-.34988
178	.93515	.09375	-.34988
179	.93515	.25613	-.25613
180	.93515	.34988	-.09375
181	1.25215	.34988	.09375
182	1.25215	.25613	.25613
183	1.25215	.09375	.34988
184	1.25215	-.09375	.34988
185	1.25215	-.25613	.25613
186	1.25215	-.34988	.09375
187	1.25215	-.34988	-.09375
188	1.25215	-.25613	-.25613
189	1.25215	-.09375	-.34988
190	1.25215	.09375	-.34988
191	1.25215	.25613	-.25613
192	1.25215	.34988	-.09375

FIG. A-6(g). Continued.

BODY INFLUENCE PANEL PROPERTIES

J	YCPT(J)	LENGTH	WIDTH	THETA(J)	FY(J)	FZ(J)	FN(J)	DELTA-CP
145	.34988	.31700	.19411	30.00000	.01111	.00298	.01150	.18695
146	.25613	.31700	.19411	60.00000	.00077	.00077	.00108	.01758
147	.09375	.31700	.19411	90.00000	-.00152	-.00568	-.00588	-.09561
148	-.09375	.31700	.19411	120.00000	-.00182	.00678	.00702	.11408
149	-.25613	.31700	.19411	150.00000	-.00261	.00261	.00369	.05989
150	-.34988	.31700	.19411	180.00000	-.01171	.00314	.01212	.19703
151	-.34988	.31700	.19411	210.00000	.01111	.00298	-.01150	-.18695
152	-.25613	.31700	.19411	240.00000	.00077	.00077	-.00108	-.01758
153	-.09375	.31700	.19411	270.00000	-.00152	-.00568	.00588	.09561
154	.09375	.31700	.19411	300.00000	-.00182	.00678	-.00702	-.11408
155	.25613	.31700	.19411	330.00000	-.00261	.00261	-.00369	-.05989
156	.34988	.31700	.19411	.00000	-.01171	.00314	-.01212	-.19703
157	.34988	.31700	.19411	30.00000	.02382	.00638	.02466	.40080
158	.25613	.31700	.19411	60.00000	.00227	.00227	.00321	.05219
159	.09375	.31700	.19411	90.00000	-.00293	-.01093	-.01131	-.18382
160	-.09375	.31700	.19411	120.00000	-.00540	.02014	.02085	.33882
161	-.25613	.31700	.19411	150.00000	-.00846	.00846	.01197	.19452
162	-.34988	.31700	.19411	180.00000	-.02896	.00776	.02998	.48726
163	-.34988	.31700	.19411	210.00000	.02382	.00638	-.02466	-.40080
164	-.25613	.31700	.19411	240.00000	.00227	.00227	-.00321	-.05219
165	-.09375	.31700	.19411	270.00000	-.00293	-.01093	.01131	.18382
166	.09375	.31700	.19411	300.00000	-.00540	.02014	-.02085	-.33882
167	.25613	.31700	.19411	330.00000	-.00846	.00846	-.01197	-.19452
168	.34988	.31700	.19411	.00000	-.02896	.00776	-.02998	-.48726
169	.34988	.31700	.19411	30.00000	.02105	.00564	.02179	.35413
170	.25613	.31700	.19411	60.00000	.00551	.00551	.00779	.12662
171	.09375	.31700	.19411	90.00000	-.00309	-.01155	-.01195	-.19426
172	-.09375	.31700	.19411	120.00000	-.00519	.01938	.02006	.32598
173	-.25613	.31700	.19411	150.00000	-.02200	.02200	.03111	.50561
174	-.34988	.31700	.19411	180.00000	-.02636	.00706	.02729	.44354
175	-.34988	.31700	.19411	210.00000	.02105	.00564	-.02179	-.35413
176	-.25613	.31700	.19411	240.00000	.00551	.00551	-.00779	-.12662
177	-.09375	.31700	.19411	270.00000	-.00309	-.01155	.01195	.19426
178	.09375	.31700	.19411	300.00000	-.00519	.01938	-.02006	-.32598
179	.25613	.31700	.19411	330.00000	-.02200	.02200	-.03111	-.50561
180	.34988	.31700	.19411	.00000	-.02636	.00706	-.02729	-.44354
181	.34988	.31700	.19411	30.00000	.01171	.00314	.01213	.19708
182	.25613	.31700	.19411	60.00000	.00345	.00345	.00487	.07921
183	.09375	.31700	.19411	90.00000	-.00044	-.00166	-.00172	-.02789
184	-.09375	.31700	.19411	120.00000	-.00701	.02616	.02708	.44007
185	-.25613	.31700	.19411	150.00000	-.01945	.01945	.02750	.44698
186	-.34988	.31700	.19411	180.00000	-.02666	.00714	.02760	.44859
187	-.34988	.31700	.19411	210.00000	.01171	.00314	-.01213	-.19708
188	-.25613	.31700	.19411	240.00000	.00345	.00345	-.00487	-.07921
189	-.09375	.31700	.19411	270.00000	-.00044	-.00166	.00172	.02789
190	.09375	.31700	.19411	300.00000	-.00701	.02616	-.02708	-.44007
191	.25613	.31700	.19411	330.00000	-.01945	.01945	-.02750	-.44698
192	.34988	.31700	.19411	.00000	-.02666	.00714	-.02760	-.44859

FIG. A-6(h). Continued.

THRUST, LIFT, AND SIDE FORCE INFORMATION

```
          MACH NUMBER =   .17500E+01
      ANGLE OF ATTACK =   20.000 DEGREES
      SIDE SLIP ANGLE =     .000 DEGREES
            WING AREA =     .783
       REFERENCE AREA =   .44180
    REFERENCE LENGTH =   .75000
```

U/VINF TYPE LOADING PRESSURE

	TOTAL	RIGHT WING	LEFT WING	UPPER WING	LOWER WING
DEFL. ANGLE DEG. =		.00000	.00000	20.00000	20.00000
CN =	.44289E+01	.22144E+01	.22144E+01		
CY =	-.30851E+01			-.15425E+01	-.15425E+01
CTHRUST =	IIIII	.0	.0	.0	.0
CL =	IIIII	IIIII	IIIII	IIIII	IIIII
CDI =	IIIII	IIIII	IIIII	IIIII	IIIII
CDI/CL**2 =	IIIII				
CNADDV =	.0				
CYADDH =	.0				
CY*BIP =	-.42521E+00				
CN*BIP =	.68083E+00				
ROLMOMR =	-.25504E+01				
ROLMOML =	.25503E+01				
ROLMOMU =	-.18136E+01				
ROLMOMD =	.18136E+01				

SPANWISE DISTRIBUTION

I	Y/(B/2)	CN*C/(2*B)	CT*C/(2*B)
	RIGHT WING		
1	.34725	.21573	.00000
2	.45801	.21464	.00000
3	.56871	.20406	.00000
4	.67932	.18811	.00000
5	.78975	.16564	.00000
6	.89012	.14251	.00000
7	.98956	.12266	.00000
8	1.09945	.08088	.00000
9	1.21615	.03262	.00000

FIG. A-6(i). Continued.

---------- LEFT WING----------

I	Y/(B/2)	CN*C/(2*B)	CT*C/(2*B)
1	-.34725	.21573	.00000
2	-.45801	.21464	.00000
3	-.56871	.20406	.00000
4	-.67932	.18811	.00000
5	-.78975	.16564	.00000
6	-.89012	.14251	.00000
7	-.98956	.12266	.00000
8	-1.09945	.08088	.00000
9	-1.21615	.03262	.00000

----------UPPER WING----------

I	Z/(B/2)	CY*C/(2*B)	CT*C/(2*B)
1	.34725	.13420	.00000
2	.45801	.14092	.00000
3	.56871	.14108	.00000
4	.67932	.13563	.00000
5	.78975	.12336	.00000
6	.89012	.10694	.00000
7	.98956	.08659	.00000
8	1.09945	.05506	.00000
9	1.21615	.02862	.00000

----------LOWER WING----------

I	Z/(B/2)	CY*C/(2*B)	CT*C/(2*B)
1	-.34725	.13420	.00000
2	-.45801	.14092	.00000
3	-.56871	.14108	.00000
4	-.67932	.13563	.00000
5	-.78975	.12335	.00000
6	-.89012	.10694	.00000
7	-.98956	.08659	.00000
8	-1.09945	.05506	.00000
9	-1.21615	.02862	.00000

ROLLING MOMENT = -.00003
BETA = .00000 DEGREES.

PRESSURE LOADINGS AT CONTROL POINTS

J	X(J)	Y(J)	Z(J)	DELTP,LIN.	DELTP UBAR	DELTP,1STORD.	DELTP 2NDORD.	DELTP,EXACT
1	.3582E+00	.4445E+00	.0	.1251E+01	.1175E+01	.1324E+01	.1540E+01	.1049E+01
2	.6565E+00	.4445E+00	.0	.9791E+00	.9200E+00	.1031E+01	.1216E+01	.9524E+00
3	.9548E+00	.4445E+00	.0	.8032E+00	.7547E+00	.8306E+00	.1038E+01	.8602E+00
4	.1253E+01	.4445E+00	.0	.6753E+00	.6346E+00	.6945E+00	.9356E+00	.7914E+00
5	.4747E+00	.5863E+00	.0	.1525E+01	.1433E+01	.1624E+01	.1893E+01	.1156E+01
6	.7348E+00	.5863E+00	.0	.1088E+01	.1023E+01	.1143E+01	.1363E+01	.1045E+01
7	.9949E+00	.5863E+00	.0	.8650E+00	.8128E+00	.9138E+00	.1086E+01	.8937E+00
8	.1255E+01	.5863E+00	.0	.7548E+00	.7093E+00	.7795E+00	.1009E+01	.8498E+00
9	.5912E+00	.7280E+00	.0	.1676E+01	.1575E+01	.1804E+01	.2091E+01	.1195E+01
10	.8131E+00	.7280E+00	.0	.1203E+01	.1130E+01	.1278E+01	.1506E+01	.1126E+01

FIG. A-6(j). Continued.

11	.1035E+01	.7280E+00	.0	.1005E+01	.9446E+00	.1060E+01	.1265E+01	.1023E+01
12	.1257E+01	.7280E+00	.0	.8356E+00	.7852E+00	.8685E+00	.1091E+01	.9149E+00
13	.7075E+00	.8695E+00	.0	.1747E+01	.1641E+01	.1869E+01	.2189E+01	.1206E+01
14	.8913E+00	.8695E+00	.0	.1393E+01	.1309E+01	.1483E+01	.1747E+01	.1245E+01
15	.1075E+01	.8695E+00	.0	.1142E+01	.1073E+01	.1205E+01	.1439E+01	.1141E+01
16	.1259E+01	.8695E+00	.0	.9781E+00	.9191E+00	.1031E+01	.1234E+01	.1021E+01
17	.8237E+00	.1011E+01	.0	.1757E+01	.1651E+01	.1869E+01	.2209E+01	.1208E+01
18	.9693E+00	.1011E+01	.0	.1598E+01	.1501E+01	.1709E+01	.2003E+01	.1347E+01
19	.1115E+01	.1011E+01	.0	.1326E+01	.1246E+01	.1407E+01	.1664E+01	.1281E+01
20	.1261E+01	.1011E+01	.0	.1175E+01	.1104E+01	.1239E+01	.1482E+01	.1201E+01
21	.9292E+00	.1139E+01	.0	.1735E+01	.1630E+01	.1834E+01	.2187E+01	.1207E+01
22	.1040E+01	.1139E+01	.0	.1724E+01	.1620E+01	.1835E+01	.2169E+01	.1398E+01
23	.1151E+01	.1139E+01	.0	.1653E+01	.1554E+01	.1760E+01	.2070E+01	.1498E+01
24	.1262E+01	.1139E+01	.0	.1499E+01	.1409E+01	.1586E+01	.1878E+01	.1463E+01
25	.1013E+01	.1267E+01	.0	.1792E+01	.1684E+01	.1913E+01	.2675E+01	.1793E+01
26	.1096E+01	.1267E+01	.0	.1948E+01	.1831E+01	.2071E+01	.2890E+01	.1954E+01
27	.1180E+01	.1267E+01	.0	.1953E+01	.1835E+01	.2066E+01	.2871E+01	.2021E+01
28	.1264E+01	.1267E+01	.0	.1858E+01	.1746E+01	.1952E+01	.2707E+01	.1981E+01
29	.1084E+01	.1407E+01	.0	.1677E+01	.1576E+01	.1814E+01	.1853E+01	.1250E+01
30	.1144E+01	.1407E+01	.0	.1703E+01	.1600E+01	.1848E+01	.1860E+01	.1314E+01
31	.1205E+01	.1407E+01	.0	.1757E+01	.1651E+01	.1899E+01	.1899E+01	.1383E+01
32	.1265E+01	.1407E+01	.0	.1823E+01	.1713E+01	.1958E+01	.1955E+01	.1448E+01
33	.1160E+01	.1557E+01	.0	.1209E+01	.1136E+01	.1324E+01	.1497E+01	.1146E+01
34	.1195E+01	.1557E+01	.0	.1215E+01	.1142E+01	.1284E+01	.1537E+01	.1212E+01
35	.1231E+01	.1557E+01	.0	.1265E+01	.1188E+01	.1324E+01	.1620E+01	.1292E+01
36	.1266E+01	.1557E+01	.0	.1322E+01	.1242E+01	.1385E+01	.1706E+01	.1369E+01
37	.3582E+00	-.4445E+00	.0	.1251E+01	.1175E+01	.1327E+01	.1540E+01	.1050E+01
38	.6565E+00	-.4445E+00	.0	.9791E+00	.9200E+00	.1039E+01	.1218E+01	.9546E+00
39	.9548E+00	-.4445E+00	.0	.8032E+00	.7547E+00	.8646E+00	.9722E+00	.7950E+00
40	.1253E+01	-.4445E+00	.0	.6753E+00	.6346E+00	.7293E+00	.7632E+00	.6151E+00
41	.4747E+00	-.5863E+00	.0	.1525E+01	.1433E+01	.1629E+01	.1893E+01	.1157E+01
42	.7348E+00	-.5863E+00	.0	.1088E+01	.1023E+01	.1166E+01	.1353E+01	.1038E+01
43	.9949E+00	-.5863E+00	.0	.8650E+00	.8128E+00	.9150E+00	.1082E+01	.8898E+00
44	.1255E+01	-.5863E+00	.0	.7548E+00	.7093E+00	.8129E+00	.8901E+00	.7291E+00
45	.5912E+00	-.7280E+00	.0	.1676E+01	.1575E+01	.1809E+01	.2091E+01	.1195E+01
46	.8131E+00	-.7280E+00	.0	.1203E+01	.1130E+01	.1281E+01	.1504E+01	.1125E+01
47	.1035E+01	-.7280E+00	.0	.1005E+01	.9446E+00	.1068E+01	.1257E+01	.1016E+01
48	.1257E+01	-.7280E+00	.0	.8356E+00	.7852E+00	.8959E+00	.1009E+01	.8323E+00
49	.7075E+00	-.8695E+00	.0	.1747E+01	.1641E+01	.1869E+01	.2189E+01	.1206E+01
50	.8913E+00	-.8695E+00	.0	.1393E+01	.1309E+01	.1487E+01	.1745E+01	.1245E+01
51	.1075E+01	-.8695E+00	.0	.1142E+01	.1073E+01	.1219E+01	.1425E+01	.1129E+01
52	.1259E+01	-.8695E+00	.0	.9781E+00	.9192E+00	.1036E+01	.1223E+01	.1010E+01
53	.8237E+00	-.1011E+01	.0	.1757E+01	.1651E+01	.1869E+01	.2209E+01	.1208E+01
54	.9693E+00	-.1011E+01	.0	.1598E+01	.1501E+01	.1712E+01	.2002E+01	.1347E+01
55	.1115E+01	-.1011E+01	.0	.1326E+01	.1246E+01	.1410E+01	.1661E+01	.1279E+01
56	.1261E+01	-.1011E+01	.0	.1175E+01	.1104E+01	.1246E+01	.1463E+01	.1164E+01
57	.9292E+00	-.1139E+01	.0	.1735E+01	.1630E+01	.1834E+01	.2187E+01	.1207E+01
58	.1040E+01	-.1139E+01	.0	.1724E+01	.1620E+01	.1835E+01	.2169E+01	.1398E+01
59	.1151E+01	-.1139E+01	.0	.1653E+01	.1554E+01	.1762E+01	.2068E+01	.1497E+01
60	.1262E+01	-.1139E+01	.0	.1499E+01	.1409E+01	.1588E+01	.1874E+01	.1459E+01
61	.1013E+01	-.1267E+01	.0	.1792E+01	.1684E+01	.1858E+01	.1857E+01	.1184E+01
62	.1096E+01	-.1267E+01	.0	.1948E+01	.1831E+01	.2040E+01	.2028E+01	.1350E+01
63	.1180E+01	-.1267E+01	.0	.1953E+01	.1835E+01	.2062E+01	.2036E+01	.1434E+01
64	.1264E+01	-.1267E+01	.0	.1858E+01	.1746E+01	.1976E+01	.1939E+01	.1423E+01
65	.1084E+01	-.1407E+01	.0	.1677E+01	.1576E+01	.1671E+01	.2425E+01	.1582E+01
66	.1144E+01	-.1407E+01	.0	.1703E+01	.1600E+01	.1728E+01	.2465E+01	.1707E+01
67	.1205E+01	-.1407E+01	.0	.1757E+01	.1651E+01	.1800E+01	.2549E+01	.1823E+01
68	.1265E+01	-.1407E+01	.0	.1823E+01	.1713E+01	.1882E+01	.2655E+01	.1928E+01

FIG. A-6(k). Continued.

69	.1160E+01	-.1557E+01	.0	.1209E+01	.1136E+01	.1324E+01	.1497E+01	.1146E+01
70	.1195E+01	-.1557E+01	.0	.1215E+01	.1142E+01	.1284E+01	.1537E+01	.1212E+01
71	.1231E+01	-.1557E+01	.0	.1265E+01	.1188E+01	.1324E+01	.1620E+01	.1292E+01
72	.1266E+01	-.1557E+01	.0	.1322E+01	.1242E+01	.1385E+01	.1706E+01	.1369E+01
73	.3582E+00	.0	.4445E+00	.6829E+00	.3900E+00	.6225E+00	.6621E+00	.4849E+00
74	.6565E+00	.0	.4445E+00	.5921E+00	.3927E+00	.5539E+00	.6078E+00	.4660E+00
75	.9548E+00	.0	.4445E+00	.5382E+00	.4066E+00	.5132E+00	.5723E+00	.4452E+00
76	.1253E+01	.0	.4445E+00	.4934E+00	.4181E+00	.4977E+00	.5337E+00	.3967E+00
77	.4747E+00	.0	.5863E+00	.9381E+00	.5358E+00	.7352E+00	.7561E+00	.5187E+00
78	.7348E+00	.0	.5863E+00	.6988E+00	.4635E+00	.5900E+00	.6142E+00	.4657E+00
79	.9949E+00	.0	.5863E+00	.5933E+00	.4482E+00	.5132E+00	.5487E+00	.4363E+00
80	.1255E+01	.0	.5863E+00	.5490E+00	.4653E+00	.5117E+00	.5420E+00	.4313E+00
81	.5912E+00	.0	.7280E+00	.1130E+01	.6455E+00	.8319E+00	.8362E+00	.5270E+00
82	.8131E+00	.0	.7280E+00	.8161E+00	.5412E+00	.6311E+00	.6471E+00	.4852E+00
83	.1035E+01	.0	.7280E+00	.7014E+00	.5298E+00	.5891E+00	.6094E+00	.4780E+00
84	.1257E+01	.0	.7280E+00	.6156E+00	.5217E+00	.5570E+00	.5785E+00	.4631E+00
85	.7075E+00	.0	.8695E+00	.1274E+01	.7274E+00	.8792E+00	.8775E+00	.5159E+00
86	.8913E+00	.0	.8695E+00	.9857E+00	.6538E+00	.7406E+00	.7471E+00	.5363E+00
87	.1075E+01	.0	.8695E+00	.8188E+00	.6185E+00	.6792E+00	.6863E+00	.5283E+00
88	.1259E+01	.0	.8695E+00	.7144E+00	.6055E+00	.6364E+00	.6508E+00	.5183E+00
89	.8237E+00	.0	.1011E+01	.1373E+01	.7843E+00	.9105E+00	.9051E+00	.5023E+00
90	.9693E+00	.0	.1011E+01	.1180E+01	.7823E+00	.8787E+00	.8744E+00	.5903E+00
91	.1115E+01	.0	.1011E+01	.9682E+00	.7313E+00	.7817E+00	.7859E+00	.5927E+00
92	.1261E+01	.0	.1011E+01	.8395E+00	.7115E+00	.7456E+00	.7493E+00	.5891E+00
93	.9292E+00	.0	.1139E+01	.1426E+01	.8141E+00	.9191E+00	.9122E+00	.4897E+00
94	.1040E+01	.0	.1139E+01	.1313E+01	.8709E+00	.9552E+00	.9485E+00	.6116E+00
95	.1151E+01	.0	.1139E+01	.1171E+01	.8845E+00	.9468E+00	.9404E+00	.6807E+00
96	.1262E+01	.0	.1139E+01	.1052E+01	.8915E+00	.9248E+00	.9253E+00	.7122E+00
97	.1013E+01	.0	.1267E+01	.1204E+01	.8566E+00	.8261E+00	.9578E+00	.6655E+00
98	.1096E+01	.0	.1267E+01	.1402E+01	.1077E+01	.1054E+01	.1218E+01	.8395E+00
99	.1180E+01	.0	.1267E+01	.1415E+01	.1168E+01	.1152E+01	.1330E+01	.9507E+00
100	.1264E+01	.0	.1267E+01	.1310E+01	.1157E+01	.1147E+01	.1324E+01	.9894E+00
101	.1084E+01	.0	.1407E+01	.1110E+01	.7897E+00	.7537E+00	.8744E+00	.6210E+00
102	.1144E+01	.0	.1407E+01	.1130E+01	.8683E+00	.8356E+00	.9701E+00	.7075E+00
103	.1205E+01	.0	.1407E+01	.1191E+01	.9836E+00	.9577E+00	.1110E+01	.8225E+00
104	.1265E+01	.0	.1407E+01	.1307E+01	.1154E+01	.1135E+01	.1312E+01	.9774E+00
105	.1160E+01	.0	.1557E+01	.1098E+01	.7812E+00	.7505E+00	.7681E+00	.5485E+00
106	.1195E+01	.0	.1557E+01	.1098E+01	.8440E+00	.8474E+00	.8514E+00	.6307E+00
107	.1231E+01	.0	.1557E+01	.1099E+01	.9076E+00	.9218E+00	.9185E+00	.6979E+00
108	.1266E+01	.0	.1557E+01	.1102E+01	.9727E+00	.9883E+00	.9806E+00	.7586E+00
109	.3582E+00	.0	-.4445E+00	.6829E+00	.8935E+00	.7839E+00	.8926E+00	.6186E+00
110	.6565E+00	.0	-.4445E+00	.5921E+00	.7201E+00	.6598E+00	.7474E+00	.5379E+00
111	.9548E+00	.0	-.4445E+00	.5382E+00	.6050E+00	.5844E+00	.6570E+00	.4887E+00
112	.1253E+01	.0	-.4445E+00	.4934E+00	.5091E+00	.5197E+00	.6375E+00	.4793E+00
113	.4747E+00	.0	-.5863E+00	.9381E+00	.1227E+01	.1143E+01	.1197E+01	.8582E+00
114	.7348E+00	.0	-.5863E+00	.6988E+00	.8498E+00	.8077E+00	.8703E+00	.6655E+00
115	.9949E+00	.0	-.5863E+00	.5933E+00	.6669E+00	.6546E+00	.6732E+00	.5316E+00
116	.1255E+01	.0	-.5863E+00	.5490E+00	.5665E+00	.5729E+00	.6139E+00	.4892E+00
117	.5912E+00	.0	-.7280E+00	.1130E+01	.1479E+01	.1418E+01	.1413E+01	.9994E+00
118	.8131E+00	.0	-.7280E+00	.8161E+00	.9924E+00	.9647E+00	.9656E+00	.7491E+00
119	.1035E+01	.0	-.7280E+00	.7014E+00	.7883E+00	.7785E+00	.7899E+00	.6282E+00
120	.1257E+01	.0	-.7280E+00	.6156E+00	.6352E+00	.6398E+00	.6537E+00	.5259E+00
121	.7075E+00	.0	-.8695E+00	.1274E+01	.1666E+01	.1616E+01	.1608E+01	.1108E+01
122	.8913E+00	.0	-.8695E+00	.9857E+00	.1199E+01	.1176E+01	.1157E+01	.8858E+00
123	.1075E+01	.0	-.8695E+00	.8188E+00	.9203E+00	.9120E+00	.9179E+00	.7282E+00
124	.1259E+01	.0	-.8695E+00	.7144E+00	.7371E+00	.7408E+00	.7386E+00	.5938E+00
125	.8237E+00	.0	-.1011E+01	.1373E+01	.1797E+01	.1753E+01	.1758E+01	.1184E+01
126	.9693E+00	.0	-.1011E+01	.1180E+01	.1434E+01	.1416E+01	.1375E+01	.1029E+01

FIG. A-6(ℓ). Continued.

127	.1115E+01	.0	-.1011E+01	.9682E+00	.1088E+01	.1082E+01	.1051E+01	.8266E+00
128	.1261E+01	.0	-.1011E+01	.8395E+00	.8663E+00	.8694E+00	.8623E+00	.6898E+00
129	.9292E+00	.0	-.1139E+01	.1426E+01	.1865E+01	.1824E+01	.1852E+01	.1228E+01
130	.1040E+01	.0	-.1139E+01	.1313E+01	.1597E+01	.1579E+01	.1555E+01	.1140E+01
131	.1151E+01	.0	-.1139E+01	.1171E+01	.1316E+01	.1311E+01	.1265E+01	.9792E+00
132	.1262E+01	.0	-.1139E+01	.1052E+01	.1085E+01	.1088E+01	.1051E+01	.8298E+00
133	.1013E+01	.0	-.1267E+01	.1204E+01	.1405E+01	.1392E+01	.1123E+01	.8577E+00
134	.1096E+01	.0	-.1267E+01	.1402E+01	.1557E+01	.1550E+01	.1239E+01	.9537E+00
135	.1180E+01	.0	-.1267E+01	.1415E+01	.1491E+01	.1492E+01	.1164E+01	.9012E+00
136	.1264E+01	.0	-.1267E+01	.1310E+01	.1306E+01	.1311E+01	.9981E+00	.7681E+00
137	.1084E+01	.0	-.1407E+01	.1110E+01	.1296E+01	.1278E+01	.1118E+01	.8564E+00
138	.1144E+01	.0	-.1407E+01	.1130E+01	.1255E+01	.1250E+01	.1021E+01	.7909E+00
139	.1205E+01	.0	-.1407E+01	.1191E+01	.1255E+01	.1256E+01	.1003E+01	.7788E+00
140	.1265E+01	.0	-.1407E+01	.1307E+01	.1303E+01	.1310E+01	.1050E+01	.8089E+00
141	.1160E+01	.0	-.1557E+01	.1098E+01	.1282E+01	.1309E+01	.8944E+00	.6693E+00
142	.1195E+01	.0	-.1557E+01	.1098E+01	.1219E+01	.1219E+01	.1152E+01	.9009E+00
143	.1231E+01	.0	-.1557E+01	.1099E+01	.1158E+01	.1159E+01	.1223E+01	.9599E+00
144	.1266E+01	.0	-.1557E+01	.1102E+01	.1098E+01	.1110E+01	.1219E+01	.9559E+00

FIG. A-6(m). Continued.

THRUST, LIFT, AND SIDE FORCE INFORMATION

```
        MACH NUMBER =   .17500E+01
  ANGLE OF ATTACK =   20.000 DEGREES
  SIDE SLIP ANGLE =     .000 DEGREES
        WING AREA =     .783
   REFERENCE AREA =   .44180
 REFERENCE LENGTH =   .75000
```

BERNOUILLI TYPE LOADING PRESSURE

	TOTAL	RIGHT WING	LEFT WING	UPPER WING	LOWER WING
DEFL. ANGLE DEG. =		.00000	.00000	20.00000	20.00000
CN =	.39695E+01	.20218E+01	.19477E+01		
CY =	-.22618E+01			-.95169E+00	-.13101E+01
CTHRUST =	IIIII	.0	.0	.0	.0
CL =	IIIII	IIIII	IIIII	IIIII	IIIII
CDI =	IIIII	IIIII	IIIII	IIIII	IIIII

```
   CDI/CL**2 =   IIIII
      CNADDV =   .0
      CYADDH =   .0
    CY-BIP   =   .0
    CN-BIP   =   .0

     ROLMOMR =  -.23088E+01
     ROLMOML =   .22301E+01
     ROLMOMU =  -.10900E+01
     ROLMOMD =   .14950E+01
```

SPANWISE DISTRIBUTION

RIGHT WING

I	Y/(B/2)	CN*C/(2*B)	CT*C/(2*B)
1	.34725	.21253	.00000
2	.45801	.20002	.00000
3	.56871	.18411	.00000
4	.67932	.16498	.00000
5	.78975	.14250	.00000
6	.89012	.11997	.00000
7	.98956	.12586	.00000
8	1.09945	.06269	.00000
9	1.21615	.03268	.00000

FIG. A-6(n). Continued.

LEFT WING

I	Y/(B/2)	CN*C/(2*B)	CT*C/(2*B)
1	-.34725	.19867	.00000
2	-.45801	.19339	.00000
3	-.56871	.18024	.00000
4	-.67932	.16410	.00000
5	-.78975	.14194	.00000
6	-.89012	.11987	.00000
7	-.98956	.08759	.00000
8	-1.09945	.08181	.00000
9	-1.21615	.03267	.00000

UPPER WING

I	Z/(B/2)	CY*C/(2*B)	CT*C/(2*B)
1	.34725	.10430	.00000
2	.45801	.09391	.00000
3	.56871	.08445	.00000
4	.67932	.07505	.00000
5	.78975	.06434	.00000
6	.89012	.05376	.00000
7	.98956	.05596	.00000
8	1.09945	.03636	.00000
9	1.21615	.01716	.00000

LOWER WING

I	Z/(B/2)	CY*C/(2*B)	CT*C/(2*B)
1	-.34725	.12360	.00000
2	-.45801	.12902	.00000
3	-.56871	.12549	.00000
4	-.67932	.11857	.00000
5	-.78975	.10551	.00000
6	-.89012	.09005	.00000
7	-.98956	.05654	.00000
8	-1.09945	.03759	.00000
9	-1.21615	.02269	.00000

ROLLING MOMENT = .32632
BETA = .00000 DEGREES.

FIG. A-6(o). Concluded.

Appendix B

CRUTRJ, A COMPUTER PROGRAM FOR CALCULATING THE TRAJECTORIES OF FREE VORTICES IN THE PRESENCE OF A CRUCIFORM WING-BODY COMBINATION

INTRODUCTION

The purpose of the program named CRUTRJ is to calculate the trajectories of free vortices in the presence of a cruciform wing-body combination. Slender-body theory is used. The calculation procedure is described in section 4.7 of Ref. B-1, Appendix A of Ref. B-2 and section 9.4 of Ref. B-3.

The program is written in the FORTRAN IV language (026 punch) and has been run on the CDC 6600 machine belonging to Boeing Computer Services, Inc.

DESCRIPTION OF INPUT

In the following discussion, the content of all input cards is specified. The input formats for all cards are shown in Fig. B-1. All the input variables are listed at the end of this section in the order of appearance in the input deck. Input cases may be stacked. The input for a sample case is given in Fig. B-2.

Item 1

The first card tells the computer how many identification cards will be read in.

Item 2

The second group of cards serve as identifiers and may contain any alphanumeric information desired.

Item 3

The input card for this item contains dimensional information for the fins and body as shown in Fig. B-3. The body is assumed to be a circular cylinder in the region of calculation. Since the vortex information supplied to CRUTRJ will usually be nondimensionalized by the body radius, it is suggested that the fin-body dimensions also be nondimensionalized by the body radius to avoid confusion. If this is done, set RBDY=1. The trajectories of free vortices in the presence of a cylinder alone can be obtained by setting SBW = RBDY.

Item 4

This card contains information required for the integration package. It also contains the included angle of attack and bank angle. The IBM Scientific Subroutine Package, HPCG, (see Ref. B-4) which is used to integrate the differential equations of motion of the vortices uses a predictor-corrector scheme together with a Runge-Kutta starting procedure. DXI is the initial integration interval required by HPCG for the trajectory calculations. The integration package will cut the interval in half if necessary for reasonable accuracy, and this halving process can occur ten times before the program automatically terminates execution. If the input value of DXI is too large, the program will stop because of unacceptable accuracy; and if DXI is too small, the running time will become large. The accuracy check by HPCG is based on the change in position of each of the vortices for a given time step. If the change is greater than 1 percent, the integration interval is halved. A value of DXI between 2 and 5 percent of the fin root chord will work for most cases. Under circumstances when two vortices get very close together or when a vortex gets very near the wing or body, a smaller value of DXI may be required.

DXOUT is the length of the interval for which print out of results is desired. DXI should not be larger than DXOUT.

Item 5

This item contains vortex strength and position information in unrolled body coordinates as shown in Fig. B-4. The nondimensional strength and position of the Nth vortex are given on a single card.

PROGRAM VARIABLE	ALGEBRAIC SYMBOL (IF APPLICABLE)	COMMENTS
Item 1		
NHEAD		Number of title cards to be read in Item 2.
Item 2		Any alphanumeric information may be put on NHEAD cards for identification of the calculation.
Item 3		
XWLE		x' coordinate of leading edge of fin root chord, see Fig. B-3.

PROGRAM VARIABLE	ALGEBRAIC SYMBOL (F APPLICABLE)	COMMENTS
XWTIPL		x' coordinate of leading edge of fin tip chord, see Fig. B-3.
XWTIPT		x' coordinate of trailing edge of tip chord, see Fig. B-3.
XWTE		x' coordinate of trailing edge of fin root chord, see Fig. B-3.
SBW	s_m	Semispan of fin measured from body centerline (dimensional), see Fig. B-3.
RBDY	a	Cylindrical body radius in region of fin (dimensional), see Fig. B-3.
Item 4		
NV		Number of vortices present, $1 \leq NV \leq 10$.
XI		x' coordinate where vortex trajectory calculation is to start, dimensional.
XF		x' coordinate where vortex trajectory calculation is to terminate, dimensional.
DXI		Maximum value of integration interval, DX', dimensional.
DXOUT		DX' between points at which output is desired, dimensional.
ALPHAC	α_c	Included angle, degrees.
PHI	ϕ	Bank angle, degrees.
Item 5		
GAM(J)	$\frac{\Gamma}{2\pi V_\infty}$	Strength of Jth vortex divided by $2\pi V_\infty$. If geometry is to be nondimensionalized on the body radius, set $GAM(J)=\Gamma/2\pi V_\infty a$. Positive when sense is counterclockwise, $1 \leq J \leq NV$.
YG(J)	y_v	y coordinate of the Jth vortex, $1 \leq J \leq NV$.
ZG(J)	z_v	z coordinate of the Jth vortex, $1 \leq J \leq NV$.

DESCRIPTION OF OUTPUT

The output for each run begins with the NHEAD title cards of Item 2. The input geometry and vortex information follow. Next follows vortex position information for each station at which printout is to be generated. The first line gives the x' coordinate, the integration interval used by HPCG at that step, the body radius (should remain constant), the fin span, the radius of the cylinder in the transformed plane and the derivative of the body radius with respect to the x' coordinate (should always be zero). The next NV lines give the following information for each vortex: the complex position in rolled body coordinates in the real plane, the complex position in rolled body coordinates in the transformed plane, the complex derivative dW/dS and the complex position in unrolled body coordinates.

The output for a sample case is given in Fig. B-5. The input for the run is shown in Fig. B-2.

PROGRAM LISTING

The CRUTRJ program consists of a main program and four subroutines. One of the routines, HPCG, was taken from the IBM Scientific Subroutines Package (Ref. B-4). Each source deck is identified in columns 73 through 80 by a four-character identification and a three-digit number sequencing the cards within that deck. The program listing is given on the following pages. The table below will act as a table of contents for the listing.

PROGRAM	IDENTIFICATION	PAGE NO.
CRUTRJ	CW01	157
FCT	CW02	157
OUTP	CW03	158
SHAPE	CW04	158
HPCG	CW05	158

```
      PROGRAM CHUTRJ(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C     PROGRAM FOR CALCULATING THE PATHS OF FREE VORTICES IN THE
C          PRESENCE OF A CRUCIFORM-WING-BODY COMBINATION
C          BODY RADIUS IS CONSTANT
C          NO IMAGE VORTEX AT BODY CENTERLINE
C
      COMPLEX SIGMA,EYE,EMIPHI,E2IPHI
      EXTERNAL FCT,OUTP
      DIMENSION TITLE(20),GAM(10),XG(10),YG(10),ZG(10)
      DIMENSION PRMT(5),AUX(16,20),Y(20),Z(20)
      DIMENSION SIGMA(10)
C
      COMMON /R/ WW,W
      COMMON /BODY/       RBDY,          XWLE,XWTIPL,XWTIPT,XWTE,SBW
      COMMON /VORTEX/ NV,NV2,GAM,YG,ZG
      COMMON /FLOW/ ALPHAC,PHI,ALPHA,EYE,EMIPHI,E2IPHI
      COMMON /PARAM/ DXOUT,XPRNT
C
  700 FORMAT (20A4)
  701 FORMAT (5I5)
  702 FORMAT (5X,20A4)
  703 FORMAT (1H1)
  704 FORMAT (8F10.5)
  705 FORMAT (//11X,2HXI,8X4HXWLE,4X6HXWTIPL,4X6HXWTIPT,6X4HXWTE,
     1   6X4HBW/2,6X4HRBDY)
  706 FORMAT (5X,12F10.4)
  707 FORMAT (//6X6HVORTEX,3X5HGAMMA,6X1HX,9X1HY,9X1HZ)
  708 FORMAT (I10,4F10.5)
  709 FORMAT (//5X25HTABLE OF BODY COORDINATES/15X,1HX,9X1HR)
  710 FORMAT (/10X7HALPHAC=,F8.2/,11X6HPHI  =,F8.2//)
  711 FORMAT (3F10.5)
  712 FORMAT (I2,F8.5,7F10.5)
  715 FORMAT (/// 5X42HVELOCITY INDUCED AT SPECIFIED FIELD POINTS)
  716 FORMAT (//10X1HX,9X1HY,9X1HZ,11X8HV/V(INF),4X8HW/V(INF))
  717 FORMAT (I4,3F10.3,5X,2(1PE12.4))
  718 FORMAT (3F10.5)
  719 FORMAT (//10X,28HFIELD POINT OUTSIDE OF TABLE ,5XI3,3F10.4/)
C
      EYE=CMPLX(0.0,1.0)
      NVMAX=10
      RAD=180./3.1415926
   10 READ(5,701) NHEAD
      IF (EOF(5)) 97,98
   97 STOP
   98 CONTINUE
      WRITE(6,703)
      DO 9 J=1,NVMAX
      YG(J)=0.0
    9 ZG(J)=0.0
      DO 11 J=1,NHEAD
      READ(5,700) TITLE
   11 WRITE (6,702) TITLE
      READ (5,704) XWLE,XWTIPL,XWTIPT,XWTE,SBW,RBDY
   20 READ (5,712) NV,XI,XF,DXI,DXOUT,ALPHAC,PHI
      IF (NV.EQ.0) GO TO 10
      READ (5,718) (GAM(J),       YG(J),ZG(J),J=1,NV)
      WRITE (6,705)
      WRITE (6,706) XI,XWLE,XWTIPL,XWTIPT,XWTE,SBW,RBDY
      WRITE (6,710) ALPHAC,PHI
      WRITE (6,707)
      DO 13 J=1,NV
      XG(J)=0.
   13 WRITE (6,708) J,GAM(J),XG(J),YG(J),ZG(J)
      ALPHA=SIN(ALPHAC/RAD)
      PHI=PHI/RAD
      EMIPHI=CEXP(-EYE*PHI)
      E2IPHI=CEXP(2.0*EYE*PHI)
      PRMT(1)=XI
      PRMT(2)=XF
      PRMT(3)=DXI
      PRMT(4)=.01
      NV2=NV+2
      NDIM=2*NV
      DO 18 J=1,NV
      JN=2*J
      RA=SQRT(YG(J)**2+ZG(J)**2)
      THA=ATAN2(ZG(J),YG(J))
      IF (THA.LT.0.0) THA=6.2831853+THA
      THA=THA+PHI
      YY=RA*COS(THA)
      ZZ=RA*SIN(THA)
      Y(JN-1)=YY
   18 Y(JN)=ZZ
      DUM=NDIM
      DUM=1./DUM
      DO 15 J=1,NDIM
   15 Z(J)=DUM
      XPRNT=XI-.0001
      CALL HPCG (PRMT,Y,Z,NDIM,IHLF,FCT,OUTP,AUX)
      IF (IHLF.GT.10) WRITE (6,701) IHLF
      GO TO 10
      END
```

```
      SUBROUTINE FCT(X,Y,Z)
C
      COMPLEX SIG,SIGS,CTA,CTB,CNUS,CNU,SIGMA,ENU,CENU,CTC,CTD,DNDS,
     1 D2NDS,CVEL,EYE,EMIPHI,E2IPHI
      DIMENSION SIGMA(10),ENU(10),CENU(10)
      DIMENSION Y(20),Z(20),GAM(10),YG(10),ZG(10)
      COMMON /VORTEX/ NV,NV2,GAM,YG,ZG
      COMMON /FLOW/ ALPHAC,PHI,ALPHA,EYE,EMIPHI,E2IPHI
      COMMON /RESULT/        SIGMA,ENU,A,S,RZ,       DS
C
C     LOOK UP BODY RADIUS AND LOCAL WING SEMISPAN
C
      CALL SHAPE (X,A,S,DS)
      S2=S*S
      S4=S2*S2
      A4=A**4
      RZ2=0.5*S2*(1.0+A4/S4)
      RZ4=RZ2*RZ2
      RZ=SQRT(RZ2)
C
C     CALCULATE SIGMA AND NU FOR ALL VORTICES
C
      DO 1 N=1,NV
      K=2*N
      SIG=CMPLX(Y(K-1),Y(K))
      SIGS=SIG*SIG
      CTS=SIGS+A4/SIGS
      CTA=CTS+CTS-4.0*RZ4
      CTA=CSQRT(CTA)
      YY=Y(K-1)
      ZZ=Y(K)
      IF (ABS(ZZ).GT.ABS(YY)) CTA=-CTA
      CNUS=0.5*(CTS+CTA)
      CNU=CSQRT(CNUS)
      IF (YY.LT.0.0) CNU=-CNU
      IF (YY.EQ.0.0.AND.ZZ.LT.0.0) CNU=-CNU
      SIGMA(N)=SIG
      ENU(N)=CNU
      CENU(N)=CONJG(CNU)
    1 CONTINUE
C
C     CALCULATE VELOCITIES
C
      DO 2 J=1,NV
      SIG=SIGMA(J)
      CNU=ENU(J)
      CTC=1.0-A4/(SIG**4)
      CTD=1.0-RZ4/(CNU**4)
      DNDS=SIG*CTC/(CNU*CTD)
```

```
      D2NDS=DNDS*(DNDS*(3.0-4.0/CTD)/CNU-(3.0-4.0/CTC)/SIG)
      CVEL=EYE*ALPHA*EMIPHI*(1.0+RZ2*E2IPHI/(CNU*CNU))
      DO 3 I=1,NV
      CTA=1.0/(CNU-RZ2/CFNU(I))
      IF (I.EQ.J) GO TO 4
      CTA=CTA+1.0/(ENU(I)-CNU)
    4 CVEL=CVEL+EYE*GAM(I)*CTA
    3 CONTINUE
      CVEL=CVEL*DNDS-0.5*EYE*GAM(J)*D2NDS/DNDS
      JJ=2*J
      Z(JJ)=-AIMAG(CVEL)
      Z(JJ-1)=REAL(CVEL)
    2 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE OUTP (X,Y,Z,IHLF,NDIM,PRMT)
      COMPLEX SIGMA,ENU,EYE,EMIPHI,E2IPHI
      DIMENSION Y(20),Z(20),PRMT(5),                    SIGMA(10),ENU(10),
     1          GAM(10),YG(10),ZG(10)
      COMMON /VORTEX/ NV,NV2,GAM,YG,ZG
      COMMON /RESULT/        SIGMA,ENU,A,B,RZ,      DS
      COMMON /PARAM/ DXOUT,XPRNT
      COMMON /B/ MM,M
      COMMON /FLOW/ ALPHAC,PHI,ALPHA,EYE,EMIPHI,E2IPHI
C
      IF (X.LT.XPRNT) RETURN
  700 FORMAT (//5X1HX,8X2HDX,11X1HA,9X1HS,8X2HRO,6X5HOR/DX)
  701 FORMAT (F9.4,F11.7,4F10.4)
  702 FORMAT (/1X6HVORTEX,1X11HSIGMA(REAL),3X6H(IMAG),5X8HNU(REAL),
     1          4X6H(IMAG),3X11HDN/DS(REAL),3X6H(IMAG),
     2    7X,1HY,11X,1HZ)
  703 FORMAT (I4,2X4(1PE12.3,E11.3))
      WRITE (6,700)
      WRITE (6,701) X,H,A,S,RZ,DS
      WRITE (6,702)
      DO 10 N=1,NV
      NN=2*N
      YP=REAL(SIGMA(N))
      ZP=AIMAG(SIGMA(N))
      RA=SQRT(YP*YP+ZP*ZP)
      THA=ATAN2(ZP,YP)
      IF (THA.LT.0.0) THA=6.2831853+THA
      THA=THA-PHI
      YY=RA*COS(THA)
      ZZ=RA*SIN(THA)
      WRITE (6,703) N,SIGMA(N),ENU(N),Z(NN-1),Z(NN),YY,ZZ
   10 CONTINUE
      XPRNT=X+DXOUT
      RETURN
      END
```

```
      SUBROUTINE SHAPE (X,A,S,DS)
C
C      TABLE LOOK-UP OF BODY COORDINATES
C
      COMMON /BODY/       RBDY,            XWLE,XWTIPL,XWTIPT,XWTE,SBW
      A=RBDY
      DS=0.0
      IF (X.LE.XWLE) GO TO 30
      IF (X.GT.XWLE .AND. X.LT.XWTIPL) GO TO 31
      IF (X.GE.XWTIPL .AND. X.LE.XWTIPT) GO TO 35
      IF (X.GT.XWTIPT.AND. X.LT.XWTE) GO TO 32
   30 S=A
      GO TO 40
   31 S=(X-XWLE)/(XWTIPL-XWLE)*(SBW-A) + A
      GO TO 40
   35 S=SBW
      GO TO 40
   32 S=(XWTE-X)/(XWTE-XWTIPT)*(SBW-A) + A
   40 CONTINUE
      IF (S.LT.A) S=A
      RETURN
      END
```

```
      SUBROUTINE  WPCG(PRMT,Y,DERY,NDIM,IHLF,FCT,OUTP,AUX)
C
      DIMENSION PRMT(5),Y(20),DERY(20),AUX(16,20)
      COMMON /B/ MM,M
      N=1
      IHLF=0
      X=PRMT(1)
      H=PRMT(3)
      PRMT(5)=0.
      DO 1 I=1,NDIM
      AUX(16,I)=0.
      AUX(15,I)=DERY(I)
    1 AUX(1,I)=Y(I)
      IF(H*(PRMT(2)-X))3,2,4
C
C     ERROR RETURNS
    2 IHLF=12
      GO TO 4
    3 IHLF=13
C
C     COMPUTATION OF DERY FOR STARTING VALUES
    4 CALL FCT(X,Y,DERY)
      IF(MM.GT.1) RETURN
C
C     RECORDING OF STARTING VALUES
      CALL OUTP(X,Y,DERY,IHLF,NDIM,PRMT)
      IF(PRMT(5))6,5,6
    5 IF(IHLF)7,7,6
    6 RETURN
    7 DO 8 I=1,NDIM
    8 AUX(8,I)=DERY(I)
C
C     COMPUTATION OF AUX(2,I)
      IBW=1
      GO TO 100
C
    9 X=X+H
      DO 10 I=1,NDIM
   10 AUX(2,I)=Y(I)
C
C     INCREMENT H IS TESTED BY MEANS OF BISECTION
   11 IHLF=IHLF+1
      X=X-H
      DO 12 I=1,NDIM
```

```
   12 AUX(4,I)=AUX(2,I)
      H=.5D0*H
      N=1
      IS=-2
      GO TO 100
C
   13 X=X+H
      CALL FCT(X,Y,DERY)
      IF(MM.GT.1) RETURN
      N=2
      DO 14 I=1,NDIM
      AUX(2,I)=Y(I)
   14 AUX(9,I)=DERY(I)
      IS=-3
      GO TO 100
C
C     COMPUTATION OF TEST VALUE DELT
   15 DELT=0.
      DO 16 I=1,NDIM
   16 DELT=DELT+AUX(15,I)*ABS(Y(I)-AUX(4,I))
      DELT=.066666667*DELT
      IF(DELT-PRMT(4))19,19,17
   17 IF(IHLF-10)11,18,18
C
C     NO SATISFACTORY ACCURACY AFTER 10 BISECTIONS, ERROR MESSAGE.
   18 IHLF=11
      X=X+H
      GO TO 4
C
C     THERE IS SATISFACTORY ACCURACY AFTER LESS THAN 11 BISECTIONS.
   19 X=X+H
      CALL FCT(X,Y,DERY)
      IF(MM.GT.1) RETURN
      DO 20 I=1,NDIM
      AUX(3,I)=Y(I)
   20 AUX(10,I)=DERY(I)
      N=3
      IS=-4
      GO TO 100
C
   21 N=1
      X=X+H
      CALL FCT(X,Y,DERY)
      IF(MM.GT.1) RETURN
      X=PRMT(1)
      DO 22 I=1,NDIM
      AUX(11,I)=DERY(I)
   22 Y(I)=AUX(1,I)+H*(.375*AUX(8,I)+.79166667*AUX(9,I)-.20833333*AUX(10C05 92
     1,I)+.041666667*DERY(I))
   23 X=X+H
      N=N+1
      CALL FCT(X,Y,DERY)
      IF(MM.GT.1) RETURN
      CALL OUTP(X,Y,DERY,IHLF,NDIM,PRMT)
      IF(PRMT(5))6,24,6
   24 IF(N-4)25,200,200
   25 DO 26 I=1,NDIM
      AUX(N,I)=Y(I)
   26 AUX(N+7,I)=DERY(I)
      IF(N-3)27,29,200
C
   27 DO 28 I=1,NDIM
      DELT=AUX(9,I)+AUX(9,I)
      DELT=DELT+DELT
   28 Y(I)=AUX(1,I)+.33333333*H*(AUX(8,I)+DELT+AUX(10,I))
      GO TO 23
C
   29 DO 30 I=1,NDIM
      DELT=AUX(9,I)+AUX(10,I)
      DELT=DELT+DELT+DELT
   30 Y(I)=AUX(1,I)+.375*H*(AUX(8,I)+DELT+AUX(11,I))
      GO TO 23
C
C
C     ***********************************************************
C     THE FOLLOWING PART OF SUBROUTINE DHPCG COMPUTES BY MEANS OF
C     RUNGE-KUTTA METHOD STARTING VALUES FOR THE NOT SELF-STARTING
C     PREDICTOR-CORRECTOR METHOD.
```

```
  100 DO 101 I=1,NDIM
      Z=H*AUX(N+7,I)
      AUX(5,I)=Z
  101 Y(I)=AUX(N,I)+.4*Z
C     Z IS AN AUXILIARY STORAGE LOCATION
C
      Z=X+.4*H
      CALL FCT(Z,Y,DERY)
      IF(MM.GT.1) RETURN
      DO 102 I=1,NDIM
      Z=H*DERY(I)
      AUX(6,I)=Z
  102 Y(I)=AUX(N,I)+.29697761*AUX(5,I)+.15875964*Z
C
      Z=X+.45573725*H
      CALL FCT(Z,Y,DERY)
      IF(MM.GT.1) RETURN
      DO 103 I=1,NDIM
      Z=H*DERY(I)
      AUX(7,I)=Z
  103 Y(I)=AUX(N,I)+.21810039*AUX(5,I)-3.05096515*AUX(6,I)+3.83286476*Z C05 143
C
      Z=X+H
      CALL FCT(Z,Y,DERY)
      IF(MM.GT.1) RETURN
      DO 104 I=1,NDIM
  104 Y(I)=AUX(N,I)+.17476028*AUX(5,I)-.55148066*AUX(6,I)+1.2055356*AUX(C05 149
     17,I)+.17118478*H*DERY(I)
      GO TO(9,13,15,21),IS
C     ***********************************************************
C
C
C     POSSIBLE BREAK-POINT FOR LINKAGE
C
C
C     STARTING VALUES ARE COMPUTED.
C     NOW START HAMMINGS MODIFIED PREDICTOR-CORRECTOR METHOD.
  200 ISTEP=3
  201 IF(N-8)204,202,204
C
C     N=8 CAUSES THE ROWS OF AUX TO CHANGE THEIR STORAGE LOCATIONS
  202 DO 203 N=2,7
      DO 203 I=1,NDIM
      AUX(N-1,I)=AUX(N,I)
  203 AUX(N+6,I)=AUX(N+7,I)
      N=7
C
C     N LESS THAN 8 CAUSES N+1 TO GET N
  204 N=N+1
C
C     COMPUTATION OF NEXT VECTOR Y
      DO 205 I=1,NDIM
      AUX(N-1,I)=Y(I)
  205 AUX(N+6,I)=DERY(I)
      X=X+H
  206 ISTEP=ISTEP+1
      DO 207 I=1,NDIM
      DELT=AUX(N-4,I)+1.33333333*H*(AUX(N+6,I)+AUX(N+6,I)-AUX(N+5,I)+AUXC05 180
     1(N+4,I)+AUX(N+4,I))
      Y(I)=DELT-.92561983*AUX(16,I)
  207 AUX(16,I)=DELT
C     PREDICTOR IS NOW GENERATED IN ROW 16 OF AUX, MODIFIED PREDICTOR
C     IS GENERATED IN Y. DELT MEANS AN AUXILIARY STORAGE.
C
      CALL FCT(X,Y,DERY)
      IF (MM.GT.1) RETURN
C     DERIVATIVE OF MODIFIED PREDICTOR IS GENERATED IN DERY
C
      DO 208 I=1,NDIM
      DELT=.12500*(9.00*AUX(N-1,I)-AUX(N-3,I)+3.00*H*(DERY(I)+AUX(N+6,I)C05 192
     1+AUX(N+6,I)-AUX(N+5,I)))
      AUX(16,I)=AUX(16,I)-DELT
  208 Y(I)=DELT+.074380165*AUX(16,I)
C
C     TEST WHETHER H MUST BE HALVED OR DOUBLED
      DELT=0.
      DO 209 I=1,NDIM
  209 DELT=DELT+AUX(15,I)*ABS(AUX(16,I))
```

```
      IF(DELT-PRMT(4))210,222,222
C
C     H MUST NOT BE HALVED, THAT MEANS Y(I) ARE GOOD.
  210 CALL FCT(X,Y,DERY)
      IF(MM.GT.1) RETURN
      CALL OUTP(X,Y,DERY,IHLF,NDIM,PRMT)
      IF(PRMT(5))212,211,212
  211 IF(IHLF-11)213,212,212
  212 RETURN
  213 IF(H*(X-PRMT(2)))214,212,212
  214 IF(ABS(X-PRMT(2))-.1*ABS(H))212,215,215
  215 IF(DELT-.02*PRMT(4))216,216,201
C
C
C     H COULD BE DOUBLED IF ALL NECESSARY PRECEDING VALUES ARE
C     AVAILABLE
  216 IF(IHLF)201,201,217
  217 IF(N-7)201,218,218
  218 IF(ISTEP-4)201,219,219
  219 IMOD=ISTEP/2
      IF(ISTEP-IMOD-IMOD)201,220,201
  220 H=H+H
      IHLF=IHLF-1
      ISTEP=0
      DO 221 I=1,NDIM
      AUX(N-1,I)=AUX(N-2,I)
      AUX(N-2,I)=AUX(N-4,I)
      AUX(N-3,I)=AUX(N-6,I)
      AUX(N+6,I)=AUX(N+5,I)
      AUX(N+5,I)=AUX(N+3,I)
      AUX(N+4,I)=AUX(N+1,I)
      DELT=AUX(N+6,I)+AUX(N+5,I)
      DELT=DELT+DELT+DELT
  221 AUX(16,I)=8.96296296*(Y(I)-AUX(N-3,I))-3.36111111*H*(DERY(I)+DELT+
     1AUX(N+4,I))
      GO TO 201
C
C
C     H MUST BE HALVED
  222 IHLF=IHLF+1
      IF(IHLF-10)223,223,210
  223 H=.5*H
      ISTEP=0
      DO 224 I=1,NDIM
      Y(I)=.390625E-2*(8.E1*AUX(N-1,I)+135.00*AUX(N-2,I)+4.E1*AUX(N-3,I)
     1+AUX(N-4,I))-.1171875*(AUX(N+6,I)-6.*AUX(N+5,I)-AUX(N+4,I))*H
      AUX(N-4,I)=.390625E-2*(12.00*AUX(N-1,I)+135.00*AUX(N-2,I)+
     1108.00*AUX(N-3,I)+AUX(N-4,I))-.0234375*(AUX(N+6,I)+
     218.00*AUX(N+5,I)-9.00*AUX(N+4,I))*H
      AUX(N-3,I)=AUX(N-2,I)
  224 AUX(N-4,I)=AUX(N+5,I)
      X=X-H
      DELT=X-(H+H)
      CALL FCT(DELT,Y,DERY)
      IF(MM.GT.1) RETURN
      DO 225 I=1,NDIM
      AUX(N-2,I)=Y(I)
      AUX(N+5,I)=DERY(I)
  225 Y(I)=AUX(N-4,I)
      DELT=DELT-(H+H)
      CALL FCT(DELT,Y,DERY)
      IF(MM.GT.1) RETURN
      DO 226 I=1,NDIM
      DELT=AUX(N+5,I)+AUX(N+4,I)
      DELT=DELT+DELT+DELT
      AUX(16,I)=8.96296296*(AUX(N-1,I)-Y(I))
     1-3.36111111*H*(AUX(N+6,I)+DELT+DERY(I))
  226 AUX(N+3,I)=DERY(I)
      GO TO 206
      END
```

REFERENCES

B-1. Nielsen, J. N. Missile Aerodynamics. New York, N. Y., McGraw-Hill Book Co., 1960.

B-2. Nielsen Engineering & Research, Inc. Further Studies of the Induced Rolling Moments of Canard-Cruciform Missiles as Influenced by Canard and Body Vortices, by J. N. Nielsen, M. J. Hemsch, and M. F. E. Dillenius. Mountain View, Calif., NEAR, January 1975. (NEAR TR 79.)

B-3. ———. A Study of Induced Rolling Moments for Cruciform-Winged Missiles, by J. N. Nielsen, S. B. Spangler, and M. J. Hemsch. Mountain View, Calif., NEAR, December 1973. (NEAR TR 61.)

B-4. IBM Corporation. System/360 Scientific Subroutine Package, Version III Programmer's Manual. IBM Technical Publications Department, White Plains, N. Y., 1970.

Item No. 1: Format (5I5)
(1 card)

Column Number	5				
Program Variable	NHEAD				
Data					

Item No. 2: Format (20A4), any alphabetic or numeric information.
(NHEAD cards)

Column Number	1 - 80
Program Variable	TITLE
Data	

Item No. 3: Format (8F10.5)
(1 card)

Column Number	10	20	30	40	50	60
Program Variable	XWLE	XWTIPL	XWTIPT	XWTE	SBW	RBDY
Data						

FIG. B-1(a). Input Formats for CRUTRJ Computer Program.

Item No. 4: Format (I2, F8.5, 7F10.5)
(1 card)

Column Number	2	10	20	30	40	50	60	
Program Variable	NV	XI	XF	DXI	DXOUT	ALPHAC	PHI	
Data								

Item No. 5: Format (3F10.5)
(NV cards)

(1)

Column Number	10	20	30	
Program Variable	GAM(1)	YG(1)	ZG(1)	
Data				

(NV)

Column Number	10	20	30	
Program Variable	GAM(NV)	YG(NV)	ZG(NV)	
Data				

FIG. B-1(b). Concluded.

```
    1
SAMPLE CASE FOR CRUTRJ
      3.997      7.379      7.379      7.379      4.413        1.
  2   3.997      6.252       .05        .2        20.         20.
      .0252       .41       1.08
     -.0252      -.41       1.08
```

FIG. B-2. CRUTRJ Input for Sample Case.

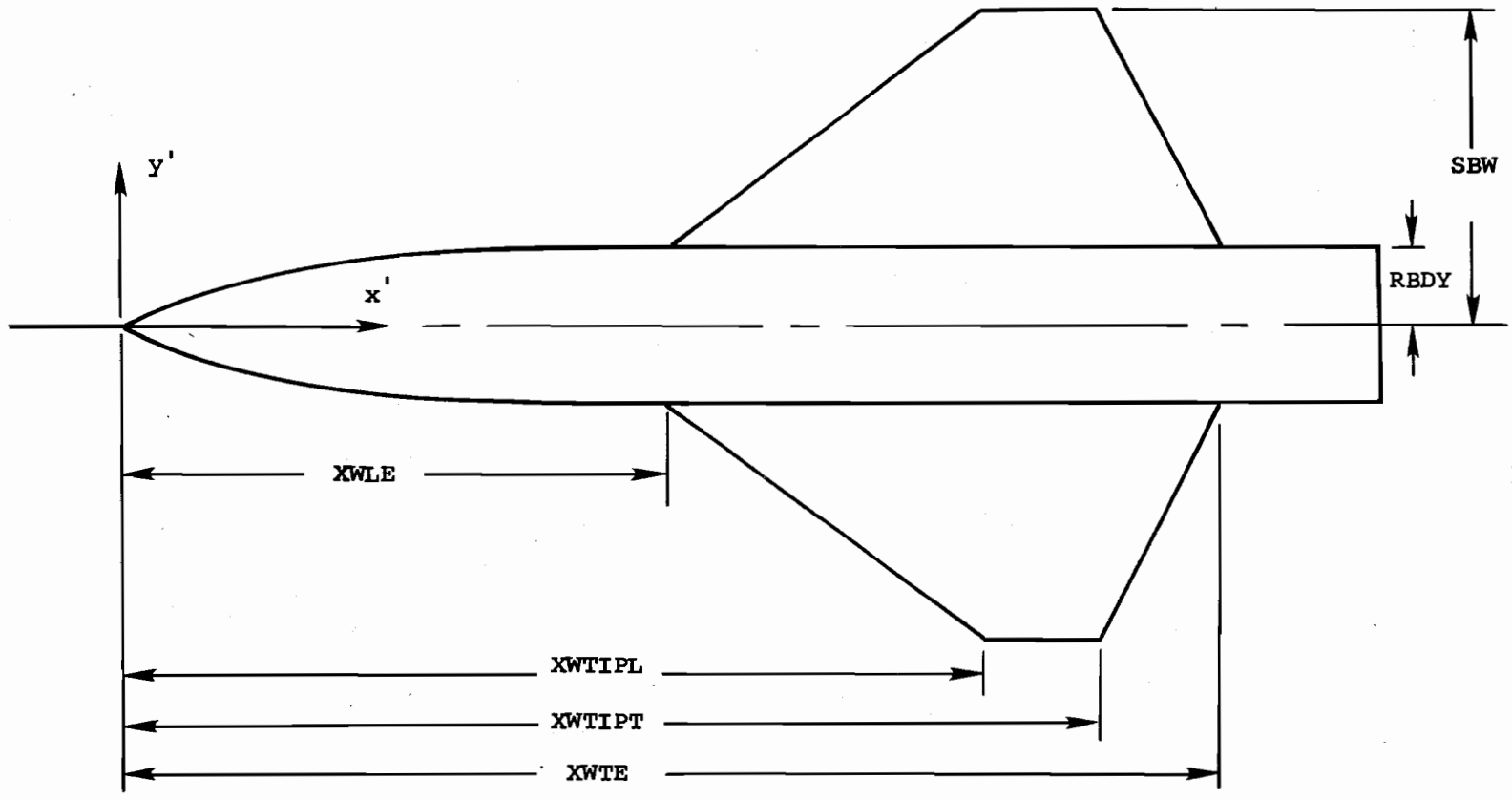

FIG. B-3. Variables Defining Configuration.

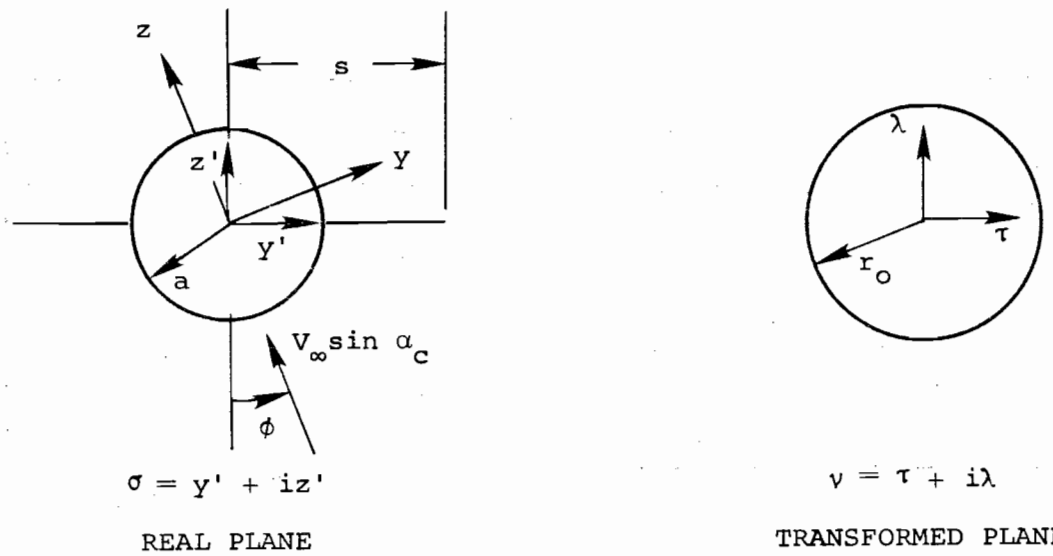

FIG. B-4. Coordinate Systems.

SAMPLE CASE FOR CRUTRJ

XI	XWLE	XWTIPL	XWTIPT	XWTE	BW/2	RBDY
3.9970	3.9970	7.3790	7.3790	7.3790	4.4130	1.0000

ALPHAC= 20.00
PHI = 20.00

VORTEX	GAMMA	X	Y	Z
1	.02520	.00000	.41000	1.08000
2	-.02520	.00000	-.41000	1.08000

X	DX	A	B	RO	DR/DX
3.9970	.0500000	1.0000	1.0000	1.0000	.0000

VORTEX	SIGMA(REAL)	(IMAG)	NU(REAL)	(IMAG)	DW/DS(REAL)	(IMAG)	Y	Z
1	1.589E-02	1.155E+00	1.589E-02	1.155E+00	-1.351E-01	7.792E-02	4.100E-01	1.080E+00
2	-7.547E-01	8.746E-01	-7.547E-01	8.746E-01	5.343E-02	1.465E-01	-4.100E-01	1.080E+00

X	DX	A	B	RO	DR/DX
4.1970	.0062500	1.0000	1.2018	1.0336	.0000

VORTEX	SIGMA(REAL)	(IMAG)	NU(REAL)	(IMAG)	DW/DS(REAL)	(IMAG)	Y	Z
1	5.605E-03	1.136E+00	1.343E-01	1.030E+00	-1.664E-02	-1.969E+00	3.938E-01	1.066E+00
2	-7.452E-01	9.031E-01	-7.677E-01	9.198E-01	3.812E-02	1.355E-01	-3.914E-01	1.104E+00

X	DX	A	B	RO	DR/DX
4.3978	.0031250	1.0000	1.4045	1.1134	.0000

VORTEX	SIGMA(REAL)	(IMAG)	NU(REAL)	(IMAG)	DW/DS(REAL)	(IMAG)	Y	Z
1	9.891E-01	1.569E-01	1.047E+00	3.802E-01	1.313E+00	-8.291E+00	9.831E-01	-1.908E-01
2	-7.377E-01	9.290E-01	-8.148E-01	9.840E-01	3.696E-02	1.216E-01	-3.755E-01	1.125E+00

X	DX	A	B	RO	DR/DX
4.5980	.0031250	1.0000	1.6065	1.2183	.0000

VORTEX	SIGMA(REAL)	(IMAG)	NU(REAL)	(IMAG)	DW/DS(REAL)	(IMAG)	Y	Z
1	-3.955E-01	-9.205E-01	-6.314E-01	-1.043E+00	-6.576E+00	2.827E+00	-6.864E-01	-7.297E-01
2	-7.303E-01	9.518E-01	-8.808E-01	1.057E+00	3.709E-02	1.069E-01	-3.607E-01	1.144E+00

X	DX	A	B	RO	DR/DX
4.7980	.0031250	1.0000	1.8083	1.3371	.0000

VORTEX	SIGMA(REAL)	(IMAG)	NU(REAL)	(IMAG)	DW/DS(REAL)	(IMAG)	Y	Z
1	-9.961E-01	1.152E-01	-1.176E+00	6.383E-01	5.497E-01	4.735E+00	-8.966E-01	4.489E-01
2	-7.229E-01	9.719E-01	-9.582E-01	1.137E+00	3.684E-02	9.370E-02	-3.469E-01	1.161E+00

FIG. B-5. CRUTRJ Output for Sample Case.

X	DX	A	S	RO	DR/DX
5.0105	.0125000	1.0000	2.0228	1.4724	.0000

VORTEX	SIGMA(REAL)	(IMAG)	NU(REAL)	(IMAG)	DW/DS(REAL)	(IMAG)	Y	Z
1	-4.407E-01	9.007E-01	-8.825E-01	1.181E+00	4.152E+00	2.030E+00	-1.061E-01	9.971E-01
2	-7.153E-01	9.904E-01	-1.048E+00	1.225E+00	3.640E-02	8.033E-02	-3.334E-01	1.175E+00

X	DX	A	S	RO	DR/DX
5.2136	.0062500	1.0000	2.2278	1.6069	.0000

VORTEX	SIGMA(REAL)	(IMAG)	NU(REAL)	(IMAG)	DW/DS(REAL)	(IMAG)	Y	Z
1	-1.892E-03	1.363E+00	-8.322E-01	1.375E+00	8.814E-05	6.682E+00	4.644E-01	1.281E+00
2	-7.081E-01	1.006E+00	-1.139E+00	1.312E+00	3.426E-02	7.237E-02	-3.213E-01	1.188E+00

X	DX	A	S	RO	DR/DX
5.4136	.0062500	1.0000	2.4296	1.7425	.0000

VORTEX	SIGMA(REAL)	(IMAG)	NU(REAL)	(IMAG)	DW/DS(REAL)	(IMAG)	Y	Z
1	-1.220E-02	2.451E+00	-4.886E-02	1.913E+00	-3.222E-01	2.016E-01	8.267E-01	2.307E+00
2	-7.014E-01	1.020E+00	-1.232E+00	1.400E+00	3.434E-02	6.611E-02	-3.103E-01	1.198E+00

X	DX	A	S	RO	DR/DX
5.6511	.0500000	1.0000	2.6693	1.9060	.0000

VORTEX	SIGMA(REAL)	(IMAG)	NU(REAL)	(IMAG)	DW/DS(REAL)	(IMAG)	Y	Z
1	-4.277E-02	2.488E+00	-4.951E-01	1.899E+00	-3.484E-02	2.101E-01	8.109E-01	2.353E+00
2	-6.938E-01	1.034E+00	-1.344E+00	1.507E+00	3.065E-02	5.781E-02	-2.981E-01	1.209E+00

X	DX	A	S	RO	DR/DX
5.8511	.0500000	1.0000	2.8711	2.0451	.0000

VORTEX	SIGMA(REAL)	(IMAG)	NU(REAL)	(IMAG)	DW/DS(REAL)	(IMAG)	Y	Z
1	-4.734E-02	2.535E+00	-6.847E-01	1.977E+00	-1.543E-02	2.505E-01	8.225E-01	2.398E+00
2	-6.879E-01	1.045E+00	-1.441E+00	1.599E+00	2.825E-02	5.241E-02	-2.888E-01	1.218E+00

X	DX	A	S	RO	DR/DX
6.0511	.0500000	1.0000	3.0729	2.1850	.0000

VORTEX	SIGMA(REAL)	(IMAG)	NU(REAL)	(IMAG)	DW/DS(REAL)	(IMAG)	Y	Z
1	-4.969E-02	2.587E+00	-8.394E-01	2.062E+00	-9.000E-03	2.689E-01	8.381E-01	2.448E+00
2	-6.825E-01	1.055E+00	-1.538E+00	1.692E+00	2.591E-02	4.778E-02	-2.803E-01	1.225E+00

X	DX	A	S	RO	DR/DX
6.2511	.0500000	1.0000	3.2748	2.3257	.0000

VORTEX	SIGMA(REAL)	(IMAG)	NU(REAL)	(IMAG)	DW/DS(REAL)	(IMAG)	Y	Z
1	-5.115E-02	2.642E+00	-9.776E-01	2.152E+00	-5.881E-03	2.795E-01	8.555E-01	2.500E+00
2	-6.775E-01	1.065E+00	-1.637E+00	1.785E+00	2.366E-02	4.377E-02	-2.725E-01	1.232E+00

FIG. B-5. Concluded.

Appendix C

REVFLO, A COMPUTER PROGRAM FOR CALCULATING VORTEX-INDUCED ROLLING MOMENTS OF CRUCIFORM WING-BODY COMBINATIONS

INTRODUCTION

The purpose of the program named REVFLO is to calculate the vortex-induced angles of attack and centers of pressure for each fin of a cruciform wing-body combination. Reverse-flow theorems and slender-body theory are used to calculate overall rolling moments due to the vortex-induced velocities. The overall loads due to each fin are treated as equivalent angles of attack and centers of pressure. The method is described in more detail in Appendix I of Ref. C-1, section 6.2.2 of Ref. C-2, section 7.6 of Ref. C-3, and Ref. C-4.

The program is written in FORTRAN IV language (026 punch) and has been run on the CDC 6600 machine belonging to Boeing Computer Services.

DESCRIPTION OF INPUT

In the following discussion, the content of all input cards is specified. The input formats for all cards are shown in Fig. C-1. All the input variables are listed at the end of this section in the order of appearance in the input deck. Input cases may be stacked. The input for a sample case is given in Fig. C-2.

Item 1

The first card serves as identification and may contain any alphanumeric information desired.

Item 2

The second card contains dimensional information, the number of vortices present and the number of integration intervals to be used in the Simpson Rule integration package. Geometry and coordinate system conventions are given in Fig. C-3. The program has the capability of approximating the effects of viscous cores for the vortices. The core radius is input as a fraction of the body radius. The program can also limit the velocities induced on the fins to a maximum fraction of the

free-stream velocity V_{max}/V_∞. To use this option, the core radius is input as a negative number whose magnitude is equal to V_{max}/V_∞.

Item 3

The third item contains vortex strength and position information in unrolled body coordinates. The nondimensional strength and position of each vortex are given on a single card.

PROGRAM VARIABLE	ALGEBRAIC SYMBOL (IF APPLICABLE)	COMMENTS
Item 1		Any alphanumeric information may be put on this card for identification of the calculation.
Item 2		
NI		One plus the number of intervals to be used in the Simpson Rule integration package. Must be odd.
NVOR		Number of vortices present, $1 \leq NVOR \leq 10$.
A	a	Missile body radius, dimensional.
S	s_m	Distance from body axis to fin tip chord, dimensional.
PHI	ϕ	Bank angle, degrees.
RZOA		Vortex core radius divided by body radius.
Item 3		
GAM(N)	$\frac{\Gamma}{2\pi V_\infty a}$	Nondimensional vortex strength of the Nth vortex. Positive when the sense is counterclockwise, $1 \leq N \leq NVOR$.
YVS(N)	$\frac{y_v}{a}$	y coordinate of the Nth vortex divided by the body radius, $1 \leq N \leq NVOR$.
ZVS(N)	$\frac{z_v}{a}$	z coordinate of the Nth vortex divided by the body radius, $1 \leq N \leq NVOR$.

DESCRIPTION OF OUTPUT

The output for each run of program REVFLO is printed on one page. The output begins with a program heading followed by the title of Item 1. The input geometry and vortex information follow. The calculated results

are presented as vortex-induced equivalent angles of attack and centers of pressure. The centers of pressure are measured from the body axis and are nondimensionalized by the body diameter. The geometry and coordinate system conventions are given in Fig. C-3. The fins are numbered clockwise beginning with the upper yaw panel.

The output for a sample case is given in Fig. C-4. The input for the run is shown in Fig. C-2.

PROGRAM LISTING

The REVFLO program consists of a main program and six subroutines. Four of the routines were taken from the IBM Scientific Subroutine Package (Ref. C-5). Each source deck is identified in columns 73 through 80 by a four-character identification and a three-digit number sequencing the cards within that deck. The program listing is given on the following pages. The table below will act as a table of contents for the listing.

PROGRAM	IDENTIFICATION	PAGE NO.
REVFLO	RF01	172
SIMSON	RF02	173
VEL	RF03	173
CEL1	RF04	174
CEL2	RF05	174
ELI1	RF06	175
ELI2	RF07	176

```
      PROGRAM REVPL(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C
C PROGRAM TO CALCULATE FORCES AND MOMENTS ON A CRUCIFORM WING-BODY COMB-
C  INATION DUE TO INTERACTION OF AN UPSTREAM-GENERATED SYSTEM OF
C  VORTICES WITH FINS.  THE CENTER VORTEX REQUIRED BY THE CIRCLE THEOREM
C  IS NOT INCLUDED.  HENCE, THE PROGRAM IS NOT SUITABLE FOR CALCULATION
C  OF LOADS DUE TO A VORTEX NOT GENERATED BY THE MISSILE ITSELF.  THE
C  COORDINATE SYSTEM USED IS THAT OF NEAR TR 85.  THE METHOD USES
C  REVERSE FLOW THEOREMS AND SLENDER BODY THEORY.  IT IS DESCRIBED
C  IN APPENDIX I OF AFFDL TR 72-83 AND IN NEAR TR 61.
C
C
C WRITTEN BY S.H. SPANGLER AND M.J. HEMSCH FOR NWC - JAN 1975.
C
C
      DIMENSION  YF(99),ZF(99),          CCL6(99),DUMF(99),GAM(10),YVS(10
     1),ZVS(10),YVF(10),ZVF(10),W1(99),W2(99),V1(99),V2(99),
     2                HEAD(20),CCL1(99),DUMR(99),ANG(4,99),CN(4),CRM(4)
C
C
  100 FORMAT (20A4)
  101 FORMAT (  2I5,7F10.0)
  102 FORMAT (8F10.0)
  103 FORMAT (1H1)
  104 FORMAT(1H ,14X,63HCALCULATION OF ROLLING MOMENTS INDUCED ON A CRUC
     1IFORM WING-BODY/1H ,17X,57HCOMBINATION BY UPSTREAM-GENERATED BODY
     2OR CANARD VORTICES///)
  105 FORMAT (5X,20A4)
  106 FORMAT(1H ,4X,11HBODY RADIUS,7X,8HFIN SPAN,4X,11HCORE RADIUS,5X,10
     1HBANK ANGLE,8X,2HNI)
  107 FORMAT(1H ,4E15.4,I10)
  108 FORMAT (1H )
  109 FORMAT(1H ,35X,11HVORTEX DATA//1H ,19X,15HGAM/2*PI*A*VINF,11X,8HYV
     1/A,11X,8HZV/A)
  110 FORMAT(1H ,20X,F14.4,2E15.4)
  111 FORMAT(1H ,///,34X,5HFIN 1,10X,5HFIN 2,10X,5HFIN 3,10X,5HFIN 4/1H
     1,1X,25HVORTEX INDUCED EQUIVALENT/1H ,2X,24HANGLE OF ATTACK, DEGREE
     2S,E13.4,3E15.4)
  112 FORMAT(1H0,4X,22HCENTER OF PRESSURE FOR/1H ,5X,20HVORTEX INDUCED L
     1OADS,E14.4,3E15.4)
C
C
C
C          NVOR IS NUMBER OF VORTICES                MAX OF 10
C          A AND S ARE BODY RADIUS AND SEMISPAN      DIMENSIONAL
C          PHI IS RANK ANGLE                         DEGREES
C          GAM IS VORTEX STRENGTH MADE NONDIM BY 2 PI A V
C          YVS AND ZVS ARE VORTEX COORDINATES MADE NONDIM BY A
C          RZOA IS VORTEX CORE RADIUS MADE NONDIM BY A
C
C
C          NUMBERING SYSTEM FOR FINS IN PROGRAM IS -
C             1, RIGHT HORIZ.  CN POS UP,  CRM POS CCW
C             2, LEFT  HORIZ,  CN POS UP,  CRM POS  CW
C             3, LOWER VERT,   CN POS  LEFT,  CRM POS  CW
C             4, UPPER VERT,   CN POS   LEFT, CRM POS CCW
C
C  PROGRAM OUTPUT USES THE CONVENTION THAT FIN 1 IS THE UPPER VERTICAL
C   AND THE REST ARE NUMBERED CLOCKWISE WHEN VIEWED FROM THE REAR.
C
    1 READ(  5,100)HEAD
      IF(EOF(  5))999,150
  150 READ (5,101)   NI,NVOR,A,S,PHI,RZOA
      ELREF=2.*A
      CLALF=1.
      RAD=57.29578
      PI=3.1415927
      PHI=PHI/RAD
      SINP=SIN(PHI)
      COSP=COS(PHI)
      SOA=S/A
C
C     INITIALIZATION
C
      DO 30 N=1,10
      GAM(N)=0.0
      YVS(N)=0.0
      ZVS(N)=0.0
      YVF(N)=0.0
      ZVF(N)=0.0
   30 CONTINUE
C
      DO 2 N=1,NVOR
      READ (5,102) GAM(N),YVS(N),ZVS(N)
      YVF(N)=YVS(N)*COSP-ZVS(N)*SINP
    2 ZVF(N)=YVS(N)*SINP+ZVS(N)*COSP
C
      WRITE (6,103)
      WRITE (6,104)
      WRITE (6,105) HEAD
      WRITE (6,108)
      WRITE (6,108)
      WRITE (6,106)
      PHI=PHI*RAD
      WRITE (6,107) A,S,RZOA,PHI,NI
      WRITE (6,108)
      WRITE (6,108)
      WRITE (6,108)
      WRITE (6,108)
      WRITE (6,109)
      DO 3 N=1,NVOR
      WRITE (6,110) GAM(N),YVS(N),ZVS(N)
    3 CONTINUE
      WRITE (6,108)
      WRITE (6,108)
C
C     COMPUTE FLOW ANGLES ALONG PANELS
C
      YF(1)=1.
      ZF(1)=1.
      NM1=NI-1
      XNI=NM1
      DO 4 N=2,NI
      EN=N
      YF(N)=1.+(SOA-1.)*(EN-1.)/XNI
    4 CONTINUE
      IF(RZOA.LT.-1.E-6)GO TO 60
C
C
C USE VISCOUS CORE AND ARCTANGENT TO LIMIT VELOCITIES.
C
      CALL VEL (YF,YVF,ZVF,W1,W2,V1,V2,NVOR,GAM,NI,   RZOA)
      DO 50 N=1,NI
      ANG(1,N)=ATAN(W1(N))
      ANG(2,N)=ATAN(W2(N))
      ANG(3,N)=ATAN(V1(N))
   50 ANG(4,N)=ATAN(V2(N))
      GO TO 65
C
C
C MAGNITUDES OF VELOCITIES ARE LIMITED TO VMAX EQUALS -RZOA.
C
   60 CALL VEL(YF,YVF,ZVF,W1,W2,V1,V2,NVOR,GAM,NI,0.)
      DO 61 N=1,NI
      ANG(1,N)=W1(N)
      ANG(2,N)=W2(N)
      ANG(3,N)=V1(N)
   61 ANG(4,N)=V2(N)
      VMAX=-RZOA
      DO 62 I=1,4
      DO 62 N=1,NI
   62 IF(ABS(ANG(I,N)).GT.VMAX)ANG(I,N)=SIGN(VMAX,ANG(I,N))
C
C     COMPUTE SECTION LOADING COEFFICIENTS
C
   65 SOA2=SOA*SOA
      WRITE(6,103)
      SMA2=(SOA-1.)**2
      DO 20 N=1,NM1
      YFOA2=YF(N)*YF(N)
      YMA2=(YF(N)-1.)**2
      CCL1(N)=4.*SQRT(SMA2-YMA2)
   20 CONTINUE
      CCL1(NI)=0.
```

```
C
      ROA2=0.25*(SOA2+1./SOA2)
      C2GAM=0.5/ROA2
      S2GAM=SQRT(1.-C2GAM*C2GAM)
      AK1=S2GAM
      IER=0
      CK=1.-AK1*AK1
      CALL CEL1 (AKK1,AK1,IER)
      CALL CEL2 (EPIK1,AK1,1.0,CK,IER)
      DO 8 N=1,NM1
      YFOA2=YF(N)*YF(N)
      C2THT=0.25*(YFOA2+1./YFOA2)/ROA2
      S2THT=SQRT(1.-C2THT*C2THT)
      S4THT=2.*S2THT*C2THT
      IF (N.EQ.1) GO TO 9
      A1=ASIN(S2THT/S2GAM)
      T2THT=S2THT/C2THT
      T2GAM=S2GAM/C2GAM
      HTAN1=0.5*ALOG((1.+S2THT/S2GAM)/(1.-S2THT/S2GAM))
      HTAN2=0.5*ALOG((1.+T2THT/T2GAM)/(1.-T2THT/T2GAM))
      TANA1=TAN(A1)
      CALL FLI1 (FA1K1,TANA1,C2GAM)
      CALL ELI2 (EA1K1,TANA1,C2GAM,1.0,CK)
      AKK1Z=AKK1*EA1K1-EPIK1*FA1K1
      CCL6(N)=8.*ROA2*(C2THT*HTAN1-C2GAM*HTAN2)/PI
      CCL6(N)=CCL6(N)+4.*ROA2*(AKK1*S4THT-2.*AK1*COS(A1)*AKK1Z)/PI
      GO TO 8
    9 CCL6(N)=8.*ROA2*(-C2GAM*ALOG  (C2GAM)+0.5*AKK1*S4THT)/PI
    8 CONTINUE
      CCL6(NI)=0.
C
C     COMPUTE FORCE AND MOMENT COEFFICIENTS
C
      DYA=(SOA-1.)/XNI
      DENOMN=2.*PI*(SOA-1.)**2
      DENOMR=DENOMN*ELREF/A
      DO 200 I=1,4
      DO 201 N=1,NI
      DUMF(N)=ANG(I,N)*CCL1(N)*CLALF/DENOMN
  201 DUMR(N)=ANG(I,N)*CCL6(N)*CLALF/DENOMR
      CALL SIMSON(NI,DUMF,DYA,CN(I))
  200 CALL SIMSON(NI,DUMR,DYA,CRM(I))
      CN(3)=-CN(3)
      CN(4)=-CN(4)
      CRM(3)=-CRM(3)
      CRM(4)=-CRM(4)
       YBAR1=CRM(1)/CN(1)
      YBAR2=CRM(2)/CN(2)
      YBAR3=CRM(3)/CN(3)
      YBAR4=CRM(4)/CN(4)
      ALF1=CN(1)*RAD*2.
      ALF2=CN(2)*RAD*2.
      ALF3=CN(3)*RAD*2.
      ALF4=CN(4)*RAD*2.
      WRITE(6,111)ALF4,ALF1,ALF3,ALF2
      WRITE(6,112)YBAR4,YBAR1,YBAR3,YBAR2
      GO TO 1
  999 STOP
      END
```

```
      SUBROUTINE SIMSON(N,F,DX,SUM)
      DIMENSION F(101)
      SUM=F(1)+F(N)
      DO 1 I=2,N,2
    1 SUM=SUM+4.0*F(I)
      M=N-2
      DO 2 I=3,M,2
    2 SUM=SUM+2.0*F(I)
      SUM=DX*SUM/3.0
      RETURN
      END
```

```
      SUBROUTINE VEL (YF,YVF,ZVF,W1,W2,V1,V2,NVOR,GAM,NI,   RZOA)
C
C     SUBROUTINE TO CALCULATE VELOCITIES ON PANEL
C
      DIMENSION  YF(99),ZF(99),CCL3(99),CCL6(99),DUMF(99),GAM(10),YVS(10
     1),ZVS(10),YVF(10),ZVF(10),W1(99),W2(99),V1(99),V2(99),AS(99),AU(99
     2),BS(99),BU(99)
C
      PI=3.1415927
      DO 1 N=1,NT
      W1(N)=0.0
      W2(N)=0.0
      V1(N)=0.0
      V2(N)=0.0
    1 CONTINUE
C
      DO 2 N=1,NI
      DO 2 M=1,NVOR
      RVF2=YVF(M)**2 + ZVF(M)**2
      ZABS=ABS(ZVF(M))
      GAMM=ATAN2((YF(N)-YVF(M)),ZABS)
      GAMMI=ATAN2((YF(N)-YVF(M)/RVF2),ZABS/RVF2)
      RR=SQRT((YF(N)-YVF(M))**2 + ZVF(M)**2)
      RRI=SQRT((YF(N)-YVF(M)/RVF2)**2 + (ZVF(M)/RVF2)**2)
      IF (RR-RZOA) 10,11,11
   10 DW1=GAM(M)*RR*       SIN(GAMM)/(RZOA*RZOA) - GAM(M)*       SIN(GAMMI
     1)/RRI
      GO TO 12
   11 DW1=GAM(M)*       SIN(GAMM)/RR - GAM(M)*       SIN(GAMMI)/RRI
C
   12 YF(N)=-YF(N)
      GAMM=ATAN2((YF(N)-YVF(M)),ZABS)
      GAMMI=ATAN2((YF(N)-YVF(M)/RVF2),ZABS/RVF2)
      RR=SQRT((YF(N)-YVF(M))**2 + ZVF(M)**2)
      RRI=SQRT((YF(N)-YVF(M)/RVF2)**2 + (ZVF(M)/RVF2)**2)
      IF (RR-RZOA) 13,14,14
   13 DW2=GAM(M)*RR*       SIN(GAMM)/(RZOA*RZOA) - GAM(M)*       SIN(GAMMI
     1)/RRI
      GO TO 15
   14 DW2=GAM(M)*       SIN(GAMM)/RR - GAM(M)*       SIN(GAMMI)/RRI
C
   15 YABS=ABS(YVF(M))
      DEL=ATAN2((ZVF(M)-YF(N)),YABS)
      DELI=ATAN2((ZVF(M)/RVF2-YF(N)),YABS/RVF2)
      RR=SQRT(YVF(M)**2 + (ZVF(M)-YF(N))**2)
      RRI=SQRT((YVF(M)/RVF2)**2 + (ZVF(M)/RVF2-YF(N))**2)
      IF (RR-RZOA) 16,17,17
   16 DV1=GAM(M)*RR*       SIN(DEL)/(RZOA*RZOA) - GAM(M)*       SIN(DELI)/
     1RRI
      GO TO 18
   17 DV1=GAM(M)*       SIN(DEL)/RR - GAM(M)*       SIN(DELI)/RRI
C
   18 YF(N)=-YF(N)
      DEL=ATAN2((ZVF(M)-YF(N)),YABS)
      DELI=ATAN2((ZVF(M)/RVF2-YF(N)),YABS/RVF2)
      RR=SQRT(YVF(M)**2 + (ZVF(M)-YF(N))**2)
      RRI=SQRT((YVF(M)/RVF2)**2 + (ZVF(M)/RVF2-YF(N))**2)
      IF (RR-RZOA) 19,20,20
   19 DV2=GAM(M)*RR*       SIN(DEL)/(RZOA*RZOA) - GAM(M)*       SIN(DELI)/
     1RRI
```

```
      GO TO 21
   20 DV2=GAM(M)*       SIN(DEL)/RR - GAM(M)*       SIN(DELI)/RRI
C
   21 W1(N)=W1(N)+DW1
      W2(N)=W2(N)+DW2
      V1(N)=V1(N)+DV1
      V2(N)=V2(N)+DV2
    2 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CEL1(RES,AK,IER)
C
C     ..................................................................
C
C        SUBROUTINE CEL1
C
C        PURPOSE
C           CALCULATE COMPLETE ELLIPTIC INTEGRAL OF FIRST KIND
C
C        USAGE
C           CALL CEL1(RES,AK,IER)
C
C        DESCRIPTION OF PARAMETERS
C           RES    - RESULT VALUE
C           AK     - MODULUS (INPUT)
C           IER    - RESULTANT ERROR CODE WHERE
C                     IER=0  NO ERROR
C                     IER=1  AK NOT IN RANGE -1 TO +1
C
C        REMARKS
C           FOR AK=+1,-1 THE RESULT IS SET TO 1.E30.
C           FOR MODULUS AK AND COMPLEMENTARY MODULUS CK,
C           EQUATION AK*AK+CK*CK=1.0 IS USED.
C           AK MUST BE IN THE RANGE -1 TO +1
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           DEFINITION
C           CEL1(AK)=INTEGRAL(1/SQRT((1+T*T)*(1+(CK*T)**2)), SUMMED
C           OVER T FROM 0 TO INFINITY).
C           EQUIVALENT ARE THE DEFINITIONS
C           CEL1(AK)=INTEGRAL(1/(COS(T)SQRT(1+(CK*TAN(T))**2)),SUMMED
C           OVER T FROM 0 TO PI/2),
C           CEL1(AK)=INTEGRAL(1/SQRT(1-(AK*SIN(T))**2),SUMMED OVER T
C           FROM 0 TO PI/2), WHERE K=SQRT(1.-CK*CK).
C           EVALUATION
C           LANDENS TRANSFORMATION IS USED FOR CALCULATION.
C           REFERENCE
C           R.BULIRSCH, 'NUMERICAL CALCULATION OF ELLIPTIC INTEGRALS
C           AND ELLIPTIC FUNCTIONS', HANDBOOK SERIES SPECIAL FUNCTIONS,
C           NUMERISCHE MATHEMATIK VOL. 7, 1965, PP. 78-90.
C
C     ..................................................................
C
C
      IER=0
C
C     TEST MODULUS
C
      GEO=1.-AK*AK
      IF(GEO)1,2,3
    1 IER=1
      RETURN
C
C     SET RESULT VALUE =OFLO=
C
    2 RES=1.E30
      RETURN
    3 GEO=SQRT(GEO)
      ARI=1.
    4 AARI=ARI
      TEST=AARI*1.E-4
      ARI=GEO+ARI
C
C     TEST OF ACCURACY
C
      IF(AARI-GEO-TEST)6,6,5
    5 GEO=SQRT(AARI*GEO)
      ARI=0.5*ARI
      GO TO 4
    6 RES=3.14159265/ARI
      RETURN
      END
```

```
      SUBROUTINE CEL2(RES,AK,A,B,IER)
C
C     ..................................................................
C
C        SUBROUTINE CEL2
C
C        PURPOSE
C           COMPUTES THE GENERALIZED COMPLETE ELLIPTIC INTEGRAL OF
C           SECOND KIND.
C
C
C        USAGE
C           CALL CEL2(RES,AK,A,B,IER)
C
C        DESCRIPTION OF PARAMETERS
C           RES    - RESULT VALUE
C           AK     - MODULUS (INPUT)
C           A      - CONSTANT TERM IN NUMERATOR
C           B      - FACTOR OF QUADRATIC TERM IN NUMERATOR
C           IER    - RESULTANT ERROR CODE WHERE
C                     IER=0  NO ERROR
C                     IER=1  AK NOT IN RANGE -1 TO +1
C
C        REMARKS
C           FOR AK = +1,-1 THE RESULT VALUE IS SET TO 1.E30 IF B IS
C           POSITIVE, TO -1.E30 IF B IS NEGATIVE.
C           SPECIAL CASES ARE
C           K(K) OBTAINED WITH A = 1, B = 1
C           E(K) OBTAINED WITH A = 1, B = CK*CK WHERE CK IS
C           COMPLEMENTARY MODULUS.
C           B(K) OBTAINED WITH A = 1, B = 0
C           D(K) OBTAINED WITH A = 0, B = 1
C           WHERE K, E, B, D DEFINE SPECIAL CASES OF THE GENERALIZED
C           COMPLETE ELLIPTIC INTEGRAL OF SECOND KIND IN THE USUAL
C           NOTATION, AND THE ARGUMENT K OF THESE FUNCTIONS MEANS
C           THE MODULUS.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           DEFINITION
C           RES=INTEGRAL((A+B*T*T)/(SQRT((1+T*T)*(1+(CK*T)**2))*(1+T*T))
C           SUMMED OVER T FROM 0 TO INFINITY).
C           EVALUATION
```

```
C          LANDENS TRANSFORMATION IS USED FOR CALCULATION.                RF05  46
C          REFERENCE                                                      RF05  47
C          R,BULIRSCH, NUMERICAL CALCULATION OF ELLIPTIC INTEGRALS        RF05  48
C          AND ELLIPTIC FUNCTIONS', HANDBOOK SERIES SPECIAL FUNCTIONS,    RF05  49
C          NUMERISCHE MATHEMATIK VOL. 7, 1965, PP. 78-90.                 RF05  50
C                                                                         RF05  51
C     ..................................................................RF05  52
C                                                                         RF05  53
C                                                                         RF05  54
      IER=0                                                               RF05  55
C                                                                         RF05  56
C     TEST MODULUS                                                        RF05  57
C                                                                         RF05  58
      GEO=1.-AK*AK                                                        RF05  59
      IF(GEO)1,2,6                                                        RF05  60
    1 IER=1                                                               RF05  61
      RETURN                                                              RF05  62
C                                                                         RF05  63
C     SET RESULT VALUE = OVERFLOW                                         RF05  64
C                                                                         RF05  65
    2 IF(B)3,5,4                                                          RF05  66
    3 RES=1.E30                                                           RF05  67
      RETURN                                                              RF05  68
    4 RES=1.E30                                                           RF05  69
      RETURN                                                              RF05  70
    5 RES=A                                                               RF05  71
      RETURN                                                              RF05  72
C                                                                         RF05  73
C     COMPUTE INTEGRAL                                                    RF05  74
C                                                                         RF05  75
    6 GEO=SQRT(GEO)                                                       RF05  76
      ARI=1.                                                              RF05  77
      AA=A                                                                RF05  78
      AN=A+B                                                              RF05  79
      W=B                                                                 RF05  80
    7 W=W+AA*GEO                                                          RF05  81
      W=W+W                                                               RF05  82
      AA=AN                                                               RF05  83
      AARI=ARI                                                            RF05  84
      ARI=GEO+ARI                                                         RF05  85
      AN=W/ARI+AN                                                         RF05  86
C                                                                         RF05  87
C     TEST OF ACCURACY                                                    RF05  88
C                                                                         RF05  89
      IF(AARI-GEO-1.E-4*AARI)9,9,8                                        RF05  90
    8 GEO=SQRT(GEO*AARI)                                                  RF05  91
      GEO=GEO+GEO                                                         RF05  92
      GO TO 7                                                             RF05  93
    9 RES=.78539816*AN/ARI                                                RF05  94
      RETURN                                                              RF05  95
      END                                                                 RF05  96
```

```
      SUBROUTINE ELI1(RES,X,CK)                                           RF06   1
C                                                                         RF06   2
C     ..................................................................RF06   3
C                                                                         RF06   4
C        SUBROUTINE ELI1                                                  RF06   5
C                                                                         RF06   6
C        PURPOSE                                                          RF06   7
C           COMPUTES THE ELLIPTIC INTEGRAL OF FIRST KIND                  RF06   8
C                                                                         RF06   9
C        USAGE                                                            RF06  10
C           CALL ELI1(RES,X,CK)                                           RF06  11
C                                                                         RF06  12
C        DESCRIPTION OF PARAMETERS                                        RF06  13
C           RES   - RESULT VALUE                                          RF06  14
C           X     - UPPER INTEGRATION BOUND (ARGUMENT OF ELLIPTIC         RF06  15
C                   INTEGRAL OF FIRST KIND)                               RF06  16
C           CK    - COMPLEMENTARY MODULUS                                 RF06  17
C                                                                         RF06  18
C        REMARKS                                                          RF06  19
C           MODULUS K = SQRT(1.-CK*CK).                                   RF06  20
C                                                                         RF06  21
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED                    RF06  22
C           NONE                                                          RF06  23
C                                                                         RF06  24
C        METHOD                                                           RF06  25
C           DEFINITION                                                    RF06  26
C           RES=INTEGRAL(1/SQRT((1+T*T)*(1+(CK*T)**2)), SUMMED            RF06  27
C           OVER T FROM 0 TO X).                                          RF06  28
C           EQUIVALENT ARE THE DEFINITIONS                                RF06  29
C           RES=INTEGRAL(1/(COS(T)*SQRT(1+(CK*TAN(T))**2)), SUMMED        RF06  30
C           OVER T FROM 0 TO ATAN(X)),                                    RF06  31
C           RES=INTEGRAL(1/SQRT(1-(K*SIN(T))**2), SUMMED OVER             RF06  32
C           T FROM 0 TO ATAN(X)).                                         RF06  33
C           EVALUATION                                                    RF06  34
C           LANDENS TRANSFORMATION IS USED FOR CALCULATION.               RF06  35
C           REFERENCE                                                     RF06  36
C           R. BULIRSCH, NUMERICAL CALCULATION OF ELLIPTIC INTEGRALS AND  RF06  37
C                 ELLIPTIC FUNCTIONS,                                     RF06  38
C                 HANDBOOK SERIES OF SPECIAL FUNCTIONS                    RF06  39
C                 NUMERISCHE MATHEMATIK VOL. 7, 1965, PP. 78-90.          RF06  40
C                                                                         RF06  41
C     ..................................................................RF06  42
C                                                                         RF06  43
C                                                                         RF06  44
      IF(X)2,1,2                                                          RF06  45
    1 RES=0.                                                              RF06  46
      RETURN                                                              RF06  47
    2 IF(CK)4,3,4                                                         RF06  48
    3 RES=ALOG(ABS(X)+SQRT(1.+X*X))                                       RF06  49
      GOTO 13                                                             RF06  50
    4 ANGLE=ABS(1./X)                                                     RF06  51
      GEO=ABS(CK)                                                         RF06  52
      ARI=1.                                                              RF06  53
      PIM=0.                                                              RF06  54
    5 SQGEO=ARI*GEO                                                       RF06  55
      AARI=ARI                                                            RF06  56
      ARI=GEO+ARI                                                         RF06  57
      ANGLE=-SQGEO/ANGLE+ANGLE                                            RF06  58
      SQGEO=SQRT(SQGEO)                                                   RF06  59
      IF(ANGLE)7,6,7                                                      RF06  60
C     REPLACE 0 BY SMALL VALUE                                            RF06  61
    6 ANGLE=SQGEO*1.E-8                                                   RF06  62
    7 TEST=AARI*1.E-4                                                     RF06  63
      IF(ABS(AARI-GEO)-TEST)10,10,8                                       RF06  64
    8 GEO=SQGEO+SQGEO                                                     RF06  65
      PIM=PIM+PIM                                                         RF06  66
      IF(ANGLE)9,5,5                                                      RF06  67
    9 PIM=PIM+3.1415927                                                   RF06  68
      GOTO 5                                                              RF06  69
   10 IF(ANGLE)11,12,12                                                   RF06  70
   11 PIM=PIM+3.1415927                                                   RF06  71
   12 RES=(ATAN(ARI/ANGLE)+PIM)/ARI                                       RF06  72
   13 IF(X)14,15,15                                                       RF06  73
   14 RES=-RES                                                            RF06  74
   15 RETURN                                                              RF06  75
      END                                                                 RF06  76
```

```
      SUBROUTINE ELI2(R,X,CK,A,B)                                       RF07   1
C                                                                       RF07   2
C     ******************************************************************RF07   3
C                                                                       RF07   4
C        SUBROUTINE ELI2                                                RF07   5
C                                                                       RF07   6
C        PURPOSE                                                        RF07   7
C           COMPUTES THE GENERALIZED ELLIPTIC INTEGRAL OF SECOND KIND   RF07   8
C                                                                       RF07   9
C        USAGE                                                          RF07  10
C           CALL ELI2(R,X,CK,A,B)                                       RF07  11
C                                                                       RF07  12
C        DESCRIPTION OF PARAMETERS                                      RF07  13
C           R      - RESULT VALUE                                       RF07  14
C           X      - UPPER INTEGRATION BOUND (ARGUMENT OF ELLIPTIC      RF07  15
C                    INTEGRAL OF SECOND KIND)                           RF07  16
C           CK     - COMPLEMENTARY MODULUS                              RF07  17
C           A      - CONSTANT TERM IN NUMERATOR                         RF07  18
C           B      - QUADRATIC TERM IN NUMERATOR                        RF07  19
C                                                                       RF07  20
C        REMARKS                                                        RF07  21
C           MODULUS K = SQRT(1.-CK*CK).                                 RF07  22
C           SPECIAL CASES OF THE GENERALIZED ELLIPTIC INTEGRAL OF       RF07  23
C           SECOND KIND ARE                                             RF07  24
C           P(ATAN(X),K) OBTAINED WITH A=1., B=1.                       RF07  25
C           E(ATAN(X),K) OBTAINED WITH A=1., B=CK*CK.                   RF07  26
C           B(ATAN(X),K) OBTAINED WITH A=1., B=0.                       RF07  27
C           D(ATAN(X),K) OBTAINED WITH A=0., B=1.                       RF07  28
C                                                                       RF07  29
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED                  RF07  30
C           NONE                                                        RF07  31
C                                                                       RF07  32
C        METHOD                                                         RF07  33
C           DEFINITION                                                  RF07  34
C           R=INTEGRAL((A+B*T*T)/(SQRT((1+T*T)*(1+(CK*T)**2))*(1+T*T)), RF07  35
C                  SUMMED OVER T FROM 0 TO X).                          RF07  36
C           EQUIVALENT IS THE DEFINITION                                RF07  37
C           R=INTEGRAL((A+(B-A)*(SIN(T))**2)/SQRT(1-(K*SIN(T))**2),     RF07  38
C                  SUMMED OVER T FROM 0 TO ATAN(X)).                    RF07  39
C           EVALUATION                                                  RF07  40
C           LANDENS TRANSFORMATION IS USED FOR CALCULATION.             RF07  41
C           REFERENCE                                                   RF07  42
C           R. BULIRSCH, NUMERICAL CALCULATION OF ELLIPTIC INTEGRALS AND RF07  43
C                  ELLIPTIC FUNCTIONS                                   RF07  44
C                  HANDBOOK SERIES OF SPECIAL FUNCTIONS                 RF07  45
C                  NUMERISCHE MATHEMATIK VOL. 7, 1965, PP. 78-90.       RF07  46
C                                                                       RF07  47
C     ******************************************************************RF07  48
C                                                                       RF07  49
C        TEST ARGUMENT                                                  RF07  50
      IF(X)2,1,2                                                        RF07  51
    1 R=0.                                                              RF07  52
      RETURN                                                            RF07  53
C        TEST MODULUS                                                   RF07  54
    2 C=0.                                                              RF07  55
      D=0.5                                                             RF07  56
      IF(CK)7,3,7                                                       RF07  57
    3 R=SQRT(1.+X*X)                                                    RF07  58
      R=(A-B)*ABS(X)/R+B*ALOG(ABS(X)+R)                                 RF07  59
C        TEST SIGN OF ARGUMENT                                          RF07  60
    4 R=R+C*(A-B)                                                       RF07  61
      IF(X)5,6,6                                                        RF07  62
    5 R=-R                                                              RF07  63
    6 RETURN                                                            RF07  64
C        INITIALIZATION                                                 RF07  65
    7 AN=(B+A)*0.5                                                      RF07  66
      AA=A                                                              RF07  67
      R=B                                                               RF07  68
      ANG=ABS(1./X)                                                     RF07  69
      PIM=0.                                                            RF07  70
      ISI=0                                                             RF07  71
      ARI=1.                                                            RF07  72
      GEO=ABS(CK)                                                       RF07  73
C        LANDEN TRANSFORMATION                                          RF07  74
    8 R=AA*GEO+R                                                        RF07  75
      SGEO=ARI*GEO                                                      RF07  76
      AA=AN                                                             RF07  77
      AART=ARI                                                          RF07  78
C        ARITHMETIC MEAN                                                RF07  79
      ARI=GEO+ARI                                                       RF07  80
C        SUM OF SINE VALUES                                             RF07  81
      AN=(R/ART+AA)*0.5                                                 RF07  82
      AANG=ABS(ANG)                                                     RF07  83
      ANG=-SGEO/ANG+ANG                                                 RF07  84
      PIMA=PIM                                                          RF07  85
      IF(ANG)10,9,11                                                    RF07  86
    9 ANG=-1.E-8*AANG                                                   RF07  87
   10 PIM=PIM+3.14159/7                                                 RF07  88
      ISI=ISI+1                                                         RF07  89
   11 AANG=ARI*ART+ANG*ANG                                              RF07  90
      P=D/SQRT(AANG)                                                    RF07  91
      IF(ISI-4)13,12,12                                                 RF07  92
   12 ISI=ISI-4                                                         RF07  93
   13 IF(ISI-2)15,14,14                                                 RF07  94
   14 P=-P                                                              RF07  95
   15 C=C+P                                                             RF07  96
      D=D*(AART-GEO)*0.5/ARI                                            RF07  97
      IF(ABS(AART-GEO)-1.E-4*AART)17,17,16                              RF07  98
   16 SGEO=SQRT(SGEO)                                                   RF07  99
C        GEOMETRIC MEAN                                                 RF07 100
      GEO=SGEO+SGEO                                                     RF07 101
      PIM=PIM+PIMA                                                      RF07 102
      ISI=ISI+ISI                                                       RF07 103
      GOTO 8                                                            RF07 104
C        ACCURACY WAS SUFFICIENT                                        RF07 105
   17 R=(ATAN(ART/ANG)+PIM)*AN/ARI                                      RF07 106
      C=C+D*ANG/AANG                                                    RF07 107
      GOTO 4                                                            RF07 108
      END                                                               RF07 109
```

REFERENCES

C-1. Air Force Flight Dynamics Laboratory. Prediction of Six-Degree-of-Freedom Store Separation Trajectories at Speeds Up to the Critical Speed, by F. K. Goodwin, M. F. E. Dillenius, and J. N. Nielsen, Nielsen Engineering & Research, Inc. Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, October 1972. (AFFDL-TR-72-83, Vol. I.)

C-2. Nielsen Engineering & Research, Inc. A Study of Induced Rolling Moments for Cruciform-Winged Missiles, by J. N. Nielsen, S. B. Spangler, and M. J. Hemsch. Mountain View, Calif., NEAR, December 1973. (NEAR TR 61.)

C-3. Nielsen, J. N. Missile Aerodynamics. New York, N. Y., McGraw-Hill Book Co., 1960.

C-4. Nielsen Engineering & Research, Inc. Further Studies of the Induced Rolling Moments of Canard-Cruciform Missiles as Influenced by Canard and Body Vortices, by J. N. Nielsen, M. J. Hemsch, and M. F. E. Dillenius. Mountain View, Calif., NEAR, January 1975. (NEAR TR 79.)

C-5. IBM Corporation. System/360 Scientific Subroutine Package, Version III Programmer's Manual. IBM Technical Publications Department, White Plains, N. Y., 1970.

Item No. 1: Format (20A4), any alphabetic or numeric information.
(1 card)

Column Number	1 - 80
Program Variable	HEAD
Data	

Item No. 2: Format (2I5, 7F10.0)
(1 card)

Column Number	5	10	20	30	40	50	
Program Variable	NI	NVOR	A	S	PHI	RZOA	
Data							

FIG. C-1(a). Input Formats for REVFLO Computer Program.

Item No. 3: Format (3F10.0)

(NVOR cards)

(1)

Column Number	10	20	30	
Program Variable	GAM(1)	YVS(1)	ZVS(1)	
Data				

(NVOR)

Column Number	10	20	30	
Program Variable	GAM(NVOR)	YVS(NVOR)	ZVS(NVOR)	
Data				

FIG. C-1(b). Concluded.

```
SAMPLE CASE FOR REVFLO
   21     7        .375       1.744          0.          0.
  -.6639     -.8421       2.586
   .1368      1.157       1.009
   .5377      1.621       2.898
    .141      1.122       8.921
    .193      3.492       8.921
   -.169      .8387       2.182
   -.186     -.8249       7.482
```

FIG. C-2. REVFLO Input for Sample Case.

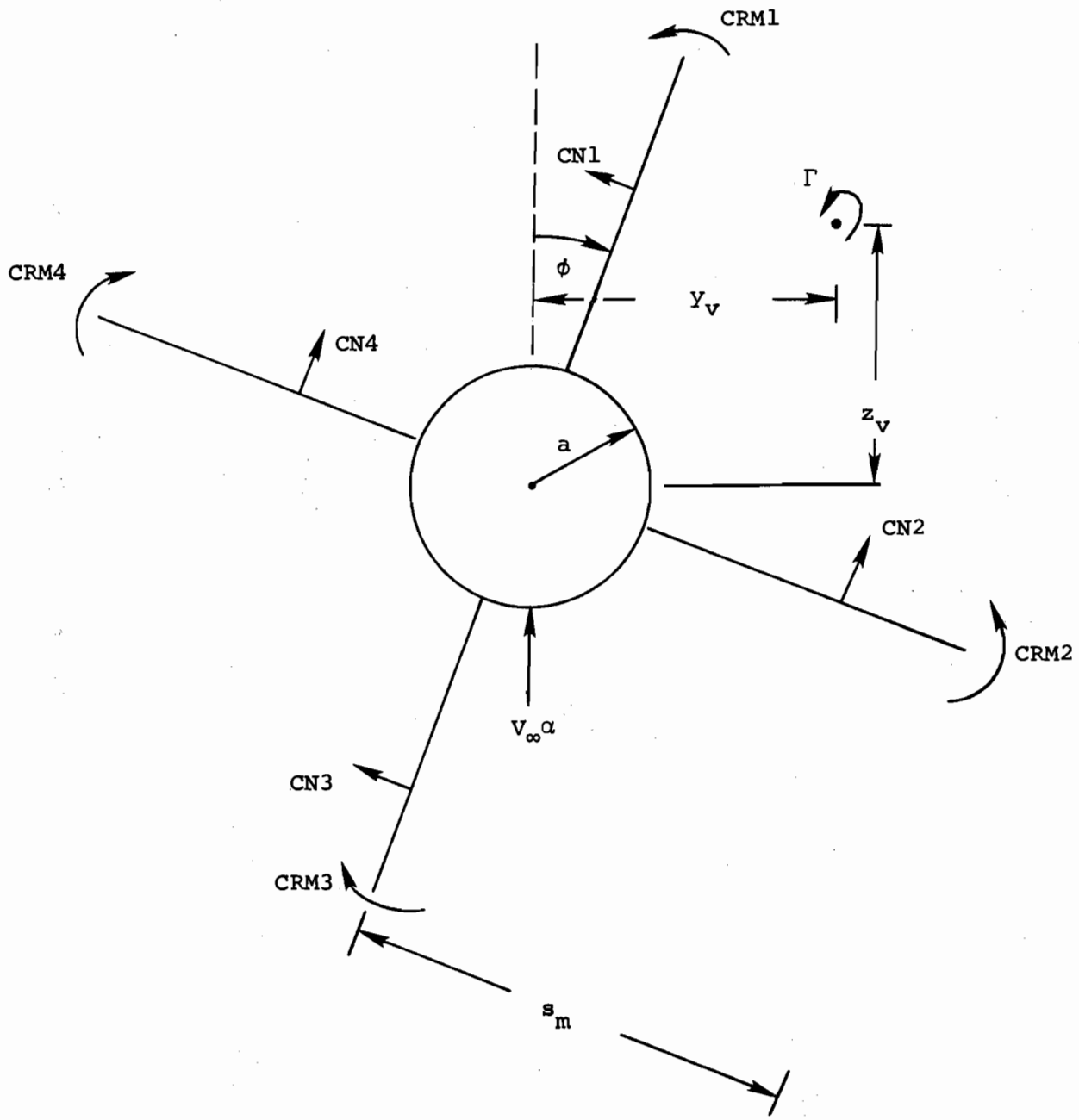

FIG. C-3. Geometry and Coordinate System Conventions.

CALCULATION OF ROLLING MOMENTS INDUCED ON A CRUCIFORM WING-BODY
COMBINATION BY UPSTREAM-GENERATED BODY OR CANARD VORTICES

SAMPLE CASE FOR REVFLO

BODY RADIUS	FIN SPAN	CORE RADIUS	BANK ANGLE	NI
.3750E+00	.1744E+01	0.	0.	21

VORTEX DATA

GAM/2*PI*A*VINF	YV/A	ZV/A
-.6639E+00	-.8421E+00	.2586E+01
.1368E+00	.1157E+01	.1009E+01
.5377E+00	.1621E+01	.2898E+01
.1410E+00	.1122E+01	.8921E+01
.1930E+00	.3492E+01	.8921E+01
-.1690E+00	.8387E+00	.2182E+01
-.1860E+00	-.8249E+00	.7482E+01

	FIN 1	FIN 2	FIN 3	FIN 4
VORTEX INDUCED EQUIVALENT ANGLE OF ATTACK, DEGREES	.3144E+01	-.6839E+01	.2164E+01	-.2210E+01
CENTER OF PRESSURE FOR VORTEX INDUCED LOADS	-.6413E+00	.4403E+00	.5116E+00	.2053E+00

FIG. C-4. REVFLO Output for Sample Case.

Appendix D

VCHASE, A COMPUTER PROGRAM FOR CALCULATING THE TRAJECTORIES OF CANARD AND AFTERBODY VORTICES

INTRODUCTION

The purpose of the program named VCHASE is to calculate the trajectories of canard and afterbody vortices as they pass from the canard trailing edge to the tail. Slender-body theory is used for the vortex tracking as discussed in section 9.4 of Ref. D-1. The crossflow drag approach together with the vortex impulse theorem is used to model the growth of the afterbody vortices as discussed in Ref. D-2. The method has been simplified somewhat by allowing the use of the calculated crossflow velocity vector at the initial axial station to obtain the initial positions. This procedure is discussed in the main text on page 21.

The program is written in the FORTRAN IV language (026 punch) and has been run on the CDC 6600 machine belonging to Boeing Computer Services. The differential equation solver, HPCG, was taken from Ref. D-3.

DESCRIPTION OF INPUT

In the following discussion, the content of all input cards is specified. The input formats for all cards are shown in Fig. D-1. All the input variables are listed at the end of this section in the order of appearance in the input deck. Input cases may be stacked. The input for a sample case is given in Fig. D-2.

Item 1

The first card serves as an identifier and may contain any alphanumeric information desired.

Item 2

The second card contains control information. NVOR, NXOUT and NCDC tell the machine how many entries there will be in the vortex, printout, and crossflow drag coefficient tables. If NCDC is less than two, all vortices will be treated as free; that is, their strengths will be held constant and the drag coefficient table will not be read in. NBODL and

NBODR are used to control the input for the initial positions of the afterbody vortices if they are present. If NCDC is less than two or if the user wishes to input the initial positions, set NBODL and NBODR equal to a value other than one. If the user wishes the program to calculate the initial positions of the afterbody vortices, set NBODL and NBODR equal to one.

Item 3

This card contains the initial values of the nondimensional vortex strengths, $\Gamma/2\pi V_\infty a$. Vortices numbered 1 and 2 must be the left and right afterbody vortices, respectively, if present. Normally, the afterbody vortices will have zero initial strengths unless the program is being restarted for some reason.

Item 4

This set of cards contains the initial positions of the vortices nondimensionalized by the body radius. The first NVOR entries are the y_v/a values and the second NVOR entries are the z_v/a values. If NBODL is equal to one, the first and NVOR+1 entries will be replaced by the program. Similarly, if NBODR is equal to one, the second and NVOR+2 entries will be replaced by the program. The program uses unrolled body coordinates.

Item 5

This card contains information required for the integration package. XBEG and XEND are the initial and final axial coordinates between which the integration is to take place. Experience on the CDC 6600 indicates that XEND should be a small increment larger than the final position in the output table. The increment must be less than DX. DX is the initial integration interval used by HPCG which uses a predictor-corrector scheme with a Runge-Kutta starting procedure. DX can be halved up to ten times to satisfy the accuracy interim ERR which is the maximum fractional change in vortex positions allowed between intervals. XMACH is the free-stream Mach number and ALPHA is the included angle of attack.

If two vortices of like sign get too close together, the program can be asked to combine them at their centroid based on their strengths. RZERO, which is the minimum allowable distance between vortices of like sign divided by the body radius, is used to control this option. RVOA is

the radius at which the afterbody vortices are to be placed initially divided by the body radius if NBODL and/or NBODR are equal to one. RVOA is ignored if NBODL and/or NBODR are not equal to one.

Item 6

This group of cards contains NXOUT entries in ascending value. The entries are the axial coordinates at which printout is desired nondimensionalized by the body radius.

Item 7

This optional group of cards contains NCDC entries (if NCDC is at least two) which are the abscissas, M_c, of the crossflow drag coefficient table. The entries must be in ascending order.

Item 8

This optional group of cards contains NCDC entries (if NCDC is at least two) which are the ordinates corresponding to the abscissae values input as Item 7.

PROGRAM VARIABLE	ALGEBRAIC SYMBOL (IF APPLICABLE)	COMMENTS
Item 1		Any alphanumeric information used for identification of the calculation.
Item 2		
NVOR		Number of vortices present, $2 \leq$ NVOR ≤ 10.
NXOUT		Number of axial stations at which printout is desired.
NCDC		Number of entries in the crossflow drag coefficient table. If NCDC ≤ 1, the table is not input and the vortex strengths all remain constant.
NBODL		Control value. If NBODL = 1, the program will calculate the initial position of the left body vortex.
NBODR		Control value. If NBODR = 1, the program will calculate the initial position of the right afterbody vortex.

PROGRAM VARIABLE	ALGEBRAIC SYMBOL (IF APPLICABLE)	COMMENTS
Item 3		
GAM(I)	$\frac{\Gamma}{2\pi V_\infty a}$	Initial strengths of the vortices, $1 \leq I \leq$ NVOR.
Item 4		
YOLD(I)	$\frac{y_v}{a}$, $1 \leq I \leq$ NVOR	Initial positions of the vortices in unrolled body coordinates.
	$\frac{z_v}{a}$, NVOR + $1 \leq I \leq 2$(NVOR)	The first NVOR entries are the y_v/a values and the next NVOR entries are the z_v/a entries.
Item 5		
XBEG		Axial coordinate at which integration is to begin, nondimensionalized by the body radius.
XEND		Axial coordinate at which integration is to end, nondimensionalized by the body radius.
DX		Initial integration interval used by HPCG. Try 0.1 to start with.
ERR		Accuracy criterion used by HPCG. Try 0.001 to start with.
XMACH	M_∞	Free-stream Mach number, Ignored if NCDC $\leq$ 1.
ALPHA	α_c	Included angle of attack, degrees.
RZERO	$\frac{r_o}{a}$	Minimum distance for separation of vortices with like signs, nondimensionalized by the body radius.
RVOA	$\frac{r_v}{a}$	Radius at which afterbody vortices are positioned initially, nondimensionalized by the body radius. Ignored if NBODL and/or NBODR $\neq$ 1.
Item 6		
XOUT(I)		Axial coordinates in ascending value at which printout is desired, nondimensionalized by the body radius. $1 \leq I \leq$ NXOUT. XOUT(1) must be greater than XBEG.

PROGRAM VARIABLE	ALGEBRAIC SYMBOL (IF APPLICABLE)	COMMENTS
Item 7		Optional vector of crossflow Mach numbers used in drag coefficient table. Not input if NCDC $\leq$ 1.
XMC(I)	M_c	Crossflow Mach number for which crossflow drag coefficient is given, in ascending value. $1 \leq I \leq$ NCDC.
Item 8		Optional vector of crossflow drag coefficient corresponding to XMC(I). Not input if NCDC $\leq$ 1.
CDC(I)	c_{d_c}	Crossflow drag coefficient corresponding to XMC(I). $1 \leq I \leq$ NCDC.

DESCRIPTION OF OUTPUT

The output for each run begins with a standard heading followed by the title card of Item 1. The input quantities α_c, M_∞, DX, ERR, RZERO and RVOA are output on the next line. Then follows the crossflow drag coefficient table if NCDC $\geq$ 2. Next, the program prints out vortex and flow-field information for each axial station including XBEG for which printout was specified. From left to right the output reads: (1) X/A, the axial station nondimensionalized by the body radius; I, the identification number of the vortices; GAMMA(I), the nondimensional strength of the vortices at X/A; Y(I)/A, the nondimensional y-coordinate of the vortices; Z(I)/A, the nondimensional z-coordinate of the vortices; CDC, the crossflow drag coefficient used at X/A; FLOANG and THETA.

FLOANG and THETA are obtained as follows. The upwash and sidewash at the body axis due to the external vortices are calculated. The quantity sin α_c is added to the upwash to account for the flow of the free stream around the cylinder. FLOANG is the arc sine in degrees of the magnitude of the crossflow velocity vector (divided by V_∞) and THETA is the polar angle in degrees of the vector measured from the positive y-axis counterclockwise. The output for a sample case is given in Fig. D-3.

PROGRAM LISTING

The VCHASE program consists of a main program and four subroutines. One of the routines was taken from the IBM Scientific Subroutine Package (Ref. D-3). Each source deck is identified in columns 73 through 80 by

a four-character identification and a three-digit number sequencing the cards within that deck. The program listing is given on the following pages. The table below will act as a table of contents for the listing.

PROGRAM	IDENTIFICATION	PAGE NO.
VCHASE	VC01	189
OUTP	VC02	189
DERIV	VC03	190
INTERP	VC04	191
HPCG	VC05	191

```
      PROGRAM VCHASE(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C
C  PROGRAM TO CHASE CANARD AND BODY VORTICES FROM TRAILING EDGE OF
C  CANARDS TO LEADING EDGE OF TAIL.  AFTERBODY IS ASSUMED TO BE
C  CYLINDRICAL WITH CONSTANT RADIUS.  PROGRAM USES UNROLLED BODY COORDI-
C  NATES.  METHOD IS DESCRIBED IN NEAR TR 79.
C
C       WRITTEN BY M.HEMSCH,  NEAR,INC. FOR NWC --- OCT 9, 1974.
C
C
      DIMENSION HEAD(20),Y(20),DERY(20),PRMT(5),AUX(16,20)
      COMMON XOUT(100),NOUT,C1,C2,GAM(10),XOLD,YOLD(20),NVOR,NVOR2
      COMMON CDC(20),XMC(20) ,XMACH,NCDC,RZERO2
       EXTERNAL OUTP,DERIV
C
C
    1 FORMAT(20A4)
    2 FORMAT(8F10.5)
    3 FORMAT(8I10)
    4 FORMAT(23H1VORTEX CHASING PROGRAM,///)
    5 FORMAT(1H0,9X,3HX/A,9X,1HI,7X,8HGAMMA(I),9X,6HY(I)/A,9X,6HZ(I)/A,
     112X,3HCDC,9X,6HFLOANG,10X,5HTHETA,//)
    6 FORMAT(E13.4, I5,4E15.4,2F15.2)
    7 FORMAT(13X, I5,3E15.4)
    8 FORMAT(35H1PROGRAM TERMINATED BY HPCG, IHLF =,I5)
    9 FORMAT(1H0,32X,16HINPUT PARAMETERS)
   10 FORMAT(1H ,20A4)
   11 FORMAT(1H0,7HALPHA =,F6.2,2X,6HMACH =,F6.3,2X,4HDX =,E9.3,2X,5HERR
     1 =,E9.3,2X,7HRZERO =,F6.2,2X,6HRVOA =,F6.2)
   12 FORMAT(1H0, 43HINPUT TABLE OF CROSS-FLOW DRAG COEFFICIENTS,//,18X,
     12HMC,13X,3HCDC,//)
   13 FORMAT(E20.4,E16.4)
C
C
  100 READ (5,1)HEAD
      IF(EOF(5))999,101
  101 READ(5,3)NVOR,NXOUT,NCDC,NBODL,NBODR
      READ(5,2)(GAM(I),I=1,NVOR)
      NVOR2=2*NVOR
      READ(5,2)(YOLD(I),I=1,NVOR2)
      READ(5,2)XBEG,XEND,DX,ERR,XMACH,ALPHA,RZERO,RVOA
      RZERO2=RZERO*RZERO
      READ(5,2)(XOUT(I),I=1,NXOUT)
      IF(NCDC.LE.1)GO TO 200
      READ(5,2)(XMC(I),I=1,NCDC)
      READ(5,2)(CDC(I),I=1,NCDC)
  200 WRITE(6,4)
      WRITE(6,10)HEAD
      WRITE(6,9)
      WRITE(6,11)ALPHA,XMACH,DX,ERR,RZERO,RVOA
      IF(NCDC.LE.1)GO TO 201
      WRITE(6,12)
      DO 102 I=1,NCDC
  102 WRITE(6,13)XMC(I),CDC(I)
  201 ALPHA=ALPHA/57.29578
      C1=SIN(ALPHA)
      C2=.1591549
      NOUT=1
  103 WRITE(6,5)
      PRMT(1)=XBEG
      PRMT(2)=XEND
      PRMT(3)=DX
      PRMT(4)=ERR
      PRMT(5)=0.
      UPWASH=C1
      SIWASH=0.
      IF(NVOR.LE.2)GO TO 106
      ISTART=3
      IF(NCDC.LE.1)ISTART=1
      DO 104 I=ISTART,NVOR
      COEFF=GAM(I)/(YOLD(I)+YOLD(I)+YOLD(I+NVOR)+YOLD(I+NVOR))
      UPWASH=UPWASH-YOLD(I)*COEFF
  104 SIWASH=SIWASH+YOLD(I+NVOR)*COEFF
  106 VCF=SQRT(UPWASH*UPWASH+SIWASH*SIWASH)
      XM=XMACH*VCF
      FLOANG=ABS(ASIN(VCF))*57.29578
      THETA=ATAN2(UPWASH,SIWASH)
      IF(NBODL.NE.1)GO TO 107
      YOLD(1)=RVOA*COS(THETA+.872665)
      YOLD(1+NVOR)=RVOA*SIN(THETA+.872665)
  107 IF(NBODR.NE.1)GO TO 108
      YOLD(2)=RVOA*COS(THETA-.872665)
      YOLD(2+NVOR)=RVOA*SIN(THETA-.872665)
  108 THETA=THETA*57.29578
      IF(NCDC.LE.1)GO TO 202
      JSAV=2
      CALL INTERP(NCDC,0,XMC,CDC,DM,XM,XCDC,0.,JSAV)
  202 I=1
      WRITE(6,6)XBEG,I,GAM(1),YOLD(1),YOLD(1+NVOR),XCDC,FLOANG,THETA
C
C
      DO 105 I=2,NVOR
  105 WRITE(6,7)I,GAM(I),YOLD(I),YOLD(I+NVOR)
C
C
      XOLD=XBEG
      HGTS=1./NVOR2
C
C
      DO 110 I=1,NVOR2
      Y(I)=YOLD(I)
  110 DERY(I)=HGTS
C
C
      CALL HPCG(PRMT,Y,DERY,NVOR2,IHLF,DERIV,OUTP,AUX)
      IF(IHLF.GE.10)WRITE(6,8)IHLF
      XBEG=XOLD
      IF(PRMT(5).EQ.1.)GO TO 103
      GO TO 100
  999 CONTINUE
      END
```

```
      SUBROUTINE OUTP(X,Y,DERY,IHLF,NDIM,PRMT)
C
C
C PROGRAM CALCULATES SOLUTION AT REQUIRED OUTPUT POINTS BY LINEAR
C INTERPOLATION AND UPDATES THE BODY VORTEX STRENGTHS.
C
C
      DIMENSION Y(1),DERY(1),PRMT(1)
      COMMON XOUT(100),NOUT,C1,C2,GAM(10),XOLD,YOLD(20),NVOR,NVOR2
      COMMON CDC(20),XMC(20) ,XMACH,NCDC,RZERO2
C
C
    6 FORMAT(//,E13.4, I5,4E15.4,2F15.2)
    7 FORMAT(    13X, I5,3E15.4)
    8 FORMAT(1H0,6HVORTEX,I2,11H AND VORTEX,I2,25H HAVE BEEN COMBINED AT
     1 X=,F10.5,//38H THE OLD STRENGTHS AND POSITIONS ARE =,//)
    9 FORMAT(1H ,6HVORTEX,I3,10X,4HGAM=,F10.5,5X,2HY=,F10.5,5X,2HZ=,F10.
     15)
   10 FORMAT(1H0,59HTHE COMBINED VORTEX HAS THE FOLLOWING STRENGTH AND P
     1OSITION,//,5H GAM=,F10.5,5X,2HY=,F10.5,5X,2HZ=,F10.5,//)
C
C
      DELTAX=X-XOLD
      IF(DELTAX.LE.0.) RETURN
      XX=XOUT(NOUT)
      IF(X.LT.XX)GO TO 100
      I=1
      XRATIO=(XX-XOLD)/(X-XOLD)
      YA=YOLD(1)+(Y(1)-YOLD(1))*XRATIO
      YB=YOLD(1+NVOR)+(Y(1+NVOR)-YOLD(1+NVOR))*XRATIO
```

```
      FLOANG=ARS(ASIN(VCF))*57.29578
      THETA=ATAN2(UPWASH,SIWASH)*57.29578
      WRITE(6,6)XX,I,GAM(I),YA,YB,XCOC,FLOANG,THETA
C
C
      DO 50 J=2,NVOR
      YA=YOLD(I)+(Y(I)-YOLD(I))*XRATIO
      YB=YOLD(I+NVOR)+(Y(I+NVOR)-YOLD(I+NVOR))*XRATIO
   50 WRITE(6,7)I,GAM(I),YA,YB
C
C
      NOUT=NOUT+1
  100 XOLD=X
C
C
       UPWASH=C1
      SIWASH=0.
      IF(NVOR.LE.2)GO TO 121
      ISTART=3
      IF(NCOC.LE.1)ISTART=1
      DO 120 I=ISTART,NVOR
      COEFF=GAM(I)/(Y(I)*Y(I)+Y(I+NVOR)*Y(I+NVOR))
      UPWASH=UPWASH+Y(I)*COEFF
  120 SIWASH=SIWASH+Y(I+NVOR)*COEFF
  121 VCF=SQRT(UPWASH*UPWASH+SIWASH*SIWASH)
      IF(NCOC.LE.1)GO TO 130
      XM=XMACH*VCF
      JSAV=2
      CALL INTERP(NCOC,0,XMC,COC,DM,XM,XCOC,0.,JSAV)
      TEMP=C2*XCOC*DELTAX*VCF
      Y1=Y(1)
      Y2=Y(2)
      Z1=Y(1+NVOR)
      Z2=Y(2+NVOR)
      YOLD1=YOLD(1)
      YOLD2=YOLD(2)
      ZOLD1=YOLD(1+NVOR)
      ZOLD2=YOLD(2+NVOR)
      CONST=1.-1./(Y1*Y1+Z1*Z1)
      Y1=Y1*CONST
      Z1=Z1*CONST
      CONST=1.-1./(Y2*Y2+Z2*Z2)
      Y2=Y2*CONST
      Z2=Z2*CONST
      CONST=1.-1./(YOLD1 *YOLD1+ZOLD1*ZOLD1)
      YOLD1=YOLD1*CONST
      ZOLD1=ZOLD1*CONST
      CONST=1.-1./(YOLD2*YOLD2+ZOLD2*ZOLD2)
      YOLD2=YOLD2*CONST
      ZOLD2=ZOLD2*CONST
      RHSZ=TEMP*SIWASH
      RHSY=TEMP*UPWASH
      AY=.5*(Y1+YOLD1)
      AZ=-.5*(Z1+ZOLD1)
      BY=.5*(Y2+YOLD2)
      BZ=-.5*(Z2+ZOLD2)
      COEFF=1./(BZ*AY-BY*AZ)
      GAM(1)=GAM(1)+COEFF*(BZ*RHSY-BY*RHSZ)
      GAM(2)=GAM(2)+COEFF*(AY*RHSZ-AZ*RHSY)
C
C
C DETERMINE IF VORTICES SHOULD BE COMBINED
C
C
  130 NVOR1=NVOR-1.
      DO 12 I=1,NVOR1
      JSTART=I+1
      DO 12 J=JSTART,NVOR
      DELY=Y(J)-Y(I)
      DELZ=Y(J+NVOR)-Y(I+NVOR)
      RVORTZ=DELY*DELY+DELZ*DELZ
      IF(RVORTZ.LE.RZERO2.AND.GAM(I)/GAM(J).GE.0.)GO TO 11
   12 CONTINUE
      GO TO 105
   11 WRITE(6,8)I,J,X
      WRITE(6,9)I,GAM(I),Y(I),Y(I+NVOR)
      WRITE(6,9)J,GAM(J),Y(J),Y(J+NVOR)
      RATIO=ABS(GAM(J))/(ABS(GAM(I))+ABS(GAM(J)))
      Y(I)=Y(I)+DELY*RATIO
      Y(I+NVOR)=Y(I+NVOR)+DELZ*RATIO
      GAM(I)=GAM(I)+GAM(J)
      WRITE(6,10)GAM(I),Y(I),Y(I+NVOR)
C
C
C SCALE DOWN ARRAY SIZE TO ELIMINATE INGESTED VORTEX
C
      JEND=J-1
      DO 20 I=1,JEND
      YOLD(I)=Y(I)
   20 YOLD(I+NVOR-1)=Y(I+NVOR)
      NVOR=NVOR-1
      NVOR2=2*NVOR
      DO 22 I=J,NVOR
      GAM(I)=GAM(I+1)
      YOLD(I)=Y(I+1)
   22 YOLD(I+NVOR)=YOLD(I+NVOR+2)
      PRMT(5)=1.
C
C RETURN TO MAIN PROGRAM AND RESTART AT PRESENT VALUE OF X
C
      RETURN
  105 DO 110 I=1,NVOR2
  110 YOLD(I)=Y(I)
      RETURN
      END
```

```
      SUBROUTINE DERIV(X,Y,DERY)
C
C
C PROGRAM CLCULATES THE DERIVATIVES NEEDED FOR THE DIFFERENTIAL EQUATION
C SOLVER HPCG.  SEE EQUATION (42) OF %A STUDY OF INDUCED ROLLING MOMENTS
C FOR CRUCIFORM-WINGED MISSILES% --- NEAR,INC, TR 61.
C
C
      COMMON XOUT(100),NOUT,C1,C2,GAM(10),XOLD,YOLD(20),NVOR,NVOR2
      COMMON COC(20),XMC(20) ,XMACH,NCOC,RZERO2
      DIMENSION Y(1),DERY(1)
      COMPLEX S(10),TEMP,SJ,SCONJ(10),SJD
C
C
      DO 10 I=1,NVOR
      S(I)=CMPLX(Y(I),Y(I+NVOR))
   10 SCONJ(I)=1./CONJG(S(I))
C
C
      DO 20 J=1,NVOR
      SJ=S(J)
      SJD=1./SJ
      TEMP=C1*(1.+SJD*SJD)+GAM(J)*(-1./(SJ-SCONJ(J)))
C
      DO 15 K=1,NVOR
      IF(K.EQ.J)GO TO 15
      TEMP=TEMP+GAM(K)*(1./(SJ-S(K))-1./(SJ-SCONJ(K)))
   15 CONTINUE
C
      DERY(J)=AIMAG(TEMP)
   20 DERY(J+NVOR)=REAL(TEMP)
C
C
      RETURN
      END
```

```
      SUBROUTINE INTERP (N,NS,X,F,DF,ARG,VALUE,SLOPE,JSAV)
C
C     LINEAR INTERPOLATION SUBROUTINE WITH OPTION FOR LINEAR
C     INTERPOLATION FOR SLOPE
C
C     DIMENSION STATEMENT
C
      DIMENSION X(1),F(1),DF(1)
C
      IF(N-1)1,10,20
C
C     NO ENTRIES IN TABLE,  SET VALUE TO ZERO.
C
    1 VALUE=0.0
      SLOPE=0.0
      RETURN
C
C     ONE ENTRY,  USE THIS VALUE.
C
   10 VALUE=F(1)
      SLOPE=0.0
      RETURN
C
C     CHECK FOR ARG BEING LESS THAN X(1)
C
   20 IF (ARG-X(1))21,21,22
C
C     SET VALUE EQUAL TO FIRST ENTRY.
C
   21 VALUE=F(1)
      SLOPE=0.0
      RETURN
C
C     CHECK FOR ARG BEING GREATER THAN X(N)
C
   22 IF(ARG-X(N))24,23,23
C
C     SET VALUE EQUAL TO LAST ENTRY
C
   23 VALUE=F(N)
      SLOPE=0.0
      RETURN
C
C     T-O OR MORE ENTRIES IN TABLE ,INTERPOLATE LINEARLY.
C
   24 CONTINUE
   40 J=JSAV-1
   42 J=J+1
   41 IF(ARG-X(J))50,43,42
   43 VALUE=F(J)
      SLOPE=DF(J)
      RETURN
   50 VALUE=0.0
      JSAV=J-1
      ML=J-1
      VALUE=F(ML)+(ARG-X(ML))*(F(J)-F(ML))/(X(J)-X(ML))
C
C     COMPUTE SLOPE BY LINEAR INTERPOLATION IF DESIRED
C
  100 IF(NS) 61,61,60
   60 SLOPE=DF(ML)+(ARG-X(ML))*(DF(J)-DF(ML))/(X(J)-X(ML))
   61 RETURN
      END
```

```
      SUBROUTINE HPCG (PRMT,Y,DERY,NDIM,IHLF,FCT,OUTP,AUX)
C
      DIMENSION PRMT(5),Y(8),DERY(8),AUX(16,8)
      COMMON /B/ MM,M
      N=1
      IHLF=0
      X=PRMT(1)
      H=PRMT(3)
      PRMT(5)=0.
      DO 1 I=1,NDIM
      AUX(16,I)=0.
      AUX(15,I)=DERY(I)
    1 AUX(1,I)=Y(I)
      IF(H*(PRMT(2)-X))3,2,4
C
C     ERROR RETURNS
    2 IHLF=12
      GO TO 4
    3 IHLF=13
C
C     COMPUTATION OF DERY FOR STARTING VALUES
    4 CALL FCT(X,Y,DERY)
      IF(MM.GT.1) RETURN
C
C     RECORDING OF STARTING VALUES
      CALL OUTP(X,Y,DERY,IHLF,NDIM,PRMT)
      IF(PRMT(5))6,5,6
    5 IF(IHLF)7,7,6
    6 RETURN
    7 DO 8 I=1,NDIM
    8 AUX(8,I)=DERY(I)
C
C     COMPUTATION OF AUX(2,I)
      ISW=1
      GO TO 100
C
    9 X=X+H
      DO 10 I=1,NDIM
   10 AUX(2,I)=Y(I)
C
C     INCREMENT H IS TESTED BY MEANS OF BISECTION
   11 IHLF=IHLF+1
      X=X-H
      DO 12 I=1,NDIM
   12 AUX(4,I)=AUX(2,I)
      H=.500*H
      N=1
      ISW=2
      GO TO 100
C
   13 X=X+H
      CALL FCT(X,Y,DERY)
      IF(MM.GT.1) RETURN
      N=2
      DO 14 I=1,NDIM
      AUX(2,I)=Y(I)
   14 AUX(9,I)=DERY(I)
      ISW=3
      GO TO 100
C
C     COMPUTATION OF TEST VALUE DELT
   15 DELT=0.
      DO 16 I=1,NDIM
   16 DELT=DELT+AUX(15,I)*ABS(Y(I)-AUX(4,I))
      DELT=.06666667*DELT
      IF(DELT-PRMT(4))19,19,17
   17 IF(IHLF-10)11,18,18
C
C     NO SATISFACTORY ACCURACY AFTER 10 BISECTIONS, ERROR MESSAGE.
   18 IHLF=11
      X=X+H
      GO TO 4
C
C     THERE IS SATISFACTORY ACCURACY AFTER LESS THAN 11 BISECTIONS.
   19 X=X+H
      CALL FCT(X,Y,DERY)
      IF(MM.GT.1) RETURN
```

```
      DO 20 I=1,NDIM                                                    VC05  78
      AUX(3,I)=Y(I)                                                     VC05  79
   20 AUX(10,I)=DERY(I)                                                 VC05  80
      N=3                                                               VC05  81
      IS=-4                                                             VC05  82
      GO TO 100                                                         VC05  83
C                                                                       VC05  84
   21 N=1                                                               VC05  85
      X=X+H                                                             VC05  86
      CALL FCT(X,Y,DERY)                                                VC05  87
      IF(MM.GT.1) RETURN                                                VC03  88
      X=PRMT(1)                                                         VC05  89
      DO 22 I=1,NDIM                                                    VC05  90
      AUX(11,I)=DERY(I)                                                 VC05  91
   22 Y(I)=AUX(1,I)+H*(.375*AUX(8,I)+.79166667*AUX(9,I)-.20833333*AUX(10VC05  92
     1,I)+.041666667*DERY(I))                                           VC05  93
   23 X=X+H                                                             VC05  94
      N=N+1                                                             VC05  95
      CALL FCT(X,Y,DERY)                                                VC05  96
      IF(MM.GT.1) RETURN                                                VC05  97
      CALL OUTP(X,Y,DERY,IHLF,NDIM,PRMT)                                VC05  98
      IF(PRMT(5))16,24,6                                                VC05  99
   24 IF(N-4)25,200,200                                                 VC05 100
   25 DO 26 I=1,NDIM                                                    VC05 101
      AUX(N,I)=Y(I)                                                     VC05 102
   26 AUX(N+7,I)=DERY(I)                                                VC05 103
      IF(N-3)27,29,200                                                  VC05 104
C                                                                       VC05 105
   27 DO 28 I=1,NDIM                                                    VC05 106
      DELT=AUX(9,I)+AUX(9,I)                                            VC05 107
      DELT=DELT+DELT                                                    VC05 108
   28 Y(I)=AUX(1,I)+.33333333*H*(AUX(8,I)+DELT+AUX(10,I))               VC05 109
      GO TO 23                                                          VC05 110
C                                                                       VC05 111
   29 DO 30 I=1,NDIM                                                    VC05 112
      DELT=AUX(9,I)+AUX(10,I)                                           VC05 113
      DELT=DELT+DELT+DELT                                               VC05 114
   30 Y(I)=AUX(1,I)+.375*H*(AUX(8,I)+DELT+AUX(11,I))                    VC05 115
      GO TO 23                                                          VC05 116
C                                                                       VC05 117
C                                                                       VC05 118
C     ******************************************************************VC05 119
C     THE FOLLOWING PART OF SUBROUTINE DMPCG COMPUTES BY MEANS OF       VC05 120
C     RUNGE-KUTTA METHOD STARTING VALUES FOR THE NOT SELF-STARTING      VC05 121
C     PREDICTOR-CORRECTOR METHOD.                                       VC05 122
  100 DO 101 I=1,NDIM                                                   VC05 123
      Z=H*AUX(N+7,I)                                                    VC05 124
      AUX(5,I)=Z                                                        VC05 125
  101 Y(I)=AUX(N,I)+.4*Z                                                VC05 126
C     Z IS AN AUXILIARY STORAGE LOCATION                                VC05 127
C                                                                       VC05 128
      Z=X+.4*H                                                          VC05 129
      CALL FCT(Z,Y,DERY)                                                VC05 130
      IF(MM.GT.1) RETURN                                                VC05 131
      DO 102 I=1,NDIM                                                   VC05 132
      Z=H*DERY(I)                                                       VC05 133
      AUX(6,I)=Z                                                        VC05 134
  102 Y(I)=AUX(N,I)+.29697761*AUX(5,I)+.15875964*Z                      VC05 135
C                                                                       VC05 136
      Z=X+.45573725*H                                                   VC05 137
      CALL FCT(Z,Y,DERY)                                                VC05 138
      IF(MM.GT.1) RETURN                                                VC05 139
      DO 103 I=1,NDIM                                                   VC05 140
      Z=H*DERY(I)                                                       VC05 141
      AUX(7,I)=Z                                                        VC05 142
  103 Y(I)=AUX(N,I)+.21810039*AUX(5,I)-3.05096515*AUX(6,I)+3.83286476*Z VC05 143
C                                                                       VC05 144
      Z=X+H                                                             VC05 145
      CALL FCT(Z,Y,DERY)                                                VC05 146
      IF(MM.GT.1) RETURN                                                VC05 147
      DO 104 I=1,NDIM                                                   VC03 148
  104 Y(I)=AUX(N,I)+.17476028*AUX(5,I)-.55148066*AUX(6,I)+1.2055356*AUX(VC05 149
     17,I)+.17118478*H*DERY(I)                                          VC05 150
      GO TO(9,15,15,21),ISW                                             VC05 151
C     ******************************************************************VC05 152
C                                                                       VC05 153
C                                                                       VC05 154
C     POSSIBLE BREAK-POINT FOR LINKAGE                                  VC05 155
C                                                                       VC05 156
C                                                                       VC05 157
C     STARTING VALUES ARE COMPUTED.                                     VC05 158
C     NOW START HAMMINGS MODIFIED PREDICTOR-CORRECTOR METHOD.           VC05 159
  200 ISTEP=3                                                           VC05 160
  201 IF(N-8)204,202,204                                                VC05 161
C                                                                       VC05 162
C     N=8 CAUSES THE ROWS OF AUX TO CHANGE THEIR STORAGE LOCATIONS      VC05 163
  202 DO 203 N=2,7                                                      VC05 164
      DO 203 I=1,NDIM                                                   VC05 165
      AUX(N-1,I)=AUX(N,I)                                               VC05 166
  203 AUX(N+6,I)=AUX(N+7,I)                                             VC05 167
      N=7                                                               VC05 168
C                                                                       VC05 169
C     N LESS THAN 8 CAUSES N+1 TO GET N                                 VC05 170
  204 N=N+1                                                             VC05 171
C                                                                       VC05 172
C     COMPUTATION OF NEXT VECTOR Y                                      VC05 173
      DO 205 I=1,NDIM                                                   VC05 174
      AUX(N-1,I)=Y(I)                                                   VC05 175
  205 AUX(N+6,I)=DERY(I)                                                VC05 176
      X=X+H                                                             VC05 177
  206 ISTEP=ISTEP+1                                                     VC05 178
      DO 207 I=1,NDIM                                                   VC05 179
      DELT=AUX(N-4,I)+1.33333333*H*(AUX(N+6,I)+AUX(N+6,I)-AUX(N+5,I)+AUXVC05 180
     1(N+4,I)+AUX(N+4,I))                                               VC05 181
      Y(I)=DELT-.92561983*AUX(16,I)                                     VC05 182
  207 AUX(16,I)=DELT                                                    VC05 183
C     PREDICTOR IS NOW GENERATED IN ROW 16 OF AUX, MODIFIED PREDICTOR   VC05 184
C     IS GENERATED IN Y, DELT MEANS AN AUXILIARY STORAGE.               VC05 185
C                                                                       VC05 186
      CALL FCT(X,Y,DERY)                                                VC05 187
      IF (MM.GT.1) RETURN                                               VC05 188
C     DERIVATIVE OF MODIFIED PREDICTOR IS GENERATED IN DERY             VC05 189
C                                                                       VC05 190
      DO 208 I=1,NDIM                                                   VC05 191
      DELT=.12500*(9.00*AUX(N-1,I)-AUX(N-3,I)+3.00*H*(DERY(I)+AUX(N+6,I)VC05 192
     1+AUX(N+6,I)-AUX(N+5,I)))                                          VC05 193
      AUX(16,I)=AUX(16,I)-DELT                                          VC05 194
  208 Y(I)=DELT+.074380165*AUX(16,I)                                    VC05 195
C                                                                       VC05 196
C     TEST WHETHER H MUST BE HALVED OR DOUBLED                          VC05 197
      DELT=0.                                                           VC05 198
      DO 209 I=1,NDIM                                                   VC05 199
  209 DELT=DELT+AUX(15,I)*ABS(AUX(16,I))                                VC05 200
      IF(DELT-PRMT(4))210,222,222                                       VC05 201
C                                                                       VC05 202
C     H MUST NOT BE HALVED. THAT MEANS Y(I) ARE GOOD.                   VC05 203
  210 CALL FCT(X,Y,DERY)                                                VC05 204
      IF(MM.GT.1) RETURN                                                VC05 205
      CALL OUTP(X,Y,DERY,IHLF,NDIM,PRMT)                                VC05 206
      IF(PRMT(5))212,211,212                                            VC05 207
  211 IF(IHLF-11)213,212,212                                            VC05 208
  212 RETURN                                                            VC05 209
  213 IF(H*(X-PRMT(2)))214,212,212                                      VC05 210
  214 IF(ABS(X-PRMT(2))-.1*ABS(H))212,215,215                           VC05 211
  215 IF(DELT-.02*PRMT(4))216,216,201                                   VC05 212
C                                                                       VC05 213
C                                                                       VC05 214
C     H COULD BE DOUBLED IF ALL NECESSARY PRECEDING VALUES ARE          VC05 215
C     AVAILABLE                                                         VC05 216
  216 IF(IHLF)201,201,217                                               VC05 217
  217 IF(N-7)201,218,218                                                VC05 218
  218 IF(ISTEP-4)201,219,219                                            VC05 219
  219 IMOD=ISTEP/2                                                      VC05 220
      IF(ISTEP-IMOD-IMOD)201,220,201                                    VC05 221
  220 H=H+H                                                             VC05 222
      IHLF=IHLF-1                                                       VC05 223
      ISTEP=0                                                           VC05 224
      DO 221 I=1,NDIM                                                   VC05 225
      AUX(N-1,I)=AUX(N-2,I)                                             VC05 226
      AUX(N-2,I)=AUX(N-4,I)                                             VC05 227
      AUX(N-3,I)=AUX(N-6,I)                                             VC05 228
      AUX(N+6,I)=AUX(N+5,I)                                             VC05 229
      AUX(N+5,I)=AUX(N+3,I)                                             VC05 230
      AUX(N+4,I)=AUX(N+1,I)                                             VC05 231
```

```
      DELT=AUX(N+6,I)+AUX(N+5,I)                                        VC05 232
      DELT=DELT+DELT+DELT                                               VC05 233
  221 AUX(16,I)=8.96296296*(Y(I)-AUX(N-3,I))-3.36111111*H*(DERY(I)+DELT+VC05 234
     1AUX(N+4,I))                                                       VC05 235
      GO TO 201                                                         VC05 236
C                                                                       VC05 237
C                                                                       VC05 238
C     H MUST BE HALVED                                                  VC05 239
  222 IHLF=IHLF+1                                                       VC05 240
      IF(IHLF-10)223,223,210                                            VC05 241
  223 H=.5*H                                                            VC05 242
      ISTEP=0                                                           VC05 243
      DO 224 I=1,NDIM                                                   VC05 244
      Y(I)=.390625E-2*(8.E1*AUX(N-1,I)+135.00*AUX(N-2,I)+4.E1*AUX(N-3,I)VC05 245
     1+AUX(N-4,I))-.1171875*(AUX(N+6,I)-6.*AUX(N+5,I)-AUX(N+4,I))*H     VC05 246
      AUX(N-4,I)=.390625E-2*(12.00*AUX(N-1,I)+135.00*AUX(N-2,I)+        VC05 247
     1108.00*AUX(N-3,I)+AUX(N-4,I))-.0234375*(AUX(N+6,I)+               VC05 248
     218.00*AUX(N+5,I)-9.00*AUX(N+4,I))*H                               VC05 249
      AUX(N-3,I)=AUX(N-2,I)                                             VC05 250
  224 AUX(N+4,I)=AUX(N+5,I)                                             VC05 251
      X=X-H                                                             VC05 252
      DELT=X-(H+H)                                                      VC05 253
      CALL FCT(DELT,Y,DERY)                                             VC05 254
      IF(MM.GT.1) RETURN                                                VC05 255
      DO 225 I=1,NDIM                                                   VC05 256
      AUX(N-2,I)=Y(I)                                                   VC05 257
      AUX(N+5,I)=DERY(I)                                                VC05 258
  225 Y(I)=AUX(N-4,I)                                                   VC05 259
      DELT=DELT-(H+H)                                                   VC05 260
      CALL FCT(DELT,Y,DERY)                                             VC05 261
      IF(MM.GT.1) RETURN                                                VC05 262
      DO 226 I=1,NDIM                                                   VC05 263
      DELT=AUX(N+5,I)+AUX(N+4,I)                                        VC05 264
      DELT=DELT+DELT+DELT                                               VC05 265
      AUX(16,I)=8.96296296*(AUX(N-1,I)-Y(I))                            VC05 266
     1-3.36111111*H*(AUX(N+6,I)+DELT+DERY(I))                           VC05 267
  226 AUX(N+3,I)=DERY(I)                                                VC05 268
      GO TO 206                                                         VC05 269
      END                                                               VC05 270
```

REFERENCES

D-1. Nielsen Engineering & Research, Inc. A Study of Induced Rolling Moments for Cruciform-Winged Missiles, by J. N. Nielsen, S. B. Spangler, and M. J. Hemsch. Mountain View, Calif., NEAR, December 1973. (NEAR TR 61.)

D-2. ———. Further Studies of the Induced Rolling Moments of Canard-Cruciform Missiles as Influenced by Canard and Body Vortices, by J. N. Nielsen, M. J. Hemsch, and M. F. E. Dillenius. Mountain View, Calif., NEAR, January 1975. (NEAR TR 79.)

D-3. IBM Corporation. System/360 Scientific Subroutine Package, Version III Programmer's Manual. IBM Technical Publications Department, White Plains, N. Y., 1970.

Item No. 1: Format (20A4), any alphabetic or numeric information.
(1 card)

Column Number	1 - 80
Program Variable	HEAD
Data	

Item No. 2: Format (8I10)
(1 card)

Column Number	10	20	30	40	50	
Program Variable	NVOR	NXOUT	NCDC	NBODL	NBODR	
Data						

Item No. 3: Format (8F10.5)
(1 + (NVOR - 1)/8 cards)

Column Number	10	20	30	40	50	
Program Variable	GAM(1)	GAM(2)	GAM(3)	...	GAM(NVOR)	
Data						

FIG. D-1(a). Input Formats for Computer Program VCHASE.

Item No. 4: Format (8F10.5)
(1 + (2*NVOR - 1)/8 cards.

Column Number	10	20	30	40	50	
Program Variable	YOLD(1)	YOLD(2)	YOLD(3)	....	YOLD(Z* NVOR)	
Data						

Item No. 5: Format (8F10.5)
(1 card)

Column Number	10	20	30	40	50	60	70	80
Program Variable	XBEG	XEND	DX	ERR	XMACH	ALPHA	RZERO	RVOA
Data								

Item No. 6: Format (8F10.5)
(1 + (NXOUT - 1)/8 cards.

Column Number	10	20	30	40	50	
Program Variable	XOUT(1)	XOUT(2)	XOUT(3)	....	XOUT(NXOUT)	
Data						

FIG. D-1(b). Continued.

Item No. 7 (Option): Format (8F10.5)
(1 + (NCDC - 1)/8 cards)

Column Number	10	20	30	40	50	
Program Variable	XMC(1)	XMC(2)	XMC(3)	....	XMC(NCDC)	
Data						

Item No. 8 (Option): Format (8F10.5)
(1 + (NCDC - 1)/8 cards)

Column Number	10	20	30	40	50	
Program Variable	CDC(1)	CDC(2)	CDC(3)	....	CDC(NCDC)	
Data						

FIG. D-1(c). Concluded.

```
SAMPLE CASE FOR VCHASE
        7        8        8        0        1
   -.6166       0.    .5377     .141     .193     -.169     -.186
   -.6853    1.142    1.603      .86    3.457     1.205    -1.473     1.892
      .36    3.098    7.833    6.835    4.253     6.097
      28.    44.54       .1     .001     1.75       20.       .2       1.2
      29.      30.      31.      32.      33.     34.33    40.28     44.54
       0.       .1       .2       .3       .4        .5       .6        .7
      .29      .34      .45       .7      .98      1.28      1.5      1.67
```

FIG. D-2. VCHASE Input for Sample Case.

VORTEX CHASING PROGRAM

SAMPLE CASE FOR VCHASE

INPUT PARAMETERS

ALPHA = 20.00 MACH = 1.750 DX = .100E+00 ERR = .100E-02 RZERO = .20 RV/A = 1.20

INPUT TABLE OF CROSS-FLOW DRAG COEFFICIENTS

MC	CDC
0.	.2900E+00
.1000E+00	.3400E+00
.2000E+00	.4500E+00
.3000E+00	.7000E+00
.4000E+00	.9800E+00
.5000E+00	.1280E+01
.6000E+00	.1500E+01
.7000E+00	.1670E+01

X/A	I	GAMMA(I)	Y(I)/A	Z(I)/A	CDC	FLOANG	THETA
.2800E+02	1	-.6166E+00	-.6853E+00	.1892E+01	.1272E+01	16.51	66.8R
	2	0.	.1148E+01	.3484E+00			
	3	.5377E+00	.1603E+01	.3098E+01			
	4	.1410E+00	.8600E+00	.7833E+01			
	5	.1930E+00	.3487E+01	.6835E+01			
	6	-.1690E+00	.1205E+01	.4853E+01			
	7	-.1860E+00	-.1473E+01	.6097E+01			
.2900E+02	1	-.6240E+00	-.7101E+00	.1977E+01	.1279E+01	16.58	67.4R
	2	.2975E-01	.1185E+01	.5505E+00			
	3	.5377E+00	.1584E+01	.3144E+01			
	4	.1410E+00	.8917E+00	.8018E+01			
	5	.1930E+00	.3461E+01	.7159E+01			
	6	-.1690E+00	.9814E+00	.4811E+01			
	7	-.1860E+00	-.1372E+01	.6330E+01			
.3000E+02	1	-.6310E+00	-.7342E+00	.2067E+01	.1282E+01	16.63	67.9R
	2	.5254E-01	.1116E+01	.6872E+00			
	3	.5377E+00	.1567E+01	.3164E+01			
	4	.1410E+00	.9261E+00	.8196E+01			
	5	.1930E+00	.3465E+01	.7485E+01			
	6	-.1690E+00	.7979E+00	.4093E+01			
	7	-.1860E+00	-.1268E+01	.6559E+01			
.3100E+02	1	-.6389E+00	-.7614E+00	.2163E+01	.1283E+01	16.64	68.3R
	2	.7467E-01	.1120E+01	.7902E+00			
	3	.5377E+00	.1549E+01	.3156E+01			
	4	.1410E+00	.9635E+00	.8370E+01			

FIG. D-3(a). VCHASE Output for Sample Case.

	5	.1930E+00	.3470E+01	.7813E+01			
	6	-.1690E+00	.6635E+00	.3888E+01			
	7	-.1860E+00	-.1163E+01	.6780E+01			
.3200E+02	1	-.6467E+00	-.7948E+00	.2268E+01	.1282E+01	16.63	68.[illegible]
	2	.9422E-01	.1134E+01	.8741E+00			
	3	.5377E+00	.1532E+01	.3111E+01			
	4	.1410E+00	.1005E+01	.8539E+01			
	5	.1930E+00	.3476E+01	.8143E+01			
	6	-.1690E+00	.5929E+00	.3554E+01			
	7	-.1860E+00	-.1059E+01	.6996E+01			
.3300E+02	1	-.6548E+00	-.8311E+00	.2394E+01	.1278E+01	16.58	69.[illegible]
	2	.1134E+00	.1155E+01	.9451E+00			
	3	.5377E+00	.1532E+01	.3017E+01			
	4	.1410E+00	.1051E+01	.8705E+01			
	5	.1930E+00	.3483E+01	.8476E+01			
	6	-.1690E+00	.6271E+00	.2999E+01			
	7	-.1860E+00	-.9571E+00	.7206E+01			
.3433E+02	1	-.6637E+00	-.8417E+00	.2586E+01	.1293E+01	16.80	73.[illegible]
	2	.1350E+00	.1165E+01	.1015E+01			
	3	.5377E+00	.1621E+01	.2898E+01			
	4	.1410E+00	.1122E+01	.8921E+01			
	5	.1930E+00	.3492E+01	.8921E+01			
	6	-.1690E+00	.8388E+00	.2182E+01			
	7	-.1860E+00	-.8249E+00	.7482E+01			
.4028E+02	1	-.6909E+00	-.7718E+00	.3228E+01	.8099E+00	11.18	77.[illegible]
	2	.3038E+00	.1199E+01	-.2384E+00			
	3	.5377E+00	.1682E+01	.3021E+01			
	4	.1410E+00	.1599E+01	.9834E+01			
	5	.1930E+00	.3490E+01	.1093E+02			
	6	-.1690E+00	-.7901E+00	.1132E+01			
	7	-.1860E+00	-.2329E+00	.8692E+01			
.4454E+02	1	-.6996E+00	-.7754E+00	.3465E+01	.1081E+01	14.35	64.44
	2	.1982E+00	-.9978E+00	.5526E+00			
	3	.5377E+00	.1434E+01	.3082E+01			
	4	.1410E+00	.2080E+01	.1054E+02			
	5	.1930E+00	.3439E+01	.1233E+02			
	6	-.1690E+00	-.1912E+01	.1871E+01			
	7	-.1860E+00	.1730E+00	.9567E+01			

FIG. D-3(b). Concluded.

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