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Prepared for COMMANDER SPACE SYSTEMS DIVISION
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Inglewood, California

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ABSTRACT

In this report we present a method for calculating the aerodynamic influence coefficients (AICs) based on third-order piston theory with an optional correction to agree with Van Dyke's quasi-steady second-order theory. The AICs are computed assuming the airfoil to have a rigid chord with or without a (rigid chord) control surface. The influence coefficients relate the surface deflections to the aerodynamic forces through the following definitions. In the oscillatory case,

$$\{F\} = \rho\omega^2 b_r^2 s[C_h] \{h\}$$

and in the steady case,

$$\{F_s\} = (1/2)\rho V^2(S/\bar{c}) [C_{hs}] \{h\}$$

The piston theory is limited to high Mach number (or high reduced frequency), but Van Dyke's quasi-steady correction extends the validity to some lower supersonic Mach number at low reduced frequency.

The Aerospace IBM 7090 Computer Program Number HM11 provides the AICs from this theory in both a printed and an optional punched-card output format. The program capacity is 25 surface strips, 15 Mach numbers, and 20 reduced velocities for each Mach number.

CONTENTS

SYMBOLS

a_o	Ambient speed of sound
b	Local semichord
b_r	Reference semichord
C_h	Element of oscillatory aerodynamic influence coefficient matrix
C_{hs}	Element of steady aerodynamic influence coefficient matrix
C_n	Coefficients in expressions for pressure coefficient
C_p	Pressure coefficient
c	Local chord
c_a	Control surface chord
$\bar{c}$	Mean aerodynamic chord
d	Distance between forward and aft control points
F	Control point force
g	Airfoil semithickness
g_x	Slope of airfoil, $g_x = dg/dx$
h	Vertical deflection
I_n, J_n	Thickness integrals
K_n	Coefficients in expressions for oscillatory aerodynamic coefficients
k	Local reduced frequency, $k = \omega b/V$
k_r	Reference reduced frequency
$L_{h_o}, L_{\alpha_o}, L_{\beta_o}$	Oscillatory leading edge lift coefficients

L_o	Lift referred to leading edge motion
M	Free stream Mach number
$M_{h_o}, M_{\alpha_o}, M_{\beta_o}$	Oscillatory leading edge pitching moment coefficients
M_o	Pitching moment about leading edge referred to leading edge motion
p	Surface pressure; p_o is ambient pressure
q	Free stream dynamic pressure
r_h, r_t	Ratios of hinge-line and trailing-edge thicknesses to maximum thickness, respectively
S	Wing area
s	Wing semispan
$T_{h_o}, T_{\alpha_o}, T_{\beta_o}$	Oscillatory leading edge hinge moment coefficients
T_o	Hinge moment referred to leading edge motion
t_{max}	Airfoil maximum thickness
V	Free stream velocity
$V/b_r\omega$	Reference reduced velocity, $V/b_r\omega = 1/k_r$
v	Unsteady component of downwash velocity
w	Downwash velocity
x	Chordwise coordinate; x_o is coordinate of pitching axis; x_m is coordinate of maximum thickness point; x_h is coordinate of hinge line
α	Angle of attack; α_o is initial angle of attack
β	Control surface incidence; also, $\beta = (M^2 - 1)^{1/2}$
γ	Specific heat ratio of air, $\gamma = 1.400$
Δy	Strip width

Λ	Leading edge sweep angle
ξ	Dimensionless chordwise coordinate, $\xi = x/c$
ρ	Free stream density
τ, τ_h, τ_t	Airfoil thickness ratios at point of maximum thickness, hinge line, and trailing edge, respectively
ω	Circular frequency
$(\bar{\ })$	Bar denotes term depends on flow characteristics normal to leading edge
$[\ ]$	Square matrix
$\{\ \}$	Column matrix

SECTION I

FORMULATION OF THE PROBLEM

A. Introduction

The pressure on a lifting surface is normally given by a surface functional relationship. However, in the limit of a high Mach number (or high reduced frequency), this relationship becomes a point function. As a consequence of this limit, aerodynamic influence coefficients (AICs) may be specified exactly by a strip theory, and control surface and camber effects may be determined in a straightforward manner.

The present formulation derives the AICs from third-order piston theory for a lifting surface with control surface (both assumed rigid in the chordwise direction; i. e. , no camber is presently considered). The derivation differs only slightly from that of Ashley and Zartarian[1] in that in the present case the third-order pressure coefficient is generalized to account for sweep and steady angle of attack, and, following a suggestion of Morgan, Huckel, and Runyan,[2] a correction (optional) is suggested to give agreement with the second-order quasi-steady supersonic theory of Van Dyke.[3] This quasi-steady correction should extend the validity of the piston theory to lower supersonic Mach numbers at low reduced frequencies. The derivation given here is taken from Ref. 4; further, the computational aspects of the present report are an extension of the computing procedure of Ref. 4.

B. Sign Convention

The flutter sign convention is used in the oscillatory case: forces and deflections are positive down; rotations are positive with leading edge up. The aerodynamic sign convention is used in the steady case: forces and deflections are positive up; rotations are positive with leading edge up.

C. Derivation of Equations

We quote here the development of Miles[5] in obtaining the piston theory pressure coefficient. There are two cases of interest. The first assumes that the angle of attack is small enough that there are pressure perturbations on the expansion side of the surface. The second assumes that the angle of attack is large, and that the expansion pressure approaches a vacuum and is ineffective in producing perturbations. Because of the difficulty in specifying the transition from low to high angle of attack, we shall restrict the present consideration to the first case, the low angle of attack.

"Hayes' hypersonic approximation states that any plane slab of fluid initially perpendicular to the undisturbed flow may be assumed to remain so as it is swept downstream and to move in its own plane under the laws of one-dimensional, unsteady motion. Thus, the problem of a wing having an arbitrarily prescribed motion normal to its surface may be reduced to the consideration of the one-dimensional motion of a piston into an otherwise undisturbed flow. This problem is relatively simple if the disturbances produced by the piston are treated as simple waves, for then the pressure on the piston depends only on the instantaneous velocity there, w, and is given by

M_{pist}

$$p/p_o = [1 + (1/2)(\gamma - 1)(w/a_o)]^{2\gamma/(\gamma-1)} \qquad w/a_0 \qquad (1)$$

where p_o and a_o are the values of pressure and sonic velocity in the undisturbed flow.

"The result, Eq. (1), is exact for an expansion, but the presence of a shock front (and consequent departure from isentropic flow) renders it only approximate for a compression. Lighthill has suggested a cubic approximation to be adequate for practical application if $|w/a_o| < 1$. The series expansion yields

$$p/p_o = 1 + \gamma(w/a_o) + (1/4)\,\gamma(\gamma + 1)\,(w/a_o)^2 + (1/12)\,\gamma(\gamma + 1)\,(w/a_o)^3 \quad . \tag{2}$$

Lighthill has shown that this expression, Eq. (2), is within six percent of the value given by either Eq. (1) or the exact solution with the shock at maximum permissible strength."[5]

The pressure coefficient $C_p = (p - p_o)/q$ is found from Eq. (2) after noting that $q = (\gamma/2)\, p_o M^2$.

$$C_p = (2/M^2)\,[\,(w/a_o) + (1/4)\,(\gamma + 1)\,(w/a_o)^2 + (1/12)\,(\gamma + 1)\,(w/a_o)^3\,] \tag{3}$$

Following a suggestion of Morgan, Huckel, and Runyan,[2] we may generalize this result, Eq. (3), by writing

$$C_p = (2/M^2)\,[\,C_1(w/a_o) + C_2(w/a_o)^2 + C_3(w/a_o)^3\,] \tag{4}$$

in which for piston theory

$$C_1 = 1, \qquad C_2 = (\gamma + 1)/4, \qquad C_3 = (\gamma + 1)/12 \tag{5}$$

and for the quasi-steady theory of Van Dyke[3]

$$C_1 = M/\beta, \qquad C_2 = [\,M^4(\gamma + 1) - 4\beta^2\,]\,/\,4\beta^4, \qquad C_3 = (\gamma + 1)/12 \tag{6}$$

Van Dyke gives only the second-order solution so that the value of C_3 is taken from the piston theory result. The use of the modified coefficients C_1 and C_2 could extend the lower Mach number limit of piston theory.

We may now calculate the lifting pressure coefficient from Eq. (4) and the local piston velocity. The normal velocity (positive away from the surface) on the upper and lower surfaces of a symmetrical thin airfoil having thickness distribution 2g(x) and angle of attack α_o is given by

$$w_u = V (g_x - \alpha_o - v) \quad , \tag{7a}$$

$$w_\ell = V (g_x + \alpha_o + v) \quad , \tag{7b}$$

where v is the unsteady component of the dimensionless downwash.

For the case of small angles of attack, the lifting pressure (positive down) is

$$C_p = C_{p_u} - C_{p_\ell} = - (4/M) [(C_1 + 2C_2Mg_x + 3C_3M^2g_x^2) (\alpha_o + v) + C_3M^2(\alpha_o + v)^3] \quad . \tag{8}$$

If, consistent with the small perturbation assumptions of aeroelastic analysis, only the terms linear in v are retained, Eq. (8) becomes

$$C_p = - (4v/M) [C_1 + 2C_2Mg_x + 3C_3M^2(g_x^2 + \alpha_o^2)] \quad . \tag{9}$$

Before discussing the swept wing transformation, it is appropriate to review the limitations of Eq. (9). Ashley and Zartarian[1] have shown that the piston theory is applicable if any of the conditions $M^2 >> 1$, $Mk >> 1$, or

$k^2 >> 1$ is met. We see that for low reduced frequency the Mach number necessarily must be high. However, if the reduced frequency is large the Mach number is not necessarily large; in fact it could be transonic or even subsonic. At this point it is apparent that any sweep correction introduced to bring piston theory into line with linearized supersonic theory must be considered as a low frequency approximation.

The result, Eq. (9), applies to the swept wing case if all quantities are determined by the flow characteristics normal to the leading edge. The expressions may be rewritten in the form

$$\overline{C}_p = - (4\overline{v}/\overline{M}) [\overline{C}_1 + 2\overline{C}_2\overline{M}\overline{g}_{\overline{x}} + 3C_3\overline{M}^2(\overline{g}_{\overline{x}}^2 + \overline{\alpha}_o^2)] \qquad (10)$$

The transformation from the normal values to the free stream values are the following:

the Mach number

$$\overline{M} = M \cos \Lambda \quad ; \qquad (11a)$$

the geometry

$$\overline{x} = x \cos \Lambda \qquad (11b)$$

$$\overline{b} = b \cos \Lambda \quad ; \qquad (11c)$$

the angles of attack and slope

$$\overline{\alpha}_o = \alpha_o / \cos \Lambda \qquad (11d)$$

$$\overline{\beta} = \beta / \cos \Lambda \qquad (11e)$$

$$\overline{g}_{\overline{x}} = g_x / \cos \Lambda \quad ; \qquad (11f)$$

the dynamic pressure

$$\overline{q} = q \cos^2 \Lambda \quad ; \qquad (11g)$$

and the pressure coefficient

$$C_p = \overline{C}_p \cos^2 \Lambda \quad . \tag{11h}$$

We note that h and k are invariant. From the dimensionless downwash

$$\begin{aligned} v = (1/V) \{ & \dot{h} + V\alpha + (x - x_o)\dot{\alpha} \\ & + [V\beta + (x - x_h)\dot{\beta}] \ \underline{1}(x - x_h) \} \quad , \end{aligned} \tag{12}$$

which for harmonic motion becomes

$$\begin{aligned} v = & \ ikh/b + [1 + i(k/b)(x - x_o)] \alpha \\ & + [1 + i(k/b)(x - x_h)] \beta \ \underline{1}(x - x_h) \quad , \end{aligned} \tag{13}$$

we find the transformed value

$$\begin{aligned} \overline{v} = & \ ikh/\overline{b} + [1 + i(k/\overline{b})(\overline{x} - \overline{x}_o)] \overline{\alpha} \\ & + [1 + i(k/\overline{b})(\overline{x} - \overline{x}_h)] \overline{\beta} \ \underline{1}(\overline{x} - \overline{x}_h) \end{aligned} \tag{14a}$$

$$\begin{aligned} = & \ ikh/b \cos \Lambda + [1 + i(k/b)(x - x_o)] \alpha/\cos \Lambda \\ & + [1 + i(k/b)(x - x_h)] \ (\beta/\cos \Lambda) \ \underline{1}(x - x_h) \end{aligned} \tag{14b}$$

$$= v/\cos \Lambda \tag{14c}$$

The transformed pressure coefficient becomes

$$C_p = \overline{C}_p \cos^2 \Lambda = [-4(v/\cos \Lambda) \cos^2 \Lambda / M \cos \Lambda]$$

$$\times [\overline{C}_1 + 2\overline{C}_2(M \cos \Lambda)(g_x/\cos \Lambda)$$

$$+ 3\overline{C}_3(M \cos \Lambda)^2 (g_x^2 + a_o^2)/\cos^2 \Lambda] \qquad (15a)$$

$$= -(4v/M) [\overline{C}_1 + 2\overline{C}_2 M g_x + 3C_3 M^2(g_x^2 + a_o^2)] \quad . \qquad (15b)$$

We note that the sweep effect shows up only in the coefficients $\overline{C}_1$ and $\overline{C}_2$; for piston theory, there is no effect

$$\overline{C}_1 = C_1 = 1, \quad \overline{C}_2 = C_2 = (\gamma + 1)/4 \quad , \qquad (16)$$

and for the quasi-steady supersonic theory

$$\overline{C}_1 = M/(M^2 - \sec^2 \Lambda)^{1/2} \quad ,$$

$$\overline{C}_2 = [M^4(\gamma + 1) - 4 \sec^2 \Lambda (M^2 - \sec^2 \Lambda)]/[4(M^2 - \sec^2 \Lambda)^2 \quad . \qquad (17)$$

Equation (17) is seen to be the most general result. If sec Λ is taken as zero then the piston theory results, Eqs. (16), are obtained; and if sec Λ is taken as unity the sweep correction is not made in the quasi-steady supersonic result.

We next consider the integration of the pressure coefficients obtained above. The oscillatory aerodynamic coefficients referred to the leading edge are defined by the following equations.

$$dL/dy = 4\rho\omega^2 b^3 \left(L_{h_o} h_o/b + L_{\alpha_o} \alpha + L_{\beta_o} \beta \right) \tag{18a}$$

$$dM/dy = 4\rho\omega^2 b^4 \left(M_{h_o} h_o/b + M_{\alpha_o} \alpha + M_{\beta_o} \beta \right) \tag{18b}$$

$$dT/dy = 4\rho\omega^2 b^4 \left(T_{h_o} h_o/b + T_{\alpha_o} \alpha + T_{\beta_o} \beta \right) \tag{18c}$$

The lift, moment, and hinge moment are found from the pressure coefficient

$$dL/dy = q \int_0^{2b} C_p \, dx \tag{19a}$$

$$dM/dy = q \int_0^{2b} x \, C_p \, dx \tag{19b}$$

$$dT/dy = q \int_0^{2b} (x - x_h) \, C_p \, dx \tag{19c}$$

where the pressure coefficient is given by Eq. (15b).

$$\begin{aligned} C_p = -(4/M) & \left[\overline{C}_1 + 2\overline{C}_2 M g_x + 3C_3 \, M^2 (g_x^2 + \alpha_o^2) \right] \\ & \times \left\{ ikh_o/b + [\,1 + ikx/b\,]\,\alpha + [\,1 + ik(x - x_h)/b\,]\,\beta \; \underline{1}(x - x_h) \right\} \end{aligned} \tag{20}$$

and we have taken the pitch axis at the leading edge $x_o = 0$. We define the following dimensionless thickness integrals

$$I_1 = (1/2b) \int_0^{2b} g_x \, dx \tag{21a}$$

$$I_2 = (1/4b^2) \int_0^{2b} x\, g_x\, dx \tag{21b}$$

$$I_3 = (1/8b^3) \int_0^{2b} x^2\, g_x\, dx \tag{21c}$$

$$I_4 = (1/2b) \int_0^{2b} g_x^2\, dx \tag{21d}$$

$$I_5 = (1/4b^2) \int_0^{2b} x\, g_x^2\, dx \tag{21e}$$

$$I_6 = (1/8b^3) \int_0^{2b} x^2 g_x^2\, dx \tag{21f}$$

$$J_1 = (1/2b) \int_{x_h}^{2b} g_x\, dx \tag{22a}$$

$$J_2 = (1/4b^2) \int_{x_h}^{2b} x\, g_x\, dx \tag{22b}$$

$$J_3 = (1/8b^3) \int_{x_h}^{2b} x^2\, g_x\, dx \tag{22c}$$

$$J_4 = (1/2b) \int_{x_h}^{2b} g_x^2\, dx \tag{22d}$$

$$J_5 = (1/4b^2) \int_{x_h}^{2b} x\, g_x^2\, dx \qquad (22e)$$

$$J_6 = (1/8b^3) \int_{x_h}^{2b} x^2\, g_x^2\, dx \quad . \qquad (22f)$$

These thickness integrals are evaluated at the end of this section for a typical airfoil. If we substitute Eq. (20) into Eqs. (19), make use of the definitions Eqs. (21) and (22) of the thickness integrals, and identify the resulting expressions with Eqs. (18), we obtain the oscillatory aerodynamic coefficients

$$L_{h_o} = - iK_1/k \qquad (23a)$$

$$L_{\alpha_o} = - K_1/k^2 - iK_2/k \qquad (23b)$$

$$L_{\beta_o} = - K_4/k^2 - i(K_5 - 2K_4\xi_h)/k \qquad (23c)$$

$$M_{h_o} = - iK_2/k \qquad (23d)$$

$$M_{\alpha_o} = - K_2/k^2 - iK_3/k \qquad (23e)$$

$$M_{\beta_o} = - K_5/k^2 - i(K_6 - 2K_5\xi_h)/k \qquad (23f)$$

$$T_{h_o} = - i\,(K_5 - 2K_4\,\xi_h)/k \qquad (23g)$$

$$T_{\alpha_o} = -(K_5 - 2K_4\xi_h)/k^2 - i(K_6 - 2K_5\xi_h)/k \qquad (23h)$$

$$T_{\beta_o} = -(K_5 - 2K_4\xi_h)/k^2 - i(K_6 - 4K_5\xi_h + 4K_4\xi_h^2)/k \tag{23i}$$

where

$$\xi_h = x_h/2b \tag{24a}$$

$$K_1 = (1/M)\,[\overline{C}_1 + 2\overline{C}_2 M I_1 + 3C_3 M^2 (I_4 + a_o^2)] \tag{24b}$$

$$K_2 = (1/M)\,[\overline{C}_1 + 4\overline{C}_2 M I_2 + 3C_3 M^2 (2I_5 + a_o^2)] \tag{24c}$$

$$K_3 = (4/3M)\,[\overline{C}_1 + 6\overline{C}_2 M I_3 + 3C_3 M^2 (3I_6 + a_o^2)] \tag{24d}$$

$$K_4 = (1/M)\left\{\overline{C}_1(1 - \xi_h) + 2\overline{C}_2 M J_1 + 3C_3 M^2 [J_4 + a_o^2 (1 - \xi_h)]\right\} \tag{24e}$$

$$K_5 = (1/M)\left\{\overline{C}_1(1 - \xi_h^2) + 4\overline{C}_2 M J_2 + 3C_3 M^2 [2J_5 + a_o^2 (1 - \xi_h^2)]\right\} \tag{24f}$$

$$K_6 = (4/3M)\left\{\overline{C}_1(1 - \xi_h^3) + 6\overline{C}_2 M J_3 + 3C_3 M^2 [3J_6 + a_o^2 (1 - \xi_h^3)]\right\} \quad . \tag{24g}$$

To conclude the derivation of the oscillatory aerodynamic coefficients, we calculate the thickness integrals for the typical airfoil of Fig. 1. We approximate the airfoil by two parabolas and a line. The equation of the forward parabola that goes through the leading edge* and is horizontal at the point of the maximum thickness is

$$g_1(x)/c = (\tau/2)\,(x/x_m)\,(2 - x/x_m) \tag{25}$$

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*The approximation by a sharp leading edge is consistent with the theory having ruled out detached shock waves.

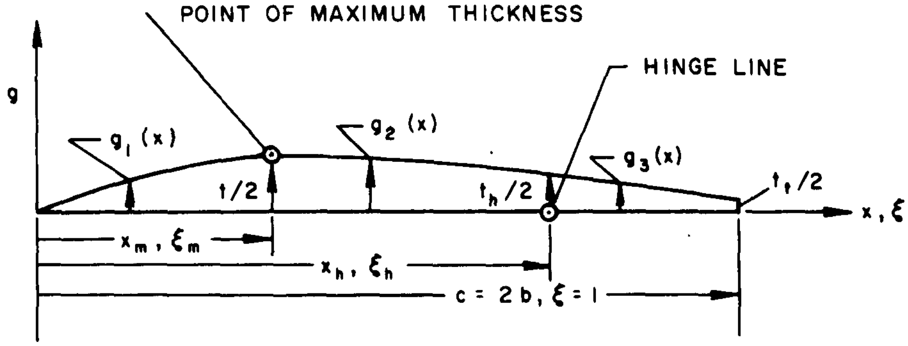


Fig. 1. Typical Airfoil Cross Section.

where $\tau = t_{max}/c$. The second parabola, horizontal at the point of maximum thickness and going through the hinge line, is

$$g_2(x)/c = (\tau/2) \left\{1 - (1 - r_h) \left[(x - x_m)/(x_h - x_m)\right]^2\right\} \quad (26)$$

where $r_h = \tau_h/\tau$ and $\tau_h = t_h/c$. The line connecting the hinge line and blunt trailing edge is given by

$$g_3(x)/c = (\tau_h/2) \left[1 - (1 - r_t)(x - x_h)/(c - x_h)\right] \quad (27)$$

where $r_t = \tau_t/\tau_h$ and $\tau_t = t_t/c$. By differentiating we find the desired slopes

$$g_1'(x)/c = (\tau/x_m)(1 - x/x_m) \tag{28a}$$

$$g_2'(x)/c = -\tau(1 - r_h)(x - x_m)/(x_h - x_m)^2 \tag{28b}$$

$$g_3'(x)/c = -(\tau_h/2)(1 - r_t)/(c - x_h) \quad . \tag{28c}$$

From the slopes, the thickness integrals follow immediately. Computing the control surface integrals first yields

$$J_1 = \int_{\xi_h}^{1} g_\xi d\xi = -(1/2)(\tau_h - \tau_t) \tag{29a}$$

$$J_2 = \int_{\xi_h}^{1} \xi g_\xi d\xi = -(1/4)(\tau_h - \tau_t)(1 + \xi_h) \tag{29b}$$

$$J_3 = \int_{\xi_h}^{1} \xi^2 g_\xi d\xi = -(1/6)(\tau_h - \tau_t)(1 + \xi_h + \xi_h^2) \tag{29c}$$

$$J_4 = \int_{\xi_h}^{1} g_\xi^2 d\xi = (1/4)(\tau_h - \tau_t)^2/(1 - \xi_h) \tag{29d}$$

$$J_5 = \int_{\xi_h}^{1} \xi g_\xi^2 d\xi = (1/8)(\tau_h - \tau_t)^2 (1 + \xi_h)/(1 - \xi_h) \tag{29e}$$

$$J_6 = \int_{\xi_h}^{1} \xi^2 g_\xi^2 d\xi = (1/12)(\tau_h - \tau_t)^2 (1 + \xi_h + \xi_h^2)/(1 - \xi_h) \quad ; \tag{29f}$$

The complete airfoil integrals become

$$I_1 = \int_0^{\xi_h} g_\xi d\xi + J_1 = \tau_h/2 + J_1 \tag{30a}$$

$$I_2 = \int_0^{\xi_h} \xi g_\xi d\xi + J_2 = -(\tau/3)\xi_h + (\tau_h/6)(2\xi_h + \xi_m) + J_2 \tag{30b}$$

$$I_3 = \int_0^{\xi_h} \xi^2 g_\xi d\xi + J_3$$

$$= (\tau/12)\xi_m^2 - (1/12)(\tau - \tau_h)(3\xi_h^2 + 2\xi_h\xi_m + \xi_m^2) + J_3 \tag{30c}$$

$$I_4 = \int_0^{\xi_h} g_\xi^2 d\xi + J_4 = \tau^2/3\xi_m + (1/3)(\tau - \tau_h)^2/(\xi_h - \xi_m) + J_4 \tag{30d}$$

$$I_5 = \int_0^{\xi_h} \xi g_\xi^2 d\xi + J_5$$

$$= \tau^2/12 + (1/12)(\tau - \tau_h)^2 (3\xi_h + \xi_m)/(\xi_h - \xi_m) + J_5 \tag{30e}$$

$$I_6 = \int_0^{\xi_h} \xi^2 g_\xi^2 d\xi + J_6$$

$$= (\tau^2/30)\xi_m + (1/30)(\tau - \tau_h)^2 (6\xi_h^2 + 3\xi_h\xi_m + \xi_m^2)/(\xi_h - \xi_m) + J_6 \tag{30f}$$

where $\xi = x/c$, $\xi_m = x_m/c$, and $\xi_h = x_h/c$.

Having obtained the oscillatory aerodynamic coefficients, we are now in a position to derive the AICs. We consider the given and equivalent force systems in Fig. 2. The equivalent forces are arbitrarily placed at the quarter-chord, the control surface hinge line, and the trailing edge. The derivation must relate the forces F_1, F_2, F_3 to the deflections h_1, h_2, h_3 through the given leading edge aerodynamic coefficients and deflections h_o, α, β. We begin with the force equivalence.

$$\begin{bmatrix} 1 & 1 & 1 \\ b/2 & (b/2 + d) & 2b \\ 0 & 0 & c_a \end{bmatrix} \begin{Bmatrix} F_1 \\ F_2 \\ F_3 \end{Bmatrix} = \begin{Bmatrix} L_o \\ M_o \\ T_o \end{Bmatrix} \qquad (31)$$

The loads and deflections are related through the definitions of the oscillatory coefficients.

$$\begin{Bmatrix} L_o \\ M_o \\ T_o \end{Bmatrix} = 4\rho\omega^2 b^2 \Delta y \begin{bmatrix} 1 & 0 & 0 \\ 0 & b & 0 \\ 0 & 0 & b \end{bmatrix} \begin{bmatrix} L_{h_o} & L_{\alpha_o} & L_{\beta_o} \\ M_{h_o} & M_{\alpha_o} & M_{\beta_o} \\ T_{h_o} & T_{\alpha_o} & T_{\beta_o} \end{bmatrix} \begin{Bmatrix} h_o \\ b\alpha \\ b\beta \end{Bmatrix} . \qquad (32)$$

The equivalence in the deflections is given by

$$\begin{Bmatrix} h_o \\ b\alpha \\ b\beta \end{Bmatrix} = \begin{bmatrix} (1 + b/2d) & -b/2d & 0 \\ -b/d & b/d & 0 \\ b/d & -(b/d + b/c_a) & b/c_a \end{bmatrix} \begin{Bmatrix} h_1 \\ h_2 \\ h_3 \end{Bmatrix} . \qquad (33)$$

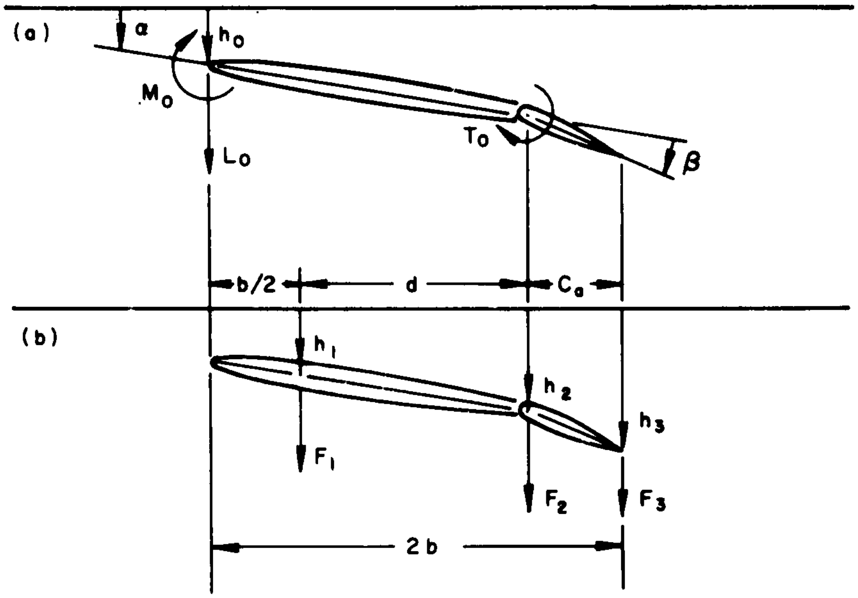


Fig. 2. Original (a) and Equivalent (b) Force Systems and Geometry for Oscillatory Case.

Substituting Eq. (33) into (32), Eq. (32) into (31), and solving for the forces yields

$$\left\{\begin{matrix} F_1 \\ F_2 \\ F_3 \end{matrix}\right\} = 4\rho\omega^2 b^2 \Delta y \begin{bmatrix} (1 + b/2d) & -b/d & (b/c_a)(3b/2d - 1) \\ -b/2d & b/d & -(b/c_a)(3b/2d) \\ 0 & 0 & b/c_a \end{bmatrix}$$

$$\times \begin{bmatrix} L_{h_o} & L_{\alpha_o} & L_{\beta_o} \\ M_{h_o} & M_{\alpha_o} & M_{\beta_o} \\ T_{h_o} & T_{\alpha_o} & T_{\beta_o} \end{bmatrix} \begin{bmatrix} (1 + b/2d) & -b/2d & 0 \\ -b/d & b/d & 0 \\ b/d & -(b/d + b/c_a) & b/c_a \end{bmatrix} . \qquad (34)$$

From the definition of the AIC matrix

$$\left| F \right| = \rho\omega^2 b_r^2 s \, [C_h] \left| h \right| \quad , \qquad (35)$$

and by identity with Eq. (34), we find the AICs for a single strip.

$$[C_h] = 4(b/b_r)^2(\Delta y/s) \begin{bmatrix} (1 + b/2d) & -b/d & (b/c_a)(3b/2d - 1) \\ -b/2d & b/d & -(b/c_a)(3b/2d) \\ 0 & 0 & b/c_a \end{bmatrix}$$

$$\times \begin{bmatrix} L_{h_o} & L_{\alpha_o} & L_{\beta_o} \\ M_{h_o} & M_{\alpha_o} & M_{\beta_o} \\ T_{h_o} & T_{\alpha_o} & T_{\beta_o} \end{bmatrix} \begin{bmatrix} (1 + b/2d) & -b/2d & 0 \\ -b/d & b/d & 0 \\ b/d & -(b/d + b/c_a) & b/c_a \end{bmatrix} . \qquad (36)$$

In the absence of a control surface Eq.(36) reduces to

$$[C_h] = 4(b/b_r)^2\,(\Delta y/s) \begin{bmatrix} (1 + b/2d) & -b/d \\ -b/2d & b/d \end{bmatrix}$$

$$\times \begin{bmatrix} L_{h_o} & L_{\alpha_o} \\ M_{h_o} & M_{\alpha_o} \end{bmatrix} \begin{bmatrix} (1 + b/2d) & -b/2d \\ -b/d & b/d \end{bmatrix} . \tag{37}$$

The complete AIC matrix for a surface of N strips appears in the partitioned form

$$[C_h] = \left[\begin{array}{c|c|c|cccc|c} 0 & 0 & 0 & \cdot & \cdot & \cdot & \cdot & 0 \\ \hline 0 & C_{h1} & 0 & \cdot & \cdot & \cdot & \cdot & 0 \\ \hline 0 & 0 & C_{h2} & \cdot & \cdot & \cdot & \cdot & 0 \\ \hline \cdot & \cdot & \cdot & \cdot & & & & \cdot \\ \cdot & \cdot & \cdot & & \cdot & & & \cdot \\ \cdot & \cdot & \cdot & & & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & & & \cdot & \cdot \\ \hline 0 & 0 & 0 & \cdot & \cdot & \cdot & \cdot & C_{hN} \end{array}\right] \tag{38}$$

in which the first null partition is reserved for control points at which the aerodynamic forces are negligible (e.g., external stores) and in which the remaining partitions are of the size 3 x 3 or 2 x 2 according to whether or not the strip has a control surface.

The steady AIC matrix follows from the oscillatory solution as a limiting case. If we compare the definition of the steady matrix

$$\left|F\right| = (1/2)\rho\ V^2(S/\bar{c})\ [C_{hs}]\ \left|h\right| \tag{39}$$

with the oscillatory definition Eq. (35), we observe

$$[C_{hs}] = 2(s\bar{c}/S) \lim_{k_r \to 0} k_r^2[C_h] \tag{40}$$

From the previous section we find the limiting values of the oscillatory coefficients to be

$$\lim_{k_r \to 0} \left(k_r^2 L_{h_o},\ k_r^2 M_{h_o},\ k_r^2 T_{h_o}\right) = 0 \tag{41}$$

$$\lim_{k_r \to 0} k_r^2 L_{\alpha_o} = -\ K_1(b_r/b)^2 \tag{42a}$$

$$\lim_{k_r \to 0} k_r^2 M_{\alpha_o} = -\ K_2(b_r/b)^2 \tag{42b}$$

$$\lim_{k_r \to 0} k_r^2 T_{\alpha_o} = -\ (K_5 - 2K_4\xi_h)\ (b_r/b)^2 \tag{42c}$$

$$\lim_{k_r \to 0} k_r^2 L_{\beta_o} = -\ K_4(b_r/b)^2 \tag{43a}$$

$$\lim_{k_r \to 0} k_r^2 M_{\beta_o} = - K_5 (b_r/b)^2 \tag{43b}$$

$$\lim_{k_r \to 0} k_r^2 T_{\beta_o} = - (K_5 - 2K_4 \xi_h)(b_r/b)^2 \tag{43c}$$

D. References

1. H. Ashley and G. Zartarian. "Piston Theory--A New Aerodynamic Tool for the Aeroelastician." Journal of the Aeronautical Sciences, 23 (1956), 1109.

2. H. G. Morgan, V. Huckel, and H. L. Runyan. "Procedure for Calculating Flutter at High Supersonic Speed Including Camber Deflections, and Comparison with Experimental Results." NACA TN 4335, September 1958.

3. M. D. Van Dyke. "A Study of Second-Order Supersonic Flow Theory." NACA Report 1081, 1952.

4. W. P. Rodden, E. F. Farkas, P. E. Williams, and F. C. Slack. "Aerodynamic Influence Coefficients by Piston Theory: Analytical Development and Procedure ~~for the IBM 7090 Computer~~." Northrop Corporation Report NOR-61-57, 14 April 1961.

5. J. W. Miles. The Potential Theory of Unsteady Supersonic Flow. London: Cambridge University Press, 1959, pp. 184-185.

SECTION II

GENERAL DESCRIPTION OF INPUT

A. Units

Since all dimensional input is geometrical and the aerodynamic matrix is dimensionless, only a consistent set of length units is necessary--inches or feet.

B. Classes of Numerical Data and Limitations

The data required by the program are control and option indicators, geometry, Mach numbers, and a set of reduced velocities for each Mach number. The example problem illustrates their use.

1. Example Problem

We consider the four-strip wing shown in Fig. 3 at Mach numbers 1.8 and 2.5. We use reduced velocities of 4.0 and 8.0 for both Mach numbers, and compute the steady case for Mach 2.5. The aerodynamic matrices will be computed by piston theory and by Van Dyke's quasi-steady variation. Strips 2 and 3 are considered to have control surfaces. The thickness integrals will be computed for an assumed airfoil (constant across the span) having 10 percent thickness, maximum thickness at 40 percent chord, and a blunt trailing edge having 1.5 percent thickness.

2. Program Restrictions and Options

a. The number of strips into which a wing may be subdivided must be ≤ 25.

b. The number of Mach numbers must be ≤ 15.

c. The number of reduced velocities used with any one Mach number must be ≤ 20.

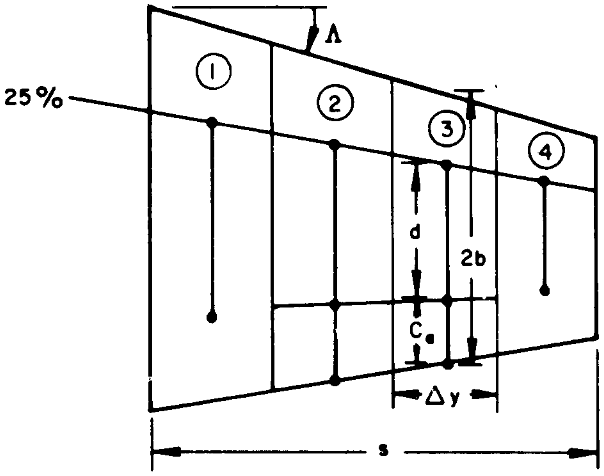


Fig. 3. Example of Four-Strip Wing.

Strip No.	Δy(ft)	b(ft)	c_a(ft)	d(ft)
1	4.7	12.28120	0	11.9
2	4.2	9.50000	5.25000	9.0
3	3.6	7.06250	3.99375	6.6
4	3.1	4.96875	0	4.5

Strip No.	ξ_m	ξ_h	τ	τ_h	τ_t
1	0.4	(not used)	0.1	0.015[*]	(not used)
2	0.4	0.72368421	0.1	0.050	0.015
3	0.4	0.71725664	0.1	0.050	0.015
4	0.4	(not used)	0.1	0.015[*]	(not used)

$\sec \Lambda = 1.25$

$b_r = 6.5$ ft

$s = 15.6$ ft

$S = 554.0$ sq ft

$\bar{c} = 21.0$ ft

α_o's (constant) $= 5.0^{\circ}$

---

[*] **N. B. The trailing edge thickness is listed as the hinge line thickness in the case of no control surface.**

d. If it is desired to compute the steady matrix $[C_{hs}]$, a zero or negative value of $V/b_r\omega$ must be supplied to the program. (S and $\bar{c}$ must also be provided.)

e. Thickness integrals may be given or computed. If given they may be given only once with each deck and are considered constant with strips. α_o's may be constant or vary with strips (for each Mach number). (τ, τ_h, τ_t)'s may be constant or vary with strips. ξ_m and ξ_h may be constant or vary with strips.

f. The control surface strips must be a continuation of the main surface strips; e.g., in the case of a partial span control surface the inboard and outboard span stations should be used as boundaries of the main surface strips.

g. As many complete sets (decks) of input data may be supplied as desired (one following the other).

SECTION III

DATA DECK SETUP

A. Loading Order

Input decks punched from keypunch forms are loaded behind column binary deck HM11. The data for each deck should be in the following order:

(1) Heading Card 1

(2) Heading Card 2

(3) NTHRY, NTHICK, NALPHA, NTAUS, NZETAS*

(4) ISZ, MSZ, NO PUNJ, JSZ_1, JSZ_2, . . . JSZ_{MSZ}

(5) $\sec \Lambda$, b_r, s, S, $\overline{c}$

(6) Δy_1, Δy_2, . . . , Δ_{ISZ}

(7) b_1, b_2, . . . , b_{ISZ}

(8) c_{a1}, c_{a2}, . . . , c_{aISZ}

(9) d_1, d_2, . . . , d_{ISZ}

(10) $Mach_1$, $Mach_2$, . . . , $Mach_{MSZ}$

(11a) If thickness integrals are given:

- (a) When all $c_{ai} = 0$ tabulate only I_1, I_2, ... , I_6.
- (b) Any $c_{ai} \neq 0$ then include J_1, J_2, ... , J_6, and ξ_{h1}, ξ_{h2}, ... , ξ_{hISZ} (if NZETAS = 1 only ξ_{h1} is needed).

(11b) If thickness integrals are computed:

- (a) τ_1, τ_{h1}, τ_{t1}; τ_2, τ_{h2}, τ_{t2}; . . ; . . ; τ_{ISZ}, τ_{hISZ}, τ_{tISZ} [if NTAUS = 1 only τ_1, τ_{h1}, and τ_{t1} are needed; if $c_{ai} = 0$ (i. e., no control surface), the trailing edge thickness (τ_{ti}) is listed as τ_{hi}, and the location for τ_{ti} may be left blank for these strips].

---

*Please, no remarks about our Greek!

(b) ξ_{m1}, ξ_{h1}; ξ_{m2}, ξ_{h2}; . . . ; ξ_{mISZ}, ξ_{hISZ} [if NZETA = 1 only ξ_{m1} and ξ_{h1} are needed; if $c_{ai} = 0$, the program uses $\xi_h = 1.0$ (ξ for trailing edge), and the location for ξ_{hi} may be left blank for these strips].

(12a) If alphas do not vary with strips:

$\alpha_1, \alpha_2, \ldots, \alpha_{MSZ}$

(12b) If alphas vary with strips:

(a) $\alpha_1, \alpha_2, \ldots, \alpha_{ISZ}$ for first Mach number

(b) $\alpha_1, \alpha_2, \ldots, \alpha_{ISZ}$ for second Mach number

(c) $\alpha_1, \alpha_2, \ldots, \alpha_{ISZ}$ for MSZ Mach number

(13) $V/b_r\omega$ series

(a) $(V/b_r\omega)_1, (V/b_r\omega)_2, \ldots, (V/b_r\omega)_{JSZ}$ for first Mach number

(b) $(V/b_r\omega)_1, (V/b_r\omega)_2, \ldots, (V/b_r\omega)_{JSZ}$ for second Mach number

(c) $(V/b_r\omega)_1, (V/b_r\omega)_2, \ldots, (V/b_r\omega)_{JSZ}$ for MSZ Mach number

B. Input Data Description

(1), (2) Heading Card 1 and Heading Card 2 may contain any characters desired in Columns 2 through 72. These cards are convenient for identifying the vehicle, surface, date, engineer, etc. Both cards may be blank but must be included in the data deck.

(3) Control card: FORMAT (18I4)

(a) NTHRY = 0, piston theory is used to compute $\mathcal{C}_1$ and $\mathcal{C}_2$

NTHRY $\neq 0$, Van Dyke's theory is used to compute $\bar{C}_1$ and $\bar{C}_2$ (If sec $\Lambda = 0$, then with either theory $\bar{C}_1$ and $\bar{C}_2$ are the same)

(b) NTHICK $= 0$, when thickness integrals are computed
NTHICK $\neq 0$, when thickness integrals are given (in this case they are constant for the surface)

(c) NALPHA $= 1$, the alphas are constant (do not vary with each strip)
NALPHA = ISZ, the alphas vary with each strip

(d) NTAUS $= 1$, the τ, τ_h, and τ_t are constant for all strips
NTAUS = ISZ, the τ, τ_h, and τ_t vary with each strip

(e) NZETAS $= 1$, ξ_m and ξ_h are constant for all strips
NZETAS = ISZ, ξ_m and ξ_h vary with each strip

(4) Control card: FORMAT (18I4)

(a) ISZ = number of strips, ≤ 25

(b) MSZ = number of Mach numbers, ≤ 15

(c) NO PUNJ $= 0$, or blank, when punched card output is desired
NO PUNJ $\neq 0$, no punched output is desired

(d) JSZ_1 = number of $(V/b_r\omega)$'s for first Mach number, ≤ 20
JSZ_2 = number of $(V/b_r\omega)$'s for second Mach number, ≤ 20

.
.
.

JSZ_{MSZ} = number of $(V/b_r\omega)$'s for last Mach number, ≤ 20

(5) Single parameters: FORMAT (6E12.8)

(a) sec Λ, secant of leading edge sweep angle

(b) b_r, reference semichord

(c) s, wing semispan

(d) S, wing area

(e) $\bar{c}$, mean aerodynamic chord

(6) Δy_i series: FORMAT (6E12.8)

$\Delta y_1 \ldots \Delta y_{ISZ}$, strip widths

(7) b_i series: FORMAT (6E12.8)

$b_1 \ldots b_{ISZ}$, local semichords

(8) c_{ai} series: FORMAT (6E12.8)

$c_{a1} \cdots c_{aISZ}$, control surface chords; in the absence of a control surface, c_{ai} may be zero or blank, but a sufficient number of cards must be included

(9) d_i series: FORMAT (6E12.8)

$d_1 \ldots d_{ISZ}$, distance between forward and aft control points

(10) Mach number series: FORMAT (6E12.8)

$\text{Mach}_1 \ldots \text{Mach}_{MSZ}$, in any order desired, but the number listed must agree with MSZ

(11a) Thickness integrals given: FORMAT (6E12.8)

(a) $I_1, I_2, \ldots\ldots, I_6$, the complete airfoil thickness integrals

(b) $J_1, J_2, \ldots\ldots, J_6$, the control surface thickness integrals, use only when $c_{ai} \neq 0$

$\xi_{h1}, \xi_{h2}, \ldots\ldots, \xi_{hISZ}$, dimensionless chordwise coordinate (x_h/c) for the control surface hinge line

(11b) Thickness integrals are computed: FORMAT (6E12.8)

(a) τ_i, τ_{hi}, and τ_{ti}, airfoil thickness ratios (t/c) at point of maximum thickness, hinge line, and trailing edge, respectively

(b) ξ_{mi} and ξ_{hi}, dimensionless chordwise coordinates for point of maximum thickness and hinge line

(12a) Alphas do not vary with strips (alpha is α_o, the initial angle of attack). FORMAT (6E12.8)

$\alpha_1, \alpha_2 \ldots \alpha_{MSZ}$ (degrees) are tabulated in order for each Mach number

(12b) Alphas vary with strips: FORMAT (6E12.8)

$\alpha_1, \alpha_2, \ldots, \alpha_{ISZ}$ (degrees) are tabulated for each Mach number. The series for each Mach number starts on a new line (card).

(13) $V/b_r\omega$ series, reference reduced velocity: FORMAT (6E12.8)

There is a reduced velocity series for each Mach number; each series starts on a new line (card), and the number of $V/b_r\omega$'s must agree with the JSZ for the respective Mach number.

C. Example Keypunch Forms

Example keypunch forms are given on the following pages. Columns 73 through 80 are reserved for data deck identification. This space may be used in any fashion; however, it is suggested that the last three columns be used for sequencing. Only the cards with sequencing in Columns 73 through 80 are to be used in the sample data deck; the lines (cards) with Columns 73 through 80 blank are for clarification of input.

```
 EXAMPLE PRØBLEM HEADING                                                HM110001
 BLØØPER JET  JAN.25, 1960  P.E. WILLIAMS                               HM110002
   0   0   1   4   4                                                    HM110003
   4   2   0   2   3                                                    HM110004
```

Heading Card 1

Heading Card 2

NZETAS

NTAUS

NALPHA

NTHICK

NTHRY

JSZ--for second Mach number

JSZ--for first Mach number

NO PUNJ

MSZ

ISZ

$\sec \Lambda$	b_r	s	S	$\bar{c}$		
1.25	6.5	15.6	554.0	21.0		HM110005
Δy_1	Δy_2	Δy_3	Δy_4	Δy_5	Δy_6	
4.7	4.2	3.6	3.1			HM110006
b_1	b_2	b_3	b_4	b_5	b_6	
12.2812	9.5	7.0625	496875 +01			HM110007
ca_1	ca_2	ca_3	ca_4	ca_5	ca_6	
0	5.25	3.99375	0			HM110008
d_1	d_2	d_3	d_4	d_5	d_6	
11.9	9.	6.6	4.5			HM110009
$Mach_1$	$Mach_2$	$Mach_3$	$Mach_4$	$Mach_5$	$Mach_6$	
1.8	2.5					HM110010
τ_1	τ_{h1}	τ_{t1}	τ_2	τ_{h2}	τ_{t2}	
.1	.015		.1	.05	.015	HM110011
τ_3	τ_{h3}	τ_{t3}	τ_4	τ_{h4}	τ_{t4}	
.1	.05	.015	.1	.015	0	HM110012
ξ_{m1}	ξ_{h1}	ξ_{m2}	ξ_{h2}	ξ_{m3}	ξ_{h3}	
.4		.4	72368421	.4	71725664	HM110013

```
     ξm4        ξh4         ξm5         ξh5          ξm6        ξh6
     .4        0                                                        HM110014
      a1         a2          a3          a4          a5          a6
   5.        5.                                                         HM110015
   (V/b_r ω)1  (V/b_r ω)2  (for first Mach number)
   4.0         8.0                                                      HM110016
   (V/b_r ω)1  (V/b_r ω)2  (for second Mach number)
  4.0         8.0          0                                            HM110017

                                    NOTE:  EACH NEW SERIES STARTS ON A NEW
                                           LINE (CARD):  FORMAT (6E12.8)

      The second case is identical except for the following card (Van Dyke's
      quasi-steady correction is used).

   1   0   1   4   4                                                    HM110003
```

SECTION IV

PROGRAM OUTPUT

A. Printed Output

1. All input data
2. Thickness integrals (I's and J's)
3. Each group of aerodynamics influence coefficients (comprising a complete aerodynamic matrix), associated Mach number, and $V/b_r\omega$
4. Sequencing numbers (Columns 73 through 80) of the first and last punched cards (output) for each group (one $V/b_r\omega$) of influence coefficients
5. Example problem printed output is shown on the following pages

```
                       AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY

                                            INPUT DATA

                                  4 STRIPS
                                  2 MACH NUMBERS
                                  5 REDUCED FREQUENCIES (TOTAL)

                                  SECANT LAMBDA =  0.12499999E 01
                                             BR =  0.64999999E 01
                                              S =  0.15600000E 02
                                              $ =  0.55400000E 03
                                          C BAR =  0.20999999E 02
          STRIP     DELTA Y (I)          B(I)               CA(I)               D(I)

            1      0.46999999E 01    0.12281200E 02    0.
            2      0.41999999E 01    0.95000000E 01    0.52499999E 01    0.11900000E 02
            3      0.35999999E 01    0.70625000E 01    0.39937499E 01    0.89999999E 01
            4      0.30999999E 01    0.49687500E 01    0.                0.65999999E 01
                                                                         0.45000000E 01
       STRIP       XI M              XI H              TAU               TAU H             TAU T

         1     0.40000000E-00    0.09999999E 01    0.09999999E-00    0.15000000E-01    0.
         2     0.40000000E-00    0.72368421E 00    0.09999999E-00    0.49999999E-01    0.15000000E-01
         3     0.40000000E-00    0.71725664E 00    0.09999999E-00    0.49999999E-01    0.15000000E-01
         4     0.40000000E-00    0.09999999E 01    0.09999999E-00    0.15000000E-01    0.

                                  MACH NUMBER =       1.80000000
                                       1/K(R) =   0.40000000E 01
                                       1/K(R) =   0.80000000E 01
     ALPHA ZERO SERIES (DEGREES) =    5.00       5.00       5.00       5.00

                                  MACH NUMBER =       2.50000000
                                       1/K(R) =   0.40000000E 01
                                       1/K(R) =   0.80000000E 01
                                       1/K(R) =   0.
     ALPHA ZERO SERIES (DEGREES) =    5.00       5.00       5.00       5.00
```

```
                                        COMPUTED THICKNESS INTEGRALS
 STRIP        J(1)             J(2)             J(3)             J(4)             J(5)             J(6)

   1     0.               0.               0.               0.               0.               0.
   2    -0.17500000E-01  -0.15082236E-01  -0.13109850E-01   0.11083332E-02   0.95520827E-03   0.83029052E-03
   3    -0.17500000E-01  -0.15023999E-01  -0.13018329E-01   0.10831376E-02   0.93001267E-03   0.80575106E-03
   4     0.               0.               0.               0.               0.               0.
 STRIP        I(1)             I(2)             I(3)             I(4)             I(5)             I(6)

   1     0.74999999E-02  -0.27333333E-01  -0.26716666E-01   0.97783331E-02   0.42451386E-02   0.30875553E-02
   2     0.75000000E-02  -0.23810306E-01  -0.21401949E-01   0.97114031E-02   0.34433518E-02   0.20373899E-02
   3     0.75000000E-02  -0.23646939E-C1  -0.21173231E-01   0.96808512E-02   0.34390200E-02   0.20179822E-02
   4     0.74999999E-02  -0.27333333E-01  -0.26716666E-01   0.97783331E-02   0.42451386E-02   0.30875553E-02
```

```
                   AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY          3

                                    OSCILLATORY CASE

                                 MACH =        1.80000000

                               1/K(R) =  0.40000000E 01

                                         4STRIPS

                                    CH(1) SIZE = 2 BY 2
           0.71788753E 01 -0.39289374E 01I -0.71788753E 01  0.64322150E 00I
           0.44294456E 01  0.64322149E 00I -0.44294456E 01 -0.26705447E 01I

                                    CH(2) SIZE = 3 BY 3
  0.70593633E 01 -0.26495353E 01I -0.70593633E 01  0.20590959E-00I -0.46521193E-07  0.19383830E-08I
  0.10759644E 01  0.20590963E-00I  0.10439030E 01 -0.86372529E 00I -0.21198674E 01 -0.14268377E-00I
 -0.             -0.              I  0.21198682E 01 -0.14268376E-00I -0.21198682E 01 -0.28536656E-00I

                                    CH(3) SIZE = 3 BY 3
  0.61164010E 01 -0.16911002E 01I -0.61164010E 01  0.13847534E-00I -0.57432242E-07  0.89737879E-08I
  0.89529782E 00  0.13847534E-00I  0.92739177E 00 -0.55239360E 00I -0.18226895E 01 -0.93325315E-01I
 -0.              0.15223674E-07I  0.18226899E 01 -0.93325322E-01I -0.18226900E 01 -0.18665039E-00I

                                    CH(4) SIZE = 2 BY 2
           0.48474802E 01 -0.10759194E 01I -0.48474802E 01  0.23693249E-00I
           0.33442195E 01  0.23693250E-00I -0.33442195E 01 -0.81573974E 00I

                           PUNCHED CARDS NOS. HM11   0 THRU HM11  12
```

```
                     AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY

                                     OSCILLATORY CASE

                                    MACH =       1.80000000

                                  1/K(R) =  0.80000000E 01

                                          4STRIPS

                                    CH(1) SIZE = 2 BY 2
               0.28715501E 02 -0.78578748E 01I -0.28715501E 02  0.12864430E 01I
               0.17717782E 02  0.12864430E 01I -0.17717782E 02 -0.53410894E 01I

                                    CH(2) SIZE = 3 BY 3
 0.28237453E 02 -0.52990707E 01I -0.28237453E 02  0.41181920E-00I -0.18608477E-06  0.38767660E-08I
 0.43038578E 01  0.41181927E-00I  0.41756120E 01 -0.17274506E 01I -0.84794699E 01 -0.28536754E-00I
-0.             -0.             I  0.84794731E 01 -0.28536753E-00I -0.84794731E 01 -0.57073312E 00I

                                    CH(3) SIZE = 3 BY 3
 0.24465604E 02 -0.33822004E 01I -0.24465603E 02  0.27695068E-00I -0.22972897E-06  0.17947575E-07I
 0.35811912E 01  0.27695069E-00I  0.37095670E 01 -0.11047871E 01I -0.72907583E 01 -0.18665063E-00I
-0.              0.30447347E-07I  0.72907599E 01 -0.18665064E-00I -0.72907600E 01 -0.37330078E-00I

                                    CH(4) SIZE = 2 BY 2
               0.19389921E 02 -0.21518388E 01I -0.19389921E 02  0.47386498E-00I
               0.13376877E 02  0.47386500E-00I -0.13376877E 02 -0.16314794E 01I

                             PUNCHED CARDS NOS. HM11  13 THRU HM11  25
```

```
                    AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY        5

                                   OSCILLATORY CASE

                                MACH =       2.50000000

                               1/K(R) =  0.40000000E 01

                                        4STRIPS

                                   CH(1) SIZE = 2 BY 2
           0.57621686E 01 -0.31458882E 01I -0.57621686E 01  0.50858803E 00I
           0.28960149E 01  0.50858802E 00I -0.28960149E 01 -0.18340717E 01I

                                   CH(2) SIZE = 3 BY 3
 0.55877510E 01 -0.21343287E 01I -0.55877510E 01  0.20010731E-00I  0.38767660E-07  0.58151491E-08I
 0.60791197E 00  0.20010730E-00I  0.86290549E 00 -0.60853299E 00I -0.14708174E 01 -0.98997385E-01I
-0.              0.21424233E-08I  0.14708177E 01 -0.98997386E-01I -0.14708177E 01 -0.19799466E-00I

                                   CH(3) SIZE = 3 BY 3
 0.48428045E 01 -0.13624670E 01I -0.48428044E 01  0.13313967E-00I -0.15793866E-06 -0.17947575E-08I
 0.40889528E-00  0.13313968E-00I  0.76718581E 00 -0.38943376E-00I -0.12660810E 01 -0.64825930E-01I
-0.             -0.30447347E-08I  0.12660816E 01 -0.64825933E-01I -0.12660816E 01 -0.12965150E-00I

                                   CH(4) SIZE = 2 BY 2
           0.39233785E 01 -0.86084867E 00I -0.39233785E 01  0.18180238E-00I
           0.21864834E 01  0.18180237E-00I -0.21864834E 01 -0.56023222E 00I

                         PUNCHED CARDS NOS. HM11  26 THRU HM11  38
```

```
                     AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY

                                    OSCILLATORY CASE

                                    MACH =      2.50000000

                                 1/K(R) =  0.80000000E 01

                                        4STRIPS

                                    CH(1) SIZE = 2 BY 2
               0.23048674E 02 -0.62917764E 01I -0.23048674E 02  0.10171760E 01I
               0.11584059E 02  0.10171760E 01I -0.11584059E 02 -0.36681435E 01I

                                    CH(2) SIZE = 3 BY 3
  0.22351003E 02 -0.42686575E 01I -0.22351003E 02  0.40021462E-00I  0.15507064E-06  0.11630298E-07I
  0.24316479E 01  0.40021461E-00I  0.34516219E 01 -0.12170660E 01I -0.58832698E 01 -0.19799477E-00I
 -0.              0.42848467E-08I  0.58832709E 01 -0.19799477E-00I -0.58832709E 01 -0.39598934E-00I

                                    CH(3) SIZE = 3 BY 3
  0.19371218E 02 -0.27249340E 01I -0.19371217E 02  0.26627934E-00I -0.63175466E-06 -0.35895152E-08I
  0.19956811E 01  0.26627935E-00I  0.30687432E 01 -0.77886754E 00I -0.50643244E 01 -0.12965186E-00I
 -0.             -0.60894696E-08I  0.50643262E 01 -0.12965187E-00I -0.50643263E 01 -0.25930300E-00I

                                    CH(4) SIZE = 2 BY 2
               0.15693514E 02 -0.17216973E 01I -0.15693514E 02  0.36360475E-00I
               0.87459339E 01  0.36360475E-00I -0.87459339E 01 -0.11204644E 01I

                         PUNCHED CARDS NOS. HM11  39 THRU HM11  51
```

7

```
AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY

                    STEADY CASE

                   MACH =      2.50000000

                 1/K(R) = INFINITY

                      4STRIPS

                CH(1) SIZE = 2 BY 2
          0.42592202E-00   -0.42592202E-00
          0.21406464E-00   -0.21406464E-00

                CH(2) SIZE = 3 BY 3
 0.41302960E-00  -0.41302960E-00   0.28655878E-08
 0.44935007E-01   0.63783355E-01  -0.10871836E-00
-0.               0.10871838E-00  -0.10871838E-00

                CH(3) SIZE = 3 BY 3
 0.35796542E-00  -0.35796541E-00  -0.11674347E-07
 0.36876824E-01   0.56708048E-01  -0.93584874E-01
-0.               0.93584908E-01  -0.93584909E-01

                CH(4) SIZE = 2 BY 2
          0.29000423E-00   -0.29000423E-00
          0.16161823E-00   -0.16161823E-00

        PUNCHED CARDS NOS. HM11  52 THRU HM11  59
```

```
                                                  HM110686          9

                                                  HM110687
                    AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY
                     (WITH VAN DYKES QUASI-STEADY THEORY  FINAGLING FACTOR)

                                          INPUT DATA

                                   4 STRIPS
                                   2 MACH NUMBERS
                                   5 REDUCED FREQUENCIES (TOTAL)

                                  SECANT LAMBDA =  0.12499999E 01
                                             BR =  0.64999999E 01
                                              S =  0.15600000E 02
                                              $ =  0.55400000E 03
                                          C BAR =  0.20999999E 02

           STRIP      DELTA Y (I)           B(I)              CA(I)                 D(I)

             1      0.46999999E 01      0.12281200E 02    -0.                   0.11900000E 02
             2      0.41999999E 01      0.95000000E 01     0.52499999E 01       0.89999999E 01
             3      0.35999999E 01      0.70625000E 01     0.39937499E 01       0.65999999E 01
             4      0.30999999E 01      0.49687500E 01    -0.                   0.45000000E 01

       STRIP       XI M             XI H              TAU              TAU H            TAU T

         1     0.40000000E-00   0.09999999E 01   0.09999999E-00   0.15000000E-01   0.
         2     0.40000000E-00   0.72368421E 00   0.09999999E-00   0.49999999E-01   0.15000000E-01
         3     0.40000000E-C0   0.71725664E 00   0.09999999E-00   0.49999999E-01   0.15000000E-01
         4     0.4C000000E-0C   0.09999999E 01   0.09999999E-00   0.15000000E-01   0.

                                     MACH NUMBER =       1.80000000
                                          1/K(R) =  0.40000000E 01
                                          1/K(R) =  0.80000000E 01
     ALPHA ZERO SERIES (DEGREES) =     5.00        5.00        5.00        5.00

                                     MACH NUMBER =       2.50000000
```

```
                                          1/K(R) =  0.40000000E 01
                                          1/K(R) =  0.8C000000E 01              9
                                          1/K(R) = -0.
      ALPHA ZERO SERIES (DEGREES) =    5.00        5.00        5.00        5.00

                                          COMPUTED THICKNESS INTEGRALS
STRIP       J(1)           J(2)           J(3)           J(4)           J(5)           J(6)

  1    0.             0.             0.             0.             0.             0.
  2   -0.17500000E-01 -0.15082236E-01 -0.13109850E-01  0.11083332E-02  0.95520827E-03  0.83029052E-03
  3   -0.175000C0E-01 -0.15025995E-01 -0.13018329E-01  0.10831376E-02  0.93001267E-03  0.80575106E-03
  4    0.             0.             0.             0.             0.             0.

STRIP       I(1)           I(2)           I(3)           I(4)           I(5)           I(6)

  1    0.74999999E-02 -0.27333333E-01 -0.26716666E-01  0.97783331E-02  0.42451386E-02  0.30875553E-02
  2    0.75000000E-02 -0.23813306E-01 -0.21401949E-01  0.97114031E-02  0.34433518E-02  0.20373899E-02
  3    0.75C00000E-02 -0.23646939E-01 -0.21173231E-01  0.96808512E-02  0.34390200E-02  0.20179822E-02
  4    0.74999999E-02 -0.27333333E-01 -0.26716666E-01  0.97783331E-02  0.42451386E-02  0.30875553E-02
```

```
                    AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY
                     (WITH VAN DYKES QUASI-STEADY THEORY  FINAGLING FACTOR)

                                    OSCILLATORY CASE

                                 MACH =       1.80000000

                               1/K(R) =  0.40000000E 01

                                        4STRIPS

                                 CH(1) SIZE = 2 BY 2
          0.11171371E 02 -0.60500227E 01I -0.11171371E 02  0.93697202E 00I
          0.49569440E 01  0.93697204E 00I -0.49569440E 01 -0.32057271E 01I

                                 CH(2) SIZE = 3 BY 3
 0.10692380E 02 -0.41086720E 01I -0.10692380E 02  0.40746380E-00I -0.77535321E-07 -0.23260596E-07I
 0.93588296E 00  0.40746372E-00I  0.17310714E 01 -0.10904364E 01I -0.26669544E 01 -0.17950657E-00I
-0.             -0.32136350E-07I  0.26669553E 01 -0.17950655E-00I -0.26669554E 01 -0.35901324E-00I

                                 CH(3) SIZE = 3 BY 3
 0.92699547E 01 -0.26240122E 01I -0.92699547E 01  0.27086976E-00I -0.14358060E-07  0.53842727E-08I
 0.75487661E 00  0.27086976E-00I  0.15442599E 01 -0.69793279E 00I -0.22991365E 01 -0.11772014E-00I
-0.              0.81192928E-08I  0.22991367E 01 -0.11772015E-00I -0.22991368E 01 -0.23544054E-00I

                                 CH(4) SIZE = 2 BY 2
          0.76388664E 01 -0.16535902E 01I -0.76388664E 01  0.33147874E-00I
          0.37424795E 01  0.33147871E-00I -0.37424795E 01 -0.97921555E 00I

                        PUNCHED CARDS NOS. HM11  60 THRU HM11  72
```

```
                    AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY
                     (WITH VAN DYKES QUASI-STEADY THEORY  FINAGLING FACTOR)

                                   OSCILLATORY CASE

                                MACH =        1.80000000

                              1/K(R) =  0.80000000E 01

                                       4STRIPS

                                CH(1) SIZE = 2 BY 2
            0.44685484E 02 -0.12100045E 02I -0.44685484E 02  0.18739440E 01I
            0.19827776E 02  0.18739440E 01I -0.19827776E 02 -0.64114542E 01I

                                CH(2) SIZE = 3 BY 3
  0.42769518E 02 -0.82173441E 01I -0.42769518E 02  0.81492759E 00I -0.31014128E-06 -0.46521193E-07I
  0.37435318E 01  0.81492744E 00I  0.69242857E 01 -0.21808727E 01I -0.10667817E 02 -0.35901315E-00I
 -0.           -0.64272700E-07I  0.10667821E 02 -0.35901310E-00I -0.10667821E 02 -0.71802649E 00I

                                CH(3) SIZE = 3 BY 3
  0.37079819E 02 -0.52480243E 01I -0.37079319E 02  0.54173952E 00I -0.57432242E-07  0.10768545E-07I
  0.30198064E 01  0.54173952E 00I  0.61770397E 01 -0.13958655E 01I -0.91965462E 01 -0.23544029E-00I
 -0.            0.16238585E-07I  0.91965472E 01 -0.23544030E-00I -0.91965473E 01 -0.47088108E-00I

                                CH(4) SIZE = 2 BY 2
            0.30555465E 02 -0.33071805E 01I -0.30555465E 02  0.66295747E 00I
            0.14969917E 02  0.66295743E 00I -0.14969917E 02 -0.19584311E 01I

                        PUNCHED CARDS NOS. HM11  73 THRU HM11  85
```

12

```
                    AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY
                     (WITH VAN DYKES QUASI-STEADY THEORY  FINAGLING FACTOR)

                                    OSCILLATORY CASE

                                MACH =       2.50000000

                             1/K(R) =  0.40000000E 01

                                        4STRIPS

                                  CH(1) SIZE = 2 BY 2
           0.67178680E 01 -0.36588867E 01I -0.67178680E 01  0.58417013E 00I
           0.32115138E 01  0.58417010E 00I -0.32115138E 01 -0.20540553E 01I

                                  CH(2) SIZE = 3 BY 3
  0.64845489E 01 -0.24841341E 01I -0.64845489E 01  0.23948260E-00I -0.38767660E-07  0.58151491E-08I
  0.64685941E 00  0.23948264E-00I  0.10177666E 01 -0.68747969E 00I -0.16646261E 01 -0.11204223E-00I
 -0.            -0.              I  0.16646264E 01 -0.11204222E-00I -0.16646265E 01 -0.22408430E-00I

                                  CH(3) SIZE = 3 BY 3
  0.56206739E 01 -0.15859851E 01I -0.56206737E 01  0.15919863E-00I -0.12922254E-06  0.17947575E-08I
  0.62780043E 00  0.15919863E-00I  0.90578000E 00 -0.43999702E-00I -0.14336204E 01 -0.73404239E-01I
 -0.             0.40596464E-08I  0.14336210E 01 -0.73404244E-01I -0.14336210E 01 -0.14680822E-00I

                                  CH(4) SIZE = 2 BY 2
           0.45822304E 01 -0.10008494E 01I -0.45822304E 01  0.20777106E-00I
           0.24246843E 01  0.20777106E-00I -0.24246843E 01 -0.62742798E 00I

                          PUNCHED CARDS NOS. HM11  86 THRU HM11  98
```

13

```
                         AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY
                         (WITH VAN DYKES QUASI-STEADY THEORY  FINAGLING FACTOR)

                                      OSCILLATORY CASE

                                     MACH =       2.50000000

                                    1/K(R) =  0.80000000E 01

                                          4STRIPS

                                    CH(1) SIZE = 2 BY 2
               0.26871472E 02 -0.73177734E 01I -0.26871472E 02  0.11683402E 01I
               0.12846056E 02  0.11683401E 01I -0.12846056E 02 -0.41081105E 01I

                                    CH(2) SIZE = 3 BY 3
  0.25938195E 02 -0.49682683E 01I -0.25938195E 02  0.47896520E-00I -0.15507064E-06  0.11630298E-07I
  0.25874376E 01  0.47896529E-00I  0.40710666E 01 -0.13749593E 01I -0.66585043E 01 -0.22408446E-00I
-0.            -0.             I  0.66585060E 01 -0.22408444E-00I -0.66585062E 01 -0.44816859E-00I

                                    CH(3) SIZE = 3 BY 3
  0.22482695E 02 -0.31719703E 01I -0.22482695E 02  0.31839728E-00I -0.51689018E-06  0.35895152E-08I
  0.21113617E 01  0.31839726E-00I  0.36231200E 01 -0.87999405E 00I -0.57344817E 01 -0.14680848E-00I
-0.              0.81192928E-08I  0.57344840E 01 -0.14680848E-00I -0.57344840E 01 -0.29361644E-00I

                                    CH(4) SIZE = 2 BY 2
               0.18328921E 02 -0.20016988E 01I -0.18328921E C2  0.41554212E-00I
               0.96987373E 01  0.41554213E-00I -0.96987373E 01 -0.12548559E 01I

                            PUNCHED CARDS NOS. HM11  99 THRU HM11 111
```

14

```
                     AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY
                      (WITH VAN DYKES QUASI-STEADY THEORY  FINAGLING FACTOR)

                                     STEADY CASE

                                     MACH =       2.50000000

                                    1/K(R) = INFINITY

                                        4STRIPS

                                  CH(1) SIZE = 2 BY 2
                           0.49656443E-00    -0.49656443E-00
                           0.23738536E-00    -0.23738536E-00

                                  CH(2) SIZE = 3 BY 3
                      0.47931818E-00    -0.47931818E-00    -0.28655878E-08
                      0.47813884E-01     0.75230224E-01    -0.12304410E-00
                     -0.                 0.12304414E-00    -0.12304414E-00

                                  CH(3) SIZE = 3 BY 3
                      0.41546316E-00    -0.41546316E-00    -0.95517385E-08
                      0.39016362E-01     0.66952509E-01    -0.10596887E-00
                     -0.                 0.10596891E-00    -0.10596891E-00

                                  CH(4) SIZE = 2 BY 2
                           0.33870457E-00    -0.33870457E-00
                           0.17922531E-00    -0.17922531E-00

                         PUNCHED CARDS NOS. HM11 112 THRU HM11 119
```

B. Punched Output

1. A deck of punched cards (output) from this program is suitable as an input deck to other programs requiring the use of AICs.

2. All punched output is sequenced in order on Columns 73 through 80 starting with HM110000. The data is punched in the following order:

   a. Card 1 contains $(V/b_r\omega)_1$ and M_1: FORMAT (6E12.8)

   b. Card 2 contains the size (number of control points) of the AIC matrix and the number of strips: FORMAT (18I4)

   c. The AIC matrix punched in column binary form and its TRA card make up the remainder of the punched output for $(V/b_r\omega)_1$

3. The order of Statement 2 above is repeated for all reduced velocities and associated Mach numbers per input deck.

4. Each AIC matrix is punched by columns. Column 1 starts in Origin 1 and Column 2 in Location (1 + matrix size).

5. The oscillatory AIC matrix is punched in the order -- Column 1 (real), Column 1 (imaginary), Column 2 (real), Column 2 (imaginary), . . . , Column N (real), Column N (imaginary). In the steady case all columns are real and are punched in order.

SECTION V

PROCESSING INFORMATION

A. Operation

STANDARD FORTRAN MONITOR system

B. Estimated Machine Time

T = time in minutes

ISZ = number of strips

JSZM = total number of reduced velocities

MSZ = number of Mach numbers

n = number of sets (decks) of input data

$$T = 1.0 + .02 \left[(ISZ \cdot MSZ \cdot JSZM)_1 + (ISZ \cdot MSZ \cdot JSZM)_2 + \cdot \cdot \cdot + (ISZ \cdot MSZ \cdot JSZM)_n \right]$$

C. Machine Components Used

Core storage, about 5300

Standard FORTRAN input tape (NTAPE 2)

Standard FORTRAN output print tape (NTAPE 3)

Standard FORTRAN output punch tape (NTAPE 7)

SECTION VI

PROGRAM NOTES

A. Subroutines Used

RDLN, reads and prints title cards

AEROP4, punch AIC matrix

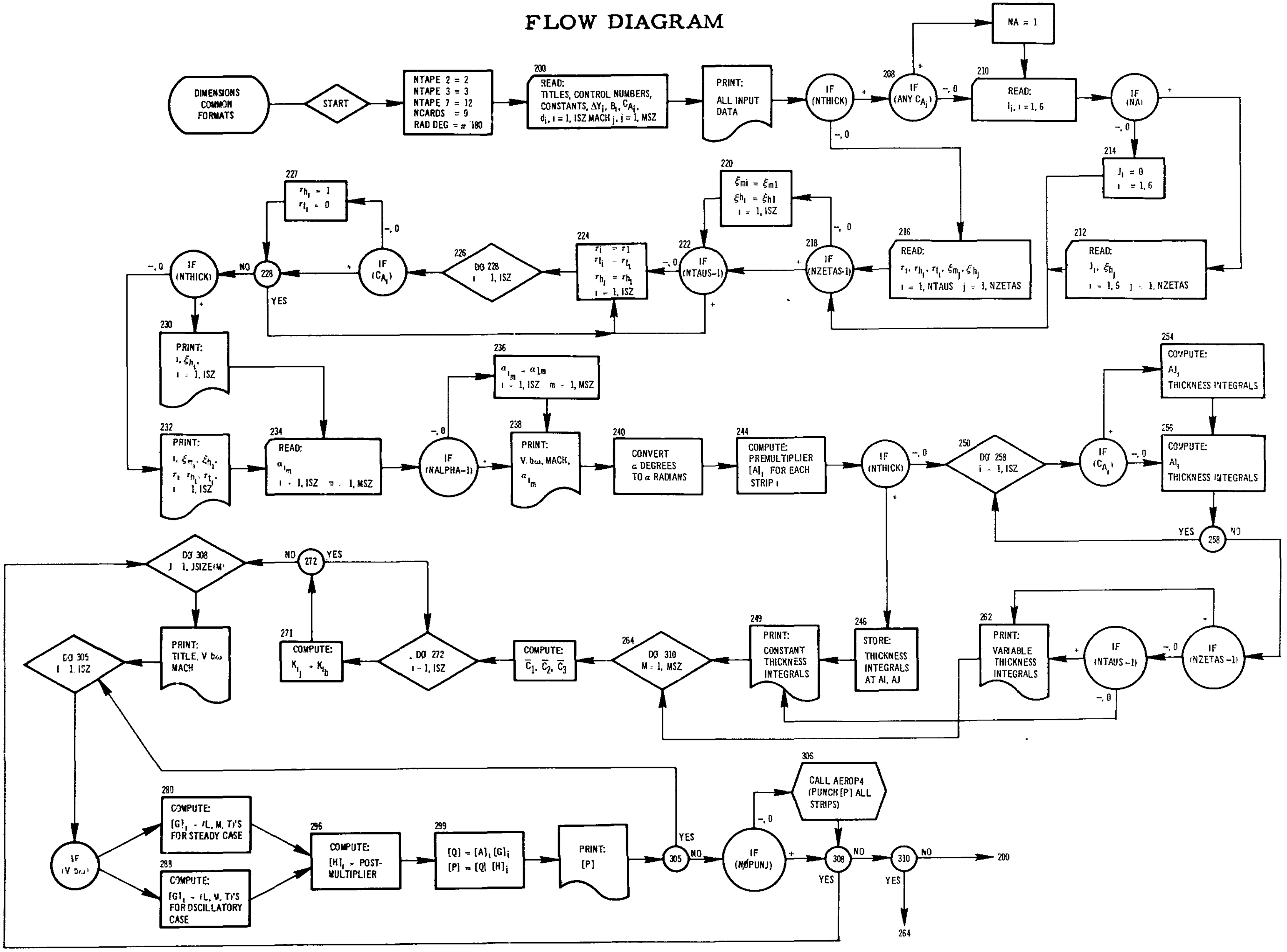
BINPU, column binary punch

All other subroutines are on library tapes

B. Generalized Tapes

Input, print,and punch tapes in this coding are defined as Units 2, 3, and 12, respectively; however, these may be altered by placing the desired units on symbolic cards HM110060, HM110061, and HM110062.

SECTION VII
FLOW DIAGRAM



SECTION VIII

SYMBOLIC LISTING

Some of the symbols used in the program are defined as follows:

FORTRAN Symbols	Definition
NTHRY	Option--theory used for $\overline{C}_1$, $\overline{C}_2$
NTHICK	Option--thickness integrals given or computed
NALPHA	Option--α's constant or vary
NTAUS	Option--τ's constant or vary
NZETAS*	Option--ξ's constant or vary
N0 PUNJ	Option--punching or no punching
ISZ	Number of strips
MSZ	Number of Mach numbers
J SIZE (M)	Number of reduced velocities for Mach number
JSZ	Number of reduced velocities for a Mach number
SEC LAM	sec Λ
BR	b_r
S	s
CAP S	S
C BAR	$\bar{c}$

---

[*] Please, no remarks about our Greek!

SYMBOLIC LISTING (continued)

FORTRAN Symbols	Definition
C BAR 1	$\overline{C}_1$
C BAR 2	$\overline{C}_2$
RAD DEG	$\pi/180.0$ (program constant)
DELTA Y(I)	Δy for strip i
B (I)	b for strip i
CA (I)	c_a for strip i
D (I)	d for strip i
EMACH (M)	m'th Mach number
EKR (J, M)	$1/k_r=(V/b_r\omega)$ for reduced velocity j, for m'th Mach number
EI (N)	I series (thickness integrals)
EJ (N)	J series (thickness integrals)
AI (I, N)	I series for strip i
AJ (I, N)	J series for strip i
ZETA H (I)	ξ_h for strip i
ZETA M (I)	ξ_m for strip i
TAU (I)	τ for strip i
TAU H (I)	τ_h for strip i
TAU T (I)	τ_t for strip i
ALPHA (I, M)	α for strip i, for m'th Mach number
EK (I, N)	K series for strip i

SYMBOLIC LISTING (continued)

FORTRAN Symbols	Definition
C0NST (I)	$4(b/b_r)^2 \Delta y/s$ for strip i
A (I, N, K)	Premultiplying matrix in oscillatory coefficients matrix equation
G (N, K)	Real, oscillatory leading edge coefficient matrix
GI (N, K)	Imaginary matrix
H (N, K)	Postmultiplying matrix in oscillatory coefficients matrix equation
Q (N, K)	Working array
QI (N, K)	Working array
P (N, K)	AIC matrix, complex

The symbolic listing of the program is shown on the following pages.

```
      AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.                4/20/62

                                                                         HM110002
                                                                         HM110003
C  (DIM. FOR (I) )          I=25                                         HM110004
      DIMENSION  A(25,3,3),DELTAY(25), B(25),  TAU(25), ZETAM(25),       HM110005
     1           AJ(25,6), CONST(25), CA(25), TAUH(25), ZETAH(25),       HM110006
     2           AI(25,6), EK(25,6) ,  D(25), TAUT(25)                   HM110007
C  (DIM. FOR (M),(J),(I),--MIXED)      M=15,J=20,I=25                    HM110008
      DIMENSION EKR(20,15),ALPHA(25,15),E MACH(15),J SIZE(15)            HM110009
C  (DIM. FOR CONSTANT ARRAYS)                                            HM110010
      DIMENSION  G(3,3), GI(3,3), H(3,3), P(3,6,25), Q(3,3), QI(3,3)     HM110011
     1,EJ(6),EI(6)                                                       HM110012
                                                                         HM110013
      COMMON EKR,ALPHA,E MACH,J SIZE,G,GI,H,P,PI,Q,QI,EJ                 HM110014
     1,EI,A,AJ,AI,EK,DELTA Y,B,CA,D,TAU,TAU H,TAU T,ZETA M               HM110015
     2,ZETA H,CONST                                                      HM110016
                                                                         HM110017
    1 FORMAT  (18I4)                                                     HM110018
    2 FORMAT  (6E12.8)                                                   HM110019
    3 FORMAT  (1HO  33X, 35HAERODYNAMIC INFLUENCE COEFFICIENTS           HM110020
     1         16HBY PISTON THEORY       )                               HM110021
    4 FORMAT  (1H   34X, 36H(WITH VAN DYKES QUASI-STEADY THEORY          HM110022
     1         18H FINAGLING FACTOR)      )                              HM110023
    5 FORMAT  (1HO 54X, 10HINPUT DATA  // 1H  44X, 1I2, 7H STRIPS  / 1H HM110024
     1         44X, 1I2, 13H MACH NUMBERS  / 1I47, 16H REDUCED FREQUEN   HM110025
     2         14HCIES (TOTAL)    / 1HO 44X, 15HSECANT LAMBDA = 1E16.8,  HM110026
     3         /1H  55X, 4HBR =  1E16.8, / 1H  56X, 3HS =  1E16.8 / 1H   HM110027
     4          56X, 3HS =  1E16.8  / 1H  52X, 7HC BAR =  1E16.8 / 1HO   HM110028
     5         19X, 5HSTRIP  6X, 11HDELTA Y (I)  12X, 4HB(I)  15X,       HM110029
     6          5HCA(I)  16X, 4HD(I)  //(1H 1I22,  2E20.8, 1E19.8,       HM110030
     7          1E21.8 )  )                                              HM110031
    6 FORMAT  ( 1HO 51X, 18HSTRIP          XI H   // (1H  1I54, 1E19.8)) HM110032
    7 FORMAT  (1HO 14X, 5HSTRIP 7X, 6H XI M   11X, 6H XI H   13X,        HM110033
     1          3HTAU  13X, 5HTAU H  12X, 5HTAU T  //  (1H  1I17, 2X,    HM110034
     2          5E17.8  )  )                                             HM110035
    8 FORMAT  (1HO 48X, 13HMACH NUMBER =  1F16.8  / (1H  53X, 8H1/K(R) =HM110036
     1          1E16.8  )  )                                             HM110037
    9 FORMAT  (1H  11X, 29HALPHA ZERO SERIES (DEGREES) =  6(1F8.2, 3X ) HM110038
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      AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.       4/20/62

     1         / (1H  40X,  6(1F8.2, 3X) )  )                         HM110039
  10 FORMAT  (1H0  33X, 38HGIVEN THICKNESS INTEGRALS (CONSTANT)       HM110040
     1        16H FOR ALL STRIPS)    )                                HM110041
  11 FORMAT  (1H0 32X, 38HCOMPUTED THICKNESS INTEGRALS (CONSTANT      HM110042
     1        16H FOR ALL STRIPS)    )                                HM110043
  12 FORMAT  (1H0 45X, 28HCOMPUTED THICKNESS INTEGRALS    )           HM110044
  13 FORMAT  (1H0 5X, 5HSTRIP 7X, 4HJ(1) 12X, 4HJ(2) 12X, 4HJ(3) 12X, HM110045
     1         4HJ(4)  12X, 4HJ(5) 12X, 4HJ(6) // (1I9, 3X, 6E16.8) ) HM110046
  14 FORMAT  (1H0 5X, 5HSTRIP 7X, 4HI(1) 12X, 4HI(2) 12X, 4HI(3) 12X, HM110047
     1         4HI(4)  12X, 4HI(5) 12X, 4HI(6) // (1I9, 3X, 6E16.8) ) HM110048
                                                                      HM110049
  15 FORMAT  (1H1 )
  16 FORMAT  (1H0 53X, 11HSTEADY CASE  // 1H  52X, 6HMACH =  1F 16.8, HM110050
     1         // 1H  50X, 17H1/K(R) = INFINITY  // 1I57, 7HSTRIPS    ) HM110051
  17 FORMAT  (1H0 51X, 16HOSCILLATORY CASE  // 1H  49X, 6HMACH = 1F16.8HM110052
     1         // 1H  47X,  8H1/K(R) = 1E16.8  // 1I57, 7HSTRIPS    )   HM110053
  18 FORMAT  (1H0 49X, 3HCH( 1I1, 8H) SIZE =  1I2, 3H BY  1I2  )       HM110054
  19 FORMAT  (1H  30X, 3E18.8)                                        HM110055
  20 FORMAT  (1H  3X, 2E16.8, 1HI 2E16.8, 1HI  2E16.8, 1HI )          HM110056
  21 FORMAT  (1H 19X, 2E16.8, 1HI 2E16.8, 1HI   )                     HM110057
  22 FORMAT (1H   39X,  2E18.8)                                       HM110058
                                                                      HM110059
      NTAPE2=2                                                        HM110060
      NTAPE3=3                                                        HM110061
      NTAPE7=12                                                       HM110062
      NCARDS=0                                                        HM110063
      RAD DEG=3.14159265 / 180.                                       HM110064
 200  CALL RDLN  (NTAPE2, NTAPE3, 1)                                  HM110065
      CALL CDLN  (NTAPE2, NTAPE3, 2)                                  HM110066
      READ INPUT TAPE NTAPE2, 1, NTHRY, NTHICK, NALPHA, NTAUS, NZETAS  HM110067
      READ INPUT TAPE NTAPE2, 1, ISZ, MSZ, NOPUNJ, (JSIZE(M),M=1,MSZ) HM110068
      READ INPUT TAPE NTAPE2, 2, SECLAM, BR, S, CAPS, CBAR            HM110069
      READ INPUT TAPE NTAPE2, 2,  (DELTAY(I),I=1,ISZ)                 HM110070
      READ INPUT TAPE NTAPE2, 2,  (B(I),I=1,ISZ)                      HM110071
      READ INPUT TAPE NTAPE2, 2,  (CA(I),I=1,ISZ)                     HM110072
      READ INPUT TAPE NTAPE2, 2,  (D(I),I=1,ISZ)                      HM110073
      READ INPUT TAPE NTAPE2, 2,  (EMACH(I),I=1,MSZ)                  HM110074
                                                                      HM110075
      JDOG=0                                                          HM110076
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      DO  202  I=1,MSZ                                                  HM110077
202     JDOG=JDOG+JSIZE(I)                                              HM110078
      WRITE OUTPUT TAPE NTAPE3, 3                                       HM110079
      IF (NTHRY)  206,206,204                                           HM110080
204   WRITE OUTPUT TAPE NTAPE3, 4                                       HM110081
206   WRITE OUTPUT TAPE NTAPE3, 5, ISZ, MSZ, JDOG, SECLAM, BR, S, CAPS, HM110082
     1                              CBAR,  (I, DELTAY(I), B(I), CA(I),  HM110083
     2                              D(I),I=1,ISZ)                       HM110084
      IF  (NTHICK)    216,216,208                                       HM110085
208   NA=0                                                              HM110086
      DO  210  I=1,ISZ                                                  HM110087
        IF (CA(I))   210,210,209                                        HM110088
209     NA=1                                                            HM110089
210     CONTINUE                                                        HM110090
      READ INPUT TAPE NTAPE2, 2,  (EI(I),I=1,6)                         HM110091
      IF  (NA)        214,214,212                                       HM110092
212   READ INPUT TAPE NTAPE2, 2,  (EJ(I),I=1,6)                         HM110093
      READ INPUT TAPE NTAPE2, 2,  (ZETAH(I),I=1,NZETAS)                 HM110094
      GOTO  216                                                         HM110095
214   DO  215  I=1,6                                                    HM110096
215     EJ(I)=0.                                                        HM110097
      GOTO  218                                                         HM110098
216   READ INPUT TAPE NTAPE2, 2,  (TAU(I), TAUH(I),TAUT(I),I=1,NTAUS)   HM110099
      READ INPUT TAPE NTAPE2, 2,  (ZETAM(I),ZETAH(I),I=1,NZETAS)        HM110100
218   IF (NZETAS-1)  220,220,222                                        HM110101
220   DO  221  I=1,ISZ                                                  HM110102
        ZETAM(I)=ZETAM(1)                                               HM110103
221     ZETAH(I)=ZETAH(1)                                               HM110104
                                                                        HM110105
222   IF (NTAUS-1)   224,224,226                                        HM110106
224   DO  225  I=1,ISZ                                                  HM110107
        TAU(I)=TAU(1)                                                   HM110108
        TAUH(I)=TAUH(1)                                                 HM110109
225     TAUT(I)=TAUT(1)                                                 HM110110
                                                                        HM110111
226   DO  228  I=1,ISZ                                                  HM110112
        IF (CA(I))   227,227,228                                        HM110113
227     ZETAH(I)=1.                                                     HM110114
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         TAUT(I)=0.                                                     HM110115
  228    CONTINUE                                                       HM110116
                                                                        HM110117
        IF ( NTHICK )   232,232,230                                     HM110118
  230 WRITE OUTPUT TAPE NTAPE3, 6, (I, ZETAH(I),I=1,ISZ)                HM110119
      GOTO  234                                                         HM110120
  232 WRITE OUTPUT TAPE NTAPE3, 7, (I, ZETAM(I), ZETAH(I), TAU(I),      HM110121
     1                               TAUH(I), TAUT(I), I=1, ISZ  )      HM110122
                                                                        HM110123
  234 READ INPUT TAPE NTAPE2, 2, ((ALPHA(I,M),M=1,MSZ),I=1,NALPHA)      HM110124
      IF  (NALPHA-1) 236,236,238                                        HM110125
  236 DO  237  I=1,ISZ                                                  HM110126
        DO  237  M=1,MSZ                                                HM110127
  237     ALPHA(I,M)=ALPHA(1,M)                                         HM110128
                                                                        HM110129
  238 DO  240  I=1,MSZ                                                  HM110130
        JSZ=JSIZE(I)                                                    HM110131
      READ INPUT TAPE NTAPE2, 2,  (EKR(J,I),J=1,JSZ)                    HM110132
      WRITE OUTPUT TAPE NTAPE3, 8,  EMACH(I), (EKR(J,I),J=1,JSZ)        HM110133
      WRITE OUTPUT TAPE NTAPE3, 9,  (ALPHA(J,I),J=1,ISZ)                HM110134
                                                                        HM110135
      DO  240  J=1,ISZ                                                  HM110136
  240   ALPHA(J,I)=ALPHA(J,I)*RADDEG                                    HM110137
                                                                        HM110138
                                                                        HM110139
      CO  244  I=1,ISZ                                                  HM110140
      CONST(I)=4.0*(B(I)/BR)*(B(I)/BR)*(DELTA Y(I)/S)                   HM110141
      A(I,1,1)=1.0+B(I)/(2.0*D(I) )                                     HM110142
      A(I,1,2)=-B(I)/D(I)                                               HM110143
      A(I,2,1)=-B(I)/(2.0*D(I) )                                        HM110144
      A(I,2,2)=-A(I,1,2)                                                HM110145
                                                                        HM110146
      IF  ( CA(I) )   244,244,242                                       HM110147
  242 A(I,1,3)=(B(I)/CA(I))*(3.*B(I)/(2.*D(I))-1.)                      HM110148
      A(I,2,3)=-(B(I)/CA(I) )*(3.0*B(I)/(2.0*D(I) ) )                   HM110149
      A(I,3,1)=0.0                                                      HM110150
      A(I,3,2)=0.0                                                      HM110151
      A(I,3,3)=B(I)/CA(I)                                               HM110152
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        AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.              4/20/62

   244 CONTINUE                                                            HM110153
                                                                           HM110154
       IF  ( NTHICK )        250,250,246                                   HM110155
   246 NUMBER=1                                                            HM110156
       DO  248  I=1,ISZ                                                    HM110157
         DO  248  N=1,6                                                    HM110158
           AI(I,N)=EI(N)                                                   HM110159
           AJ(I,N)=0.                                                      HM110160
           IF  ( CA(I) )   248,248,247                                     HM110161
   247     AJ(I,N)=EJ(N)                                                   HM110162
           NUMBER=I                                                        HM110163
   248     CONTINUE                                                        HM110164
       WRITE OUTPUT TAPE NTAPE3, 10                                        HM110165
   249 WRITE OUTPUT TAPE NTAPE3, 13, NUMBER,  (AJ(NUMBER,N),N=1,6)         HM110166
       WRITE OUTPUT TAPE NTAPE3, 14, NUMBER,  (AI(NUMBER,N),N=1,6)         HM110167
       GOTO  264                                                           HM110168
                                                                           HM110169
   250 NUMBER=1                                                            HM110170
       DO  258  I=1,ISZ                                                    HM110171
       T=TAU H(I)-TAU T(I)                                                 HM110172
       IF  ( CA(I) )   252,252,254                                         HM110173
   252 DO  253  K=1,6                                                      HM110174
   253   AJ(I,K)=0.                                                        HM110175
       GOTO   256                                                          HM110176
                                                                           HM110177
   254 NUMBER=I                                                            HM110178
       AJ(I,1)=-0.5*T                                                      HM110179
       AJ(I,2)=-0.25*T*(1.0+ZETA H(I))                                     HM110180
       AJ(I,3)=-(1.0/6.0)*T*(1.0+ZETA H(I)+ZETA H(I)*ZETA H(I) )           HM110181
       AJ(I,4)=0.25*T*T/(1.0-ZETA H(I) )                                   HM110182
       AJ(I,5)=0.125*T*T*(1.0+ZETA H(I) )/(1.0-ZETA H(I) )                 HM110183
       AJ(I,6)=(1.0/12.0)*T*T*(1.0+ZETA H(I)+ZETA H(I)*ZETA H(I) )         HM110184
      1    /(1.0-ZETA H(I) )                                               HM110185
                                                                           HM110186
   256 CONTINUE                                                            HM110187
       TS=(TAU(I)-TAU H(I))*(TAU(I)-TAU H(I))                              HM110188
       AI(I,1)=(TAU H(I)/2.0)+AJ(I,1)                                      HM110189
       AI(I,2)=-(TAU(I)/3.0)*ZETA H(I)+(TAU H(I)/6.0)                      HM110190
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      AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.              4/20/62

    1     *(2.0*ZETA H(I)+ZETA M(I) )+AJ(I,2)                                 HM110191
      AI(I,3)=-(TAU(I)/12.0)*ZETA H(I)*(3.0*ZETA H(I)+2.0                     HM110192
    1     *ZETA M(I) )+(TAU H(I)/12.0)*(3.0*ZETA H(I)*ZETA H(I)               HM110193
    2     +2.0*ZETA H(I)*ZETA M(I)+ZETA M(I)*ZETA M(I) )+AJ(I,3)              HM110194
      AI(I,4)=(TAU(I)*TAU(I)/(3.0*ZETA M(I) ))+(1.0/3.0)*TS                   HM110195
    1     *(ZETA H(I)-ZETA M(I) )+AJ(I,4)                                     HM110196
      AI(I,5)=(TAU(I)*TAU(I)/12.0)+(1.0/12.0)*TS*(3.0                         HM110197
    1     *ZETA H(I)+ZETA M(I) )/(ZETA H(I)-ZETA M(I) )+AJ(I,5)               HM110198
      AI(I,6)=(TAU(I)*TAU(I)/30.0)*ZETA M(I)+(1.0/30.0)                       HM110199
    1     *TS*(6.0*ZETA H(I)*ZETA H(I)+3.0*ZETA H(I)*ZETA M(I)                HM110200
    2     +ZETA M(I)*ZETA M(I) )/(ZETA H(I)-ZETA M(I) )+AJ(I,6)               HM110201
  258 CONTINUE                                                                HM110202
                                                                              HM110203
      IF  (NZETAS-1)     260,260,262                                          HM110204
  260 IF  (NTAUS-1)      261,261,262                                          HM110205
  261 WRITE OUTPUT TAPE NTAPE3, 11                                            HM110206
      GOTO  249                                                               HM110207
                                                                              HM110208
  262 WRITE OUTPUT TAPE NTAPE3, 12                                            HM110209
      WRITE OUTPUT TAPE NTAPE3, 13, (I, (AJ(I,N),N=1,6),I=1,ISZ)              HM110210
      WRITE OUTPUT TAPE NTAPE3, 14, (I, (AI(I,N),N=1,6),I=1,ISZ)              HM110211
                                                                              HM110212
  264 DO  310  M=1,MSZ                                                        HM110213
      EMS=E MACH(M)*E MACH(M)                                                 HM110214
      SECS=SEC LAM*SEC LAM                                                    HM110215
      IF  (NTHRY)       266,266,268                                           HM110216
  266 CBAR1=1.                                                                HM110217
      CBAR2=(1.4+1.0)/4.0                                                     HM110218
      GOTO  270                                                               HM110219
  268 CBAR1= EMACH(M) / SQRTF (EMS-SECS)                                      HM110220
      CBAR2= (    EMS*EMS*(1.4+1.0)-4.0*SECS*(EMS-SECS)    ) /(4.0*           HM110221
    1     (EMS-SECS)*(EMS-SECS) )                                             HM110222
  270 CBAR3= (1.4+1.)  /12.                                                   HM110223
                                                                              HM110224
      DO  272  I=1,ISZ                                                        HM110225
      EK(I,1)=(1.0/E MACH(M) )*(CBAR1+2.0*CBAR2*E MACH(M)*AI(I,1)             HM110226
    1     +3.0*CBAR3*EMS*(AI(I,4)+ALPHA(I,M)*ALPHA(I,M) ) )                   HM110227
      EK(I,2)=(1.0/E MACH(M) )*(CBAR1+4.0*CBAR2*E MACH(M)                     HM110228
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      AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.            4/20/62

     1    *AI(I,2)+3.0*CBAR3*EMS*(2.0*AI(I,5)+ALPHA(I,M)*ALPHA(I,M)))    HM110229
      EK(I,3)=(4.0/(3.0*E MACH(M)))*(CBAR1+6.0*CBAR2*E MACH(M)*AI(I,3)  HM110230
     1    +3.0*CBAR3*EMS*(3.0*AJ(I,6)+ALPHA(I,M)*ALPHA(I,M)))            HM110231
                                                                         HM110232
      IF  ( CA(I) )   272,272,271                                        HM110233
  271 EK(I,4)=(1./EMACH(M) )*(CBAR1*(1.0-ZETAH(I) )+2.*CBAR2             HM110234
     1    *EMACH(M)*AJ(I,1)+3.0*CBAR3*EMS*(AJ(I,4)+ALPHA(I,M)            HM110235
     2    *ALPHA(I,M)*(1.0-ZETA H(I) )))                                 HM110236
      EK(I,5)=(1.0/EMACH(M) ) * (CBAR1*(1.0-ZETA H(I)*ZETA H(I))         HM110237
     1    +4.0*CBAR2*EMACH(M)*AJ(I,2)+3.0*CBAR3*EMS                      HM110238
     2    *(2.0*AJ(I,5)+ALPHA(I,M)*ALPHA(I,M)*(1.0-ZETAH(I)*ZETAH(I)) ))HM110239
      EK(I,6)=(4.0/(3.0*E MACH(M) )) * (CBAR1*(1.0-ZETA H(I)             HM110240
     1    *ZETA H(I)*ZETA H(I) )+6.0*CBAR2*EMACH(M)*AJ(I,3)              HM110241
     2    +3.0*CBAR3*EMS*(3.0*AJ(I,6)+ALPHA(I,M)*ALPHA(I,M)              HM110242
     3    *(1.0-ZETA H(I)*ZETA H(I)*ZETA H(I) )))                        HM110243
  272 CONTINUE                                                           HM110244
                                                                         HM110245
      JSZ=JSIZE(M)                                                       HM110246
      DO  308  J=1,JSZ                                                   HM110247
      WRITE OUTPUT TAPE NTAPE3, 15                                       HM110248
      WRITE OUTPUT TAPE NTAPE3, 3                                        HM110249
      IF  ( NTHRY )      275,275,274                                     HM110250
  274 WRITE OUTPUT TAPE NTAPE3, 4                                        HM110251
  275 IF  ( EKR(J,M) )  276,276,277                                      HM110252
  276 WRITE OUTPUT TAPE NTAPE3, 16, EMACH(M), ISZ                         HM110253
      GOTO  278                                                          HM110254
  277 WRITE OUTPUT TAPE NTAPE3, 17, EMACH(M), EKR(J,M), ISZ               HM110255
  278 DO  305  I=1,ISZ                                                   HM110256
      IF  ( EKR(J,M) )   280,280,288                                     HM110257
  280 G(1,1)=0.                                                          HM110258
      G(2,1)=0.0                                                         HM110259
      BB=BR*BR/(B(I)*B(I) )                                              HM110260
      G(1,2)=-EK(I,1)*BB                                                 HM110261
      G(2,2)=-EK(I,2)*BB                                                 HM110262
      IF  ( CA(I) )   284,284,282                                        HM110263
  282 G(1,3)=-EK(I,4)*BB                                                 HM110264
      G(2,3)=-EK(I,5)*BB                                                 HM110265
      G(3,1)=0.0                                                         HM110266
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      G(3,2)=-(EK(I,5)-2.0*EK(I,4)*ZETA H(I) )*BB                        HM110267
      G(3,3)=G(3,2)                                                      HM110268
  284 DO  286  IT=1,3                                                    HM110269
      DO  286  IN=1,3                                                    HM110270
  286 GI(IT,IN)=0.                                                       HM110271
      GOTO  292                                                          HM110272
  288 E1K=EKR(J,M)*BR/B(I)                                               HM110273
      E1KS=E1K*E1K                                                       HM110274
      G(1,1)=0.0                                                         HM110275
      GI(1,1)=-EK(I,1)*E1K                                               HM110276
      G(1,2)=-EK(I,1)*E1KS                                               HM110277
      GI(1,2)=-EK(I,2)*E1K                                               HM110278
      G(2,1)=0.0                                                         HM110279
      GI(2,1)=-EK(I,2)*E1K                                               HM110280
      G(2,2)=-EK(I,2)*E1KS                                               HM110281
      GI(2,2)=-EK(I,3)*E1K                                               HM110282
      IF  ( CA(I) )   292,292,290                                        HM110283
                                                                         HM110284
  290 G(1,3)=-EK(I,4)*E1KS                                               HM110285
      GI(1,3)=-(EK(I,5)-2.0*EK(I,4)*ZETA H(I) )*E1K                      HM110286
      G(2,3)=-EK(I,5)*E1KS                                               HM110287
      GI(2,3)=-(EK(I,6)-2.0*EK(I,5)*ZETA H(I) )*E1K                      HM110288
      G(3,1)=0.0                                                         HM110289
      GI(3,1)=-(EK(I,5)-2.0*EK(I,4)*ZETA H(I) )*E1K                      HM110290
      G(3,2)=-(EK(I,5)-2.0*EK(I,4)*ZETA H(I) )*E1KS                      HM110291
      GI(3,2)=-(EK(I,6)-2.0*EK(I,5)*ZETA H(I) )*E1K                      HM110292
      G(3,3)=-(EK(I,5)-2.0*EK(I,4)*ZETA H(I) )*E1KS                      HM110293
      GI(3,3)=-(EK(I,6)-4.0*EK(I,5)*ZETA H(I)+4.0*EK(I,4)*ZETA H(I)      HM110294
     1    *ZETA H(I) )*E1K                                               HM110295
  292 CONTINUE                                                           HM110296
                                                                         HM110297
      NU=2                                                               HM110298
      IF  ( CA(I) )   295,295,294                                        HM110299
  294 NU=3                                                               HM110300
  295 DO  296  IT=1,NU                                                   HM110301
      DO  296  IN=1,NU                                                   HM110302
  296 H(IT,IN)=A(I,IN,IT)                                                HM110303
      H(3,1)=H(2,2)                                                      HM110304
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      H(3,2)=-(H(3,1)+H(3,3) )                                          HM110305
                                                                        HM110306
C  MULT A(I,N,N)*(  G(N,N)+GI(N,N)  )*H(N,N)    STORE IN P(N,N),PI(N,N) HM110307
      DO  297  K=1,NU                                                   HM110308
      DO  297  L=1,NU                                                   HM110309
      Q (K,L)=0.0                                                       HM110310
      QI(K,L)=0.0                                                       HM110311
      DO  297  M1=1,NU                                                  HM110312
      Q (K,L)=Q (K,L)+A(I,K,M1)*G (M1,L)                                HM110313
  297 QI(K,L)=QI(K,L)+A(I,K,M1)*GI(M1,L)                                HM110314
      IN=2*NU                                                           HM110315
      DO  299  K=1,NU                                                   HM110316
      DO  299  L=1,IN,2                                                 HM110317
      IT=L/2+1                                                          HM110318
      P(K,L,I)=0.                                                       HM110319
      P(K,L+1,I)=0.                                                     HM110320
      DO  298  M1=1,NU                                                  HM110321
      P(K,L,I)=P(K,L,I)+Q(K,M1)*H(M1,IT)                                HM110322
  298 P(K,L+1,I)=P(K,L+1,I)+QI(K,M1)*H (M1,IT)                          HM110323
      P(K,L,I)=P(K,L,I)*CONST(I)                                        HM110324
  299 P(K,L+1,I)=P(K,L+1,I)*CONST(I)                                    HM110325
      WRITE OUTPUT TAPE NTAPE3, 18,  I, NU, NU                          HM110326
      IF  ( EKR(J,M) )   300,300,302                                    HM110327
  300 CORR=2.*S*CBAR/CAPS                                               HM110328
      DO  301  K=1,NU                                                   HM110329
      DO  301  L=1,IN,2                                                 HM110330
  301 P(K,L,I)=P(K,L,I)*CORR                                            HM110331
      IF ( NU-2)       311,312,311                                      HM110332
  311 WRITEOUTPUT TAPE NTAPE3, 19,  ((P(K,L,I),L=1,IN,2),K=1,NU)        HM110333
      GOTO  305                                                         HM110334
  312 WRITE OUTPUT TAPE NTAPE3, 22, ((P(K,L,I),L=1,IN,2),K=1,NU)        HM110335
      GOTO  305                                                         HM110336
  302 IF  (NU-2)   304,304,303                                          HM110337
  303 WRITE OUTPUT TAPE NTAPE3, 20, ((P(K,L,I),L=1,IN),K=1,NU)          HM110338
      GOTO  305                                                         HM110339
  304 WRITE OUTPUT TAPE  NTAPE3, 21,  ((P(K,L,I),L=1,IN),K=1,NU)        HM110340
  305 CONTINUE                                                          HM110341
      IF ( NOPUNJ )     308,306,308                                     HM110342
```

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     AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.              4/20/62

 306 CALL AERO P4  (EKR(J,M),EMACH(M),P,ISZ,NCARDS,NTAPE3,NTAPE7,CA)    HM110343
                                                                        HM110344
 308 CONTINUE                                                           HM110345
                                                                        HM110346
 310 CONTINUE                                                           HM110347
                                                                        HM110348
     GOTO  200                                                          HM110349
     END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
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   AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.                 4/20/62       PAGE 11

                                         STORAGE NOT USED BY PROGRAM

         DEC   OCT                   DEC   OCT
        2372 04504                 30423 73327

                            STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

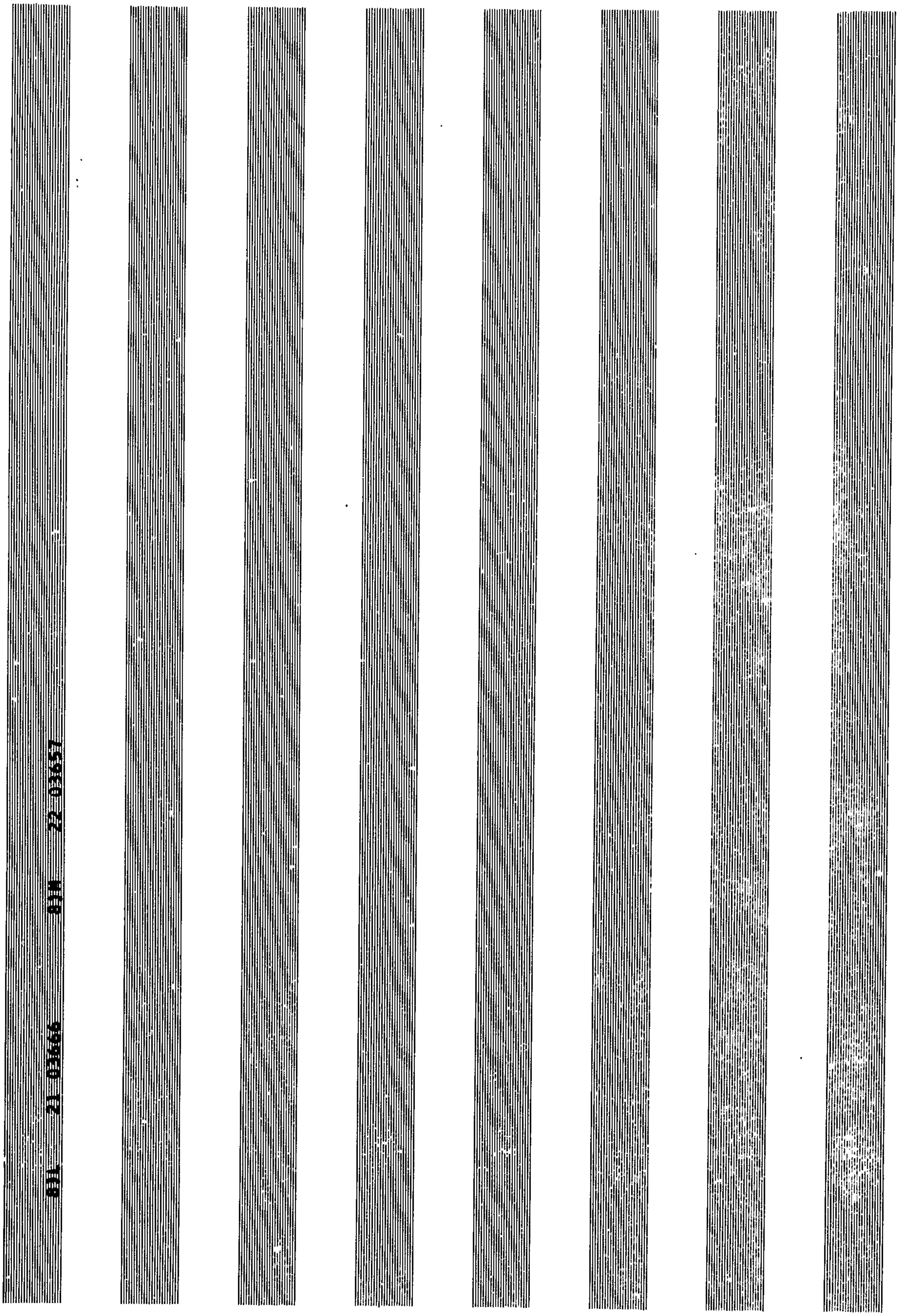
         DEC   OCT                   DEC   OCT                   DEC   OCT                   DEC   OCT
     AI 30973 74375             AJ 31123 74623          ALPHA 32261 77005               A 31348 75164
      B 30648 73670             CA 30623 73637          CONST 30448 73360          DELTAY 30673 73721
      D 30598 73606             EI 31354 75172             EJ 31360 75200             EKR 32561 77461
     EK 30823 74147          EMACH 31886 76216             GI 31847 76147               G 31856 76160
      H 31838 76136          JSIZE 31871 76177             PI 31379 75223               P 31829 76125
     QI 31369 75211              Q 31378 75222           TAUH 30548 73524             TAU 30573 73555
   TAUT 30523 73473          ZETAH 30473 73411          ZETAM 30498 73442

   STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENTS

          DEC   OCT                  DEC   OCT                   DEC   OCT                   DEC   OCT
      BB  2371 04503          BR    2370 04502          CAPS   2369 04501          CBAR1   2368 04500
   CBAR2  2367 04477       CBAR3    2366 04476          CBAR   2365 04475           CORR   2364 04474
     EIK  2363 04473        EIKS    2362 04472           EMS   2361 04471             IN   2360 04470
       I  2359 04467         ISZ    2358 04466            IT   2357 04465           JDOG   2356 04464
     JSZ  2355 04463           L    2354 04462             M   2353 04461            MSZ   2352 04460
  NALPHA  2351 04457          NA    2350 04456        NCARDS   2349 04455         NOPUNJ   2348 04454
  NTAPE2  2347 04453      NTAPE3    2346 04452        NTAPE7   2345 04451          NTAUS   2344 04450
  NTHICK  2343 04447       NTHRY    2342 04446        NUMBER   2341 04445             NU   2340 04444
  NZETAS  2339 04443      RADDEG    2338 04442        SECLAM   2337 04441           SECS   2336 04440
       S  2335 04437           T    2334 04436            TS   2333 04435

                              SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

          EFN   LOC                  EFN   LOC                   EFN   LOC                   EFN   LOC
  8)1       1 04400         8)2        2 04376         8)3         3 04374         8)4         4 04354
  8)5       5 04334         8)6        6 04214         8)7         7 04202         8)8         8 04151
  8)9       9 04133         8)A       10 04112         8)B        11 04072         8)C        12 04052
  8)D      13 04042         8)E       14 04015         8)F        15 03770         8)G        16 03766
  8)H      17 03741         8)I       18 03714         8)J        19 03703         8)K        20 03677
```



01L 21 03666 01M 22 03657

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      AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.                 4/20/62          PAGE 12

                           LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

           DEC    OCT                 DEC    OCT                 DEC    OCT                 DEC    OCT
      1)  2305  04401          2)   1936  03620          3)   1945  03631          4)  32767  77777
      6)  1959  03647       C)G0   2313  04411       C)G1   2314  04412       C)100   2315  04413
   C)103  2316  04414      C)104   2317  04415      C)106   2318  04416       C)107   2319  04417
   C)108  2320  04420      C)10B   2321  04421      C)10D   2322  04422       C)10E   2323  04423
   C)162  2324  04424      C)200   2325  04425      C)20A   2326  04426       C)20C   2327  04427
   C)206  2328  04430      C)201   2329  04431      C)20M   2330  04432       C)20N   2331  04433
   C)20D  2332  04434      D)12B    493  00755      D)12D    503  00767       D)142   1305  02431
   C)42L   615  01147      D)430   1022 .01776      D)43Q   1221  02305       D)455   1763  03343
   C)45G  1844  03464      D)45R   1903  03557      D)45S   1924  03604       D)53Q   1220  02304
   D)542  1304  02430      D)555   1762  03342      D)55G   1843  03463       D)62L    614  01146
   D)640  1021  01775      D)655   1923  03603       E)3P   1107  02123        E)4R   1648  03160

                                   LOCATIONS OF NAMES IN TRANSFER VECTOR

           DEC    OCT                 DEC    OCT                 DEC    OCT                 DEC    OCT
  AEROP4     7  00007       RDLN       1  00001       SQRT       6  00006       (FIL)      5  00005
   (FPT)     0  00000      (RTN)       3  00003      (STH)       4  00004       (TSH)      2  00002

                                ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

  AEROP4        RDLN          SQRT          (FIL)         (FPT)         (RTN)         (STH)         (TSH)

                EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

     EFN   IFN   LOC            EFN   IFN   LOC            EFN   IFN   LOC            EFN   IFN   LOC
     200    33  00026           202    74  00207           204    77  00224           206    78  00230
     208    85  00302           209    88  00313           210    89  00315           212    96  00334
     214   107  00361           215   108  00362           216   110  00367           218   120  00423
     220   121  00427           221   123  00434           222   124  00440           224   125  00444
     225   128  00453           226   129  00457           227   131  00465           228   133  00471
     230   135  00477           232   141  00520           234   146  00550           236   154  00602
     237   156  00616           238   157  00626           240   176  00770           242   184  01066
     244   189  01125           246   191  01134           247   197  01161           248   199  01165
     249   201  01202           250   214  01235           252   218  01257           253   219  01257
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     AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.          4/20/62        PAGE 13

    254     221 01265         256     228 01364         258     236 01566         260     238 01577
    261     239 01603         262     241 01610         264     256 01666         266     260 01705
    268     263 01714         270     265 01751         271     271 02124         272     274 02306
    274     280 02356         275     281 02362         276     282 02365         277     285 02402
    278     287 02420         280     289 02435         282     295 02464         284     300 02512
    286     302 02513         288     304 02523         290     315 02572         292     325 02722
    294     328 02730         295     329 02732         296     331 02752         297     340 03036
    298     349 03165         299     351 03201         300     355 03234         301     358 03272
    311     360 03307         312     368 03362         302     376 03431         303     377 03436
    304     385 03503         305     392 03543         306     394 03560         308     396 03605
    310     397 03613
```

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                                                                      4/20/62
      SUBROUTINE  RDLN  (NTAPE2, NTAPE3, I )                           HM110351
    1 FORMAT(80H                                                       HM110352
     1                         )                                       HM110353
    2 FORMAT(1H1)                                                      HM110354
    3 FORMAT  ( 1H0 )                                                  HM110355
                                                                       HM110356
      READ INPUT TAPE NTAPE2, 1                                        HM110357
      GOTO   (4,5),I                                                   HM110358
                                                                       HM110359
    4 WRITE OUTPUT TAPE NTAPE3, 2                                      HM110360
      GOTO  6                                                          HM110361
                                                                       HM110362
    5 WRITE OUTPUT TAPE NTAPE3, 3                                      HM110363
                                                                       HM110364
    6 WRITE OUTPUT TAPE NTAPE3, 1                                      HM110365
                                                                       HM110366
      RETURN                                                           HM110367
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

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                                                                              4/20/62        PAGE 2

                                          STORAGE NOT USED BY PROGRAM

         DEC    OCT                 DEC    OCT
          76 00114                32561 77461

                              SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

         EFN    LOC                 EFN    LOC                 EFN    LOC                 EFN    LOC
   8)1      1 00112          8)2      2 00073         8)3      3 00072

                              LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

         DEC    OCT                 DEC    OCT                 DEC    OCT                 DEC    OCT
   6)     52 00064         C)GO     75 00113         E)1      28 00034

                                        LOCATIONS OF NAMES IN TRANSFER VECTOR

         DEC    OCT                 DEC    OCT                 DEC    OCT                 DEC    OCT
  (FIL)     3 00003        (RTN)      1 00001        (STH)      2 00002        (TSH)      0 00000

                                  ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

  (FIL)        (RTN)        (STH)        (TSH)

                  EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

   EFN   IFN    LOC          EFN   IFN    LOC          EFN   IFN    LOC          EFN   IFN    LOC
     4     8 00035             5    10 00044             6    11 00052
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                                                                      6/12/62
                                                                     HM110369
      SUBROUTINE  AERO P4  (VBRW,XMACH,CH,ISTRIP,NSTART,NTAPE3,NTAPE7,  HM110370
     1                      CA)                                          HM110371
      DIMENSION  CH(3,6,25), A(22), CA(25)                               HM110372
                                                                         HM110373
    1 FORMAT  (2E12.8, 48X, 4HHM11   1I4)                                HM110374
    2 FORMAT  (1H0 40X, 24H PUNCHED CARDS NOS. HM11  1I4,                HM110375
     1          10H THRU HM11  1I4 )                                     HM110376
    3 FORMAT  (2I4,  64X,  4HHM11   1I4 )                                HM110377
                                                                         HM110378
 8    BCDZ =603044010160                                                 HM110379
      IORG=1                                                             HM110380
      IS=NSTART                                                          HM110381
      NITS=1                                                             HM110382
      IF (VBRW)   4,4,5                                                  HM110383
    4 NITS=2                                                             HM110384
    5 WRITE OUTPUT TAPE NTAPE7, 1, VBRW, XMACH, IS                       HM110385
      IS=IS+1                                                            HM110386
      K=0                                                                HM110387
      DO  7  I=1,ISTRIP                                                  HM110388
        IF  (CA(I))   7,7,6                                              HM110389
    6 K=K+1                                                              HM110390
    7 K=K+2                                                              HM110391
      WRITE OUTPUT TAPE NTAPE7, 3, K, ISTRIP, IS                         HM110392
      IS=IS+1                                                            HM110393
                                                                         HM110394
      DO  8  I=1,22                                                      HM110395
    8   A(I)=0.                                                          HM110396
      M=0                                                                HM110397
      DO  15  I=1,ISTRIP                                                 HM110398
         NUTS=4                                                          HM110399
         IF  (CA(I))   10,10,9                                           HM110400
    9    NUTS=6                                                          HM110401
   10    NURTS=NUTS/2                                                    HM110402
         DO  14  L=1,NUTS,NITS                                           HM110403
            DO  13  J=1,NURTS                                            HM110404
               M=M+1                                                     HM110405
   18          IF (M-23)   13,11,11                                      HM110406
   11          M=M-22
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                                                      6/12/62
                                                      HM110407
         CALL BINPU  (A,22,IORG,BCDZ,IS,NTAPE7)       HM110408
         IORG=IORG+22                                 HM110409
         IS=IS+1                                      HM110410
         DO  12  N=1,22                               HM110411
12         A(N)=0.                                    HM110412
   GOTO  18                                           HM110413
13       A(M)=CH(J,L,I)                               HM110414
14    M=M+K-NURTS                                     HM110415
15 M=M+NURTS                                          HM110416
   M=M-K                                              HM110417
   IF  (M)    17,17,16                                HM110418
16 CALL BINPU  (A,M,IORG,BCDZ,IS,NTAPE7)              HM110419
   IS=IS+1                                            HM110420
17 CALL BINPU  (A,0,0,BCDZ,IS,NTAPE7)                 HM110421
   WRITE OUTPUT TAPE NTAPE3, 2, NSTART, IS            HM110422
   NSTART=IS+1                                        HM110423
   RETURN                                             HM110424

   END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

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                                                                                         6/12/62        PAGE 3

                                                STORAGE NOT USED BY PROGRAM

              DEC    OCT                  DEC    OCT
              335 00517                 32561 77461

                          STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

              DEC    OCT                  DEC    OCT                  DEC    OCT                  DEC    OCT
         A    334 00516

       STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENTS

              DEC    OCT                  DEC    OCT                  DEC    OCT                  DEC    OCT
      BCDZ    312 00470          IORG     311 00467            I      310 00466           IS      309 00465
         K    308 00464             M     307 00463         NITS      306 00462        NURIS      305 00461
      NUTS    304 00460

                                   SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

              EFN    LOC                  EFN    LOC                  EFN    LOC                  EFN    LOC
       8)1      1 00445           8)2       2 00440          8)3        3 00421

                                  LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

              DEC    OCT                  DEC    OCT                  DEC    OCT                  DEC    OCT
        1)    295 00447            2)     253 00375           3)      262 00406           6)      264 00410
        9)    294 00446          C)G0     299 00453         C)G2      300 00454       C)1G0      301 00455
     C)200    302 00456         C)201     303 00457         D)20C     145 00221

                                         LOCATIONS OF NAMES IN TRANSFER VECTOR

              DEC    OCT                  DEC    OCT                  DEC    OCT                  DEC    OCT
     BINPU      2 00002         (FIL)       1 00001         (STH)       0 00000

                                     ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY
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                                                                    6/12/62      PAGE 4

   BINPU      (FIL)      (STH)

             EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

   EFN  IFN   LOC        EFN  IFN   LOC        EFN  IFN   LOC        EFN  IFN   LOC
     4   12 00061          5   13 00063          6   19 00111          7   20 00114
     8   25 00137          9   30 00163         10   31 00165         18   35 00232
    11   36 00237         12   42 00261         13   44 00266         14   45 00276
    15   46 00311         16   49 00333         17   52 00347
```

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BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE. FIBII                              4/20/62     PAGE 1

                                 ***********************************************************************HM110429
                                 *                                                                      HM110430
                                 * CALLING SEQUENCE                                                     HM110431
                                 *         TSX       BINPU,4                                            HM110432
                                 *         TSX       LOC (ARRAY TO BE PUNCHED)                          HM110433
                                 *         TSX       LOC (NO. WORDS TO PUNCH)                           HM110434
                                 *         TSX       LOC (CARD ORIGIN FOR 1ST CARD)                     HM110435
                                 *        *TSX       LOC (SEQ NO. OF 1ST CARD)                          HM110436
                                 *        *TSX       LOC (BCD ID FOR THIS DECK, 1ST AND 2ND CHARACTER BLANKS) HM110437
                                 *         TSX       LOC (OUTPUT TAPE NUMBER)                           HM110438
                                 *****CONTRARY TO BELOW, NO ITEMS MAY BE OMITTED IN THIS MODIFICATION.  HM110439
                                 *                                                                      HM110440
                                 * ITEMS MARKED (*) MAY BE DELETED. BCD ID WILL BE                      HM110441
                                 *         UNCHANGED AND SEQ. NOS. WILL BE CONTINUOUS STARTING          HM110442
                                 *         FROM  000. ALSO ORDER MAY BE SWITCHED.                       HM110443
                                 *                                                                      HM110444
                                 * THIS VERSION PUNCHES OFF-LINE ONLY.                                  HM110445
                                 *                                                                      HM110446
                                 ***********************************************************************HM110447
                         00006             ENTRY   BINPU                                                HM110448
                                 *                                                                      HM110449
      TRANSFER VECTOR
     00000   743146623460        (IOS)
     00001   746651623460        (WRS)
     00002   745123303460        (RCH)
     00003   746663233460        (WTC)
     00004   746625513460        (WER)
     00005   746325623460        (TES)

     00006   0634 00 1 00142    BINPU SXA     X1,1                                                      HM110450
     00007   0634 00 2 00143          SXA     X2,2                                                      HM110451
     00010 -0500 60 4 00006           CAL*    6,4                                                       HM110452
     00011   0622 00 0 00331          STD     14D                                                       HM110453
     00012   0500 00 4 00001          CLA     1,4                   LOC OF ARRAY                        HM110454
     00013   0621 00 0 00062          STA     ARRAY                                                     HM110455
     00014 -0500 60 4 00002           CAL*    2,4                   WORD COUNT                          HM110456
     00015   0602 00 0 77776          SLW     END                   END=0 IF TRANSFER CARD              HM110457
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  0C016  0402 00 0 00325        SUB    D1                                                HM110458
  CC017  0622 00 0 00066        STD    LCCN                                              HM110459
  00020  0634 00 0 00061        SXA    CCUNT,0                                           HM110460
  00021  0500 60 4 00003        CLA*   3,4              SET UP CONTROL WORD              HM110461
  0C022  0771 00 0 00022        ARS    18                                                HM110462
  0C023 -0120 00 0 00025        TMI    *+2                                               HM110463
  0C024 -0501 00 0 00266        ORA    REL              ADD RELATIVE BIT                 HM110464
  00025 -0501 00 0 00334        ORA    IMAGE            7-9, WORD COUNT=22               HM110465
  00026  0602 00 0 77740        SLW    CIMAGE           CONTROL WORD ESTABLISHED.        HM110466
                          *******************************************************************HM110467
                          *     TEST FOR FOURTH AND-OR FIFTH ARGUMENTS.                  HM110468
                          *     DETERMINE WHETHER ARGUMENT REFERS TO ID OR SEQ NUMBER    HM110469
                          *     AND SET CELLS FROM CALLING SEQUENCE.                     HM110470
                          *******************************************************************HM110471
  00027  0774 00 2 00002        AXT    2,2                                               HM110472
  00030 -0625 00 0 00302        STL    BLSEQ            SET BLSEQ TO ITS NORMAL STATE    HM110473
  00031 -0500 00 4 00004   G4   CAL    4,4              TEST FOR 4TH, 5TH ARGS           HM110474
  0C032 -0320 00 0 00265        ANA    MSKPDT                                            HM110475
  CC033  0322 00 0 00307        ERA    MSKTSX                                            HM110476
  00034 -0100 00 0 00054        TNZ    G2               NO MORE TSXES                    HM110477
  00035  0500 60 4 00004        CLA*   4,4                                               HM110478
  00036 -0340 00 0 00262        LAS    BCI8                                              HM110479
  CC037  0020 00 0 00051        TRA    G3               BIG, THIS IS ID                  HM110480
  00040  0600 00 0 00302        STZ    BLSEQ            EQUAL, FLAG BLANK SEQ. NO.       HM110481
  00041 -0100 00 0 00043        TNZ    *+2              IS SEQ NO NON-ZERO.              HM110482
T 00042 -0754 00 0 00000        PXD                     NO                               HM110483
  00043 -0130 00 0 00000        XCL                     SMALL, THIS IS SEQ NO.           HM110484
  0C044  0634 00 4 00046        SXA    *+2,4                                             HM110485
  C0045  0074 00 4 00172        TSX    COSEQ,4          CONVERT SEQ NO TO BCD            HM110486
  CC046  0774 00 4 0C000        AXT    **,4                                              HM110487
  00047  0602 00 0 00267        SLW    SEQNO            SAVE                             HM110488
  00050  1 77777 4 00053        TXI    G5,4,-1                                           HM110489
  00051  0601 00 0 00305   G3   STO    BCDID                                             HM110490
  00052  1 77777 4 00053        TXI    G5,4,-1          MOVE TO NEXT ARGUMENT            HM110491
  00053  2 00001 2 00031   G5   TIX    G4,2,1           AT MOST 2 EXTRA ARGS.            HM110492
  00054  0634 00 4 00144   G2   SXA    X4,4                                              HM110493
  0C055 -0520 00 0 77776        NZT    END              IS WORD COUNT ZERO               HM110494
  0C056  0020 00 0 00152        TRA    TRCD             MUST BE A TRANSFER CARD          HM110495
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                          BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE. FIBII                  4/20/62     PAGE 3

                          *                                                                       HM110496
                          ************************************************************************HM110497
                          *       BUILD THE CARD IMAGE.                                           HM110498
                          ************************************************************************HM110499
                          *                                                                       HM110500
  00057  0774 00 2 00026  NEXT   AXT     22,2                                                     HM110501
T 00060 -0754 00 0 00000         PXD                         CLEAR AC FOR CHECKSUM.               HM110502
  00061  0774 00 4 00000  COUNT  AXT     **,4                                                     HM110503
  00062  0560 00 4 00000  ARRAY  LDQ     **,4                MOVE ARRAY INTO CORE.                HM110504
  00063 -0600 00 2 77770         STQ     CIMAGE+24,2                                              HM110505
  00064  0361 00 2 77770         ACL     CIMAGE+24,2         ACCUMULATE CHECKSUM FOR BODY.        HM110506
  00065  1 00001 4 00066         TXI     *+1,4,1                                                  HM110507
  00066  3 00000 4 00160  LOCN   TXH     OUT,4,**            FINISH WHEN SPECIFIED                HM110508
  00067  2 00001 2 00062         TIX     ARRAY,2,1           BY NO. WORDS DESIRED.(2,4)           HM110509
  00070  0634 00 4 00061  IN     SXA     COUNT,4             SET COUNT FOR NEXT LOOP.             HM110510
  00071  0361 00 0 77740         ACL     CIMAGE              ADD IN CONTROL WORD.                 HM110511
  00072  0602 00 0 77741         SLW     CIMAGE+1            PUT CHECKSUM IN IMAGE.               HM110512
                          *                                                                       HM110513
                          ************************************************************************HM110514
                          *       EDIT THE IDENTIFICATION FIELD.                                  HM110515
                          ************************************************************************HM110516
                          *                                                                       HM110517
  00073 -0500 00 0 00267  EDIT   CAL     SEQNO                                                    HM110518
  00074  0560 00 0 00327         LDQ     L(1)                                                     HM110519
  00075 -0765 00 0 00022         LGR     18                                                       HM110520
  00076 -0500 00 0 00305         CAL     BCDID                                                    HM110521
  00077 -0763 00 0 00006         LGL     6                                                        HM110522
  00100 -0600 00 0 00326         STQ     IDLCD           SAVE FOR FINISHING.                      HM110523
  00101 -0130 00 0 00000         XCL                                                              HM110524
  00102  0634 00 1 00120         SXA     SV1,1                                                    HM110525
  00103  0774 00 2 00004         AXT     4,2                                                      HM110526
  00104  0774 00 4 00002         AXT     2,4                                                      HM110527
  00105  0774 00 1 00003  ABC    AXT     3,1                                                      HM110528
T 00106 -0754 00 0 00000         PXD                                                              HM110529
  00107 -0114 01 0 00230         CAQ     TAB,,1                                                   HM110530
  00110 -2 00001 1 00113         TNX     *+3,1,1                                                  HM110531
  00111  0767 00 0 00014         ALS     12                                                       HM110532
  00112  0020 00 0 00107         TRA     *-3                                                      HM110533
```

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 BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE. FIBII                     4/20/62     PAGE 4
00113  0602 00 2 77734          SLW     LAST+4,2        COL BIN AT LAST TO LAST+3           HM110534
00114  1 77777 2 00115          TXI     *+1,2,-1                                            HM110535
00115  2 00001 4 00105          TIX     ABC,4,1                                             HM110536
00116  0560 00 0 00326          LDQ     IDLCD           FINISH W/SAVED C(MQ).               HM110537
00117  3 00000 2 00104          TXH     ABC-1,2,0                                           HM110538
00120  0774 00 1 00000  SV1     AXT     **,1                                                HM110539
                        *                                                                   HM110540
                        ********************************************************************HM110541
                        *       THE ENTIRE CARD IMAGE IS BUILT, WITH THE BODY               HM110542
                        *       AT CIMAGE THRU CIMAGE+23, AND ID AT LAST THRU LAST+3.       HM110543
                        *       NOW ***** WRITE THE CARD ON TAPE. ********                  HM110544
                        ********************************************************************HM110545
00121  0761 00 0 00000  WRITE   NOP                                                         HM110546
00122 -0500 00 0 00331  WRITE1  CAL     14D                                                 HM110547
00123  0074 00 4 00000          CALL    (IOS)           ESTABLISH I/O FOR TAPE 14.          HM110548
00124  0522 60 0 00001          XEC*    $(WRS)                                              HM110549
00125 -0774 00 4 00213          AXC     PUNCMD,4                                            HM110550
00126  0522 60 0 00002          XEC*    $(RCH)                                              HM110551
00127  0754 00 4 00000          PXA     0,4             SET (WER) FOR RETRY.                HM110552
00130  0621 60 0 00003          STA*    $(WTC)                                              HM110553
00131  0074 00 4 00004  BPTES   TSX     $(WER),4                                            HM110554
00132 -0500 00 0 00267          CAL     SEQNO                                               HM110555
00133  0400 00 0 00327          ADD     L(1)            INCREMENT CARD COUNT.               HM110556
00134  0114 06 0 00215          CVR     TB1,,6                                              HM110557
00135  0602 00 0 00267          SLW     SEQNO                                               HM110558
00136  0520 C0 0 77776          ZET     END             TEST IF LAST CARD.                  HM110559
00137  0020 00 0 00146          TRA     SWTCH               NOT THE LAST CARD....           HM110560
00140 -0500 00 0 00131          CAL     BPTES                                               HM110561
00141  0602 60 0 00005          SLW*    $(TES)                                              HM110562
00142  0774 00 1 00000  X1      AXT     **,1                ALL DONE. EXIT                  HM110563
00143  0774 00 2 00000  X2      AXT     **,2                                                HM110564
00144  0774 00 4 0C000  X4      AXT     **,4                                                HM110565
00146  0020 00 4 00005          TRA     5,4                                                 HM110566
                        *                                                                   HM110567
                        ********************************************************************HM110568
00146 -0500 00 0 77740  SWTCH   CAL     CIMAGE              UPDATE THE CARD ORIGIN.         HM110569
00147  0361 00 0 00333          ACL     A22                                                 HM110570
00150  0602 00 0 77740          SLW     CIMAGE                                              HM110571
```

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    BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE. FIBII                               4/20/62    PAGE 5
                                                                                               HM110572
00151  0020 00 0 00057          TRA     NEXT                                                   HM110573
                         ***********************************************************************HM110574
                         *                                                                     HM110575
00152  0774 00 2 00027   TRCD   AXT     23,2                      CLEAR REST OF                HM110576
00153  0600 00 2 77770          STZ     CIMAGE+24,2               CARD IMAGE.                  HM110577
00154  2 00001 2 00153          TIX     *-1,2,1                                                HM110578
00155  0500 00 0 00322          CLA     ZWC                       STORE ZERO WORD COUNT        HM110579
00156  0622 00 0 77740          STD     CIMAGE                                                 HM110580
00157  0020 00 0 00073          TRA     EDIT                                                   HM110581
                         *                                                                     HM110582
                         ***********************************************************************HM110583
                         *                                                                     HM110584
00160  0600 00 0 77776   OUT    STZ     END                       WORD COUNT EXHAUSTED         HM110585
00161 -2 00001 2 00070          TNX     IN,2,1                    RETURN IF CARD IS FULL       HM110586
00162  0602 00 0 77777          SLW     COMMON                    SAVE CHECKSUM.               HM110587
00163 -0754 00 2 00000          PXD     0,2                       CORRECT WORD COUNT           HM110588
00164  0402 00 0 77740          SUB     CIMAGE                                                 HM110589
00165  0622 00 0 77740          STD     CIMAGE                                                 HM110590
00166 -0500 00 0 77777          CAL     COMMON                    RETURN CHECKSUM.             HM110591
00167 -3 00000 2 00070          TXL     IN,2,0                                                 HM110592
00170  0600 00 2 77770          STZ     CIMAGE+24,2               CLEAR REST OF CARD.          HM110593
00171  1 77777 2 00167          TXI     *-2,2,-1                                               HM110594
                         *                                                                     HM110595
                         ***********************************************************************HM110596
                         * THIS ROUTINE CONVERTS A BINARY INTEGER TO BCD. (4 DIGITS DECR-MQ)   HM110597
                         ***********************************************************************HM110598
                         *                                                                     HM110599
T     00172 -0754 00 0 00000   COSEQ  PXD                                                       HM110600
      00173 -0520 00 0 00302          NZT     BLSEQ              TEST IF BLANKS DESIRED.        HM110601
      00174  0020 00 0 00211          TRA     COSEQX                                            HM110602
      00175  0765 00 0 00022          LRS     18                 RIGHT ADJUST BIN INTEGER       HM110603
      00176  0221 00 0 00332          DVP     TEN                                               HM110604
      00177  0601 00 0 77777          STO     COMMON                                            HM110605
T     00200 -0754 00 0 00000          PXD                                                       HM110606
      00201  0221 00 0 00332          DVP     TEN                                               HM110607
      00202  0767 00 0 00006          ALS     6                                                 HM110608
      00203 -0602 00 0 77777          ORS     COMMON                                            HM110609
T     00204 -0754 00 0 00000          PXD
```

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                                                                              4/20/62     PAGE 6
   BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE. FIBII                                      HM110610
                                                                                            HM110611
   00205  0221 00 0 00332          DVP    TEN                                               HM110612
   00206  0767 00 0 00014          ALS    12                                                HM110613
   00207 -0501 00 0 77777          ORA    COMMON           RIGHT ADJUSTED SEQ NO.           HM110614
   00210  0020 00 4 00001          TRA    1,4                                               HM110615
   00211 -0500 00 0 00306   COSEQX CAL    BLANK            BLANK OUT SEQ. NO.               HM110616
   00212  0020 00 4 00001          TRA    1,4                                               HM110617
                            *                                                               HM110618
                            ****************************************************************HM110619
                            *                                                               HM110620
   00213 -0 00030 0 77740   PUNCMD IOCP   CIMAGE,0,24                                       HM110621
   00214  0 00003 0 77730          IOCD   LAST,0,3                                          HM110622
                            *                                                               HM110623
                            * TABLE FOR BCD ADDITION OF 1 TO C(ACC)                         HM110624
                            *                                                               HM110625
   00215  0000 00 0 00215   TB1    HTR    TB1                 0                             HM110626
   00216  0100 00 0 00215   TB     TZE    TB1                 1                             HM110627
   00217  0200 00 0 00215          MPY    TB1                 2                             HM110628
   00220  0300 00 0 00215          FAD    TB1                 3                             HM110629
   00221  0400 00 0 00215          ADD    TB1                 4                             HM110630
   00222  0500 00 0 00215          CLA    TB1                 5                             HM110631
   00223  0600 00 0 00215          STZ    TB1                 6                             HM110632
4  00224  0700 00 0 00215          CPY    TB1                 7                             HM110633
TD 00225  1 00000 0 00215          TXI    TB1                 8                             HM110634
   00226  1 10000 0 00215          TXI    TB1,0,4096          9                             HM110635
   00227  0000 00 0 00216          HTR    TB                  0 WITH CARRY                  HM110636
                            * TABLES FOR BCD-COL. BIN. CONVERSION                           HM110637
                            * HOLES ARE FILLED IN WITH CONSTANTS
                              TAB    OCT    1000,400,200,100,40,20,10,4,2,1
   00230 +000000001000
   00231 +000000000400
   00232 +000000000200
   00233 +000000000100
   00234 +000000000040
   00235 +000000000020
   00236 +000000000010
   00237 +000000000004
   00240 +000000000002                                                                      HM110638
   00241 +000000000001
   00242 -377777770000      MSK2CH OCT     777777770000,102,42
```

```
     00205  0221 00 0 00332          DVP     TEN                                                       HM110610
     00206  0767 00 0 00014          ALS     12                                                        HM110611
     00207 -0501 00 0 77777          ORA     COMMON           RIGHT ADJUSTED SEQ NO.                   HM110612
     00210  0020 00 4 00001          TRA     1,4                                                       HM110613
     00211 -0500 00 0 00306   COSEQX CAL     BLANK            BLANK OUT SEQ. NO.                       HM110614
     00212  0020 00 4 00001          TRA     1,4                                                       HM110615
                              *                                                                        HM110616
                              ******************************************************************************HM110617
                              *                                                                        HM110618
     00213 -0 00030 0 77740   PUNCHD IOCP    CIMAGE,0,24                                               HM110619
     00214  0 00003 0 77730          IOCD    LAST,0,3                                                  HM110620
                              *                                                                        HM110621
                              * TABLE FOR BCD ADDITION OF 1 TO C(ACC)                                  HM110622
                              *                                                                        HM110623
     00215  0000 00 0 00215   TB1    HTR     TB1                  0                                    HM110624
     00216  0100 00 0 00215   TB     TZE     TB1                  1                                    HM110625
     00217  0200 00 0 00215          MPY     TB1                  2                                    HM110626
     00220  0300 00 0 00215          FAD     TB1                  3                                    HM110627
     00221  0400 00 0 00215          ADD     TB1                  4                                    HM110628
     00222  0500 00 0 00215          CLA     TB1                  5                                    HM110629
     00223  0600 00 0 00215          STZ     TB1                  6                                    HM110630
4    00224  0700 00 0 00215          CPY     TB1                  7                                    HM110631
TD   00225  1 00000 0 00215          TXI     TB1                  8                                    HM110632
     00226  1 10000 0 00215          TXI     TB1,0,4096           9                                    HM110633
     00227  0000 00 0 00216          HTR     TB                   0 WITH CARRY                         HM110634
                              * TABLES FOR BCD-COL. BIN. CONVERSION                                    HM110635
                              * HOLES ARE FILLED IN WITH CONSTANTS                                     HM110636
     00230 +000000001000      TAB    OCT     1000,400,200,100,40,20,10,4,2,1                           HM110637
     00231 +000000000400
     00232 +000000000200
     00233 +000000000100
     00234 +000000000040
     00235 +000000000020
     00236 +000000000010
     00237 +000000000004
     00240 +000000000002
     00241 +000000000001
     00242 -377777770000      MSK2CH OCT     777777770000,102,42                                       HM110638
```

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     BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE. FIBII                            4/20/62     PAGE 7
    00243 +000000000102
    00244 +000000000042
    00245 +000000000000         ID123 OCT      0,0,0
    00246 +000000000000
    00247 +000000000000                                                                           HM110639
    00250 +000000004000               OCT      4000,4400,4200,4100,4040,4020,4010,4004,4002,4001  HM110640
    00251 +000000004400
    00252 +000000004200
    00253 +000000004100
    00254 +000000004040
    00255 +000000004020
    00256 +000000004010
    00257 +000000004004
    00260 +000000004002
    00261 +000000004001
    00262  106060606060         BCI8  BCI      1,8
    00263 +000000004102               OCT      4102,4042                                          HM110641
    00264 +000000004042                                                                           HM110642
    00265 -3 77777 7 00000     MSKPDT TXL      0,7,-1
A   00266  0400 00 0 00000     REL    ADD                                                         HM110643
    00267  606060606060        SEQNO  BCI      1,                                                 HM110644
    00270 +000000002000               OCT      2000,2400,2200,2100,2040,2020,2010,2004,2002,2001  HM110645
    00271 +000000002400                                                                           HM110646
    00272 +000000002200
    00273 +000000002100
    00274 +000000002040
    00275 +000000002020
    00276 +000000002010
    00277 +000000002004
    00300 +000000002002
    00301 +000000002001
    00302  0 00000 0 00000     BLSEQ
    00303 +000000002102               OCT      2102,2042                                          HM110647
    00304 +000000002042                                                                           HM110648
    00305  606060606060        BCDID  BCI      1,
    00306  606060606060        BLANK  BCI      1,                                                 HM110649
    00307  0074 00 0 00000     MSKTSX TSX      ,0                                                 HM110650
    00310 +000000000000               OCT      0,1400,1200,1100,1040,1020,1010,1004,1002,1001     HM110651
                                                                                                  HM110652
```

```
00311 +000C00001400
00312 +000000001200
00313 +000000001100
00314 +00CC00001040
00315 +000C00001020
00316 +00CC0C001010
00317 +00000CC01004
00320 +0C0000001002
00321 +000000001001
00322 +000500000000       ZWC    OCT      000500000000        ZERO WORDS FOR TCD           HM110653
00323 +000000001102              OCT      1102,1042                                        HM110654
00324 +000000001042
00325  0 00001 0 00000   D1              0,0,1                                            HM110655
00326  0 00000 0 0C000   IDLCD  PZE                                                       HM110656
00327  0 00000 0 00001   L(1)   PZE      1                                                HM110657
00330  0 00000 0 00005   SA     PZE      5                                                HM110658
00331  0 00014 0 00020   14D    PZE 16,,12                                                HM110659
00332 +000000000012      TEN    DEC      10                                               HM110660
00333  0000 00 0 00026    A22   HTR      22                                               HM110661
00334 +000526000C00       IMAGE DCT      000526000000        CONTROL WORC SKELETON        HM110662
                  77777  COMMON EQU      -1                                               HM110663
                  77740  CIMAGE EQU      -32                                              HM110664
                  77730  LAST   EQU      -40                                              HM110665
                  77776   END   SYN      COMMON-1                                         HM110666
                                END                                                       HM110667
```

```
    BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE, FIBII                           4/20/62     P
                           POST PROCESSOR ASSEMBLY DATA

    335 IS THE FIRST LOCATION NOT USED BY THIS PROGRAM

REFERENCES TO DEFINED SYMBOLS
    330      5A
    325      D1     16
     54      G2     34
     51      G3     37
     31      G4     53
     53      G5     50,    52
     70      IN    161,   167
    216      TB    227
    142      X1      6
    143      X2      7
    144      X4     54
    331     I40     11,   122
    333     A22    147
    105     ABC    115,   117
  77776     END     15,    55,   136,   160
    160     OUT     66
    266     REL     24
    120     SV1    102
    230     TAB    107
    215     TB1    134,   215,   216,   217,   220,   221,   222,   223,   224,   225,   226
    332     TEN    176,   201,   205
    322     ZWC    155
    262    BCIB     36
     73    EDIT    157
  77730    LAST    113,   214
     66    LOCN     17
    327    L(1)     74,   133
     57    NEXT    151
    152    TRCD     56
     62   ARRAY     13,    67
    305   BCDID     51,    76
      6   BINPU      0
    306   BLANK    211
    302   BLSEQ     30,    40,   173
```

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        BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE. FIBII                          4/20/62     P
                                    POST PROCESSOR ASSEMBLY DATA

        131  BPTES   140
        172  COSEQ    45
         61  COUNT    20,   70
        245  (012)
        326  IDLCD   100,  116
        334  IMAGE    25
        267  SEQNO    47,   73,  132,  135
        146  SWTCH   137
        121  WRITE
          0  (IOS)   123
          2  (RCH)   126
          5  (TES)   141
          4  (WER)   131
          1  (WRS)   124
          3  (WTC)   130
      77740 CIMAGE    26,   63,   64,   71,   72,  146,  150,  153,  156,  164,  165,  170,  213
      77777 COMMON   162,  166,  177,  203,  207,  335
        211 COSEQX   174
        242 MSK2CH
        265 MSKPDT    32
        307 MSKTSX    33
        213 PUNCMD   125
        122 WRITE1

NO ERROR IN ABOVE ASSEMBLY.
```

```
*     CATA                                                            HM110668

ENTRY POINTS TO SUBROUTINES REQUESTED FROM LIBRARY,
     (FPT)      (TSHM)      (RTN)      (STHM)      (FIL)      SORT      (IOS)      (WRS)      (RCH)
     (WEC)      (WER)       (TES)

        MACHINE      TOTAL      TOTAL       NOISE RECORDS          TOTAL REDUNDANCIES        POSITIONING
          TAPE      WRITES      READS     WRITING    READING      WRITING    READING              ERRORS

          A 1            0        530           0          0            0          0                   0
          B 2          591        646           0          0            0          0                   0
          B 3          125        153           0          0            0          0                   0
          A 4          450        535           0          0            0          0                   0
          A 2            0        677           0          0            0          0                   0
          A 3          579          3           0          0            0          0                   0
          B 4          159        162           0          0            0          0                   0

      EXECUTION 12.525
```

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Aerospace Corporation, El Segundo, California.
AERODYNAMIC INFLUENCE COEFFICIENTS FROM PISTON THEORY: ANALYTICAL DEVELOPMENT AND COMPUTATIONAL PROCEDURE, prepared by W.P. Rodden, E.F. Farkas, H.A. Malcom and A. M. Kliszewski. 15 August 1962. [90] p. incl. illus.
(Report TDR-169(3230-11)TN-2;SSD-TDR-62-75)
(Contract AF 04(695)-169) Unclassified report

In this report we present a method for calculating the aerodynamic influence coefficients (AICs) based on third-order piston theory with an optional correction to agree with Van Dyke's quasi-steady second-order theory. The AICs are computed assuming the airfoil to have a rigid chord with or without a (rigid chord) control surface. The influence coefficients relate the surface deflections to the aerodynamic forces through the following definitions in the oscillatory case, $\{F\} = \rho\omega^2 b_r^2 s[C_h]\{h\}$ and in the steady

(over)

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case, $\left\{F_s\right\} = (1/2)\rho V^2(S/\bar{c})\,[C_{hs}]\,\left\{h\right\}$. The piston theory is limited to high Mach number (or high reduced frequency), but Van Dyke's quasi-steady correction extends the validity to some lower supersonic Mach number at low reduced frequency. The Aerospace IBM 7090 Computer Program Number HM11 provides the AICs from this theory in both a printed and an optional punched-card output format. The program capacity is 25 surface strips, 15 Mach numbers, and 20 reduced velocities for each Mach number.

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