

UNCLASSIFIED

AD NUMBER
AD872190
NEW LIMITATION CHANGE
TO Approved for public release, distribution unlimited
FROM Distribution authorized to U.S. Gov't. agencies and their contractors; Critical Technology; APR 1970. Other requests shall be referred to Naval Air Systems Command, ATTN: AIR-530214, Washington, DC 20360.
AUTHORITY
USNASC ltr dtd 26 Oct 1971

THIS PAGE IS UNCLASSIFIED

AD872190



MSD-P70-192



CONTRACT NO. 00019-69-C-0427

AD NO. _____
DDC FILE COPY

COLLOCATION FLUTTER ANALYSIS STUDY II

THIS DOCUMENT IS SUBJECT TO SPECIAL EXPORT CONTROLS AND TRANSMITTAL TO FOREIGN GOVERNMENTS OR FOREIGN NATIONALS MAY BE MADE ONLY WITH PRIOR APPROVAL OF THE NAVAL AIR SYSTEMS COMMAND (AIR-530214).

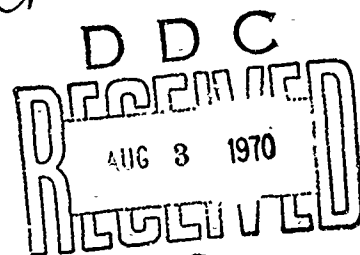
VOLUME I

SUBSONIC STRIP THEORY UNSTEADY AERODYNAMICS PROGRAM
AND SUPERSONIC PISTON THEORY UNSTEADY AERODYNAMICS PROGRAM

APRIL 1970



MISSILE SYSTEMS DIVISION



COFA II

COLLOCATION FLUTTER ANALYSIS STUDY II

VOLUME I

SUBSONIC STRIP THEORY UNSTEADY AERODYNAMICS PROGRAM

SUPERSONIC PISTON THEORY UNSTEADY AERODYNAMICS PROGRAM

PREPARED BY DYNAMICS & ENVIRONMENTS SECTION PERSONNEL, HUGHES

AIRCRAFT COMPANY, MISSILE SYSTEMS DIVISION, CONTRACT NO.

00019-69-C-0427

April 1970

This document is subject to special export controls and transmittal to foreign governments or foreign nationals may be made only with prior approval of the Naval Air Systems Command (AIR-530214).

Wash D.C. 20360

TABLE OF CONTENTS

Section	Page No.
1.0 INTRODUCTION	1
2.0 SUBSONIC STRIP THEORY AERODYNAMICS PROGRAM	2
2.1 THEORETICAL DEVELOPMENT	2
2.2 PROGRAM DESCRIPTION	12
2.2.1 PROCESSING INFORMATION	12
2.3 INPUT INSTRUCTIONS	13
2.4 SAMPLE PROBLEM	16
2.5 PROGRAM LISTING	29
3.0 PISTON THEORY AERODYNAMIC PROGRAM	43
3.1 THEORETICAL DEVELOPMENT	43
3.2 PROGRAM DESCRIPTION	51
3.2.1 PROCESSING INFORMATION	51
3.3 INPUT INSTRUCTIONS	52
3.4 SAMPLE PROBLEM	57
3.5 PROGRAM LISTING	63
4.0 REFERENCES	75

1.0 INTRODUCTION

The work presented in this report is a continuation of work started under NASC Contract No. 00019-68-C-0274, Collocation Flutter Analysis Study. This work, which is presented in three volumes, is to update and document computer automated flutter analysis techniques. The volumes contain:

- Volume I - Subsonic Strip Theory Unsteady Aerodynamics Program (Strip),
Supersonic Piston Theory Unsteady Aerodynamics Program (Piston),
- Volume II - Unsteady Aerodynamics Generalized Force Programs for the Subsonic, Sonic and Supersonic Flight Regimes
- Volume III - Structural Analysis Program - FLUENC-100C
Component Mode Synthesis Program (COMSYN)
Modal Flutter Analysis Program (MOFA)

The report contains a set of instruction manuals with sufficient information to operate each program. The programs are coded in Fortran IV, and require only a minimum amount of modification to be operable on most computers.

The two programs presented in Volume I, the Subsonic Strip Theory Unsteady Aerodynamics Program and Supersonic Piston Theory Unsteady Aerodynamics Program, calculate unsteady aerodynamic influence coefficients, AICs. These AICs can be used directly as input for the Collocation Flutter Analysis Program presented in Volume IV of Reference 1; and when transformed into generalized aerodynamic forces, they can satisfy the input requirements for the Modal Flutter Analysis Program described in Volume III of this report. The programs were developed using the strip theory approach so that chordwise camber could be incorporated into the analysis. The subsonic program is applicable to wings of moderate to high aspect ratios. The supersonic program is applicable to wings of all aspect ratios; however, for wings of low aspect ratio, it is recommended that the computer program presented in Reference 2 be used. This program, uses a normal mode analysis technique, which is inherently less accurate than the AIC-Collocation Method. However, the deformation modes of wings of low aspect ratio are more accurately described in the modal analysis. It is for this reason that the normal mode method is recommended for wings of low-aspect ratio.

2.0 SUBSONIC STRIP THEORY AERODYNAMICS PROGRAM

2.1 THEORETICAL DEVELOPMENT

It is desirable to consider the derivations of the AIC's in the simplest form, that is from a strip theory approach in which the flow along any section of the wing can be considered two dimensional. The derivation for the rigid chord shown is taken from Reference 3. The derivation for the flexible chord is an extension of the rigid chord case and is developed in a parallel manner. Three basic relationships must be established to obtain AIC's from any aerodynamic theory; they are (1) the pressure-downwash relation; (2) force-pressure relation; and (3) downwash-deflection relation. For the strip theory case the pressure-downwash relationships are available in an equivalent form. Theodorsen (Ref. 4) has integrated the pressure relationships and has presented the above information as a tabulation of oscillatory coefficients; L , M , N , T . The force-pressure relationship is established through the oscillatory coefficients and a correlation of the force systems in Figs. 2.1.1 a & b. The downwash-deflection relationship is established through the geometrical relationships shown in Figs. 2.1.1 a & b.

In the case of strip theory, the matrix of AIC's appears in a partitioned form. For example, the AIC's for the two-strip wing appear as

$$C_h = \begin{bmatrix} C_{h1} & 0 \\ 0 & C_{h2} \end{bmatrix}$$

where the C_{hi} are the AIC's for strip "i". Thus it is only necessary to derive in general form the AIC's for one strip. This is then applied to each strip, and the complete matrix is compiled as shown above.

A survey of two-dimensional oscillatory aerodynamic theory yielded the incompressible solutions of Theodorsen, Ref. 4, and of Theodorsen and Garrick, Refs. 5,6, and the tabulations of Smilg and Wasserman, Ref. 7. The subsonic solution has been tabulated by Timman, Van de Vooren, and Griedanus, Ref. 8. These solutions are for the case of a rigid airfoil and control surface. The incompressible solution for the case of a flexible chord undergoing parabolic changes in camber has been obtained by Spielberg, Ref. 9. The incompressible case for the cambering airfoil with control surface was solved by Tyler, Ref. 10.

Rigid Chord

The theory is developed for the general case with control surface, and degenerates to a second order matrix (upper left partition) for the non-control surface configuration.

DEFINITION

$$\{F\} = \rho \omega^2 b_r^2 s \begin{bmatrix} c_h \end{bmatrix} \{h\}$$

2.1.1

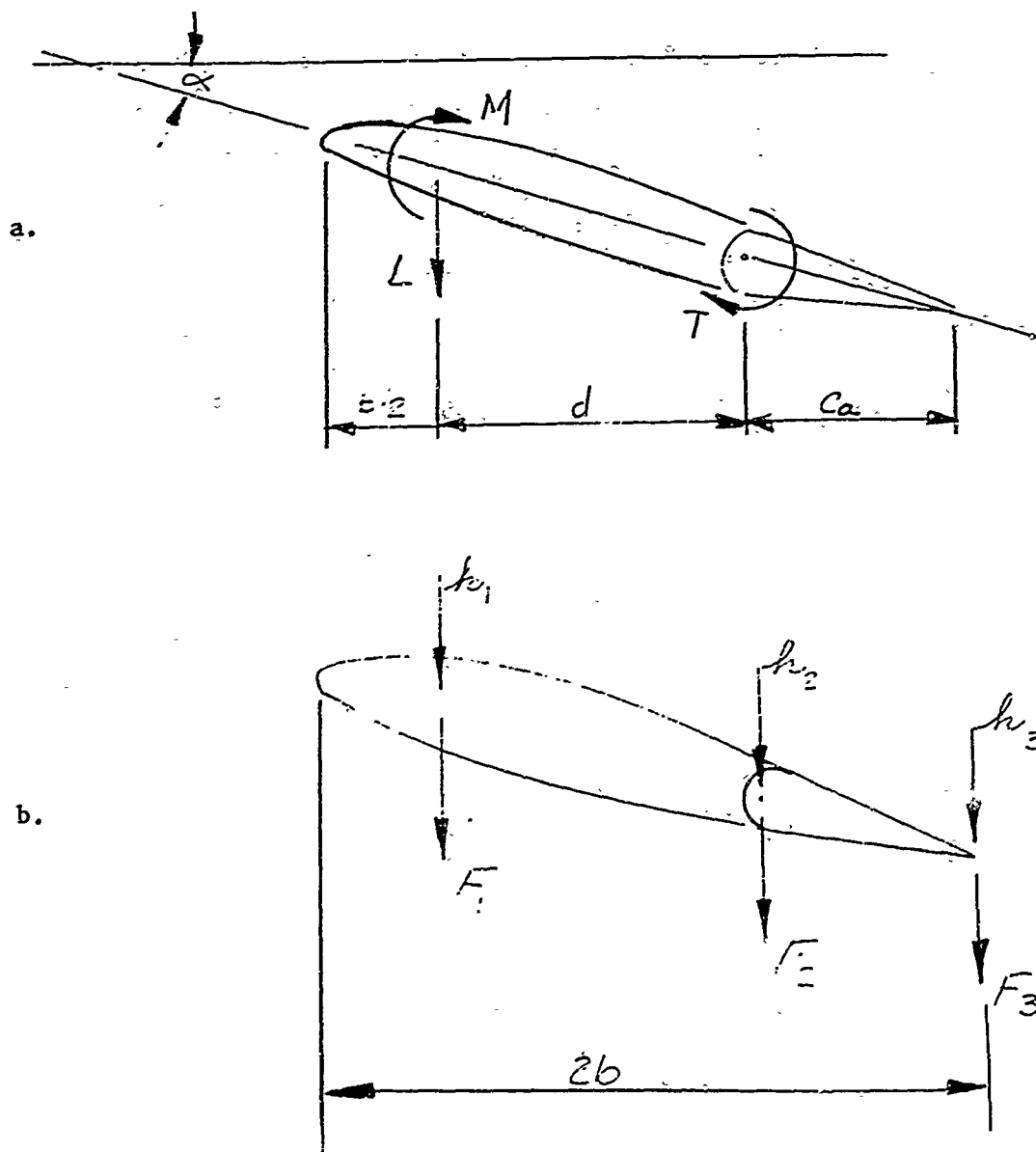


Figure 2.1.1

The force-pressure relationship derived from Fig. 2.1.1 is

$$\begin{bmatrix} 1 & 1 & 1 \\ 0 & d & (d+c_a) \\ 0 & 0 & c_a \end{bmatrix} \begin{Bmatrix} F_1 \\ F_2 \\ F_3 \end{Bmatrix} = \begin{Bmatrix} L \\ M \\ T \end{Bmatrix} \quad 2.1.2$$

from Ref. 4, the oscillatory coefficients are defined as

$$\begin{Bmatrix} L \\ M \\ T \end{Bmatrix} = \pi \cos \Delta \rho \omega^2 b^2 \Delta y \begin{bmatrix} 1 & 0 & 0 \\ 0 & b & 0 \\ 0 & 0 & b \end{bmatrix} \begin{bmatrix} L_h & L_\alpha & L_\beta \\ M_h & M_\alpha & M_\beta \\ T_h & T_\alpha & T_\beta \end{bmatrix} \begin{Bmatrix} h \\ b\alpha \\ b\beta \end{Bmatrix} \quad 2.1.3$$

The geometrical relationship between the downwash and the deflection as derived from Fig. 2.1.1 is

$$\begin{Bmatrix} h \\ b\alpha \\ b\beta \end{Bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ -b/d & b/d & 0 \\ b/d & -(b/d+b/c_a) & b/c_a \end{bmatrix} \begin{Bmatrix} h_1 \\ h_2 \\ h_3 \end{Bmatrix} \quad 2.1.4$$

Substituting 2.1.4 into 2.1.3 and the result into 2.1.2, inverting and multiplying, we get

$$\begin{Bmatrix} F_1 \\ F_2 \\ F_3 \end{Bmatrix} = \pi \cos \Delta \rho \omega^2 b^2 \Delta y \begin{bmatrix} 1 & -b/d & b/d \\ 0 & b/d & -(b/d+b/c_a) \\ 0 & 0 & b/c_a \end{bmatrix} \begin{bmatrix} L_h & L_\alpha & L_\beta \\ M_h & M_\alpha & M_\beta \\ T_h & T_\alpha & T_\beta \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ -b/d & b/d & 0 \\ b/d & -(b/d+b/c_a) & b/c_a \end{bmatrix} \begin{Bmatrix} h_1 \\ h_2 \\ h_3 \end{Bmatrix} \quad 2.1.5$$

Comparing 2.1.5 with 2.1.1 we see that

$$[C_h] = \pi \cos \Lambda (b/b_r)^2 (\Delta y/s) \begin{bmatrix} 1 & -b/d & b/d \\ 0 & b/d & -(b/d+b/c_a) \\ 0 & 0 & b/c_a \end{bmatrix} \begin{bmatrix} L_h & L_\alpha & L_\beta \\ M_h & M_\alpha & M_\beta \\ T_h & T_\alpha & T_\beta \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ -b/d & b/d & 0 \\ b/d & -(b/d+b/c_a) & b/c_a \end{bmatrix}$$

2.1.6

Flexible Chord with Parabolic Camber

The theory is developed for the general case with control surface and degenerates to a third order matrix (upper left partition) when the control surface is absent.

Using virtual work to establish the force-pressure relation

$$\delta W = L \delta h_{c/4} + M \delta \alpha + N \delta \zeta + T \delta \beta \quad 2.1.7a$$

$$= \begin{pmatrix} \delta h_{c/4} \\ b \delta \alpha \\ \delta \zeta \\ b \delta \beta \end{pmatrix}^T \begin{pmatrix} L \\ M/b \\ N \\ T/b \end{pmatrix} \quad 2.1.7b$$

$$\delta W = F_1 \delta h_1 + F_2 \delta h_2 + F_3 \delta h_3 + F_4 \delta h_4 \quad 2.1.8a$$

$$= \begin{pmatrix} \delta h_1 \\ \delta h_2 \\ \delta h_3 \\ \delta h_4 \end{pmatrix}^T \begin{pmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \end{pmatrix} \quad 2.1.8b$$

$$\begin{Bmatrix} \delta h_1 \\ \delta h_2 \\ \delta h_3 \\ \delta h_4 \end{Bmatrix}^T \begin{Bmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \end{Bmatrix} = \begin{Bmatrix} \delta h_{c/4} \\ b\delta\alpha \\ \delta\zeta \\ b\delta\beta \end{Bmatrix}^T \begin{Bmatrix} L \\ M/b \\ N \\ T/b \end{Bmatrix}$$

2.1.9

Substituting the oscillatory coefficients as defined in Ref. 9

$$= \pi \rho \omega^2 b^2 \Delta y \begin{Bmatrix} \delta h_{c/4} \\ b\delta\alpha \\ \delta\zeta \\ b\delta\beta \end{Bmatrix}^T \begin{bmatrix} L_h & L_\alpha & L_\zeta & L_\beta \\ M_h & M_\alpha & M_\zeta & M_\beta \\ N_h & N_\alpha & N_\zeta & N_\beta \\ T_h & T_\alpha & T_\zeta & T_\beta \end{bmatrix} \begin{Bmatrix} h_{c/4} \\ b\alpha \\ \zeta \\ b\beta \end{Bmatrix}$$

2.1.10

The downwash deflection relationship can be expressed as,

$$\begin{Bmatrix} h_{c/4} \\ b\alpha \\ \zeta \\ b\beta \end{Bmatrix} = [A] \begin{Bmatrix} h_1 \\ h_2 \\ h_3 \\ h_4 \end{Bmatrix} \text{ where } (A) \text{ is to be defined later.}$$

2.1.11a

Taking the transpose, we obtain

$$\begin{Bmatrix} h_{c/4} \\ b\alpha \\ \zeta \\ b\beta \end{Bmatrix}^T = \begin{Bmatrix} h_1 \\ h_2 \\ h_3 \\ h_4 \end{Bmatrix}^T [A]^T$$

2.1.11b

Substituting 2.1.11b into 2.1.10 to obtain

$$\begin{Bmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \end{Bmatrix} = \pi \rho \omega^2 b^2 \Delta y \begin{bmatrix} L_h & L_\alpha & L_\zeta & L_\beta \\ M_h & M_\alpha & M_\zeta & M_\beta \\ N_h & N_\alpha & N_\zeta & N_\beta \\ T_h & T_\alpha & T_\zeta & T_\beta \end{bmatrix} \begin{bmatrix} A \end{bmatrix}^T \begin{Bmatrix} h_1 \\ h_2 \\ h_3 \\ h_4 \end{Bmatrix} \quad 2.1.12$$

$$\text{or } \{F\} = \pi \rho \omega^2 b^2 \Delta y \begin{bmatrix} A \end{bmatrix}^T \begin{bmatrix} L \end{bmatrix} \begin{bmatrix} A \end{bmatrix} \quad 2.1.13$$

therefore

$$\begin{bmatrix} C_h \end{bmatrix} = \pi (b^2 \Delta y / b^2 s) \begin{bmatrix} A \end{bmatrix}^T \begin{bmatrix} L \end{bmatrix} \begin{bmatrix} A \end{bmatrix} \quad 2.1.14$$

Development of the $\begin{bmatrix} A \end{bmatrix}$ matrix.

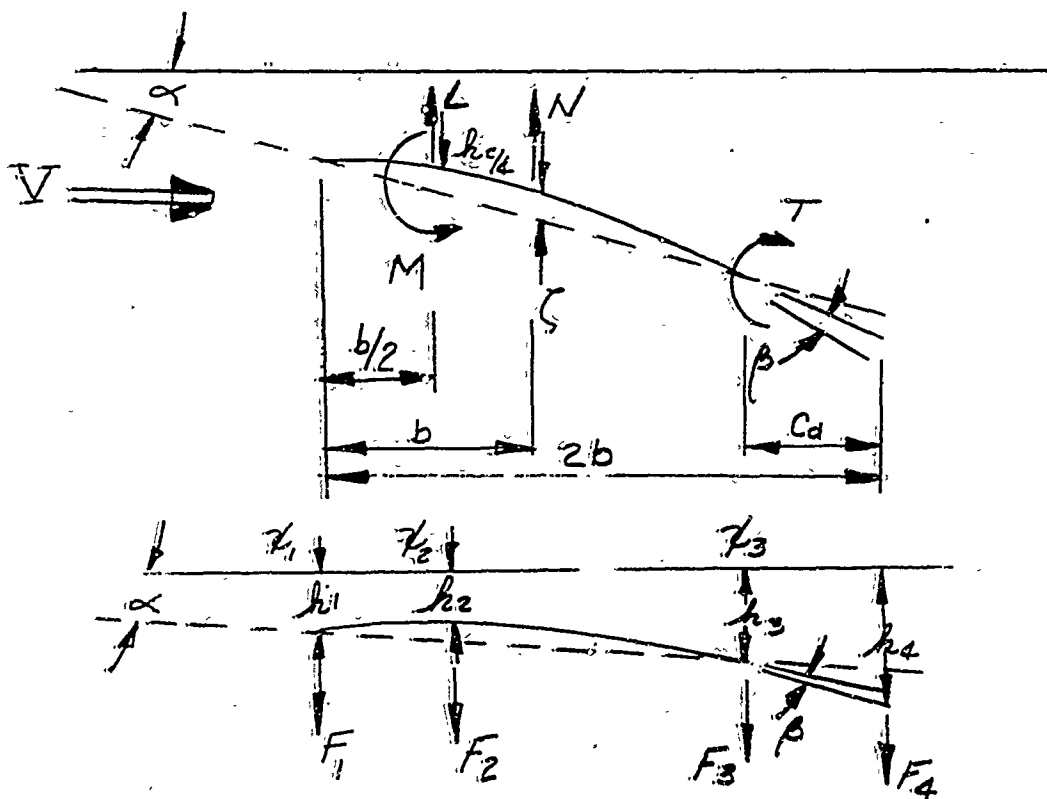


Figure 2.1.2

Using Lagrangian Curve Fit with Figure 2.1.2

$$h(x) = h_1 \frac{(x-x_2)(x-x_3)}{(x_1-x_2)(x_1-x_3)} + h_2 \frac{(x-x_1)(x-x_3)}{(x_2-x_1)(x_2-x_3)} + h_3 \frac{(x-x_1)(x-x_2)}{(x_3-x_1)(x_3-x_2)} \quad 2.1.15$$

$$h'(x) = h_1 \frac{2x-x_2-x_3}{(x_1-x_2)(x_1-x_3)} + h_2 \frac{2x-x_1-x_3}{(x_2-x_1)(x_2-x_3)} + h_3 \frac{2x-x_1-x_2}{(x_3-x_1)(x_3-x_2)} \quad 2.1.16$$

We can now relate h_1, h_2, h_3, h_4 to $h_{c/4}, b\alpha, \zeta, b\beta$

$$h_{le} = \{h_{le}/h_1\} h_1 + \{h_{le}/h_2\} h_2 + \{h_{le}/h_3\} h_3$$

$$h_{c/2} = \{h_{c/2}/h_1\} h_1 + \{h_{c/2}/h_2\} h_2 + \{h_{c/2}/h_3\} h_3$$

$$h_{te} = \{h_{te}/h_1\} h_1 + \{h_{te}/h_2\} h_2 + \{h_{te}/h_3\} h_3 \quad 2.1.17$$

where we have used the following notations

$$\{h_{le}/h_1\} = (x_{le}-x_2)(x_{le}-x_3)(x_1-x_2)(x_1-x_3)$$

$$\{h_{le}/h_2\} = (x_{le}-x_1)(x_{le}-x_3)(x_2-x_1)(x_2-x_3)$$

$$\{h_{le}/h_3\} = (x_{le}-x_1)(x_{le}-x_2)(x_3-x_1)(x_3-x_2)$$

$$\{h_{c/2}/h_1\} = (x_{c/2}-x_2)(x_{c/2}-x_3)(x_1-x_2)(x_1-x_3)$$

$$\{h_{c/2}/h_2\} = (x_{c/2}-x_1)(x_{c/2}-x_3)(x_2-x_1)(x_2-x_3)$$

$$\{h_{c/2}/h_3\} = (x_{c/2}-x_1)(x_{c/2}-x_2)(x_3-x_1)(x_3-x_2)$$

$$\{h_{te}/h_1\} = (x_{te}-x_2)(x_{te}-x_3)(x_1-x_2)(x_1-x_3)$$

$$\{h_{te}/h_2\} = (x_{te}-x_1)(x_{te}-x_3)(x_2-x_1)(x_2-x_3)$$

$$\{h_{te}/h_3\} = (x_{te}-x_1)(x_{te}-x_2)(x_3-x_1)(x_3-x_2)$$

2.1.18

$$h_{c/4} = \frac{1}{2} (3h_{le} + h_{te})$$

$$= \{h_{c/4}/h_1\} h_1 + \{h_{c/4}/h_2\} h_2 + \{h_{c/4}/h_3\} h_3 \quad 2.1.19$$

where

$$h_{c/4}/h_i = (3/4)h_{le}/h_i + (1/4)h_{te}/h_i, \quad i = 1, 2, 3 \quad 2.1.20$$

$$ba = (1/2)(h_{te} - h_{le})$$

$$= \{ba/h_1\} h_1 + \{ba/h_2\} h_2 + \{ba/h_3\} h_3 \quad 2.1.21$$

$$\text{where } ba/h_i = (1/2)(h_{te}/h_i - h_{le}/h_i), \quad i = 1, 2, 3 \quad 2.1.22$$

$$\zeta = h_{c/2} = (1/2)(h_e + h_{te})$$

$$= \{\zeta/h_1\} h_1 + \{\zeta/h_2\} h_2 + \{\zeta/h_3\} h_3 \quad 2.1.23$$

where

$$\zeta/h_i = h_{c/2}/h_i = (1/2)(h_{te}/h_i + h_e/h_i), \quad i = 1, 2, 3 \quad 2.1.24$$

$$h'(x_3) = \frac{x_3 - x_2}{(x_1 - x_2)(x_1 - x_3)} h_1 + \frac{x_3 - x_1}{(x_2 - x_1)(x_2 - x_3)} h_2$$

$$+ \frac{2x_3 - x_1 - x_2}{(x_3 - x_1)(x_3 - x_2)} h_3 \quad 2.1.25$$

$$b\beta = \frac{b(h_4 - h_3)}{c_a} + bh'(x_3)$$

2.1.26

$$= \frac{b(x_3 - x_2)}{(x_1 - x_2)(x_1 - x_3)} h_1 + \frac{b(x_3 - x_1)}{(x_2 - x_1)(x_2 - x_3)} h_2 + \frac{b(2x_3 - x_1 - x_2)}{(x_3 - x_1)(x_3 - x_2)} - \frac{1}{c_a} h_3 + \frac{b}{c_a} h_4$$

$$b\beta = b\{h'(x_3)/h_1\} h_1 + b\{h'(x_3)/h_2\} h_2 + b\{h'(x_3)/h_3\} h_3 + \frac{b}{c_a} h_4 \quad 2.1.27$$

where

$$\{h'(x_3)/h_1\} = \frac{(x_3 - x_2)}{(x_1 - x_2)(x_1 - x_3)}$$

$$\{h'(x_3)/h_2\} = \frac{(x_3 - x_1)}{(x_2 - x_1)(x_2 - x_3)}$$

$$\{h'(x_3)/h_3\} = \frac{2x_3 - x_1 - x_2}{(x_3 - x_1)(x_3 - x_2)} - \frac{1}{c_a}$$

$$\{h'(x_3)/h_3\} = \frac{1}{c_a} \quad 2.1.28$$

Thus we may write the geometrical relation matrix.

$$\begin{Bmatrix} h_{c/4} \\ b\alpha \\ \zeta \\ b\beta \end{Bmatrix} = \begin{bmatrix} \{h_{c/4}/h_1\} & \{h_{c/4}/h_2\} & \{h_{c/4}/h_3\} & 0 \\ b\{\alpha/h_1\} & b\{\alpha/h_2\} & b\{\alpha/h_3\} & 0 \\ \{\zeta/h_1\} & \{\zeta/h_2\} & \{\zeta/h_3\} & 0 \\ b\{h'(x_3)/h_1\} & b\{h'(x_3)/h_2\} & b\{h'(x_3)/h_3\} & b\{h'(x_3)/h_4\} \end{bmatrix} \begin{Bmatrix} h_1 \\ h_2 \\ h_3 \\ h_4 \end{Bmatrix} \quad 2.1.29$$

$$\begin{Bmatrix} h_{c/4} \\ b\alpha \\ \zeta \\ b\beta \end{Bmatrix} = [A] \begin{Bmatrix} h_1 \\ h_2 \\ h_3 \\ h_4 \end{Bmatrix}$$

2.1.30

where the elements of $[A]$ are defined in equation 2.1.29

2.2 PROGRAM DESCRIPTION

A general program to calculate a set of aerodynamic influence coefficients using incompressible strip theory has been developed. The method is applicable to wings of moderate to high aspect ratio and speeds in the subsonic regime. The analysis can be performed for wings with a rigid chord or a flexible chord. The effects of a flexible chord are accounted for by the introduction of parabolic cambering if the bending mode is parabolic and the torsion mode linear in the region surrounding the strip under consideration. The analysis can be performed with or without a control surface. The method used is based upon the most fundamental solution in unsteady flow by Theodorsen for the oscillating two-dimensional airfoil in an incompressible flow and the extensions to include camber by Speilberg and Tyler. The steady state case is available as a limiting case of the oscillating case for use in static aerelastic analysis. The AICs relate the aerodynamic forces to the surface deflections through the following definitions. In the oscillatory case,

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

and in the steady case,

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

The AICs are derived for each strip considering the airfoil to have up to four degrees of freedom: pitching, plunging, cambering, and control surface rotation. The program provides the AICs in printed and optional punched-card output format. The punched-card output satisfies the input requirements of the Collocation Flutter Analysis Program (Ref.1). The program capacity is 25 surface strips and 50 values of reduced velocity.

2.2.1 PROCESSING INFORMATION

A. OPERATION

Standard FORTRAN IV processor system. Operable on the GE 635 computer.

B. CORE STORAGE

The program STRIP requires a minimum of 20,000 memory units for execution.

C. ADDITIONAL MACHINE COMPONENTS

Standard FORTRAN input tape (5)

Standard FORTRAN output print tape (6)

Standard FORTRAN output punch tape

2.3 INPUT INSTRUCTIONS

UNITS

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

PROGRAM CAPABILITIES

Analyses can be performed for surfaces with or without cambering and/or with or without a control surface. Analyses can be performed for $1/k_r = 0$ to ∞ . $1/k_r = 0$ is equivalent to zero forward velocity, and yields the aerodynamics associated with a ground vibration test. $1/k_r = \infty$ is equivalent to the steady state flow case, $\omega = 0$. The surface may be divided into as many as 25 strips. The number of reduced velocities used in any one analysis (one input deck) must be < 50 . If it is desired to compute the matrix of steady AICs C_{hs} , a negative value of $1/k_r$ should be supplied to the program (S and c must also be provided).

DATA DECK SETUP

1. Title Card 1
2. Title Card 2
3. NCAM, ISZ, JSZ, NØPUNJ
4. $\cos A, b, r, s, S, c$
5. $\Delta y, b, \tau_1, \tau_2, \tau_3$ for each strip
6. $1/k_r$ series

INPUT DATA DESCRIPTION

1. & 2. Title Card 1 and 2 may contain any characters desired in Column 2 through 72. Column 1 should be blank. Characters on these two cards appear at the top of the first page of printed output.
3. Control card (Format 18I4)

Column	1-4	5-8	9-16	17-20
Name	NCAM	ISZ	JSZ	NØPUNJ
Item	(1)	(2)	(3)	(4)

NCAM = 0, Camber not considered in analysis (rigid chord).

= 1, Camber included in analysis.

ISZ = Number of strips ≤ 25

JSZ = Number of reduced velocities ≤ 50

NØPUNJ = $0 \sim \frac{1}{k_r}$ & $[C_h]$ Punched out

1~ No punched output

4. Data Card (Format 6E12,8)

Column	1-12	13-24	25-36	37-48	49-60
Name	CØSLMD	BR	S	CAPS	CBAR
Item	(1)	(2)	(3)	(4)	(5)

CØSLMD = $\cos A$ = cosine value of the quarter chord sweep angle

BR = b_r = reference semi-chord

S = s = semi-span

CAPS = S = surface area of wing (required only for steady-state analysis)

CBAR = $\bar{c}$ = mean aerodynamic chord of wing (required only for steady-state analysis)

5. Data Card (Format 6E12,8) Repeat for each strip.

Column	1-12	13-23	25-36	37-48	49-60	61-72
Name	DELTAY	B	Z ₁	Z ₂	Z ₃	
Item	(1)	(2)	(3)	(4)	(5)	

DELTAY = Δy_i = Strip width of strip "i".

B = b_i = Local semichord of strip "i".

Z₁ = ζ_{1i} = Fraction of chord for location of forward control point on strip "i". When NCAM = 0, ζ_1 must equal .25.

Z₂ = ζ_{2i} = Fraction of chord for location second control point on strip "i". ζ_2 is negative for control surface on strip. When NCAM = 0, ζ_2 must be the percent chord that corresponds to the control surface hinge line.

Z₃ = ζ_{3i} = Fraction of chord to third control point on strip "i". When NCAM = 0; ζ_3 must equal zero. When NCAM = 1, ζ_3 must be the percent chord that corresponds to the control surface hinge line.

NOTE: When NCAM = 0 and ζ_2 is negative, ζ_3 is located internally in the program and is placed at the trailing edge ($\zeta_3 = 1.0$).

The distance between the forward and middle control points (d) and the control surface local chord (c_a) are computed internally in the program and are printed along with the strip data in the program output. When NCAM = 1 and ζ_2 is negative, ζ_4 is located internally in the program and is placed at the trailing edge ($\zeta_4 = 1.0$). The control surface local chord (c_a) also is determined internally in the program, and can be found in the printed output with the geometric data for the strip.

6. Data Card ~ 1/k series (Format 6E12.8)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	$1/k_1$	$1/k_2$	...	$1/k_i$	...	$1/k_{JSZ}$
Item						

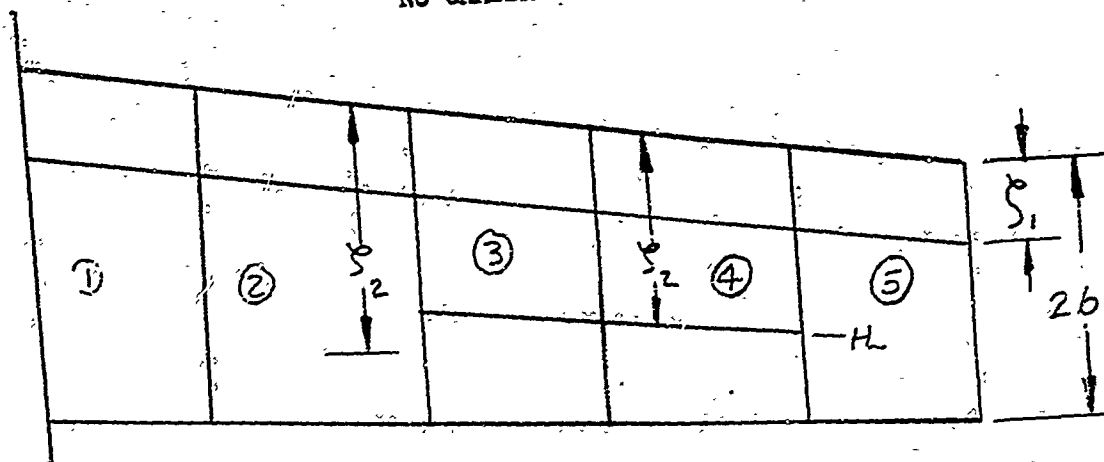
$1/k = 1/k_r$ = Reduced velocity $V/b_r w$; continue on successive cards until
 $i = JSZ$ (6 values per card).

2.4 EXAMPLE PROBLEM

As an example problem, the subsonic AIC's are calculated for the high aspect ratio swept-back wing shown below. The wing is analyzed for the rigid chord case (no camber) and for the flexible chord case (parabolic cambering). The analysis is performed for the reduced frequencies ($1/k$) of 0, 5.0, 8.0, and -16.0. A $1/k = 0.0$ calculates the aerodynamics associated with a ground vibration test. A negative $1/k$ calculates aerodynamics associated with steady state flight.

Note: Any number may be used for the steady-state case as long as it is negative.

PROGRAM INPUT DATA
NO CAMBER CASE



STRIP	Δy (ft)	b (ft)	ζ_1	ζ_2
1	3.8	7.5	.25	.803
2	3.6	6.8	.25	.779
3	3.4	6.2	.25	-.734
4	3.2	5.5	.25	-.723
5	3.0	5.0	.25	.700

$$\begin{aligned}\cos A &= .75 \\ b &= 6.0 \text{ ft} \\ r &= 20.0 \text{ ft} \\ s &= 200 \text{ ft}^2 \\ c &= 15.0 \text{ ft}\end{aligned}$$

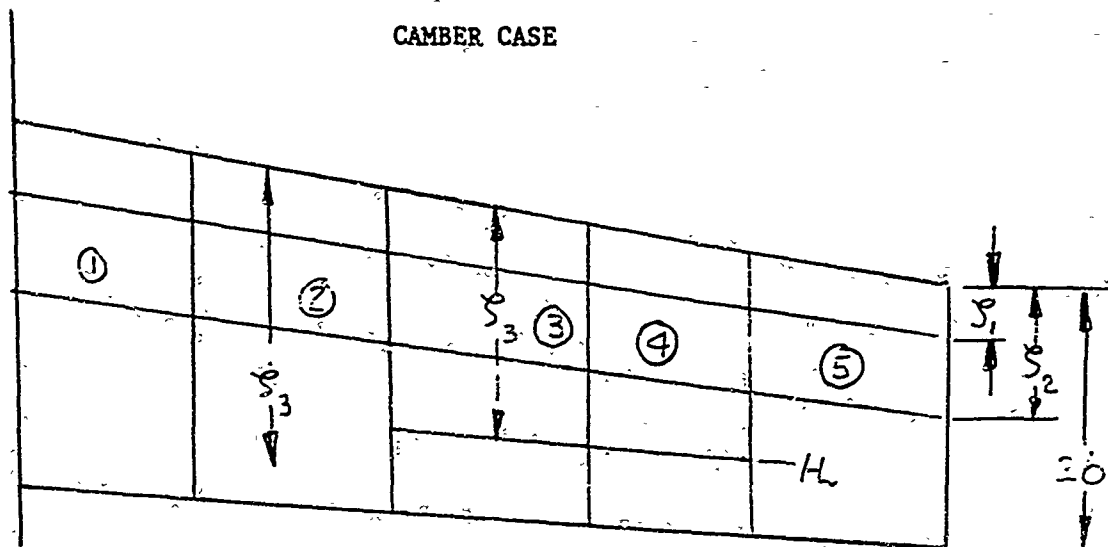
$$1/k = 5.0, 8.0, 0.0, -16.0$$

ζ_1 must always be the 25% chordline for the no camber case. ζ_2 must be on the hinge line when a control surface is present; when no control surface is present, ζ_2 may be any arbitrary position.

NOTE: Negative ζ_2 for strips 3 and 4 indicates a control surface on these strips.

PROGRAM INPUT DATA

CAMBER CASE



STRIP NO.	ΔY	b(ft)	ζ_1	ζ_2	ζ_3
1	3.8	7.5	.3	.55	.803
2	3.6	6.8	.3	.55	.779
3	3.4	6.2	.3	-.55	.734
4	3.2	5.5	.3	-.55	.723
5	3.0	5.0	.3	.55	.700

$$\cos A = .75$$

$$b_r = 6.0 \text{ ft}$$

$$s = 20.0 \text{ ft}$$

$$S = 200 \text{ ft}^2$$

$$\bar{c} = 15.0 \text{ ft}$$

$$1/k = 5.0, 8.0, 0.0, -16.0$$

ζ_1 , ζ_2 , and ζ_3 may be any arbitrary position when no control surface is present; when a control surface is present, ζ_1 and ζ_2 may be arbitrarily located and ζ_3 must be located at the hinge line. In both cases, however, ζ_1 , ζ_2 , and ζ_3 should be distributed across the chord so that the chamber can be properly defined, e.g., $\zeta_1 = .20$, $\zeta_2 = .50$, and $\zeta_3 = .80$.

NOTE: Negative ζ_2 for strips 3 and 4 indicates a control surface on these strips.

SAMPLE PROGRAM CHECK FROM AIC STRIP THEORY REPORT

NEW COMPUTER PROGRAM, JULY 1969, ANALYSIS DOES NOT CONSIDER CARRIER

AERO-DYNAMIC INFLUENCE COEFFICIENTS BY INCOMPRESSIBLE STRIP THEORY WITHOUT CARRIER

INPUT DATA

5 STRIPS
4 REDUCED VELOCITIES

COSINE LAMBDA = 0.75000E 00
REFERENCE SPAN-CHORD = 0.60000E 01
SPAN-SPAN = 0.20000E 02
SURFACE AREA = 0.20000E 03
C BAR = 0.15000E 02

STRIP NO.	DELTA Y (i)	P(i)	Z1(i)	Z2(i)	Z3(i)	D(i)	CA(i)
1	0.38000E 01	0.25000E 01	0.25000E 00	0.80000E 00	0.	0.82950E 01	0.
2	0.36000E 01	0.25000E 01	0.25000E 00	0.77900E 00	0.	0.71944E 01	0.
3	0.34000E 01	0.25000E 01	0.25000E 00	0.73400E 00	0.	0.60016E 01	0.32984E 01
4	0.32000E 01	0.25000E 01	0.25000E 00	0.72300E 00	0.	0.52030E 01	0.30470E 01
5	0.30000E 01	0.25000E 01	0.25000E 00	0.70000E 00	0.	0.45000E 01	0.
1/K(u) =	0.50000E 01	0.80000E 01	0.	-0.10000E 01			

ACROPTIC INFLUENCE COEFFICIENTS BY INCOMPRESSIBLE STRIP THEORY WITHOUT CAMBER

1/A(R) = 0.580000E 01

NUMBER OF STRIPS = 9

CH(1) SIZE = 2 BY 2

0.14198394E 02 -0.36781232E 01 -0.14851708E 02 0.26252100E-02
0.10178752E 00 0.22873504E 01 0.21443998E 00 -0.22873598E 01

CH(2) SIZE = 2 BY 2

0.14350164E 02 -0.36156036E 01 -0.14963014E 02 0.41329598E 00
0.74945082E-01 0.21470391E 01 0.18249833E 00 -0.21470391E 01

CH(3) SIZE = 3 BY 3

0.97946620E 01 -0.17477092E 01 -0.28092038E 00 -0.49169357E 01 -0.10072808E 02 0.36338994E 01
-0.27743458E 01 0.12954607E 01 0.98700978E 01 -0.16044629E 00 -0.59029569E 01 -0.10200663E 01
-1.36700891E 00 0.76521571E-01 0.17364282E 01 0.12415739E 00 -0.13503692E 01 -0.27478038E 00

CH(4) SIZE = 3 BY 3

0.04670092E 01 -0.16173923E 01 -0.25165163E 00 -0.43767697E 01 -0.97110947E 01 0.33925828E 01
-0.37191645E 01 0.11016132E 01 0.92127358E 01 -0.10785272E 00 -0.53454694E 01 -0.88644213E 00
-0.35860909E 00 0.62720004E-01 0.16545232E 01 0.96378678E-01 -0.12837247E 01 -0.22678080E 00

CH(5) SIZE = 2 BY 2

0.14999422E 02 -0.36273400E 01 -0.15444298E 02 0.13996130E 01
0.22725642E-01 0.18180512E 01 0.11362820E 00 -0.18180512E 01

AERODYNAMIC INFLUENCE COEFFICIENTS BY INCOMPRESSIBLE STRIP THEORY WITHOUT CAMBER

1/K(R) = 0.800000E 01

NUMBER OF STRIPS = 5

CH(1) SIZE = 2 BY 2

1.39832077E 02 -0.90686625E 01
 1.10178752E 00 0.36597757E 01

CH(2) SIZE = 2 BY 2

1.40237128E 02 -0.96322888E 01
 1.74945082E-01 0.34352627E 01

CH(3) SIZE = 3 BY 3

6.26456532E 02 -0.41958733E 01
 -0.08007894E 01 0.21206943E 01
 -0.03579820E 00 0.84207310E-01
 -0.29932875E 02 0.95719907E 01
 -0.14983438E 02 -0.17745148E 01
 -0.35742555E 01 -0.34774754E 00

CH(4) SIZE = 3 BY 3

6.25529613E 02 -0.37993414E 01
 -0.06444943E 01 0.18125570E 01
 -0.09015689E 00 0.61833520E-01
 -0.28610311E 02 0.86573733E 01
 -0.13552388E 02 -0.15515176E 01
 -0.33966297E 01 -0.27883805E 00

CH(5) SIZE = 2 BY 2

0.41714949E 02 -0.86152389E 01
 0.22725642E-01 0.29088820E 01

AEROY-DYNAMIC INFLUENCE COEFFICIENTS BY INCOMPRESSIBLE STRIP THEORY WITHOUT GAMMA

OUTPUT DATA

1/A(N) = 0.

NUMBER OF STRIPS = 5

CH(1) SIZE = 2 BY 2

0.28148023E 00 0.
0.10178752E 00 0.

0.10178752E 00 0.
0.21443998E 00 0.

CH(2) SIZE = 2 BY 2

0.21236187E 00 0.
0.74945982E-01 0.

0.74945982E-01 0.
0.18249838E 00 0.

CH(3) SIZE = 3 BY 3

0.16356951E 00 0.
0.55000439E-01 0.
0.88108998E-02 0.

0.55000183E-01 0.
0.89577124E-01 0.
0.18261766E-01 0.

CH(4) SIZE = 3 BY 3

0.11978942E 00 0.
0.39963172E-01 0.
0.68239803E-02 0.

0.39962984E-01 0.
0.66564077E-01 0.
0.14253438E-01 0.

CH(5) SIZE = 2 BY 2

0.86357438E-01 0.
0.22725642E-01 0.

0.22725643E-01 0.
0.11362820E 00 0.

0.68240997E-02 0.
0.14253438E-01 0.
0.83426490E-02 0.

AEROHYDRAULIC INFLUENCE COEFFICIENTS BY INCOMPRESSIBLE STRIP THEORY WITHOUT CAMBER

OUTPUT DATA

STEADY CASE

1/(ACR) = LARGE NUMBER (OMEGA = 0)

NUMBER OF STRIPS = 5

CH(1) SIZE = 2 BY 2

0.24246272E 01
0. -0.24286272E 01
0.

CH(2) SIZE = 2 BY 2

0.24051091E 01
0. -0.24051091E 01
0.

CH(3) SIZE = 3 BY 3

0.14363675E 01 0.52915428E 00 -0.19655218E 01
0.47013872E 00 0.11520449E 01 -0.68190620E 00
-0.38354762E-01 0.22013051E 00 -0.15177575E 00

CH(4) SIZE = 3 BY 3

0.13648245E 01 0.45073082E 00 -0.1815553E 01
-0.46112590E 00 0.10775839E 01 -0.6163779E 00
-0.37526021E-01 0.20946889E 00 -0.17194287E 00

CH(5) SIZE = 2 BY 2

0.23561944E 01
0. -0.23561944E 01
0.

SAMPLE PROGRAM CHECK FROM AIC STRIP THEORY REPORT

NEW COMPUTER PROGRAM, JULY 1969. ANALYSIS INCLUDES CAMBER

AIR DYNAMIC INFLUENCE COEFFICIENTS BY INCOMPRESSIBLE STRIP THEORY WITH CAMBER

INPUT DATA

5 STRIPS

4 REDUCED FREQUENCIES

COSINE LAMBDA = 0.75000E 00
REFERENCE SECT-CHORD = 0.60000E 01
SINI-SPAN = 0.20000E 02
SURFACE AREA = 0.200000E 03
C GAP = 0.150000E 02

STRIP NO.	DELTA Y (1)	Q(1)	Z1(1)	Z2(1)	Z3(1)	CA(1)
1	0.48000E 01	1.75000E 01	0.30000E 00	0.55000E 00	0.80300E 00	0.
2	0.36000E 01	0.64000E 01	0.30000E 00	0.55000E 00	0.77900E 00	0.
3	0.34000E 01	0.62000E 01	0.30000E 00	0.55000E 00	0.73400E 00	0.32084E 01
4	0.32000E 01	0.55000E 01	0.30000E 00	0.55000E 00	0.72300E 00	0.30470E 01
5	0.30000E 01	0.50000E 01	0.30000E 00	0.55000E 00	0.70000E 00	0.
1/K(R) =	0.50000E 01	0.50000E 01	0.	-0.10000E 01		

OUTPUT DATA AERODYNAMIC INFLUENCE COEFFICIENTS BY INCOMPRESSIBLE STRIP THEORY WITH CARREL

1/A (K) = 0.500000E 01

NUMBER OF STRIPS = 5

CH (1) SIZE = 3 BY 3

0.36610055E 02	0.31172043E 01	-0.16775730E 02	-0.29771671E 02	-0.21285244E 02	0.15614888E 02
-0.48793316E 02	0.19222220E 01	0.53485538E 02	0.19564602E 02	-0.3235831E 01	-0.12963095E 02
0.31263940E 01	-0.28862023E 00	0.12553154E 02	-0.37162614E 01	-0.16022285E 02	0.16447257E 01

CH (2) SIZE = 3 BY 3

0.33329764E 02	0.38250940E 01	-0.87614241E 01	-0.27886900E 02	-0.25883718E 02	0.17696800E 02
-0.46498572E 02	0.72329661E 00	0.46338436E 02	0.19553389E 02	0.14950370E 01	-0.14990942E 02
0.23734164E 01	-0.22441665E 01	0.13326042E 02	-0.50681930E 01	-0.21074719E 02	0.26868301E 01

CH (3) SIZE = 4 BY 4

0.37542058E 02	0.19668808E 01	-0.36328233E 02	-0.36794363E 02	0.13684806E 02	0.19991082E 01	-0.16107109E 02	0.71380384E 01
-0.57682258E 02	0.29776308E 01	0.81677783E 02	0.98540570E 01	-0.38122027E 02	0.19560618E 00	0.11495902E 02	-0.72777999E 01
0.16378388E 02	-0.18627305E 01	-0.14629442E 02	-0.12344600E 01	0.34084900E 02	-0.23474759E 01	-0.11364599E 02	0.27535622E 01
-0.30832350E 01	0.251697617E 00	0.61159590E 01	-0.10181037E 01	-0.37442037E 01	0.70178674E 00	-0.13503692E 01	-0.27478038E 00

CH (4) SIZE = 4 BY 4

0.34882550E 02	0.25883140E 01	-0.31265324E 02	-0.17518209E 02	0.11702643E 02	0.34475332E 01	-0.15865430E 02	0.66463180E 01
-0.55153984E 02	0.15895272E 01	0.75517445E 02	0.11891923E 02	-0.32401484E 02	-0.15063109E 01	0.12241208E 02	-9.99751492E 01
0.16015774E 02	-0.10847127E 01	-0.17908813E 02	-0.31302309E 01	0.12822244E 02	-0.13049694E 01	-0.11432342E 02	0.28349720E 01
-0.30361922E 01	0.36277633E 00	0.66443279E 01	-0.71553770E 00	-0.21111120E 01	0.51185963E 00	-0.12837247E 01	-0.22678079E 00

CH (5) SIZE = 3 BY 3

0.23648804E 02	0.63502504E 01	0.31016181E 02	-0.59925893E 02	-0.53573112E 02	0.29175878E 02
-0.35841466E 02	-0.37920034E 01	-0.81615307E 01	0.35788049E 02	0.44311284E 02	-0.29937625E 02
-0.36316681E 01	0.19230944E 01	0.57362014E 02	-0.19963003E 02	-0.64332519E 02	0.11262499E 02

OUTPUT DATA

AIR DYNAMIC INFLUENCE COEFFICIENTS BY INCOMPRESSIBLE STRIP THEORY WITH CARRIER

1/1(R) = 0.890000E 01

NUMBER OF STRIPS = 5

CH(1) SIZE = 3 BY 3

0.89183514F 02 0.883685546E 01 -0.105333011F 02 -0.618827945E 02 -0.72262853E 02 0.42926537E 02
 -0.12160237E 03 0.55531245E 01 0.11838210E 03 0.442332852E 02 0.55881215E 01 -0.34507146E 02
 0.64877301F 01 0.42059273E 00 0.309991893E 02 -0.13521394E 02 -0.47211779E 02 0.05135183E 01

CH(2) SIZE = 3 BY 3

0.80190393F 02 0.10502727E 02 0.38819500E 03 -0.88709059E 02 -0.86155313E 02 0.47103389E 02
 -0.11491744F 03 -0.25299231E 01 0.05383334E 02 0.51656157E 02 0.20528141E 02 -0.39788363E 02
 0.41066501F 03 0.16403825E 01 0.50950727F 02 -0.17372520F 02 -0.01863086E 02 0.11485382E 02

CH(3) SIZE = 4 BY 4

0.92554308F 02 0.56081317E 01 -0.7166752F 02 -0.39281267E 02 0.31541381E 02 0.49590108E 01
 -0.14314310F 03 0.25413066E 01 0.10778000E 03 0.26425820E 02 -0.78840972E 02 -0.46406707E 00
 0.38884952F 02 -0.19883800E 01 -0.34559617E 02 -0.73107602E 01 0.31516209E 02 -0.35848197E 01
 -0.717950546F 01 0.86046635E 00 0.14555507F 02 -0.17975546E 01 -0.37641618E 01 0.11542485E 01
 -0.48794601E 02 0.18688290E 02 -0.36355336E 02 -0.18901490E 02
 -0.32476849E 02 0.88186769E 01 -0.35742330E 01 -0.34774754E 00

CH(4) SIZE = 4 BY 4

0.84317828F 02 0.66752307E 01 -0.61832395E 02 -0.540554233E 02 0.25412351E 02 0.83333024E 01
 -0.13662938F 03 -0.15918427F 01 0.17689874E 03 0.30880670E 02 -0.76551568E 02 -0.45618669E 01
 0.37858638F 02 -0.4545920F 02 -0.34296156E 02 -0.10937692E 02 0.28312179E 02 -0.85528835E 00
 -0.74197341F 01 0.61821584E 00 0.15780112E 02 -0.13233033F 01 -0.48883724E 01 0.86526887E 00
 -0.47584237E 02 0.16918988E 02 -0.38123989E 02 -0.17678654E 02
 -0.32782464E 02 0.78735235E 01 -0.33966297E 01 -0.27883885E 00

CH(5) SIZE = 3 BY 3

0.48114194F 02 0.16016425E 02 0.11870997E 03 -0.90155584E 02 -0.16026764E 03 0.72448255E 02
 -0.81418120F 02 -0.12789446F 02 -0.66155767E 02 0.99048458E 02 0.14928749E 03 -0.77472288E 02
 -0.13842803F 02 0.67467207E 01 0.10838364E 03 -0.46648372E 02 -0.18538643E 03 0.34871735E 02

OUTPUT DATA
AERODYNAMIC INFLUENCE COEFFICIENTS BY INCOMPRESSIBLE STRIP THEORY WITH GAMMA

$1/\alpha(R) = 0.$

NUMBER OF STRIPS = 5

CH(1) SIZE = 3 BY 3

0.49656010E 00 0.	-0.22741400E 00 0.	0.16277974E 00 0.
-0.22741400E 00 0.	0.28626741E 00 0.	-0.79865826E-01 0.
0.16277973E 00 0.	-0.79865810E-01 0.	0.28626741E 00 0.

CH(2) SIZE = 3 BY 3

0.39098527E 00 0.	-0.20870270E 00 0.	0.15649452E 00 0.
-0.20870270E 00 0.	-0.25629107E 00 0.	-0.1134101E 00 0.
0.15649455E 00 0.	-0.1134100E 00 0.	0.25629107E 00 0.

CH(3) SIZE = 4 BY 4

0.65127079E 00 0.	-0.14816247E 01 0.	0.314545134E 01 0.	-0.34857458E 00 0.
-0.14816256E 01 0.	0.4978644E 01 0.	-0.39135078E 01 0.	0.84535827E 00 0.
0.314545148E 01 0.	-0.39135093E 01 0.	0.38952510E 01 0.	-0.46971866E-00 0.
-0.34857500E 00 0.	0.84535904E 00 0.	-0.46971128E 00 0.	0.10488987E-01 0.

CH(4) SIZE = 4 BY 4

0.48441975E 00 0.	-0.11604174E 01 0.	0.11366484E 01 0.	-0.25336185E 00 0.
-0.11604182E 01 0.	0.36740302E 01 0.	-0.32031635E 01 0.	0.63814949E 00 0.
0.11366495E 01 0.	-0.32031645E 01 0.	0.25616953E 01 0.	-0.36371810E 00 0.
-0.4844222E 00 0.	0.63815007E 00 0.	-0.36371043E 00 0.	0.83426490E-02 0.

CH(5) SIZE = 3 BY 3

0.20890262E 00 0.	-0.19198618E 00 0.	0.14102506E 00 0.
-0.19198620E 00 0.	0.31561365E 00 0.	-0.27088900E 00 0.
0.14102505E 00 0.	-0.27088958E 00 0.	0.32462153E 00 0.

AERODYNAMIC INFLUENCE COEFFICIENTS BY INCOMPRESSIBLE STRIP THEORY WITH CAMBER

OUTPUT DATA

STEADY CASE

$1/r(R) = \text{LARGE NUMBER (OMEGA} = 0)$

NUMBER OF STRIPS = 5

CH(1) SIZE = 3 BY 3

0.35531636E 01	0.22583468E 01	-0.61336324E 01
-0.52130445E 01	0.27982983E 01	0.24147962E 01
0.92946494E-01	0.30480078E 01	-0.31409542E 01

CH(2) SIZE = 3 BY 3

0.30654865E 01	0.34510233E 01	-0.69165098E 01
-0.48094739E 01	0.14274260E 01	0.33820480E 01
-0.72849490E-01	0.40780093E 01	-0.40051199E 01

CH(3) SIZE = 4 BY 4

0.55246984E 01	-0.11260617E 02	0.13108536E 02	-0.73726168E 01
-0.93548383E 01	0.2782725E 02	-0.30692469E 02	0.12219582E 02
0.25541705E 01	-0.11015882E 02	0.15956105E 02	-0.74943934E 01
0.15907057E 00	-0.47821159E 00	0.50001676E 00	-0.10177575E 00

CH(4) SIZE = 4 BY 4

0.50323672E 01	-0.10870670E 02	0.12785028E 02	-0.69473247E 01
-0.88418380E 01	0.28315548E 02	-0.31496604E 02	0.12822894E 02
0.24066617E 01	-0.11544082E 02	0.16644923E 02	-0.75075826E 01
0.155504934E 00	-0.44170913E 00	0.49860265E 00	-0.11942866E 00

CH(5) SIZE = 3 BY 3

0.13916275E 01	0.10249445E 02	-0.11641073E 02
-0.28274337E 01	-0.84822983E 01	0.11309732E 02
-0.12149125E 01	0.12370020E 02	-0.11155107E 02

2.5 PROGRAM LISTING

```

S      FORTRAN DECK
CHAIN  PROGRAM STRIP - AERODYNAMIC INFLUENCE COEFFICIENTS BY
C      INCOMPRESSIBLE STRIP THEORY.
C      WITH OR WITHOUT CAMBER
C      WITH OR WITHOUT A CONTROL SURFACE
C      NCAM = 0, CAMBER NOT CONSIDERED      NCAM = 1, CAMBER INCLUDED
C      Z1, Z2, Z3 ARE PERCENT CHORDS OF C.P. 1,2,3 RESP. ON EACH STRIP.
C      A NEGATIVE Z2 INDICATES PRESENCE OF A CONTROL SURFACE ON THE STRIP
C
      DIMENSION TITLE(24),X1(25),X2(25),X3(25),Z1(25),Z2(25),Z3(25),
      1AM(3,3,25),RM(3,6),NU(25),B(25),SCALER(25),CH(4,8,25),PARTA(4,8),
      2CA(25),C(25),JOX(30),ANT(3,3,25),DELTAY(25),D(25),EYOX(7),
      3THR1(25),TAP1(25),TAI2(25),TBR3(25),TBI2(25),THR2(25),TAR2(25),
      4TRP1(25),TRP4(25),TRI3(25),THI1(25),TAI1(25),TBR2(25),TBI1(25),
      5ERR1(25),ERR3(25),ELB12(25),EMBR1(25),EMRI1(25),ELBR2(25),
      6TR11(25),ERR13(25),EMRP2(25),EKR(50),Z2A(25),XL(25),XH(25),XT(25),
      7HI1(25),HL2(25),HL3(25),HT1(25),HT2(25),HT3(25),CAH(4,4,25),
      8CON(25),HH1(25),HH2(25),HH3(25),CAM1(4,4,25),XN1(25),XN2(25),
      9XN3(25),XN4(25),XN5(25),T1(25),T2(25),T3(25),T4(25),T5(25),CM(4,8)
C
1  FORMAT(4I4/5E12.8)
2  FORMAT(1H1)
3  FORMAT(5E12.8)
4  FORMAT(1H0 10X,81H AERODYNAMIC INFLUENCE COEFFICIENTS BY INCOMPRES
5  ISIBLE STRIP THEORY WITHOUT CAMBER//)
6  FORMAT(1H0 54X,11H INPUT DATA //1H 48X,12,7H STRIPS/1H 48X,12,
7  122H REDUCED VELOCITIES //1H 45X,15HCOSINE LAMBDA = 1E14.6/1H 38
8  2,22HREFERENCE SEMI-CHORD = 1E14.6/1H 49X,11HSEMI-SPAN = 1E14.6/
9  31H 46X,14HSURFACE AREA = 1E14.6/1H 53X,7HC BAR = 1E14.6//)
10 FORMAT(14H0 1/K(R) = 2E18.5,4E15.5/(14X,2E18.5,4E15.5))
11 FORMAT(6E12.8)
12 FORMAT(1H0 4X,9HSTRIP NO.,7X,11HDELTA Y (1),1X,4HB(1),
13 110X,5HZ1(1),10X,5HZ2(1),10X,5HZ3(1),10X,4HD(1),10X,5HCA(1)//(19,
14 2,23.5,E18.5,5E15.5))
15 FORMAT(1H0 48X,8H1/K(R) = E13.6)
16 FORMAT(1H0 53X,11HSTEADY CASE//43X,33H1/K(R) = LARGE NUMBER (OMEGA
17 1 = 0))
18 FORMAT(1H 20X,4E18.8)
19 FORMAT(12A6)
20 FORMAT(1H0 48X,19HNUMBER OF STRIPS = 12)
21 FORMAT(12H 2E16.8,1X, 2E16.8, 1X, 2E16.8)
22 FORMAT(53H0 CH(12,
23 19H) SIZE = 1L,4H BY 11//)
24 FORMAT(1H1 12A6//1X,12A6//)
25 FORMAT(1H 2E16.8,1X,2E16.8,1X,2E16.8,1X,2E16.8)
C
216 FORMAT(1H0 22X,78H AERODYNAMIC INFLUENCE COEFFICIENTS BY INCOMPRES
217 ISIBLE STRIP THEORY WITH CAMBER//)
218 FORMAT(1H0 4X,9HSTRIP NO.,7X,11HDELTA Y (1),11X,4HB(1),10X,5HZ1(1)
219 1,10X,5HZ2(1),10X,5HZ3(1),10X,5HCA(1)//(19,E23.5,E18.5,4E15.5))
220 READ INPUT DATA AND PRINT
221 READ(5,12)(TITLE(I),I=1,24)
222 WRITE(6,16)(TITLE(I),I=1,24)
223 READ(5,1) NCAM,ISZ,JSZ,NOPUNJ,COSLMD,BR,S,CAPS,CBAR
224 READ(5,3)(DELTAY(I),B(I),Z1(I),Z2(I),Z3(I),I=1,ISZ)
225 READ(5,7)(ERR(I),I=1,JSZ)
226 DO 50 I=1,157
227 22A(I)=ABS(Z2(I))
228 IF(NCAM.EQ.1) GO TO 300
229 WRITE(6,4)

```

	GO TO 310	160
300	WRITE(6,216)	165
310	WRITE(6,5) ISZ,JSZ,COSLMD,HR,S,CAPS,CBAR	170
	CAMBER OR NO CAMBER OPTIONS	184
	IF(NCAM.EQ.1) GO TO 500	185
	DO 55 I=1,ISZ	190
	Q(I)=2.0*B(I)*(Z2A(I)-Z1(I))	195
	IF(Z2(I).LT.0.0) GO TO 17	200
	CA(I)=0.0	205
	GO TO 55	206
17	CA(I)=2.0*B(I)*(1.0-Z2A(I))	210
55	CONTINUE	225
	GO TO 550	226
500	DO 58 I=1,ISZ	230
	X1(I)= 2.0*B(I)*Z1(I)	235
	X2(I)= 2.0*B(I)*Z2A(I)	240
	X3(I)= 2.0*B(I)*Z3(I)	245
	XI(I)=0.0	250
	YH(I)= B(I)	255
	XT(I)= 2.0*B(I)	260
	IF(Z2(I).LT.0.0) GO TO 51	265
	CA(I)=0.0	270
	GO TO 58	271
51	CA(I)=2.0*B(I)*(1.0-Z3(I))	275
58	CONTINUE	290
	WRITE(6,220)(I, DELTAY(I),B(I),Z1(I),Z2A(I),Z3(I),CA(I),I=1,ISZ)	291
	GO TO 551	292
550	WRITE(6,8)(I,DELTA Y(I),B(I),Z1(I),Z2A(I),Z3(I),D(I),CA(I),I=1,ISZ)	294
551	WRITE(6,6) (EXR(J),J=1,JSZ)	295
	DO CA=0	296
	DO 23 I=1,ISZ	300
	IF(NCAM.EQ.1) GO TO 510	301
	IF (CA(I)) 21,22,21	305
510	IF(CA(I))511,512,511	306
21	QU(I)=3	310
	DO CA=1	315
	GO TO 23	320
511	QU(I)=4	321
	NOCA=1	322
	GO TO 23	323
512	QU(I)=3	324
	GO TO 23	325
22	QU(I)=2	326
23	CONTINUE	330
	PI = 3.14159265	335
	PI11 = 1.0/PI	340
	PI112 = PI11**2	345
	IF(NCAM.EQ.1) GO TO 600	350
	SCA CON =(PI* COSLMD)/((HR**2) *S)	355
DO 26 I=1,ISZ		360
	SCAIFR(I) = SCA CON * (B(I) **2) * DELTA Y(I)	365
	R1D = B(I)/Q(I)	370
	AM(1,1,I)= 1.0	375
	AM(1,2,I)=-1.0*R1D	380
	AM (2,1,I) =0.0	385
	AM (2,2,I) =R1D	390
	IF (CA(I)) 24,25,24	395
24	AM (1,3,I) =R1D	400
	R1CA = B(I)/CA(I)	410
	AM (2,3,I) =-R1D-R1CA	415
	AM (3,1,I) =0.0	420

```

      AM (3,2,I) = 0.0                                425
      AM (3,3,I) = R1CA                                430
25  N= NU(1)                                           435
      DO 26 K=1,N                                       440
      DO 26 L=1,N                                       445
26  AMT (K,L,I) = AM(L,K,I)*SCALER(I)               450
      GO TO 41                                           459
600 CAMCON=(P1*COS(LMD))/( (BR**2)*S)               460
      DO 610 I=1,ISZ                                    465
      CON(I)=CAMCON*(R(I)**2)*DELTAY(I)               470
      HL1(I)=(XL(I)-X2(I))*(X1(I)-X3(I))/((X1(I)-X2(I))*(X1(I)-X3(I))) 475
      HT1(I)=(XT(I)-X2(I))*(X1(I)-X3(I))/((X1(I)-X2(I))*(X1(I)-X3(I))) 480
      HL2(I)=(XL(I)-X1(I))*(X1(I)-X3(I))/((X2(I)-X1(I))*(X2(I)-X3(I))) 485
      HT2(I)=(XT(I)-X1(I))*(X1(I)-X3(I))/((X2(I)-X1(I))*(X2(I)-X3(I))) 490
      HL3(I)=(XL(I)-X1(I))*(X1(I)-X2(I))/((X3(I)-X1(I))*(X3(I)-X2(I))) 495
      HT3(I)=(XT(I)-X1(I))*(X1(I)-X2(I))/((X3(I)-X1(I))*(X3(I)-X2(I))) 500
      HHL1(I)=(XH(I)-X2(I))*(XH(I)-X3(I))/((X1(I)-X2(I))*(X1(I)-X3(I))) 505
      HH2(I)=(XH(I)-X1(I))*(XH(I)-X3(I))/((X2(I)-X1(I))*(X2(I)-X3(I))) 510
      HH3(I)=(XH(I)-X1(I))*(XH(I)-X2(I))/((X3(I)-X1(I))*(X3(I)-X2(I))) 515
      CAM(1,1,I)=.75*HL1(I)+.25*HT1(I)               520
      CAM(1,2,I)=.75*HL2(I)+.25*HT2(I)               525
      CAM(1,3,I)=.75*HL3(I)+.25*HT3(I)               530
      CAM(2,1,I)=.5*(HT1(I)-HL1(I))                   535
      CAM(2,2,I)=.5*(HT2(I)-HL2(I))                   540
      CAM(2,3,I)=.5*(HT3(I)-HL3(I))                   545
      CAM(3,1,I)=HH1(I)-.5*(HL1(I)+HT1(I))            550
      CAM(3,2,I)=HH2(I)-.5*(HL2(I)+HT2(I))            555
      CAM(3,3,I)=HH3(I)-.5*(HL3(I)+HT3(I))            560
      IF (CA(I)).602,605,607                             565
602 CAM(1,4,I)=0.0                                     570
      CAM(2,4,I)=0.0                                     575
      CAM(3,4,I)=0.0                                     580
      CAM(4,1,I)=-R(I)*(X3(I)-X2(I))/((X1(I)-X2(I))*(X1(I)-X3(I))) 585
      CAM(4,2,I)=-R(I)*(X3(I)-X1(I))/((X2(I)-X1(I))*(X2(I)-X3(I))) 590
      CAM(4,3,I)=-R(I)*(2.0*X3(I)-X1(I)-X2(I))/((X3(I)-X1(I))*(X3(I)-X2(I))) 595
      CAM(4,4,I)=R(I)/CA(I)                             600
      CAM(4,4,I)=R(I)/CA(I)                             605
605 N=NU(I)                                           610
      DO 610 K=1,N                                       615
      DO 610 L=1,N                                       620
610 CAMT(K,L,I)=CAM(L,K,I)*CON(I)                   625
41  IF (NOCA) 31,31,27                                630
27  IF (JSZ-1) 29,28,29                                635
28  IF (EKR(1)) 30,29,29                                640
29  CALL ORANGE                                         645
      J (IS7,CA,R,THR1,THR2,THI1,TAR1, TAR2,TAI1,TAI2, TBR1,TBR2,TBR3, 650
      2TBR4, TH11, TH12, TH13, ELBR1, ELBR2, ELBR3, ELBI1, ELBI2,ELBI3, 655
      3FMBR1, FMBR2, FMB11 )                           660
30  IF (NCAM)31,31,515                                661
515 CALL CSCAM (IS7,CA,P,XN1,XN2,XN3,XN4,XN5, [1,T2,T3,T4,T5) 662
31  CONTINUE                                           665
      ISFO=0                                             666
      DO 70 J=1,JSZ                                       670
      DO 60 I=1,ISZ                                       675
      I1K=EKR(J)*PR/R(I)                                 680
      IF (EKR(J)) 37,33,34                               685
37  IF (NCAM.FO.1) GO TO 91                             686
      GO TO 90                                           687
33  C=0.5                                               690
      G=0.0                                               695

```

```

GOTO 35
34 EK NOW=1.0/E1K
CALL RESSEL (EK NOW, 1, EJOX, FYOX, 0)
E = (EJOX(2) * (FYOX(2) + FYOX(1)) + EYOX(2) * (EYOX(2) - EJOX(1)))
1/ ((FYOX(2) + FYOX(1)) ** 2.0 + (EYOX(2) - EJOX(1)) ** 2.0)
E = -1.0 * (EYOX(2) * EYOX(1) + EJOX(2) * EJOX(1)) / ((EJOX(2) + EYOX(1))
1) ** 2.0 + (FYOX(2) - EJOX(1)) ** 2.0)
35 CONTINUE
EK2=F1K*F1K
QM(1,1)=1.0+2.0*G*F1K
QM(1,2)=-2.0*F*E1K
QM(1,3)=0.5+2.0*G*E1K-2.0*F*EK2
QM(1,4)=-F1K-2.0*F*F1K-2.0*G*EK2
QM(2,1)=0.5
QM(2,2)=0.0
QM(2,3)=0.375
QM(2,4)=-E1K
F(CA(1)) 36,540,36
36 QM(1,5)=G*E1K*FLR1(1)-F*EK2*ELR2(1)+ELR3(1)
QM(1,6)=-F*F1K*ELR1(1)-G*EK2*FLR2(1)+F1K*ELR3(1)
QM(2,5)=ENBR1(1)-EK2*FMR2(1)
QM(2,6)=-F1K*FMR1(1)
QM(3,1)=THR1(1)+G*F1K*THR2(1)
QM(3,2)=-F*F1K*THR1(1)
QM(3,3)=TAR1(1)+(G*F1K-F*EK2)*TAR2(1)
QM(3,4)=-F*F1K-G*EK2*TAR1(1)+F1K*TAR2(1)
QM(3,5)=G*F1K*THR1(1)-F*EK2*THR2(1)+TAR3(1)
1-FK2*THR4(1)
QM(3,6)=-F*F1K*THR1(1)-G*EK2*THR2(1)+F1K*THR3(1)
540 F(NCAM,F0,1) GO F0 541
GOTO 40
541 QM(1,1)=PM(1,1)
QM(1,2)=PM(1,2)
QM(1,3)=BM(1,3)
QM(1,4)=BM(1,4)
QM(2,1)=BM(2,1)
QM(2,2)=BM(2,2)
QM(2,3)=BM(2,3)
QM(2,4)=BM(2,4)
QM(1,5)=.75+F1K*G+2.0*FK2*F
QM(1,6)=-F1K*F+2.0*FK2*G
QM(2,5)=.375+FK2
QM(2,6)=.5*F1K
QM(3,1)=.75+F1K*G
QM(3,2)=-F1K*F
QM(3,3)=.375+F1K*G-FK2*F
QM(3,4)=-F1K*F-FK2*G
QM(3,5)=.5833333+.5*E1K*G+.5*FK2+FK2*F
QM(3,6)=-.5*F1K*F+FK2*G
F(1A(1)) 542,40,542
542 QM(1,7)=BM(1,5)
QM(1,8)=BM(1,6)
QM(2,7)=BM(2,5)
QM(2,8)=BM(2,6)
QM(3,7)=-F*FK2*XM1(1)+G*E1K*XM2(1)-FK2*XM3(1)+XM5(1)
QM(3,8)=-G*FK2*XM1(1)-F*E1K*XM2(1)+E1K*XM3(1)
QM(4,1)=BM(3,1)
QM(4,2)=BM(3,2)
QM(4,3)=BM(3,3)
QM(4,4)=BM(3,4)
QM(4,5)=-F*FK2*T1(1)+G*F1K*T2(1)-EK2*T3(1)+T5(1)

```

```

      CM(4,6)=-G*FK2*T1(I)-F*E1K*T2(I)-E1K*T4(I)
      CM(4,7)=BM(3,5)
      CM(4,8)=BM(3,6)
      GO TO 40
C
      STEADY CASE OPTION
90  N=NU(I)
      N2=N*2
      DO 38 JJ=1,N2
      DO 38 II=1,N
38  CM(II,JJ)=0.0
91  CORR=(2.0*S*CAPR/CAPS)*BR*BR/(B(I)*B(I))
      CM(1,3)=-2.0*CORR
      IF(CA(I))39,92,39
39  CT(I)=1.0-CA(I)/n(I)
      PH=ARCS(-C(I))
      COSP=-C(I)
      SINP=SIN(PH)
      CM(3,3)=-PI11*((PI-PH)*(-1.0+COSP+COSF)+(2.0-COSP)*SINP)*CORR
      CM(1,5)=-2.0*PI11*(PI-PH+SINP)*CORR
      CM(2,5)=-PI11*SINP*(1.0-COSP)*CORR
      CM(3,5)=CM(3,3)*PI11*(PI-PH+SINP)-PI11*PI11
1  CM(1,7)=SINP*(1.0-COSP)*(PI-PH-SINP)*CORR
92  IF(NCAM.EQ.1)GO TO 93
      GO TO 40
93  N=NU(I)
      N2=N*2
      DO 94 JJ=1,N2
      DO 94 II=1,N
94  CM(II,JJ)=0.0
      CM(1,3)=BM(1,3)
      CM(1,5)=2.0*CORR
      CM(2,5)=CORR
      CM(3,3)=-1.0*CORR
      CM(3,5)=CORR*1.0
      IF(CA(I))95,40,95
95  CM(1,7)=BM(1,5)
      CM(2,7)=BM(2,5)
      CM(4,3)=BM(3,3)
      CM(4,7)=BM(3,5)
      CM(3,7)=CORR*(-XN1-XN3)
      CM(4,5)=CORR*(1-I1-I3)
40  CONTINUE
      IF(NCAM.EQ.1)GO TO 580
C
      GENERATE AIC MATRICES, PRINT RESULTS AND PUNCH OUTPUT.
      CALL WMATH1(CA,BM,APT,CH1,NU,1,3,6)
      GO TO 60
580  CALL WMATH1(CAM1,CM,CAM,CH1,NU,1,4,8)
60  CONTINUE
      WRITE(6,2)
      IF(NCAM.EQ.1)GO TO 800
      WRITE(6,4)
      GO TO 801
800  WRITE(6,2E6)
801  IF(FKR(J)) 61,62,62
61  WRITE(6,10)
      GO TO 63
62  WRITE(6,9) FKR(J)
63  WRITE(6,15) IS7
      DO 68 I=1,IS7
        WRITE(6,15) I,NU(I),NU(I)

```

995
 1000
 1005
 1006
 1009
 1010
 1020
 1025
 1030
 1035
 1036
 1045
 1050
 1060
 1065
 1070
 1075
 1085
 1090
 1095
 1100
 1105
 1106
 1107
 1108
 1109
 1110
 1111
 1112
 1113
 1114
 1115
 1116
 1117
 1118
 1119
 1120
 1121
 1122
 1123
 1124
 1125
 1126
 1127
 1129
 1130
 1133
 1134
 1135
 1136
 1137
 1138
 1139
 1140
 1145
 1150
 1155
 1160
 1165
 1170

I=NI(I)	1175
N2=N*2	1180
IF(IKR(J)) 64,66,66	1185
64 GO 65 K=1,N	1190
65 WRITE(6,11) (CH1(K,I,I),I=1,N2,2)	1195
GO TO 68	1200
66 GO 67 K=1,I	1205
IF(NCAP.EQ.1) GO TO 80	1210
WRITE(6,14) (CH1(K,I,I),I=1,N2)	1215
GO TO 67	1220
80 WRITE(6,85) (CH1(K,I,I),I=1,N2)	1225
67 CONTINUE	1230
68 CONTINUE	1235
IF(NOPURJ) 70,69,70	1240
69 ISFII=KSFII+1	1245
CALL PURJ (IKR(J),NI,CH1,ISZ,NSFO)	1250
70 CONTINUE	1255
GO TO 20	1260
END	

* FORTRAN DECK
 CORDAC: COMPUTE PARTS OF OSCILLATORY COEFFICIENTS WHICH ARE
 C INVARIANT WITH REDUCED VELOCITY.

```

SUBROUTINE ORANGE
  DIMENSION CA(6), THR1, THR2, TH11, TAR1, TAR2, TA11, TA12, TBR1, TBR2, TBR3,
  TBR4, TB11, TB12, TB13, FLR1, FLR2, ELR1, ELR2, ELR3, FLB1, FLB2, FLB3,
  FBR1, FBR2, FBR3
  DIMENSION R(12, CA(1), THR1(1), THR2(1), TH11(1), TAR1(1), TAR2(1),
  TA11(1), TA12(1), TBR1(1), TBR2(1), TBR3(1), TBR4(1), TB11(1), TB12(1),
  TB13(1), FLR1(1), FLR2(1), FLR3(1), FLB1(1), FLB2(1), FLB3(1),
  FBR1(1), FBR2(1), FBR3(1), C(25)
  T = 3.14159265
  P111 = 1.0/P1
  P112 = P111*x2
  DO 50 I=1,147
    P(CA(I)) = 6.54, 56
    C(I) = 1.0-CA(I) / R(11)
    PH = APC*(C(I))
    COSP = -1.0+C(I)
    SINP = SIN(PH)
    COS2 = COSC * C2
    COS3 = COSC * COS2
    SIN2 = SINP * C2
    SIN3 = SINP * C3
    PH = (PI-PH) * (-1.0 + 2.0*COSP) + (2.0-COSP)*SINP
    PPH = (PI-PH) * (1.0+2.0*COSP)*SINP + (2.0+COSP)
    PPH = (PI-PH) * (0.5+2.0*COSP) + (SINP/3.0) * (8.0+5.0*COSP + 4.0
    1 COS2 - 2.0 * COS3)
    PH1(1) = P111 * ((PI-PH) * COSP + 0.3333 * (2.0 + COS2)*SINP)
    PH2(1) = P111 * PH1(1)
    PH3(1) = P111 * PH2(1)
    PH1(2) = P111 * 0.25 * GR11
    PH2(2) = P111 * PH1(2)
    PH3(2) = P111 * PH2(2)
    PH1(3) = P111 * PH1(3)
    PH2(3) = P111 * PH2(3)
    PH3(3) = P111 * PH3(3)
    PH1(4) = P111 * PH1(4)
    PH2(4) = P111 * PH2(4)
    PH3(4) = P111 * PH3(4)
    PH1(5) = P111 * PH1(5)
    PH2(5) = P111 * PH2(5)
    PH3(5) = P111 * PH3(5)
    PH1(6) = P111 * PH1(6)
    PH2(6) = P111 * PH2(6)
    PH3(6) = P111 * PH3(6)
    PH1(7) = P111 * PH1(7)
    PH2(7) = P111 * PH2(7)
    PH3(7) = P111 * PH3(7)
    PH1(8) = P111 * PH1(8)
    PH2(8) = P111 * PH2(8)
    PH3(8) = P111 * PH3(8)
    PH1(9) = P111 * PH1(9)
    PH2(9) = P111 * PH2(9)
    PH3(9) = P111 * PH3(9)
    PH1(10) = P111 * PH1(10)
    PH2(10) = P111 * PH2(10)
    PH3(10) = P111 * PH3(10)
    PH1(11) = P111 * PH1(11)
    PH2(11) = P111 * PH2(11)
    PH3(11) = P111 * PH3(11)
    PH1(12) = P111 * PH1(12)
    PH2(12) = P111 * PH2(12)
    PH3(12) = P111 * PH3(12)
    PH1(13) = P111 * PH1(13)
    PH2(13) = P111 * PH2(13)
    PH3(13) = P111 * PH3(13)
    PH1(14) = P111 * PH1(14)
    PH2(14) = P111 * PH2(14)
    PH3(14) = P111 * PH3(14)
    PH1(15) = P111 * PH1(15)
    PH2(15) = P111 * PH2(15)
    PH3(15) = P111 * PH3(15)
    PH1(16) = P111 * PH1(16)
    PH2(16) = P111 * PH2(16)
    PH3(16) = P111 * PH3(16)
    PH1(17) = P111 * PH1(17)
    PH2(17) = P111 * PH2(17)
    PH3(17) = P111 * PH3(17)
    PH1(18) = P111 * PH1(18)
    PH2(18) = P111 * PH2(18)
    PH3(18) = P111 * PH3(18)
    PH1(19) = P111 * PH1(19)
    PH2(19) = P111 * PH2(19)
    PH3(19) = P111 * PH3(19)
    PH1(20) = P111 * PH1(20)
    PH2(20) = P111 * PH2(20)
    PH3(20) = P111 * PH3(20)
    PH1(21) = P111 * PH1(21)
    PH2(21) = P111 * PH2(21)
    PH3(21) = P111 * PH3(21)
    PH1(22) = P111 * PH1(22)
    PH2(22) = P111 * PH2(22)
    PH3(22) = P111 * PH3(22)
    PH1(23) = P111 * PH1(23)
    PH2(23) = P111 * PH2(23)
    PH3(23) = P111 * PH3(23)
    PH1(24) = P111 * PH1(24)
    PH2(24) = P111 * PH2(24)
    PH3(24) = P111 * PH3(24)
    PH1(25) = P111 * PH1(25)
    PH2(25) = P111 * PH2(25)
    PH3(25) = P111 * PH3(25)
  50 CONTINUE
  RETURN
  END

```

```

S      FORTRAN DECK
CWMATH1  COMPUTES AERODYNAMIC MATRIX BY PARTITIONS
SUBROUTINE WMATH 1(AH,BH,AMT,CH1,NU,1,M1,M2)
  DIMENSION AH(M1,M1,25),BH(M1,M2),CH1(4,8,25),AMT(M1,M1,25)
  1, PARTA(4,8),NU(1)
  NU1 = NU(1)
  NU2 = NU(1) * 2
  DO 80 K=1,NU1
  DO 80 L=1,NU2
    PART A(K,L) = 0.0
  DO 80 J=1,NU1
  80  PART A(K,L) = PART A(K,L)+AH(K,J,1) * BH(J,L)
  DO 83 K=1,NU1
  DO 81 L=1,NU2,2
    M = (L+1)/2
    CH1 (K,L,1) = 0.0
  DO 81 J=1,NU1
  81  CH1 (K,L,1) = CH1(K,L,1) + PART A (K,2*J-1) * AMT (J,M,1)
  DO 83 L=2,NU2,2
    M = L/2
    CH1 (K,L,1) = 0.0
  DO 83 J=1,NU1
  83  CH1 (K,L,1) = CH1 (K,L,1) + PART A (K,2*J) * AMT (J,M,1)
  RETURN
END

```

3001
3002
3005
3010
3011
3015
3020
3025
3030
3035
3040
3045
3050
3055
3060
3065
3070
3075
3080
3085
3090
3095
3100
3105
3110

```

S      FORTRAN DECK
CARCS    COMPUTES THE ARCCOSINE, IN RADIANS, OF A REAL ARGUMENT,
C
FUNCTION ARCS(X)
  F(Y) = 1.57079633 - .21460184 * X + .08904567 * X**2 - .05072733
  1 * X**3 + .03315246 * X**4 - .02199838 * X**5 + .01261235 * X**6
  2 - .00495706 * X**7 + .00095128 * X**8
  AX = ABS(X)
  IF (AX-1.0) 50,50,40
  40 WRITE (6,45) X
  45 FORMAT (1//7H***** /25H*ERFOR* IN SUBR. ARCS, X=,E11.4,
  133H WHOSE ABS VALUE IS LARGER THAN 1/7H***** /)
  ARCS = 0.
  GO TO 60
  50 IF (Y) 52,55,55
  52 ARCS = 3.14159265 - SORT(1.0-AX)*F(AX)
  GO TO 60
  55 ARCS = SORT(1.0-X)*F(X)
  60 RETURN
END

```

ARCS0000
ARCS0001
ARCS0002
ARCS0003
ARCS0004
ARCS0005
ARCS0006
ARCS0007
ARCS0008
ARCS0009
ARCS0010
ARCS0011
ARCS0012
ARCS0013
ARCS0014
ARCS0015
ARCS0016
ARCS0017
ARCS0018
ARCS0019

```

S      FORTRAN DECK
CRESSF COMPUTES BESSEL FUNCTIONS (1) OF THE FIRST KIND ( JN(X) )      6002
C      AND/OR (2) OF THE SECOND KIND ( YN(X) )      6003
C      6006
C      Y = ARGUMENT      N = ORDER (0,1,2,3,4, OR 5 )      6007
C      FJ = J ANSWERS      T = +1 , COMPUTE ONLY Y      6008
C      FY = Y ANSWERS      = 0 , COMPUTE BOTH Y AND J      6009
C      = -1 , COMPUTE ONLY J      6010
C      6011
C      USES FUNCTIONS A=BJ0(X) OR R=BY0(X) FOR ORDER 0      6012
C      AND A=BJ1(X) OR R=BY1(X) FOR ORDER 1      6013
C      6014
C      SUBROUTINE Bessel ( X, N, FJ, FY, T )      6020
C      DIMENSION F(1), FY(1)      6025
C      6030
C      ALWAYS FIND ZERO ORDER VALUES      6035
C      6040
C      FJ(1)=BJ0(X)      6045
C      FY(1)=BY0(X)      6046
C      IF ( N ) 50,50,10      6058
C 10 FJ(2)=BJ1(X)      6055
C      FY(2)=BY1(X)      6056
C      IF ( N-1 ) 50,50,12      6060
C 12 IF ( T ) 16,14,14      6065
C 14 FY(3) = 2.*FY(2)/X - FY(1)      6070
C 16 IF ( T ) 17,17,18      6075
C 17 FJ(3) = 2.*FJ(2)/X - FJ(1)      6080
C 18 IF ( N-2 ) 50,50,20      6085
C 20 IF ( T ) 24,22,22      6090
C 22 FY(4) = (8./(X*X)-1.)*FY(2) - 4.*FY(1)/X      6095
C 24 IF ( T ) 26,26,28      6100
C 26 FJ(4) = (8./(X*X)-1.)*FJ(2) - 4.*FJ(1)/X      6105
C 28 IF ( N-3 ) 50,50,30      6110
C 30 Y = (1. - 24./(X*X))      6115
C      Z = 8.*(6./(X*X)-1.)/X      6120
C      IF ( T ) 34,32,32      6125
C 32 FY(5) = Y*FY(1) + Z*FY(2)      6130
C 34 IF ( T ) 36,36,38      6135
C 36 FJ(5) = Y*FJ(1) + Z*FJ(2)      6140
C 38 IF ( N-4 ) 50,50,40      6145
C 40 Y = 12.*(1.-16./(X*X))/X      6150
C      Z = (1.-72./(X*X)+364./(X**4))      6155
C      IF ( T ) 44,42,42      6160
C 42 FY(6) = Y*FY(1) + Z*FY(2)      6165
C 44 IF ( T ) 46,46,50      6170
C 46 FJ(6) = Y*FJ(1) + Z*FJ(2)      6175
C 50 RETURN      6180
C      END      6185

```

* FORTRAN DECK		5002
CSCAM DETERMINES THE CONSTANTS INVARIANT WITH REDUCED VELOCITY		5003
C INVOLVED IN THE OSCILLATORY COEFFICIENTS FOR THE CONTROL		5004
C SURFACE UNDERGOING CHANGES IN CAMBER.		5004
SUBROUTINE CSCAM (ISZ,CA,R,XN1,XN2,XN3,XN4,XN5,T1,T2,T3,T4,T5)		5010
DIMENSION B(1),CA(1), XN1(1),XN2(1),XN3(1),XN4(1),XN5(1),T1(1)		5020
1,T2(1),T3(1),T4(1),T5(1),C(25)		5021
PI=3.14159265		5025
PI11=1.0/PI		5030
DO 700 I=1,ISZ		5035
IF(CA(I))706,700,706		5040
706 C(I)=1.0-CA(I)/B(I)		5045
PH=ARCS(-C(I))		5050
PH2=PH/2.0		5055
PH3=PH/3.0		5060
PH30=PH/30.0		5065
XN1(I)=PI11*(PI-PH+SIN(PH))		5070
XN2(I)=PI11*(((PI-PH)/2.0)*(1.0+2.0*COS(PH))+SIN(PH2)*(2.0+COS(PH)		5075
1))		5080
XN3(I)=(2.0/(3.0*PI))*((SIN(PH))*3)		5085
XN4(I)=PI11*(PI-PH+1.333*SIN(PH)*COS(PH)-(SIN(PH)*((COS(PH3))*3)		5090
1))		5095
XN5(I)=PI11*(.75*(PI-PH)*COS(PH)+SIN(PH2)*(1.0+((COS(PH2))*2))-((		5100
1SIN(PH30))*5))		5105
T1(I)=PI11*((PI-PH)*(1.0-2.0*COS(PH))+SIN(PH)*(COS(PH)-2.0))		5110
T2(I)=-T1(I)/2.0		5115
T3(I)=PI11*(-COS(PH)*SIN(PH)-(PI-PH)+(.6667*((SIN(PH))*3))		5120
T4(I)=PI11*(-(COS(PH)*SIN(PH2))-(COS(PH)*((SIN(PH3))*3))-(PI-PH)/		5125
12.0)		5130
T5(I)=XN5(I)		5135
700 CONTINUE		5140
RETURN		5145
END		5150

7001
7002
7003
7004
7006
7007
7008
7009
7010
7011
7012
7013
7014
7019
7020
7025
7030
7035
7040
7045
7046
7047
7048
7050
7055
7060
7065
7070
7075
7080
7085
7090
7095
7100
7105
7110
7115
7120
7125
7126
7129
7130
7131
7132
7134
7135
7136
7137
7138
7140
7145
7150
7155
7160
7165
7170
7175
7180
7185

FORTRAN DECK

CPUNCH PUNCHES THE AIC MATRIX IN FORTRAN FORMAT SO THAT IT CAN BE
USED IN COFA - FLUTTER ANALYSIS BY COLLOCATION METHOD
THE AIC MATRIX FOR EACH 1/KR CONTAINS THE FOLLOWING CARDS -
CARD 1 - 1/KR, COLUMNS 1-12, (1P1E12.5)
CARD 2 - NSIZE, NPART, NFORM, NROW, COLUMNS 1-4, 5-8, 9-12, 13-16
(4I4), NFORM=NROW=1
THE FOLLOWING CARDS ARE REPEATED FOR EACH NON-ZERO PARTITION IN
THE AIC MATRIX (AS MANY TIMES AS THE NUMBER OF STRIPS INTO WHICH
THE SURFACE IS DIVIDED).
CARD 1 - N, COLUMNS 1-4, (I4) - ORDER OF PARTITION
FOLLOWED BY 1 OR 2 CARDS FOR EACH ROW OF PARTITION MATRIX,
FORMAT(1P6E12.5)

```

SUBROUTINE PUNCH (EKR, NU, CH, ISZ, NSEQ)
  DIMENSION NU(1), CH(4,8,25)
  1 FORMAT(1P1E12.5, 60X, 3HSTP, 12, 3H001)
  2 FORMAT(4I4, 56X, 3HSTP, 12, 3H002)
  3 FORMAT(I4, 66X, 3HSTP, 12, 12, 11)
  4 FORMAT(1P6E12.5, 3HSTP, 12, 12, 11)
  5 FORMAT(1P2E12.5, 48X, 3HSTP, 12, 12, 11)
  6 FORMAT(1P3E12.5, 36X, 3HSTP, 12, 12, 11)
  7 FORMAT(1P4E12.5, 24X, 3HSTP, 12, 12, 11)
  PUNCH 1, EKR, NSEQ
  NSIZE=0
  DO 8 I=1, ISZ
  8 NSIZE=NSIZE+NU(I)
  NFORM=1
  NROW =1
  PUNCH 2, NSIZE, ISZ, NFORM, NROW, NSEQ
  DO 20 I=1, ISZ
  NSF=1
  N=NU(I)
  PUNCH 3, N, NSEQ, I, NSF
  NSF=NSF+1
  I2=N*2
  DO 19 K=1, N
  IF (EKR) 13, 14, 14
  13 IF (N-2) 22, 21, 22
  21 PUNCH 5, (CH(K, I, I), I=1, N2, 2), NSEQ, I, NSF
  GO TO 18
  22 IF (I-3) 26, 23, 26
  23 PUNCH 6, (CH(K, I, I), I=1, N2, 2), NSEQ, I, NSF
  GO TO 18
  26 PUNCH 7, (CH(K, I, I), I=1, N2, 2), NSEQ, I, NSF
  GO TO 18
  14 IF (N.EQ.4) GO TO 15
  IF (N-2) 25, 24, 25
  24 PUNCH 7, (CH(K, I, I), I=1, N2), NSEQ, I, NSF
  GO TO 18
  25 PUNCH 4, (CH(K, I, I), I=1, N2), NSEQ, I, NSF
  GO TO 18
  15 PUNCH 4, (CH(K, I, I), I=1, 6), NSEQ, I, NSF
  NSF=NSF+1
  PUNCH 5, (CH(K, I, I), I=7, 8), NSEQ, I, NSF
  18 NSF=NSF+1
  19 CONTINUE
  20 CONTINUE
  RETURN
END

```

It is

RETURN
END

BJY10061
BJY10062

BJY0000

[illegible]

3.0 PISTON THEORY AERODYNAMICS PROGRAM

3.1 THEORETICAL DEVELOPMENT

The pressure on a lifting surface is normally given by a surface functional relationship. However, in the limits of high Mach number ($M^2 \gg 1$) or high reduced frequency ($M^2 k \gg 1$ or $M^2 k^2 \gg 1$), this relationship becomes a point function. As a consequence of this limit, aerodynamic influence coefficients (AICs) may be specified exactly by a strip theory, so only a single strip need be considered in the basic development, 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 (parabolically) cambering airfoil with or without a (rigid chord) control surface. The derivation differs only slightly from that of Ashley and Zartarian¹ 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 piston theory to lower supersonic Mach numbers at low reduced frequencies. The derivation given here is a combination and generalization of those given in Ref. 4 for the rigid chord airfoil with control surface and in Ref. 5 for the parabolically cambering airfoil without control surface.

The AICs are defined to relate the surface to the aerodynamic forces at the same points in the oscillatory case by

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

and in the steady case by

$$\{F\} = (qS/\bar{c}) [C_{hs}] \{h\}$$

Development of the General Oscillatory Case Including Camber and Control

Surface

We wish to determine the AICs that relate the four deflections h_1 , h_2 , h_3 , and h_4 to the forces F_1 , F_2 , F_3 , and F_4 acting at the same points as shown in Fig. 1. If the airfoil has no control surface x_3 may be located arbitrarily; if there is a control surface x_3 must be located at the hinge line and h_4 is the deflection of the trailing edge. The deflections are those of the mean camber line and the control surface is assumed to be rigid.

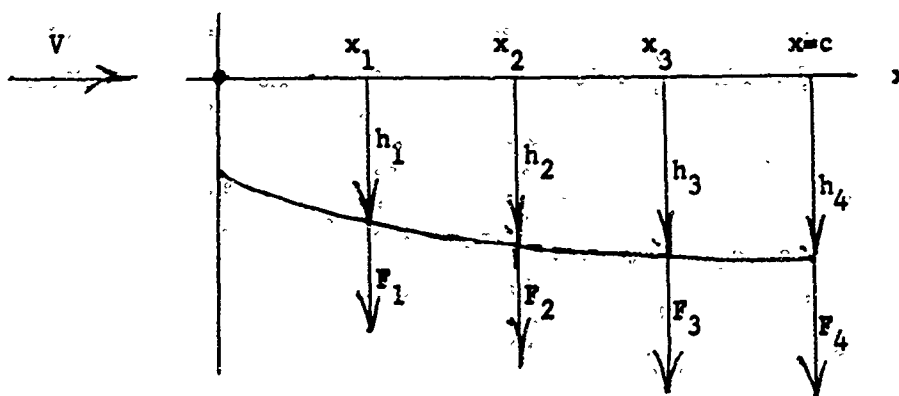


Figure 3.1.1- Forces and Geometry for AICs

We consider two airfoil cross-sections. The first is typical of airfoils employed in missile applications while the second is representative of aircraft applications. The first airfoil consists of three straight lines as shown in Fig. 2. The second consists of two tangent parabolas and a straight line as shown in Fig. 3.

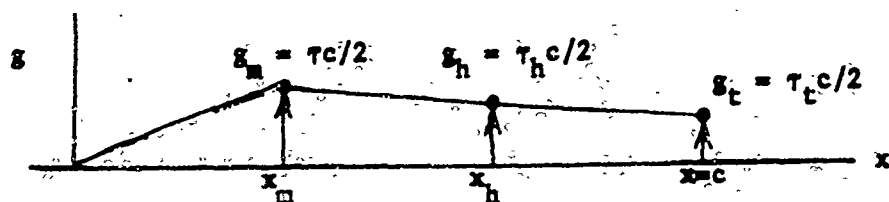


Fig. 3.1.2 - First Airfoil Idealization



Fig. 3.1.3 - Second Airfoil Idealization

The equations for the deflection curve of either airfoil are

$$h = [h(x)/h_1]h_1 + [h(x)/h_2]h_2 + [h(x)/h_3]h_3$$

for $0 \leq x \leq x_h$, and on the control surface

$$h_c = [h_c(x)/h_3]h_3 + [h_c(x)/h_4]h_4$$

for $x_h \leq x \leq c$ where

$$h(x)/h_1 = (x-x_2)(x-x_3)/(x_1-x_2)(x_1-x_3)$$

$$h(x)/h_2 = (x-x_1)(x-x_3)/(x_2-x_1)(x_2-x_3)$$

$$h(x)/h_3 = (x-x_1)(x-x_2)/(x_3-x_1)(x_3-x_2)$$

$$h_c(x)/h_3 = (c-x)/(c-x_h)$$

and

$$h_c(x)/h_4 = (x-x_h)/(c-x_h)$$

The equations for the semi-thickness distribution of the first airfoil are

$$g_1(x)/c = (\tau/2)(x/x_m) \quad , \quad 0 \leq x \leq x_m$$

$$g_2(x)/c = (\tau/2)[1 - (1-r_h)(x-x_m)/(x_h-x_m)] \quad , \quad x_m \leq x \leq x_h$$

$$\text{and } g_3(x)/c = (\tau_h/2)[1 - (1-r_c)(x-x_h)/(c-x_h)] \quad , \quad x_h \leq x \leq c$$

where the symbols are defined in the Nomenclature. The semi-thickness equations for the second airfoil are

$$g_1(x)/c = (\tau/2)(x/x_m)(2-x/x_m) \quad , \quad 0 \leq x \leq x_m$$

$$g_2(x)/c = (\tau/2)[1 - (1-r_h)[(x-x_m)/(x_h-x_m)]^2] \quad , \quad x_m \leq x \leq x_h$$

$$\text{and } g_3(x)/c = (\tau_h/2)[1 - (1-r_c)(x-x_h)/(c-x_h)] \quad , \quad x_h \leq x \leq c$$

The linearized lifting pressure coefficient for small disturbances about the trim angle of attack α_0 is given in Ref. 4 by

$$C_p = - (4v/M)[\bar{C}_1 + 2\bar{C}_2 M g_x + 3C_3 M^2 (g_x^2 + \alpha_0^2)]$$

where the coefficients $\bar{C}_1$, $\bar{C}_2$, and C_3 are discussed in Ref. 4 and are given by

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

$$\bar{C}_2 = [M^4(\gamma+1) - 4\sec^2 \Lambda(M^2 - \sec^2 \Lambda)]/4(M^2 - \sec^2 \Lambda)^2$$

$$C_3 = (\gamma+1)/12$$

and the dimensionless harmonic disturbance downwash v is

$$v = \frac{dh}{dx} + ik \frac{h}{b}$$

If the secant of the sweep angle Λ of the leading edge is taken as zero the usual piston theory is obtained; if $\sec \Lambda$ is taken as unity no sweep correction is made to the quasi-steady supersonic result.

The necessary derivatives for the calculation of the pressure coefficient are the following.

$$\begin{aligned} \frac{dh}{dx} = & [h'(x)/h_1]h_1 + [h'(x)/h_2]h_2 \\ & + [h'(x)/h_3]h_3, \quad 0 \leq x \leq x_3 \end{aligned}$$

and

$$\frac{dh}{dx} = [h'_c(x)/h_3]h_3 + [h'_c(x)/h_4]h_4, \quad x_3 \leq x \leq c$$

where

$$h'(x)/h_1 = (2x - x_2 - x_3)/(x_1 - x_2)(x_1 - x_3)$$

$$h'(x)/h_2 = (2x - x_1 - x_3)/(x_2 - x_1)(x_2 - x_3)$$

$$h'(x)/h_3 = (2x - x_1 - x_2)/(x_3 - x_1)(x_3 - x_2)$$

$$h'_c(x)/h_3 = -1/(c - x_h)$$

and

$$h'_c(x)/h_4 = 1/(c - x_h)$$

For the first airfoil the thickness derivatives are

$$g_{1x}/c = (\tau/2x_m) , \quad 0 \leq x \leq x_m$$

$$g_{2x}/c = -(\tau/2)(1-r_h)/(x_h-x_m) , \quad x_m \leq x \leq x_h$$

$$g_{3x}/c = -(\tau_h/2)(1-r_c)/(c-x_h) , \quad x_h \leq x \leq c$$

and for the second airfoil they are

$$g_{1x}/c = (\tau/x_m)(1-x/x_m) , \quad 0 \leq x \leq x_m$$

$$g_{2x}/c = -\tau(1-r_h)(x-x_m)/(x_h-x_m)^2 , \quad x_m \leq x \leq x_h$$

$$g_{3x}/c = -(\tau_h/2)(1-r_c)/(c-x_h) , \quad x_h \leq x \leq c$$

We may write the downwash as

$$v_1 = [v(x)/h_1]h_1 + [v(x)/h_2]h_2 + [v(x)/h_3]h_3 , \quad 0 \leq x \leq x_h$$

and

$$v_c = [v_c(x)/h_3]h_3 + [v_c(x)/h_4]h_4 , \quad x_h \leq x \leq c$$

where

$$\begin{aligned} v(x)/h_i &= h'(x)/h_i + i(k/b)h(x)/h_i , \quad i = 1, 2, 3 \\ &= 0 , \quad i = 4 \end{aligned}$$

and

$$\begin{aligned} v_c(x)/h_i &= 0 , \quad i = 1, 2 \\ &= h'_c(x)/h_i + i(k/b)h_c(x)/h_i , \quad i = 3, 4 \end{aligned}$$

Then the pressure coefficients in the three airfoil regions are

$$C_{p1} = -(4v/M) [\bar{C}_1 + 2\bar{C}_2 M g_{1x} + 3C_3 M^2 (g_{1x}^2 + \alpha_0^2)]$$

$$C_{p2} = -(4v/M) [\bar{C}_1 + 2\bar{C}_2 M g_{2x} + 3C_3 M^2 (g_{2x}^2 + \alpha_0^2)]$$

$$C_{p3} = -(4v_c/M) [\bar{C}_1 + 2\bar{C}_2 M g_{3x} + 3C_3 M^2 (g_{3x}^2 + \alpha_0^2)]$$

From the principle of virtual work as applied in Ref. 5 and from the definition of the AICs the control point forces F_i are

$$\begin{aligned} F_i &= \Delta y \left\{ \int_0^{x_m} C_{p1} [h(x)/h_1] dx + \int_{x_m}^{x_h} C_{p2} [h(x)/h_1] dx \right. \\ &\quad \left. + \int_{x_h}^c C_{p3} [h_c(x)/h_1] dx \right\}, \quad i = 1, 2, 3, 4 \\ &= \rho \omega^2 b_r^2 s \sum_{j=1}^4 (C_h)_{ij} h_j \end{aligned}$$

Therefore, the elements of the fourth order AIC matrix elements for the strip are

$$\begin{aligned} (C_h)_{ij} &= -(2/M) (1/k_r^2) (\Delta y/s) \left\{ (\bar{C}_1 + 3C_3 M^2 \alpha_0^2) \left(\int_0^{x_h} [h(x)/h_1] [v(x)/h_j] dx \right. \right. \\ &\quad \left. \left. + \int_{x_h}^c [h_c(x)/h_1] [v_c(x)/h_j] dx \right) \right. \\ &\quad + 2\bar{C}_2 M \left(\int_0^{x_m} g_{1x} [h(x)/h_1] [v(x)/h_j] dx + \int_{x_m}^{x_h} g_{2x} [h(x)/h_1] [v(x)/h_j] dx \right. \\ &\quad \left. + \int_{x_h}^c g_{3x} [h_c(x)/h_1] [v_c(x)/h_j] dx \right) \\ &\quad \left. + 3C_3 M^2 \left(\int_0^{x_m} g_{1x}^2 [h(x)/h_1] [v(x)/h_j] dx + \int_{x_m}^{x_h} g_{2x}^2 [h(x)/h_1] [v(x)/h_j] dx \right. \right. \\ &\quad \left. \left. + \int_{x_h}^c g_{3x}^2 [h_c(x)/h_1] [v_c(x)/h_j] dx \right) \right\} \end{aligned}$$

where we note that $i, j = 1, 2, 3$, and 4 and also that $h(x)/h_i = 0$ for $i = 4$, $h_c(x)/h_i = 0$ for $i = 1$ and 2. We define the following definite integrals

$$R_{ij}^{(n)}(\xi, \eta) = i(k/b)I_{ij}^{(n)}(\xi, \eta) = \int_{\xi}^{\eta} g_x^n(x) [h(x)/h_i] [v(x)/h_j] dx$$

so that

$$R_{ij}^{(n)}(\xi, \eta) = \int_{\xi}^{\eta} g_x^n(x) [h(x)/h_i] [h'(x)/h_j] dx$$

and

$$I_{ij}^{(n)}(\xi, \eta) = \int_{\xi}^{\eta} g_x^n(x) [h(x)/h_i] [h(x)/h_j] dx$$

Then the AIC becomes

$$\begin{aligned} (C_h)_{ij} = & -(2/M) (1/k_r^2) (\Delta y/s) \left\{ (\bar{C}_1 + 3C_3 M^2 \alpha_0^2) [R_{ij}^{(0)}(0, x_m) \right. \\ & + i(k/b) I_{ij}^{(0)}(0, x_m) + R_{ij}^{(0)}(x_m, x_h) + i(k/b) I_{ij}^{(0)}(x_m, x_h) \\ & + R_{cij}^{(0)}(x_h, c) + i(k/b) I_{cij}^{(0)}(x_h, c)] + 2\bar{C}_2 M [R_{ij}^{(1)}(0, x_m) + i(k/b) I_{ij}^{(1)}(0, x_m) \\ & + R_{ij}^{(1)}(x_m, x_h) + i(k/b) I_{ij}^{(1)}(x_m, x_h) \\ & + R_{cij}^{(1)}(x_h, c) + i(k/b) I_{cij}^{(1)}(x_h, c)] \\ & + 3C_3 M^2 [R_{ij}^{(2)}(0, x_m) + i(k/b) I_{ij}^{(2)}(0, x_m) + R_{ij}^{(2)}(x_m, x_h) + i(k/b) I_{ij}^{(2)}(x_m, x_h) \\ & \left. + R_{cij}^{(2)}(x_h, c) + i(k/b) I_{cij}^{(2)}(x_h, c)] \right\} \end{aligned}$$

where $i, j = 1, 2, 3$, and 4, and we note that $R_{ij} = I_{ij} = 0$ if i or $j = 4$, and $R_{cij} = I_{cij} = 0$ if i or $j = 1$ or 2.

3.2 PROGRAM DESCRIPTION

A general program to calculate a set of aerodynamic influence coefficients using piston theory has been developed. The method is applicable to wings of moderate to high aspect ratio and speeds in the supersonic regime. The analysis can be performed for wings with a rigid chord or a flexible chord. The effects of a flexible chord are accounted for by the introduction of parabolic cambering. Parabolic camber is induced if a bending mode is parabolic and if a torsion mode is linear in the region surrounding the strip under consideration. The analysis can be performed with or without a control surface. The steady state case is available as a limiting case of the oscillating case for use in static aeroelastic analysis. The AICs relate the aerodynamic forces to the surface deflections through the following definitions. In the oscillatory case,

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

and in the steady case,

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

The AICs are derived for each strip considering the airfoil to have up to four degrees of freedom: pitching, plunging, cambering, and control surface rotation. The program provides the AICs in printed and optional punched-card output format. The punched-card output format is identical to that required as input into the COFA, Collocation Flutter Analysis Program (Ref.1). The program capacity is 25 surface strips and 15 variations of Mach Number. There can be as many as 20 reduced velocities for each Mach Number.

3.2.1 PROCESSING INFORMATION

A. OPERATION

Standard FORTRAN IV processor system.
Operable on the GE 635 computer.

B. CORE STORAGE

The program STRIP requires a minimum of 20,000 memory units for execution.

C. ADDITIONAL MACHINE COMPONENTS

Standard FORTRAN input tape (5)
Standard FORTRAN output print tape (6)
Standard FORTRAN output punch tape.

3.3 PROGRAM INPUT INSTRUCTIONS

UNITS Since all of the input dimensions are geometrical and the aerodynamic Matrix is dimensionless, only a consistent set of length units is necessary - inches or feet.

DATA DECK SETUP

1. Title Card 1
2. Title Card 2
3. NVAN, NCAM, NFOIL, NALPHA, NTAUS
4. ISZ, MSZ, NOPUNJ, JSIZE
5. sec λ , br, s, S, $\bar{c}$
6. Δy , b, $\xi_1, \xi_2, \xi_3, \xi_m$ for each strip
7. T, T_h, T_t for each strip
8. Mach Number Series
9. Alpha Series
10. $1/k_r$ Series

Item 1 Title Card (Any alphanumeric character Columns 1-80)

Item 2 Title Card (Any alphanumeric character Columns 1-80)

Item 3 Control Card (Format 1814)

Field	1	2	3	4	5
Name	NVAN	NCAM	NFOIL	NALPHA	NTAUS
Column	1-4	5-8	9-12	13-16	17-20

NVAN = 0 No Van Dyke Correction Included
= 1 Van Dyke Correction Factor

NCAM = 0 No Camber Effects Included
= 1 Camber Effects Included

NFOIL = 1 Airfoil 1 (See Figure 3.1.2)
= 2 Airfoil 2 (See Figure 3.1.3)

NALPHA = 1 Angle of Attack, Alpha is constant for each strip
= ISZ Angle of Attack, Alpha varies with each strip

NTAUS = 1 Airfoil Thickness is identical for each strip
= ISZ Airfoil Thickness varies for each strip

Item 4 Control Card (Format 18I4)

Field	1	2	3	4	5
Name	ISZ	MSZ	NOPUNJ	JSIZE ₁	JSIZE ₂
Column	1-4	5-8	9-12	13-16	

ISZ = Number of strips; ≤ 25

MSZ = Number of Mach Numbers; ≤ 15

NOPUNJ = 0 Output Punched
 = 1 No Output Punched

JSIZE₁ = Number of Reduced Velocities, $(V/b\omega)$, ≤ 20
 for each Mach Number "i" where $i = 1$ to MSZ;

Item 5 Data Card (Format 6E12.8)

Field	1	2	3	4	5
Name	SECLAM	BR	S	CAPS	CBAR
Column	1-12	13-24	25-36	37-48	49-60

SECLAM = Secant λ where λ is the leading edge sweepback angle

BR = Reference Semi-Chord

S = Reference Semi-Span

CAPS = Total Planform Area, $CAPS = \sum_{i=1}^{ISZ} 2\Delta y_i b_i$

CBAR = Mean Aerodynamic Chord

Item 6. Data Card (Format 6E12.8) Repeat for each strip.

Field	1	2	3	4	5	6
Name	DELTAY	B	Z1	Z2	Z3	ZM
Column	1-12	13-24	25-36	37-48	49-60	61-72

DELTAY = Δy , Strip Width

b = B ~ Strip Semi-Chord

ξ_1 = Z1 ~ Fraction of Chord to First Control Point

ξ_2 = Z2 ~ Fraction of Chord to Second Control Point (Use negative if there is a control surface on this particular strip)

ξ_3 = Z3 ~ Fraction of Chord to Third Control Point (Use hinge line coordinate if there is a control surface on this particular strip)

ξ_m = ZM ~ Fraction of chord at maximum thickness point on the airfoil

Item 7 Data Card (Format 6E12.8)

Field	1	2	3	4	5	6
Name	TAU_1	TAUH_1	TAUT_1	TAU_2	TAUH_2	TAUT_2
Column	1-12	13-24	25-36	37-48	49-60	61-72

TAU ~ Maximum Airfoil Thickness Divided by the Local Strip Chord Length

TAUH ~ Airfoil Thickness at Control Surface Hinge Divided by the Local Strip Chord Length; if there is no control surface set $\text{TAUH} = 0.0$

TAUT ~ Airfoil Thickness at Trailing Edge Divided by the Local Strip Chord Length.

Repeat for each strip consecutively; two strips per card; continue on successive cards as necessary.

Item 8 Data Card (Format 6E12.8)

Field	1	2	3	4	5	6
Name	EMACH_1	EMACH_2	...	...	$\text{EMACH}_{\text{MSZ}}$	
Column	1-12	13-24	25-36	37-48	49-60	61-72

EMACH ~ Mach Number

Continue on next card as necessary

Item 9 Data Card (Format 6E12.8)

Repeat this card or Series of Cards for each Mach Number when
NALPHA = 1

Field	1	2	3	4	5	6
Name	ALPHA					
Column	1-12	13-24	25-36	37-48	49-60	61-72

ALPHA = Angle of attack, α . ALPHA is constant for each strip.
Repeat this card MSZ times.

When NALPHA = ISZ

Field	1	2	3	4	5	6
Name	ALPHA ₁	ALPHA ₂	...	...	ALPHA _{ISZ}	
Column	1-12	13-24	25-36	37-48	49-60	61-72

ALPHA = Angle of attack, α . ALPHA varies for each strip.
Continue ALPHA₁ on next card if necessary. Repeat
this card or series of cards MSZ times.
(Start new card for each Mach Number)

Item 10 Data Card (Format 6E12.8)

Field	1	2	3	4	5	6
Name	EKR ₁	EKR ₂	.	.	EKR _J SIZE	
Column						

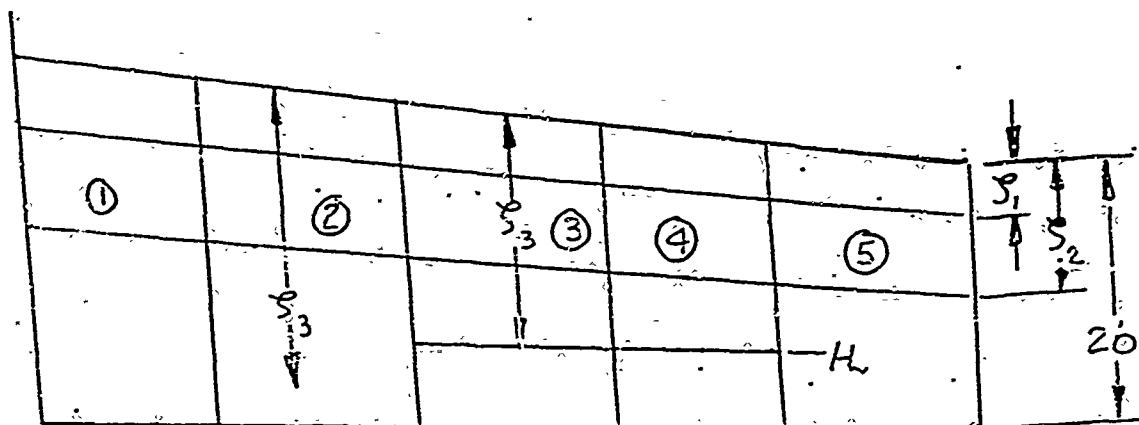
EKR_i = Reduced Velocity Series; continue on next card if necessary. Repeat the above card or series of cards MSZ times.

(Start new card for each Mach Number)

3.4 SAMPLE PROBLEM

As an example problem, the supersonic AIC's are calculated at Mach No. =2.5 for the high aspect ratio swept back wing shown below. The wing is analyzed for airfoil number one with parabolic cambering. The analysis is performed for the reduced frequencies ($1/k$) of 0.0, 2.0, and 5.0. A $1/k = 0$ calculates the aerodynamics associated with steady state flight. A control surface exists on strips 3 and 4.

PROGRAM INPUT DATA



STRIP NO.	Δy	$b(\text{ft})$	ζ_1	ζ_2	ζ_3	ζ_{max}
1	3.0	4.0	.25	.45	.8	.35
2	3.0	4.0	.25	.45	.8	.35
3	3.0	4.0	.25	-.45	.8	.35
4	3.0	3.75	.25	-.45	.8	.35
5	3.0	3.75	.25	.45	.8	.35

$$\cos \Lambda = 0$$

$$b_r = 4.5 \text{ ft}$$

$$s = 12.0 \text{ ft}$$

$$S = 96 \text{ ft}^2$$

$$\bar{c} = 5.0 \text{ ft}$$

$$1/k_r = 5.0, 2.0, 0.0$$

$$M = 2.5$$

ζ_1 , ζ_2 , and ζ_3 may be any arbitrary position when no control surface is present; when a control surface is present, ζ_1 and ζ_2 may be arbitrarily located and ζ_3 must be located at the hinge line. In both cases, however, ζ_1 , ζ_2 , and ζ_3 should be distributed across the chord so that the camber can be properly defined, e.g., $\zeta_1 = .20$, $\zeta_2 = .50$, and $\zeta_3 = .80$.

NOTE: Negative ζ_2 for strips 3 and 4 indicates a control surface on these strips.

SAMPLE CASE

5 STRIPS WITH CAMBER AND PARTIAL CONTROL SURFACE

AERODYNAMIC INFLUENCE COEFFICIENTS BY PISON THEORY WITH CAMBER

INTEGRAL INTEGRALS CALCULATED FOR AIRFOIL 1

INPUT DATA

5 STRIPS
 1 MACH NUMBERS
 3 REDUCED VELOCITIES (TOTAL)
 SEGMENT LENGTH = 0.450000E 01
 REFERENCE SEMI-CHORD = 0.120000E 02
 SEMI-SPAN = 0.960000E 02
 SURFACE AREA = 0.500000E 01
 C BAR = 0.500000E 01

STRIP NO.	DELTA Y	R	Z1	Z2	Z3	ZMAX
1	0.300000E 01	0.400000E 01	0.250000E 00	0.450000E 00	0.800000E 00	0.350000E 03
2	0.300000E 01	0.400000E 01	0.250000E 00	0.450000E 00	0.800000E 00	0.350000E 00
3	0.300000E 01	0.400000E 01	0.250000E 00	0.450000E 00	0.800000E 00	0.350000E 00
4	0.300000E 01	0.375000E 01	0.250000E 00	0.450000E 00	0.800000E 00	0.350000E 00
5	0.300000E 01	0.375000E 01	0.250000E 00	0.450000E 00	0.800000E 00	0.350000E 00

STRIP NO. TAU(H) TAU(T)

1	0.100000E 00	0.500000E-01	0.200000E-01
2	0.100000E 00	0.500000E-01	0.200000E-01
3	0.100000E 00	0.500000E-01	0.200000E-01
4	0.900000E-01	0.450000E-01	0.150000E-01
5	0.900000E-01	0.450000E-01	0.150000E-01

MACH NUMBER = 2.50000

1/K(R) = 0.500000E 01
 1/K(R) = 0.200000E 01
 1/K(R) = 0.

STRIP NO. ALPHA ZERO (DEGREES)

1	20.00
2	20.00
3	20.00
4	20.00
5	20.00

AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY WITH GAMMA

OSCILLATORY CASE

MACH NO. = 2.500000

1/K(R) = 0.500000E 01

5 STRIPS

CH(1) SIZE = 3 BY 3

0.49038045E 02	-0.43590173E 01	01	-0.60051707E 02	0.30517045E 01	01	0.11011722E 02	-0.80924049E 03
-0.18783624E 02	0.30517057E 01	01	0.24574031E 02	-0.33385200E 01	01	-0.57912167E 01	0.18018539E 01
-0.59628029E 01	-0.80924000E 00	00	0.19060707E 02	0.10018537E 01	01	-0.13097904E 02	-0.13985530E 01

CH(2) SIZE = 3 BY 3

0.49038045E 02	-0.43590173E 01	01	-0.60051707E 02	0.30517045E 01	01	0.11011722E 02	-0.80924049E 03
-0.18783624E 02	0.30517057E 01	01	0.24574031E 02	-0.33385200E 01	01	-0.57912167E 01	0.18018539E 01
-0.59628029E 01	-0.80924000E 00	00	0.19060707E 02	0.10018537E 01	01	-0.13097904E 02	-0.13985530E 01

CH(3) SIZE = 4 BY 4

0.52260736E 02	-0.42327588E 01	01	-0.66741170E 02	0.27743902E 01	01	0.14800435E 02	-0.45592069E 00
-0.25858131E 02	0.27743908E 01	01	0.39359303E 02	-0.26356579E 01	01	-0.1328702E 02	0.21992172E 00
0.43529136E 01	-0.45592071E 00	00	-0.27691812E 01	0.21992160E 00	00	0.15487974E 01	-0.41913664E 00
0.	0.	0.	0.	0.	0.	0.31325497E 01	-0.74253031E 01
						-0.31325497E 01	-0.74253031E 01
						-0.31325497E 01	-0.74253031E 01

CH(4) SIZE = 4 BY 4

0.50753866E 02	-0.38538464E 01	01	-0.64857799E 02	0.25284424E 01	01	0.14103933E 02	-0.41272818E 00
-0.24963462E 02	0.25284424E 01	01	0.38262165E 02	-0.26892908E 01	01	-0.1328702E 02	0.19357208E 00
0.4178723E 01	-0.41272818E 00	00	-0.25044263E 01	0.19357286E 00	00	0.1461037E 01	-0.39291104E 00
0.	0.	0.	0.	0.	0.	0.31325497E 01	-0.69612215E 01
						-0.31325497E 01	-0.69612215E 01
						-0.31325497E 01	-0.69612215E 01

CH(5) SIZE = 3 BY 3

0.47504683E 02	-0.39729517E 01	01	-0.58111483E 02	0.27901039E 01	01	0.18606700E 02	-0.74668204E 00
-0.17846880E 02	0.27901039E 01	01	0.23360184E 02	-0.31763259E 01	01	-0.55133042E 01	0.93279522E 00
-0.62170298E 01	-0.74668204E 00	00	0.19476205E 02	0.93279512E 00	00	-0.13259175E 02	-0.13185474E 01

OUTPUT DATA
AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY WITH CANBER
OSCILLATORY CASE

MACH NO. = 2.500000

1/K(R) = 0.200000E 01

5 STRIPS

CH(1) SIZE = 3 BY 3

0.78460872E 01 -0.17430609E 01 -0.96082027E 01 2.12206410E 01 0.17621955E 01 -0.32369620E 00
-0.30053798E 01 0.12206823E 01 0.39319745E 01 -0.13754080E 01 -0.92659466E 00 0.40074158E 00
-0.17404845E 00 -0.32369624E 00 0.30497131E 01 0.40074149E 00 -0.20956647E 01 -0.55942110E 00

CH(2) SIZE = 3 BY 3

0.78460872E 01 -0.17430609E 01 -0.96082027E 01 0.12206410E 01 0.17621955E 01 -0.32369620E 00
-0.30053798E 01 0.12206823E 01 0.39319745E 01 -0.13754080E 01 -0.92659466E 00 0.40074158E 00
-0.95404845E 00 -0.32369624E 00 0.30497131E 01 0.40074149E 00 -0.20956647E 01 -0.55942110E 00

CH(3) SIZE = 4 BY 4

0.83617176E 01 -0.16931115E 01 -0.10678078E 02 0.11097561E 01 0.23168635E 01 -0.182336820E 00 0.
-0.41373010E 01 0.11097563E 01 0.62974809E 01 -0.11342631E 01 -0.21601875E 01 0.7968688E-01 0.
0.69646616E 00 -0.182336820E 00 -0.44386579E 00 0.87968640E-01 0.24780752E 00 -0.16765466E 00 -0.58120796E 00 -0.29701212E-01
0. -0.58120796E 00 -0.594482425E-01

CH(4) SIZE = 4 BY 4

0.81206185E 01 -0.15415336E 01 -0.10377248E 02 0.19113770E 01 0.22566293E 01 -0.10509127E 00 0.
-0.39941539E 01 0.10113770E 01 0.61219463E 01 0.10437196E 01 -0.21277924E 01 0.77428831E-01 0.
0.66755956E 00 -0.16509127E 00 -0.100070821E 00 0.77428831E-01 0.23425659E 00 -0.15716474E 00 -0.58120796E 00 -0.27844886E-01
0. -0.58120796E 00 -0.55689773E-01

CH(5) SIZE = 3 BY 3

0.76007493E 01 -0.15891807E 01 -0.92978213E 01 0.11108410E 01 0.16970720E 01 -0.29867313E 00
-0.28555008E 01 0.11160416E 01 0.37376294E 01 -0.12705304E 01 -0.88212868E 00 0.37311805E 00
-0.99472477E 00 -0.29867313E 00 0.31161926E 01 0.37311805E 00 0.21214601E 01 -0.92741897E 00

OUTPUT DATA

AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY WITH CARHET

STEADY CASE

MACH NO. = 2.500000

$\gamma/K(R) = INFINITY$

5 STRIPS

CP(1) SIZE = 3 BY 3

0.2451902E 01	-0.3002584E 01	0.5506011E 00
-0.9391816E 00	0.1228742E 01	-0.2895803E 00
-0.2981401E 00	0.9530353E 00	-0.65489521E 00

CP(2) SIZE = 3 BY 3

0.2451902E 01	-0.3002584E 01	0.5506011E 00
-0.9391812E 00	0.1228742E 01	-0.2895803E 00
-0.2981401E 00	0.9530353E 00	-0.65489521E 00

CP(3) SIZE = 4 BY 4

0.2613036E 01	-0.3337050E 01	0.7240217E 00	0.
-0.1292906E 01	0.1967952E 01	-0.6750505E 00	0.
0.2176456E 00	-0.1384588E 00	0.7743969E 01	-0.15662749E 00
0.	0.	0.15662749E 00	-0.15662749E 00

CP(4) SIZE = 4 BY 4

0.2537693E 01	-0.3242889E 01	0.7051956E 00	0.
-0.1248173E 01	0.1913102E 01	-0.6649351E 00	0.
0.2886436E 00	-0.1252313E 00	0.7320518E 01	-0.15662749E 00
0.	0.	0.15662749E 00	-0.15662749E 00

CP(5) SIZE = 3 BY 3

0.2375234E 01	-0.2905569E 01	0.5303349E 00
-0.8923448E 00	0.1168092E 01	-0.27586521E 00
-0.3108514E 00	0.9738102E 00	-0.6628587E 00

3.5 PROGRAM LISTING

```

S      FORTRAN DECK
CHAIN  PROGRAM PISTON - AERODYNAMIC INFLUENCE COEFFICIENTS BY
C      PISTON THEORY
C      WITH OR WITHOUT CAMBER
C      WITH OR WITHOUT A CONTROL SURFACE
C      NCAM = 0, CAMBER NOT CONSIDERED      NCAM = 1, CAMBER INCLUDED
C      NFOIL = 1 OR 2 INDICATES WHICH AIRFOIL IS TO BE CONSIDERED.
C      NVAN IS THE CONTROL FOR THE VAN DYKE CORRECTION OPTION FOR USE
C      WITH LOWER SUPERSONIC MACH NOS. AT LOW REDUCED FREQUENCIES.
C      NVAN = 0, OPTION NOT EXECUTED      NVAN = 1, OPTION EXECUTED
C      Z1,Z2 AND Z3 ARE PERCENT CHORDS OF 1ST,2ND AND 3RD CONTROL POINTS
C      IN EACH STRIP.
C      NEGATIVE Z2 INDICATES PRESENCE OF A CONTROL SURFACE ON THE STRIP.
C      THE 3RD C.P. MUST BE AT HINGE LINE IF THERE IS A CONTROL SURFACE.
C
C      DIMENSION TITLE(24),DELTAY(25),H(25),TAU(25),Z1(25),Z2(25),Z3(25),
172A(25),TAUH(25),TAUT(25),X(25),X1(25),X2(25),X3(25),XM(25),
27H(25),JSIZE(15),EMACH(15),NU(25)
C      DIMENSION EKR(20,15),ALPHA(25,15),CH1(4,8,25),CH2(3,6,25),CH3(3,6,
195),CH4(2,4,25),TN(3,2),RHO(4,4),RA1(4,4),RA2(4,4),RB1(4,4),
25HO(4,4),SA1(4,4),SA2(4,4),SB1(4,4),SB2(4,4),RC0(4,4),RC1(4,4),
35C2(4,4),SC0(4,4),SC1(4,4),SC2(4,4),T(4,3),RB2(4,4),D1(3,8),
42(2,6),TT(3,4),TNT(2,3)
C
C      COMMON X,X1,X2,X3,XM,TAU,TAUH,TAUT,RHO,RA1,RA2,RB1,RB2,SH0,SA1,
15A2,SB1,SB2,RC0,RC1,RC2,SC0,SC1,SC2
C
1  FORMAT(10I4)
2  FORMAT(6E12,8)
3  FORMAT(1H0 26X,66HAERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THE
1  RY WITHOUT CAMBER )
4  FORMAT(1H 17X,85H(THE VAN DYKE QUASI-STEADY THEORY IS USED TO DET
1  ERMINE THE AERODYNAMIC COEFFICIENTS.))
5  FORMAT(1H0 54X,10HINPUT DATA //1H 44X,12, 7H STRIPS/1H 44X,12,
113H MACH NUMBERS /147,28H REDUCED VELOCITIES (TOTAL) /1H0 45X,
205HSECANT LAMHDA = E14.6 /39X,22HREFERENCE SEMI-CHORD = E14.6 /1H
3 49X,11HSEMI-SPAN = E14.6 /1H 46X,14HSURFACE AREA = E14.6 /1H 53
4X,7HCBAR = E14.6 /1H0 4X,9HSTRIP NO. ,10X,7HDELTA Y,13X,1HB,17X,
52HZ1,16X,2HZ2,16X,2HZ3,14X,4HZMAX//(19,E24.6,5E18.6))
6  FORMAT(1H0 42X,9HSTRIP NO.,10X,20HALPHA ZERO (DEGREES)//(46X,12,
114X,F10.2))
8  FORMAT(1H0 48X,13HMACH NUMBER = F14.6//(1H 53X,8H1/K(R) = E14.6))
23 FORMAT(12A6)
24 FORMAT(1H0 29X,63HAERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THE
1  RY WITH CAMBER)
25 FORMAT(1H0 51X,16HOSCILLATORY CASE//1H 45X,10HMACH NO. = F14.6,
1//1H 47X,8H1/K(R) = E14.6 //157,7H STRIPS)
27 FORMAT(1H1 12A6//1X,12A6//)
28 FORMAT(1H0 4X,9HSTRIP NO.,12X,3HTAU,13X,6HTAU(H),12X,6HTAU(T)//
1(19,E24.6,2E18.6))
29 FORMAT(1H0 49X,3HCH(12,8H) SIZE = 12,3H BY 12 //)
30 FORMAT(1H 2E16.8,1X,2E16.8,1X,2E16.8,1X,2E16.8)
31 FORMAT(1H1)
32 FORMAT(1P1E12.5,60X,3HPTN,12,3H001)
33 FORMAT(4I4,46X,3HPTN,12,3H002)
34 FORMAT(14,64X,3HPTN,12,12,11)
35 FORMAT(1P6E12.5,3HPTN,12,12,11)
36 FORMAT(1P2E12.5,48X,3HPTN,12,12,11)
37 FORMAT(1P3E12.5,36X,3HPTN,12,12,11)
38 FORMAT(1P4E12.5,24X,3HPTN,12,12,11)

```

39	FORMAT(1H0 53X,11HSTEADY CASE //1H 45X,10HMACH NO. = F14.6,	104
	1//1H 47X,17H1/K(R) = INFINITY //157.7H STRIPS)	105
40	FORMAT(1H 29X,4E10.8)	106
41	FORMAT(1H0 42X,44HTHICKNESS INTEGRALS CALCULATED FOR AIRFOIL 1)	107
42	FORMAT(1H0 42X,44HTHICKNESS INTEGRALS CALCULATED FOR AIRFOIL 2)	108
		110
C	READ INPUT DATA AND PRINT	111
200	READ(5,23)(TITLE(I),I=1,24)	112
	READ(5,1) NVAN,NCAM,NFOIL,NALPHA,NTAUS	113
	READ(5,1) ISZ,MSZ,NUPUNJ,(JSIZE(M),M=1,MSZ)	115
	READ(5,2) SECLAM,BR,S,CAPS,CBAR	116
	READ(5,2) (DELTAY(I),H(I),Z1(I),Z2(I),Z3(I),ZM(I),I=1,ISZ)	117
	READ(5,2) (TAU(I),TAUH(I),TAUT(I),I=1,NTAUS)	118
	WRITE(6,27)(TITLE(I),I=1,24)	120
	ADDEG = 3.14159265/180.	121
	IF(NTAUS-1) 224,224,226	129
224	GO 225 I=1,ISZ	130
	TAU(I)=TAU(1)	131
	TAUH(I)=TAUH(1)	132
225	TAUT(I)=TAUT(1)	133
226	READ(5,2) (EMACH(I),I=1,MSZ)	134
	GO 227 M=1,MSZ	135
227	READ(5,2) (ALPHA(I,M),I=1,NALPHA)	136
	IF(NCAM.EQ.0) GO TO 250	137
	WRITE(6,3)	138
	GO TO 251	139
250	WRITE(6,24)	140
251	IF(NVAN.EQ.0) GO TO 252	141
	WRITE(6,4)	142
252	IF(NFOIL.EQ.2) GO TO 253	143
	WRITE(6,41)	144
	GO TO 254	145
253	WRITE(6,42)	146
254	SUM = 0	147
	GO 255 I=1,MSZ	148
255	SUM = JSUM + JSIZE(I)	149
	GO 300 I=1,ISZ	150
	Z2A(I)=ABS(Z2(I))	151
	X(I)=2.0*B(I)	152
	Z1(I)=X(I)*Z1(I)	153
	Z2(I)=X(I)*Z2A(I)	154
	Z3(I)=X(I)*Z3(I)	155
300	ZM(I)=X(I)*ZM(I)	156
	WRITE(6,5) ISZ,MSZ,JSUM,SECLAM,BR,S,CAPS,CBAR,(I,DELTAY(I),B(I),	157
	Z1(I),Z2A(I),Z3(I),ZM(I),I=1,ISZ)	158
	WRITE(6,28)(I,TAU(I),TAUH(I),TAUT(I),I=1,ISZ)	159
	IF(NALPHA-1)236,236,238	160
236	GO 237 I=1,ISZ	161
	GO 237 M=1,MSZ	162
237	ALPHA(I,M)=ALPHA(I,M)	163
238	GO 240 I=1,MSZ	164
	ISZ = JSIZE(I)	165
	READ(5,2) (EKR(J,I),J=1,JSZ)	166
	WRITE(6,8) EMACH(I),(EKR(J,I),J=1,JSZ)	167
	WRITE(6,6)(J,ALPHA(J,I),J=1,ISZ)	168
	GO 240 J=1,ISZ	170
240	ALPHA(J,I)=ALPHA(J,I)*RADDEG	171
	GO 1000 M=1,MSZ	250
	MS=EMACH(M)*EMACH(M)	255
	SECS=SECLAM*SECLAM	260

```

C VAN DYKE OPTION
IF(NVAN) 310,310,312
310 CBAR1=1.0
CBAR2=(1.4+1.0)/4.0
GO TO 320
312 CBAR1=EMACH(M)/SQRT(EMS-SECS)
CBAR2=(EMS*EMS*(2.4)-4.0*SECS*(EMS-SECS))/(4.0*(EMS-SECS)*(EMS-
1*SECS))
320 CBAR3=2.4/12.
SFU=0
S7=JSIZE(M)
DO 900 J=1,JSZ
IF(EKR(J,M))325,330,325
325 F1 = 1.0/EKR(J,M)
F2=1.0/(F1+1)
F3 = F1/BR
330 DO 800 I=1,ISZ
C STEADY CASE OPTION
IF(EKR(J,M))340,335,340
335 CON = (4./EMACH(M))*(CBAR*DELTAY(I)/CAPS)
GO TO 344
340 CON = (2./EMACH(M))*F2*(DELTAY(I)/S)
C IRFOIL OPTION
344 IF(NFOIL.EQ.2) GO TO 350
IF(Z2(I).GT.0.0) GO TO 345
CALL THIN1(J,I)
GO TO 360
345 CALL THIN1(0,I)
GO TO 360
350 IF(Z2(I).GT.0.0) GO TO 355
CALL THIN2(1,I)
GO TO 360
355 CALL THIN2(0,I)
360 DO 500 K=1,4
DO 400 L=1,7,2
IF (K.EQ.1.OR.K.EQ.2) GO TO 361
GO TO 362
361 IF(L.EQ.7) GO TO 399
GO TO 365
362 IF (K.EQ.4) GO TO 363
GO TO 365
363 IF (L.EQ.1.OR.L.EQ.3) GO TO 399
GO TO 365
399 CH1(K,L,I)=F.0
GO TO 400
365 LL=(L+1)/2
C BASIC AIC MATRIX EQUATION FOR PISTON THEORY (CAMBER WITH A CONTROL
C SURFACE) - REAL ELEMENTS.
CH1(K,L,I) = -CON*((CBAR1+3.*CBAR3*
1*EMACH(M)**2*ALPHA(I,M)**2)*(RHO(K,LL)+RC0(K,LL))+2.*CBAR2*EMACH(M)
2*(RA1(K,LL)+RH1(K,LL)+RC1(K,LL))+3.*CBAR3*EMACH(M)**2*(RA2(K,LL)+
3*RB2(K,LL)+RC2(K,LL)))
400 CONTINUE
DO 450 L=2,8,2
IF(EKR(J,M))370,409,370
370 IF (K.EQ.1.OR.K.EQ.2) GO TO 371
GO TO 372
371 IF(L.EQ.8)GO TO 409
GO TO 375
372 IF(K.EQ.4) GO TO 373

```

264
265
270
275
280
285
290
291
305
306
310
315
319
320
325
330
335
340
345
350
355
360
404
405
406
409
410
411
415
419
420
421
422
425
435
436
437
438
439
440
441
442
443
444
445
446
448
449
450
455
460
465
470
475
480
481
482
483
484
485

	GO TO 375	486
473	IF(L.EQ.2.OR.L.EQ.4) GO TO 409	487
	GO TO 375	488
489	H1(K,L,I)=0.0	489
	GO TO 450	490
475	L=L/2	491
C	BASIC AIC MATRIX EQUATION FOR PISTON THEORY (CAMBER WITH A CONTROL	493
C	SURFACE) - IMAGINARY ELEMENTS.	494
	CH1(K,L,I) = -CON*((CBAR1+3.*CBAR3*	495
	1FMACH(M)**2*ALPHA(I,M)**2)*F3*(SHU(K,LL)+SCU(K,LL))+2.*CBAR2*	500
	2FMACH(M)*F3*(SA1(K,LL)+SB1(K,LL)+SC1(K,LL))+3.*CBAR3*EMACH(M)**2	505
	3F3*(SA2(K,LL)+SB2(K,LL)+SC2(K,LL)))	510
450	CONTINUE	515
500	CONTINUE	520
C	GENERATE AIC MATRICES	525
C	CH1 - CAMBER WITH A CONTROL SURFACE	530
C	CH2 - RIGID CHORD WITH A CONTROL SURFACE.	535
C	CH3 - CAMBER WITHOUT A CONTROL SURFACE	540
C	CH4 - RIGID CHORD WITHOUT A CONTROL SURFACE	545
	IF(Z2(I).GT.0.0)GO TO 566	635
	IF(NCAM.EQ.0) GO TO 550	636
	U(I)=4	637
	GO TO 800	639
550	GO 560 KK=1,4	640
	GO 560 JJ=1,3	645
560	H(KK,JJ)=0.0	650
	H(1,1)=1.	655
	H(2,1)=(Z2A(I)-Z3(I))/(Z1(I)-Z3(I))	660
	H(2,2)=(Z1(I)-Z2A(I))/(Z1(I)-Z3(I))	665
	H(3,2)=1.	670
	H(4,3)=1.	675
	ALL MULT (1,CH1,CH2,D1,T1,3,6,4,8,I)	695
	U(I)=3	696
	GO TO 800	698
566	GO 567 K=1,4	699
	GO 567 L=1,6	700
567	CH3(K,L,I)=CH1(K,L,I)	701
	IF(NCAM.EQ.0)GO TO 600	702
	U(I)=3	703
	GO TO 800	704
600	H(1,1)=1.	705
	H(1,2)=0.0	706
	H(2,1)=(Z2A(I)-Z3(I))/(Z1(I)-Z3(I))	710
	H(2,2)=(Z1(I)-Z2A(I))/(Z1(I)-Z3(I))	715
	H(3,1)=0.0	720
	H(3,2)=1.	725
	ALL MULT (1N,CH3,CH4,D2,T1,2,4,3,6,I)	745
	U(I)=2	746
800	CONTINUE	750
C	PRINT AIC MATRICES	800
	WRITE(6,31)	805
	IF(NCAM.EQ.1) GO TO 825	810
	WRITE(6,3)	811
	GO TO 830	812
825	WRITE(6,24)	813
830	IF(NVAN.EQ.0) GO TO 835	814
	WRITE(6,4)	815
835	IF(EKR(J,M))836,837,836	816
836	WRITE(6,25) FMACH(M),EKR(J,M),ISZ	817
	GO TO 838	818

837	WRITE(6,39) EMACH(M),ISZ	819
838	DO 875 I=1,ISZ	825
	I = NU(I)	826
	I2 = 2*N	827
	WRITE(6,29) I,N,N	828
	DO 874 K=1,N	829
	IF(EKR(J,M)) 840,871,840	830
840	IF(Z2(I).GT.0.0) GO TO 866	831
	IF(NCAM.EQ.0) GO TO 850	832
	WRITE(6,30) (CH1(K,L,I),L=1,N2)	835
	GO TO 874	838
850	WRITE(6,30) (CH2(K,L,I),L=1,N2)	843
	GO TO 874	845
866	IF(NCAM.EQ.0) GO TO 870	848
	WRITE(6,30) (CH3(K,L,I),L=1,N2)	853
	GO TO 874	855
870	WRITE(6,30) (CH4(K,L,I),L=1,N2)	860
	GO TO 874	861
871	IF(Z2(I).GT.0.0) GO TO 873	862
	IF(NCAM.EQ.0) GO TO 872	863
	WRITE(6,40) (CH1(K,L,I),L=1,N2,2)	864
	GO TO 874	865
872	WRITE(6,40) (CH2(K,L,I),L=1,N2,2)	866
	GO TO 874	867
873	IF(NCAM.EQ.0) GO TO 855	868
	WRITE(6,40) (CH3(K,L,I),L=1,N2,2)	869
	GO TO 874	870
855	WRITE(6,40) (CH4(K,L,I),L=1,N2,2)	871
874	CONTINUE	872
875	CONTINUE	873
C	PUNCH AIC MATRICES IN FORTRAN FORMAT SO THAT IT CAN BE USED IN	875
C	COFA - FLUTTER ANALYSIS BY COLLOCATION METHOD.	878
C	THE AIC MATRIX FOR EACH 1/KR CONTAINS THE FOLLOWING CARDS -	880
C	CARD 1 - 1/KR, COLUMNS 1-12, (1P1E12.5)	883
C	CARD 2 - NSIZE, NPART, NFORM, NROW, (4I4), NFORM=NROW=1	885
C	THE FOLLOWING CARDS ARE REPEATED FOR EACH NON-ZERO PARTITION IN	888
C	THE AIC MATRIX (AS MANY TIMES AS THE NUMBER OF STRIPS INTO WHICH	890
C	THE SURFACE IS DIVIDED).	893
C	CARD 1 - N, ORDER OF PARTITION, COLUMNS 1-4, (I4)	895
C	FOLLOWED BY 1 OR 2 CARDS FOR EACH ROW OF PARTITION MATRIX	897
C	PUNCHED FORMAT (1P6E12.5)	898
C		899
	IF(NOPUNJ) 900,876,900	900
876	ISEQ=NSEQ+1	905
	PUNCH 32,EKR(J,M),NSEQ	910
	SIZE = 0	915
	DO 877 I= 1,ISZ	920
877	SIZE = NSIZE + NU(I)	925
	FORM = 1	930
	ROW = 1	935
	PUNCH 33,NSIZE,ISZ,NFORM,NROW,NSEQ	940
	DO 895 I=1,ISZ	945
	SF = 1	950
	I = NU(I)	955
	PUNCH 34,N,NSEQ,I,NSE	960
	SE = NSE + 1	965
	I2 = N*2	970
	DO 894 K=1,N	975
	IF(EKR(J,M)) 878,881,878	976
878	IF(Z2(I).GT.0.0) GO TO 886	980

IF(NCAM.EQ.0) GO TO 880	985
PUNCH 35,(CH1(K,L,I),L=1,6),NSEQ,I,NSE	990
SE = NSE + 1	991
PUNCH 36,(CH1(K,L,I),L=7,8),NSEQ,I,NSE	992
GO TO 893	995
880 PUNCH 35,(CH2(K,L,I),L=1,N2),NSEQ,I,NSE	1000
GO TO 893	1005
886 IF(NCAM.EQ.0) GO TO 890	1010
PUNCH 35,(CH3(K,L,I),L=1,N2),NSEQ,I,NSE	1015
GO TO 893	1020
890 PUNCH 38,(CH4(K,L,I),L=1,N2),NSEQ,I,NSE	1025
GO TO 894	1030
881 IF(Z2(I).GT.0.0) GO TO 883	1031
IF(NCAM.EQ.0) GO TO 882	1032
PUNCH 38,(CH1(K,L,I),L=1,N2,2),NSEQ,I,NSE	1033
GO TO 893	1034
882 PUNCH 37,(CH2(K,L,I),L=1,N2,2),NSEQ,I,NSE	1035
GO TO 893	1036
883 IF(NCAM.EQ.0) GO TO 884	1037
PUNCH 37,(CH3(K,L,I),L=1,N2,2),NSEQ,I,NSE	1038
GO TO 893	1039
884 PUNCH 36,(CH4(K,L,I),L=1,N2,2),NSEQ,I,NSE	1040
893 SE=NSE+1	1041
894 CONTINUE	1042
895 CONTINUE	1043
900 CONTINUE	1044
1000 CONTINUE	1045
GO TO 200	1050
END	1055
* FORTRAN DECK	2000
CT-IN1 COMPUTES THE THICKNESS INTEGRALS, BOTH REAL AND IMAGINARY	2001
C FOR AIRFOIL 1.	2002
C	2003
SUBROUTINE IHIN1(NC0,I)	2005
DIMENSION X(25),X1(25),X2(25),X3(25),XM(25),TAU(25),TAUH(25),	2010
1A1(4,4),RA2(4,4),RB1(4,4),SH0(4,4),SA1(4,4),SA2(4,4),SB1(4,4),	2011
2SB2(4,4),RA(4,4,3),RB(4,4,3),SA(4,4,3),SB(4,4,3),RC(4,4,3),	2012
3SC(4,4,3),RHO(4,4),TAUT(25),RB2(4,4),RC0(4,4),RC1(4,4),RC2(4,4),	2013
4SC0(4,4),SC1(4,4),SC2(4,4)	2014
COMMON X,X1,X2,X3,XM,TAU,TAUH,TAUT,RHO,RA1,RA2,RB1,RB2,SH0,SA1,	2015
1SA2,SB1,SB2,RC0,RC1,RC2,SC0,SC1,SC2	2016
C	2020
S1 = (TAU(I)/2.)*(X(I)/XM(I))	2025
IF(NC0.EQ.1) GO TO 5	2030
XH=X(I)	2031
TAUH(I)=TAUT(I)	2035
GO TO 6	2040
5 XH=X3(I)	2045
S3 = -(TAUH(I)/2.)*(1.-TAUT(I)/TAUH(I))*X(I)/(X(I)-XH)	2046
6 S2 = -(TAU(I)/2.)*(1.-TAUH(I)/TAU(I))*X(I)/(XH-XM(I))	2055
DO 100 II=1,4	2065
DO 100 J=1,4	2070
GO TO(10,15,20,50),II	2075
10 I=X1(I)	2080
K=X2(I)	2085
L=X3(I)	2090
GO TO 30	2095
15 I=X2(I)	2100
K=X1(I)	2105
L=X3(I)	2110

0 TO 30	2115
20 XI=X3(I)	2120
XK=X1(I)	2125
XL=X2(I)	2130
30 0 TO (35,40,45,50),J	2190
35 XJ=X1(I)	2195
XP=X2(I)	2200
XQ=X3(I)	2205
0 TO 55	2210
40 XJ=X2(I)	2215
XP=X1(I)	2220
XQ=X3(I)	2225
0 TO 55	2230
45 XJ=X3(I)	2235
XP=X1(I)	2240
XQ=X2(I)	2245
0 TO 55	2250
50 H0(I1,J)=0.0	2255
A1(I1,J)=0.0	2260
A2(I1,J)=0.0	2265
R1(I1,J)=0.0	2270
R2(I1,J)=0.0	2275
A1(I1,J)=0.0	2280
A2(I1,J)=0.0	2285
R1(I1,J)=0.0	2290
R2(I1,J)=0.0	2295
H0(I1,J)=0.0	2300
IF(NC0.EQ.0) GO TO 90	2301
IF(I1.EQ.3.OR.I1.EQ.4) GO TO 54	2302
0 TO 90	2305
54 IF(J.EQ.3.OR.J.EQ.4) GO TO 100	2306
0 TO 90	2307
55 EI=(XI-XK)*(XI-XL)*(XJ-XP)*(XJ-XQ)	2310
0 TO 75 K=1,3	2315
0 TO (60,62,64),K	2320
60 I1 = 1.0	2321
I2 = 1.0	2322
0 TO 69	2324
62 I1 = G1	2325
I2 = G2	2326
0 TO 69	2327
64 I1 = G1*G1	2329
I2 = G2*G2	2330
69 IF(K-1)71,70,71	2330
70 XMAX =XH	2337
0 TO 72	2338
71 XMAX =XM(I)	2339
72 A(I1,J,K)=(P1/DEL)*(XMAX**4/2.-1./3.*(2.*XK+2.*XL+XP+XQ)*XMAX	2340
1.*3+.5*(2.*XK*XL+(XK+XL)*(XP+XQ))*XMAX**2-XK*XL*(XP+XQ)*XMAX)	2345
A(I1,J,K)=(P1/DEL)*(((XMAX**5)/5.)-(XK+XL+XP+XQ)*((XMAX**4)/4.)	2350
1.*(XK*XL+XP*XQ+(XK+XL)*(XP+XQ))*((XMAX**3)/3.)-(XK*XL*(XP+XQ)+	2355
2*P*XQ*(XK+XL))*((XMAX**2)/2.)+XK*XL*XP*XQ*XMAX)	2360
IF(K-1)73,75,73	2361
73 B(I1,J,K)=(P2/DEL)*((XH**4-XM(I)**4)/2.-1./3.*(2.*XK+2.*XL+XP+XQ)	2365
1.*(XH**3-XM(I)**3)+(2.*XK*XL+(XL+XK)*(XP+XQ))*((XH**2-XM(I)**2)/2.-	2370
2*XK*XL*(XP+XQ)*(XH-XM(I)))	2375
B(I1,J,K)=(P2/DEL)*((XH**5-XM(I)**5)/5.-(XK+XL+XP+XQ)*(XH**4-	2380
1*XM(I)**4)/4.+(XK*XL+XP*XQ+(XK+XL)*(XP+XQ))*((XH**3-XM(I)**3)/3.-	2385
2*(XK*XL*(XP+XQ)+XP*XQ*(XK+XL))*((XH**2-XM(I)**2)/2.+XK*XL*XP*XQ*	2390
3*(XH-XM(I)))	2395

75	CONTINUE	2400
	RA1(I1,J)=RA(I1,J,2)	2405
	RA2(I1,J)=RA(I1,J,3)	2410
	RB1(I1,J)=RB(I1,J,2)	2415
	RB2(I1,J)=RB(I1,J,3)	2420
	SA1(I1,J)=SA(I1,J,2)	2425
	SA2(I1,J)=SA(I1,J,3)	2430
	SB1(I1,J)=SB(I1,J,2)	2435
	SB2(I1,J)=SB(I1,J,3)	2440
	SH0(I1,J)=RA(I1,J,1)	2445
	SH0(I1,J)=SA(I1,J,1)	2450
	IF(I1.EQ.3.AND.J.EQ.3)GO TO 79	2455
	GO TO 90	2459
79	IF(NC0.EQ.1) GO TO 80	2460
	GO TO 90	2461
80	DO 85 KK=1,3	2465
	DO 10(R1,83,82),KK	2470
81	P3 = 1.0	2475
	DO 10 84	2480
83	P3 = G3	2481
	GO TO 84	2482
82	P3 = G3*G3	2485
84	RC(3,3,KK)=-P3/2.	2490
	RC(4,3,KK)=RC(3,3,KK)	2495
	RC(4,4,KK)=-RC(3,3,KK)	2500
	RC(3,4,KK)=RC(4,4,KK)	2505
	RC(3,5,KK)=P3*(X(I)-XH)/3.	2510
	RC(4,4,KK)=SC(3,3,KK)	2515
	RC(3,4,KK)=P3*(X(I)-XH)/6.	2520
	RC(4,3,KK)=SC(3,4,KA)	2525
85	CONTINUE	2526
	DO 88 LM=3,4	2530
	DO 88 LN=3,4	2535
	RC(LM,LN)=RC(LM,LN,1)	2540
	RC1(LM,LN)=RC(LM,LN,2)	2545
	RC2(LM,LN)=RC(LM,LN,3)	2550
	SC(LM,LN)=SC(LM,LN,1)	2555
	SC1(LM,LN)=SC(LM,LN,2)	2560
	SC2(LM,LN)=SC(LM,LN,3)	2565
88	CONTINUE	2566
	GO TO 100	2570
90	RC0(I1,J)=0.0	2575
	RC1(I1,J)=0.0	2580
	RC2(I1,J)=0.0	2585
	SC0(I1,J)=0.0	2590
	SC1(I1,J)=0.0	2595
	SC2(I1,J)=0.0	2600
100	CONTINUE	2605
	RETURN	2610
	END	2615
3	FORTRAN DECK	3000
CTHIN2	COMPUTES THE THICKNESS INTEGRALS, BOTH REAL AND IMAGINARY,	3001
C	FOR AIRFOIL 2.	3002
C		3003
		3005
	SUBROUTINE THIN2(NC0,I)	3010
	IMENSION X(25),X1(25),X2(25),X3(25),XH(25),TAU(25),TAUK(25),	3011
1	H0(4,4),RA1(4,4),RA2(4,4),RB1(4,4),RB2(4,4),SH0(4,4),SA1(4,4),	3012
2	A2(4,4),SB1(4,4),SB2(4,4),RC0(4,4),RC1(4,4),RC2(4,4),SC0(4,4),	3013
3	SC1(4,4),SC2(4,4),RC(4,4,3),SC(4,4,3),XJ1(4,4,2),XK1(4,4,2),	3014
4	J2(4,4,2),XK2(4,4,2),RA(4,4,2),RB(4,4,2),SA(4,4,2),SB(4,4,2),	

5	JO(4,4),AJ1(4,4),AJ2(4,4),BJ0(4,4),BJ1(4,4),BJ2(4,4),AK0(4,4),	3015
6	AK1(4,4),AK2(4,4),BK0(4,4),BK1(4,4),BK2(4,4),TAUT(25)	3016
	COMMON X,X1,X2,X3,XH,TAU,TAUH,TAUT,RHO,RA1,RA2,RB1,RB2,SHU,SA1,	3017
	SA2,SB1,SB2,RC0,RC1,RC2,SC0,SC1,SC2	3018
	IF(NCO.EQ.1) GO TO 5	3019
	XH=X(I)	3020
	TAUH(I)=TAUT(I)	3025
	DO TO 6	3030
5	XH=X3(I)	3035
	Z3=((TAUH(I)/2.)*(1.-TAUT(I)/TAUH(I))*X(I)/(X(I)-XH)	3040
6	X1=TAU(I)*(X(I)/XH(I))	3041
	X2=TAU(I)*(1.-TAUH(I)/TAU(I))*X(I)*XH(I)/(XH-XH(I))*2	3045
	XH1=-B1/XH(I)	3050
	XH2=-B2/XH(I)	3055
	DO 150 I1=1,4	3060
	DO 150 J=1,4	3065
	DO 10(10,15,20,50),I1	3070
10	X1=X1(I)	3075
	XK=X2(I)	3080
	XL=X3(I)	3085
	DO TO 30	3090
15	I=X2(I)	3095
	XK=X1(I)	3100
	XL=X3(I)	3105
	DO TO 30	3110
20	I=X3(I)	3115
	XK=X1(I)	3120
	XL=X2(I)	3125
30	DO 10(35,40,45,50),J	3130
35	J=X1(I)	3135
	XP=X2(I)	3140
	XQ=X3(I)	3145
	DO TO 55	3150
40	J=X2(I)	3155
	XP=X1(I)	3160
	XQ=X3(I)	3165
	DO TO 55	3170
45	J=X3(I)	3175
	XP=X1(I)	3180
	XQ=X2(I)	3185
	DO TO 55	3190
50	H0(I1,J)=0.0	3195
	RA1(I1,J)=0.0	3205
	RA2(I1,J)=0.0	3210
	RB1(I1,J)=0.0	3215
	RB2(I1,J)=0.0	3220
	HQ(I1,J)=0.0	3225
	SA1(I1,J)=0.0	3230
	SA2(I1,J)=0.0	3235
	SB1(I1,J)=0.0	3240
	SB2(I1,J)=0.0	3245
	IF(NCO.EQ.0) GO TO 135	3250
	IF(I1.F0.3.OR.I1.EQ.4) GO TO 54	3251
	DO TO 135	3252
54	IF(J.EQ.3.OR.J.EQ.4) GO TO 150	3255
	DO TO 135	3256
55	EL=(X1-XK)*(X1-XL)*(XJ-XP)*(XJ-XQ)	3257
	DO 75 K=1,2	3260
	IF(K.EQ.2) GO TO 70	3265
		3270

```

      MAX=XH
      GO TO 71
70 MAX=XH(1)
71 A(11,J,K)=(1./DEL)*(XMAX**4/2.-1./3.*(2.*XK+2.*XL+XP+XU)*XMAX**3
  1+1./2.*(2.*XK*XL+(XK+XL)*(XP+XQ))*XMAX**2-XK*XL*(XP+XQ)*XMAX)
  SA(11,J,K)=(1./DEL)*(((XMAX**5)/5.)-(XK*XL+XP+XQ)*((XMAX**4)/4.)
  1-(XK*XL+XP*XQ+(XK+XL)*(XP+XQ))*((XMAX**3)/3.)-(XK*XL*(XP+XQ)+
  2*P*XQ*(XK+XL))*((XMAX**2)/2.)+XK*XL*XP*XQ*XMAX)
  F(K,EO,1) GO TO 75
  B(11,J,K)=(1./DEL)*((XH**4-XMAX**4)/2.-{1./3.)*(2.*XK+2.*XL+XP+XU
  1*(XH**3-XMAX**3)+(2.*XK*XL+(XL+XK)*(XP+XQ))*(XH**2-XMAX**2)/2.-
  2*XK*XL*(XP+XQ)*(XH-XMAX))
  B(11,J,K)=(1./DEL)*((XH**5-XMAX**5)/5.-(XK*XL+XP+XU)*(XH**4-XMAX
  1**4)/4.+(XK*XL*XP*XQ+(XK+XL)*(XP+XQ))*(XH**3-XMAX**3)/3.-(XK*XL*
  2*XP+XQ)+XP*XQ*(XK+XL))*(XH**2-XMAX**2)/2.+XK*XL*XP*XQ*(XH-XMAX))
75 CONTINUE
  H0(11,J)=RA(11,J,1)
  H0(11,J)=SA(11,J,1)
  J0(11,J)=RA(11,J,2)
  J0(11,J)=RB(11,J,2)
  K0(11,J)=SA(11,J,2)
  K0(11,J)=SB(11,J,2)
  N=5 L=1,2
  F(1,EO,2) GO TO 80
  Z=0.0
  N=XH(1)
  GO TO 81
80 Z=XH(1)
  N=XH
81 J1(11,J,L)=(1./DEL)*(.4*(XN**5-XZ**5)-.25*(2.*XK+2.*XL+XP+XU)*(
  1*XN**4-XZ**4)+(2.*XK*XL+(XK+XL)*(XP+XQ))*(XN**3-XZ**3)/3.-.5*XK*XL*
  2*XP+XU)*(XN**2-XZ**2))
  K1(11,J,L)=(1./DEL)*((XN**6-XZ**6)/6.-.2*(XK+XL+XP+XU)*(XN**5-
  1*XZ**5)+.25*(XK*XL+XP*XQ+(XK+XL)*(XP+XQ))*(XN**4-XZ**4)-(XK*XL*(XP+
  2*XP+XU)*(XN**3-XZ**3)/3.+.5*XK*XL*XP*XU*(XN**2-XZ**2))
  J2(11,J,L)=(1./DEL)*((XN**6-XZ**6)/3.-.2*(2.*XK+2.*XL+XP+XU)*(XN
  1**5-XZ**5)+.25*(2.*XK*XL+(XK+XL)*(XP+XQ))*(XN**4-XZ**4)-(XK*XL*(XP
  2*XP+XU)*(XN**3-XZ**3)/3.))
  K2(11,J,L)=(1./DEL)*((XN**7-XZ**7)/7.-((XK+XL+XP+XU)*(XN**6-XZ**6
  1)/6.+.2*(XP*XL+XP*XQ+(XK+XL)*(XP+XQ))*(XN**5-XZ**5)-.25*(XK*XL*(
  2*XP+XQ)+XP*XQ*(XK+XL))*(XN**4-XZ**4)+((XK*XL*XP*XQ*(XN**3-XZ**3))/
  3.))
85 CONTINUE
  J1(11,J)=XJ1(11,J,1)
  J1(11,J)=XJ1(11,J,2)
  J2(11,J)=XJ2(11,J,1)
  J2(11,J)=XJ2(11,J,2)
  K1(11,J)=XK1(11,J,1)
  K1(11,J)=XK1(11,J,2)
  K2(11,J)=XK2(11,J,1)
  K2(11,J)=XK2(11,J,2)
  A1(11,J)=F*1*AJ1(11,J)+H1*AJ0(11,J)
  B1(11,J)=E*2*B1(11,J)+R2*B10(11,J)
  A1(11,J)=E*1*AK1(11,J)+B1*AK0(11,J)
  B1(11,J)=E*2*BK1(11,J)+R2*BK0(11,J)
  A2(11,J)=E*1**2*AJ2(11,J)+2.*E*1*B1*AJ1(11,J)+H1**2*AJ0(11,J)
  B2(11,J)=E*2**2*B1(11,J)+2.*E*2*B2*B1(11,J)+H2**2*B10(11,J)
  A2(11,J)=E*1**2*AK2(11,J)+2.*E*1*B1*AK1(11,J)+H1**2*AK0(11,J)
  B2(11,J)=E*2**2*BK2(11,J)+2.*E*2*B2*BK1(11,J)+H2**2*BK0(11,J)
  F(11,EO,3,AND,1,EO,3) GO TO 124

```

3275
 3280
 3285
 3290
 3295
 3300
 3305
 3310
 3315
 3320
 3325
 3330
 3335
 3340
 3345
 3350
 3355
 3360
 3365
 3370
 3375
 3380
 3385
 3390
 3395
 3400
 3405
 3410
 3415
 3420
 3425
 3430
 3435
 3440
 3445
 3450
 3455
 3460
 3465
 3470
 3475
 3480
 3485
 3490
 3495
 3500
 3505
 3510
 3515
 3520
 3525
 3530
 3535
 3540
 3545
 3550
 3555
 3560
 3565
 3570

```

      GO TO 135
124 IF(NCO.EQ.1) GO TO 125
      GO TO 135
125 GO 130 KK=1,3
      GO TO(126,128,127),KK
126 G3 = 1.0
      GO TO 129
128 G3 = G3
      GO TO 129
127 G3 = G3*G3
129 C(3,3,KK)=-P3/2.
      C(4,3,KK)=C(3,3,KK)
      C(4,4,KK)=-RC(3,3,KK)
      C(3,4,KK)=C(4,4,KK)
      C(3,3,KK)=P3*(X(I)-XH)/3.
      C(4,4,KK)=SC(3,3,KK)
      C(3,4,KK)=P3*(X(I)-XH)/6.
      C(4,3,KK)=SC(3,4,KK)
130 CONTINUE
      GO 131 LH=3,4
      GO 131 LH=3,4
      C0(LH,LN)=PC(LH,LN,1)
      C1(LH,LN)=PC(LH,LN,2)
      C2(LH,LN)=PC(LH,LN,3)
      C0(LH,LN)=SC(LH,LN,1)
      C1(LH,LN)=SC(LH,LN,2)
      C2(LH,LN)=SC(LH,LN,3)
131 CONTINUE
      GO TO 150
135 C0(I1,J)=0.0
      C1(I1,J)=0.0
      C2(I1,J)=0.0
      C0(I1,J)=0.0
      C1(I1,J)=0.0
      C2(I1,J)=0.0
150 CONTINUE
      RETURN
      NO

```

FORTRAN DECK

PRE AND POST MULTIPLIES A COMPLEX MATRIX BY REAL MATRICES.
 IS THE POST-MULTIPLIER (REAL) OF SIZE N X M.
 A, THE TRANSPOSE OF A, IS GENERATED IN THE SUBROUTINE.
 T IS THE PRE-MULTIPLIER (REAL) OF SIZE M X N.
 IS THE COMPLEX MATRIX OF SIZE N X 2N IN REAL NOTATION.
 IS RESULTANT MATRIX (COMPLEX) OF SIZE M X 2M IN REAL NOTATION.

SUBROUTINE MULT (A,B,C,D,AT,M,M2,N,N2,I)

IMENSION A(N,M),B(M,N2,25),C(M,M2,25),D(M,N2),AT(M,N)

```

      GO 10 KK=1,M
      GO 10 JJ=1,N
10 A(JJ,KK) = A(KK,JJ)
      GO 20 K=1,M
      GO 20 L=1,N2
      (K,L)=0.0
      GO 20 J=1,N
20 (K,L) = D(K,L)+A(J,K)*B(J,L,1)
      GO 30 K=1,M
      GO 25 L=1,M2,2
      M = (L+1)/2

```

3575
 3580
 3585
 3590
 3595
 3600
 3605
 3606
 3607
 3610
 3615
 3620
 3625
 3630
 3635
 3640
 3645
 3650
 3655
 3660
 3665
 3670
 3675
 3680
 3685
 3690
 3695
 3700
 3705
 3710
 3715
 3720
 3725
 3730
 3735
 3740
 3745
 3750
 4000
 4001
 4002
 4003
 4004
 4005
 4006
 4007
 4010
 4015
 4016
 4020
 4025
 4030
 4035
 4040
 4045
 4050
 4055
 4060
 4065
 4070

```

      C(K,L,I)=0.0
      DO 25 J=1,N
25    C(K,L,I) = C(K,L,I)+D(K,2*J-1)*A(J,MM)
      DO 30 L=2,M2,2
      MM=L/2
      C(K,L,I) = 0.0
      DO 30 J = 1,N
30    C(K,L,I)=C(K,L,I) + D(K,2*J) * A(J,MM)
      RETURN
      END

```

```

4075
4080
4085
4090
4095
4100
4105
4110
4115
4120

```

4.0 REFERENCES

SECTION 2.0

1. Hughes Aircraft Co. MSD-P69-144, Collocation Flutter Analysis Program, Vol. I-IV, NASC Contract 00019-68-C-0274, dated April 1969.
2. Hughes Aircraft Co. Rpt., Supersonic Flutter Analysis Computer Program with Piston Theory Aerodynamic Derivative, NASC Contract N62269-68-C-0039, dated December 1967.
3. W. P. Rodden. "Aerodynamic Influence Coefficients from Strip Theory," J. Aero Sci., 26 (1959), 883.
4. T. Theodorsen. "General Theory of Aerodynamic Instability and the Mechanism of Flutter." NACA Rpt. 496, 1934.
5. T. Theodorsen and I. E. Garrick. "Mechanism of Flutter -- A Theoretical and Experimental Investigation of the Flutter Problem." NACA Rpt 685, 1938.
6. T. Theodorsen and I. E. Garrick. "Nonstationary Flow About a Wing-Aileron-Tab Combination Including Aerodynamic Balance." NACA 736, 1941.
7. B. Smilg and L. S. Wasserman. "Application of Three-Dimensional Flutter Theory to Aircraft Structures." U. S. Army Airforce TR 4798, 8 July 1942.
8. R. Timman, A. I. van de Vorren, and J. H. Greidanus. "Aerodynamic Coefficients of an Oscillating Airfoil in Two-Dimensional Subsonic Flow." J. Aero. Sci., 21 (1954), 499.
9. I. N. Spielberg. "The Two-Dimensional Incompressible Aerodynamic Coefficients for Oscillating Changes in Airfoil Camber." J. Aero. Sci., 20 (1953), 432.
10. E. F. Tyler. "Aerodynamic Coefficients for Cambering and Aileron Motions." J. Aero. Sci. 22 (1955), 340.

SECTION 3.0

1. H. Ashley and G. Zartarian. "Piston Theory -- A New Aerodynamic Tool for the Aeroelastician." J. Aero. Sci., 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, H. A. Malcom, and Adam M. Kliszewski. "Aerodynamic Influence Coefficients from Piston Theory: Analytical Development and Computational Procedure." Aerospace Corporation Report No. TDR-169 (3231-11) TN-2, 15 August 1962.
5. W. P. Rodden. "Aerodynamic Influence Coefficients for a Cambering Airfoil from Piston Theory with Applications to Aero-Servo-Elastic Stability Analysis." Consultation Report No. WPR(HAC)TN-67-3 prepared for the Hughes Aircraft Company, 17 March 1967.