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A COMPUTER PROGRAM FOR CALCULATING AERODYNAMIC CHARACTERISTICS OF LOW ASPECT-RATIO WINGS WITH PARTIAL LEADING-EDGE SEPARATION

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LIST OF SYMBOLS

Symbols	Description	Dimensions
b	Wing span	m (ft)
c	Local chord	m (ft)
C_R	Root chord	m (ft)
M	Number of spanwise strips plus one	
N	Number of bound elements	
x,y,z	Wing rectangular coordinate system with x in the streamwise direction and y to the right	m (ft)
Greek		
α	Angle of attack	deg
Subscripts		
cp	Control point	
i	Chordwise bound element number	
j	Spanwise strip number	
k	Chordwise bound element number	
ℓ	Leading-edge	

1. INTRODUCTION

This document describes in detail the necessary information for using a computer program to predict distributed and total aerodynamic characteristics for low aspect-ratio wings with partial leading-edge separation. This program is based on the numerical method developed in reference 1. The flow is assumed to be steady and inviscid. The wing boundary condition is formulated by the Quasi-Vortex-Lattice method. The leading-edge separated vortices are represented by discrete free vortex elements which are aligned with the local velocity vector at mid-points to satisfy the force free condition. The wake behind the trailing-edge is also force free. The flow tangency boundary condition is satisfied on the wing, including the leading- and trailing-edges.

The program is restricted to delta wings with zero thickness and no camber. It is written in Fortran language and runs on CDC 6600 Computer.

2. COMPUTER PROGRAM DESCRIPTION

2.1 PROBLEM DEFINITION

In steady symmetric flight at a high angle of attack, the flow over a thin low aspect-ratio highly sweptback wing separates along the leading-edge and the tips. In the following, only delta wings are considered. The wing can be represented by a bound vortex sheet, across which there exists a pressure difference, and the separated flow along leading-edges by force free vortex sheets, across which there is no pressure difference. In the present method, the Quasi-Vortex-Lattice method (reference 2) is used to simplify the induced velocity expressions due to the bound vortex sheet and discrete force free vortex elements for separated vortex sheets. The following boundary conditions are imposed on the flow model:

a. The flow must be tangential to the wing surface.

b. The leading-edge boundary condition and the trailing-edge Kutta condition are to be satisfied.

c. The vortex elements over the wing and wake behind the trailing-edge are force free.

This is a non-linear problem because the strengths of the wing bound vortices and free vortices, and the locations of the free vortex elements are unknown. Thus, the problem is solved by an iterative method.

2.2 PROGRAM CAPABILITIES

This computer program provides a theoretical method for determining the aerodynamic characteristics of low aspect-ratio thin delta wings without camber, with partial leading-edge separation. The following is a list of the aerodynamic characteristics the program calculates:

a. Spanwise and chordwise ΔC_p distributions

b. Spanwise distribution of sectional lift, induced-drag and pitching moment coefficients.

c. Total lift, induced-drag, pitching-moment and leading-edge thrust coefficients.

2.3 GEOMETRY DESCRIPTION

The origin of the rectangular coordinate system is at the wing apex. The wing lies in the x-y plane and the x-axis is taken along the wing center-line The wing span is given by b and the surface area S.

2.3.1 WING GEOMETRY

The location of bound- and trailing-vortex elements for a typical case are shown in figure 1. The x-location of bound elements is given by the cosine law and is illustrated in figure 1.

$$x_i = x_\ell + \frac{c}{2}\left(1 - \cos\left(\frac{2i - 1}{2N}\pi\right)\right), \quad (1)$$

$$i = 1,2,\text{---}N$$

where x_ℓ is the leading-edge x-coordinate, c is the chord and N is the number of bound elements in a chordwise direction. The spanwise location of trailing elements is given by,

$$y_j = \frac{b}{4}\left(1 - \cos\left(\frac{2j - 1}{2M}\pi\right)\right), \quad (2)$$

$$j = 1,2,\text{---}M$$

where b is the span and M is the number of legs of trailing vorticity, which is one higher than the number of spanwise strips of bound elements. The locations of control points are given by,

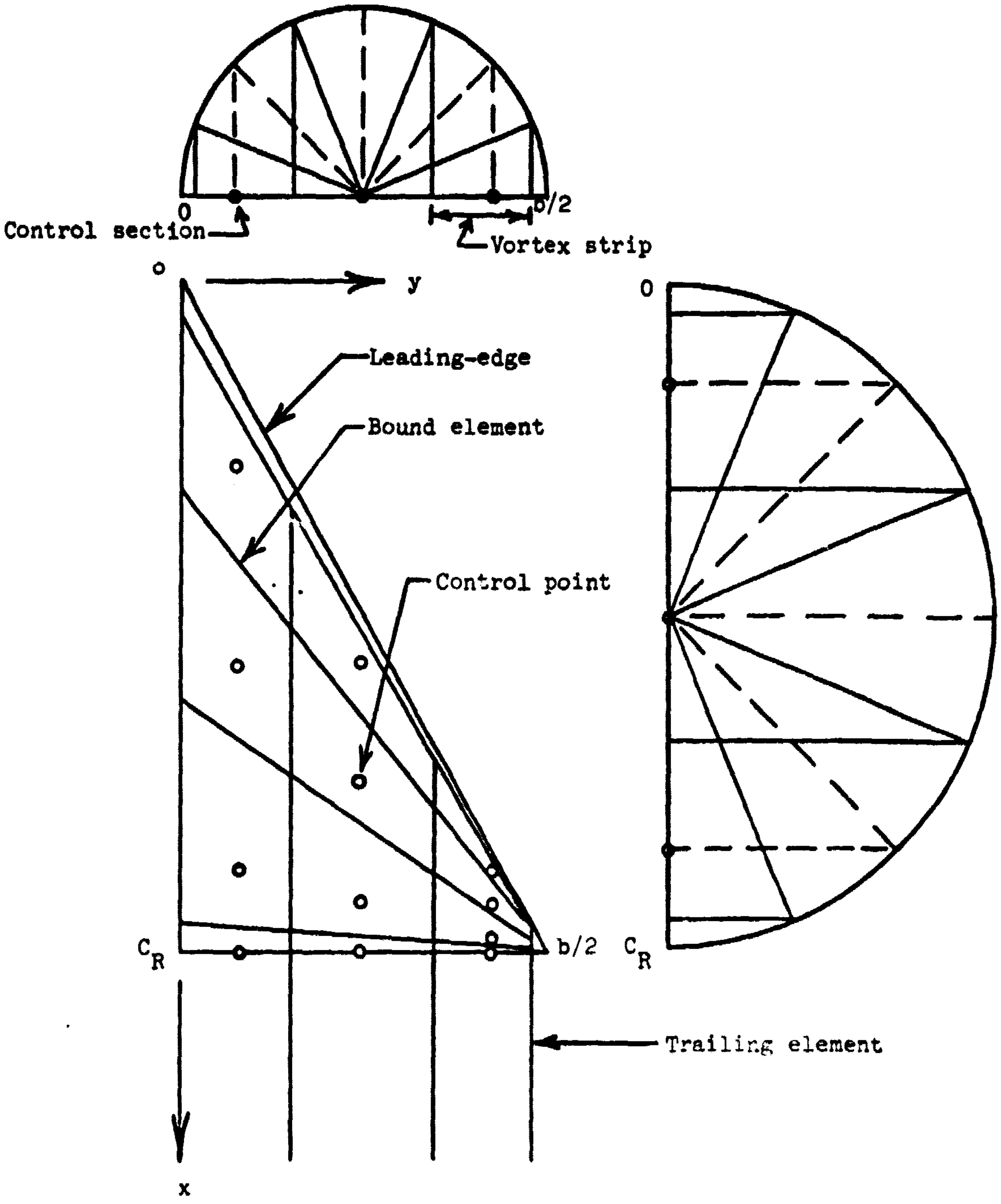

Figure 1. Wing geometry without leading-edge vortex system

$$x_{cp_k} = x_{\ell_j} + \frac{c_j}{2}\left(1 - \mathrm{Cos}\left(\frac{\pi k}{N}\right)\right) , \qquad (3)$$

$k = 0,1,2,---N$

$$y_{cp_j} = \frac{b}{4}\left(1 - \mathrm{Cos}\left(\frac{\pi j}{M}\right)\right) , \qquad (4)$$

$j = 1,2,---(M - 1)$

where x_{ℓ_j} and c_j are the leading-edge x-coordinate and chord at y_{cp_j} respectively.

It has been found numerically that the aerodynamic characteristics depended on the number of spanwise strips, i.e. M of equation (2). Therefore, a parametric study has been made to find a relation between the aspect ratio and the number of spanwise strips for reasonably accurate results (Fig. 2) (Section 3 of ref. 1). It is to be noted that as the aspect ratio is decreased, the number of spanwise strips has to be increased. This is due to the fact that the spanwise variation of aerodynamic characteristics, such as pressure coefficient and thrust coefficient, is large for small aspect ratio wings. This study was performed by matching the lift coefficients obtained by using the present method to those obtained by using suction analogy (ref. 3) at one angle of attack.

2.3.2 LEADING-EDGE VORTEX SYSTEM GEOMETRY

The leading-edge vortex system is superimposed on the regular quasi-vortex-lattice grid. A typical vortex element is shown by points A through J in figure 3. These points are connected by a series of short straight segments. The initial location of these segments is shown by dashed lines and final

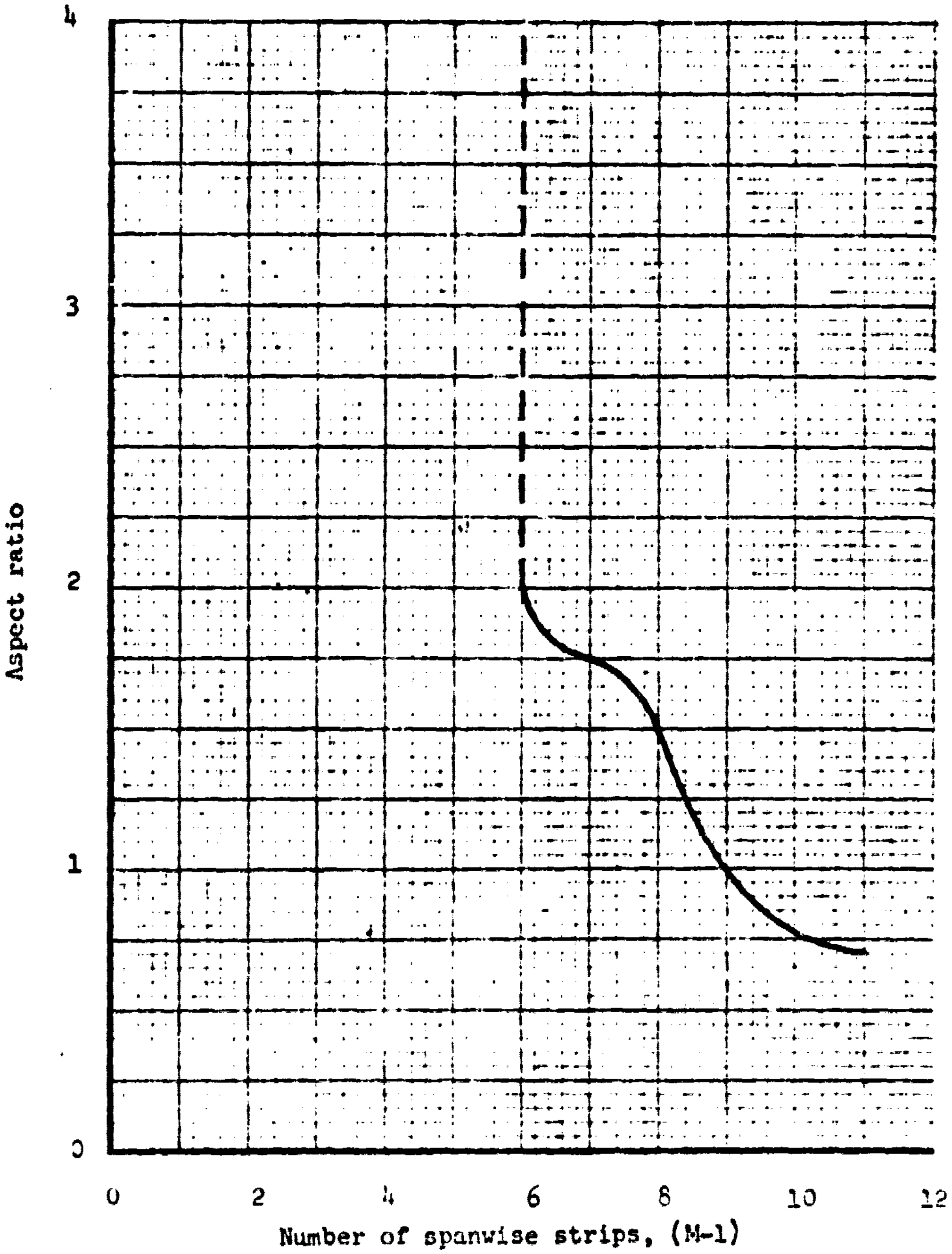

Figure 2. Variation of number of spanwise strips with aspect ratio

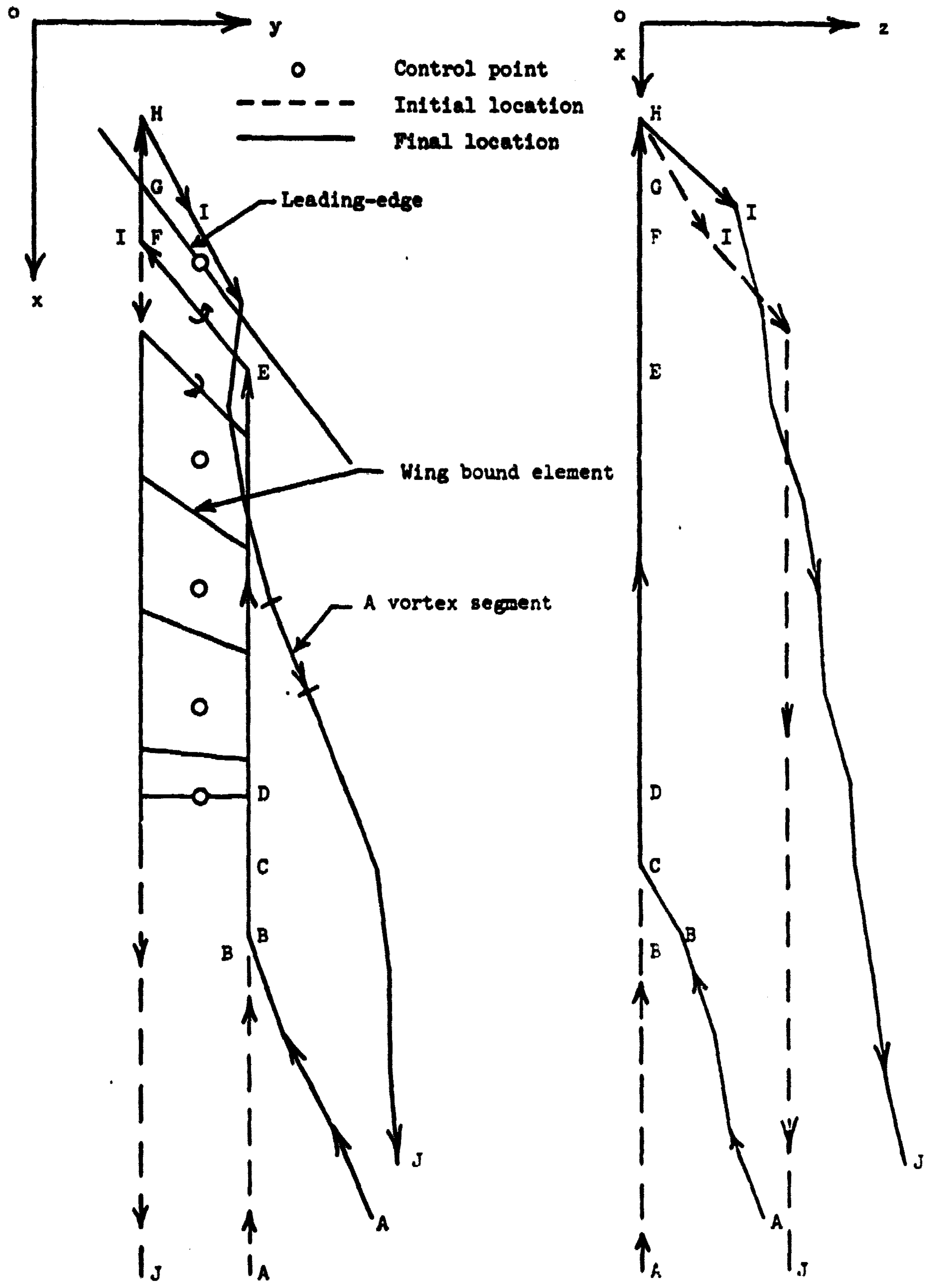

Figure 3. A typical vortex element of leading-edge vortex system

location by solid lines. These segments have the following characteristics;

a. Points A through E lie along a wing trailing vortex element. Initially point A is one root chord away from the trailing-edge in the downstream direction and the line segments between A and D are parallel to the axis of symmetry. The line segments between points A and B are of equal length. In the final converged position these segments are aligned in the direction of the local velocity vector. The segments B-C and C-D are 0.1 C_R long. B-C is allowed to move only in the vertical direction whereas C-D is fixed in the wing plane because the flow is tangential to the trailing-edge. Segment D-E is also fixed in the wing plane.

b. Points E, F, G and H also lie in the wing plane. The location of segment E-F is ahead of the wing first bound element and is given by,

$$x_E = x_{\ell_E} + \frac{c_E}{2} \left(1 - \mathrm{Cos}\left(\frac{\pi}{2(N+1)}\right)\right) \qquad (5.a)$$

$$x_F = x_{\ell_F} + \frac{c_F}{2} \left(1 - \mathrm{Cos}\left(\frac{\pi}{2(N+1)}\right)\right) \qquad (5.b)$$

where the subscripts E and F refer to the points under consideration. The above two equations are similar to equation (1). It is to be noted that segment E-F is located at the first bound element for a grid of (N + 1) bound elements in a chordwise direction. The segments F-G and G-H are of the same length and point G lies on the leading-edge. The segment G-H is fixed in the wing plane due to the leading-edge boundary condition.

c. The initial location of point I is given by,

$$x_I = x_F \quad (6.a)$$

$$y_I = y_F \quad (6.b)$$

$$z_I = 0.1\, C_R \tan(22.5 - 0.5\alpha) \quad \text{for} \quad \alpha \leq 15^\circ \quad (6.c)$$

or $$z_I = 0.1\, C_R \tan\alpha \quad \text{for} \quad \alpha \geq 15^\circ \quad (6.d)$$

where C_R is the root chord and α is the angle of attack. Initially point J is one root chord away from the trailing-edge. The segments between point I and J are of equal length and lie in a plane parallel to x-z plane. These segments are approximately at a height of $0.1 \cdot C_R$ above the wing plane. In the final converged position all the segments between points H and J are aligned in the direction of the local velocity vector.

d. The semi-infinite segments from points A to infinity and J to infinity are straight and are parallel to the undisturbed free-stream direction.

2.4 SOLUTION PROCEDURE

The basic unknowns of the problem are the bound vortex density on the wing, and the strengths and the locations of the elements of the leading-edge vortex system and the wake. The problem is nonlinear because the locations of the leading-edge vortex system and the wake are unknown a priori. Therefore, the problem is solved by the iterative process described below;

a. Prescribe the vortex lattice for the wing surface, and the initial locations of the free elements over the wing and in the wake.

b. By satisfying the wing boundary condition, obtain the bound vortex density of the wing and the strengths of free elements.

c. Calculate all the aerodynamic characteristics.

d. Calculate the forces acting on the free elements over the wing surface.

e. Adjust the free elements of the leading-edge vortex system and the wake in the local velocity vector direction.

f. Repeat steps b through e until a converged solution is obtained.

The initial locations of the free vortex elements are assumed by letting them leave the leading-edge in the undisturbed free-stream direction up-to a height of about ten percent of the root chord beyond which the elements are parallel to the wing plane. Initially, all the elements of the wake lie in the plane of the wing. In the iteration process, the force free condition is satisfied on the free elements from the root to the tip in the down-stream direction. The elements over the wing are adjusted before the elements of the wake. In the first iteration the segments over the wing are moved 100 percent according to the velocity computed at their mid-points. This movement is gradually reduced in steps of 90, 80 and 75 percent in the next three iterations, after which it remains at 75 percent (Section 2.5.2 of ref. 1). The segments in the wake are moved only 50 percent in each iteration. Thus, exact force free condition is not enforced because whenever the free elements come close to each other they induce unreasonably large velocities because viscous effects are not included in the present theory. These large velocities increase the forces on the segments and induce fluctuations in their locations.

The solution is assumed to have converged if in two consecutive iterations the difference between the total strengths of leading-edge free vortex elements is less than one percent and the absolute force acting on the free elements is in the neighborhood of a minimum. Thus, an exact force free condition is not enforced as discussed in the previous paragraph.

3. INPUT DATA FORMAT

The following is the description of input data cards for this program.

Card 1. Format (16A5)

TTL	Any title identifying the case to be run. END in first three columns terminates the job.

Card 2. Format (6I5)

NCW	Number of chordwise lines (limited to nine)
NSW	Number of spanwise lines (one higher than number of spanwise strips of panels, limited to twenty). It depends on aspect-ratio and is determined by using figure 2.
NBRR	Number of constant x-locations where ΔC_p's are to be interpolated (limited to twenty-five).
NCONTS	= 0, Initial locations of free elements will be calculated in the program. = 1, Initial locations of free elements will be read from data cards.
MITER	Maximum number of iterations to be performed (usually between 10 and 15)
IPUNCH	= 0, Coordinates of free elements will not be punched out after last iteration. = 1, Coordinates of free elements will be punched out after last iteration.

Card 3. Format (6F10.5)

XXL(1)	Leading-edge x-coordinate of the root chord.

XXT(1)	Trailing-edge x-coordinate of the root chord.
YL(1)	y-coordinate of the root chord
XXL(2)	Leading-edge x-coordinate of the tip chord.
XXT(2)	Trailing-edge x-coordinate of the tip chord.
YL(2)	y-coordinate of the tip chord.

Card 4. Format (7F10.5)

ALPHA	Angle of attack (in degrees).
AMACH	Mach number.
DELTA	Length of a segment of leading-edge free vortex elements (may be taken as 0.15 C_R).
DL	Length of a segment of wake elements (may be taken as 0.15 C_R).
XEND	x-coordinate beyond which free elements of leading-edge and wake system are represented by a single element going to infinity.
CBAR	Reference chord.
AREA	Total reference wing area.

Card 5. Format (8F10.5)

XBRR(I), I = 1, NBRR	Constant x-locations where ΔC_p's are to interpolated.

Card 6. Format (8F10.5)

CTT(I), I = 1,(NSW-1)	Sectional leading-edge thrust coefficients for spanwise strips. All these values are set equal to zero for complete leading-edge separation.

*** If NCONTS = 0, go back to card number 1 ***

Card 7. Format (10I2)

NELM(I), I = 1,(NSW-1)	One higher than the number of segments for each leading-edge free vortex element (numbered from root to tip).

Card 8. Format (8F10.5)

XE(K) K = 1,NELM(I)	x-coordinates of the end-points of segments of Ith leading-edge free vortex element.

Card 9. Format (8F10.5)

YE(K), K = 1,NELM(I)	y-coordinates of the end-points of segments of Ith leading-edge free vortex element.

Card 10. Format (8F10.5)

ZE(K) K = 1,NELM(I)	z-coordinates of the end-points of segments of Ith leading-edge free vortex element.

Cards 8 thru 10 are repeated (NSW-1) times.

Card 11. Format (10I2)

NNELM(I), I = 1,NSW	One higher than the number of segments for each wake element (numbered from root to tip).

Card 12. Format (8F10.5)

XXE(K) K = 1,NNELM(I)	x-coordinates of the end-points of segments of Ith trailing wake element.

Card 13. Format (8F10.5)

YYE(K) K = 1,NNELM(I)	y-coordinates of the end-points of segments of Ith trailing wake element.

Card 14. Format (8F10.5)

ZZE(K), K = 1,NNEM(I)	z-coordinates of the end-points of segments of Ith trailing wake element.

*** Cards 12 thru 14 are repeated NSW times.***

*** Go back to card number 1.***

Note: The punched data cards obtained by running this program with IPUNCH = 1, can be directly used for cards 7 thru 14 for further iterations.

4. OUTPUT DATA FORMAT

All the input data cards for each case are listed at the beginning of the output. The output data at each iteration step is as follows:

The title card (input data card number 1) is printed-out as it is inputted. The angle-of-attack (in degrees), Mach Number and iteration number are also listed. The end-point locations of the leading-edge free elements are listed next. The first row of numbers in each group are the x-coordinates, second row the y-coordinates and third row the z-coordinates. The end-point locations of the wake elements are listed in the similar manner. On the next two pages, x-y and y-z digital plots for leading-edge free-elements are made. It is to be noted that the leading-edge elements lying in the plane of the wing and along center line are not plotted. So, the elements next to the center line are represented by "1". When similar numbers are connected by straight lines, they represent the path of a free vortex element. A "+" sign represents a duplicate point. In these two plots there are (NSW-2) rows of free elements. The digital plots for wake elements are made on next two pages. The elements along center line are again not plotted. There are (NSW-1) elements.

Some of the intermediate variables are listed under following labels:

X/C	Percent chord location
2Y/B	Percent span location
GAMAY	Bound vortex density over the wing (γ_y) at the given (X/C, 2Y/B)
CAPGAMA	Strength of leading-edge free element (Γ) at the given 2Y/B
DELTA-CP	The total ΔC_p at the given (X/C, 2Y/B)

The sectional properties are listed under the following labels:

I	**Spanwise station number (numbered from root to tip)**
CLI	**The sectional lift coefficient**
CMI	**The sectional pitching moment coefficient about the y-axis**
CDI	**The sectional induced drag coefficient**
CTI	**The sectional leading-edge thrust coefficient.**

The total lift, pitching moment, induced drag and leading-edge thrust **coefficients are listed after** sectional properties. The spanwise pressures at constant x-locations are listed under following labels:

Y	y-coordinate
2Y/B(LOCAL)	Percent span location based on local span
DELTA-CP	The total ΔC_p at the given (x,y)

The last item listed for each iteration is the absolute force acting on leading-edge free elements.

The last page of the output is the "Summary Sheet", which is used to pick up final converged solution. It has the following format:

The title (input data card number 1) is printed again. The angle of attack (in degrees) and Mach Number are also listed. The other variables listed are,

ITERATION	Iteration number
CL	The total lift coefficient
CM	The total pitching moment coefficient about y-axis
CD	The total induced drag coefficient
CT	The total leading-edge thrust coefficient
GMSUM	Total sum of the strengths of leading-edge free vortex elements, except the one at the center line.

PERR	Percent change in GMSUM values of two consecutive iterations
TFABS	Total absolute force acting on leading-edge free elements

This program has not yet been completely automated and the converged solution is to be picked by the user, from the Summary Sheet, by using the following criteria:

The solution is assumed to have converged if in two consecutive iterations the difference between the total strengths of leading-edge free vortex elements is less than one percent and the absolute force acting on the free elements is in the neighborhood of a minimum.

5. REFERENCES

1. Mehrotra, S. C. and Lan, C. E., "A Theoretical Investigation of the Aerodynamics of Low-Aspect-Ratio Wings with Partial Leading-Edge Separation", NASA CR-145304, January 1978.

2. Lan, C. E., "A Quasi-Vortex-Lattice Method in Thin Wing Theory", Journal of Aircraft, Vol. 11, No. 9, pp. 518-527, Sept. 1974.

3. Lamar, J. E. and Gloss, B. B., "Subsonic Aerodynamic Characteristics of Interacting Lifting Surfaces with Separated Flows around Sharp Edges Predicted by a Vortex Lattice Method", NASA TN D-7921, Sept. 1975.

6. APPENDICES

6.1 APPENDIX A: EXAMPLE INPUT AND OUTPUT

The following is an example of delta wing of aspect-ratio 2 at an angle-of-attack of 30 degrees. The flow is assumed to be completely separated from the leading-edge and so sectional leading-edge thrust coefficients are set to zero on card number 6. Listing of input data cards is given below:

Listing of Input Data Cards

```
                                         C O L U M N   N U M B E R
                      11111111112222222222333333333344444444445555555555666666666677777777778
             12345678901234567890123456789012345678901234567890123456789012345678901234567890
CARD NUMBER
      1                          ASPECT RATIO = 2.0
      2          6    7    5    0   10    0
      3      0.        4.        0.        4.        4.        2.
      4      30.       0.        0.6       0.6       7.5       2.        8.
      5      1.        2.        3.        3.5       3.75
      6      0.        0.        0.        0.        0.        0.
      7      END
```

Output data is listed on the following pages. An inspection of the "Summary Sheet" suggests that the converged solution has been reached at 8th iteration.

```
INPUT DATA CARDS
                    ASPECT RATIO = 2.0
   6    7    5    0   10    0
  0.00000   4.00000   0.00000   4.00000   4.00000   2.00000
 30.00000   0.00000    .60000    .60000   7.50000   2.00000   8.00000
  1.00000   2.00000   3.00000   3.50000   3.75000
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
END OF INPUT DATA
```

```
                       ASPECT RATIO = 2.0
ALPHA(DEG.)=30.000  MACH NUMBER= 0.000  ITERATION NUMBER= 0

LEADING EDGE ELEMENTS
**********************
**** 1*****
  4.0000     .4810     .0501    0.0000    -.2000     .2000     .7196
   .2182     .2182    0.0000    0.0000    0.0000    0.0000    0.0000
  0.0000    0.0000    0.0000    0.0000    0.0000     .2309     .5309
**** 2*****
  4.0000    1.1682     .4810     .4353     .2582     .6145    1.1341    1.7341    2.3341    2.9341    3.5341    4.1341    4.7341    5.3341
  5.9341    6.5341    7.1341    7.7341
   .5661     .5661     .2182     .2182     .2182     .2182     .2182     .2182     .2182     .2182     .2182     .2182     .2182     .2182
   .2182     .2182     .2182     .2182
  0.0000    0.0000    0.0000    0.0000    0.0000     .2309     .5309     .5309     .5309     .5309     .5309     .5309     .5309     .5309
   .5309     .5309     .5309     .5309
**** 3*****
  4.0000    2.0251    1.1682    1.1322     .9388    1.2756    1.7952    2.3952    2.9952    3.5952    4.1952    4.7952    5.3952    5.9952
  6.5952    7.1952    7.7952
  1.0000    1.0000     .5661     .5661     .5661     .5661     .5661     .5661     .5661     .5661     .5661     .5661     .5661     .5661
   .5661     .5661     .5661
  0.0000    0.0000    0.0000    0.0000    0.0000     .2309     .5309     .5309     .5309     .5309     .5309     .5309     .5309     .5309
   .5309     .5309     .5309
**** 4*****
  4.0000    2.8820    2.0251    2.0000    1.9000    2.1000    2.6196    3.2196    3.8196    4.4196    5.0196    5.6196    6.2196    6.8196
  7.4196    8.0196
  1.4339    1.4339    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
  1.0000    1.0000
  0.0000    0.0000    0.0000    0.0000    0.0000     .2309     .5309     .5309     .5309     .5309     .5309     .5309     .5309     .5309
   .5309     .5309
**** 5*****
  4.0000    3.5691    2.8320    2.8578    2.8112    2.9244    3.4440    4.0440    4.6440    5.2440    5.8440    6.4440    7.0440    7.6440
  1.7819    1.7819    1.4339    1.4339    1.4339    1.4339    1.4339    1.4339    1.4339    1.4339    1.4339    1.4339    1.4339    1.4339
  0.0000    0.0000    0.0000    0.0000    0.0000     .2309     .5309     .5309     .5309     .5309     .5309     .5309     .5309     .5309
**** 6*****
  4.0000    3.9505    3.5691    3.5537    3.5418    3.5855    4.1051    4.7051    5.3051    5.9051    6.5051    7.1051    7.7051
  1.9749    1.9749    1.7818    1.7818    1.7818    1.7818    1.7818    1.7818    1.7818    1.7818    1.7818    1.7818    1.7818
  0.0000    0.0000    0.0000    0.0000    0.0000     .2309     .5309     .5309     .5309     .5309     .5309     .5309     .5309
```

```
WAKE ELEMENTS
*************
**** 1****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 2****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
   .2182     .2182     .2182     .2182     .2182     .2182     .2182     .2182
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 3****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
   .5661     .5661     .5661     .5661     .5661     .5661     .5661     .5661
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 4****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
  1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 5****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
  1.4339    1.4339    1.4339    1.4339    1.4339    1.4339    1.4339    1.4339
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 6****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
  1.7818    1.7818    1.7818    1.7818    1.7818    1.7818    1.7818    1.7818
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 7****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
  1.9749    1.9749    1.9749    1.9749    1.9749    1.9749    1.9749    1.9749
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
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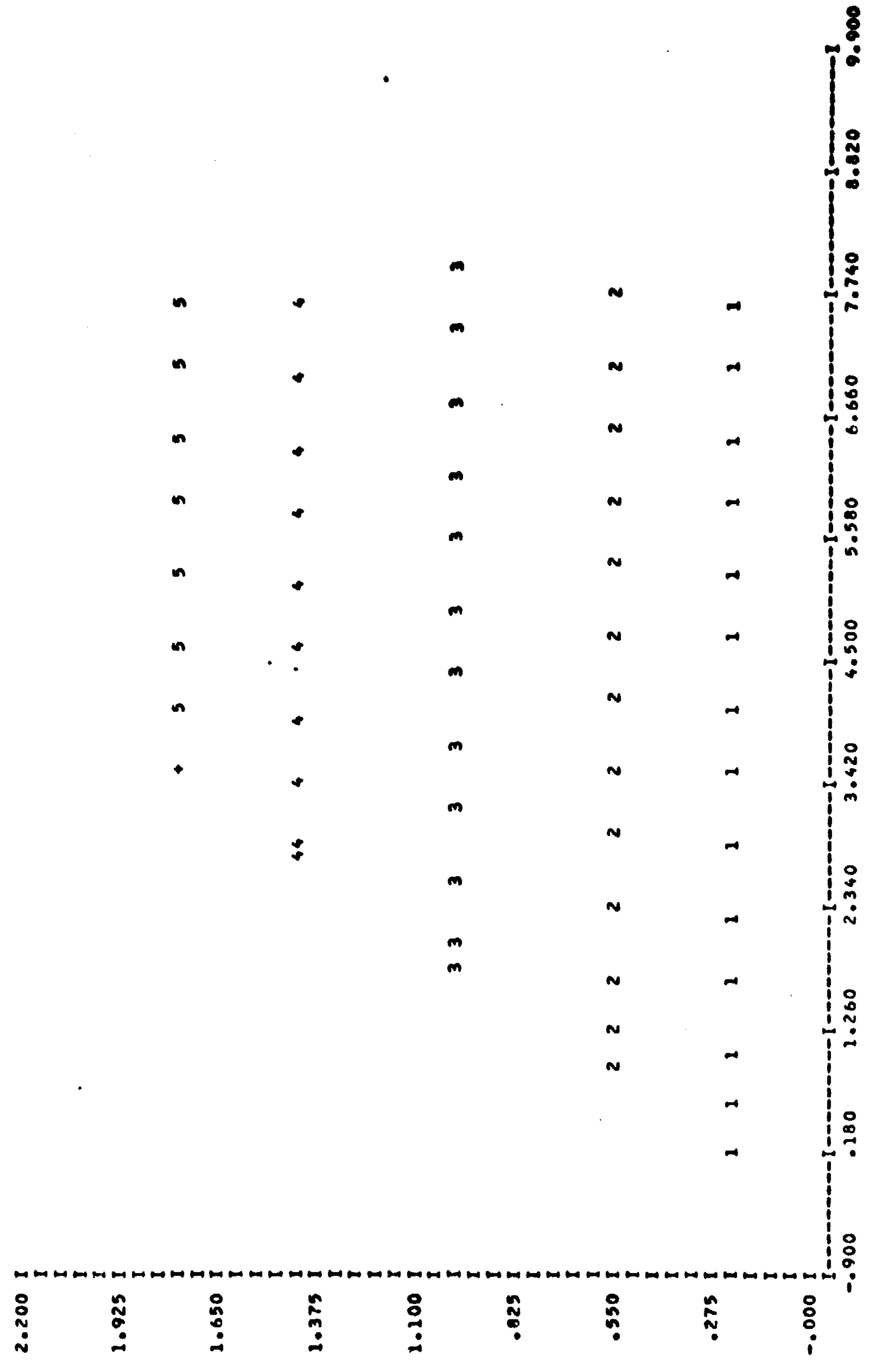
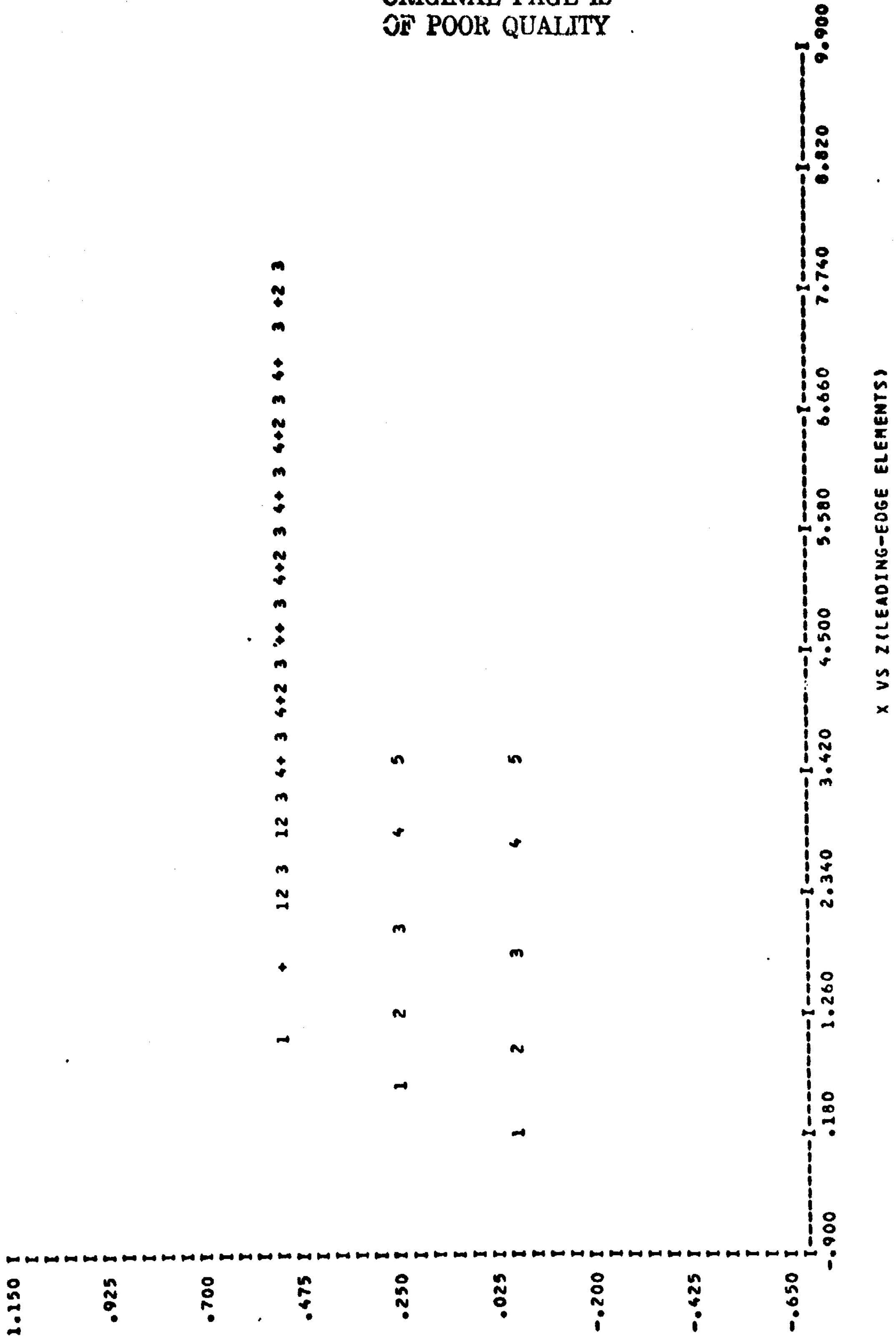
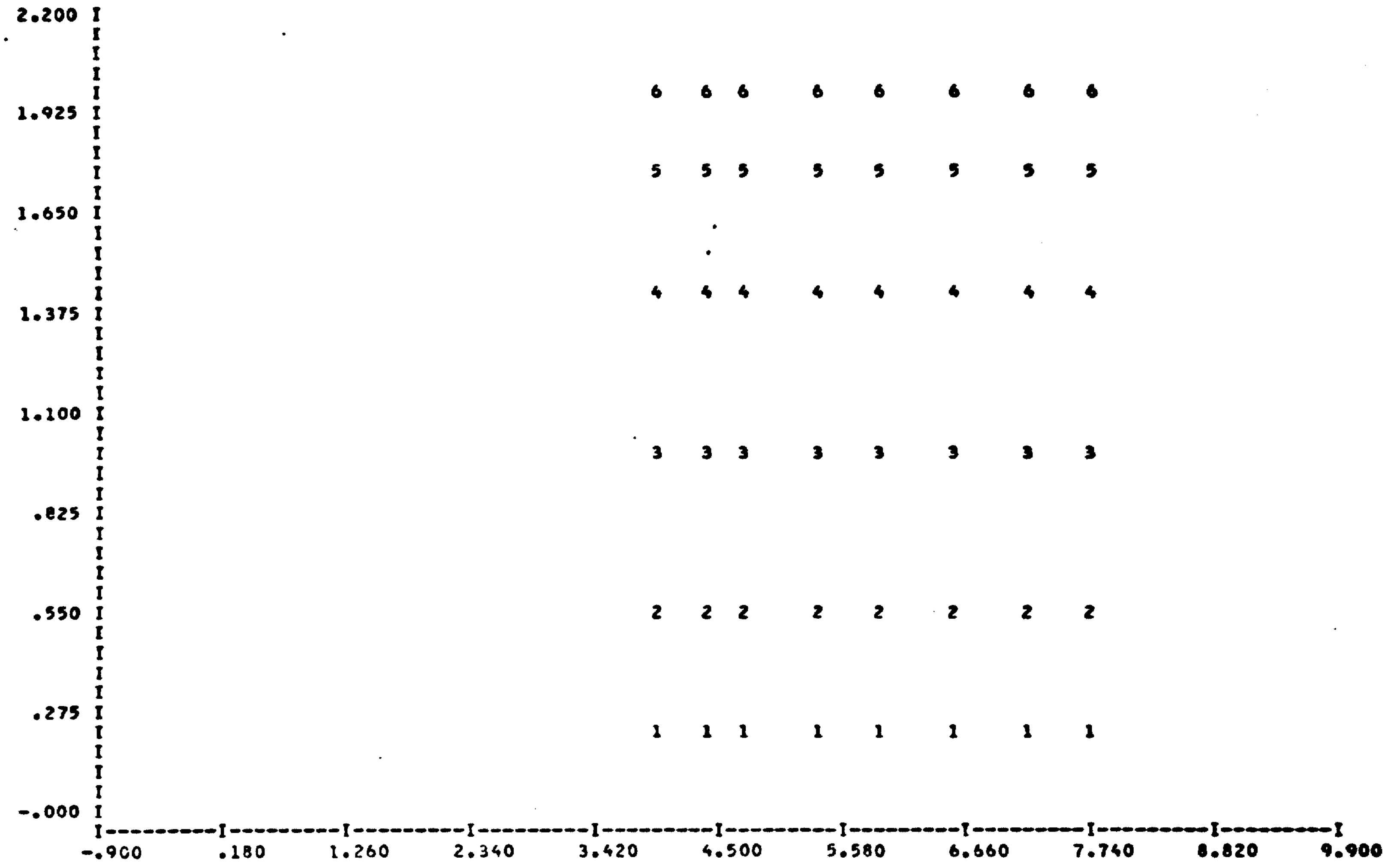
ORIGINAL PAGE IS
OF POOR QUALITY



X VS Y(LEADING-EDGE ELEMENTS)

ORIGINAL PAGE IS
OF POOR QUALITY





X VS Y(WAKE ELEMENTS)

ORIGINAL PAGE IS
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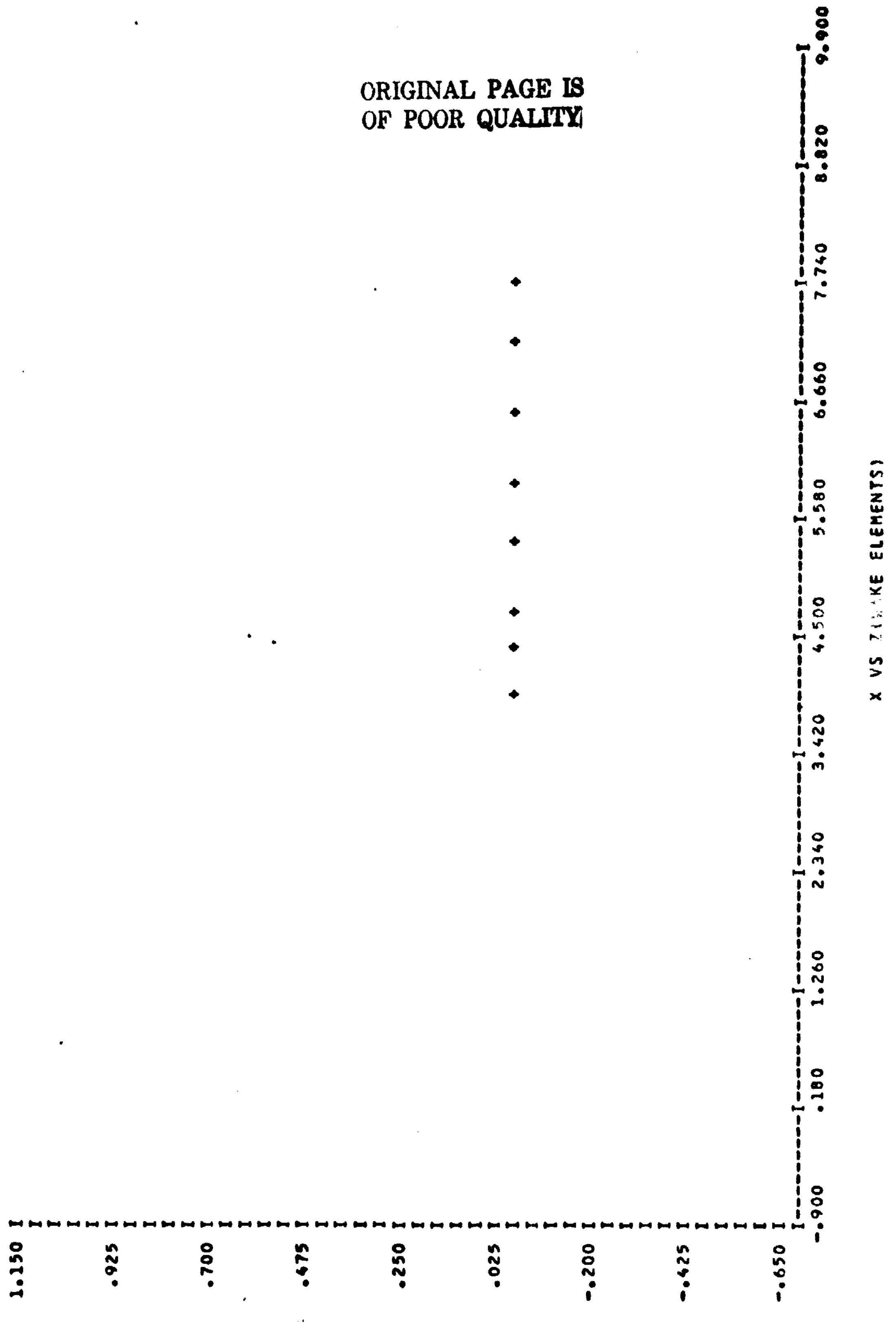

```
WING VORTEX STRENGTHS
*********************

     X/C         2Y/B       GAMAY
     ***         ****       *****
   .01704      .04952     8.33720
   .14645      .04952     1.56297
   .37059      .04952      .80264
   .62941      .04952      .44407
   .85355      .04952      .22943
   .98296      .04952      .07193
   .01704      .18826     5.99420
   .14645      .18826     1.18337
   .37059      .18826      .73233
   .62941      .18826      .44816
   .85355      .18826      .23360
   .98296      .18826      .07046
   .01704      .38874     6.94864
   .14645      .38874     1.00875
   .37059      .38874      .71030
   .62941      .38874      .44483
   .85355      .38874      .23903
   .98296      .38874      .07214
   .01704      .61126     8.69819
   .14645      .61126     1.01388
   .37059      .61126      .75967
   .62941      .61126      .47910
   .85355      .61126      .25817
   .98296      .61126      .07882
   .01704      .81174    11.59210
   .14645      .81174     1.22090
   .37059      .81174      .82058
   .62941      .81174      .56037
   .85355      .81174      .30312
   .98296      .81174      .09232
   .01704      .95048    17.69230
   .14645      .95048     1.80028
   .37059      .95048     1.10401
   .62941      .95048      .77418
   .85355      .95048      .44792
   .98296      .95048      .13807


LEADING-EDGE VORTICES STRENGTHS
*******************************

    2Y/B     CAPGAMA
```

```
 ****     *******
.04952   1.59529
.18826   1.00437
.38874    .89376
.61126    .71560
.81174    .46288
.95048    .18600
```

```
DELTA-CP DISTRIBUTION
*********************
  X/C        2Y/B    DELTA-CP
  ***        ****    ********
.01254     .04952   10.99014
.10908     .04952    5.20072
.28306     .04952    1.89953
.50000     .04952    1.53386
.71694     .04952     .63537
.89092     .04952     .60226
.98746     .04952     .19361
.01254     .18826   10.23401
.10908     .18826    3.02399
.28306     .18826    1.66076
.50000     .18826    1.48151
.71694     .18826    1.05696
.89092     .18826     .88171
.98746     .18826     .53502
.01254     .38874    5.78581
.10908     .38874    3.46117
.28306     .38874    1.78347
.50000     .38874    1.32014
.71694     .38874    1.35983
.89092     .38874     .93750
.98746     .38874     .90278
.01254     .61126    4.22909
.10908     .61126    2.96873
.28306     .61126    1.38105
.50000     .61126     .92197
.71694     .61126     .95365
.89092     .61126     .59231
.98746     .61126     .44996
.01254     .81174    3.41732
.10908     .81174    2.72773
.28306     .81174    1.32286
.50000     .81174     .79997
.71694     .81174     .50924
.89092     .81174     .25959
.98746     .81174    -.08718
.01254     .95048    2.86271
.10908     .95048    2.70303
.28306     .95048    1.17791
.50000     .95048     .82040
.71694     .95048     .18540
.89092     .95048    -.14688
.98746     .95048    -.76388
```

```
     SECTIONAL PROPERTIES
     ********************

     I      CLI        CMI        CDI        CTI
     *      ***        ***        ***        ***
     1   1.92867   -1.25424   1.11352    0.00000
     2   1.70269   -1.71973    .98305    0.00000
     3   1.62912   -2.27566    .94057    0.00000
     4   1.22177   -2.08599    .70539    0.00000
     5    .98222   -1.95844    .56708    0.00000
     6    .79862   -1.77018    .46108    0.00000

     TOTAL LIFT COEFFICIENT=    1.55805
     TOTAL PITCHING MOMENT COEFFICIENT=  -1.83185
     TOTAL DRAG COEFFICIENT=     .89954
     TOTAL THRUST COEFFICIENT=    0.00000


 SPANWISE PRESSURES AT CONSTANT X=    1.00000
        Y     2Y/B(LOCAL) DELTA-CP
    .09903     .19806      2.73389
    .37651     .75302      3.83013


 SPANWISE PRESSURES AT CONSTANT X=    2.00000
        Y     2Y/B(LOCAL) DELTA-CP
    .09903     .09903      1.55729
    .37651     .37651      1.55829
    .77748     .77748      2.62486


 SPANWISE PRESSURES AT CONSTANT X=    3.00000
        Y     2Y/B(LOCAL) DELTA-CP
    .09903     .06602       .54461
    .37651     .25101      1.11094
    .77748     .51832      1.37594
   1.22252     .81501      1.05633


 SPANWISE PRESSURES AT CONSTANT X=    3.50000
        Y     2Y/B(LOCAL) DELTA-CP
    .09903     .05659       .50101
    .37651     .21515       .8919[illegible]
    .77748     .44427      1.223[illegible]
   1.22252     .69858       .98009
   1.623[illegible]9     .92771      1.[illegible]34[illegible]
```

```
SPANWISE PRESSURES AT CONSTANT X=    3.75000
       Y     2Y/B(LOCAL) DELTA-CP
     .09903     .05282       .79304
     .37651     .20081       .86444
     .77748     .41466       .91482
    1.22252     .65201       .73136
    1.62349     .86586       .59463

TOTAL ABSOLUTE FORCE ACTING ON LEADING-EDGE FREE ELEMENTS=    1.28618
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OF POOR QUALITY

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                    ASPECT RATIO = 2.0
ALPHA(DEG.)=30.000  MACH NUMBER= 0.000  ITERATION NUMBER= 1

LEADING EDGE ELEMENTS
*********************
**** 1****
  4.0000    .4810    .0501   0.0000   -.2000    .2000    .7196
   .2182    .2182   0.0000   0.0000   0.0000   0.0000   0.0000
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5309
**** 2****
  4.0000   1.1682    .4810    .4363    .2562    .6067   1.1952   1.7829   2.3561   2.9027   3.4649   4.0129   4.5776   5.1348
  5.6827   6.2333   6.7860   7.3369
   .5661    .5661    .2182    .2182    .2182    .2926    .2742    .3201    .4976    .7449    .9539   1.1836   1.3443   1.4359
  1.4581   1.4401   1.4047   1.3561
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .3463    .2349    .2309    .2309    .2488    .3321    .4558    .6586
   .9021   1.1398   1.3705   1.6032
**** 3****
  4.0000   2.0251   1.1682   1.1322    .9888   1.2612   1.7944   2.3666   2.9451   3.5112   4.0768   4.6509   5.2020   5.7484
  6.2891   6.8571   7.4311
  1.0000   1.0000    .5661    .5661    .5661    .6558    .6364    .5219    .3673    .3268    .4114    .5858    .8231   1.0709
  1.3310   1.5069   1.6063
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5054    .6450    .6069    .4122    .2309    .2309    .2309    .2309
   .2402    .3201    .4636
**** 4****
  4.0000   2.8820   2.0251   2.0000   1.9000   2.0917   2.6107   3.1595   3.7208   4.2938   4.8801   5.4734   6.0696   6.6667
  7.2642   7.8624
  1.4339   1.4339   1.0000   1.0000   1.0000   1.0570   1.0825   1.0573    .9651    .8359    .7247    .6371    .5714    .5284
   .5127    .5381
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5309    .7722    .9629   1.0855   1.1476   1.1665   1.1515   1.1108
  1.0585   1.0192
**** 5****
  4.0000   3.5691   2.8820   2.8578   2.8112   2.9228   3.4416   3.9669   4.4859   5.0027   5.5286   6.0679   6.6213   7.1861
  1.7818   1.7818   1.4339   1.4339   1.4339   1.4528   1.4817   1.5146   1.4893   1.4114   1.3013   1.1750   1.0484    .9276
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5309    .8190   1.1190   1.4137   1.6808   1.9114   2.1057   2.2681
**** 6****
  4.0000   3.9505   3.5691   3.5637   3.5418   3.5651   4.1043   4.6211   5.1400   5.6595   6.1774   6.6921   7.2028
  1.9749   1.9749   1.7818   1.7818   1.7818   1.7761   1.7972   1.8516   1.8787   1.8686   1.8269   1.7553   1.6596
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5309    .8309   1.1309   1.4309   1.7309   2.0309   2.3309
```

```
WAKE ELEMENTS
**************
**** 1****
   4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 2****
   4.0000    4.4000    4.7969    5.3953    5.9940    6.5920    7.1890    7.7847
    .2182     .2182     .2578     .3015     .3359     .3660     .3956     .4263
   0.0000    0.0000    -.0295    -.0380    -.0191     .0188     .0711     .1362
**** 3****
   4.0000    4.4000    4.7766    5.3421    5.9134    6.4944    7.0814    7.6696
    .5661     .5661     .7009     .9010    1.0842    1.2337    1.3542    1.4563
   0.0000    0.0000    -.0047    -.0174    -.0124    -.0047     .0257     .0859
**** 4****
   4.0000    4.4000    4.7883    5.3637    5.9220    6.4620    7.0440    7.6423
   1.0000    1.0000    1.0935    1.2481    1.4221    1.5050    1.3919    1.3901
   0.0000    0.0000     .0225     .0931     .2274     .4753     .5674     .5224
**** 5****
   4.0000    4.4000    4.7857    5.3673    5.9494    6.5284    7.1000    7.6664
   1.4339    1.4339    1.5302    1.6578    1.7672    1.8533    1.9251    1.9971
   0.0000    0.0000     .0440     .1184     .2137     .3459     .5135     .6979
**** 6****
   4.0000    4.4000    4.7877    5.3675    5.9425    6.5136    7.0814    7.6465
   1.7918    1.7918    1.8458    1.9524    2.0615    2.1512    2.2193    2.2745
   0.0000    0.0000     .0750     .1866     .3185     .4793     .6607     .8548
**** 7****
   4.0000    4.4000    4.7740    5.3314    5.8961    6.4717    7.0506    7.6294
   1.9749    1.9749    2.0235    2.0791    2.0785    2.0702    2.0623    2.0566
   0.0000    0.0000     .1334     .3483     .5509     .7203     .8778    1.0359
```

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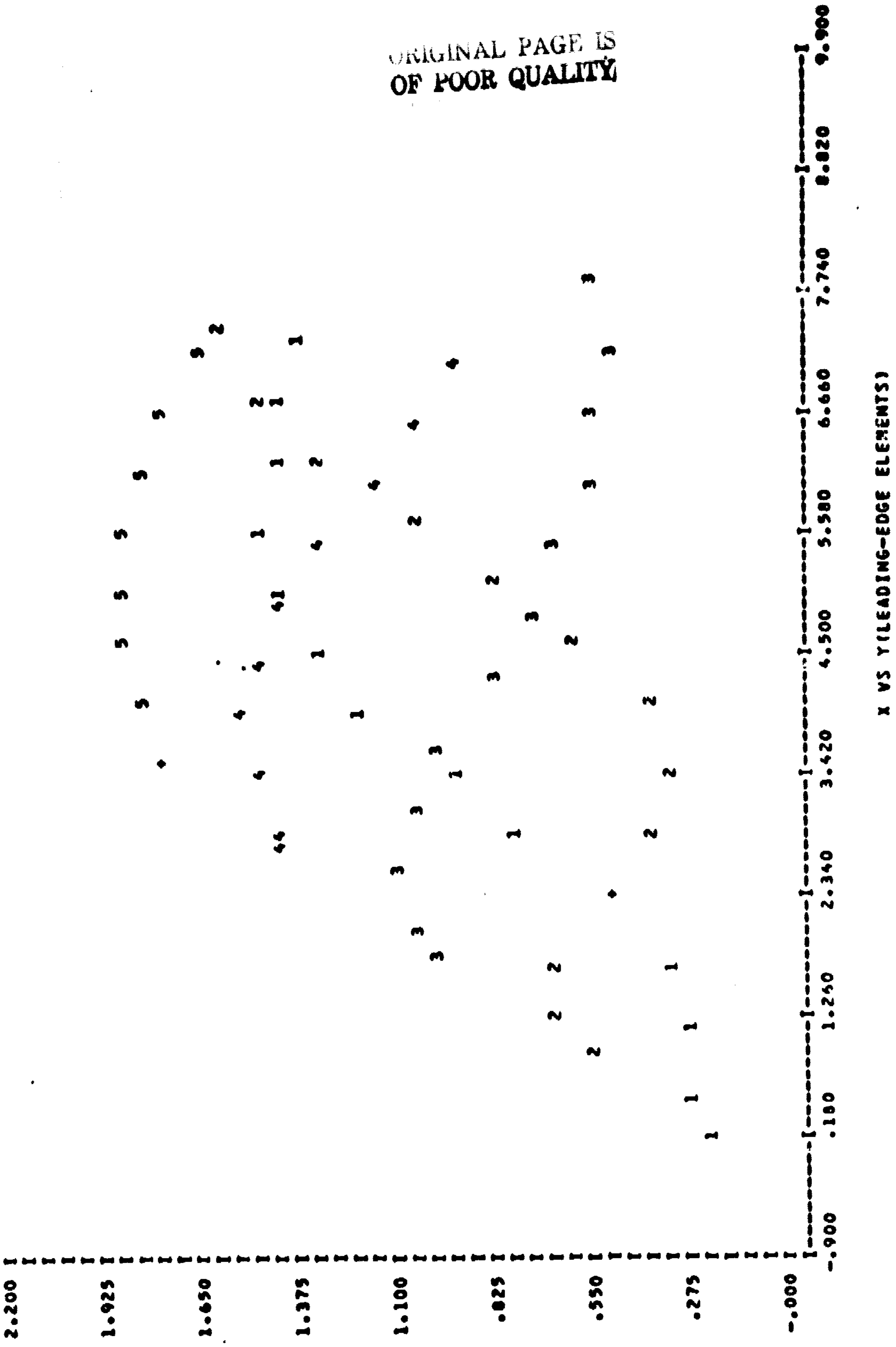

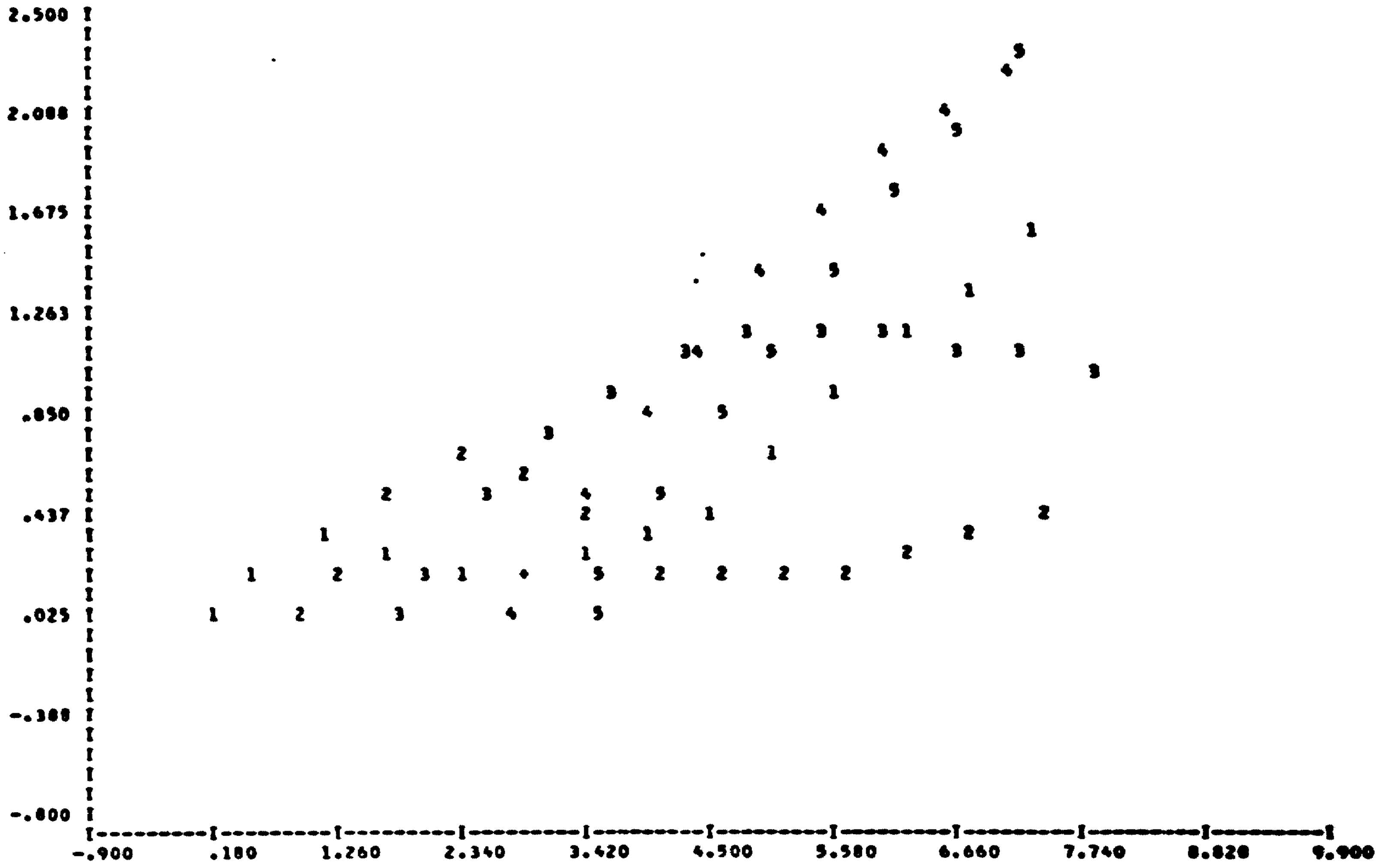

X VS Z(LEADING-EDGE ELEMENTS)

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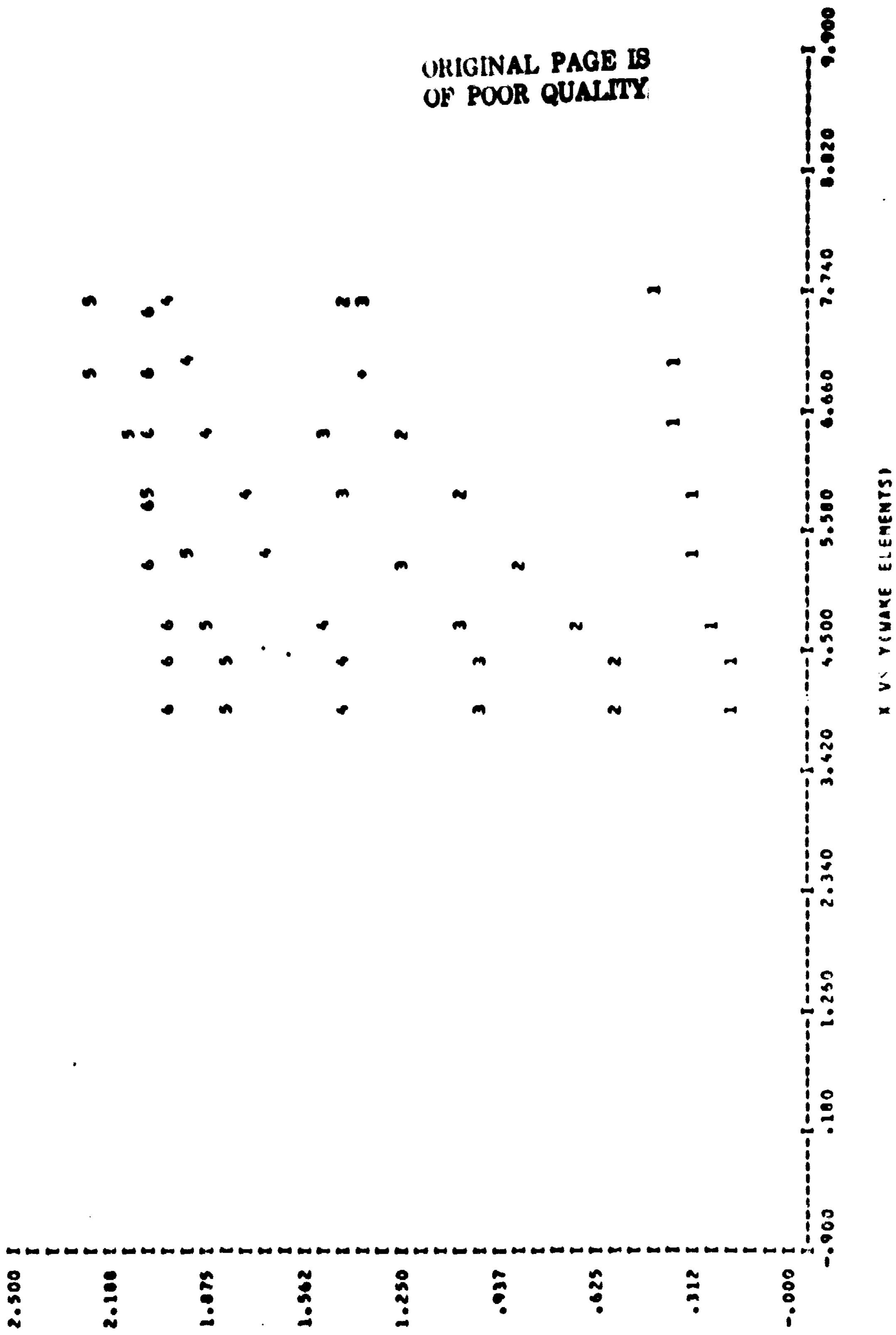
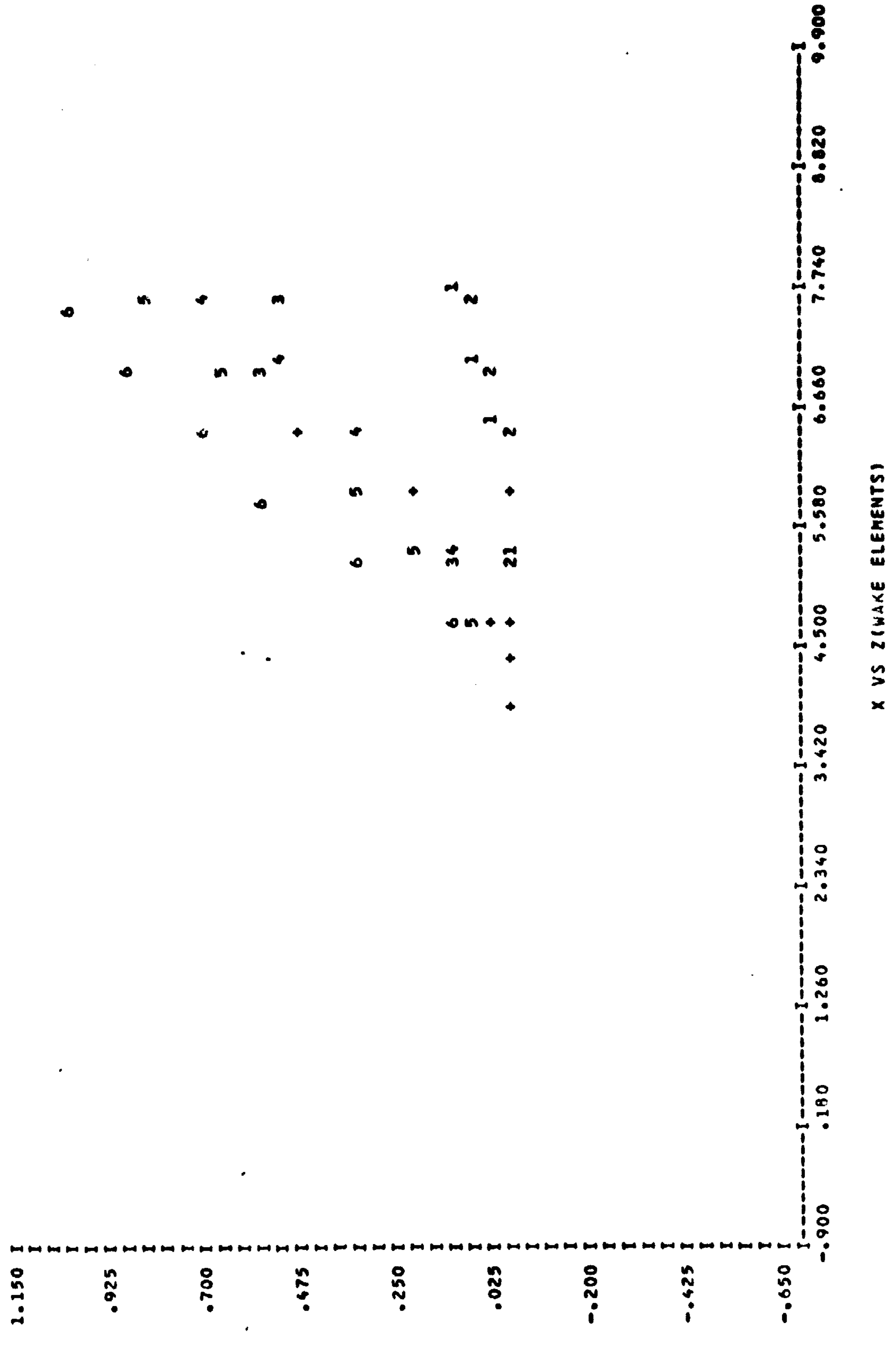
OF POOR QUALITY





X VS Z(WAKE ELEMENTS)

```
WING VORTEX STRENGTHS
*********************

      X/C         2Y/B       GAMAY
      ***         ****       *****
    .01704      .04952     8.25052
    .14645      .04952     1.36927
    .37059      .04952      .61192
    .62941      .04952      .51188
    .85355      .04952      .22160
    .98296      .04952      .03334
    .01704      .18826     5.80367
    .14645      .18826     1.10192
    .37059      .18826      .47379
    .62941      .18826      .46969
    .85355      .18826      .29190
    .98296      .18826      .03814
    .01704      .38874     7.13406
    .14645      .38874     1.02614
    .37059      .38874      .61492
    .62941      .38874      .11650
    .85355      .38874      .30132
    .98296      .38874      .13724
    .01704      .61126     8.92539
    .14645      .61126     1.04178
    .37059      .61126      .75280
    .62941      .61126      .40170
    .85355      .61126      .08733
    .98296      .61126     -.00273
    .01704      .81174    11.70835
    .14645      .81174     1.22415
    .37059      .81174      .80887
    .62941      .81174      .53281
    .85355      .81174      .27362
    .98296      .81174      .08046
    .01704      .95048    17.57687
    .14645      .95048     1.78459
    .37059      .95048     1.09015
    .62941      .95048      .76081
    .85355      .95048      .43806
    .98296      .95048      .13460

LEADING-EDGE VORTICES STRENGTHS
*******************************

     2Y/B     C  GAMA
```

```
  ****     *******
 .04952    1.58978
 .18826     .96851
 .38874     .91597
 .61126     .73407
 .81174     .46763
 .95048     .18480
```

```
DELTA-CP DISTRIBUTION
*********************
  X/C        2Y/B    DELTA-CP
  ***        ****    ********
.01254     .04952    9.56653
.10908     .04952    4.96700
.28306     .04952    1.65211
.50000     .04952    1.42061
.71694     .04952     .79068
.89092     .04952     .52909
.98746     .04952     .24339
.01254     .18826    8.81633
.10908     .18826    2.68645
.28306     .18826    1.96220
.50000     .18826    1.82361
.71694     .18826    1.35237
.89092     .18826     .90122
.98746     .18826     .65134
.01254     .38874    5.57613
.10908     .38874    3.48906
.28306     .38874    2.25933
.50000     .38874    1.84106
.71694     .38874    1.93991
.89092     .38874    1.54343
.98746     .38874    1.23947
.01254     .61126    4.02855
.10908     .61126    2.83133
.28306     .61126    1.32986
.50000     .61126    1.00104
.71694     .61126    1.23559
.89092     .61126     .90902
.98746     .61126     .97263
.01254     .81174    3.29553
.10908     .81174    2.57849
.28306     .81174    1.22989
.50000     .81174     .66425
.71694     .81174     .38255
.89092     .81174     .14927
.98746     .81174    -.14288
.01254     .95048    2.58105
.10908     .95048    2.40211
.28306     .95048    1.07138
.50000     .95048     .69590
.71694     .95048     .11024
.89092     .95048    -.21056
.98746     .95048    -.78007
```

```
          SECTIONAL PROPERTIES
          ********************

          I      CLI        CMI         CDI         CTI
          *      ***        ***         ***         ***
          1   1.79394   -1.20941    1.03573     0.00000
          2   1.77886   -1.91614    1.02703     0.00000
          3   1.99753   -2.92693    1.15327     0.00000
          4   1.31320   -2.30045     .75818     0.00000
          5    .87826   -1.74180     .50706     0.00000
          6    .68555   -1.51759     .39580     0.00000

          TOTAL LIFT COEFFICIENT=    1.66094
          TOTAL PITCHING MOMENT COEFFICIENT=  -2.07341
          TOTAL DRAG COEFFICIENT=     .95894
          TOTAL THRUST COEFFICIENT=   0.00000

   SPANWISE PRESSURES AT CONSTANT X=   1.00000
         Y     2Y/B(LOCAL) DELTA-CP
      .09903      .19806      2.52115
      .37651      .75302      3.26689

   SPANWISE PRESSURES AT CONSTANT X=   2.00000
         Y     2Y/B(LOCAL) DELTA-CP
      .09903      .09903      1.40684
      .37651      .37651      1.92070
      .77748      .77748      2.89741

   SPANWISE PRESSURES AT CONSTANT X=   3.00000
         Y     2Y/B(LOCAL) DELTA-CP
      .09903      .06602       .69986
      .37651      .25101      1.41881
      .77748      .51832      1.89848
     1.22252      .81501      1.03833

   SPANWISE PRESSURES AT CONSTANT X=   3.50000
         Y     2Y/B(LOCAL) DELTA-CP
      .09903      .05659       .47866
      .37651      .21515      1.01330
      .77748      .44427      1.84657
     1.22252      .69858      1.23076
     1.62349      .92771       .99452
```

```
SPANWISE PRESSURES AT CONSTANT X=   3.75000
      Y     2Y/B(LOCAL) DELTA-CP
   .09903     .05282       .64341
   .37651     .20081       .81792
   .77748     .41466      1.51332
  1.22252     .65201      1.05705
  1.62349     .86586       .46002

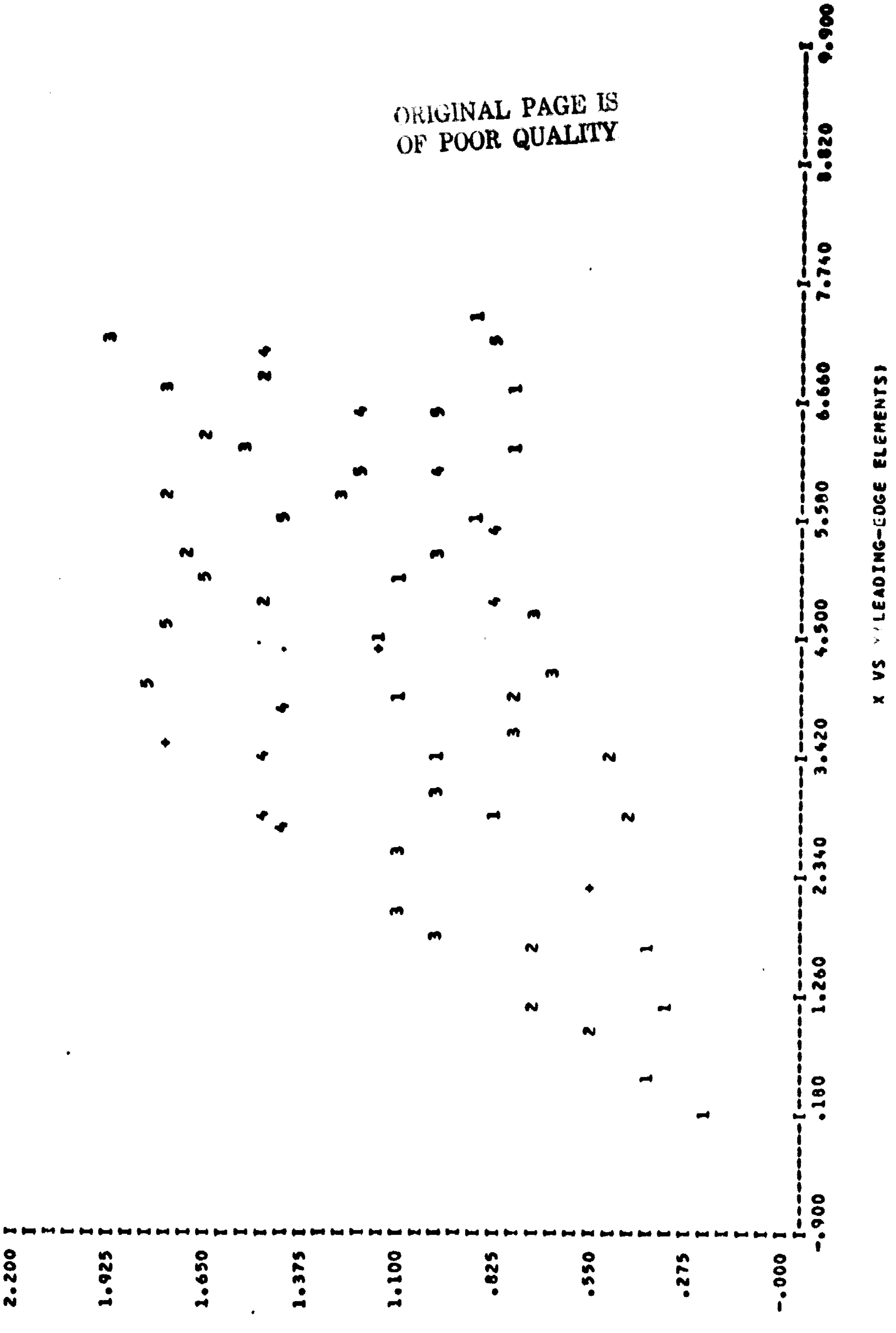
TOTAL ABSOLUTE FORCE ACTING ON LEADING-EDGE FREE ELEMENTS=    .42133
```

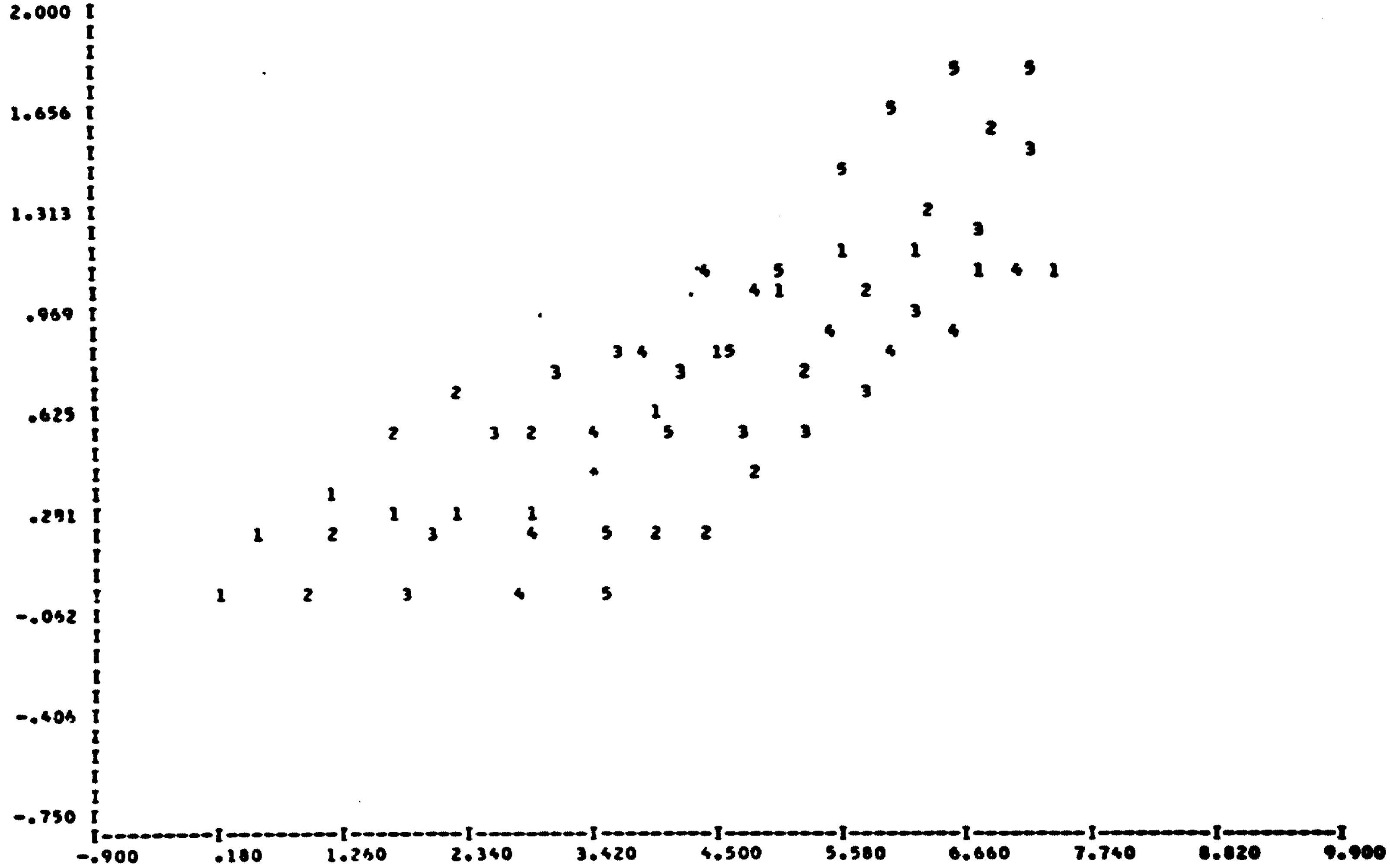
Similar type of output data is printed for iterations 2 through 7.

```
                    ASPECT RATIO = 2.0
ALPHA(DEG.)=30.000  MACH NUMBER= 0.000  ITERATION NUMBER= 8

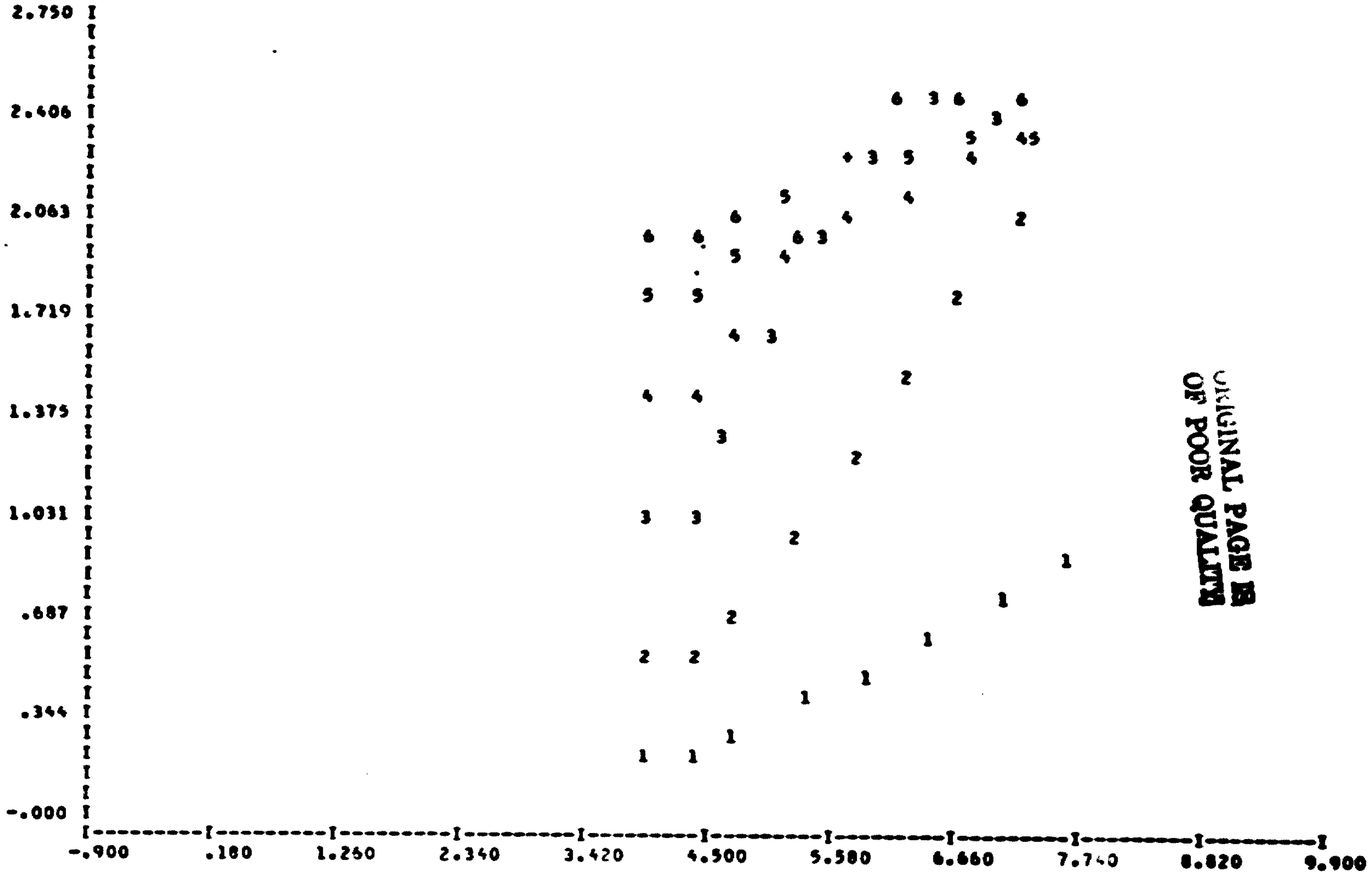
LEADING EDGE ELEMENTS
*********************
**** 1****
   4.0000     .4810     .0501    0.0000    -.2000     .2000     .7196
    .2182     .2182    0.0000    0.0000    0.0000    0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000     .2309     .5309
**** 2****
   4.0000    1.1682     .4810     .4363     .2582     .5650    1.1710    1.7672    2.3353    2.8862    3.4324    3.9932    4.5647    5.1110
   5.6620    6.2497    6.8483    7.4432
    .5661     .5661     .2182     .2182     .2182     .3602     .3285     .3778     .5667     .8023    1.0120    1.1187    1.1469    1.1043
    .9062     .7887     .7942     .8710
   0.0000    0.0000    0.0000    0.0000    0.0000     .2309     .3558     .3103     .2705     .3024     .4353     .6199     .8005    1.0432
   1.1773    1.1488    1.1069    1.1172
**** 3****
   4.0000    2.0251    1.1682    1.1322     .9888    1.2219    1.7408    2.3013    2.8852    3.4520    3.9704    4.4306    4.8799    5.3570
   5.8736    6.3955    6.9000
   1.0000    1.0000     .5661     .5661     .5661     .7332     .7057     .5427     .4330     .4975     .7547    1.1397    1.4856    1.6890
   1.7523    1.6634    1.4875
   0.0000    0.0000    0.0000    0.0000    0.0000     .2309     .5309     .6696     .5856     .3995     .2412     .2379     .4342     .7342
   1.0342    1.3342    1.5879
**** 4****
   4.0000    2.8820    2.0251    2.0000    1.9000    2.0647    2.5843    3.1060    3.6644    4.2410    4.8107    5.3498    5.8446    6.3287
   6.7251    7.2909
   1.4339    1.4339    1.0000    1.0000    1.0000    1.1134    1.1207     .9813     .7743     .6542     .7287     .9888    1.2918    1.5357
   1.7940    1.9033
   0.0000    0.0000    0.0000    0.0000    0.0000     .2309     .5309     .7925     .8654     .7505     .5779     .5352     .6879     .9452
   1.2452    1.5452
**** 5****
   4.0000    3.5691    2.8820    2.8678    2.8112    2.9160    3.4352    3.9481    4.4050    4.9161    5.4848    6.0602    6.6140    7.1320
   1.7815    1.7818    1.4339    1.4339    1.4339    1.4766    1.4982    1.4150    1.1436     .8326     .8487    1.0159    1.2308    1.4633
   0.0000    0.0000    0.0000    0.0000    0.0000     .2309     .5309     .8309    1.1095    1.0644     .8736     .8428     .9269    1.1209
**** 6****
   4.0000    3.9505    3.5691    3.5637    3.5418    3.5838    4.1026    4.6214    5.1255    5.6052    6.1112    6.6537    7.2250
   1.9749    1.9749    1.7818    1.7818    1.7818    1.7699    1.7988    1.7683    1.6423    1.4425    1.2061     .9784     .7998
   0.0000    0.0000    0 0000    0.0000    0.0000     .2309     .5309     .8309    1.1309    1.4309    1.6501    1.7677    1.8090
```

```
WAKE ELEMENTS
*************
**** 1****
   4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 2****
   4.0000    4.4000    4.7950    5.3837    5.9691    6.5489    7.1210    7.6835
    .2182     .2182     .2762     .3819     .4978     .6256     .7667     .9181
   0.0000    0.0000     .0241     .0720     .1345     .2209     .3340     .4778
**** 3****
   4.0000    4.4000    4.7722    5.3152    5.8277    6.3064    6.7535    7.2188
    .5661     .5661     .7118     .9591    1.2379    1.5255    1.7972    2.0284
   0.0000    0.0000    -.0152     .0480     .1880     .4030     .6998     .9998
**** 4****
   4.0000    4.4000    4.6777    5.1049    5.5289    6.0000    6.4677    6.9853
   1.0000    1.0000    1.2874    1.6665    1.9858    2.2392    2.4657    2.4202
   0.0000    0.0000     .0154     .1994     .4791     .7509    1.0509    1.3509
**** 5****
   4.0000    4.4000    4.7294    5.2543    5.7812    6.2922    6.7917    7.3062
   1.4339    1.4339    1.6403    1.9193    2.0575    2.1515    2.2946    2.3672
   0.0000    0.0000     .0943     .1759     .4275     .7275    1.0275    1.3275
**** 6****
   4.0000    4.4000    4.7569    5.2122    5.7156    6.2566    6.8245    7.3441
   1.7818    1.7818    1.9106    2.1609    2.2897    2.2532    2.3237    2.3229
   0.0000    0.0000     .1267     .4267     .7267     .9837    1.1639    1.4639
**** 7****
   4.0000    4.4000    4.7409    5.2573    5.7463    6.2053    6.7249    7.2717
   1.9749    1.9749    2.0367    1.9795    2.2496    2.4932    2.5000    2.5000
   0.0000    0.0000     .2000     .5000     .7188    1.0168    1.3188    1.5658
```

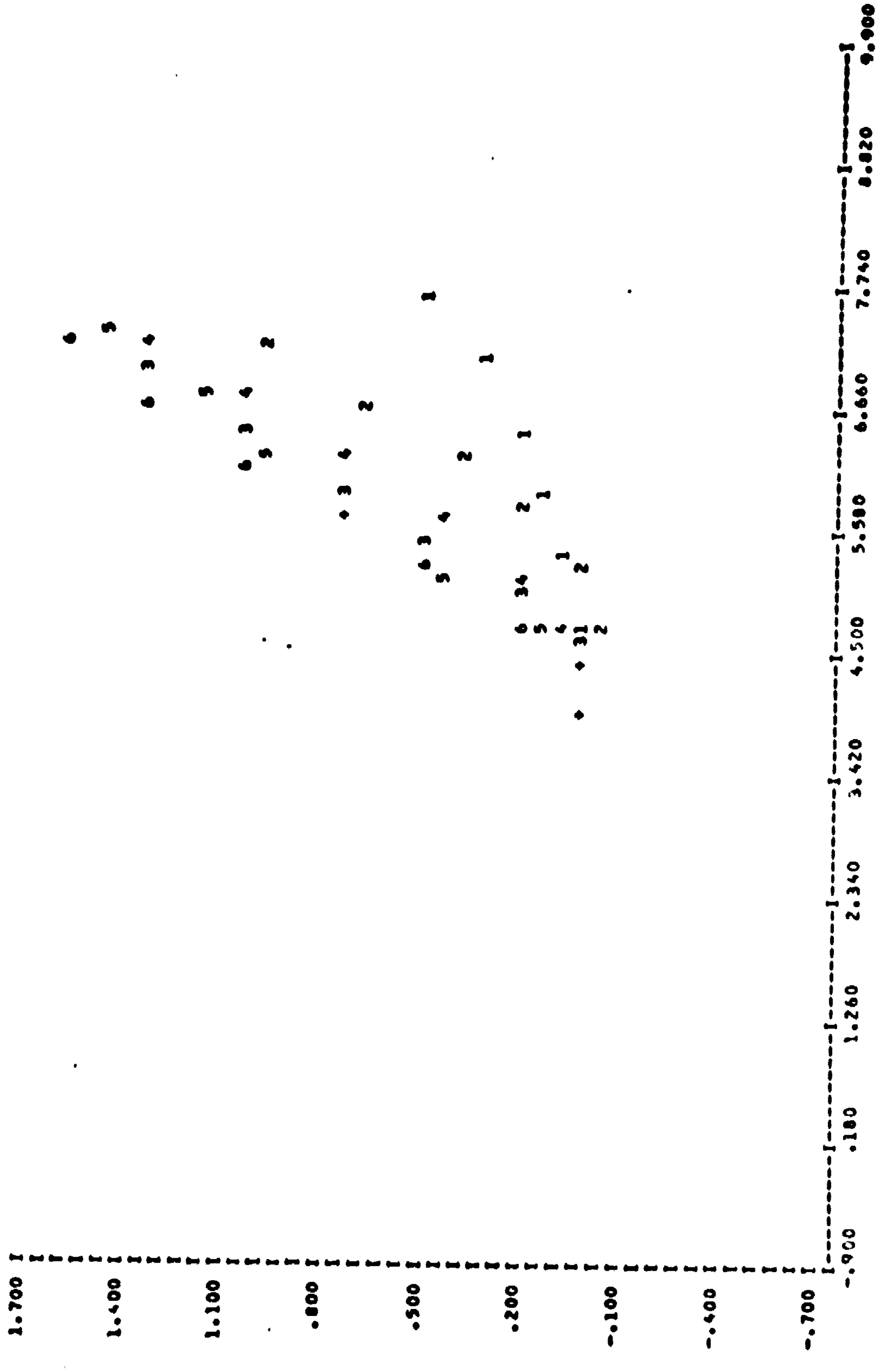

2.200
1.925
1.650
1.375
1.100
.825
.550
.275
-.000
-.900
.180
1.260
2.340
3.420
4.500
5.580
6.660
7.740
8.820
9.900
X VS Y(LEADING-EDGE ELEMENTS)



X VS Z(LEADING-EDGE ELEMENTS)



X VS Y(WAKE ELEMENTS)


X VS Z(WAKE ELEMENTS)
1.700
1.400
1.100
.800
.500
.200
-.100
-.400
-.700
-.900
.180
1.260
2.340
3.420
4.500
5.580
6.660
7.740
8.820
9.900

```
WING VORTEX STRENGTHS
*********************

      X/C        2Y/B       GAMAY
      ***        ****       *****
    .01704     .04952     8.29778
    .14645     .04952     1.29432
    .37059     .04952      .66099
    .62941     .04952      .47469
    .85355     .04952      .20774
    .98296     .04952      .07803
    .01704     .18826     5.46306
    .14645     .18826     1.03076
    .37059     .18826      .54839
    .62941     .18826      .47055
    .85355     .18826      .16869
    .98296     .18826      .04794
    .01704     .38874     5.73815
    .14645     .38874      .99339
    .37059     .38874      .54775
    .62941     .38874      .37491
    .85355     .38874      .22647
    .98296     .38874     -.03010
    .01704     .61126     8.64016
    .14645     .61126     1.01289
    .37059     .61126      .72101
    .62941     .61126      .45620
    .85355     .61126      .28402
    .98296     .61126      .09298
    .01704     .81174    11.55106
    .14645     .81174     1.21739
    .37059     .81174      .82212
    .62941     .81174      .56278
    .85355     .81174      .30692
    .98296     .81174      .09418
    .01704     .95048    17.73351
    .14645     .95048     1.80304
    .37059     .95048     1.10434
    .62941     .95048      .77341
    .85355     .95048      .44698
    .98296     .95048      .13769

LEADING-EDGE VORTICES STRENGTHS
*******************************

     2Y/B      C P    MA
```

```
  ****     *******
.04952    1.60568
.18826     .90490
.38874     .86239
.61126     .71020
.81174     .46124
.95048     .18644
```

```
 DELTA-CP DISTRIBUTION
 *********************
  X/C        2Y/B    DELTA-CP
  ***        ****    ********
.01254     .04952    7.61337
.10908     .04952    4.55513
.28306     .04952    1.52432
.50000     .04952    1.29877
.71694     .04952     .66802
.89092     .04952     .36277
.98746     .04952     .15258
.01254     .18826    6.34274
.10908     .18826    2.29859
.28306     .18826    1.73239
.50000     .18826    1.58317
.71694     .18826    1.21972
.89092     .18826     .77920
.98746     .18826     .50958
.01254     .38874    4.33651
.10908     .38874    2.91581
.28306     .38874    1.97543
.50000     .38874    1.63405
.71694     .38874    1.76146
.89092     .38874    1.44152
.98746     .38874    1.15567
.01254     .61126    3.55946
.10908     .61126    2.62342
.28306     .61126    1.33923
.50000     .61126     .97921
.71694     .61126    1.18459
.89092     .61126     .90131
.98746     .61126     .86762
.01254     .81174    3.13069
.10908     .81174    2.47576
.28306     .81174    1.27152
.50000     .81174     .73556
.71694     .81174     .48107
.89092     .81174     .22523
.98746     .81174    -.11281
.01254     .95048    2.63992
.10908     .95048    2.47422
.28306     .95048    1.11563
.50000     .95048     .74813
.71694     .95048     .15061
.89092     .95048    -.18024
.98746     .95048    -.76758
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
          SECTIONAL PROPERTIES
          ********************

          I      CLI        CMI        CDI        CTI
          *      ***        ***        ***        ***
          1   1.56797  -1.04769     .90527    0.00000
          2   1.49362  -1.64737     .86234    0.00000
          3   1.73731  -2.58121    1.00304    0.00000
          4   1.25071  -2.19754     .72210    0.00000
          5    .90756  -1.80956     .52399    0.00000
          6    .72602  -1.60837     .41917    0.00000

          TOTAL LIFT COEFFICIENT=    1.45997
          TOTAL PITCHING MOMENT COEFFICIENT=  -1.86231
          TOTAL DRAG COEFFICIENT=     .84292
          TOTAL THRUST COEFFICIENT=    0.00000

SPANWISE PRESSURES AT CONSTANT X=    1.00000
       Y     2Y/B(LOCAL) DELTA-CP
    .09903     .19806      2.34285
    .37651     .75302      2.68275

SPANWISE PRESSURES AT CONSTANT X=    2.00000
       Y     2Y/B(LOCAL) DELTA-CP
    .09903     .09903      1.28618
    .37651     .37651      1.66734
    .77748     .77748      2.47956

SPANWISE PRESSURES AT CONSTANT X=    3.00000
       Y     2Y/B(LOCAL) DELTA-CP
    .09903     .06602       .57516
    .37651     .25101      1.27410
    .77748     .51832      1.69580
   1.22252     .81501      1.06014

SPANWISE PRESSURES AT CONSTANT X=    3.50000
       Y     2Y/B(LOCAL) DELTA-CP
    .09903     .05659       .31908
    .37651     .21515       .89992
    .77748     .44427      1.69872
   1.22252     .69858      1.17457
   1.62349     .92771      1.05241
```

```
SPANWISE PRESSURES AT CONSTANT X=    3.75000
      Y     2Y/B(LOCAL) DELTA-CP
    .09903     .05282      .47436
    .37651     .20081      .68765
    .77748     .41466     1.41464
   1.22252     .65201     1.03999
   1.62349     .86586      .55153

TOTAL ABSOLUTE FORCE ACTING ON LEADING-EDGE FREE ELEMENTS=    .17432
```

Similar type of output data is printed for iterations 9 and 10.

```
                      SUMMARY SHEET
                      *************

                    ASPECT RATIO = 2.0

ALPHA(DEG.)=30.000  MACH NUMBER= 0.000

ITERATION    CL      CM       CD      CT      GMSUM    PERR    TFABS
*********    **      **       **      **      *****    ****    *****
    0      1.5581 -1.8319   .8995  0.0000   3.2626           1.2862
    1      1.6609 -2.0734   .9589  0.0000   3.2710    .2571   .4213
    2      1.5024 -1.9132   .8674  0.0000   3.1577  3.5233   .3423
    3      1.4260 -1.8073   .8233  0.0000   3.1057  1.6609   .3454
    4      1.4328 -1.8182   .8272  0.0000   3.1027   .0976   .2999
    5      1.4558 -1.8541   .8405  0.0000   3.1204   .5712   .2140
    6      1.4632 -1.8670   .8448  0.0000   3.1257   .1698   .1865
    7      1.4648 -1.8697   .8457  0.0000   3.1292   .1117   .1858
    8      1.4600 -1.8673   .8429  0.0000   3.1252   .1308   .1743
    9      1.4598 -1.8618   .8428  0.0000   3.1260   .0263   .1754
   10      1.4598 -1.8614   .8428  0.0000   3.1270   .0318   .1732




         ALL CASES COMPLETED
```

6.2 APPENDIX B: COMPUTER PROGRAM LISTING

A listing of the computer program is given on the following pages.

```
      OVERLAY (LEVSP,0,0)                                               LEV  10
      PROGRAM LEVSP(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3,TAPE5=INPUT,TAPE6=OUTLEV  20
     1PUT,PUNCH,TAPE4,TAPE7)                                            LEV  30
C                                                                       LEV  40
C     AERODYNAMICS OF LOW ASPECT-RATIO WINGS WITH PARTIAL LEADING-EDGE  LEV  50
C     SEPARATION (LEADING-EDGE VORTEX SEPARATION PROGRAM)               LEV  60
C     BY - SUDHIR C. MEHROTRA AND C. EDWARD LAN                         LEV  70
C          UNIVERSITY OF KANSAS                                         LEV  80
C                                                                       LEV  90
C     THIS PROGRAM IS RESTRICTED TO DELTA AND ARROW WINGS               LEV 100
C                                                                       LEV 110
C     PROGRAM IS DIVIDED INTO FIVE OVERLAYS.                            LEV 120
C     OVERLAY (1,0) READS ALL THE DATA CARDS AND SETSUP INETIAL GEOMETRYLEV 130
C                   OF THE WING AND THE FREE ELEMENTS                   LEV 140
C     OVERLAY (2,0) PLOTS FREE ELEMENTS OVER THE WING AND IN THE WAKE ONLEV 150
C                   THE LINE PRINTER OUTPUT                             LEV 160
C     OVERLAY (3,0) SOLVES FOR THE STRENGTHS OF WING AND LEADING-EDGE   LEV 170
C                   VORTEX SYSTEM                                       LEV 180
C     OVERLAY (4,0) COMPUTES THE AERODYNAMIC CHARACTERSTICS             LEV 190
C     OVERLAY (5,0) COMPUTES THE NEW LOCATIONS OF THE LEADING-EDGE AND  LEV 200
C                   TRAILING-EDGE VORTICES                              LEV 210
C     AS THE PROBLEM IS NONLINEAR, IT IS SOLVED BY ITERATION. ITERATION LEV 220
C     IS PERFORMED OVER OVERLAYS (2,0) THRU (4,0) TO OBTAIN THE FINAL   LEV 230
C     CONVERGED SOLUTION.                                               LEV 240
C                                                                       LEV 250
C     THE DIMENSIONS OF THE FOLLOWING VARIABLES MUST BE CHECKED BEFORE  LEV 260
C     RUNNING THE PROGRAM.                                              LEV 270
C                                                                       LEV 280
C     -D- APPEARS IN BLANK COMMON OF MAIN LINE (OVERLAY(0,0))           LEV 290
C         MUST BE DIMENSIONED MAXIMUM OF THE FOLLOWING VARIABLES.       LEV 300
C         N1=2286                                                       LEV 310
C         N2=3*NMAX*(NSW-1)+NSW                                         LEV 320
C         N3=3*NSW*(NNMAX+2)+NSW+1                                      LEV 330
C         N4=(NCPTTL+1)**2/4+10*NWNG+10*NSW+3*NCW-6                     LEV 340
C         N5=28*NWNG+25*NSW+10*NCW-14                                   LEV 350
C         N6=21*NWNG+14*NSW+NCW-9                                       LEV 360
C                                                                       LEV 370
C     -W- APPEARS IN PROGRAM LOADS (OVERLAY(4,0))                       LEV 380
C         MUST BE DIMENSIONED AT LEAST ((NWNG+NCW+3)*(NWNG+NCW+4))      LEV 390
C                                                                       LEV 400
```

```
C     -E- APPEARS IN PROGRAM NEWSHAP (OVERLAY(5,0))
C         MUST BE DIMENSIONED AT LEAST (3*NSW*(NMAX+NNMAX)-3*NMAX+1)
C
C         WHERE,NMAX    = MAXIMUM NUMBER OF END-POINTS IN ANY ONE FREE
C                         LEADING-EDGE VORTEX ELEMENT
C               NNMAX   = MAXIMUM NUMBER OF END-POINTS IN ANY ONE WAKE
C                         ELEMENT
C               NCW     = NUMBER OF CHORDWISE LINES
C               NSW     = NUMBER OF SPANWISE LINES (ONE HIGHER THAN
C                         NUMBER OF SPANWISE ROWS OF PANELS)
C               NCPTTL  = TOTAL NUMBER OF CONTROL POINTS OVER THE WING
C                         INCLUDING THOSE AT THE LEADING-EDGE ((NCW+1)*
C                         (NSW-1))
C               NWNG    = TOTAL NUMBER OF CONTROL POINTS OVER THE WING
C                         EXCLUDING THOSE AT THE LEADING-EDGE (NCW*
C                         (NSW-1))
C
      COMMON D(3000)
      COMMON /ALLI/ NSW,NSW1,NCW,NWNG,NCPTTL,MITER,IPUNCH
      COMMON /ALLRA/ TTL(16),ALPHA,SINA,COSA,SWPLE,BETA,BETA2,TANPH1,B2P
     1H1,BSQD4P,D4,CON,PI,D4SQ2,CBAR,HALFB,AREA
      COMMON /ALLRB/ XE(40),YE(40),ZE(40),XXE(30),YYE(30),ZZE(30),ZMIN,N
     1ELM(11),NNELM(12)
      COMMON /XPLOT/ XMN,YMN,ZMN,XMX,YMX,ZMX
      COMMON /GM/ ITER,L1,L2,L3,L4,L5,L6,L7,L8
      COMMON /XSTN/ XBRR(25),NBRK
10    CALL OVERLAY (5HLEVSP,1,0)
      ITER=0
20    CONTINUE
      ALP=ALPHA*180./PI
      AMACH=SORT(1.-BETA2)
C     WRITE FREE ELEMENTS LOCATIONS
      WRITE (6,100) TTL,ALP,AMACH,ITER
      REWIND 4
      DO 30 I=1,NSW1
C     ******************************************************************
      READ (4) K,(XE(J),YE(J),ZE(J),J=1,K)
C     ******************************************************************
      WRITE (6,150) I
```

```
      WRITE (6,140) (XE(J),J=1,K)                                       LEV 800
      WRITE (6,140) (YE(J),J=1,K)                                       LEV 810
   30 WRITE (6,140) (ZE(J),J=1,K)                                       LEV 820
      WRITE (6,180)                                                     LEV 830
      DO 40 I=1,NSW                                                     LEV 840
C     ******************************************************************LEV 850
      READ (4) K,(XXE(J),YYE(J),ZZE(J),J=1,K)                           LEV 860
C     ******************************************************************LEV 870
      WRITE (6,150) I                                                   LEV 880
      WRITE (6,140) (XXE(J),J=1,K)                                      LEV 890
      WRITE (6,140) (YYE(J),J=1,K)                                      LEV 900
   40 WRITE (6,140) (ZZE(J),J=1,K)                                      LEV 910
      CALL OVERLAY (5HLEVSP,2,0)                                        LEV 920
      CALL OVERLAY (5HLEVSP,3,0)                                        LEV 930
      CALL OVERLAY (5HLEVSP,4,0)                                        LEV 940
      CALL OVERLAY (5HLEVSP,5,0)                                        LEV 950
      ITER=ITER+1                                                       LEV 960
      IF (ITER.LE.MITER) GO TO 20                                       LEV 970
      IF (IPUNCH.EQ.0) GO TO 70                                         LEV 980
C     PUNCH-OUT FREE ELEMENTS LOCATIONS AFTER LAST ITERATION            LEV 990
      REWIND 4                                                          LEV1000
C                                                                       LEV1010
      PUNCH 170, (NELM(I),I=1,NSW1)                                     LEV1020
      DO 50 I=1,NSW1                                                    LEV1030
C     ******************************************************************LEV1040
      READ (4) K,(XE(J),YE(J),ZE(J),J=1,K)                              LEV1050
C     ******************************************************************LEV1060
      PUNCH 160, (XE(J),J=1,K)                                          LEV1070
      PUNCH 160, (YE(J),J=1,K)                                          LEV1080
   50 PUNCH 160, (ZE(J),J=1,K)                                          LEV1090
      PUNCH 170, (NNELM(I),I=1,NSW)                                     LEV1100
      DO 60 I=1,NSW                                                     LEV1110
C     ******************************************************************LEV1120
      READ (4) K,(XXE(J),YYE(J),ZZE(J),J=1,K)                           LEV1130
C     ******************************************************************LEV1140
      PUNCH 160, (XXE(J),J=1,K)                                         LEV1150
      PUNCH 160, (YYE(J),J=1,K)                                         LEV1160
   60 PUNCH 160, (ZZE(J),J=1,K)                                         LEV1170
C     FORMULATION OF SUMMARY SHEET                                      LEV1180
```

```
 70   REWIND 7
      WRITE (6,110) TTL,ALP,AMACH
      MIT=MITER+1
      GM1=0.
      DO 90 I=1,MIT
      J=I-1
C     ******************************************************************
      READ (7) GMSUM
      READ (7) CL,CM,CD,CTT
      READ (7) TFABS,TAVRG,TLNTH
C     ******************************************************************
      GM2=GMSUM
      PERR=200.0*(ABS(GM1-GM2))/(GM1+GM2)
      GM1=GM2
      IF (I.EQ.1) GO TO 80
      WRITE (6,120) J,CL,CM,CD,CTT,GMSUM,PERR,TFABS
      GO TO 90
 80   WRITE (6,130) J,CL,CM,CD,CTT,GMSUM,TFABS
 90   CONTINUE
      GO TO 10
C
C
100   FORMAT (1H1,//,16A5,/,1X,12HALPHA(DEG.)=,F6.3,14H  MACH NUMBER=,F6
     1.3,19H  ITERATION NUMBER=,I2,//,1X,21HLEADING EDGE ELEMENTS,/,1X,2
     21H*********************)
110   FORMAT (1H1,//,23X,13HSUMMARY SHEET,/,23X,13H*************,//,1X,1
     16A5,//,2X,12HALPHA(DEG.)=F6.3,14H  MACH NUMBER=,F6.3,//,66H  ITERA
     2TION    CL      CM      CD      CT    GMSUM    PERR    TFABS,/,66H
     3 *********    **      **      **      **    *****    ****  *****)
120   FORMAT (I7,4X,7F8.4)
130   FORMAT (I7,4X,5F8.4,8X,F8.4)
140   FORMAT (14F9.4)
150   FORMAT (5H ****,I2,4H****)
160   FORMAT (10F8.5)
170   FORMAT (10I2)
180   FORMAT (1H1,//,14H WAKE ELEMENTS,/,14H *************)
      END
```

```
      SUBROUTINE SKIPR (NT,NR)                                          SKP  10
C     SKIPS NR-RECORDS OF TAPE NT                                       SKP  20
      DO 10 I=1,NR                                                      SKP  30
10    READ (NT)                                                         SKP  40
      RETURN                                                            SKP  50
      END                                                               SKP  60-
```

```
      FUNCTION ARCOS (X)                                                ARC  10
C     CALCULATES ARC-COSINE OF X                                        ARC  20
      ARCOS=0.                                                          ARC  30
      IF (X.EQ.1.) RETURN                                               ARC  40
      IF (X.EQ.(-1.)) GO TO 10                                          ARC  50
      XX=X/(SQRT(1.-X*X))                                               ARC  60
      ARCOS=1.5707963-ATAN(XX)                                          ARC  70
      RETURN                                                            ARC  80
10    ARCOS=3.1415926                                                   ARC  90
      RETURN                                                            ARC 100
      END                                                               ARC 110-
```

```
      SUBROUTINE DOTPRO (A,B,SUM)                                       DOT   10
C     CALCULATES DOT-PRODUCT OF TWO VECTORS                             DOT   20
      DIMENSION A(3), B(3)                                              DOT   30
      SUM=0.                                                            DOT   40
      DO 10 I=1,3                                                       DOT   50
   10 SUM=SUM+A(I)*B(I)                                                 DOT   60
      RETURN                                                            DOT   70
      END                                                               DOT   80-
```

```
      SUBROUTINE CRSPRD (A,B,C)                                         CRS  10
C     CALCULATES CROSS-PRODUCT OF TWO VECTORS                           CRS  20
      DIMENSION A(3), B(3), C(3)                                        CRS  30
      C(1)=A(2)*B(3)-A(3)*B(2)                                          CRS  40
      C(2)=A(3)*B(1)-A(1)*B(3)                                          CRS  50
      C(3)=A(1)*B(2)-A(2)*B(1)                                          CRS  60
      RETURN                                                            CRS  70
      END                                                               CRS  80-
```

```
      SUBROUTINE VDTWNG (C,THETP,XX,YY,ZZ,XN,YN,XTE,YTE,CONS,CONI1,CONI3
     1,CONJ1,CONJ2,CONJ3,CONK1,CONK2,CONK3,CONI,CONJ,CONK,SI,NSW1,NCW,NW
     2NG)
C     EVALUATES INFLUENCE COEFFICIENTS FOR CALCULATION OF INDUCED
C     VELOCITY DUE TO WING ELEMENTS
      COMMON /ALLI/ NSW
      COMMON /ALLRB/ XXE(30),YYE(30),ZZE(30)
      COMMON /NCTT/ NCT,NCON
      COMMON /XIYIZI/ XI,YI,ZI
      DIMENSION THETP(1), C(1), CONS(1), XTE(1), YTE(1), SI(1), CONI1(1)
     1, CONI3(1), CONJ1(1), CONJ2(1), CONJ3(1), CONK1(1), CONK2(1), CONK
     23(1), CONI(1), CONJ(1), CONK(1), XN(NWNG,2), YN(NWNG,2), B(3), D(3
     3)
C     DIMENSIONS OF FJ1,FJ2,FJ3-(2*NSW)  ** SEE GEOM **
C     DIMENSIONS OF FI2,FI3-(2*NCPTTL)  ** SEE GEOM **
      DIMENSION FJ1(40), FJ2(40), FJ3(40), FI2(418), FI3(418)
      XI=XX
      YI=YY
      ZI=ZZ
      NC1=NWNG+NCW
      NC2=NWNG-NCW
C     VELOCITY DUE TO BOUND ELEMENTS
      DO 10 I=1,NSW1
      DO 10 J=1,NCW
      NP=(I-1)*NCW+J
      CALL INFL2 (XN(NP,1),YN(NP,1),0.,XN(NP,2),YN(NP,2),0.,B)
      A1=-YN(NP,1)
      A2=-YN(NP,2)
      CALL INFL2 (XN(NP,1),A1,0.,XN(NP,2),A2,0.,D)
      CONI(NP)=CONS(I)*(B(1)-D(1))
      CONJ(NP)=CONS(I)*(B(2)-D(2))
   10 CONK(NP)=CONS(I)*(B(3)-D(3))
C     VELOCITY DUE TO TRAILING ELEMENTS ON THE WING SURFACE
      DO 20 I=1,NSW1
      DO 20 J=1,NCW
      NP=(I-1)*NCW+J
      CALL INFL2 (XN(NP,1),YN(NP,1),0.,XTE(I),YN(NP,1),0.,B)
      FI2(NP)=B(2)
      FI3(NP)=B(3)
      AYN=-YN(NP,1)
```

```
      NQ=NC1+NP                                                         WNG 410
      CALL INFL2 (XN(NP,1),AYN,0.,XTE(I),AYN,0.,B)                      WNG 420
      FI2(NQ)=B(2)                                                      WNG 430
      FI3(NQ)=B(3)                                                      WNG 440
20    CONTINUE                                                          WNG 450
      DO 30 J=1,NCW                                                     WNG 460
      NP1=NWNG+J                                                        WNG 470
      NP2=NC1+NP1                                                       WNG 480
      NP=NC2+J                                                          WNG 490
      CALL INFL2 (XN(NP,2),YN(NP,2),0.,XTE(NSW),YN(NP,2),0.,B)          WNG 500
      FI2(NP1)=B(2)                                                     WNG 510
      FI3(NP1)=B(3)                                                     WNG 520
      AYN=-YN(NP,2)                                                     WNG 530
      CALL INFL2 (XN(NP,2),AYN,0.,XTE(NSW),AYN,0.,B)                    WNG 540
      FI2(NP2)=B(2)                                                     WNG 550
      FI3(NP2)=B(3)                                                     WNG 560
30    CONTINUE                                                          WNG 570
      DO 40 I=1,NSW1                                                    WNG 580
      DO 40 J=1,NCW                                                     WNG 590
      NP=(I-1)*NCW+J                                                    WNG 600
      I1=NP+NC1                                                         WNG 610
      I2=NP+NCW                                                         WNG 620
      I3=I1+NCW                                                         WNG 630
      CONJ2(NP)=CONS(I)*(FI2(I1)-FI2(NP)+FI2(I2)-FI2(I3))               WNG 640
40    CONK2(NP)=CONS(I)*(FI3(I1)-FI3(NP)+FI3(I2)-FI3(I3))               WNG 650
C     VELOCITY DUE TO TRAILING ELEMENTS BEYOND TRAILING EDGE            WNG 660
C     ******************************************************************WNG 670
      REWIND 4                                                          WNG 680
      CALL SKIPR (4,NSW)                                                WNG 690
      DO 80 I=2,NSW                                                     WNG 700
      READ (4) KK,(XXE(J),YYE(J),ZZE(J),J=1,KK)                         WNG 710
C     ******************************************************************WNG 720
      FJ1(I)=0.                                                         WNG 730
      FJ2(I)=0.                                                         WNG 740
      FJ3(I)=0.                                                         WNG 750
      IF (I.EQ.NCT) GO TO 60                                            WNG 760
      DO 50 J=2,KK                                                      WNG 770
      CALL INFL2 (XXE(J-1),YYE(J-1),ZZE(J-1),XXE(J),YYE(J),ZZE(J),B)    WNG 780
      FJ1(I)=FJ1(I)+B(1)                                                WNG 790
```

```
      FJ2(I)=FJ2(I)+B(2)                                                WNG 800
      FJ3(I)=FJ3(I)+B(3)                                                WNG 810
   50 CONTINUE                                                          WNG 820
      CALL FUNA (XXE(KK),YYE(KK),ZZE(KK),B(1),B(2),B(3))                WNG 830
      FJ1(I)=FJ1(I)+B(1)                                                WNG 840
      FJ2(I)=FJ2(I)+B(2)                                                WNG 850
      FJ3(I)=FJ3(I)+B(3)                                                WNG 860
   60 CONTINUE                                                          WNG 870
      IN=I+NSW                                                          WNG 880
      FJ1(IN)=0.                                                        WNG 890
      FJ2(IN)=0.                                                        WNG 900
      FJ3(IN)=0.                                                        WNG 910
      DO 70 J=2,KK                                                      WNG 920
      AYT1=-YYE(J-1)                                                    WNG 930
      AYT2=-YYE(J)                                                      WNG 940
      CALL INFL2 (XXE(J-1),AYT1,ZZE(J-1),XXE(J),AYT2,ZZE(J),B)          WNG 950
      FJ1(IN)=FJ1(IN)+B(1)                                              WNG 960
      FJ2(IN)=FJ2(IN)+B(2)                                              WNG 970
      FJ3(IN)=FJ3(IN)+B(3)                                              WNG 980
   70 CONTINUE                                                          WNG 990
      AYT2=-YYE(KK)                                                     WNG1000
      CALL FUNA (XXE(KK),AYT2,ZZE(KK),B(1),B(2),B(3))                   WNG1010
      FJ1(IN)=FJ1(IN)+B(1)                                              WNG1020
      FJ2(IN)=FJ2(IN)+B(2)                                              WNG1030
      FJ3(IN)=FJ3(IN)+B(3)                                              WNG1040
   80 CONTINUE                                                          WNG1050
      FJ1(1)=0.                                                         WNG1060
      FJ2(1)=0.                                                         WNG1070
      FJ3(1)=0.                                                         WNG1080
      FJ1(NSW+1)=0.                                                     WNG1090
      FJ2(NSW+1)=0.                                                     WNG1100
      FJ3(NSW+1)=0.                                                     WNG1110
      DO 90 I=1,NSW1                                                    WNG1120
      I1=I+1                                                            WNG1130
      I2=I+NSW                                                          WNG1140
      I3=I2+1                                                           WNG1150
      EFJ1=CONS(I)*(FJ1(I2)-FJ1(I)+FJ1(I1)-FJ1(I3))                     WNG1160
      EFJ2=CONS(I)*(FJ2(I2)-FJ2(I)+FJ2(I1)-FJ2(I3))                     WNG1170
      EFJ3=CONS(I)*(FJ3(I2)-FJ3(I)+FJ3(I1)-FJ3(I3))                     WNG1180
```

```
      DO 90 J=1,NCW                                                     WNG1190
      NP=(I-1)*NCW+J                                                    WNG1200
      CONI3(NP)=EFJ1                                                    WNG1210
      CONJ3(NP)=EFJ2                                                    WNG1220
 90   CONK3(NP)=EFJ3                                                    WNG1230
C     TOTAL INDUCED VELOCITY                                            WNG1240
      I=1                                                               WNG1250
      DO 100 J=1,NWNG                                                   WNG1260
      CONI(J)=(CONI(J)+CONI3(J))*SI(I)                                  WNG1270
      CONJ(J)=(CONJ(J)+CONJ2(J)+CONJ3(J))*SI(I)                         WNG1280
      CONK(J)=(CONK(J)+CONK2(J)+CONK3(J))*SI(I)                         WNG1290
      I=I+1                                                             WNG1300
      IF (I.GT.NCW) I=1                                                 WNG1310
100   CONTINUE                                                          WNG1320
      RETURN                                                            WNG1330
      END                                                               WNG1340
```

```
      SUBROUTINE VDTFRE (X,Y,Z,CI,CJ,CK,NSW1,BSQD4P,XLE,YLE)             FRE  10
C     EVALUATES INFLUENCE COEFFICIENTS FOR CALCULATION OF INDUCFD        FRE  20
C     VELOCITY DUF TO FREE ELEMENTS                                      FRE  30
      COMMON /ALLRB/ XE(40),YE(40),ZE(40),XXE(30),YYE(30),ZZE(30)        FRE  40
      COMMON /NCTT/ NCT,NCON                                             FRE  50
      COMMON /XIYIZI/ XI,YI,ZI                                           FRE  60
      DIMENSION CI(1), CJ(1), CK(1), XLE(1), YLE(1), V(3), VVV(3)        FRE  70
C     DIMENSION OF VTOL-(NSW1,3)  ** SEE GEOM **                         FRE  80
      DIMENSION VTOL(19,3)                                               FRE  90
      XI=X                                                               FRE 100
      YI=Y                                                               FRE 110
      ZI=Z                                                               FRE 120
      NCT1=0                                                             FRE 130
C     ******************************************************************FRE 140
10    REWIND 4                                                           FRE 150
C     ******************************************************************FRE 160
      DO 60 I=1,NSW1                                                     FRE 170
      V(1)=0.                                                            FRE 180
      V(2)=0.                                                            FRE 190
      V(3)=0.                                                            FRE 200
      FJ1=0.                                                             FRE 210
      FJ2=0.                                                             FRE 220
      FJ3=0.                                                             FRE 230
C     ******************************************************************FRE 240
      READ (4) KK,(XE(J),YE(J),ZE(J),J=1,KK)                             FRE 250
C     ******************************************************************FRE 260
      K=KK-1                                                             FRE 270
C     VELOCITY DUE TO FREE ELEMENTS AHEAD OF TRAILING-EDGE AND THOSE     FRE 280
C     OVER THE WING                                                      FRE 290
      DO 20 J=1,K                                                        FRE 300
      IF (I.EQ.NCON.AND.J.GT.4.AND.YI.GT.0.) GO TO 20                    FRE 310
      CALL INFL2 (XE(J),YE(J),ZE(J),XE(J+1),YE(J+1),ZE(J+1),VVV)         FRE 320
      V(1)=V(1)+VVV(1)                                                   FRE 330
      V(2)=V(2)+VVV(2)                                                   FRE 340
      V(3)=V(3)+VVV(3)                                                   FRE 350
20    CONTINUE                                                           FRE 360
      IF (I.EQ.NCON.AND.YI.GT.0.) GO TO 30                               FRE 370
      CALL FUNA (XE(K+1),YE(K+1),ZE(K+1),FJ1,FJ2,FJ3)                    FRE 380
30    VTOL(I,1)=V(1)+FJ1                                                 FRE 390
      VTOL(I,2)=V(2)+FJ2                                                 FRE 400
```

```
      VTDL(I,3)=V(3)+FJ3
      FJ1=0.
      FJ2=0.
      FJ3=0.
      I1=I+1
C     ******************************************************************
      CALL SKIPR (4,NSW1)
      READ (4) II,(XXE(J),YYE(J),ZZE(J),J=1,II)
C     ******************************************************************
      IF (I1.EQ.NCT.AND.YI.GT.0.) GO TO 50
C     VELOCITY DUE TO WAKE ELEMENTS
      DO 40 J=2,II
      CALL INFL2 (XXE(J-1),YYE(J-1),ZZE(J-1),XXE(J),YYE(J),ZZE(J),V)
      FJ1=FJ1+V(1)
      FJ2=FJ2+V(2)
      FJ3=FJ3+V(3)
40    CONTINUE
      CALL FUNA (XXE(II),YYE(II),ZZE(II),V(1),V(2),V(3))
      FJ1=FJ1+V(1)
      FJ2=FJ2+V(2)
      FJ3=FJ3+V(3)
50    CONTINUE
      VTDL(I,1)=VTDL(I,1)-FJ1
      VTDL(I,2)=VTDL(I,2)-FJ2
      VTDL(I,3)=VTDL(I,3)-FJ3
C     ******************************************************************
      REWIND 4
      CALL SKIPR (4,I)
C     ******************************************************************
60    CONTINUE
      YI=-YI
      NCT1=NCT1+1
      IF (NCT1.GT.1) GO TO 80
      DO 70 I=1,NSW1
      CI(I)=VTDL(I,1)
      CJ(I)=VTDL(I,2)
      CK(I)=VTDL(I,3)
70    CONTINUE
      GO TO 10
```

```
C     TOTAL INDUCED VELOCITY                                          FRE 800
80    DO 90 I=1,NSW1                                                  FRE 810
      CI(I)=BSQD4P*(CI(I)+VTDL(I,1))                                  FRE 820
      CJ(I)=BSQD4P*(CJ(I)-VTDL(I,2))                                  FRE 830
90    CK(I)=BSQD4P*(CK(I)+VTDL(I,3))                                  FRE 840
      RETURN                                                          FRE 850
      END                                                             FRE 860-
```

```
      SUBROUTINE FUNA (XT,YT,ZT,FJ1,FJ2,FJ3)
C     INDUCED VELOCITY DUE TO A VORTEX ELEMENT OF UNIT STRENGTH TRAILING
C     FROM (XT,YT,ZT) TO INFINITY
      COMMON /ALLRA/ AA(21),BETA2,TANPH1,B2PH1,AB,D4,AC(2),D4SO2
      COMMON /XIYIZI/ XI,YI,ZI
      DIMENSION A(3), B(3), C(3)
      A(1)=XT-XI
      A(2)=YT-YI
      A(3)=ZT-ZI
      B(1)=XT+1-XI
      B(2)=YT-YI
      B(3)=ZT+TANPH1-ZI
      CALL CRSPRD (A,B,C)
      CC=SQRT(C(1)*C(1)+C(2)*C(2)+C(3)*C(3))
      IF (CC.LE.(1.E-10)) GO TO 10
      D5=2.*(B2PH1*(ZT-ZI-XT*TANPH1)-XI)
      D6=XI*XI+BETA2*((YI-YT)**2+(ZT-ZI-XT*TANPH1)**2)
      Q=4.*D4*D6-D5*D5
      IF (Q.LE.(1.E-10)) GO TO 10
      RB=SQRT(D4*XT*XT+D5*XT+D6)
      FJ4=2.*(D4SO2-(2.*D4*XT+D5)/RB)/Q
      FJ1=(YT-YI)*TANPH1*FJ4
      FJ2=(ZT-ZI+(XI-XT)*TANPH1)*FJ4
      FJ3=-(YT-YI)*FJ4
      RETURN
   10 FJ1=0.
      FJ2=0.
      FJ3=0.
      RETURN
      END
```

```
      SUBROUTINE INFL2 (X1,Y1,Z1,X2,Y2,Z2,VACL)
C     INDUCED VELOCITY DUE TO A VORTEX ELEMENT OF UNIT STRENGTH LYING
C     BETWEEN (X1,Y1,Z1) AND (X2,Y2,Z2)
      COMMON /ALLRA/ AA(20),BETA
      COMMON /XIYIZI/ XI,YI,ZI
      DIMENSION VA(3), VL(3), VAP(3), VBP(3), VLP(3), VACL(3), VAPCLP(3)
      VA(1)=X1-XI
      VA(2)=Y1-YI
      VA(3)=Z1-ZI
      VL(1)=X2-X1
      VL(2)=Y2-Y1
      VL(3)=Z2-Z1
      VAP(1)=VA(1)
      VAP(2)=BETA*VA(2)
      VAP(3)=BETA*VA(3)
      VBP(1)=X2-XI
      VBP(2)=BETA*(Y2-YI)
      VBP(3)=BETA*(Z2-ZI)
      VLP(1)=VL(1)
      VLP(2)=BETA*VL(2)
      VLP(3)=BETA*VL(3)
      CALL CRSPRD (VA,VL,VACL)
      CALL CRSPRD (VAP,VLP,VAPCLP)
      CALL DOTPRD (VAPCLP,VAPCLP,DAPCLP)
      IF (ABS(DAPCLP).LT.(1.E-10)) GO TO 10
      CALL DOTPRD (VBP,VBP,DBP)
      BPMOD=SQRT(DBP)
      CALL DOTPRD (VAP,VAP,DAP)
      APMOD=SQRT(DAP)
      CALL DOTPRD (VBP,VLP,DBPLP)
      DBPLP=DBPLP/BPMOD
      CALL DOTPRD (VAP,VLP,DAPLP)
      DAPLP=DAPLP/APMOD
      CONST=(DBPLP-DAPLP)/DAPCLP
      GO TO 20
10    CONST=0.
20    CONTINUE
      VACL(1)=VACL(1)*CONST
      VACL(2)=VACL(2)*CONST
      VACL(3)=VACL(3)*CONST
```

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      RETURN                                                                    INF 410
      END                                                                       INF 420-
```

```
      SUBROUTINE NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,COVEL  10
     1NI,CONJ,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,CPCW1,XCP,YCP,VEL  20
     2GAMA,YYM)                                                         VEL  30
C     EVALUATES TOTAL VELOCITY AT POINT (XEE,YEE,ZEE)                   VEL  40
      COMMON /ALLRA/ AA(17),SINA,COSA,AB(5),BSQD4P                      VEL  50
      COMMON /GM/ ITER,L1,L2,L3,L4,L5,L6,L7,L8                          VEL  60
      DIMENSION DUMMY(1), CONI(1), CONJ(1), CONK(1), CI(1), CJ(1), CK(1)VEL  70
     1, C(1), THETP(1), XTE(1), XLE(1), YLE(1), CONS(1), SI(1), CPCW1(1)VEL  80
     2, XCP(1), YCP(1), GAMA(1), YYM(1), XN(NWNG,2), YN(NWNG,2), NP(4), VEL  90
     3U(4,3), V(3)                                                      VEL 100
C     IF POINT IS IN THE WING PLANE, THE REGULAR METHOD FOR VELOCITY    VEL 110
C     EVALUATION IS USED.                                               VEL 120
      IF (ZEE.LE.0.00001) GO TO 110                                     VEL 130
      IF (YEE.GT.YYM(NSW1)) GO TO 110                                   VEL 140
      CH1=XTE(1)-XLF(1)                                                 VEL 150
      CH2=XTF(2)-XLE(2)                                                 VEL 160
      XLY=XLE(1)+(YEE-YLE(1))*(XLE(2)-XLF(1))/(YLF(2)-YLE(1))           VEL 170
      CHY=CH1+(YEE-YLF(1))*(CH2-CH1)/(YLE(2)-YLE(1))                    VEL 180
      XC=(XEF-XLY)/CHY                                                  VEL 190
      IF (XC.LT.0.0.OR.XC.GT.1.0) GO TO 110                             VEL 200
      ZC=ZEE/CHY                                                        VEL 210
C     IF THE POINT (XEE,YEE,ZEE) IS AT Z/C(LOCAL) LESS THAN ZTOL, THE   VEL 220
C     VELOCITY IS OBTAINED BY LINEAR INTERPOLATION OF THE VELOCITIES    VEL 230
C     CALCULATED ABOVE FOUR WING CONTROL POINTS AMONG WHICH THE POINT ISVEL 240
C     LOCATED. BY NUMERICAL EXPERIMENTATION ZTOL HAS BEEN OBTAINED TO BEVEL 250
C     0.2.                                                              VEL 260
      ZTOL=0.2                                                          VEL 270
      IF (ZC.GE.ZTOL) GO TO 110                                         VEL 280
      I=1                                                               VEL 290
      IF (YEE.LE.YYM(I)) GO TO 20                                       VEL 300
10    IF (YEE.GT.YYM(I).AND.YEE.LE.YYM(I+1)) GO TO 20                   VEL 310
      I=I+1                                                             VEL 320
      IF (I.LT.NSW1) GO TO 10                                           VEL 330
20    J=1                                                               VEL 340
      IF (XC.LE.CPCW1(1)) GO TO 50                                      VEL 350
30    IF (XC.GT.CPCW1(J).AND.XC.LE.CPCW1(J+1)) GO TO 40                 VEL 360
      J=J+1                                                             VEL 370
      IF (J.LT.NCW) GO TO 30                                            VEL 380
40    NP(1)=(I-1)*NCW+J                                                 VEL 390
      NP(2)=NP(1)+1                                                     VEL 400
```

```
      NP(3)=NP(1)+NCW
      NP(4)=NP(3)+1
      XC1=CPCW1(J)
      XC2=CPCW1(J+1)
      GO TO 60
50    NP(1)=NCW*NSW1+I
      NP(2)=(I-1)*NCW+1
      NP(3)=NP(1)+1
      NP(4)=NP(2)+NCW
      XC1=0.
      XC2=CPCW1(1)
60    CONTINUE
C     EVALUATION OF INDUCED VELOCITY AT FOUR POINTS
      DO 80 I=1,4
      NN=NP(I)
      CALL VOTWNG (C,THETP,XCP(NN),YCP(NN),ZEE,XN,YN,XTE,YLE,CONS,DUMMY(
     1L1),DUMMY(L2),DUMMY(L3),DUMMY(L4),DUMMY(L5),DUMMY(L6),DUMMY(L7),DU
     2MMY(L8),CONI,CONJ,CONK,SI,NSW1,NCW,NWNG)
      U(I,1)=0.
      U(I,2)=0.
      U(I,3)=0.
      DO 70 J=1,NWNG
      U(I,1)=U(I,1)+CONI(J)*GAMA(J)
      U(I,2)=U(I,2)+CONJ(J)*GAMA(J)
70    U(I,3)=U(I,3)+CONK(J)*GAMA(J)
80    CONTINUE
C     INTERPOLATION
      NN1=NP(1)
      NN2=NP(3)
      Y1=YCP(NN1)
      Y2=YCP(NN2)
      DO 90 I=1,3
      UA=U(1,I)+(U(3,I)-U(1,I))*(YEE-Y1)/(Y2-Y1)
      UB=U(2,I)+(U(4,I)-U(2,I))*(YEE-Y1)/(Y2-Y1)
90    V(I)=UA+(UB-UA)*(XC-XC1)/(XC2-XC1)
      UU=V(1)+COSA
      VV=V(2)
      WW=V(3)+SINA
      CALL VOTFRE (XEE,YEE,ZEE,CI,CJ,CK,NSW1,B[illegible]D4P,XLE,YLE)
```

```
C     FINAL TOTAL VELOCITY
      DO 100 J=1,NSW1
      JJ=NWNG+J
      UU=UU+CI(J)*GAMA(JJ)
      VV=VV+CJ(J)*GAMA(JJ)
100   WW=WW+CK(J)*GAMA(JJ)
      RETURN
C     EVALUATION OF VELOCITY WHEN POINT IS IN THE WING PLANE
110   CONTINUE
      CALL VOTWNG (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY(L1),DUM
     1Y(L2),DUMMY(L3),DUMMY(L4),DUMMY(L5),DUMMY(L6),DUMMY(L7),DUMMY(L8),
     2CONI,CONJ,CONK,ST,NSW1,NCW,NWNG)
      CALL VOTFRE (XEE,YEE,ZEE,CI,CJ,CK,NSW1,BSOD4P,XLE,YLE)
C     FREE STREAM VELOCITY
      UU=COSA
      VV=0.
      WW=SINA
C     VELOCITY DUE TO FREE ELEMENTS
      DO 120 I=1,NSW1
      NO=NWNG+I
      UU=UU+CI(I)*GAMA(NO)
      VV=VV+CJ(I)*GAMA(NO)
120   WW=WW+CK(I)*GAMA(NO)
C     VELOCITY DUE TO WING
      DO 130 I=1,NSW1
      DO 130 J=1,NCW
      NO=(I-1)*NCW+J
      UU=UU+CONI(NO)*GAMA(NO)
      VV=VV+CONJ(NO)*GAMA(NO)
130   WW=WW+CONK(NO)*GAMA(NO)
      RETURN
      END
```

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      OVERLAY (LEVSP,1,0)
      PROGRAM GEOM
C     DEFINES THE WING AND FREE ELEMENT GEOMETRY
C     MAXIMUM VALUES
C     ** NCW. = 9
C     ** NNCW = NCW+1 = 10
C     ** NSW = 20
C     ** NSW1 = NSW-1 = 19
C     ** NWNG = NNCW*NSW1 = 190
C     ** NCPTTL = (NNCW+1)*NSW1 = 209
      COMMON XXL(2),XXT(2),YL(2),CPCWL(10),CPCW1(10),SI(10),SN(10),SNN(1
     10),SWP(10),SLOPE(10),XL(2,10),C(19),THETP(19),CONS(19),CPSW1(19),X
     2LM(19),XTM(19),YLM(19),CTT(19),CPSWL(20),XLE(20),XTE(20),YLE(20),X
     3AVWNG(190),YAVWNG(190),XN(190,2),YN(190,2),XCP(209),YCP(209),X(10,
     420),Y(10,20)
      COMMON /ALLI/ NSW,NSW1,NCW,NWNG,NCPTTL,MITER,IPUNCH
      COMMON /ALLRA/ TTL(16),ALPHA,SINA,COSA,SWPLE,BETA,BETA2,TANPH1,B2P
     1H1,BSQD4P,D4,CON,PI,D4SQ2,CBAR,HALFB,AREA
      COMMON /XSTN/ XBRR(25),NBRR
      THEND=5HEND
C     ******************************************************************
      READ (5,130) TTL
      IF (TTL(1).EQ.THEND) GO TO 120
      READ (5,160) NCW,NSW,NBRR,NCONTS,MITER,IPUNCH
      NSW1=NSW-1
      READ (5,150) (XXL(I),XXT(I),YL(I),I=1,2)
      READ (5,150) ALPHA,AMACH,DELTA,DL,XEND,CBAR,AREA
      READ (5,150) (XBRR(I),I=1,NBRR)
      READ (5,150) (CTT(I),I=1,NSW1)
C     ******************************************************************
      WRITE (6,170) TTL
      WRITE (6,160) NCW,NSW,NBRR,NCONTS,MITER,IPUNCH
      WRITE (6,150) (XXL(I),XXT(I),YL(I),I=1,2)
      WRITE (6,150) ALPHA,AMACH,DELTA,DL,XEND,CBAR,AREA
      WRITE (6,150) (XBRR(I),I=1,NBRR)
      WRITE (6,150) (CTT(I),I=1,NSW1)
      NNCW=NCW
      NCW=NNCW+1
C     NPRCY=0, USED FOR BOUND ELEMENTS = (NCW+1)
C     NPRCY=1, USED FOR BOUND ELEMENTS = NCW
```

```
      NPRCY=0                                                           GEO 410
   10 IF (NPRCY.EQ.1) NCW=NNCW                                          GEO 420
      PI=3.14159265                                                     GEO 430
      FN2=2*NCW                                                         GEO 440
      PIJ=PI/FLOAT(NCW)                                                 GEO 450
      TWOPI=2.*PI                                                       GEO 460
      DO 20 I=1,NCW                                                     GEO 470
      CPCWL(I)=50.*(1.-COS((2.*FLOAT(I)-1.)*PI/FN2))                    GEO 480
      CPCW1(I)=50.*(1.-COS(FLOAT(I)*PI/FLOAT(NCW)))                     GEO 490
      CC=CPCWL(I)/100.                                                  GEO 500
      SNN(I)=2.*SQRT(CC*(1.-CC))                                        GEO 510
      PSIJ=(2.*FLOAT(I)-1.)*PIJ/2.                                      GEO 520
      SN(I)=SIN(PSIJ)/TWOPI                                             GEO 530
   20 SI(I)=TWOPI*SN(I)                                                 GEO 540
      SWPLE=ATAN((XXL(2)-XXL(1))/(YL(2)-YL(1)))                         GEO 550
      FM2=2*NSW                                                         GEO 560
      DO 30 J=1,NSW                                                     GEO 570
   30 CPSWL(J)=50.*(1.-COS((2.*FLOAT(J)-1.)*PI/FM2))                    GEO 580
      CPSWL(1)=0.                                                       GEO 590
      DO 40 I=1,NSW1                                                    GEO 600
   40 CPSW1(I)=50.*(1.-COS(FLOAT(I)*PI/FLOAT(NSW)))                     GEO 610
      CALL PNLWNG (NSW,NWNG,NCW)                                        GEO 620
      HALFB=YL(2)                                                       GEO 630
      DO 50 I=1,NSW1                                                    GEO 640
      C(I)=XTM(I)-XLM(I)                                                GEO 650
      YYLM=YLM(I)/HALFB                                                 GEO 660
   50 THETP(I)=ARCOS(YYLM)                                              GEO 670
      NCPTTL=NSW1+NWNG                                                  GEO 680
      IF (NPRCY.EQ.1) GO TO 60                                          GEO 690
      NCW1=NCW                                                          GEO 700
C     ..................................................................GEO 710
      REWIND 1                                                          GEO 720
      REWIND 7                                                          GEO 730
      WRITE (1) NCW,NWNG                                                GEO 740
      WRITE (1) (SI(I),SNN(I),SWP(I),I=1,NCW)                           GEO 750
      WRITE (1) (XAVWNG(I),YAVWNG(I),I=1,NWNG,NCW)                      GEO 760
C     ..................................................................GEO 770
      NPRCY=1                                                           GEO 780
      GO TO 10                                                          GEO 790
```

```
60    DO 70 I=1,NCW                                                  GEO 800
      CPCWL(I)=CPCWL(I)/100.                                         GEO 810
70    CPCW1(I)=CPCW1(I)/100.                                         GEO 820
      DO 80 I=1,NSW                                                  GEO 830
80    CPSWL(I)=CPSWL(I)/100.                                         GEO 840
      DO 90 I=1,NSW1                                                 GEO 850
90    CPSW1(I)=CPSW1(I)/100.                                         GEO 860
C     EVALUATING THF CONSTANTS                                       GEO 870
      ALPHA=ALPHA*PI/180.                                            GEO 880
      TANPH1=TAN(ALPHA)                                              GEO 890
      TANPH2=TANPH1*TANPH1                                           GEO 900
      BETA2=1.-AMACH*AMACH                                           GEO 910
      BETA=SQRT(BFTA2)                                               GEO 920
      B2PH1=BETA2*TANPH1                                             GEO 930
      D4=BETA2*TANPH2+1.                                             GEO 940
      D4SQ2=2.*SQRT(D4)                                              GEO 950
      CON=BETA2/(8.*FLOAT(NCW))                                      GEO 960
      BSQD4P=BETA2/(4.*PI)                                           GEO 970
      CON1=COS(SWPLE)                                                GEO 980
      CON2=(SIN(SWPLE))/CON1                                         GEO 990
      CON3=FLOAT(NCW)*SORT(BETA2+CON2*CON2)                          GEO1000
      CON4=2.*CON1/(PI*SORT(1.-AMACH*AMACH*CON1*CON1))               GEO1010
      DO 100 I=1,NSW1                                                GEO1020
100   CTT(I)=CON3*SORT(CON4*CTT(I))                                  GEO1030
      DO 110 I=1,NSW1                                                GEO1040
110   CONS(I)=CON*C(I)                                               GEO1050
      SINA=SIN(ALPHA)                                                GEO1060
      COSA=COS(ALPHA)                                                GEO1070
C     ...............................................................GEO1080
      WRITE (1) (SNN(I),SWP(I),I=1,NCW)                              GEO1090
      WRITE (1) (XAVWNG(I),YAVWNG(I),I=1,NWNG)                       GEO1100
      WRITE (1) (C(I),I=1,NSW1)                                      GEO1110
      WRITE (1) (THETP(I),I=1,NSW1)                                  GEO1120
      WRITE (1) (XTE(I),XLE(I),YLE(I),I=1,NSW)                       GEO1130
      WRITE (1) (XLM(I),YLM(I),I=1,NSW1)                             GEO1140
      WRITE (1) (CONS(I),I=1,NSW1)                                   GEO1150
      WRITE (1) (SI(I),SN(I),I=1,NCW)                                GEO1160
      WRITE (1) (XCP(I),YCP(I),I=1,NCPTTL)                           GEO1170
      WRITE (1) ((XN(I,J),YN(I,J),J=1,2),I=1,NWNG)                   GEO1180
```

```
      WRITE (1) (CTT(I),I=1,NSW1)                                       GE01190
      WRITE (1) (CPCWL(I),I=1,NCW)                                      GE01200
      WRITE (1) (CPCW1(I),I=1,NCW)                                      GE01210
      WRITE (1) (CPSWL(I),I=1,NSW)                                      GE01220
      WRITE (1) (CPSW1(I),I=1,NSW1)                                     GE01230
C     ..................................................................GE01240
      CALL FRELM (XXL,XXT,YL,XLE,XTE,YLE,PI,NCW1,NSW1,XEND,DELTA,ALPHA,DGE01250
     1L,NCONTS)                                                         GE01260
      RETURN                                                            GE01270
120   WRITE (6,140)                                                     GE01280
      STOP                                                              GE01290
C                                                                       GE01300
130   FORMAT (16A5)                                                     GE01310
140   FORMAT (1H1,/,10X,19HALL CASES COMPLETED)                         GE01320
150   FORMAT (8F10.5)                                                   GE01330
160   FORMAT (10I5)                                                     GE01340
170   FORMAT (1H1,/,17H INPUT DATA CARDS/,16A5)                         GE01350
      END                                                               GE01360-
```

```
      SUBROUTINE PNLWNG (NSW,LPANEL,NCW)                                PNL  10
C     GENERATES THE GRID OF BOUND AND TRAILING VORTEX ELEMENTS          PNL  20
      COMMON XXL(2),XXT(2),YL(2),CPCWL(10),CPCW1(10),SI(10),SN(10),SNN(1PNL  30
     10),SWP(10),SLOPE(10),XL(2,10),C(19),THETP(19),CONS(19),CPSW1(19),XPNL  40
     2LM(19),XTM(19),YLM(19),CTT(19),CPSWL(20),XLE(20),XTE(20),YLE(20),XPNL  50
     3AVWNG(190),YAVWNG(190),XN(190,2),YN(190,2),XCP(209),YCP(209),X(10,PNL  60
     420),Y(10,20)                                                      PNL  70
      DO 10 I=1,2                                                       PNL  80
      D=XXT(I)-XXL(I)                                                   PNL  90
      DO 10 J=1,NCW                                                     PNL 100
   10 XL(I,J)=XXL(I)+CPCWL(J)*D/100.                                    PNL 110
      SPAN=YL(2)-YL(1)                                                  PNL 120
      DO 20 I=1,NCW                                                     PNL 130
      SLOPE(I)=(XL(2,I)-XL(1,I))/SPAN                                   PNL 140
   20 SWP(I)=ATAN(SLOPE(I))                                             PNL 150
      DO 30 K=1,NSW                                                     PNL 160
      YK=CPSWL(K)*SPAN/100.                                             PNL 170
      YL1=YL(1)+YK                                                      PNL 180
      DO 30 J=1,NCW                                                     PNL 190
      Y(J,K)=YL1                                                        PNL 200
   30 X(J,K)=XL(1,J)+SLOPE(J)*YK                                        PNL 210
      NSW1=NSW-1                                                        PNL 220
      XLE(1)=XXL(1)                                                     PNL 230
      XTE(1)=XXT(1)                                                     PNL 240
      YLE(1)=Y(1,1)                                                     PNL 250
      DLE=(XXL(2)-XXL(1))/SPAN                                          PNL 260
      DTE=(XXT(2)-XXT(1))/SPAN                                          PNL 270
      DO 40 I=2,NSW                                                     PNL 280
      YLE(I)=Y(1,I)                                                     PNL 290
      YLM(I-1)=YLE(1)+CPSW1(I-1)*SPAN/100.                              PNL 300
      DLEL=DLE*(Y(1,I)-Y(1,I-1))                                        PNL 310
      DTET=DTE*(Y(1,I)-Y(1,I-1))                                        PNL 320
      XLE(I)=XLE(I-1)+DLEL                                              PNL 330
      XTE(I)=XTE(I-1)+DTET                                              PNL 340
      XLM(I-1)=XLE(1)+SPAN*CPSW1(I-1)*DLE/100.                          PNL 350
   40 XTM(I-1)=XTE(1)+SPAN*CPSW1(I-1)*DTE/100.                          PNL 360
      DO 60 K=1,NSW1                                                    PNL 370
      NP=(K-1)*NCW                                                      PNL 380
      CC=XTM(K)-XLM(K)                                                  PNL 390
      DO 60 J=1,NCW                                                     PNL 400
```

```
      NPANEL=NP+J                                                       PNL 410
      XCP(NPANEL)=XLM(K)+CC*CPCW1(J)/100.                               PNL 420
      YCP(NPANEL)=YLM(K)                                                PNL 430
      XAVWNG(NPANEL)=XLM(K)+CC*CPCWL(J)/100.                            PNL 440
      YAVWNG(NPANEL)=YLM(K)                                             PNL 450
      DO 50 I=1,2                                                       PNL 460
      KI=K+I-1                                                          PNL 470
      XN(NPANEL,I)=X(J,KI)                                              PNL 480
   50 YN(NPANEL,I)=Y(J,KI)                                              PNL 490
   60 CONTINUE                                                          PNL 500
      LPANEL=NPANEL                                                     PNL 510
      DO 70 K=1,NSW1                                                    PNL 520
      NP=LPANEL+K                                                       PNL 530
      XCP(NP)=XLM(K)                                                    PNL 540
   70 YCP(NP)=YLM(K)                                                    PNL 550
      RETURN                                                            PNL 560
      END                                                               PNL 570
```

```
      SUBROUTINE FRELM (XXL,XXT,YL,XLE,XTE,YLE,PI,NCW1,NSW1,XEND,DELTA,A
     1LPHA,DL,NCONTS)
C     FINDS THE INETIAL COORDINATES OF FREE VORTEX ELEMENTS
      COMMON /ALLRB/ XE(40),YE(40),ZE(40),XXE(30),YYE(30),ZZE(30),ZMIN,N
     1ELM(11),NNELM(12)
      COMMON /XPLOT/ XMN,YMN,ZMN,XMX,YMX,ZMX
      DIMENSION XXL(1), XXT(1), YL(1), XLE(1), XTE(1), YLE(1)
      AHPI=ALPHA
      ALP=ALPHA*180./PI
      IF (ALP.LE.15.) AHPI=(22.5-0.5*ALP)*PI/180.
      NSW=NSW1+1
      THT1=PI/(FLOAT(2*NCW1))
      CPC=0.5*(1.-COS(THT1))
      ZMIN=(XTE(1)-XLE(1))*TAN(AHPI)/10.
      SAHPI=SIN(AHPI)
      CAHPI=COS(AHPI)
      REWIND 2
      REWIND 4
C     EVALUATION OF COORDINATES OF LEADING-EDGE ELEMENTS
      DO 30 I=1,NSW1
      XE(1)=XTE(I+1)
      YE(1)=YLE(I+1)
      ZE(1)=0.
      XE(2)=XLE(I+1)+CPC*(XTE(I+1)-XLE(I+1))
      YE(2)=YLE(I+1)
      ZE(2)=0.
      XE(3)=XLE(I)+CPC*(XTE(I)-XLE(I))
      YE(3)=YLE(I)
      ZE(3)=0.
      XE(4)=XLE(I)
      YE(4)=YLE(I)
      ZE(4)=0.
      XE(5)=XLE(I)-0.05*(XTE(I)-XLE(I))
      IF (I.EQ.1) XMN=XE(5)
      YE(5)=YLE(I)
      ZE(5)=0.
      XE(6)=XE(4)+0.05*(XTE(I)-XLE(I))
      YE(6)=YE(4)
      ZE(6)=ZMIN
      J=6
```

```
      XE(7)=XE(6)+DELTA*CAHPI                                           FLM 410
      YE(7)=YE(6)                                                       FLM 420
      ZE(7)=ZE(6)+DELTA*SAHPI                                           FLM 430
      IF (I.EQ.1) GO TO 20                                              FLM 440
      J=7                                                               FLM 450
   10 XE(J+1)=XE(J)+DELTA                                               FLM 460
      YE(J+1)=YE(J)                                                     FLM 470
      ZE(J+1)=ZE(J)                                                     FLM 480
      IF (XE(J+1).GE.XEND) GO TO 20                                     FLM 490
      J=J+1                                                             FLM 500
      GO TO 10                                                          FLM 510
   20 NELM(I)=J+1                                                       FLM 520
      K=NELM(I)                                                         FLM 530
C     ..................................................................FLM 540
      IF (NCONTS.NE.0) WRITE (2) (XE(J),YE(J),ZE(J),J=1,5)              FLM 550
   30 WRITE (4) K,(XE(J),YE(J),ZE(J),J=1,K)                             FLM 560
C     ..................................................................FLM 570
      NMAX=0                                                            FLM 580
      DO 40 I=1,NSW1                                                    FLM 590
   40 IF (NMAX.LT.NELM(I)) NMAX=NELM(I)                                 FLM 600
C     EVALUATION OF COORDINATES OF WAKE ELEMENTS                        FLM 610
      DO 70 I=1,NSW                                                     FLM 620
      XXE(1)=XTE(I)                                                     FLM 630
      YYE(1)=YLE(I)                                                     FLM 640
      ZZE(1)=0.                                                         FLM 650
      XXE(2)=XXE(1)+(XXT(1)-XXL(1))/10.                                 FLM 660
      YYE(2)=YYE(1)                                                     FLM 670
      ZZE(2)=ZZE(1)                                                     FLM 680
      XXE(3)=XXE(2)+(XXT(1)-XXL(1))/10.                                 FLM 690
      YYE(3)=YYE(2)                                                     FLM 700
      ZZE(3)=ZZE(2)                                                     FLM 710
      J=3                                                               FLM 720
   50 IF (XXE(J).GE.XEND) GO TO 60                                      FLM 730
      XXE(J+1)=XXE(J)+DL                                                FLM 740
      YYE(J+1)=YYE(J)                                                   FLM 750
      ZZE(J+1)=ZZE(J)                                                   FLM 760
      J=J+1                                                             FLM 770
      GO TO 50                                                          FLM 780
   60 NNELM(I)=J                                                        FLM 790
```

```
      K=J                                                               FLM 800
C     ..................................................................FLM 810
      IF (NCONTS.NE.0) WRITE (2) (XXE(J),YYE(J),ZZE(J),J=1,2)           FLM 820
70    WRITE (4) K,(XXE(J),YYE(J),ZZE(J),J=1,K)                          FLM 830
C     ..................................................................FLM 840
      NNMAX=0                                                           FLM 850
      DO 80 I=1,NSW1                                                    FLM 860
80    IF (NNMAX.LT.NNELM(I)) NNMAX=NNELM(I)                             FLM 870
C     ..................................................................FLM 880
      WRITE (4) NMAX,NNMAX,ZMIN,NCONTS                                  FLM 890
C     ..................................................................FLM 900
      XLNT=XEND-XMN                                                     FLM 910
      XMX=XEND                                                          FLM 920
      XMX=XEND+0.20*XLNT                                                FLM 930
      YMN=0.                                                            FLM 940
      YMX=YL(2)                                                         FLM 950
      ZMN=-YL(2)/4.                                                     FLM 960
      ZMX=YL(2)/2.                                                      FLM 970
      IF (NCONTS.EQ.0) GO TO 130                                        FLM 980
C     READS LOCATION OF LEADING-EDGE ELEMENTS FROM INPUT DATA CARDS     FLM 990
C     ******************************************************************FLM1000
      REWIND 2                                                          FLM1010
      REWIND 4                                                          FLM1020
      READ (5,160) (NELM(I),I=1,NSW1)                                   FLM1030
      DO 90 I=1,NSW1                                                    FLM1040
      K=NELM(I)                                                         FLM1050
      READ (5,150) ((X1,J=1,5),(XE(J),J=6,K))                           FLM1060
      READ (5,150) ((Y1,J=1,5),(YE(J),J=6,K))                           FLM1070
      READ (5,150) ((Z1,J=1,5),(ZE(J),J=6,K))                           FLM1080
      READ (2) (XE(J),YE(J),ZE(J),J=1,5)                                FLM1090
90    WRITE (4) K,(XE(J),YE(J),ZE(J),J=1,K)                             FLM1100
C     READS LOCATION OF WAKE ELEMENTS FROM INPUT DATA CARDS             FLM1110
      READ (5,160) (NNELM(I),I=1,NSW)                                   FLM1120
      DO 100 I=1,NSW                                                    FLM1130
      K=NNELM(I)                                                        FLM1140
      READ (5,150) ((X1,J=1,2),(XXE(J),J=3,K))                          FLM1150
      READ (5,150) ((Y1,J=1,2),(YYE(J),J=3,K))                          FLM1160
      READ (5,150) ((Z1,J=1,2),(ZZE(J),J=3,K))                          FLM1170
      READ (2) (XXE(J),YYE(J),ZZE(J),J=1,2)                             FLM1180
```

```
100   WRITE (4) K,(XXE(J),YYE(J),ZZE(J),J=1,K)                          FLM1190
      WRITE (4) NMAX,NNMAX,ZMIN,NCONTS                                  FLM1200
      REWIND 4                                                          FLM1210
      WRITE (6,160) (NELM(I),I=1,NSW1)                                  FLM1220
      DO 110 I=1,NSW1                                                   FLM1230
      READ (4) K,(XE(J),YE(J),ZE(J),J=1,K)                              FLM1240
      WRITE (6,140) (XE(J),J=1,K)                                       FLM1250
      WRITE (6,140) (YE(J),J=1,K)                                       FLM1260
110   WRITE (6,140) (ZE(J),J=1,K)                                       FLM1270
      WRITE (6,160) (NNELM(I),I=1,NSW)                                  FLM1280
      DO 120 I=1,NSW                                                    FLM1290
      READ (4) K,(XXE(J),YYE(J),ZZE(J),J=1,K)                           FLM1300
      WRITE (6,140) (XXE(J),J=1,K)                                      FLM1310
      WRITE (6,140) (YYE(J),J=1,K)                                      FLM1320
120   WRITE (6,140) (ZZE(J),J=1,K)                                      FLM1330
130   WRITE (6,170)                                                     FLM1340
C     ******************************************************************FLM1350
      RETURN                                                            FLM1360
C                                                                       FLM1370
140   FORMAT (14F9.4)                                                   FLM1380
150   FORMAT (10F8.4)                                                   FLM1390
160   FORMAT (10I2)                                                     FLM1400
170   FORMAT (18H END OF INPUT DATA,//)                                 FLM1410
      END                                                               FLM1420
```

```
      OVERLAY (LEVSP,2,0)                                               PLT  10
      PROGRAM PLOT                                                      PLT  20
C     SETS UP DIMENSIONS FOR PLOTTING LEADING-EDGE AND WAKE ELEMENTS    PLT  30
      COMMON D(1)                                                       PLT  40
      COMMON /ALLI/ NSW,NSW1                                            PLT  50
C     ******************************************************************PLT  60
      REWIND 4                                                          PLT  70
      NN=NSW1+NSW                                                       PLT  80
      CALL SKIPR (4,NN)                                                 PLT  90
      READ (4) NMAX,NNMAX,ZMIN,NCONTS                                   PLT 100
C     ******************************************************************PLT 110
      MXE=1                                                             PLT 120
      MYE=MXE+NSW1*NMAX                                                 PLT 130
      MZE=MYE+NSW1*NMAX                                                 PLT 140
      MNELM=MZE+NSW1*NMAX                                               PLT 150
      MNEXT=MNELM+NSW1                                                  PLT 160
C     MNEXT=3*NSW*NMAX-3*NMAX+NSW                                       PLT 170
      CALL PLOTT (D(MXE),D(MYE),D(MZE),D(MNELM),NSW1)                   PLT 180
      MXXE=1                                                            PLT 190
      MYYE=MXXE+NSW*(NNMAX+2)                                           PLT 200
      MZZE=MYYE+NSW*(NNMAX+2)                                           PLT 210
      MNNELM=MZZE+NSW*(NNMAX+2)                                         PLT 220
      MNNEXT=MNNELM+NSW                                                 PLT 230
C     MNNEXT=3*NSW*(NNMAX+2)+NSW+1                                      PLT 240
      CALL PLOTT (D(MXXE),D(MYYE),D(MZZE),D(MNNELM),NSW)                PLT 250
      RETURN                                                            PLT 260
      END                                                               PLT 270
```

```
      SUBROUTINE PLOTT (XE,YE,ZE,NNM,NS)
C     MANIPULATES LEADING-EDGE AND WAKE ELEMENTS COORDINATES IN A FORM
C     SUITABLE FOR PLOTTING
      COMMON /ALLI/ NSW,NSW1
      COMMON /XPLOT/ XMN,YMN,ZMN,XMX,YMX,ZMX
      DIMENSION NNM(1), XE(NS,1), YE(NS,1), ZE(NS,1), LABY(14), LABZ(14)
      DATA LABY/6*6H      ,6HX VS Y,6*6H      ,2H  /
      DATA LABZ/6*6H      ,6HX VS Z,6*6H      ,2H  /
C     ******************************************************************
      REWIND 4
      IF (NS.EQ.NSW) GO TO 20
      DO 10 I=1,NSW1
      READ (4) KK,(XE(I,J),YE(I,J),ZE(I,J),J=1,KK)
   10 NNM(I)=KK
      NC=4
      LABY(8)=6H(LEADI
      LABY(9)=6HNG-EDG
      LABY(10)=6HE ELEM
      LABY(11)=6HENTS)
      LABZ(8)=6H(LEADI
      LABZ(9)=6HNG-EDG
      LABZ(10)=6HE ELEM
      LABZ(11)=6HENTS)
      GO TO 50
   20 DO 30 I=1,NSW1
   30 READ (4)
      DO 40 I=1,NSW
      READ (4) KK,(XE(I,J),YE(I,J),ZE(I,J),J=1,KK)
   40 NNM(I)=KK
      LABY(8)=6H(WAKE
      LABY(9)=6HELEMEN
      LABY(10)=6HTS)
      LABY(11)=6H
      LABZ(8)=6H(WAKE
      LABZ(9)=6HELEMEN
      LABZ(10)=6HTS)
      LABZ(11)=6H
C     ******************************************************************
      NC=0
   50 DO 70 L=2,NS
```

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```
      I=L-1                                                             PTT 410
      K=NNM(L)-NC                                                       PTT 420
      DO 60 J=1,K                                                       PTT 430
      KK=J+NC                                                           PTT 440
      XE(I,J)=XE(L,KK)                                                  PTT 450
      YE(I,J)=YE(L,KK)                                                  PTT 460
   60 ZE(I,J)=ZE(L,KK)                                                  PTT 470
      XE(I,K+1)=XMN                                                     PTT 480
      YE(I,K+1)=YMN                                                     PTT 490
      ZE(I,K+1)=ZMN                                                     PTT 500
      XE(I,K+2)=XMX                                                     PTT 510
      YE(I,K+2)=YMX                                                     PTT 520
      ZE(I,K+2)=ZMX                                                     PTT 530
   70 NNM(I)=K+2                                                        PTT 540
      NS1=NS-1                                                          PTT 550
      CALL LNPLOT (XE,YE,NNM,NS1,NS,LABY)                               PTT 560
      CALL LNPLOT (XE,ZE,NNM,NS1,NS,LABZ)                               PTT 570
      RETURN                                                            PTT 580
      END                                                               PTT 590-
```

```
      SUBROUTINE LNPLOT (X,Y,NELM,M,MMAX,LABEL)                         LNP  10
C     GENERATES PLOT ON LINE PRINTER (WRITTEN BY KU COMPUTATION CENTER) LNP  20
      DIMENSION NELM(MMAX), X(MMAX,1), Y(MMAX,1), ALINE(101), YAXIS(101)LNP  30
     1, SYM(20), LABEL(1)                                               LNP  40
      DATA SYM/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H0,1HA,1HB,1HC,1HD,1LNP  50
     1HE,1HF,1HG,1HH,1HI,1HJ/                                           LNP  60
      DATA YAXIS/1HI,9*1H-,1HI,9*1H-,1HI,9*1H-,1HI,9*1H-,1HI,9*1H-,1HI,9LNP  70
     1*1H-,1HI,9*1H-,1HI,9*1H-,1HI,9*1H-,1HI,9*1H-,1HI/                 LNP  80
      DATA BLANK,UP,PLUS/1H ,1HI,1H+/                                   LNP  90
      XMAX=X(1,1)                                                       LNP 100
      XMIN=X(1,1)                                                       LNP 110
      YMAX=Y(1,1)                                                       LNP 120
      YMIN=Y(1,1)                                                       LNP 130
      DO 10 I=1,M                                                       LNP 140
      N=NELM(I)                                                         LNP 150
      DO 10 J=1,N                                                       LNP 160
      IF (X(I,J).GT.XMAX) XMAX=X(I,J)                                   LNP 170
      IF (X(I,J).LT.XMIN) XMIN=X(I,J)                                   LNP 180
      IF (Y(I,J).GT.YMAX) YMAX=Y(I,J)                                   LNP 190
      IF (Y(I,J).LT.YMIN) YMIN=Y(I,J)                                   LNP 200
   10 CONTINUE                                                          LNP 210
      KEY=1                                                             LNP 220
      ZMAX=XMAX                                                         LNP 230
      ZMIN=XMIN                                                         LNP 240
   20 RANGE=ZMAX-ZMIN                                                   LNP 250
      IF (RANGE.EQ.0.0) RANGE=ZMAX/2.                                   LNP 260
      SCALE=1.0E-9                                                      LNP 270
   30 SCALE=10.*SCALE                                                   LNP 280
      IF (SCALE.LT.RANGE) GO TO 30                                      LNP 290
      ZMIN=ZMIN/SCALE                                                   LNP 300
      ZMAX=ZMAX/SCALE                                                   LNP 310
      MIN=20.*(ZMIN-0.025)                                              LNP 320
      MAX=20.0*(ZMAX+0.025)                                             LNP 330
      BOTTOM=0.05*FLOAT(MIN)                                            LNP 340
      TOP=0.05*FLOAT(MAX)                                               LNP 350
      RANGE=0.1*(TOP-BOTTOM)                                            LNP 360
      IF (RANGE.EQ.0.0) RANGE=0.1*(TOP/2.)                              LNP 370
   40 IF (BOTTOM.LE.ZMIN) GO TO 50                                      LNP 380
      BOTTOM=BOTTOM-RANGE                                               LNP 390
      GO TO 40                                                          LNP 400
```

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```
50    IF (TOP.GE.ZMAX) GO TO 60                                               LNP 410
      TOP=TOP+RANGE                                                           LNP 420
      GO TO 50                                                                LNP 430
60    CONTINUE                                                                LNP 440
      IF (KEY.EQ.2) GO TO 70                                                  LNP 450
      KEY=2                                                                   LNP 460
      ZMAX=YMAX                                                               LNP 470
      ZMIN=YMIN                                                               LNP 480
      YINC=0.01*(TOP-BOTTOM)                                                  LNP 490
      XINC=YINC*SCALE                                                         LNP 500
      XBOT=BOTTOM*SCALE                                                       LNP 510
      GO TO 20                                                                LNP 520
70    CONTINUE                                                                LNP 530
      YINC=0.0125*(TOP-BOTTOM)                                                LNP 540
      YLOW=TOP+YINC                                                           LNP 550
      YINC=2.*YINC                                                            LNP 560
      WRITE (6,160)                                                           LNP 570
      KEY=5                                                                   LNP 580
80    CONTINUE                                                                LNP 590
      DO 90 IJ=2,101                                                          LNP 600
90    ALINE(IJ)=BLANK                                                         LNP 610
      YHIGH=YLOW                                                              LNP 620
      YLOW=YHIGH-YINC                                                         LNP 630
      YHS=SCALE*YHIGH                                                         LNP 640
      YLS=SCALE*YLOW                                                          LNP 650
      DO 110 I=1,M                                                            LNP 660
      N=NELM(I)-2                                                             LNP 670
      DO 110 J=1,N                                                            LNP 680
      IF (Y(I,J).GT.YHS.OR.Y(I,J).LE.YLS) GO TO 110                           LNP 690
      INDEX=(X(I,J)-XBOT)/XINC                                                LNP 700
      INDEX=INDEX+1                                                           LNP 710
      IF (INDEX.GT.101) INDEX=101                                             LNP 720
      IF (ALINE(INDEX).NE.BLANK) GO TO 100                                    LNP 730
      ALINE(INDEX)=SYM(I)                                                     LNP 740
      GO TO 110                                                               LNP 750
100   ALINE(INDEX)=PLUS                                                       LNP 760
110   CONTINUE                                                                LNP 770
      ALINE(1)=UP                                                             LNP 780
      IF (KEY.NE.5) GO TO 120                                                 LNP 790
```

1-2

```
      TPP=TOP*SCALE                                                     LNP 800
      WRITE (6,170) TPP,ALINE                                           LNP 810
      GO TO 130                                                         LNP 820
  120 WRITE (6,180) ALINE                                               LNP 830
  130 CONTINUE                                                          LNP 840
      KEY=KEY-1                                                         LNP 850
      IF (KEY.EQ.0) KEY=5                                               LNP 860
      TOP=TOP-YINC                                                      LNP 870
      IF (TOP.GE.BOTTOM) GO TO 80                                       LNP 880
      IF (KEY.NE.4) GO TO 80                                            LNP 890
      WRITE (6,210) YAXIS                                               LNP 900
      XINC=10.0*XINC                                                    LNP 910
      ALINE(1)=XBOT                                                     LNP 920
      DO 140 I=2,11                                                     LNP 930
  140 ALINE(I)=ALINE(I-1)+XINC                                          LNP 940
      WRITE (6,190) (ALINE(I),I=1,11)                                   LNP 950
C                                                                       LNP 960
      WRITE (6,200) (LABEL(I),I=1,14)                                   LNP 970
  150 RETURN                                                            LNP 980
C                                                                       LNP 990
  160 FORMAT (1H1,/)                                                    LNP1000
  170 FORMAT (F10.3,1X,101A1)                                           LNP1010
  180 FORMAT (11X,101A1)                                                LNP1020
  190 FORMAT (5X,11F10.3)                                               LNP1030
  200 FORMAT (//,20X,13A6,A2)                                           LNP1040
  210 FORMAT (11X,101A1)                                                LNP1050
      END                                                               LNP1060-
```

```
      OVERLAY (LEVSP,3,0)                                               SLN  10
      PROGRAM SOLN                                                      SLN  20
C     SETS UP DIMENSIONS FOR SOLVING THE STRENGTHS OF WING AND LEADING- SLN  30
C     EDGE VORTEX SYSTEM                                                SLN  40
      COMMON D(1)                                                       SLN  50
      COMMON /ALLI/ NSW,NSW1,NCW,NWNG,NCPTTL                            SLN  60
      LC=1                                                              SLN  70
      LTHETP=LC+NSW1                                                    SLN  80
      LXTE=LTHETP+NSW1                                                  SLN  90
      LXLE=LXTE+NSW                                                     SLN 100
      LYLE=LXLE+NSW                                                     SLN 110
      LCONS=LYLE+NSW                                                    SLN 120
      LCTT=LCONS+NSW1                                                   SLN 130
      LCPWL=LCTT+NSW1                                                   SLN 140
      LCPSW=LCPWL+NCW                                                   SLN 150
      LSI=LCPSW+NSW1                                                    SLN 160
      LSN=LSI+NCW                                                       SLN 170
      LXCP=LSN+NCW                                                      SLN 180
      LYCP=LXCP+NCPTTL                                                  SLN 190
      LXN=LYCP+NCPTTL                                                   SLN 200
      LYN=LXN+2*NWNG                                                    SLN 210
      LCONI=LYN+2*NWNG                                                  SLN 220
      LCONJ=LCONI+NWNG                                                  SLN 230
      LCONK=LCONJ+NWNG                                                  SLN 240
      LCI=LCONK+NWNG                                                    SLN 250
      LCJ=LCI+NWNG                                                      SLN 260
      LCK=LCJ+NWNG                                                      SLN 270
      LDUMY=LCK+NWNG                                                    SLN 280
      LNEXT=LDUMY+8*NWNG                                                SLN 290
C     LNEXT=20*NWNG+10*NSW+3*NCW-6                                      SLN 300
      MNEXT=LCJ+(NCPTTL+1)**2/4                                         SLN 310
C     MNEXT=(NCPTTL+1)**2/4+10*NWNG+10*NSW+3*NCW-6                      SLN 320
      CALL AERODN (NWNG,D(LC),D(LTHETP),D(LXTE),D(LXLE),D(LYLE),D(LCONS)SLN 330
     1,D(LSI),D(LSN),D(LXCP),D(LYCP),D(LXN),D(LYN),D(LCONI),D(LCONJ),D(LSLN 340
     2CONK),D(LCI),D(LCJ),D(LCK),D(LDUMY),D(LCTT),D(LCPWL),D(LCPSW))    SLN 350
      RETURN                                                            SLN 360
      END                                                               SLN 370-
```

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```
      SUBROUTINE AERODN (NWNG,C,THETP,XTE,XLE,YLE,CONS,SI,SN,XCP,YCP,XN,AER  10
     1YN,CONI,CONJ,CONK,CI,CJ,CK,DUMMY,CT,CPCWL,CPSW1)                  AER  20
C     SOLVES FOR THE STRENGTHS OF WING AND LEADING-EDGE VORTEX SYSTEM   AER  30
      COMMON /ALLI/ NSW,NSW1,NCW,IWNG,NCPTTL                            AER  40
      COMMON /ALLRA/ AA(17),SINA,AB(6),BSQD4P                           AER  50
      COMMON /GM/ ITER,L1,L2,L3,L4,L5,L6,L7,L8                          AER  60
      COMMON /NCTT/ NCT,NCON                                            AER  70
      DIMENSION C(1), THETP(1), XTE(1), XLE(1), YLE(1), CONS(1), SI(1), AER  80
     1SN(1), XCP(1), YCP(1), DUMMY(1), CONI(1), CONJ(1), CONK(1), CI(1),AER  90
     2 CJ(1), CK(1), CT(1), CPCWL(1), CPSW1(1), XN(NWNG,2), YN(NWNG,2)  AER 100
C     ******************************************************************AER 110
      REWIND 1                                                          AER 120
      REWIND 2                                                          AER 130
      REWIND 3                                                          AER 140
      CALL SKIPR (1,5)                                                  AER 150
      READ (1) (C(I),I=1,NSW1)                                          AER 160
      READ (1) (THETP(I),I=1,NSW1)                                      AER 170
      READ (1) (XTE(I),XLE(I),YLE(I),I=1,NSW)                           AER 180
      CALL SKIPR (1,1)                                                  AER 190
      READ (1) (CONS(I),I=1,NSW1)                                       AER 200
      READ (1) (SI(I),SN(I),I=1,NCW)                                    AER 210
      READ (1) (XCP(I),YCP(I),I=1,NCPTTL)                               AER 220
      READ (1) ((XN(I,J),YN(I,J),J=1,2),I=1,NWNG)                       AER 230
      READ (1) (CT(I),I=1,NSW1)                                         AER 240
      READ (1) (CPCWL(I),I=1,NCW)                                       AER 250
      CALL SKIPR (1,2)                                                  AER 260
      READ (1) (CPSW1(I),I=1,NSW1)                                      AER 270
C     ******************************************************************AER 280
C     INFLUENCE COEFFICIENT MATRIX EVALUATION                           AER 290
      L1=1                                                              AER 300
      L2=L1+NWNG                                                        AER 310
      L3=L2+NWNG                                                        AER 320
      L4=L3+NWNG                                                        AER 330
      L5=L4+NWNG                                                        AER 340
      L6=L5+NWNG                                                        AER 350
      L7=L6+NWNG                                                        AER 360
      L8=L7+NWNG                                                        AER 370
      NCON=0                                                            AER 380
      NCT=0                                                             AER 390
      DO 10 I=1,NCPTTL                                                  AER 400
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```
      ZCP=0.                                                            AER 410
      CALL VDTWNG (C,THETP,XCP(I),YCP(I),ZCP,XN,YN,XTE,YLE,CONS,DUMMY(L1AER 420
     1),DUMMY(L2),DUMMY(L3),DUMMY(L4),DUMMY(L5),DUMMY(L6),DUMMY(L7),DUMMAER 430
     2Y(L8),CONI,CONJ,CONK,SI,NSW1,NCW,NWNG)                            AER 440
      WRITE (2) (CONK(J),J=1,NWNG)                                      AER 450
      CALL VDTFRE (XCP(I),YCP(I),ZCP,CI,CJ,CK,NSW1,BSQD4P,XLE,YLE)      AER 460
      WRITE (3) (CK(J),J=1,NSW1)                                        AER 470
   10 CONTINUE                                                          AER 480
C     GAMA-EVALUATION                                                   AER 490
      REWIND 2                                                          AER 500
      REWIND 3                                                          AER 510
      READ (2) (CONI(I),I=1,NWNG)                                       AER 520
      NWNG1=NWNG+1                                                      AER 530
      NWNB=NWNG+NSW1                                                    AER 540
      NWNB1=NWNB+1                                                      AER 550
      READ (3) (CONI(I),I=NWNG1,NWNB)                                   AER 560
      CONI(NWNB1)=SINA                                                  AER 570
      IJ=1                                                              AER 580
      DO 20 I=1,NWNB                                                    AER 590
   20 CJ(I)=-CONI(I+1)/CONI(1)                                          AER 600
      IJ=2                                                              AER 610
      NJ=NWNB-1                                                         AER 620
   30 CONTINUE                                                          AER 630
      READ (2) (CONI(I),I=1,NWNG)                                       AER 640
      READ (3) (CONI(I),I=NWNG1,NWNB)                                   AER 650
      CONI(NWNB1)=SINA                                                  AER 660
      IF (IJ.GT.NWNG) CONI(NWNB1)=SINA-CI(IJ-NWNG)                      AER 670
      CALL VMSEQN (NJ,IJ,CONI,CJ,CONK)                                  AER 680
      IJ=IJ+1                                                           AER 690
      NJ=NJ-1                                                           AER 700
      IF (IJ.LE.NWNB) GO TO 30                                          AER 710
      WRITE (6,80)                                                      AER 720
      DO 40 I=1,NSW1                                                    AER 730
      DO 40 J=1,NCW                                                     AER 740
      NP=(I-1)*NCW+J                                                    AER 750
   40 WRITE (6,90) CPCWL(J),CPSWL(I),CJ(NP)                             AER 760
      WRITE (6,100)                                                     AER 770
      DO 50 I=1,NSW1                                                    AER 780
      J=NWNG+I                                                          AER 790
```

```
50    WRITE (6,90) CPSW1(I),CJ(J)                                       AER 800
C     EVALUATION OF SECTIONAL LEADING-EDGE THRUST                       AER 810
      CALL THRST (CJ,CONI,CONJ)                                         AER 820
      NERR=0                                                            AER 830
      DO 60 I=1,NSW1                                                    AER 840
60    IF (ABS(CONJ(I)-CT(I)).GE.(1.0E-10)) NERR=1                       AER 850
      IF (NERR.EQ.1) WRITE (6,110)                                      AER 860
      GMSUM=0.                                                          AER 870
      DO 70 I=2,NSW1                                                    AER 880
      KS=NWNG+I                                                         AER 890
70    GMSUM=GMSUM+CJ(KS)                                                AER 900
C     ..................................................................AER 910
      REWIND 2                                                          AER 920
      WRITE (2) (CJ(I),I=1,NWNB)                                        AER 930
      WRITE (7) GMSUM                                                   AER 940
C     ..................................................................AER 950
      RETURN                                                            AER 960
C                                                                       AER 970
80    FORMAT (1H1,//,22H WING VORTEX STRENGTHS,/,22H *******************AER 980
     1**,//,29H       X/C       2Y/3      GAMAY,/,29H       ***       ****  AER 990
     2  *****)                                                          AER1000
90    FORMAT (3F10.5)                                                   AER1010
100   FORMAT (//,32H LEADING-EDGE VORTICES STRENGTHS,/,31H *************AER1020
     1*****************,//,20H     2Y/3     CAPGAMA,/,20H      ****     ***AER1030
     2****)                                                             AER1040
110   FORMAT (//,34H ERROR IN SECTIONAL CT CALCULATION,/,10F10.5)       AER1050
      END                                                               AER1060-
```

```
      SUBROUTINE VMSEQN (NC1,K,AA,A,CA)                                 VMS  10
C     SOLVES A SYSTEM OF SIMULTANEOUS EQUATIONS                         VMS  20
      DIMENSION AA(1), CA(1), A(1)                                      VMS  30
      NC=K*NC1                                                          VMS  40
      SUM1=0.                                                           VMS  50
      K1=K-1                                                            VMS  60
      JJ=1                                                              VMS  70
      DO 10 J=1,K1                                                      VMS  80
      SUM1=SUM1+AA(J)*A(JJ)                                             VMS  90
   10 JJ=JJ+NC1+1                                                       VMS 100
      SUM1=SUM1+AA(K)                                                   VMS 110
      DO 30 I=1,NC1                                                     VMS 120
      SUM2=0.                                                           VMS 130
      JJ=I+1                                                            VMS 140
      DO 20 J=1,K1                                                      VMS 150
      SUM2=SUM2+AA(J)*A(JJ)                                             VMS 160
   20 JJ=JJ+NC1+1                                                       VMS 170
      KK=K+I                                                            VMS 180
      SUM2=SUM2+AA(KK)                                                  VMS 190
   30 CA(I)=-SUM2/SUM1                                                  VMS 200
      M=1                                                               VMS 210
      L=0                                                               VMS 220
      KNC=(K-1)*NC1                                                     VMS 230
      DO 60 I=1,NC                                                      VMS 240
      IF (I.GT.KNC) GO TO 50                                            VMS 250
      MM=(M-1)*NC1+1                                                    VMS 260
      IF (I.EQ.MM) GO TO 70                                             VMS 270
   40 KK=KK+1                                                           VMS 280
      IL=I+L                                                            VMS 290
      A(I)=CA(KK)*BASE+A(IL)                                            VMS 300
      GO TO 60                                                          VMS 310
   50 II=I-KNC                                                          VMS 320
      A(I)=CA(II)                                                       VMS 330
   60 CONTINUE                                                          VMS 340
      GO TO 80                                                          VMS 350
   70 II=MM+M-1                                                         VMS 360
      BASE=A(II)                                                        VMS 370
      KK=0                                                              VMS 380
      L=L+1                                                             VMS 390
      M=M+1                                                             VMS 400
```

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      GO TO 40                                                          VMS 410
   80 CONTINUE                                                          VMS 420
      RETURN                                                            VMS 430
      END                                                               VMS 440-
```

```
      SUBROUTINE THRST (SGM,CONK,CT)
C     EVALUATES SECTIONAL LEADING-EDGE THRUST COEFFICIENTS
      COMMON /ALLI/ NSW,NSW1,NCW,NWNG
      COMMON /ALLRA/ AA(17),SINA,COSA,SWPLE,A3,BETA2,AC(5),PI
      DIMENSION SGM(1), CONK(1), CT(1)
      AM2=1.-BETA2
      FCOS=COS(SWPLE)
      FTAN=TAN(SWPLE)
      VAR1=FLOAT(NCW)*SORT(FTAN*FTAN+BETA2)
      VAR2=SORT(1.-AM2*FCOS*FCOS)
      REWIND 2
      REWIND 3
      CALL SKIPR (2,NWNG)
      CALL SKIPR (3,NWNG)
      DO 30 I=1,NSW1
      WL=0.
      READ (2) (CONK(J),J=1,NWNG)
      DO 10 J=1,NWNG
10    WL=WL+CONK(J)*SGM(J)
      READ (3) (CONK(J),J=1,NSW1)
      DO 20 J=1,NSW1
      JJ=NWNG+J
20    WL=WL+CONK(J)*SGM(JJ)
      THRT1=(WL+SINA)/VAR1
30    CT(I)=(PI/2.)*VAR2*THRT1*THRT1/FCOS
      RETURN
      END
```

```
      OVERLAY (LEVSP,4,0)                                               LOD  10
      PROGRAM LOADS                                                     LOD  20
C     SETS UP DIMENSIONS FOR EVALUATING AERODYNAMIC CHARACTERSTICS      LOD  30
      COMMON D(1)                                                       LOD  40
      COMMON /ALLI/ NSW,NSW1,NCW,NWNG                                   LOD  50
      DIMENSION W(4100)                                                 LOD  60
      NNCW=NCW+1                                                        LOD  70
      NWNP=NNCW*NSW1                                                    LOD  80
      LCI=1                                                             LOD  90
      LCJ=LCI+NWNG                                                      LOD 100
      LCK=LCJ+NWNG                                                      LOD 110
      LCONI=LCK+NWNG                                                    LOD 120
      LCONJ=LCONI+NWNG                                                  LOD 130
      LCONK=LCONJ+NWNG                                                  LOD 140
      LXVWNG=LCONK+NWNG                                                 LOD 150
      LYVWNG=LXVWNG+NWNG                                                LOD 160
      LXLE=LYVWNG+NWNG                                                  LOD 170
      LXTE=LXLE+NSW                                                     LOD 180
      LYLE=LXTE+NSW                                                     LOD 190
      LSI=LYLE+NSW                                                      LOD 200
      LC=LSI+NCW                                                        LOD 210
      LSWP=LC+NSW1                                                      LOD 220
      LXN=LSWP+NCW                                                      LOD 230
      LYN=LXN+2*NWNG                                                    LOD 240
      LSNN=LYN+2*NWNG                                                   LOD 250
      LTHETP=LSNN+NCW                                                   LOD 260
      LCONS=LTHETP+NSW1                                                 LOD 270
      LDUMMY=LCONS+NSW1                                                 LOD 280
      LCT=LDUMMY+8*NWNG                                                 LOD 290
      LOI=LCT+NSW1                                                      LOD 300
      LONN=LOI+NNCW                                                     LOD 310
      LOSWP=LONN+NNCW                                                   LOD 320
      LXVWNA=LOSWP+NNCW                                                 LOD 330
      LYVWNA=LXVWNA+NSW1                                                LOD 340
      LGAMA=LYVWNA+NSW1                                                 LOD 350
      LGML=LGAMA+NWNG+NSW1                                              LOD 360
      LXLM=LGML+NSW1                                                    LOD 370
      LTHT=LXLM+NSW1                                                    LOD 380
      LSCL=LTHT+NNCW                                                    LOD 390
      LSCM=LSCL+NSW1                                                    LOD 400
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```
      LSCD=LSCM+NSW1                                                    LOD 410
      LCOSP=LSCD+NSW1                                                   LOD 420
      LCNC =LCOSP+NNCW                                                  LOD 430
      LCSWL=LCNC+NSW1                                                   LOD 440
      LCSW1=LCSWL+NSW                                                   LOD 450
      LDCPA=LCSW1+NSW1                                                  LOD 460
      LDCP=LDCPA+NSW                                                    LOD 470
      LGMNW=LDCP+NWNP                                                   LOD 480
      LGMY =LGMNW+NWNP                                                  LOD 490
      LVY=LGMY+NWNG+NSW1                                                LOD 500
      LCOEF=LVY+NWNG                                                    LOD 510
      LDCPN=LCOEF+NSW1*(NNCW+1)                                         LOD 520
      LWX=LDCPN+NSW1                                                    LOD 530
      LWY=LWX+NWNG+NCW                                                  LOD 540
      LNEXT=LWY+NWNG+NCW                                                LOD 550
C     LNEXT=28*NWNG+25*NSW+10*NCW-14                                    LOD 560
      CALL COEFS (D(LCI),D(LCJ),D(LCK),D(LCONI),D(LCONJ),D(LCONK),D(LXVWLOD 570
     1NG),D(LYVWNG),D(LXLE),D(LXTE),D(LYLE),D(LSI),D(LC),D(LSWP),D(LXN),LOD 580
     2D(LYN),D(LSNN),D(LTHETP),D(LCONS),D(LDUMMY),D(LCT),D(LQI),D(LONN),LOD 590
     3D(LQSWP),D(LXVWNA),D(LYVWNA),NWNG,D(LGAMA),D(LGML),D(LXLM),D(LTHT)LOD 600
     4,D(LSCL),D(LSCM),D(LSCD),D(LCOSP),D(LCNC),D(LCSWL),D(LCSW1),D(LDCPLOD 610
     5A),D(LDCP),D(LGMNW),D(LGMY),D(LVY),D(LCOEF),D(LDCPN),D(LWX),D(LWY)LOD 620
     6,W,NSW1)                                                          LOD 630
      RETURN                                                            LOD 640
      END                                                               LOD 650-
```

```
      SUBROUTINE COEFS (CI,CJ,CK,CONI,CONJ,CONK,XAVWNG,YAVWNG,XLE,XTE,YLCOF  10
     1E,SI,C,SWP,XN,YN,SNN,THETP,CONS,DUMMY,CT,OI,ONN,OSWP,XAVWNA,YAVWNACOF  20
     2,NWNG,GAMA,GML,XLM,THT,SECCL,SECCM,SECCD,COSP,CNC,CPSWL,CPSW1,DCPACOF  30
     3,DCP,GMNW,GMY,VY,COEF,DCPN,WX,WY,W,NSW1)                         COF  40
C     COMPUTES THE AERODYNAMIC CHARACTERSTICS                           COF  50
      COMMON /ALLI/ NSW,NSW3,NCW                                        COF  60
      COMMON /ALLRA/ AA(17),SINA,COSA,AB(8),PI,AC,CBAR,HALF3,ARFA       COF  70
      COMMON /NCTT/ NCT,NCON                                            COF  80
      COMMON /XSTN/ XBRR(25).NBRR                                       COF  90
      DIMENSION CI(1). CJ(1); CK(1), CONI(1), CONJ(1), CONK(1), XAVWNG(1COF 100
     1), YAVWNG(1), XLF(1), XTE(1), YLE(1), SI(1), C(1), SWP(1), SNN(1),COF 110
     2 CT(1), XN(NWNG,2), YN(NWNG,2), DUMMY(1), GAMA(1), GML(1), XLM(1),COF 120
     3 THT(1), SECCL(1), SECCM(1), SECCD(1), COSP(1), CNC(1), CPSWL(1), COF 130
     4CPSW1(1). DCPA(1), DCP(1), GMNW(1), GMY(1), VY(1), DCPN(1), WX(1),COF 140
     5 WY(1), W(1), COEF(NSW1,1), CONS(1), THETP(1), OI(1), ONN(1). OSWPCOF 150
     6(1), XAVWNA(1), YAVWNA(1)                                         COF 160
C     ******************************************************************COF 170
      REWIND 1                                                          COF 180
      READ (1) NNCW,NWNP                                                COF 190
      READ (1) (OI(I),ONN(I),OSWP(I),I=1,NNCW)                          COF 200
      READ (1) (XAVWNA(I),YAVWNA(I),I=1,NSW1)                           COF 210
      READ (1) (SNN(I),SWP(I),I=1,NCW)                                  COF 220
      READ (1) (XAVWNG(I),YAVWNG(I),I=1,NWNG)                           COF 230
      READ (1) (C(I),I=1,NSW1)                                          COF 240
      READ (1) (THETP(I),I=1,NSW1)                                      COF 250
      READ (1) (XTE(I),XLE(I),YLE(I),I=1,NSW)                           COF 260
      READ (1) (XLM(I),YLM,I=1,NSW1)                                    COF 270
      READ (1) (CONS(I),I=1,NSW1)                                       COF 280
      READ (1) (SI(I),ADUM,I=1,NCW)                                     COF 290
      CALL SKIPR (1,1)                                                  COF 300
      READ (1) ((XN(I,J),YN(I,J)),J=1,2),I=1,NWNG)                      COF 310
      READ (1) (CT(I),I=1,NSW1)                                         COF 320
      CALL SKIPR (1,2)                                                  COF 330
      READ (1) (CPSWL(I),I=1,NSW)                                       COF 340
      READ (1) (CPSW1(I),I=1,NSW1)                                      COF 350
      NWNG=NWNG+NCW1                                                    COF 360
      REWIND 2                                                          COF 370
      READ (2) (CA AII [illegible])                                     COF 380
C     ******************************************************************COF 390
      PIJ=PI/(2.*FLOAT(NCW))                                            COF 400
```

```
      DO 10 J=1,NCW                                                     COF 410
10    COSP(J)=COS((2.*FLOAT(J)-1.)*PIJ)                                 COF 420
      CONST=HALFB*PI/(AREA*FLOAT(NSW))                                  COF 430
C     CALCULATION OF GMY-VALUES FOR WING SURFACE                        COF 440
      NCON=0                                                            COF 450
      NCT=0                                                             COF 460
      DO 20 II=1,NSW1                                                   COF 470
      DO 20 J=1,NCW                                                     COF 480
      I=(II-1)*NCW+J                                                    COF 490
      XEE=XAVWNG(I)                                                     COF 500
      YEE=YAVWNG(I)                                                     COF 510
      ZEE=0.                                                            COF 520
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CONCOF 530
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,ADUM,BDUM,CDUM,GAMA,COF 540
     2YLM)                                                              COF 550
      TNSP=TAN(SWP(J))                                                  COF 560
      GMY(I)=GAMA(I)*(UU-VV*TNSP)                                       COF 570
20    CONTINUE                                                          COF 580
C     READING LARGER GRID FOR THE WING                                  COF 590
C     CALCULATION OF INDUCED VELOCITIES AT BOUND ELEMENT END-POINTS ON  COF 600
C     WING SURFACE                                                      COF 610
      DO 40 I=1,NSW1                                                    COF 620
      DO 30 J=1,NCW                                                     COF 630
      NP=(I-1)*NCW+J                                                    COF 640
      XEE=XN(NP,2)                                                      COF 650
      YEE=YN(NP,2)                                                      COF 660
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CONCOF 670
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,ADUM,BDUM,CDUM,GAMA,COF 680
     2YLM)                                                              COF 690
      VY(NP)=VV                                                         COF 700
30    CONTINUE                                                          COF 710
40    CONTINUE                                                          COF 720
C     CALCULATION OF GMY-VALUES FOR BOUND ELEMENTS NEAR LEADING-EDGE    COF 730
      DO 50 J=1,NNCW                                                    COF 740
      FJ=J                                                              COF 750
50    THT(J)=(2.*FJ-1.)*PI/(2.*FLOAT(NNCW))                             COF 760
      SURA=3.*FLOAT(NNCW)/(4.*PI*SIN(THT(1)))                           COF 770
      DO 60 I=1,NSW1                                                    COF 780
      NGI=NWNG+I                                                        COF 790
```

```
60    GML(I)=GAMA(NGI)*SURA/C(I)                                        COF 800
C     ..................................................................COF 810
      REWIND 3                                                          COF 820
      WRITE (3) (GML(I),I=1,NSW1)                                       COF 830
C     ..................................................................COF 840
      TNSP=TAN(OSWP(1))                                                 COF 850
      DO 70 II=1,NSW1                                                   COF 860
      XEE=XAVWNA(II)                                                    COF 870
      YEE=YAVWNA(II)                                                    COF 880
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CONCOF 890
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,ADUM,BDUM,CDUM,GAMA,COF 900
     2YLM)                                                              COF 910
      NWNGII=NWNG+II                                                    COF 920
      GMY(NWNGII)=GML(II)*(UU-VV*TNSP)                                  COF 930
70    CONTINUE                                                          COF 940
C     CALCULATION OF DCP-VALUES FOR WING POINTS                         COF 950
      PN=PI/(FLOAT(NCW))                                                COF 960
      DO 80 I=1,NCW                                                     COF 970
      W(I)=0.                                                           COF 980
      WX(I)=XN(I,1)                                                     COF 990
80    WY(I)=YN(I,1)                                                     COF1000
      DO 150 I=1,NSW1                                                   COF1010
      DO 140 J=1,NCW                                                    COF1020
      NP=(I-1)*NCW+J                                                    COF1030
      VYY=VY(NP)                                                        COF1040
      CPG=0.                                                            COF1050
      CPH=0.                                                            COF1060
      CPI=0.                                                            COF1070
      DO 100 JJ=1,J                                                     COF1080
      NPIN=(I-1)*NCW+JJ                                                 COF1090
      IF (J.EQ.JJ) GO TO 90                                             COF1100
      CPG=CPG+GAMA(NPIN)*SI(JJ)                                         COF1110
      GO TO 100                                                         COF1120
90    CPG=CPG+0.5*GAMA(NPIN)*SI(JJ)                                     COF1130
100   CONTINUE                                                          COF1140
      CPG=-CPG+PN*C(I)*VYY                                              COF1150
      IF (I.EQ.NSW1) GO TO 130                                          COF1160
      DO 120 JJ=1,J                                                     COF1170
      NPOT=I*NCW+JJ                                                     COF1180
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```
      IF (J.EQ.JJ) GO TO 110                                            COF1190
      CPH=CPH+GAMA(NPOT)*SI(JJ)                                         COF1200
      GO TO 120                                                         COF1210
  110 CPH=CPH+0.5*GAMA(NPOT)*SI(JJ)                                     COF1220
  120 CONTINUE                                                          COF1230
      CPH=CPH*PN*C(I+1)*VYY                                             COF1240
  130 CPI=2.*GAMA(NWNG+I)*VYY                                           COF1250
      W(NP+NCW)=CPG+CPH+CPI                                             COF1260
      WX(NP+NCW)=XN(NP,2)                                               COF1270
      WY(NP+NCW)=YN(NP,2)                                               COF1280
  140 CONTINUE                                                          COF1290
  150 CONTINUE                                                          COF1300
      N3=NWNG+NCW+3                                                     COF1310
      CALL SURFSET (N3,WX,WY,W,CI)                                      COF1320
      DO 170 K=1,NCW                                                    COF1330
      DO 160 J=1,NSW1                                                   COF1340
      NP=(J-1)*NCW+K                                                    COF1350
      DCP1=2.*GMY(NP)                                                   COF1360
      XEE=XAVWNG(NP)                                                    COF1370
      YEE=YAVWNG(NP)                                                    COF1380
      CALL SURFORD (W,XEE,YEE,VV,N3)                                    COF1390
      DCPD=VV/(YLE(J+1)-YLE(J))                                         COF1400
      DCP(NP)=DCP1+DCPD                                                 COF1410
  160 CONTINUE                                                          COF1420
  170 CONTINUE                                                          COF1430
C     CALCULATION OF INDUCED VELOCITIES AT END-POINTS OF BOUND ELEMENTS COF1440
C     NEAR LEADING-EDGE                                                 COF1450
      CPC=0.5*(1.-COS(THT(1)))                                          COF1460
      DO 180 I=2,NSW                                                    COF1470
      XEE=XLE(I)+CPC*(XTE(I)-XLE(I))                                    COF1480
      YEE=YLE(I)                                                        COF1490
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CONCOF1500
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,ADUM,BDUM,CDUM,GAMA,COF1510
     2YLM)                                                              COF1520
  180 VY(I)=VV                                                          COF1530
C     DCP-INTERPOLATION FOR BOUND ELEMENTS OF WING                      COF1540
      CALL INTGMY (NCW,NSW1,DCP,SNN,COEF,DUMMY(1),DUMMY(NNCW))          COF1550
C     CALCULATION OF DECREASE IN DCP-VALUES AT THE LEADING-EDGE         COF1560
      DCPA(1)=0.                                                        COF1570
```

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      DCPA(NSW)=0.                                                      COF1580
      DO 190 I=2,NSW1                                                   COF1590
      DCPA(I)=2.*GAMA(NWNG+I)*VY(I)                                     COF1600
190   CONTINUE                                                          COF1610
      DO 200 I=1,NSW1                                                   COF1620
      CNC(I)=-2.*GMY(NWNG+I)                                            COF1630
200   CONTINUE                                                          COF1640
C     FINAL DCP-VALUES AT LARGER WING GRID                              COF1650
      DO 230 I=1,NSW1                                                   COF1660
      DO 220 J=1,NNCW                                                   COF1670
      NP=(I-1)*NNCW+J                                                   COF1680
      GMNW(NP)=COEF(I,1)                                                COF1690
      DO 210 K=1,NCW                                                    COF1700
      FK=K                                                              COF1710
      AMI1=COS(FK*THT(J))                                               COF1720
      AMI2=AMI1*COEF(I,K+1)                                             COF1730
      GMNW(NP)=GMNW(NP)+AMI2                                            COF1740
210   CONTINUE                                                          COF1750
      GMNW(NP)=GMNW(NP)/(SIN(THT(J)))                                   COF1760
      IF (J.NE.1) GO TO 220                                             COF1770
      NGI=NWNG+I                                                        COF1780
      GMNW(NP)=GMNW(NP)+CNC(I)                                          COF1790
220   CONTINUE                                                          COF1800
230   CONTINUE                                                          COF1810
      DO 240 I=1,NWNP                                                   COF1820
240   DCP(I)=GMNW(I)                                                    COF1830
      PIJ=PI/(2.*FLOAT(NNCW))                                           COF1840
      WRITE (6,370)                                                     COF1850
      DO 250 I=1,NSW1                                                   COF1860
      DO 250 J=1,NNCW                                                   COF1870
      NP=(I-1)*NNCW+J                                                   COF1880
      CPCW=0.5*(1.-COS((2.*FLOAT(J)-1.)*PIJ))                           COF1890
250   WRITE (6,380) CPCW,CPSW1(I),DCP(NP)                               COF1900
      DO 260 J=1,NNCW                                                   COF1910
260   COSP(J)=COS((2.*FLOAT(J)-1.)*PIJ)                                 COF1920
C     EVALUATION OF SECTIONAL AND TOTAL AERODYNAMIC CHARACTERSTICS      COF1930
      CL=0.                                                             COF1940
      CM=0.                                                             COF1950
      CD=0.                                                             COF1960
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      CTT=0.                                                            COF1970
      DO 280 I=1,NSW1                                                   COF1980
      SECCL(I)=0.                                                       COF1990
      SECCM(I)=0.                                                       COF2000
      PHII=PI*FLOAT(I)/FLOAT(NSW)                                       COF2010
      DO 270 J=1,NNCW                                                   COF2020
      NP=(I-1)*NNCW+J                                                   COF2030
      SECCL(I)=SECCL(I)+DCP(NP)*QI(J)                                   COF2040
      SECCM(I)=SECCM(I)-DCP(NP)*QI(J)*(XLM(I)+0.5*C(I)*(1.-COSP(J)))/CBACOF2050
     1R                                                                 COF2060
 270  CONTINUE                                                          COF2070
      SECCL(I)=SECCL(I)*PI/(2.*FLOAT(NNCW))                             COF2080
      SECCM(I)=SECCM(I)*PI/(2.*FLOAT(NNCW))                             COF2090
      SECCD(I)=SECCL(I)*SINA-CT(I)*COSA                                 COF2100
      SECCL(I)=SECCL(I)*COSA+CT(I)*SINA                                 COF2110
      CL=CL+SECCL(I)*C(I)*SIN(PHII)                                     COF2120
      CM=CM+SECCM(I)*C(I)*SIN(PHII)                                     COF2130
      CD=CD+SECCD(I)*C(I)*SIN(PHII)                                     COF2140
 280  CTT=CTT+CT(I)*C(I)*SIN(PHII)                                      COF2150
      CL=CONST*CL                                                       COF2160
      CM=CONST*CM                                                       COF2170
      CD=CONST*CD                                                       COF2180
      CTT=CONST*CTT                                                     COF2190
C     ..................................................................COF2200
      WRITE (7) CL,CM,CD,CTT                                            COF2210
C     ..................................................................COF2220
      WRITE (6,340) (I,SECCL(I),SECCM(I),SECCD(I),CT(I),I=1,NSW1)       COF2230
      WRITE (6,350) CL,CM,CD,CTT                                        COF2240
      NNCW1=NNCW+1                                                      COF2250
      CALL INTGMY (NNCW,NSW1,DCP,QNN,COEF,DUMMY(1),DUMMY(NNCW1))        COF2260
      REWIND 1                                                          COF2270
      CALL SKIPR (1,8)                                                  COF2280
      READ (1) (XLM(I),CI(I),I=1,NSW1)                                  COF2290
C     EVALUATION OF DCP AT CONSTANT X LOCATIONS                         COF2300
      DO 330 K=1,NBRR                                                   COF2310
      XBR=XBRR(K)                                                       COF2320
      KY=1                                                              COF2330
 290  IF (XBR.LT.XLM(KY)) GO TO 300                                     COF2340
      KY=KY+1                                                           COF2350
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      IF (KY.LE.NSW1) GO TO 290                                         COF2360
300   KY=KY-1                                                           COF2370
      BLOCAL=CI(KY)+(CI(KY+1)-CI(KY))*(XBR-XLM(KY))/(XLM(KY+1)-XLM(KY)) COF2380
      DO 320 I=1,KY                                                     COF2390
      CJ(I)=CI(I)/BLOCAL                                                COF2400
      XC=(XBR-XLM(I))/C(I)                                              COF2410
      THTA=ARCOS(1.-2.*XC)                                              COF2420
      DCPN(I)=COEF(I,1)                                                 COF2430
      DO 310 J=1,NNCW                                                   COF2440
310   DCPN(I)=DCPN(I)+COEF(I,J+1)*COS(FLOAT(J)*THTA)                    COF2450
320   DCPN(I)=DCPN(I)/(SIN(THTA))                                       COF2460
      WRITE (6,360) XBR,(CI(I),CJ(I),DCPN(I),I=1,KY)                    COF2470
330   CONTINUE                                                          COF2480
      RETURN                                                            COF2490
C                                                                       COF2500
340   FORMAT (1H1,//,9X,20HSECTIONAL PROPERTIES,/,9X,20H****************COF2510
     1****,//,9X,39HI     CLI       CMI       CDI       CTI,/,9X,39H*   COF2520
     2  ***       ***       ***       ***,/,(I10,4F10.5))               COF2530
350   FORMAT (/,9X,23HTOTAL LIFT COEFFICIENT=,F10.5,/,9X,34HTOTAL PITCHICOF2540
     1NG MOMENT COEFFICIENT=,F10.5,/,9X,23HTOTAL DRAG COEFFICIENT=,F10.5COF2550
     2,/,9X,25HTOTAL THRUST COEFFICIENT=,F10.5)                         COF2560
360   FORMAT (//,34H SPANWISE PRESSURES AT CONSTANT X=,F10.5,/,8X,25HY  COF2570
     1  2Y/B(LOCAL) DELTA-CP,/,(1X,2F10.5,2X,F10.5))                    COF2580
370   FORMAT (1H1,//,5X,21HDELTA-CP DISTRIBUTION,/,5X,21H***************COF2590
     1******,/,30H       X/C     2Y/B   DELTA-CP,/,30H       ***     ***COF2600
     2*   ********)                                                     COF2610
380   FORMAT (3F10.5)                                                   COF2620
      END                                                               COF2630-
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      SUBROUTINE INTGMY (NCW,NSW1,SGM,SNN,COEF,F,THETA)
C     SETS UP COEFFICIENTS OF A MATRIX FOR OCP-INTERPOLATION
      DIMENSION SGM(1), SNN(1), F(1), THETA(1), COEF(NSW1,1)
      PI=3.14159265
      N1=NCW+1
      FN=NCW
      DO 40 I=1,NSW1
      DO 10 J=1,NCW
      NK=(I-1)*NCW+J
      FJ=J
      THETA(J)=(2.*FJ-1.)*PI/(2.*FN)
10    F(J)=SGM(NK)*SNN(J)
      DO 30 J=1,N1
      COEF(I,J)=0.
      FJ=J
      DO 20 K=1,NCW
20    COEF(I,J)=COEF(I,J)+F(K)*COS((FJ-1.)*THETA(K))
      IF (J.EQ.1) COEF(I,J)=COEF(I,J)/FN
      IF (J.NE.1) COEF(I,J)=COEF(I,J)*2./FN
30    CONTINUE
40    CONTINUE
      RETURN
      END
```

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      SUBROUTINE SURFSET (N3,X,Y,W,IWK)                                 SRF  10
C       SET UP PROGRAM FOR SURFACE SPLINE                               SRF  20
C       WRITTEN BY - ROBERT N. DESMARAIS, STRUCTURES AND DYNAMICS DIV.  SRF  30
C                    LANGLEY RESEARCH CENTER, HAMPTON, VA.23665         SRF  40
      DIMENSION X(1), Y(1), W(N3,1), IWK(1)                             SRF  50
      E=1.E-10                                                          SRF  60
      NZ=1                                                              SRF  70
      N=N3-3                                                            SRF  80
      N1=N+1                                                            SRF  90
      N2=N+2                                                            SRF 100
      N4=N3+1                                                           SRF 110
      RN=1./N                                                           SRF 120
      N3Z=N3+NZ                                                         SRF 130
      NZ3=NZ+3                                                          SRF 140
C       COMPUTE SCALING PARAMETERS, UB,UX,UY,VB,VX,XY                   SRF 150
      XB=0.                                                             SRF 160
      YB=0.                                                             SRF 170
      PXX=0.                                                            SRF 180
      PXY=0.                                                            SRF 190
      PYY=0.                                                            SRF 200
      TH=0.                                                             SRF 210
      DO 10 I=1,N                                                       SRF 220
      XB=XB+X(I)                                                        SRF 230
      YB=YB+Y(I)                                                        SRF 240
      PXX=PXX+X(I)*X(I)                                                 SRF 250
      PXY=PXY+X(I)*Y(I)                                                 SRF 260
   10 PYY=PYY+Y(I)*Y(I)                                                 SRF 270
      XB=RN*XB                                                          SRF 280
      YB=RN*YB                                                          SRF 290
      PXX=RN*PXX-XB*XB                                                  SRF 300
      PXY=RN*PXY-XB*YB                                                  SRF 310
      PYY=RN*PYY-YB*YB                                                  SRF 320
      IF (PXY.NE.0) TH=.5*ATAN2(2.*PXY,PYY-PXX)                         SRF 330
      CT=COS(TH)                                                        SRF 340
      ST=SIN(TH)                                                        SRF 350
      C2=CT*CT                                                          SRF 360
      CS=2.*CT*ST                                                       SRF 370
      S2=ST*ST                                                          SRF 380
      SU=1./SQRT(PXX*C2-PXY*CS+PYY*S2)                                  SRF 390
      SV=1./SQRT(PXX*S2+PXY*CS+PYY*C2)                                  SRF 400
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```
      UX=SU*CT                                                          SRF 410
      UY=-SU*ST                                                         SRF 420
      VX=SV*ST                                                          SRF 430
      VY=SV*CT                                                          SRF 440
      UB=-(UX*XB+UY*YB)                                                 SRF 450
      VB=-(VX*XB+VY*YB)                                                 SRF 460
C       PUT Z INTO ITS W LOCATION                                       SRF 470
      IZ=N*NZ                                                           SRF 480
      DO 30 J=N4,N3Z                                                    SRF 490
      DO 20 I=1,3                                                       SRF 500
   20 W(I,J)=0                                                          SRF 510
      DO 30 I=4,N3                                                      SRF 520
      W(I,N3Z+N4-J)=W(IZ,1)                                             SRF 530
   30 IZ=IZ-1                                                           SRF 540
C       PUT 1,U,V (SCALED X,Y) INTO THEIR W LOCATIONS                   SRF 550
      DO 40 J=N1,N3                                                     SRF 560
      DO 40 I=1,3                                                       SRF 570
   40 W(I,J)=0                                                          SRF 580
      DO 50 J=1,N                                                       SRF 590
      JB=N4-J                                                           SRF 600
      W(1,J)=1.                                                         SRF 610
      W(JB,N1)=W(1,J)                                                   SRF 620
      W(2,J)=UB+UX*X(J)+UY*Y(J)                                         SRF 630
      W(JB,N2)=W(2,J)                                                   SRF 640
      W(3,J)=VB+VX*X(J)+VY*Y(J)                                         SRF 650
   50 W(JB,N3)=W(3,J)                                                   SRF 660
      DO 60 J=1,N                                                       SRF 670
      JB=N4-J                                                           SRF 680
C       COMPUTE H MATRIX IN W                                           SRF 690
      DO 60 I=4,JB                                                      SRF 700
      IB=N4-I                                                           SRF 710
      R2=(W(2,J)-W(2,IB))**2+(W(3,J)-W(3,IB))**2                        SRF 720
      W(I,J)=R2*ALOG(R2+E)                                              SRF 730
   60 W(JB,IB)=W(I,J)                                                   SRF 740
C      MATINV IS THE SYSTEM LIBRARY ROUTINE FOR SOLVING LINEAR EQUATIONSSRF 750
      N31=N3+1                                                          SRF 760
      CALL MATINV (N3,N3,W,1,W(1,N31),1,DET,ISC,IWK,IWK(N4))            SRF 770
C       PUT S,U,V IN LOW W                                              SRF 780
      W(1,1)=N3*(3.+NZ)                                                 SRF 790
```

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```
      W(2,1)=N                                                          SRF 800
      W(3,1)=E                                                          SRF 810
      DO 70 I=1,N                                                       SRF 820
      W(I+3,1)=0                                                        SRF 830
      W(I,2)=UB+UX*X(I)+UY*Y(I)                                         SRF 840
70    W(I,3)=VB+VX*X(I)+VY*Y(I)                                         SRF 850
      W(N1,2)=UB                                                        SRF 860
      W(N2,2)=UX                                                        SRF 870
      W(N3,2)=UY                                                        SRF 880
      W(N1,3)=VB                                                        SRF 890
      W(N2,3)=VX                                                        SRF 900
      W(N3,3)=VY                                                        SRF 910
      IF (NZ.EQ.0) RETURN                                               SRF 920
      DO 80 J=4,NZ3                                                     SRF 930
      DO 80 I=1,N3                                                      SRF 940
C       LEFT SHIFT A,B MATRICES N COLUMNS                               SRF 950
80    W(I,J)=W(I,N+J)                                                   SRF 960
      RETURN                                                            SRF 970
      END                                                               SRF 930-
```

```
      SUBROUTINE SURFORD (W,XP,YP,ZP,N3)                                ORD  10
C       SURFACE SPLINE INTERPOLATION (ORDINATES)                        ORD  20
C       WRITTEN BY - ROBERT N. DESMARAIS, STRUCTURES AND DYNAMICS DIV.  ORD  30
C                    LANGLEY RESEARCH CENTER, HAMPTON, VA.23665         ORD  40
      DIMENSION W(N3,1)                                                 ORD  50
      N=N3-3                                                            ORD  60
      N1=N+1                                                            ORD  70
      N2=N+2                                                            ORD  80
      U=W(N1,2)+W(N2,2)*XP+W(N3,2)*YP                                   ORD  90
      V=W(N1,3)+W(N2,3)*XP+W(N3,3)*YP                                   ORD 100
      ZP=W(N1,4)+W(N2,4)*U+W(N3,4)*V                                    ORD 110
      DO 10 I=1,N                                                       ORD 120
      R2=(U-W(I,2))**2+(V-W(I,3))**2                                    ORD 130
   10 ZP=ZP+W(I,4)*R2*ALOG(R2+W(3,1))                                   ORD 140
      RETURN                                                            ORD 150
      END                                                               ORD 160-
```

```
      SUBROUTINE MATINV (MAX,N,A,M,B,IOP,DETERM,ISCALE,IPIVOT,IWK)
C     MATRIX INVERSION WITH ACCOMPANYING SOLUTION OF LINEAR EQUATIONS
C     PROVIDED BY - ANALYSIS AND COMPUTATION DIVISION
C                   LANGLEY RESEARCH CENTER
C                   HAMPTON, VA. 23665
      DIMENSION IPIVOT(N), A(MAX,N), B(MAX,N), IWK(MAX,2)
      EQUIVALENCE (IROW,JROW), (ICOLUM,JCOLUM), (AMAX,T,SWAP)
C
C     INITIALIZATION
C
      ISCALE=0
      R1=10.0**100
      R2=1.0/R1
      DETERM=1.0
      DO 10 J=1,N
   10 IPIVOT(J)=0
      DO 370 I=1,N
C
C     SEARCH FOR PIVOT ELEMENT
C
      AMAX=0.0
      DO 60 J=1,N
      IF (IPIVOT(J)-1) 20,60,20
   20 DO 50 K=1,N
      IF (IPIVOT(K)-1) 30,50,410
   30 IF (ABS(AMAX)-ABS(A(J,K))) 40,50,50
   40 IROW=J
      ICOLUM=K
      AMAX=A(J,K)
   50 CONTINUE
   60 CONTINUE
      IF (AMAX) 80,70,80
   70 DETERM=0.0
      ISCALE=0
      GO TO 410
   80 IPIVOT(ICOLUM)=IPIVOT(ICOLUM)+1
C
C     INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL
C
      IF (IROW-ICOLUM) 90,130,90
```

```
90      DETERM=-DETERM                                                  MAT 410
        DO 100 L=1,N                                                    MAT 420
        SWAP=A(IROW,L)                                                  MAT 430
        A(IROW,L)=A(ICOLUM,L)                                           MAT 440
100     A(ICOLUM,L)=SWAP                                                MAT 450
        IF (M) 130,130,110                                              MAT 460
110     DO 120 L=1,M                                                    MAT 470
        SWAP=B(IROW,L)                                                  MAT 480
        B(IROW,L)=B(ICOLUM,L)                                           MAT 490
120     B(ICOLUM,L)=SWAP                                                MAT 500
130     IWK(I,1)=IROW                                                   MAT 510
        IWK(I,2)=ICOLUM                                                 MAT 520
        PIVOT=A(ICOLUM,ICOLUM)                                          MAT 530
        IF (IOP.EQ.1) GO TO 270                                         MAT 540
        IF (PIVOT) 140,70,140                                           MAT 550
C                                                                       MAT 560
C       SCALE THE DETERMINANT                                           MAT 570
C                                                                       MAT 580
140     PIVOTI=PIVOT                                                    MAT 590
        IF (ABS(DETERM)-R1) 170,150,150                                 MAT 600
150     DETERM=DETERM/R1                                                MAT 610
        ISCALE=ISCALE+1                                                 MAT 620
        IF (ABS(DETERM)-R1) 200,160,160                                 MAT 630
160     DETERM=DETERM/R1                                                MAT 640
        ISCALE=ISCALE+1                                                 MAT 650
        GO TO 200                                                       MAT 660
170     IF (ABS(DETERM)-R2) 180,180,200                                 MAT 670
180     DETERM=DETERM*R1                                                MAT 680
        ISCALE=ISCALE-1                                                 MAT 690
        IF (ABS(DETERM)-R2) 190,190,200                                 MAT 700
190     DETERM=DETERM*R1                                                MAT 710
        ISCALE=ISCALE-1                                                 MAT 720
200     IF (ABS(PIVOTI)-R1) 230,210,210                                 MAT 730
210     PIVOTI=PIVOTI/R1                                                MAT 740
        ISCALE=ISCALE+1                                                 MAT 750
        IF (ABS(PIVOTI)-R1) 250,220,220                                 MAT 760
220     PIVOTI=PIVOTI/R1                                                MAT 770
        ISCALE=ISCALE+1                                                 MAT 780
        GO TO 240                                                       MAT 790
```

```
230   IF (ABS(PIVOTI)-R2) 240,240,260                               MAT 800
240   PIVOTI=PIVOTI*R1                                              MAT 810
      ISCALE=ISCALE-1                                               MAT 820
      IF (ABS(PIVOTI)-R2) 250,250,260                               MAT 830
250   PIVOTI=PIVOTI*R1                                              MAT 840
      ISCALE=ISCALE-1                                               MAT 850
260   DETERM=DETERM*PIVOTI                                          MAT 860
C                                                                   MAT 870
C     DIVIDE PIVOT ROW BY PIVOT ELEMENT                             MAT 880
C                                                                   MAT 890
270   IF (PIVOT) 280,70,280                                         MAT 900
280   A(ICOLUM,ICOLUM)=1.0                                          MAT 910
      DO 290 L=1,N                                                  MAT 920
290   A(ICOLUM,L)=A(ICOLUM,L)/PIVOT                                 MAT 930
      IF (M) 320,320,300                                            MAT 940
300   DO 310 L=1,M                                                  MAT 950
310   B(ICOLUM,L)=B(ICOLUM,L)/PIVOT                                 MAT 960
C                                                                   MAT 970
C     REDUCE NON-PIVOT ROWS                                         MAT 980
C                                                                   MAT 990
320   DO 370 L1=1,N                                                 MAT1000
      IF (L1-ICOLUM) 330,370,330                                    MAT1010
330   T=A(L1,ICOLUM)                                                MAT1020
      A(L1,ICOLUM)=0.0                                              MAT1030
      DO 340 L=1,N                                                  MAT1040
340   A(L1,L)=A(L1,L)-A(ICOLUM,L)*T                                 MAT1050
      IF (M) 370,370,350                                            MAT1060
350   DO 360 L=1,M                                                  MAT1070
360   B(L1,L)=B(L1,L)-B(ICOLUM,L)*T                                 MAT1080
370   CONTINUE                                                      MAT1090
C                                                                   MAT1100
C     INTERCHANGE COLUMNS                                           MAT1110
C                                                                   MAT1120
      DO 400 I=1,N                                                  MAT1130
      L=N+1-I                                                       MAT1140
      IF (IWK(L,1)-IWK(L,2)) 380,400,380                            MAT1150
380   JROW=IWK(L,1)                                                 MAT1160
      JCOLUM=IWK(L,2)                                               MAT1170
      DO 390 K=1,N                                                  MAT1180
```

```
      SWAP=A(K,JROW)                                                    MAT1190
      A(K,JROW)=A(K,JCOLUM)                                             MAT1200
      A(K,JCOLUM)=SWAP                                                  MAT1210
 390  CONTINUE                                                          MAT1220
 400  CONTINUE                                                          MAT1230
 410  RETURN                                                            MAT1240
      END                                                               MAT1250-
```

```
      OVERLAY (LEVSP,5,0)
      PROGRAM NEWSHAP
C     SETS UP DIMENSIONS FOR COMPUTING THE NEW LOCATIONS OF LEADING-EDGE
C     AND TRAILING-EDGE VORTICES BY MAKING THOSE FORCE-FREE
      COMMON D(1)
      COMMON /ALLI/ NSW,NSW1,NCW,NWNG,NCPTTL
      DIMENSION E(2400)
C     ******************************************************************
      REWIND 4
      NN=NSW1+NSW
      CALL SKIPR (4,NN)
      READ (4) NMAX,NNMAX,ZMIN,NCONTS
C     ******************************************************************
      LC=1
      LTHETP=LC+NSW1
      LXN=LTHETP+NSW1
      LYN=LXN+2*NWNG
      LXTE=LYN+2*NWNG
      LXLE=LXTE+NSW
      LYLE=LXLE+NSW
      LCONS=LYLE+NSW
      LSI=LCONS+NSW1
      LXCP=LSI+NCW
      LYCP=LXCP+NCPTTL
      LCI=LYCP+NCPTTL
      LCJ=LCI+NWNG
      LCK=LCJ+NWNG
      LCONI=LCK+NWNG
      LCONJ=LCONI+NWNG
      LCONK=LCONJ+NWNG
      LDUMY=LCONK+NWNG
      LNELM=LDUMY+8*NWNG
      LNNELM=LNELM+NSW1
      LGAMA=LNNELM+NSW
      LGML=LGAMA+NCPTTL
      LYLM=LGML+NSW1
      LCPCW=LYLM+NSW1
      LNEXT=LCPCW+NSW1
C     LNEXT=21*NWNG+14*NSW+NCW-9
      MXE=1
```

```
      MYE=MXE+NSW1*NMAX                                                 NSP 410
      MZE=MYE+NSW1*NMAX                                                 NSP 420
      MXXE=MZE+NSW1*NMAX                                                NSP 430
      MYYE=MXXE+NSW*NNMAX                                               NSP 440
      MZZE=MYYE+NSW*NNMAX                                               NSP 450
      MNEXT=MZZE+NSW*NNMAX                                              NSP 460
C     MNEXT=3*NSW*NMAX-3*NMAX+3*NSW*NNMAX+1                             NSP 470
      CALL NEWELM (D(LC),D(LTHETP),D(LXN),D(LYN),D(LXTE),D(LXLE),D(LYLE)NSP 480
     1,D(LCONS),D(LSI),D(LXCP),D(LYCP),D(LCI),D(LCJ),D(LCK),D(LCONI),D(LNSP 490
     2CONJ),D(LCONK),D(LDUMY),NWNG,NCPTTL,E(MXE),E(MYE),E(MZE),E(MXXE),ENSP 500
     3(MYYE),E(MZZE),NSW1,NSW,NCW,ZMIN,NMAX,NNMAX,D(LNELM),D(LNNELM),NCONSP 510
     4NTS,D(LGAMA),D(LGML),D(LYLM),D(LCPCW))                            NSP 520
      RETURN                                                            NSP 530
      END                                                               NSP 540-
```

```
      SUBROUTINE NEWELM (C,THETP,XN,YN,XTE,XLE,YLE,CONS,SI,XCP,YCP,CI,CJ
     1,CK,CONI,CONJ,CONK,DUMMY,NWNG,NCPTTL,XE,YE,ZE,XXE,YYE,ZZE,NSW1,NSW
     2,NCW,ZMIN,NMAX,NNMAX,NELM,NNELM,NCONTS,GAMA,GML,YLM,CPCW1)
C     COMPUTES THE NEW LOCATIONS OF LEADING-EDGE AND TRAILING-EDGE
C     VORTICES BY MAKING THOSE FORCE-FREE
      COMMON /GM/ ITER
      COMMON /NCTT/ NCT,NCON
      COMMON /ALLRA/ TTL(16),ALPHA,SINA,AA(9),PI,AD(2),HALFB,AREA
      DIMENSION DUMMY(1), CONI(1), CONJ(1), CONK(1), CI(1), CJ(1), CK(1)
     1, C(1), THETP(1), XTE(1), XLE(1), YLE(1), CONS(1), SI(1), XCP(1),
     2YCP(1), GAMA(1), GML(1), YLM(1), CPCW1(1), XN(NWNG,2), YN(NWNG,2),
     3 NELM(1), NNELM(1), XE(NSW1,1), YE(NSW1,1), ZE(NSW1,1), XXE(NSW,1)
     4, YYE(NSW,1), ZZE(NSW,1), A(3), B(3), F(3)
C     ..................................................................
      REWIND 1
C     ******************************************************************
      CALL SKIPR (1,5)
      READ (1) (C(I),I=1,NSW1)
      READ (1) (THETP(I),I=1,NSW1)
      READ (1) (XTE(I),XLE(I),YLE(I),I=1,NSW)
      READ (1) (XLM,YLM(I),I=1,NSW1)
      READ (1) (CONS(I),I=1,NSW1)
      READ (1) (SI(I),AC,I=1,NCW)
      READ (1) (XCP(I),YCP(I),I=1,NCPTTL)
      READ (1) ((XN(I,J),YN(I,J),J=1,2),I=1,NWNG)
      CALL SKIPR (1,2)
      READ (1) (CPCW1(I),I=1,NCW)
      REWIND 2
      READ (2) (GAMA(I),I=1,NCPTTL)
      REWIND 3
      READ (3) (GML(I),I=1,NSW1)
      REWIND 4
      DO 10 I=1,NSW1
      READ (4) KK,(XE(I,J),YE(I,J),ZE(I,J),J=1,KK)
   10 NELM(I)=KK
      DO 20 I=1,NSW
      READ (4) KK,(XXE(I,J),YYE(I,J),ZZE(I,J),J=1,KK)
   20 NNELM(I)=KK
C     ******************************************************************
      BHALF=1.25*HALFB
```

```
      ATL=1.-0.1*FLOAT(ITER)                                            NLM 410
      IF (NCONTS.NE.0) ATL=0.75                                         NLM 420
      IF (ATL.LT.0.75) ATL=0.75                                         NLM 430
      BTL=1.-ATL                                                        NLM 440
C     EVALUATION OF FORCE ACTING ON LEADING-EDGE ELEMENTS               NLM 450
      TFABS=0.                                                          NLM 460
      TLNTH=0.                                                          NLM 470
      NCT=0                                                             NLM 480
      DO 40 I=2,NSW1                                                    NLM 490
      NCON=I                                                            NLM 500
      K=NELM(I)-1                                                       NLM 510
      FABS=0.                                                           NLM 520
      ALNTH=0.                                                          NLM 530
      DO 30 J=5,K                                                       NLM 540
      XEE=(XE(I,J)+XE(I,J+1))/2.                                        NLM 550
      YEE=(YE(I,J)+YE(I,J+1))/2.                                        NLM 560
      ZEE=(ZE(I,J)+ZE(I,J+1))/2.                                        NLM 570
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CONNLM 580
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,CPCW1,XCP,YCP,GAMA,YNLM 590
     2LM)                                                               NLM 600
      GMA=GAMA(NWNG+I)                                                  NLM 610
      A(1)=XE(I,J+1)-XE(I,J)                                            NLM 620
      A(2)=YE(I,J+1)-YE(I,J)                                            NLM 630
      A(3)=ZE(I,J+1)-ZE(I,J)                                            NLM 640
      AAA=SQRT(A(1)*A(1)+A(2)*A(2)+A(3)*A(3))                           NLM 650
      A(1)=A(1)*GMA/AREA                                                NLM 660
      A(2)=A(2)*GMA/AREA                                                NLM 670
      A(3)=A(3)*GMA/AREA                                                NLM 680
      B(1)=UU                                                           NLM 690
      B(2)=VV                                                           NLM 700
      B(3)=WW                                                           NLM 710
      CALL CRSPRD (A,B,F)                                               NLM 720
      FABSI=SQRT(F(1)*F(1)+F(2)*F(2)+F(3)*F(3))                         NLM 730
      FABS=FABS+FABSI                                                   NLM 740
      ALNTH=ALNTH+AAA                                                   NLM 750
   30 CONTINUE                                                          NLM 760
      TFABS=TFABS+FABS                                                  NLM 770
      TLNTH=TLNTH+ALNTH                                                 NLM 780
   40 CONTINUE                                                          NLM 790
```

```
      TAVRG=TFABS/TLNTH                                                 NLM 800
      WRITE (6,170) TFABS                                               NLM 810
C     ..................................................................NLM 820
      WRITE (7) TFABS,TAVRG,TLNTH                                       NLM 830
C     ..................................................................NLM 840
C     CALCULATION OF THE COORDINATES OF LEADING-EDGE ELEMENTS BY        NLM 850
C     SATISFYING FORCE-FREE CONDITION                                   NLM 860
      DO 110 J=5,NMAX                                                   NLM 870
      DO 110 I=2,NSW1                                                   NLM 880
      NCON=I                                                            NLM 890
      K=NELM(I)-1                                                       NLM 900
      IF (J.GT.K) GO TO 110                                             NLM 910
      XXX=XE(I,J+1)                                                     NLM 920
      YYY=YE(I,J+1)                                                     NLM 930
      ZZZ=ZE(I,J+1)                                                     NLM 940
      DLS=SQRT((XE(I,J+1)-XE(I,J))**2+(YE(I,J+1)-YE(I,J))**2+(ZE(I,J+1)-NLM 950
     1ZE(I,J))**2)                                                      NLM 960
      XEE=(XE(I,J)+XE(I,J+1))/2.                                        NLM 970
      YEE=(YE(I,J)+YE(I,J+1))/2.                                        NLM 980
      ZEE=(ZE(I,J)+ZE(I,J+1))/2.                                        NLM 990
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CONNLM1000
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,CPCW1,XCP,YCP,GAMA,YNLM1010
     2LM)                                                               NLM1020
      UVW=SQRT(UU*UU+VV*VV+WW*WW)                                       NLM1030
      IF (J.EQ.5) GO TO 50                                              NLM1040
      VVA=ATL*VV/UVW                                                    NLM1050
      WWA=ATL*WW/UVW                                                    NLM1060
      DLY=VVA*DLS+BTL*(YE(I,J+1)-YE(I,J))                               NLM1070
      DLZ=WWA*DLS+BTL*(ZE(I,J+1)-ZE(I,J))                               NLM1080
      GO TO 60                                                          NLM1090
   50 CONTINUE                                                          NLM1100
      VVA=0.5*VV/UVW                                                    NLM1110
      WWA=0.5*WW/UVW                                                    NLM1120
      DLY=VVA*DLS+0.5*(YE(I,J+1)-YE(I,J))                               NLM1130
      DLZ=WWA*DLS+0.5*(ZE(I,J+1)-ZE(I,J))                               NLM1140
      GO TO 70                                                          NLM1150
   60 CONTINUE                                                          NLM1160
      IF ((DLZ/DLS).GT.SINA) DLZ=DLS*SINA                               NLM1170
   70 CONTINUE                                                          NLM1180
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      YINT=YE(I,J)+DLY                                                  NLM1190
      ZINT=ZE(I,J)+DLZ                                                  NLM1200
      IF (YINT.LE.YE(2,5)) YINT=YE(2,5)                                 NLM1210
      IF (YINT.GE.BHALF) YINT=BHALF                                     NLM1220
      IF (ZINT.LE.ZMIN) ZINT=ZMIN                                       NLM1230
      DLY2=YINT-YE(I,J)                                                 NLM1240
      DLZ2=ZINT-ZE(I,J)                                                 NLM1250
      DLX22=DLS*DLS-DLY2*DLY2-DLZ2*DLZ2                                 NLM1260
      IF (DLX22.LE.0.) DLY2=DLY2/2.                                     NLM1270
      IF (DLX22.LE.0.) DLZ2=DLZ2/2.                                     NLM1280
      DLX2=SQRT(DLS*DLS-DLY2*DLY2-DLZ2*DLZ2)                            NLM1290
      XE(I,J+1)=XE(I,J)+DLX2                                            NLM1300
      YE(I,J+1)=YE(I,J)+DLY2                                            NLM1310
      ZE(I,J+1)=ZE(I,J)+DLZ2                                            NLM1320
      DX=XE(I,J+1)-XXX                                                  NLM1330
      DY=YE(I,J+1)-YYY                                                  NLM1340
      DZ=ZE(I,J+1)-ZZZ                                                  NLM1350
      J2=J+2                                                            NLM1360
      KP=K+1                                                            NLM1370
      IF (J2.GT.KP) GO TO 110                                           NLM1380
      DO 80 JK=J2,KP                                                    NLM1390
      XE(I,JK)=XE(I,JK)+DX                                              NLM1400
      YE(I,JK)=YE(I,JK)+DY                                              NLM1410
   80 ZE(I,JK)=ZE(I,JK)+DZ                                              NLM1420
C     ..................................................................NLM1430
      REWIND 4                                                          NLM1440
      DO 90 L=1,NSW1                                                    NLM1450
      KS=NELM(L)                                                        NLM1460
   90 WRITE (4) KS,(XE(L,M),YE(L,M),ZE(L,M),M=1,KS)                     NLM1470
      DO 100 L=1,NSW                                                    NLM1480
      KS=NNELM(L)                                                       NLM1490
  100 WRITE (4) KS,(XXE(L,M),YYE(L,M),ZZE(L,M),M=1,KS)                  NLM1500
      WRITE (4) NMAX,NNMAX,ZMIN,NCONTS                                  NLM1510
C     ..................................................................NLM1520
  110 CONTINUE                                                          NLM1530
C     CALCULATION OF THE COORDINATES OF WAKE ELEMENTS BY SATISFYING     NLM1540
C     FORCE-FREE CONDITION                                              NLM1550
      CTL=0.5                                                           NLM1560
      DTL=1.-CTL                                                        NLM1570
```

```
      NCON=0                                                            NLM1580
      DO 160 J=1,NNMAX                                                  NLM1590
      DO 160 I=2,NSW                                                    NLM1600
      NCT=I                                                             NLM1610
      K=NNELM(I)-1                                                      NLM1620
      IF (J.GT.K) GO TO 160                                             NLM1630
      XXX=XXE(I,J+1)                                                    NLM1640
      YYY=YYE(I,J+1)                                                    NLM1650
      ZZZ=ZZE(I,J+1)                                                    NLM1660
      WLS=SQRT((XXE(I,J+1)-XXE(I,J))**2+(YYE(I,J+1)-YYE(I,J))**2+(ZZE(I,NLM1670
     1J+1)-ZZE(I,J))**2)                                                NLM1680
      XEE=(XXE(I,J)+XXE(I,J+1))/2.                                      NLM1690
      YEE=(YYE(I,J)+YYE(I,J+1))/2.                                      NLM1700
      ZEE=(ZZE(I,J)+ZZE(I,J+1))/2.                                      NLM1710
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CONNLM1720
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,CPCW1,XCP,YCP,GAMA,YNLM1730
     2LM)                                                               NLM1740
      UVW=SQRT(UU*UU+VV*VV+WW*WW)                                       NLM1750
      IF (J.EQ.1) GO TO 130                                             NLM1760
      VVA=CTL*VV/UVW                                                    NLM1770
      WWA=CTL*WW/UVW                                                    NLM1780
      DLY=VVA*WLS+DTL*(YYE(I,J+1)-YYE(I,J))                             NLM1790
      DLZ=WWA*WLS+DTL*(ZZE(I,J+1)-ZZE(I,J))                             NLM1800
      IF ((DLZ/WLS).GT.SINA) DLZ=WLS*SINA                               NLM1810
      YINT=YYE(I,J)+DLY                                                 NLM1820
      IF (YINT.LE.(YLE(2)/2.)) YINT=YLE(2)/2.                           NLM1830
      IF (YINT.GE.BHALF) YINT=BHALF                                     NLM1840
      DLY2=YINT-YYE(I,J)                                                NLM1850
      DLZ2=DLZ                                                          NLM1860
      DLX22=WLS*WLS-DLY2*DLY2-DLZ2*DLZ2                                 NLM1870
      IF (DLX22.LE.0.) DLY2=DLY2/2.                                     NLM1880
      IF (DLX22.LE.0.) DLZ2=DLZ2/2.                                     NLM1890
      DLX2=SQRT(WLS*WLS-DLY2*DLY2-DLZ2*DLZ2)                            NLM1900
      XXE(I,J+1)=XXE(I,J)+DLX2                                          NLM1910
      YYE(I,J+1)=YYE(I,J)+DLY2                                          NLM1920
      ZZE(I,J+1)=ZZE(I,J)+DLZ2                                          NLM1930
      DX=XXE(I,J+1)-XXX                                                 NLM1940
      DY=YYE(I,J+1)-YYY                                                 NLM1950
      DZ=ZZE(I,J+1)-ZZZ                                                 NLM1960
```

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      J2=J+2                                                            NLM1970
      KP=K+1                                                            NLM1980
      IF (J2.GT.KP) GO TO 130                                           NLM1990
      DO 120 JK=J2,KP                                                   NLM2000
      XXE(I,JK)=XXE(I,JK)+DX                                            NLM2010
      YYE(I,JK)=YYE(I,JK)+DY                                            NLM2020
  120 ZZE(I,JK)=ZZE(I,JK)+DZ                                            NLM2030
  130 CONTINUE                                                          NLM2040
C     ..................................................................NLM2050
      REWIND 4                                                          NLM2060
      DO 140 L=1,NSW1                                                   NLM2070
      KS=NELM(L)                                                        NLM2080
  140 WRITE (4) KS,(XE(L,M),YE(L,M),ZE(L,M),M=1,KS)                     NLM2090
      DO 150 L=1,NSW                                                    NLM2100
      KS=NNELM(L)                                                       NLM2110
  150 WRITE (4) KS,(XXE(L,M),YYE(L,M),ZZE(L,M),M=1,KS)                  NLM2120
      WRITE (4) NMAX,NNMAX,ZMIN,NCCNTS                                  NLM2130
C     ..................................................................NLM2140
  160 CONTINUE                                                          NLM2150
      RETURN                                                            NLM2160
C                                                                       NLM2170
  170 FORMAT (//,59H TOTAL ABSOLUTE FORCE ACTING ON LEADING-EDGE FREE ELNLM2180
     1EMENTS=,F10.5)                                                    NLM2190
      END                                                               NLM2200-
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15. Supplementary Notes

16. Abstract

This document describes in detail the necessary information for using a computer program to predict distributed and total aerodynamic characteristics for low aspect-ratio wings with partial leading-edge separation. The flow is assumed to be steady and inviscid. The wing boundary condition is formulated by the Quasi-Vortex-Lattice method. The leading-edge separated vortices are represented by discrete free vortex elements which are aligned with the local velocity vector at mid-points to satisfy the force free condition. The wake behind the trailing-edge is also force free. The flow tangency boundary condition is satisfied on the wing, including the leading- and trailing-edges.

The program is restricted to delta wings with zero thickness and no camber. It is written in Fortran language and runs on CDC 6600 Computer.

17. Key Words (Suggested by Author(s))
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