General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)
STAYLAM: A FORTRAN PROGRAM FOR THE SUCTION TRANSITION ANALYSIS OF A YAWED WING LAMINAR BOUNDARY LAYER

James E. Carter

March 1977

This informal documentation medium is used to provide accelerated or special release of technical information to selected users. The contents may not meet NASA formal editing and publication standards, may be revised, or may be incorporated in another publication.
**STAYLAM: A FORTRAN PROGRAM FOR THE SUCTION TRANSITION ANALYSIS OF A YAWED WING LAMINAR BOUNDARY LAYER**

**Abstract**

A computer program called STAYLAM is presented for the computation of the compressible laminar boundary-layer flow over a yawed infinite wing including distributed suction. This program is restricted to the transonic speed range or less due to the approximate treatment of the compressibility effects. The prescribed suction distribution is permitted to change discontinuously along the chord measured perpendicular to the wing leading edge. Estimates of transition are made by considering leading-edge contamination, cross-flow instability, and instability of the Tollmien-Schlichting type. A program listing is given in addition to user instructions and a sample case.
STAYLAM: A FORTRAN PROGRAM FOR THE SUCTION TRANSITION ANALYSIS OF A YAWED WING LAMINAR BOUNDARY LAYER

By James E. Carter

SUMMARY

A computer program called STAYLAM is presented for the computation of the compressible laminar boundary-layer flow over a yawed infinite wing including distributed suction. This program is restricted to the transonic speed range or less due to the approximate treatment of the compressibility effects. The prescribed suction distribution is permitted to change discontinuously along the chord measured perpendicular to the wing leading-edge. Estimates of transition are made by considering leading-edge contamination, cross-flow instability, and instability of the Tollmien-Schlichting type. A program listing is given in addition to user instructions and a sample case.

INTRODUCTION

At the present time there is significant effort being made to implement boundary-layer suction on a wing to maintain laminar flow thereby resulting in a net drag reduction. Clearly such studies require a computer program which analyses the compressible laminar boundary layer on a swept wing and includes tests based on the latest technology to determine whether or not transition will occur for a given suction distribution. Based on the current
state of the art for boundary-layer computations for finite swept wings and
that for transition estimates, it is clear that such a program would be most
complex and thus difficult to use. Hence, in the present program a number of
approximations have been made in order to simplify the analysis; nonetheless,
this program should be useful, particularly for preliminary design.

SYMBOLS

a speed of sound
Cp pressure coefficient
Cf skin-friction coefficient
L reference length
M Mach number
m, n indices for x- and z-directions, respectively
p static pressure
Q free stream velocity
Re free stream Reynolds number
T1 static temperature
u velocity component in x-direction
ua velocity component in direction of inviscid streamline
uc cross flow velocity component
U transformed velocity at the boundary-layer edge in the x-direction
V velocity component at the boundary-layer edge in the y-direction
(V = V' = Q* cos Ψ)
w velocity component in the z-direction
x coordinate along the surface measured perpendicularly to the leading
edge
\( y \) coordinate along the surface measured parallel to the leading edge
\( z \) coordinate measured perpendicularly to surface
\( \alpha \) weighting factor in finite-difference scheme
\( \gamma \) ratio of specific heats
\( \Delta x \) grid spacing in x-direction
\( \Delta z \) grid spacing in z-direction
\( \delta^* \) displacement thickness
\( \Theta \) momentum thickness
\( \lambda_2 \) pressure gradient parameter \( = \frac{\delta^2}{\nu} \frac{du^*}{dx^*} \)
\( \mu \) molecular viscosity coefficient
\( \nu \) kinematic viscosity coefficient
\( \rho \) density
\( \tau \) shear stress at surface
\( \phi \) angle between direction of flow at the boundary-layer edge and the x-direction
\( \psi \) angle of shear of wing

Superscripts:

* dimensional, untransformed quantity

\' dimensional quantity after Stewartson compressibility transformation

Subscripts:

\( e \) edge of boundary layer
\( n \) normal to leading edge of wing
\( x \) in the x-direction
\( y \) in the y-direction
\( \infty \) free stream quantity
GENERAL DESCRIPTION

The present program, STAYLAM, was developed by modifying a program presented by Beasley (ref. 1) for the calculation of the incompressible laminar boundary layer and prediction of transition on an infinite sheared wing. In Beasley's program the second-order accurate Crank-Nicolson finite-difference scheme is used to compute the boundary layer from the attachment line to some desired point downstream. These boundary-layer results are then analyzed to determine whether or not leading-edge instability or cross-flow instability occurs. The Owen-Randall criterion is used for the cross-flow instability test. The Tollmien-Schlichting type of instability is estimated by using a correlation given by Stuart (ref. 2) of the critical Reynolds number as a function of the external pressure gradient. The point where transition is completed is then estimated by using a correlation given by Granville (ref. 3). These same tests are used in the present program; the only modification which has been made is that the input quantities to these tests are the actual compressible values, not the corresponding incompressible values given by the Stewartson transformation. It should be noted that the transition tests in the present program can be replaced or supplemented with relative ease.

The Beasley program has been modified by the inclusion of distributed wall suction, compressibility effects, and the finite-difference scheme has been generalized to be of arbitrary accuracy between first and second order in the streamwise, marching variable. Figure 1 gives a typical distribution of suction velocities and explains the nomenclature used in inputting this distribution to the program. Note that the suction is allowed to change discontinuously at a prescribed number of locations along the airfoil. It
was found that the Beasley program, modified to include suction, gave distributions of the local skin-friction coefficient which showed significant oscillations in a region of discontinuous suction. These oscillations were eliminated by using a first-order accurate finite-difference scheme in the streamwise marching variable, instead of the second-order accurate Crank-Nicolson scheme used by Beasley. The oscillations were expected in using the Crank-Nicolson scheme due to its known neutral stability in the wall region. The first-order accurate scheme suppresses the oscillations caused by the discontinuous suction since it has greater damping. For the same accuracy the first-order scheme requires more streamwise grid points than the second-order scheme; however, calculations showed that both schemes yield about the same result if approximately 100 grid points are used from the leading to trailing edge. Appendix A gives further details of the finite-difference scheme.

The Stewartson (ref. 4) transformation has been used to account for compressibility effects. Details of this transformation along with the Blasius transformation used by Beasley and the coordinate system are presented in Appendix B. The Prandtl number is assumed to be unity and the total temperature is assumed to be the same as the free stream value. A further approximation is made in the treatment of the streamwise pressure gradient term which allows the incompressible infinite swept wing equations to be obtained after the Stewartson transformation. This latter approximation restricts the use of the present program to speeds in the transonic range or lower. Since the present interest in LFC (laminar flow control) is in the transonic speed range it is felt that this simplifying approximation is justified.
Several calculations were made to verify the accuracy of STAYLAM. First, the incompressible boundary layer on a circular cylinder with a constant suction velocity was computed and comparisons were made with the results obtained by Terrill (ref. 5) for the same case. Excellent agreement was found in the momentum and displacement thicknesses, and skin friction distributions. The estimate of the separation point from the present program differed from that of Terrill by only 0.1°. A second test case was a comparison between the results from the present program and the analytic solution for the compressible asymptotic suction profile (ref. 3) which is obtained by applying constant suction on a flat plate. Excellent agreement was obtained in the streamwise and normal velocity distributions.

PROGRAM USAGE

The program was written in the FORTRAN programming language for use on the Control Data 6000 Series Computer Systems under the NOS. 1.1 operating system at Langley Research Center. Included in the output is a plot of the distributions of the $x$ and $y$ skin-friction coefficients, $C_{f_x}$ and $C_{f_y}$, versus the non-dimensional surface distance measured perpendicular to the leading edge. Some modification to the program might be required to obtain plots on a different computer system.

The input and output for STAYLAM are discussed in the next two sections. The program listing is given in Appendix D and a sample case is discussed in Appendix E.
## INPUT

<table>
<thead>
<tr>
<th>Read Order</th>
<th>Variables</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ITS, J, TOL, DZ, DS, USTEP, WF†</td>
<td>2I5, 5F10.5</td>
</tr>
<tr>
<td>2</td>
<td>IBLC</td>
<td>I5</td>
</tr>
<tr>
<td>3</td>
<td>MSMAX</td>
<td>I5</td>
</tr>
<tr>
<td>4</td>
<td>W WALL(MS), SDS(MS) (IBLC = 0)</td>
<td>2F10.5</td>
</tr>
<tr>
<td>5</td>
<td>INC, AMINT3D, GAMMA</td>
<td>I5, 2F10.2</td>
</tr>
<tr>
<td>6</td>
<td>B</td>
<td>8A10</td>
</tr>
<tr>
<td>7</td>
<td>INT3, CH</td>
<td>I5, F10.5</td>
</tr>
<tr>
<td>8</td>
<td>ISY, INT4, RHO (Skip if INT3 = 0)</td>
<td>2I5, F10.5</td>
</tr>
<tr>
<td>9</td>
<td>X A(N), Z A(N) (INT4 pairs of values)</td>
<td>2E16.8</td>
</tr>
<tr>
<td>10</td>
<td>ISP</td>
<td>I5</td>
</tr>
<tr>
<td>11</td>
<td>IFPT, INT1, NLLST, DX</td>
<td>3I5, 2F10.5</td>
</tr>
<tr>
<td>12</td>
<td>OPX(N), N = 2, NLLSTP1 (Skip if IFPT ≠ 2)</td>
<td>8F10.5</td>
</tr>
<tr>
<td>13</td>
<td>C</td>
<td>8A10</td>
</tr>
<tr>
<td>14</td>
<td>PSI, DTRIP</td>
<td>8F10.5</td>
</tr>
<tr>
<td>15</td>
<td>INTRL, IFR</td>
<td>2I5</td>
</tr>
<tr>
<td>16</td>
<td>RN L(I), I = 1, INTRL</td>
<td>8F10.5</td>
</tr>
<tr>
<td>17</td>
<td>INTV, L</td>
<td>2I5</td>
</tr>
<tr>
<td>18</td>
<td>X V(I), UM(I), I = 2, LP1</td>
<td>2E16.8</td>
</tr>
<tr>
<td>19</td>
<td>MGRAD, X V(I) (if INC = 0)</td>
<td>2F10.5</td>
</tr>
<tr>
<td>20</td>
<td>VGRAD, X V(I) (if INC = 1)</td>
<td>2F10.5</td>
</tr>
</tbody>
</table>

†Input which has been added to original Beasley program is underlined.
ALPHA, SL, S3 (skip if MGRAD or VGRAD > 0) 3F10.5

The definitions of these input variables are as follows:

ITS  Maximum number of iterations in subroutine WUV to calculate the u profile.
J  Number of steps in z direction.
TOL  Iterative tolerance.
DZ  Step length in z direction.
DS  Standard step length in x direction, made non-dimensional with respect to airfoil chord.
USTEP  Maximum permissible increase in velocity at edge of boundary layer across one step.
WF  Accuracy control on finite-difference expression for x derivatives.
    WF = 0.5 gives second-order accuracy (Crank-Nicolson scheme);
    WF = 1.0 gives first-order accuracy.
IBLC  Suction parameter. IBLC = 0, no suction; IBLC = 1, distributed suction permitted.
MSMAX  Total number of values of suction velocity.
WWALL  Array of suction velocity values $\frac{U^*}{U_{\infty}} \sqrt{\frac{C_{HL}}{\gamma \rho_{\infty}}}$ for suction.
    WWALL(MS) < 0.
SDS  Array of nondimensional locations along airfoil measured from attachment line, where value of suction velocity changes discontinuously. Set SDS(MSMAX) > surface distance from attachment line to trailing edge.
INC  Compressibility parameter. INC = 1, flow is incompressible.
    INC = 0, flow is compressible and Stewartson transformation
AKINF3D  Free stream Mach number.

GAMMA  Ratio of specific heats; usually \( \gamma = 1.4 \).

B  Main title.

INT3  
= 0: velocity data will be given at \( x \) co-ordinates, that is, at distances from the attachment line measured around the airfoil surface.
= 1: velocity data will be given at chord-wise stations.

CH  Airfoil chord, measured perpendicularly to leading edge.

ISY  
= 0: airfoil is cambered.
= 1: airfoil is symmetrical.

INT4  Initially is the number of 'pairs of co-ordinates to be read, subsequently becomes the total number of pairs of airfoil co-ordinates stored, including the lower surface and leading edge.

RHO  Nose radius of the airfoil in plane perpendicular to the leading edge.

XA  Coordinates of geometric data, measured perpendicularly to the leading edge and in the plane through the leading and trailing edges.

ZA  Coordinates of geometric data, measured perpendicularly to the plane through the leading and trailing edges. For a symmetrical airfoil XA and ZA are read from the leading edge to the trailing edge and include values at both points. For a cambered airfoil the geometrical data are read from the trailing edge on the lower surface to the trailing edge on the upper surface. Values of XA for the lower surface must have negative signs, and values of ZA...
ZA must have signs as appropriate.

**ISP**
- Surface parameter indicator. ISP = 2, upper surface calculation;
- ISP = 0, lower surface calculation.

**IFPT**
- = 1: Complete print-out at end of all steps.
- = 2: Complete print-out at points given in list.
- = 3: Complete print-out at points at which velocity data is given.
- = 4: Complete print-out at points DX apart, where DX is given as data.

In current program set IFPT = 3 and the print-out has been modified so that the complete print-out (boundary-layer profiles) is printed every 10% chord. This modification can be eliminated by several program changes in subroutine PRINT.

**INTL**
- Velocity profiles are printed out at values of z corresponding to
- \( n = 1, 2, 3, ..., (\text{INTL} + 1), 2(\text{INTL}) + 1, 3(\text{INTL}) + 1, ..., N \)

**NLIST**
- Number of points in output list.

**DX**
- Interval between listed output points (when IFPT = 4), made non-dimensional with respect to the airfoil chord.

**OPX**
- Points at which full output is required.

**C**
- Sub-title.

**PSI**
- Angle of shear.

**DTRIP**
- Trip-wire diameter.

**INTRL**
- Number of values of Reynolds number to be read.

**IFR**
- = 1. Data Reynolds number = \( \frac{Q_{\infty}^* \text{sec} \psi}{V_{\infty}^*} \)
- = 2. Data Reynolds number = \( \frac{Q_{\infty}^*}{V_{\infty}^*} \)
- = 3. Data Reynolds number = \( \frac{Q_{\infty}^* \cos \psi}{V_{\infty}^*} \)
In present program use IFR = 2 as this Reynolds number definition has been assumed in the suction velocity and in the skin-friction coefficient calculations.

**RNL**
Reynolds number.

**INTV**

= 1: Velocity data is given as $U$.

= 2: Velocity data is given as $U \sec \psi$.

= 3: Velocity data is given as $C_p$.

If flow is compressible set INTV = 1. See UM description for further explanation of input in compressible case.

**L**
Initially is the number of velocity data points read in, subsequently is the total number of points at which the velocity distribution is defined, including the attachment line.

**XV**
Coordinates of velocity data. Use the same sign convention as that forXA to indicate whether the upper or lower surface is to be computed.

**UM**
For incompressible flow, UM is initially the velocity data, subsequently, $U$. For compressible flow UM is initially $M_{en}$. After the Stewart-on transformation, it is $U$. The velocity (or Mach number) data, XV and UM, are read from the attachment line towards the trailing edge, but attachment-line values must not be included and the data need not extend all the way to the trailing edge.

**MGRAD**
Mach number gradient (nondimensional) at the attachment line in a plane perpendicular to the leading edge $= \frac{dM_{en}}{dx}$. 
VGRAD Velocity gradient (nondimensional) at the attachment line in a plane perpendicular to the leading edge
\[ \frac{du'/Q_n}{dx} = \frac{dU}{dx} \sec \psi \]

\( X(V) \) Location of attachment line. Use same sign convention as that used for \( XA \).

ALPHA Incidence of airfoil in streamwise plane.

\( S1, S3 \) Quantities used in equations (53-54) in reference 1. 

KUE Parameter for more data on step. 

- = 1: Read more data from ITS. 
- = 2: Read more data from B. 
- = 3: Read more data from ISY. 
- = 4: Read more data from IFPT. 
- = 5: Read more data from C. 
- = 6: Read more data from INTV. 
- = 7: Stop.

The input is printed and labeled as described above. In addition the following quantities are also printed along with the input.

STH Non-dimensional surface distance measured from lower surface trailing edge.

TH Transformed chordwise station \( X \). Lower surface, \( \theta = \cos^{-1}(2x - 1) \); upper surface, \( \theta = 2\pi - \cos^{-1}(2x - 1) \).

FSTH Second derivative of surface distance with respect to \( \theta \). Used in cubic spline interpolation.

FZTH Second derivative of \( Z \) (measured perpendicularly to the plane through the leading and trailing edges) with respect to \( \theta \). Used in cubic spline interpolation.
SXV | Non-dimensional surface distance measured from attachment line to point at which the inviscid velocity, Mach number, or pressure coefficient data is prescribed.

SXVINC | Transformed surface distance corresponding to SXV; same as $x'/L^*$ in equation (B4).

$U$ | Non-dimensional transformed surface velocity $= \frac{\alpha^* u^*}{\alpha_e^* U^*} = \frac{M_e}{M_e}$

THXV | Value of $\theta$ at the points where the velocity data is prescribed.

FUTH | Second derivative of $U$ with respect to $\theta$. Used in cubic spline interpolation.

FSVSINC | Second derivative of SXV with respect to SXVINC. Used in cubic spline interpolation.

**OUTPUT**

The displacement and momentum thicknesses, skin-friction values, and results of the transition estimates are printed at each location on the airfoil where a boundary-layer calculation is made. These locations are determined by the USTEP criterion, or if this is satisfied, then the computation is made at regular DS intervals. Furthermore, since IFPT = 3, computations are also made at the same locations at which the velocity (or Mach number) data is prescribed. Note that these latter computations are only temporary; hence results from these stations do not form upstream conditions for the next downstream station. The skin-friction coefficients are not computed at these intermediate stations.
The boundary-layer profiles are printed at approximately every 10 per cent chord. The information printed at each boundary-layer station and an explanation of the boundary-layer profiles is given as follows:

X  Non-dimensional chord location.
S  Transformed incompressible coordinate measured along airfoil from attachment line; same as $x$ in equation (12) in Appendix B.
SCOMP  Non-dimensional surface distance measured from attachment line.
U  Non-dimensional transformed velocity at the boundary-layer edge
    \[ \frac{a^*}{e} \frac{u^*}{\gamma} \frac{M_e}{M_{\infty}}. \]
AME3D  Mach number at the boundary-layer edge. See equation (18) in Appendix B.
DU/D(S/L)  Transformed inviscid velocity gradient, $\frac{dU}{dx}$.
DELTAL  Scaled displacement thickness
    \[ \sqrt{\frac{U_{e,\infty}}{x}} (\delta^*). \]
THETAL  Scaled momentum thickness
    \[ \sqrt{\frac{U_{e,\infty}}{x}} (\theta^*). \]
(DU/DZ)Z=0  Scaled skin-friction coefficient in $x$ direction
    \[ \left( \frac{1 + \frac{\gamma-1}{2} \frac{M_e^2}{M_{\infty}^2}}{1 + \frac{\gamma-1}{2} \frac{M_{\infty}^2}{M_e^2}} \right)^{\frac{2 \gamma - 1}{\gamma - 1}} \frac{\partial u}{\partial z} \big|_{z=0}. \]
(DV/DZ)Z=0  Scaled skin-friction coefficient in $y$ direction
    \[ \left( \frac{1 + \frac{\gamma-1}{2} \frac{M_{\infty}^2}{M_e^2}}{1 + \frac{\gamma-1}{2} \frac{M_e^2}{M_{\infty}^2}} \right)^{\frac{3 \gamma - 1}{2(\gamma - 1)}} \frac{\partial v}{\partial z} \big|_{z=0}. \]
AIRFOIL SLOPE  Local airfoil slope in degrees in plane perpendicular to the leading edge.
(DIMENSIONAL Z)/CHORD  Multiplicative factor to convert scaled displacement and momentum thicknesses into actual thickness divided by the chord.

DELTA/L  \( \delta^*/L^* \)

THETA/L  \( \theta^*/L^* \)

CFX  Skin-friction coefficient x direction =

\[
\frac{\tau_x^*}{\frac{1}{2} \rho^* \sigma_{x,*}^*} = \frac{2U_x^{3/2}}{\sqrt{xRe_c}} \left. \frac{\partial U}{\partial z} \right|_{z=0}.
\]

CFY  Skin-friction coefficient in y direction =

\[
\frac{\tau_y^*}{\frac{1}{2} \rho^* \sigma_{y,*}^*} = 2 \sin \psi \left. \frac{\partial U}{\sqrt{xRe_c}} \right|_{z=0}.
\]

CDFX  Skin-friction drag coefficient in direction perpendicular to leading edge based on chord measured perpendicular to leading edge.

CDFXINF  Total skin-friction drag coefficient in free stream direction based on chord measured parallel to free stream.

CHI(OWEN-RANDALL)  Cross-flow Reynolds number = \( \chi = Re_c \int_0^{\infty} \frac{u^*}{Q^*} d(z^*/L^*) \)

RTHETA  Reynolds number based on momentum thickness = \( \frac{u^* \theta^*}{v_{\text{min}}^*} \)

where \( \psi_{\text{min}}^* \) is the minimum of \( \psi_{\infty}^* \) or \( \psi_{\text{c}}^* \).

RTHETACRIT  Critical momentum thickness Reynolds number from Stuart (ref. 2) for prediction of instability in the Tollmien-Schlichting sense.

LAM2  Pressure gradient parameter, \( \lambda_e^2 = \frac{\theta^*}{\psi_{\text{min}}^*} \frac{\partial u^*}{\partial x} \)
\[ = (\text{THERMAL})^2 \left( \frac{1 + \frac{Y-1}{2} M_e^2}{1 + \frac{Y-1}{2} M_e^2} \right)^{\frac{3(Y-1)}{2(Y-1)}} \left( \frac{\frac{Y-1}{2} M_e^2 \cos^2 \psi}{1 + \frac{Y-1}{2} M_e^2 U^2} \right)^{3/2} \frac{x}{\frac{\text{d}U}{\text{d}x}} \right] \]

**INSTAB. RE. NO.**  
Momentum thickness Reynolds number at estimated point of laminar instability as determined from Stuart correlation.

**RTC-RTI**  
Critical momentum thickness Reynolds number minus momentum thickness Reynolds number at the point of laminar instability from Granville correlation.

**LAM2BAR**  
Average value of \[ \lambda_2 = \frac{x^*}{x^*_t} \]

**Z**  
Transformed coordinate normal to surface, \( z \).

**ZCOMP**  
Scaled coordinate normal to surface \[ z^* = \sqrt{\frac{\text{Re}_c}{x}} \]

**W**  
Transformed velocity component normal to surface, \( w \). See equation (12) in Appendix B.

**U**  
Velocity tangent to surface in \( x \) direction \[ U^* = \frac{U}{U^*} \]

**V**  
Velocity tangent to surface in \( y \) direction \[ V^* = \frac{V}{V^*} \]

**STV**  
Velocity component in direction of inviscid streamline \[ \frac{u^*}{u^*_e} \]. See Appendix C for further explanation.

**CFV**  
Velocity component perpendicular to direction of inviscid streamline (cross-flow component) \[ \frac{u^*_c}{Q^*} \]. See Appendix C for further explanation.

**T**  
Static temperature ratio \[ \frac{m^*}{m^*_c} \]

**RHOD**  
Density ratio \[ \frac{\rho^*}{\rho^*_c} \]
APPENDIX A

FINITE-DIFFERENCE SCHEME

The computational molecule for the finite-difference scheme is shown in the accompanying sketch. The point of evaluation moves from the midpoint between lines $m$ and $m + 1$ as $\alpha$, the weighting factor, varies from 0.5 to 1.0. With derivatives evaluated at the point $x = (m + \alpha)\Delta x$, $z = n\Delta z$ the following finite-difference approximations are given.

\[
\frac{\partial u}{\partial x} = \frac{u_{m+1,n} - u_{m,n}}{\Delta x} + (\alpha - 1/2)\Delta x \frac{\partial^2 u}{\partial x^2} + O(\Delta x^2) \tag{A1}
\]

\[
\frac{\partial u}{\partial z} = (1 - \alpha)\left(\frac{u_{m,n+1} - u_{m,n-1}}{2\Delta z}\right) + \alpha\left(\frac{u_{m+1,n+1} - u_{m+1,n-1}}{2\Delta z}\right) + O(\Delta z^2) \tag{A2}
\]

\[
\frac{\partial^2 u}{\partial z^2} = (1 - \alpha)\left(\frac{u_{m,n+1} - 2u_{m,n} + u_{m,n-1}}{\Delta z^2}\right) + \alpha\left(\frac{u_{m+1,n+1} - 2u_{m+1,n} + u_{m+1,n-1}}{\Delta z^2}\right) + O(\Delta z^2) \tag{A3}
\]

From the truncation error it is seen that if $\alpha = 0.5$ the scheme is second-order accurate, which is the Crank-Nicolson scheme used by Beasley. First-order accuracy is obtained if $\alpha = 1$ and this scheme is sometimes referred to as a fully implicit finite-difference scheme. In the program the weighting factor $\alpha$ is designated as $WF$, and should be restricted to the range $0.5 \leq WF \leq 1.0$. It should be noted that if $\alpha = 0.5$ the normal component of velocity which is printed is the value at $m + 1/2$, $n$; otherwise, for $\alpha > 0.5$ the value is at $m + 1, n$. 

ORIGINAL PAGE IS OF POOR QUALITY
Figure A-1. Finite-difference molecule.
APPENDIX B

GOVERNING EQUATIONS

The compressible, laminar boundary-layer equations are given as follows for the flow over an infinite, swept wing:

\[ \frac{\partial \rho u^*}{\partial x^*} + \frac{\partial \rho w^*}{\partial z^*} = 0 \]  \hspace{1cm} (B1)

\[ \rho u^* \frac{\partial u^*}{\partial x^*} + \rho w^* \frac{\partial u^*}{\partial z^*} = \rho \frac{u^*}{\epsilon} \frac{\partial \epsilon}{\partial x^*} + \frac{\partial}{\partial z^*} \left( \mu^* \frac{\partial u^*}{\partial z^*} \right) \]  \hspace{1cm} (B2)

\[ \rho u^* \frac{\partial v^*}{\partial x^*} + \rho w^* \frac{\partial v^*}{\partial z^*} = \frac{\partial}{\partial z^*} \left( \mu^* \frac{\partial v^*}{\partial z^*} \right) \]  \hspace{1cm} (B3)

The coordinate system is explained in figure B-1.

![Diagram of a yawed wing coordinate system](image)

**Figure B-1.** Yawed wing coordinate system.
The Stewartson transformation, which is given by

\[ x' = \int_0^{x'} \frac{p^* a^*}{p_{\infty} a_{\infty}} \, dx^* \]  
\( \quad \text{(B4)} \)

\[ z' = \int_0^{z'} \frac{a^*}{a_{\infty} \rho_{\infty}} \, dz^* \]  
\( \quad \text{(B5)} \)

\[ u' = \frac{a_{\infty}}{a_e} u \]  
\( \quad \text{(B6)} \)

\[ v' = \frac{a_{\infty}^2 p_{\infty}}{a_e^2 e} \left( u' \frac{3z'}{3x^*} + \frac{p^*}{\rho_{\infty}} v^* \right) \]  
\( \quad \text{(B7)} \)

is applied to equations (B1) - (B3). In addition it is assumed that the Prandtl number is unity, the total temperature equals the free stream value, and the viscosity coefficient varies linearly with the temperature. The transformed equations are:

\[ \frac{\partial u^*}{\partial x'} + \frac{\partial v^*}{\partial z'} = 0 \]  
\( \quad \text{(B8)} \)

\[ u' \frac{\partial u^*}{\partial x'} + w' \frac{\partial u^*}{\partial z'} = \left[ 1 + \frac{\gamma-1}{2} \frac{M_{\infty}^2 \sin^2 \psi}{1 + \frac{\gamma-1}{2} M_{\infty}^2 \cos^2 \psi} \left( 1 + \frac{\gamma \frac{v^*}{\rho_{\infty}^2 \sin^2 \psi} \frac{u^*}{e} \frac{dx^*}{dx'} \right) \right] \frac{du^*}{dx'} \]

\( + \frac{v^*}{\rho_{\infty}^2 u^*} \frac{\partial^2 u^*}{\partial z'^2} \]  
\( \quad \text{(B9)} \)

\[ u' \frac{\partial v^*}{\partial x'} + w' \frac{\partial v^*}{\partial z'} = v_{\infty} \frac{\partial^2 v^*}{\partial z'^2} \]  
\( \quad \text{(B10)} \)
The coefficient of the external velocity gradient in equation (B9) gives rise to a coupling between the $x$ and $y$ momentum equations which is not present in incompressible flow. This coefficient varies from its maximum value at the surface to unity at the boundary-layer edge as $v^*$ approaches its edge value $Q^* \sin \psi$. This maximum value increases as the Mach number and sweep angle increase; nevertheless, this coefficient remains close to unity for flows in the transonic speed range, which is the present area of interest. For example, the maximum value of this coefficient is 1.06 or less for $\psi = 35^\circ$ and free stream Mach numbers of one or less. In the present program this coefficient is set equal to unity and the $x$ momentum equation becomes

$$u' \frac{\partial u'}{\partial x'} + v' \frac{\partial u'}{\partial z'} = u' \frac{e}{e} \frac{\partial u'}{\partial x'} + v^* \frac{\partial^2 u'}{\partial z'^2} \quad (B11)$$

Thus it is seen that with the given assumptions, the Stewartson transformation converts the compressible equations into an equivalent incompressible formulation. This formulation is the starting point for Beasley's analysis which will be repeated for convenience.

Beasley applied the Blasius transformation given by

$$
\begin{align*}
    x &= \frac{x'}{L^*} \\
    z &= \left(\frac{U'x'}{v^*}\right)^{1/2} \frac{z'}{x'} \\
    U &= \frac{U'}{Q^*} \\
    v &= \frac{v'}{Q^*} \\
    u &= \frac{u'}{U'} \\
    v &= \frac{v^*}{V'} \\
    w &= \frac{v'}{U'} \left(\frac{U'x'}{v^*}\right)^{1/2}
\end{align*}
\quad (B12)
$$

to equations (B8), (B11), and (B10), respectively, and obtained
\[ x \frac{\partial u}{\partial x} + \frac{x}{U} \frac{\partial u}{\partial x} u + \frac{2}{U} \left( \frac{x}{U} \frac{\partial u}{\partial x} - 1 \right) \frac{\partial u}{\partial z} + \frac{\partial w}{\partial z} = 0 \]  \hspace{1cm} (B13)

\[ xu \frac{\partial u}{\partial x} + \left[ w + \frac{ux}{2} \left( \frac{x}{U} \frac{\partial u}{\partial x} - 1 \right) \right] \frac{\partial u}{\partial z} = (1 - u^2) \frac{x}{U} \frac{\partial u}{\partial x} + \frac{2^2 u}{\partial z^2} \]  \hspace{1cm} (B14)

\[ xu \frac{\partial v}{\partial x} + \left[ w + \frac{ux}{2} \left( \frac{x}{U} \frac{\partial u}{\partial x} - 1 \right) \right] \frac{\partial v}{\partial z} = \frac{2^2 v}{\partial z^2} \]  \hspace{1cm} (B15)

The surface boundary conditions including suction are given as

\[ z = 0, \quad u = v = 0 \]

\[ w = \frac{\left( 1 + \frac{\gamma - 1}{2} \frac{m_e^2}{e} \right)^{1/2}}{\left( 1 + \frac{\gamma - 1}{2} \frac{m_e^2}{e} \right)^{3/2} \sqrt{\frac{2}{U}} \left( \frac{w^{*} \sqrt{Re_{\infty}}}{Q_{\infty}^{*}} \right)} \]  \hspace{1cm} (B16)

The edge conditions are

\[ z \rightarrow \infty \quad u \rightarrow 1, \quad v \rightarrow 1. \]  \hspace{1cm} (B17)

Note that in equation (B16) the Mach number of the inviscid flow is given as

\[ m_{e}^2 = \frac{\left[ U^2 \left( 1 - \frac{\gamma - 1}{2} \frac{m_e^2}{e} \right) + \sin^2 \psi \right]}{1 - \frac{\gamma - 1}{2} \frac{m_e^2}{e} \cos^2 \psi} \]  \hspace{1cm} (B18)

The scaled, non-dimensional suction velocity, \( \frac{w^{*} \sqrt{Re_{\infty}}}{Q_{\infty}^{*}} \), is referred to as WWALL in STAYLAM and is part of the input.

After the solution is obtained in terms of transformed, incompressible variables the corresponding compressible quantities are obtained as follows:
The momentum and displacement thicknesses are given by

\[
\frac{\theta^*}{L^*} = \frac{x}{U_{\infty}} \sqrt{\frac{1 + \frac{\gamma - 1}{2} \frac{M^2}{\infty}}{1 + \frac{\gamma - 1}{2} \frac{M^2}{e}}} \left( \int_0^\infty (1 - u) \, dz \right) \tag{B25}
\]

\[
\frac{\delta^*}{L^*} = \frac{x}{L^* e} \sqrt{\frac{1 + \frac{\gamma - 1}{2} \frac{M^2}{\infty}}{1 + \frac{\gamma - 1}{2} \frac{M^2}{e}}} \left( \int_0^{z_e} u \, dz \right) \tag{B26}
\]

where the subscript \( e \) denotes the edge of the boundary layer. The local skin-friction coefficients are
\[ C_{f,x} = 2U \frac{U}{\sqrt{xRe_\infty}} \left( 1 + \frac{Y-1}{2} \frac{\mu^2}{\mu_e^2} \right)^{\frac{2\gamma-1}{\gamma-1}} \left. \frac{\partial u}{\partial z} \right|_{z=0} \]

\[ C_{f,y} = 2 \sin \psi \frac{U}{\sqrt{xRe_\infty}} \left( 1 + \frac{Y-1}{2} \frac{\mu^2}{\mu_e^2} \right)^{\frac{3\gamma-1}{2(\gamma-1)}} \left. \frac{\partial \psi}{\partial z} \right|_{z=0} \]
APPENDIX C
VELOCITY COMPONENTS

The resolution of the velocity components at any point in the boundary layer into the streamwise and crossflow components, respectively, is given as follows:

\[ u_s^* = u^* \cos \phi + v^* \sin \phi \] (C1)

\[ u_c^* = v^* \cos \phi - u^* \sin \phi \] (C2)

These components are non-dimensionalized by the free stream velocity, \( U_{\infty} \), and the Stewartson transformation is incorporated to give

\[ \frac{u_s^*}{U_{\infty}} = \left( \frac{1 + \frac{Y-1}{2} M_e^2}{1 + \frac{Y-1}{2} M_{\infty}^2} \right)^{1/2} \frac{U \cos \phi + v \sin \psi \sin \phi}{U_{\infty}} \] (C3)

\[ \frac{u_c^*}{U_{\infty}} = \frac{U \left( 1 + \frac{Y-1}{2} M_e^2 \right)^{1/2}}{\left( 1 + \frac{Y-1}{2} M_{\infty}^2 \right)} (v - u) \sin \phi \] (C4)

Note that at the boundary-layer edge

\[ \frac{u_s^*}{U_{\infty}} = \left[ u^2 \left( \frac{1 + \frac{Y-1}{2} M_e^2}{1 + \frac{Y-1}{2} M_{\infty}^2} \right) + \sin^2 \psi \right]^{1/2} \] (C5)

\[ u_c^* = 0 \] (C6)
Figure C-1. Resolution of velocity components.
APPENDIX D

PROGRAM LISTING

PROGRAM STAYLAM(INPUT, OUTPUT, TAPE1=INPUT, TAPE2=OUTPUT)

C MASTER LAMINAR BOUNDARY LAYER

COMMON/SURFV, ITS, TOL, IFCON, DS, DB1, NZ, WF, SH, UMGH, AG, CON3, CON6,
INTG, G, AN(170), ROO(170), RN(170), RNO(170), CIN(170), DDO(170)
2, N(170), RDL, NOO(170), NDN(170), UM1(170), UMG(170), WH(170), KH(170),
3, ND(170), (4), AN(170)
COMMON/XSANDV, UM(365), FITH(365), INTA, FZTH(365)
COMMON/XSANDV/JM(365), VMTH(365), FITH(365), XV(365), CPUM(365),
158V(365), SXVINC(365), LV8VINC(365), L, SAT, INT3, CH, ISP
COMMON/RESULT/VMUX(170), UM2(170), VM2(170), DEPA1, TMETA1, NO, DUDZ
1, DUDZ
COMMON/GENM/A(365), ZA(365)
DIMENSION XAHLD(365), ZAHLD(365)
COMMON/RH(170), INTL, IFH
COMMON/OPLIST/OPX(200), OPB(200)
COMMON/COMPRE8/INC, AMINF, AEM, 81NP, CISP, GAMMA, GAM1, GAM2, GAM3,
100GAMHQ, HRSO, TOH, SCOMP, ZCOMP(170), T(170), RHOD(170)
REAL MMGRAD
DIMENSION S(2), R(R, C(R)
DIMENSION UM1(170), UM2(170), VM2(170)
DIMENSION WMALL(15), SM6(15)
DIMENSION VCFX2(P00), VCFY2(200), HSCOMP(200), LABEL(8)
1. LAB(8), INFO(30)
REAL KMAX(lO)
P1=3.14159265
QTM=0.17453292
CALL PSEUDO
CALL LEROY
C READ BOUNDARY LAYER CALCULATION PARAMETERS
C MAXIMUM NO. OF ITERATIONS, NO. OF STEPS IN Z DIRECTION, ITERATIVE
C TOLERANCE, STEPLengthS IN Z AND X DIRECTIONS, AND MAX VARIATION IN U
C AROSS ONE STEP, WEIGHTING FACTOR FOR FINITE DIFFERENTIATION SCHEME

CALL JPARAMS(INFO)
ENCOD(RO, 025, LAB(1), INFO(1), INFO(23), INFO(22)
425 FORMAT(A7, 3X, ZA10, 50X)
24 READ(1, 6) ITS, J, TOL, NZ, DB, USTEP, WF
6 FORMAT(215, 5F10.5)

WRITE(2, (103)
103 FORMAT(1H1/1X65(2H=)1/
14X,*INPUT + SOME COMPUTED QUANTITIES*
2//1X65(2H=)1/
WRITE(2, (400) ITS, J, TOL, NZ, DB, USTEP, WF
400 FORMAT(5H ITS=, 15, 2X, ZH=, 15, 2X, UH=, 15, 2X, FH=, 15, 2X, 3HDI=, F10.5, 2X, 3HDZ=, F10.5, 2X,
13HDX=, F10.5, 2X, 6HUDSTP=, F10.5, 2X, 3HMFW=, F10.5)

C READ BOUNDARY LAYER SUCTION OR INJECTION PARAMETER, IBLC.
C IBLC=0, NO SUCTION OR INJECTION PERMITTED.
C IBLC=1, DISCONTINUOUS SUCTION OR INJECTION PERMITTED.

READ(1, 77) IBLC
77 FORMAT(15)
IF(IBLC.EQ.0) GO TO 78

C READ SUCTION OR INJECTION VELOCITY PARAMETER, WALL(MB) = WSG*GRT(DL/NU

ORIGINAL PAGE IS OF POOR QUALITY
C WHICH IS ALLOWED TO CHANGE DISCONTINUOUSLY AT SDS(MS) LOCATIONS, A
C TOTAL OF MSMAX LOCATIONS ARE PERMITTED.

READ(1,77)MSMAX,
READ(1,502)MM;WALL(MS),SDS(MS),MSMAX
WRITE(2,79)
79 FORMAT(* INLCM! DISCONTINUOUS SUCTION OR INJECTION GIVEN BELOW*)
WRITE(2,80)MSMAX
80 FORMAT(* 1X29hsuction or injection location, 5X10hs location,
$15X6MSMAX=15*)
WRITE(2,81)MM;WALL(MS),SDS(MS),MSMAX
81 FORMAT(I10,9HXWALL(MS),26XSDS(MS)/(10XF10.5,15XF10.5))
GO TO 82
76 WRITE(2,84)
74 FORMAT(* IBLCM! NO SUCTION OR INJECTION PERMITTED*)
$MM;WALL(1) = 0, SDS(1) = 100000.
92 CONTINUE

C READ COMPRESSIBILITY PARAMETER, INC, AND FREESTREAM MACH NO., AMINF30
C INC=0 FLOW IS INCOMPRESSIBLE, COMPUTATION MADE IN STEWARTSON
C TRANSFORMED VARIABLES

READ 85,INC,AMINF30,GAMMA
85 FORMAT(15,F10.2)
IF(INC.EQ.1)AMINF30=0.,
PRINT 86,INC,AMINF30,GAMMA
86 FORMAT(* INC!=I2, AMINF30=E16.8, GAMMA=E16.8)
IF(INC.EQ.1) GO TO 89
PRINT 87
87 FORMAT(* COMPRESSIBLE FLOW(INC=0), STEWARTSON TRANSFORMATION USED*)
GO TO 90
88 FORMAT(* INCOMPRESSIBLE FLOW (INC=1),*)
90 CONTINUE

C CONSTANTS NEEDED FOR COMPRESSIBLE FLOW CALCULATION
C
GAM1=GAMMA=1.,
GP1=GAMMA=1.,
GAM1=(3.*GAMMA-1.)/(2.*GAM1)
GAM2=GP1/(2.*GAM1)
GAM3=GAMMA/D1
GAM4=(2.*GAMMA-1.)/(GAMMA-1.)
AMF30=5.*GAM1*AMINF30**2
C READ MAIN TITLE (COLS 1-72)
74 READ(1,151)B
151 FORMAT(8A10)
WRITE(2,420)B
420 FORMAT(1HO,3HH,8A10)
C READ GEOMETRY PARAMETER AND CHORD LENGTH
C IF INT300 VELOCITY DATA WILL BE GIVEN AT INTERVALS MEASURED AROUND THE
C AEROFIL SURFACE AND NO GEOMETRICAL DATA IS REQUIRED

READ(1,72)INT3,CH
72 FORMAT(15,F10.5)
WRITE(2,401)INT3,CH
401 FORMAT(1HO,SHINT3*,15,2X,SHCH*,F10.5)
C MUST DISTANCES AROUND SURFACE BE CALCULATED
    IF(INT3, EQ, 0) GO TO 75

C READ GEOMETRIC DATA
C SYMMETRY PARAMETER, NO. OF PAIRS OF CO-ORDINATES, NOSE RADIUS,
C IF ISY=0 AEROFIIL IS SYMMETRY, IF ISY=1 AEROFIL IS SYMMETRICAL.

76 READ(1, 100) ISY, INT4, RHO
100 FORMAT(2I5, 2F10.5)
WRITE(2, 400) ISY, INT4, RHO
400 FORMAT(2I5, 4I1, 15, 2X, 5HINT4, 15, 2X, 9HRHO, E16.8)
RHO=RHO/CH

C READ (INT4) PAIRS OF X AND Z
   N1=[INT4]*1*ISY+1
   N2=[INT4]*1*ISY+INT4
READ(1, 510) (XAML(N), ZAML(N), N=N1, N2)
510 FORMAT(2E16.8)
502 FORMAT(2F10.5)

C READ ISP, SURFACE PARAMETER
C ISP=2 UPPFR SURFACE CALCULATION
C ISP=0 LOWER SURFACE CALCULATION
C
READ(1, 100) ISP
WRITE(2, 111) ISP
111 FORMAT(2I5, 15)
101 FORMAT(/ ' ISP=', ISP)
1F(ISP, EQ, 2) GO TO 107
DO 105 N=N1, INT4
   XP=INT4+N+1
   XA(N)=XAML(N)
   105 ZA(N)=ZAML(N)
GO TO 110
107 DO 109 N=N1, INT4
   XA(N)=XAML(N)
   ZA(N)=ZAML(N)
GO TO 110
110 CONTINUE

C CALCULATE DISTANCES AROUND SURFACE CORRESPONDING TO DISTANCES
C ALONG CHORD LINE.
   CALL GEOMETRY(ISY, RHO, CH)
   WRITE(2, 213) (N, XA(N), ZA(N), XAML(N), ZAML(N), TH(N), TH(N), 15, 2X, 5HINT4, 15, 2X, 9HRHO, E16.8)
213 FORMAT(1X, 15, 4I1, 15, 2X, 5HINT4, 15, 2X, 9HRHO, E16.8)

C READ TWO OUTPUT PARAMETERS, NO. OF POINTS IN OUTPUT LIST (IF IFPT#2)
C AND OUTPUT INTERVAL IN X (IF IFPT#4)
C IFPT#1, FULL PRINT OUT EVERY STEP, IFPT#2, FULL P/O AT POINTS IN LIST,
C IFPT#3, FULL P/O AT VELOCITY DATA POINTS, IFPT#4, FULLP/O AT EVERY
C NTH STANDARD O/P STEP,DX, IN Z DIRECTION EVERY INT1 POINT IS PRINTED.

75 READ(1, 106) IFPT, INT1, NLIST, DX
106 FORMAT(3I5, 2F10.5)
513 FORMAT(2I5, 15, 2X, 5HINT4, 15, 2X, 9HRHO, E16.8)

ORIGINAL PAGE IS
OF POOR QUALITY
IF(IFPT,NE,2)GO TO 310
C READ LIST OF OUTPUT POINTS
READ (1,501)(OPX(N),N=2,NLIST=1)
501 FORMAT(AF10,5)
WRITE(2,405)(OPX(N),N=2,NLIST=1)
405 FORMAT(1H0,6MPX(N)/(1H ,8(F10.5,2X)))
310 CONTINUE
C READ SUB-TITLE
73 READ(1,1511C
WRITE(2,421)
421 FORMAT(IO,4HPSI,F10.5,2X,6HDTTRP,F10.5)
PSI=DTTRP
COS=CO2(PSI)
SINF=SIN(PSI)
C READ NUMBER OF VALUES OF REYNOLDS NUMBER AND DEFINITION PARAMETER
C IFIR=1, RN=DL*SEC(PSI)/NU, IFR=2, RN=DL/NU, IFR=3, RN=DL*SEC(PSI)/NU
READ(1,100)INTNL,IFR
READ(1,501)(RLN(1),I=1,INRL)
WRITE(2,407)INTNL,IFR
407 FORMAT(1H0,6HINTNL,1P2X,6HIFR,E12)
WRITE(2,411)(RLN(1),I=1,INRL)
411 FORMAT(1H0,6HRLN(1)/(1H ,8(F10.1,2X)))
C READ VELOCITY DATA PARAMETER AND NO. OF PAIRS OF VALUES TO FOLLOW
C INTV=1, U FOLLOW, INTV=2, U*SEC(PSI) FOLLOW, INTV=3, CPS FOLLOW
98 READ(1,100)INTVL,L
LP1=LP1+1
READ(1,510)(XV(I),UM(I),I=1,LP1)
IF(ISP,EQ,2) GO TO 112
DO 108 LP1=1,LP1
108 XV(I)=XV(I)
112 ICOUNT=0
WRITE(2,409)INTVL,L
409 FORMAT(1H0,5HINTVL,1P2X,2HL#13)
IF(INC,NE,0) PRINT 503
503 FORMAT(4HFLOW IS COMPRESSIBLE AND THE FOLLOWING UM(I) IS THE MACH
1 NO. DISTRIBUTION NORMAL TO THE LEADING EDGE (HEN))
WRITE(2,410)(1,XV(I),UM(I),I=2,LP1)
IF(INC,EQ,1) GO TO 505
AMINFR=AMINFR
DO 504 I=2,LP1
504 UM(I)=UM(I)*AMINFR
505 CONTINUE
410 FORMAT(1H0,4X1H1,3X5HXXV(I),5X5HUM(I)/(1X,15,2F10.5))
UM(I)=0.0
C CONVERT VELOCITY DATA TO U.
IF(INTVNE,1) CALL VELOCTS (INTV,COSP)
C READ VELOCITY GRADIENT AT ATTACHMENT LINE AND, IF VGRAD > 0 AND
C INT3 NOT = 0 , DISTANCE FROM LEADING EDGE TO ATTACHMENT LINE .
IF (INC.EQ.1) GO TO 422
C FLOW IS COMPRESSIBLE, READ IN MGRAD*AMINF3D*DSCOMP, THEN COMPUTE VIA THE
C STEWARTSON TRANSFORMATION THE TRANSFORMED INCOMPRESSIBLE VELOCITY
C GRADIENT, VGRAD, WHERE
C VGRAD=UPRIME/DN*DBINC
C =VGRAD/AMINF3D*DSCOMP*DBINC*SEC(P1)
READ(1,501) MGRAD,XV(1)
IF(ISY.EQ.2) GO TO 113
XV(1)=XV(1)
113 WRITE(2,428) MGRAD
428 FORMAT(* MGRAD=*,E16.8)
429 IF(ISY.EQ.2) GO TO 113
VGRAD=MGRAD/AMINF3D*RATIO**GAM1/COSP
GO TO 427
427 READ(1,501) VGRAD,XV(1)
428 WRITE(2,411) VGRAD,XV(1)
411 FORMAT(* VGRAD=*,E16.8)
VGRAD=VGRAD/GAM1
GO TO 13
13 CALL VGRADAT(ALPHA,RHO,KN,S3,VGRAD,XV(1))
XV(1)=XV(1)*CH
C INTERPOLATE FROM TABLES TO FIND DISTANCES FROM ATTACHMENT' LINE TO
C POINTS AT WHICH VELOCITY DATA IS GIVEN.
122 CALL STHRMX (L+1,XV,SVX,THXV,OBST,INT3,CH,XV(1),SATT)
PRINT 511,BATT
511 FORMAT(* NON-DIMENSIONAL DISTANCE FROM LOWER SURFACE TRAILING EDGE
18 (IF UPPER SURFACE IS TO BE COMPUTED,ISP=2), OR FROM UPPER SURFACE
2E=TRAILING EDGE (IF LOWER SURFACE IS TO BE COMPUTED,ISP=0) TO
3=ATTACHMENT LINE = SATT/CH **E16.8/)
IF (INC.EQ.1) GO TO 508
C FLOW IS COMPRESSIBLE, USE THE STEWARTSON TRANSFORMATION IN
C S/R SINCFSR TO TRANSFORM THE ACTUAL SURFACE DISTANCE, S, INTO AN
C EQUIVALENT INCOMPRESSIBLE DISTANCE, SINC
C CALL SINCFSR(LP1,SXV,SVXING,UM,DSCOSI1,DSCOSI2)
GO TO 507
508 DO 506 K=1,LP1
506 SVXING(N)=SXV(N)
507
ORIGINAL PAGE IS
OF POOR QUALITY
GO TO 509
C FROM SXVINC AND SXV(SXVINC) COMPUTE FVVINCG FOR INTERPOLATION
FROM INCOMPRESSIBLE, TRANSFORMED (STEWARTON) PLANE TO
COMPRESSIBLE, PHYSICAL PLANE
C
517 CALL CSG(SXVINC,SXV,FBSVINC,LP1,DSDSI1, DSDSI2)
509 CONTINUE
C WRITE MAIN AND SUB TITLES
WRITE(2,83) B,C
83 FORMAT(1H1,8A10/1H0,8A10)
WRITE(2,414)
414 FORMAT(1H0,31HREYNOLDS NUMBER DEFINED BY ANM )
IF(IFR.EQ.1) WRITE(2,415)
IF(IFR.EQ.2) WRITE(2,416)
IF(IFR.EQ.3) WRITE(2,417)
415 FORMAT(1H+,31X,14HOL=SEC(PSTI)/NU)
416 FORMAT(1H+,31X,10HOL=CO.(PSTI)/NU)
417 FORMAT(1H+,31X,14HOL=CO.(PSTI)/NU)
418 WRITE(2,92) VGRAO
92 FORMAT(9HVELOCITY GRADIENT AT ATTACHMENT LINE, \FB,2)

LP1=LP1+1
C FROM THETA AND U(THETA) COMPUTE FUTH FOR VELOCITY INTERPOLATIONS.
C CALL CSG(THXV,UM,FUTH,L,DSDVGRAD*COEPL,UM(L)-UM(L-1)/(THXV(L)-
THXV(L-1)))
C WRITE TABLE OF VELOCITY DATA
CALL XSCPPNT(INTV)
MLIST=NLIST+1
C COMPIL LIST OF OUTPUT POINTS IF REQUIRED.
C IF(IFP1.EQ.1)CALL PLIST(IFP1,NLIST,SXV,SXVINC,L,DS,INT3,CH,XV(1),
IDX,INC)
C IS WING SHEARED
IF(PSTI.LT.,00001) GO TO 26
C GUES AT VELOCITIES AT ATTACHMENT LINE
C
26 AM J
DO 9 N=2,J
UM1(N)=UM1(N-1)/A
9 CONTINUE
C CONSTANT
AON=0.5/(DZ*DO2)
C SET STEP COUNT
N=1
M=1
IFCON=0
C BOUNDARY CONDITIONS INCLUDING SUCTION OR INJECTION,
32
C GO TO S/P WUV TO COMPUTE W, U AND V AT ATTACHMENT LINE.

CALL WUCV(1,0)
ANGLE1=ANGLE2,5*PI
SCOMP=0,
AME3=1.5*(AMINF3D**2*SINP**2)/(1.+AMFR3D*COSP**2))

C WRITE ATTACHMENT LINE PROFILES

C LEADING EDGE CONTAMINATION TEST

WRITE(2,104)
104 FORMAT(1H1/1X$,(2H1'=//6X$OUTPUT//1X$2H1'))
CALL CONTAM(VGRAD, DTRIP, CH, COSP, SINP, THETA1, RATIO)
CALL PRINTEXV(1,0,0,VGRAD*COSP,J,02,INT1,1,0,,0,ANGLE2)

DO 18 NAT, INTRL
KMAX(N)=0,0
18 CONTINUE

C ADVANCE STEP COUNT
11 M=M+1
LC=0

C CALCULATE LENGTH OF NEXT STEP IN X DIRECTION

10 CALL SPLNTH(SNEXT,B,INTHOLD,DS,DS1,DS2,NEXT,NLIST,LAST,
JFPT,LC,ILP,ILPINT,STEP,DUPS,X,SH,ITC,ANGLE2,WP)

C IS COMPUTATION TO END
IF(LAST.EQ.2) GO TO 239

C DOES THIS STEP END AT A LISTED OUTPUT POINT
IF(ILP.NE.1) GO TO 49

C STORE U(M=2), U(M=1) AND V(M=1) PROFILES WHILE A STEP ENDING AT A
C LISTED OUTPUT POINT IS COMPUTED
DO II,MM=2,4
UM1(N)=UM1(N)
UM2(N)=UM2(N)
46 CONTINUE
49 CONTINUE

C VARIABLES INDEPENDENT OF N
UAVG*W/2*(1.-WF)*(U(2)=U(1))=1.
CON1*(1.-W)*W
CON2*(1.-WF)/WF
CON3*SH/D81*UAVG
CON4*(1.-WF)*SH/D81
CON5*(1.-WF)/WF)*W
CON6*SH/D8/(W*WF+D81*UAVG)
CON7*SH/D81

C VARIABLES DEPENDENT ON N
DO 3 NM2,J
GAM2*(UM2(N+1)-UM2(N+1))/2,*(1.-WF)*U(1)*(UM2(N)*UM2(N+1))
AND(N)=CON2*G(WF=1.)*UM2(N)+UM2(N+1)
MNOD(N)=CON2*N(N-1)+1.)*(U(2)=U(1))+(UM2(N)*UM2(N+1))
1=CON3*(W(N-1)=U(N))+(UM2(N-1)-UM2(N-1))
IF(W.LT.5011)AND(N)=-5*MNOD(N)
RF(N)=CON3*W*CON2*(W-1.)*G*(UM2(N-1)+UM2(N+1))
CON1*(1.-WF)+(U(N)+UM2(N))=CON1*(UM2(N)*UM2(N+1))
CON2*(1.-WF)*CON1
CON3=CON4*(UM2(N)+2.)*W*CON1
NTCON(N)=CON5*(UM2(N)+2.)*W*CON1
3 CONTINUE

C COMPLETE THE SPECIFICATION OF SURFACE SUCTION OR INJECTION VELOCITY,
C COMPLETE THE SPECIFICATION OF SURFACE SUCTION OR INJECTION VELOCITY,
IF(I8L.EQ.0)GO TO 201
WCON2=SCOMP*(1.,5.)*(GAMMA=1.)*AMSD**2)/(1.+AMFB3D)**1.5
SCOMP=WF*SCOMP*(1.-WF)*SCOMP
TF(5DS(N),G1,SCOMP) GO TO 200
H5=H5
200 REM=KALL(M8)*(3*UAVG)**.5*(WF*CON2*(1.-WF)*HCON1)
GO TO 202
201 REM=0.
202 CONTINUE

C COMPUTE WM, UM AND VM PROFILES
CALL WUVW(M8(2))

C COMPUTE SKIN FRICTION DRAG BASED ON REYNOLDS NUMBER DEFINITION, IFR=2
C AND THE FIRST VALUE IN REYNOLDS NUMBER ARRAY, RNL(I).

34
C CFXITAUX/(.5*RHOINF*QINF**2) 401
C CFXITAUX/(.5*RHOINF*QINF**2) 402
C CDFX = SKIN FRICTION DRAG COEFFICIENT IN DIRECTION PERPENDICULAR TO LE 403
C BASED ON CHORD MEASURED PERPENDICULAR TO LE 404
C CDFXINF = TOTAL SKIN FRICTION DRAG COEFFICIENT IN FREESTREAM DIRECTION 405
C BASED ON CHORD MEASURED PARALLEL TO FREESTREAM 406

    IF(ILP, EQ, 1) GO TO 203
    ICONST = ICONST+1
    DSCOMP = DSCOMP + SCOMP
    CFX2 = 2.0 * (U(2) / (RNL(1) * S(2)))**0.5 * DUD2
    CFY2 = 2.0 * (U(2) / (RNL(1) * S(2)))**0.5 * DUD2
    DCFX = 5.0 * DSCOMP * (COB(ANGLE1) - CFX1) + DCFX2
    VCFX2 = ICONT * 1000.0 * CFY2
    VCFY2 = ICONT * 1000.0 * CFY2
    H8COMP(I000NT) = SCOMP
    CDFXRCOFX + DCFX
    CDFXINF = CDFXINF + DCFX
    CDFXINF = CDFXINF + DCFX * CDFX + CFY1

203 CONTINUE

C HAS ITERATION CONVERGED
IF(IFCON .EQ. 0) GO TO 239
C HAS STEP LENGTH BEEN HALVED TWICE ALREADY
IF(LC .EQ. 2) GO TO 23A
C HAVE STEP LENGTH AND TRY AGAIN
LC = LC + 1
GO TO 10

23A IFCON = 3
LAST = 2
C DETERMINE IF PRINT OUT IS TO BE COMPLETE, PARTIAL OR SKIPPED
239 CALL IFPRINT(IFPT, ILP, LAST, JACKPOT)
    IF(JACKPOT, EQ, 0) GO TO 5
C COMPUTE CROSSFLOW VELOCITIES
    IF(PSI, GT, 0.0001) CALL CRSSFLW(J, OZ, U(2))
C WRITE LAYER CALCULATION RESULTS AS REQUIRED
    CALL PRINT(X, S(2), U(2), DUO8, J, OZ, INTL, JACKPOT, PSI, LC, ANGLE2)
C CALCULATE DIMENSIONALISING FACTORS
    CALL DMNSION(S(2), U(2), COB, DELTA1, THETA1, ILP, CFX2, CFY2, CDFX, CDFXINF)
C RE-LAMINARISATION TEST
    IF(KMAX(INTRL), GT, 0.5) CALL RELAM(U, S, 8IMP, COB, KMAX)
C IS PRINTOUT COMPLETE
    IF(JACKPOT, EQ, 2) GO TO 5
C CROSSFLOW INSTABILITY TEST
    IF(PSI, GT, 0.0001) 1 CALL INSTAB(COB, S(2), U(2), CH, RATIO, AME30, AMINF30)
C VISCOUS INSTABILITY TEST
50 CALL TRANS(B(2), DUO8, THETA1, U(2), U(1), IST, JACKPOT)
C IS STEP JUST ENDED THE LAST ONE REQUIRED
IF(LAST, EQ, 1) GO TO 27

C DOES LAST STEP END AT A LISTED OUTPUT POINT
IF(FLIP, EQ, 1) GO TO 47

U(1)=U(2)
S(1)=S(2)
SCOMP1=SCOMP
WCON1=WCON2
NSZ=DS1
CFX1=CFX2
CFY1=CFY2
ANGLE1=ANGLE2
GO TO 11

C REPLACE U(M=2), U(M=1) AND V(M=1) PROFILES WITH THOSE STORED AT START
C OF LAST STEP
47 DO 48 M=2, J
UM1(N)=UM1(N)
UM2(N)=UM2(N)
VM1(N)=VM1(N)
VM2(N)=VM2(N)
48 CONTINUE
GO TO 11

27 WRITE(2,19)
19 FORMAT(33HOLAMINAR FLOW CALCULATED TO END OF DATA OR LAST POINT HE
REQUESTED)
GO TO 21
5 WRITE(2,20)
20 FORMAT(11HSEPARATION)

C READ CUE TO READ MORE DATA OR TO FINISH
21 READ(1,100)KUE
WRITE(2,101)KUE
101 FORMAT(1H3H RUEmp17)

C PLOT INSTRUCTIONS FOR X AND Y SKIN FRICTION DISTRIBUTIONS
C
NPTS=NCOUNT
HGT1=1.0S HGT1=1.0S HGT2=0.0S HGT3=0.0S
NP1=NPTS+1
NP2=NPTS+2
XORG=0.5 XORG=0.
YSCALE=2
XPG=5.
YPG=6.
XDV=0.5 XTIC=1.
YDV=0.5 YTIC=1.
ORG=0.
CALL BSCALE(VCFX2,YPG,NPTS+1,1,0.5,ORG)
YSCALE=VCFY2(NP+1)*VCFY2(NP+2)
VCFX2(NP+1)=VCFY2(NP+2)*YORG
VCFX2(NP+2)=VCFY2(NP+2)*YSCALE
HSCOMP(NP+1)*XORG
HSCOMP(NP+2)*YSCALE
CALL CALPLOT(2,1,3)
CALL AXES(0.0,0.0,0.0,90.,YPG,VCFX2(NP1),VCFX2(NP2),YTIC,YDV,1H,HGT1,

36
SUBROUTINE SINCFRS(J,SXV,SXVINC,UM,DSCD512) 634
DIMENSION SXV(1),SXVINC(1),UM(1) 635
COMMON/COMPREINC,AINF3D,AME3D,SINF,COSP,GAMMA,GAM2,GA M3,GAM4,AMF53D,RATIO,SCOMP,ZCOMP(170),TI(170),RHOD(170) 636
C 637
C USE STEWART'S TRANSFORMATION TO CONVERT SXV, THE PHYSICAL DISTANCE 638
C AROUND THE AIRFOIL AT WHICH MACH NO. IS GIVEN, TO SXVINC, AN 639
C EQUIVALENT INCOMPRESSIBLE COORDINATE 640
C
C GM1*GAMMA/.1 641
DENOM1=1/(1+AHS3D*COSP**2) 642
SXVINC(1)=0 643
CON=(1+AHS3D)**GAM1 644
FAC1=1+AHS3D 645
DO 10 N=2,J 646
AME3D=AMINF3D**2*(UM(N)**2+FAC1*SINF**2)*DENOMR 647
AME3D=AMINF3D**2*(UM(N-1)**2+FAC1*SINF**2)*DENOMR 648
AME11=AME1+5*GM1*AME3D 649
10 SXVINC(N)=SXV(N-1)+SXVINC(N-1) 650
AME3D=AMINF3D**2*(UM(N)**2+FAC1*SINF**2)*DENOMR 651
AME3D=AMINF3D**2*(UM(N-1)**2+FAC1*SINF**2)*DENOMR 652
AME11=AME1+5*GM1*AME3D 653

423 FORMAT(4AMTNF3D,45,3X,4H PSTMR4,1,3X,HPNL(1),HPE9,2,3X) 619
CALL NOTATE(J=1,X=0.00,Y=HGT,Z=0.00,1=1.05) 620
ENCODE(AO,423,LABEL(1)) 621
426 FORMAT(4AMTFR3D,45,3X,4H PSTMR4,F7.5,5X,2HCOFX,2,5X,7RHO,7,4RX) 622
CALL NOTATE(J=1,X=XPLT,Y=YPLT,Z=0.00,1=1.05) 623
ENCODE(AO,426,LABEL(1)) 624
ENCODE(AO,427,LABEL(1)) 625
STOP 0101 626
END 627

SUBROUTINE SINCFRS(J,SXV,SXVINC,UM,DSCD512) 634
DIMENSION SXV(1),SXVINC(1),UM(1) 635
COMMON/COMPREINC,AINF3D,AME3D,SINF,COSP,GAMMA,GAM2,GA M3,GAM4,AMF53D,RATIO,SCOMP,ZCOMP(170),TI(170),RHOD(170) 636
C 637
C USE STEWART'S TRANSFORMATION TO CONVERT SXV, THE PHYSICAL DISTANCE 638
C AROUND THE AIRFOIL AT WHICH MACH NO. IS GIVEN, TO SXVINC, AN 639
C EQUIVALENT INCOMPRESSIBLE COORDINATE 640
C
C GM1*GAMMA/.1 641
DENOM1=1/(1+AHS3D*COSP**2) 642
SXVINC(1)=0 643
CON=(1+AHS3D)**GAM1 644
FAC1=1+AHS3D 645
DO 10 N=2,J 646
AME3D=AMINF3D**2*(UM(N)**2+FAC1*SINF**2)*DENOMR 647
AME3D=AMINF3D**2*(UM(N-1)**2+FAC1*SINF**2)*DENOMR 648
AME11=AME1+5*GM1*AME3D 649
10 SXVINC(N)=SXV(N-1)+SXVINC(N-1) 650
AME3D=AMINF3D**2*(UM(N)**2+FAC1*SINF**2)*DENOMR 651
AME3D=AMINF3D**2*(UM(N-1)**2+FAC1*SINF**2)*DENOMR 652
AME11=AME1+5*GM1*AME3D 653

423 FORMAT(4AMTNF3D,45,3X,4H PSTMR4,1,3X,HPNL(1)) 619
CALL NOTATE(J=1,X=0.00,Y=HGT,Z=0.00,1=1.05) 620
ENCODE(AO,423,LABEL(1)) 621
426 FORMAT(4AMTFR3D,45,3X,4H PSTMR4,F7.5,5X,2HCOFX,2,5X,7RHO,7,4RX) 622
CALL NOTATE(J=1,X=XPLT,Y=YPLT,Z=0.00,1=1.05) 623
ENCODE(AO,426,LABEL(1)) 624
ENCODE(AO,427,LABEL(1)) 625
STOP 0101 626
END 627

SUBROUTINE SINCFRS(J,SXV,SXVINC,UM,DSCD512) 634
DIMENSION SXV(1),SXVINC(1),UM(1) 635
COMMON/COMPREINC,AINF3D,AME3D,SINF,COSP,GAMMA,GAM2,GA M3,GAM4,AMF53D,RATIO,SCOMP,ZCOMP(170),TI(170),RHOD(170) 636
C 637
C USE STEWART'S TRANSFORMATION TO CONVERT SXV, THE PHYSICAL DISTANCE 638
C AROUND THE AIRFOIL AT WHICH MACH NO. IS GIVEN, TO SXVINC, AN 639
C EQUIVALENT INCOMPRESSIBLE COORDINATE 640
C
C GM1*GAMMA/.1 641
DENOM1=1/(1+AHS3D*COSP**2) 642
SXVINC(1)=0 643
CON=(1+AHS3D)**GAM1 644
FAC1=1+AHS3D 645
DO 10 N=2,J 646
AME3D=AMINF3D**2*(UM(N)**2+FAC1*SINF**2)*DENOMR 647
AME3D=AMINF3D**2*(UM(N-1)**2+FAC1*SINF**2)*DENOMR 648
AME11=AME1+5*GM1*AME3D 649
10 SXVINC(N)=SXV(N-1)+SXVINC(N-1) 650
AME3D=AMINF3D**2*(UM(N)**2+FAC1*SINF**2)*DENOMR 651
AME3D=AMINF3D**2*(UM(N-1)**2+FAC1*SINF**2)*DENOMR 652
AME11=AME1+5*GM1*AME3D 653

423 FORMAT(4AMTNF3D,45,3X,4H PSTMR4,1,3X,HPNL(1)) 619
CALL NOTATE(J=1,X=0.00,Y=HGT,Z=0.00,1=1.05) 620
ENCODE(AO,423,LABEL(1)) 621
426 FORMAT(4AMTFR3D,45,3X,4H PSTMR4,F7.5,5X,2HCOFX,2,5X,7RHO,7,4RX) 622
CALL NOTATE(J=1,X=XPLT,Y=YPLT,Z=0.00,1=1.05) 623
ENCODE(AO,426,LABEL(1)) 624
ENCODE(AO,427,LABEL(1)) 625
STOP 0101 626
END 627
SUBROUTINE WhV(M,S)
C COMPUTES W, U AND V PROFILES.
C
COMMON/SURHIV/,IT5.TOL.IFCON,DS,DA1,DZ,SH,UMH,AO,CON3,CON6,
1CNVG.EAN(170),AN(170),AN(170),NO(170),NO(170),UNC(170),VAC(170),
2DAU(170),RO1,AU01,170),0111(170),UM1(170),UMG(170),UM(170),W1(170),
3HNO(170),U(4),AND(170)
C MESH/RESULTS/WM2(170),WM(170),UM1(170),WM(170),DELTA1,THETA1,NO,DUDZ
1,IVHZ
C
COMMON/CMPRES/INC,AM3,AM3,AM3,CONP,GAMMA,GAM1,GAM2,GAM3,
1GAM4,AM3,AM3; RATIO,SCOMP,2COMP(170),T(170),ADNO(170)
C DIMENSION UP(170),V(170)
C
NOM
C
CEVALUATION OF W
11 DO 2 N=2,J
1 IF(M,NE,1)GO TO 1
C AT ATTACHMENT LINE
WM(N)*WM(N-1)=05*DM*(UM1(N)+UM1(N1))
GO TO 2
C AT X(M=1/2)
1 FACT=J$CON6*(2.0*(1.0-2.0)*UMG(N)+UMG(N1))
1=J*(UM1(N)+5.0*DM*UMG(N)+WM(N1))
IF(WF.LT.5.01)GO TO 50
WM(N)=WM(N-1)+WM1(N)+CON3*U(1)*(1-WF)*(4*WF+1)*WM1(N)GO TO 31
100 WM(N)=WM(N-1)+CON3*U(1)*(1-WF)*(4*WF+1)*WM1(N)GO TO 31
2 CONTINUE
C EVALUATION OF UM,N
4 DO 2 N=2,J
2 IF(M,NE,1)GO TO 3
AN(N)=0.5*WH(N)/DZ+2*A0
BN(N)=UM1(N)-A*AO
CN(N)=AN(N)+A*AO
DN(N)=1
GO TO 4
3 IF(WF.LT.5.01)GO TO 51
AN(N)=4*A0+5*WF/DZ*(WF=WH(N)+WF=WH(N1)+N1)*UMG(N)
1=AN0(N)
DN(N)=CON3*(1.+WF)*(4.0+WF=1.)*WM2(N)+UMG(N)-5/DZ*(1.-
1WF)*UM2(N1)-UM2(N1)+WF+CON3*WM1(N)
GO TO 52
51 AN(N)=AN+25/DZ*WH(N)+(N1)*G=UMG(N)+AND(N)
38
If $R$, $N_a$, $D_N$, $CON_3$, $U_M$, 25/DZ, UM2(N+1) = UM2(N+1)

$N(N + 1) = AN(N) + 6$, $WF = AN_0$

FACT = CON3 $WF = 3$, $WF_0 = U_2$, UM2(N) = UM(N)

IF (WF, LT, .75) GO TO 4

DN(N) = DN(N) * FACT

CONTINUE

LP(J) = BN(J)

DO 5 K = 3, J

NWJ = K + 3

UP(N-1) = R(N-1) = AN(N-1) * CN(N)/UP(N)

5 CONTINUE

Y(J) = DN(J) = AN(J)

DO 6 K = 3, J

NEJ = K + 3

Y(N+1) = DN(N+1) = AN(N+1) * Y(N)/UP(N)

6 CONTINUE

UMG(2) = Y(2)/UP(2)

DO 7 N = 3, J

UMG(N) = Y(N) = CN(N) * UMG(N)*UP(N)

7 CONTINUE

COUNT NUMBER OF ITERATIONS

NO = NO + 1

IF (NO, LT, 3) GO TO 22

IF (TOL, LT, ABS(UMG(2))/DZ) GO TO 8

CHECK NUMBER OF ITERATIONS

IF (NO, GE, 10) GO TO 12

STORE U NEAREST SURFACE FOR CONVERGENCE CHECK

UMG = UMG(2)

IF (N, NE, 1) GO TO 11

UM1(N) = UMG(N)

37 CONTINUE

GO TO 11

ITERATION HAS NOT CONVERGED

12 IFCON = 2

RETURN

ITERATION HAS CONVERGED

8 IFCON = 1

EVALUATION OF VM,N

DO 16 N = 2, J

IF (M, GT, 1) GO TO 21

BND(N) = 4 * AN

DND(N) = 0

GO TO 16

21 PND(N) = BND(N) * WF * CON3 * UMG(N)

CUMMAR PAGE IS ON FORWARD
IF(WF.LT.50t) GO TO 53
FACTn.S/DZ*(1.-WF)
* (WF*WMf(N)+((1.-WF)*WMf(N))
53 FACTn.25/DZ*WM(N)
54 DND(N)*DND(N)+CNf*WMf(2(N)*VM1(N))=VM2(N+1)=VM2(N=1)*FACT+1=-
IF(N,.LT.50t) GO TO 57
16 CONTINUE
UP(1)=RAND(1)
DO 17 K=3,J
N=K+3
UP(K)=RAND(N-1)=AN(N-1)*CN(N)/UP(N)
17 CONTINUE
Y(N+1)=DND(N+1)-AN(N+1)*CN(N)/UP(N)
18 CONTINUE
VM2(N)*Y(N)/UP(N)
DO 19 N=3,J
VM2(N)*Y(N+1)*CN(N+1)*VM2(N+1)/UP(N)
19 CONTINUE
DO 23 N=1,J
C STORE Y PROFILE FOR POSSIBLE PRINTING OUT.
23 CONTINUE
C Y PROFILE AT END OF STEP BECOMES PROFILE AT START OF NEXT STEP.
24 CONTINUE
C COMPUTE TEMPERATURE RATIO, T(N)*T/TINF AND DENSITY RATIO,
C RHO(D(N)/RHO/RHOINF, AND THE COMPRESSIBLE (ACTUAL) NORMAL
C COORDINATE, ZCOMP(N)*Z/C
C IF(M,GT.1) GO TO 25
25 CONTINUE
U(N)=0.
26 CONTINUE
C CALCULATE DISPLACEMENT AND MOMENTUM THICKNESSES.
DELTA1=1.0
THETA1=0.
N=1
IS=1
40 N=N+1
DELTA1=DELTA1+(1-UH2(N))*(3+15)
THETA1=THETA1+(UH2(N)*COS(1-UH2(N))*(3+15))
IS=IS+1
IF(UH2(N),GE,1.0-TOL*OZ)GO TO 41
IF(N,LT,J+1)GO TO 40
41 DELTA1=DELTA1*OZ/3.0
THETA1=THETA1*OZ/3.0
ZEDGE=FLOAT(N=1)*OZ
DELTA1=ZCOMP(N)=DELCON*(ZEDGE-DELTA1)
THETA1=DELCON*THETA1
C ESTIMATE (DU/DZ) AND (DV/DZ) AT Z=0.
DU = (2.0*UH2(2)-0.5*UH2(3))/OZ*CFCONX
DV = (2.0*VH2(2)-0.5*VH2(3))/OZ*CFCONY
RETURN
END

FUNCTION THX(X)
C TRANSFORMS X TO THETA
ARG=2.0*ABS(X)-1.
IF(ARG,LE,1.0)GO TO 2
WRITE(2,5)X,ARG
3 FORMAT(///* ERROR NO. 2 DETECTED BY ACOSIN IN FUNCTION THX/**
* X=163.8,* ARG=163.8 ///)
IF(ARG,GT,1.0)AND,ARG,LT,1.0000001) ARG=1,
2 THX=ACOS(ARG)
IF(X,LT,0.0)GO TO 1
THX=0.2631853=THX
1 RETURN
END

FUNCTION XTH(THETA)
C TRANSFORMS THETA TO X
XTH=0.5*(1+COS(THETA))
IF(THETA,GT,3.1415926)GO TO 1
XTH=XTH
1 RETURN
END

ORIGINAL PAGE 71
OF 400 QUEUES
SUBROUTINE CSG(X,Y,F,NOP,E1,F1)

C GENERATES SECOND DERIVATIVES FOR USF IN C81 (CUBIC SPLINE)

DIMENSION X(1),Y(1),F(1),F(365),G(365)

N2=NOP+1
DO 4 N2=N2,N2
E(N)=2*(X(N+1)-X(N))
F(N)=6*(Y(N+1)-Y(N))/(X(N+1)-X(N))
G(N)=6*(Y(N+1)-Y(N))/(X(N+1)-X(N))
4 CONTINUE

N1=2
N2=NOP
E(1)=2*(X(2)-X(1))
F(1)=6*(Y(2)-Y(1))/(X(2)-X(1))
E(NOP)=2*(X(NOP)-X(NOP-1))
F(NOP)=6*(Y(NOP)-Y(NOP-1))/(X(NOP)-X(NOP-1))

DO 6 N=1,N2
G(N)=X(N)/E(N-1)
F(N)=G(N)*F(N)
6 CONTINUE

RETURN
END

SUBROUTINE CSI(X,Y,F,NOP,XI,YI,YX)

C CUBIC SPLINE INTERPOLATION

DIMENSION X(1),Y(1),F(1)

DO 12 N=2,NOP
IF(X(N)=XI)12,12,12
12 CONTINUE

N=NOP

13 A1=0.5*F(N-1)*(X(N-1)-XI)*X(N-1)*(X(N-1))/((X(N)-X(N-1)))
A2=0.5*F(N)*(XI-X(N-1))*X(N-1)*(X(N-1))/((X(N-1)-X(N)))
B1=Y(N-1)*(XI-X(N-1))*F(N-1)*(X(N-1))/6
B2=Y(N-1)/(X(N)-X(N-1))*F(N-1)*(X(N-1))/6
C1=B1+0.5*(X(N-1)-XI)*(X(N-1))/6
D1=(X(N)-XI)*(X(N)-XI)/6
YX=(A1+2*A2)*B1+1*(XI-X(N-1))/3+C1*(X(N)-XI)+D1*(XI-X(N-1))
RETURN
END
SUBROUTINE CONTAM(VGRAD, DTRIP, CH, COSP, SINP, THETA, RATIO)

C TEST FOR CONTAMINATION AT ATTACHMENT LINE

COMMON/TEST/RNL(10), INTL, IFR

WRITE(2,18)
18 FORMAT(1X,30H*** LEADING-EDGE CONTAMINATION TEST ***)

DO 1 N=1, INTL
WRITE(2,10) RNL(N)
1 CONTINUE
RETURN

C SCALE REYNOLDS NUMBER TO STANDARD FORM
C RTHETA=SINP*SINP*THETA/NEDGE
IF (IFR.EQ.1) RNL(RNL(N))
IF (IFR.EQ.2) RNL(RNL(N))/COSP
IF (IFR.EQ.3) RNL(RNL(N))/COSP**2
RTHETA=SINP*SORT(RN/VGRAD)*THETA/RATIO
WRITE(2,11) RTHETA
11 FORMAT(2,10)
WRITE(2,12) RNL(N)
12 FORMAT(1H+,32X,7HRTHETA,W9.1)
WRITE(2,13) RNL(N)/COSP
13 FORMAT(1H+,67X,34HN0 TURBULENT CONTAMINATION AT A,S)L;
WRITE(2,14) DCRTIT
14 FORMAT(1H+,67X,36HTURBULENT CONTAMINATION AT TRIP WIRE)
WRITE(2,15) DCRTIT
15 FORMAT(1H+,67X,40HTURBULENT CONTAMINATION POSSIBLE AT A,S)L;
END

SUBROUTINE CRSSFLK (J, DZ, U)
C CALCULATES CROSS-FLOW AND STREAM-FLOW PROFILES AND THICKNESSES

COMMON/RESULT/WM2(170), UM2(170), VM2(170), DELTA1, THETA1, NO, DUDZ
1, DZ
COMMON/CROSSV/8V(170), CV(170), 8DT, CDT, CVM
COMMON/COMPRESS/INC, AMINSO, AME30, SINP, COSP, GAMMA, GAM1, GAM2, GAM3,
1GAM4, AMIF30, RATIO, SCOMP, ZCOMP(170), T(170), RHOCD(170)
C VELOCITY AT EDGE OF BOUNDARY LAYER

SVJ=SORT(1*2/RATIO*SIN#**2)

C CALCULATE SIN(THETA) WHERE THETA IS ANGLE BETWEEN FLOW AT EDGE OF

C BOUNDARY LAYER AND THE PERPENDICULAR TO THE LEADING EDGE.

SIN#=SIN#1/8VJ
COST#=SORT(1=SINT #**2)

SDT#0,0
CDT#0,0
IS=1
CVM#0,0
SV(1)=CV(1)=0.

DO 1 NE2,J

C VELOCITY COMPONENT IN DIRECTION OF FLOW AT EDGE OF BOUNDARY LAYER

SV(N)=#(UM2(N)*COST#1/SORT(RATIO)+VM#2(N)*SIN#1*SIN#1)/SVJ

C DISPLACEMENT THICKNESS IN DIRECTION OF FLOW AT EDGE OF R,L.

SDT#=SDT+.5*(SV(N)-SV(N-1))*(ZCOMP(N)=ZCOMP(N+1))

C CROSS FLOW VELOCITY COMPONENT

CV(N)=#1*SINT#(VM#2(N)=VM#2(N))/SORT(RATIO)

C CROSS FLOW DISPLACEMENT THICKNESS

CDT#=CDT+.5*(CV(N)+CV(N-1))*(ZCOMP(N)=ZCOMP(N+1))

IS=15

IF(CARS(CV(N))=CVM#1,1,2)

2 CVM#=ARS(CV(N))

1 CONTINUE

CDT#=ARS(CDT)

BNT=ZCOMP(J)=SIT

RETURN

END

SUBROUTINE DMNRTN(S,U,COSP,DELTAL,THETAL,ILP,CFX2,CFY2,CFUX,
1 COFXINP)

C CALCULATES DIMENSIONALISING FACTOR AND DIMENSIONAL R,L, THICKNESSES.

COMMON/TEST/RNL(10),INTRL,IFR

DO 1 N=1,INTRL

C SCALE REYNOLDS NUMBER TO STANDARD FORM.

IF(IFR.EQ.1)RNL=RNL(N)

IF(IFR.EQ.2)RNL=RNL(N)/COSP

IF(IFR.EQ.3)RNL=RNL(N)/COSP**2

DSORT(S)(U,RNL*COSP)

D1#=#*DELTAL

D2#=#*THETAL

IF(ILP.EQ.0)GO TO 6

WRITE(2,3)RNL(N),N,01,02

3 FORMAT(1X,17HREYNOLDS NUMBER= ,F10.0,2X,23H(DIMENSIONAL Z)/CHORD=)

1,F8.6,2H1/2X,10HDELTAL/C* ,F8.6,2X,10HTHETAL/C* ,FR,6)

44
GO TO 1
4 WRITE(2,5)RHC(N),D,D1,D2,CFX2,CFY2,CFX3,CFXINF
5 FORMAT(1X,10REYNOLDS NUMBER=,F10.0,2X,23H(DIMENSIONAL Z)/CHORD=)
1,F8.6,2X,1NDELTA/CM,F8.6,2X,1NTHETA1/CM,F8.6/
25H CFX=10,1,2XUCFX=10,1,2XUCFXINF=10,3)
1 CONTINUE
RETURN
END

SUBROUTINE GEOMTPY (I,RHORCH)  
C GIVEn AEROFoil CO-ORDINATES X AND Z, TRANSFORMS X TO THETA, COMPUTEs
C DISTANCES AROUNd SURFACE S(X), NOSE RADIUS AND SECOND DERIVATIVES OF
C S(THETA) FOR USE IN CUBIC SPLINE INTERPOLATIONS.
COMMON/GEOM/XA(385),ZA(385)
COMMON/SFX/SSTH(365),STH(365),SSTH(365),INT4,FZTH(365)
DIMENSION S(170),THED(170)
PIM3,1459265
INT4M=INT4+1
C IS AEROFoil CAMBERED
IF(I .EQ. 0) GO TO 102
C SET UP LOWER SURFACE CO-ORDINATES FOR SYMMETRICAL AEROFoil
DO 103 N=1,INT4M1
XA(N)=XA(2*INT4-N)
ZA(N)=ZA(2*INT4-N)
103 CONTINUE
C TRANSFORM X TO THETA
102 NL=(INT4-1)*(I+1)
DO 105 NL=2,NL
TH(N)=THX(XA(N)/CH)
105 CONTINUE
TH(1)=0.
IF(1.EQ.0)GO TO 1
TH(INT4M)=PI
INT4M=INT4M+1
1 TH(INT4M)=2*PI
DO 145 NL=1,INT4
ZA(N)=ZA(N)/CH
145 CONTINUE
C COMPUTE INTERPOLATING FUNCTION FOR Z(THETA)
CALL CS6(TH,ZA,FZTH,INT4,0,0,0,0)
IF(RHO.GT.0.) GO TO 108
C COMPUTE NOSE RADIUS IF NOT SPECIFIED
CALL CSI(TH,ZA,FZTH,INT4,PI,ROT,RHO)

ORIGINAL PAGE IS
OF POOR QUALITY
RH0=2*(RH0**2)

10A CONTINUE
C COMPUTE ARC LENGTH STH(N) TO EACH XA(N),ZA(N) AIRFOIL POINT.
C STH(N) IS MEASURED FROM LOWER SURFACE TRAILING EDGE TO UPPER
C SURFACE TRAILING EDGE AND IS APPROXIMATED AS THE CHORDAL
C DISTANCE BETWEEN AIRFOIL COORDINATES.

STH(1)=0,
DO 111 N=2,INT4
111 STH(N)=STH(N-1)+SQRT(((XA(N)-XA(N-1))/CH)**2+(ZA(N)-ZA(N-1))**2)
C COMPUTE INTERPOLATING FUNCTIONS FOR S(THETA) AT THETA(X)
CALL CS6G(TH,S,STH,FSTH,INT4,0,0,0,0)
RETURN
END

SUBROUTINE IFPRINT(IFPT,ILP,LAST,JACKPOT)
C DETERMINE PRINT OUT REQUIRED
C BOTH PARTS=JACKPOT=1, FIRST PART=JACKPOT=3, SECOND PART=JACKPOT=2
C NO PRINT OUT=JACKPOT=0
C HAS NON-CONVERGENCE OCCURRED
IF(LAST.EQ.2)GO TO 2
C HAS LAST POINT REQUESTED BEEN COMPUTED
IF(LAST.EQ.1)JACKPOT=1
C IS FULL OUTPUT REQUIRED AT EVERY POINT OR AT THIS PARTICULAR POINT
IF(IFPT.EQ.1.OR.,(IFPT.EQ.2.AND.,ILP.EQ.1))JACKPOT=1
C IS FULL OUTPUT REQUIRED AT LISTED POINTS AND IS NOT ONE OF THEM
IF(IFPT.EQ.2.AND.,ILP,EQ.0)JACKPOT=3
RETURN
C WAS SECOND PART OF PRINT OUT SKIPPED AT END OF LAST SUCCESSFUL STEP
2 IF(JACKPOT.EQ.3)GO TO 3
JACKPOT=0
RETURN
3 JACKPOT=2
RETURN
END

SUBROUTINE INSTARC(COSP,5,U,CH,RATIO,AME30,AKINF3D)
C EVALUATES THE CROSS-FLOW REYNOLDS NUMBER, CHI;
COMMON/TEST/RNL(10),INTRL,IFR
COMMON/CROSSV/BV(170),CV(170),SDT,CDT,CVM
C CALCULATE CHI/SORT(REYNOLDS NUMBER)
C CROSS FLOW REYNOLDS NO, IS BASED ON THE MINIMUM KINEMATIC VISCOSITY
C COEFFICIENT = EITHER FREE STREAM OR EDGE VALUE
FACT=1.5

WRITE(2,3)
3 FORMAT(1X,30*** SHEEP INSTABILITY TEST ***)

DO 1 N=1,INTRL

C SCALE REYNOLDS NUMBER TO STANDARD FORM,
IF(IFR,EQ.1)RNL(N)/COSP
IF(IFR,GT.1)RNL(N)/COSP**2
CHI*CORR*SORT(R1)**(1.5)
WRITE(2,4)
4 FORMAT(1H,17HREYNOLDS NUMBER,1111,0.2X,19HCHI(OMEN-RANDALL)F7.2)
1 CONTINUE
RETURN
END

SUBROUTINE PLIST(IFPT,NLIST,SXV,SXVINC,L,D,SXVTNC,CH,XATT,DX,INC)

C PREPARE LIST OF POINTS WHERE FULL OUTPUT IS REQUIRED
COMMON/DPLIST/OPX(200),OP8(200)
DIMENSION SXV(1),DUMP(365),X(2),S(2),SXVTNC(1)

IF(IFPT,LE.3)301,303,304
301 CALL STHRMX(NLIST,OPX,OP8,DUMP,D,SXVNC,CH,XATT,N)
DO 310 N=2,NLIST
OPS(N)=OPS(N-1)
310 CONTINUE
GO TO 305

305 NLIST=L-1
DO 306 N=1,NLIST
OPS(N)*SXVINC(N+1)
306 CONTINUE
GO TO 307

304 N=1
IF(INC.EQ.0) GO TO 308
309 X(2)=DX
CALL STHRMX(2,X,D,SXVNC,CH,XATT,B)
OPS(N)=S(2)
314 CONTINUE
GO TO 309

308 DO 311 N=1,L
OPS(N)=FLOAT(N)*DX
IF(OPS(N),GT,SXVNC(L)) GO TO 307
311 NLIST=N

17
SUBROUTINE PRINT(X,S,U,DII,J,DZ,INT1,JACKPOT,PSI,LC,ANGLE2)

COMMON/RESULTS/XM2(170),UM2(170),VM2(170),DELTA1,THETA1,NO,DUDZ
J,DVDZ
COMMON/CROSSV/SV(170),CV(170),BDT,CDT,CVM
COMMON/CUMPRES/IC,AMINF3D,AME3D,SNP,COBP,GAMMA,GAM1,GAM2,GAM3,
LGAM1,AMFS3D,RATIO,SCOMP,ZCOMP(170),T(170),RHOD(170)
DIMENSION XPRINT(10)
DATA XPRINT:/1,2,3,4,5,6,7,8,9,10/1
IF(JACKPOT.EQ.2) GO TO 7
WRITE(2,11) X,S,SCOMP,U,AMFS3D,DU,NO
11 FORMAT(1Hn,3HYM,F9.6,4X,3HS
F9.6,4X,7H8COMP,F9.6,4X,3HUM,F9.6,4X7HAME3D,F9.6,4X11HDU/D(B/L)H,F12.6,4X12,11H ITERATIONS)
ANG=180./3.14159265*ANGLE2
IF(LC,NE.0) WRITE(2,20)
IF(LC,GT.2) WRITE(2,20)
20 FORMAT(1H0,40HSTEP-LENGTH HALVED AFTER NON-CONVERGENCE)
WRITE(2,12) DELTA1,THETA1,DUDZ,DVDZ,ANG
IF(JACKPOT,EQ.3) GO TO 8
C TEMPORARY FIX ON PRINT OF VELOCITY PROFILES AT EVERY 10PC CHORD
C
7 IF(X,LT.0) GO TO 10
WRITE(2,15) BD
15 FORMAT(1H0,36HSTREAM FLOW DISPLACEMENT THICKNESS=F10.6)
WRITE(2,16) CDT
16 FORMAT(1H0,36HCROSS FLOW DISPLACEMENT THICKNESS=F10.6)
WRITE(2,19) CVM
19 FORMAT(1H0,26HMAX, CROSS=FLOW VELOCITY=F10.6)
13 WRITE(2,10)
14 FORMAT(4X1Z,10X5HZCOMP,8X1H,11X1HU,11X1HV,10X3HSTV,10X3HCFV,10X1HT,4X4HGHO
17 INT1+1
DO 2 N=1,J
IF(N,GT.1,OR,N,GT.2) GO TO 3
IF(INT1,LT.2,AND,N,LE.INT1) GO TO 3
IF(N,GT.1,OR,N,GT.2) GO TO 3
GO TO 2
2 ZN=DNZ-DZ
3 ZN=DNZ-DZ
IF (PSI, LT, .0001) GO TO 1
WRITE (2, 6) ZCSEP (N), KH2 (N), UM2 (N), VM2 (N), BV (N), CV (N), T (N), RHOD (N)
GO TO 5
1 WRITE (2, 6) ZCSEP (N), KH2 (N), UM2 (N), VM2 (N), T (N), RHOD (N)
6 FORMAT (9 (F10.6, 2X))
9 FORMAT (5 (F10.6, 2X), 24X, 2 (F10.6, 2X))
5 IF (N, EQ, N1/N1+1) CONTINUE
2 CONTINUE
IF (S, LT, 1.E-08) GO TO 8
KMAX + 1
8 RETURN
END

SUBROUTINE RELAM (U, B1P, COSP, KMAX)
C EVALUATES THE RE-LAMINARISATION PARAMETER, K.
C (HAS NOT BEEN MODIFIED FOR COMPRESSIBILITY)
C
DIMENSION U(N), B(2), A(2)
COMMON/TEST/RNL(10), INTL, IFR
REAL KMAX(10)

WRITE (2, 4)
4 FORMAT (1X, 30H*** RELAMINARISATION CHECK ***)
DO 1 M = 1, 2
A(M) = SORT (U(N)) ** 2 + B1P ** 2
1 CONTINUE

DS = S(2) - S(1)
DU = U(2) - U(1)
RCOSPK = (A(2) - A(1)) / DU / DS * (A(2) + A(1)) ** 3

DO 2 M = 1, INTL
CAY = RCOSPK / RNL(N) * COSP
IF (IFR, EQ, 2) CAY = CAY * COSP
IF (IFR, EQ, 3) CAY = CAY * COSP ** 2
IF (CAY, GT, KMAX(N)) KMAX(N) = CAY
WRITE (2, 3) RNL(N), CAY, KMAX(N)
3 FORMAT (1H, 17HREYNOLDS NUMBER= ,F10.0, 3X, 3HK= ,E10.3, 3X, 6HKMAX= ,E10.3)
2 CONTINUE
C IF K, LT, 1/2 K(MAX) SET PARAMETER TO AVOID COMPUTING K DOWNSTREAM.
IF (KMAX(INTRL), GT, 2*CAY) KMAX(INTRL) = 1.0
RETURN
END

SUBROUTINE STPLNTH (SNEXT, B, INTHOLD, DA, OS1, OSZ, NEXT, MLST, LAST,
SUBROUTINE STPLNTH (SNEXT, B, INTHOLD, DA, OS1, OSZ, NEXT, MLST, LAST,
SUBROUTINE STPLNTH (SNEXT, B, INTHOLD, DA, OS1, OSZ, NEXT, MLST, LAST,
C CALCULATES LENGTH OF NEXT STEP.

COMMON/XBANDU/UM(365),THXV(365),FUTH(365),XV(365),CPUM(365),
18XV(365),SVINC(365),FBVSINC(365),L,SATT,INT3,CH,ISF
COMMON/PLIST/OPX(200),OPS(200)
COMMON/COMPRES/INC,AMIF3D,AMIE3D,SINP,COMP,GAMMA,GAM1,GAM2,GAM3,
1GAM4,AMF3D,RATIO,SCOMP,2COMP(170),T(170),RHOD(170)
DIMENSION U(41),S(2)

ILP=0
LINEAR=0

C WAS LAST STEP SUCCESSFUL
IF(LC.EQ.0)GO TO 9

C HALVE STEP LENGTH AFTER NON-CONVERGENCE
1 IF(DS1.GT.0.01*DS)GO TO 11
C STEP LENGTH LESS THAN MINIMUM PERMITTED- END CALCULATION,
LAST=0
GO TO 8

11 DS1=DS1/2.0
LAST=0
GO TO 7

9 IF(SNEXT.LT.0.) GO TO 2
S(2)=SNEXT
DS1=S(2)=8(1)
SNEXT=1.0
GO TO 4

2 IF(INTHOLD.EQ.0.)GO TO 33
C VALUE OF NEXT POINT HAS BEEN HELD WHILE A LISTED OUTPUT POINT WAS
C COMPUTED.
DB1=DBH
C STEP LENGTH IS HELD AT DBH FOR INTHOLD STEPS.
INTHOLD=INTHOLD+1
GO TO 7

C STANDARD STEP LENGTH.
33 DB1=DS
C CHECK RATIO (PROPOSED LENGTH OF NEXT STEP)/(LENGTH OF LAST STEP)
4 IF(DS1.LT.1.2*DSZ)GO TO 7
C KEEP STEPLENGTH CONSTANT OVER A NUMBER OF STEPS DEPENDING ON ABOVE,
INTHOLD=INT(5*DS1/DSZ)+5
IF(INTHOLD.GT.5)INTHOLD=5

C LIMIT LENGTH OF NEXT STEP TO TWICE LAST STEP.
IF(INTHOLD.EQ.5)DS1=2*DSZ
DSH=DB1
INTHOLD=INTHOLD+1

C PROPOSED VALUE AT END OF NEXT STEP.
7 S(2)=S(1)+DS1
IF(TFPT.EQ.1)GO TO 10
C IS PROPOSED VALUE OF X LESS THAN THAT OF NEXT LISTED OUTPUT POINT
IF(S(2).LT.OPS(NEXT)) GO TO 10
C REPLACE PROPOSED VALUE WITH THAT OF NEXT LISTED OUTPUT POINT
S(2)=OPS(NEXT)

C IS THIS THE LAST POINT IN OUTPUT LIST
IF(NEXT+1,EQ,NLIST)LAST=1

C ADVANCE OUTPUT LIST COUNT
NEXT=NEXT+1
ILP=1
IF(INTHOLD,NE,0)SNF.XT(S(1)+0)

C IS PROPOSED VALUE OF X LESS THAN THAT OF LAST VELOCITY DATA POINT
10 IF (S(2),LT.,SXVINC(L),.0001*0) GO TO 44

C VALUES AT LAST VELOCITY DATA POINT,
S(2)=SXVINC(L)
UMX(L)
U(L)=UMX(L)
DUS=UMX(L-1)/(SXVINC(L)=SXVINC(L-1))
LAST=1
GO TO 45

42 IF (INC,NE,0) GO TO 46
SCOMP=S(2)
GO TO 47

C INTERPOLATE SXV(SXVINC) TO FIND LOCATION IN PHYSICAL PLANE, SCOMP,
C CORRESPONDING TO LOCATION IN TRANSFORMED, INCOMPRESSIBLE PLANE,
S(2)

46 CALL CSI(SXVINC,SXV,FSVINC,L,S(2),SCOMP,ROT)

C FIND VELOCITY AT END OF PROPOSED STEP
47 CALL XNDFRMS(SCOMP,U(2),DUDS,X,TTC,ILP,ANGLE2,LINEAR,THETAS)

C DID NON-CONVERGENCE OCCUR IN SUBROUTINE XNDFRMS
IF(ITC,NE,20)GO TO 15

45 DSIM(S(2)=S(1)

C CHECK THAT USTEP IS NOT EXCEEDED AND REDUCE STEPLENGTH IF NECESSARY.

17 IF(ABS(U(2)-U(1)),LT.,USTEP)GO TO 19
IF(ILP,NE,1)NEXT=NEXT-1
ILP=0

C ITERATION TO FIND S FOR (U(1)+USTEP)
INT=0
S(2)=S(2)=081*(1+USTEP/(U(2)=U(1)))
IF(INC,NE,0) GO TO 48
SCOMP=S(2)
GO TO 12

48 CALL CSI(SXVINC,SXV,FSVINC,L,S(2),SCOMP,ROT)

12 CALL XNDFRMS(SCOMP,U(2),DUDS,X,TTC,ILP,ANGLE2,LINEAR,THETAS)

11 IF(ITC,NE,20)GO TO 15
IF(ABS(U(2)=U(1)),LT.,01*USTEP)GO TO 111
INT=INT+1
IF(INT,NE,25)GO TO 24
S(2)=S(2)=(U(2)=U(1)+USTEP)/DUDS

100 STOP
IF(INC,ED,0) GO TO 48
SCOMP=S(2)
GO TO 12

15 WRITE(2,26)
26 FORMAT(1H0,41HNON-CONVERGENCE IN X AND U FROM S ROUTINE)
GO TO 120

20 IF(ABS(U(2)-U(1)),GT,USTEP) WRITE(2,3)
3 FORMAT(1H0,* INCREMENT IN U HAS EXCEEDED SET LIMIT*)

C EITHER NON-CONVERGENCE HAS OCCURRED IN FINDING THETAS FOR A GIVEN
C SCOMP IN S/R XNDFRMS OR NON-CONVERGENCE HAS OCCURRED IN FINDING U(2)
C THAT SATISFIES THE USTEP CRITERION. SET U(2)=U(1) + USTEP AND USE
C LINEAR INTERPOLATION TO FIND S(2).  

120 LINEAR=1
U(2)=U(1)+USTEP
DO 60 N=1,L
IF(U(2),LT,UM(N)) GO TO 65
IF(SXVINC(N),GT,.S) GO TO 63
60 CONTINUE
63 PRINT 66
66 FORMAT(* LEADING-END FUNCTIONAL LINEAR INTERPOLATION OF U(2) VS. S(2) TO
IF FIND S(2) FOR A GIVEN U(2) RESULTS IN S(2) GREATER THAN .5*)
STOP 66

65 FACT=(U(2)-UM(N))/UM(N-1)
S(2)=SXVINC(N-1)+(SXVINC(N)-SXVINC(N-1))*FACT
THETAS=THXV(N-1)+(S(2)-S(N-1))*FACT
DUDS=(U(2)-U(1))/(S(2)-S(1))
IF(INC,ED,0) GO TO 110
SCOMP=8(2)
GO TO 112
110 CALL CST(SXVINC,SXV,FBVINC,L,S(2),SCOMP,ROT)
112 CALL XNDFRMSCBCOMP(J,P,ODJ,OD2,X,TC,TLP,ANGLE2,LINEAR,THETAS)
111 LAST=0

C LENGTH OF NEXT STEP.
140 DS=S(2)-S(1)
C S LOCATION OF NEXT STEP
SH=KF*S(2)+(1.,-KF)*S(1)

8 RETURN
END

SUBROUTINE STHFRMX(J,X,S,THXV,DS,DT,INT3,CM,XATT,BATT)
C FINDS S(N) AT POINTS X(N) FOR N=1(J) AND DS/DTHETA AT X(1)
C WHERE S IS MEASURED FROM THE ATTACHMENT LINE.
COMMON/BFX/UTH(365),TH(365),F8TH(365),INT4,FTH(365)
DIMENSION X(1),S(1),THXV(1)
X(1)=XATT
DO 1 N=1,J
THXV(N)=THX(X(N)/CM)
IF (INT3.EQ.0) GO TO 2

CALL CSI (TH, STH, FSTH, INT4, THXV(N), B(N), DBDTH)

IF (N.GT.1) GO TO 3
DSDT*DSDTH
GO TO 1

2 S(N)*X(N)/CH
GO TO 1

3 S(N)*S(N)=S(1)
CONTINUE
SATT=S(1)
S(1)=0.
RETURN
FND

SUBROUTINE TRANS(SC, USM, THETA1, UTWO, UDNE, IST, JACKPOT)
C ESTIMATES THE POSITIONS OF VISCOS INSTABILITY AND SUBSEQUENT TRANSITION.

COMMON /TEST/RNL(10), INTRL, IFR
COMMON /BIRTHAN/RHS(17), AMH(17), GRAN(13), AMT(13)
COMMON/COMPRES/IN-C, AMINF3D, AMES3P, BINP, CINSP, GAMMA, GAM1, GAM2, GAM3
S=1
AMFS3D, RATIO, SCOMP, ZCOMP(170), T(170), RHON(170)
COMMON/XSAND/UM(365), THXV(365), FTH(365), X(365), CPUM(365),
SXV(365), SXVINC(365), FSVINC(365), L, SATT, INT3, CH, IRP
DIMENSION SCTR(10), SCI(10), SUMP(10), RTCL(10), RDL(10), RTL(10),
INFT(10), SICOMP(10)

R=(1./RATIO)**GAM1*8RT(1.+AMFS3D*C08P**2)/(1.+AMFS3D*UTWO**2)**1,5
IF (IST,NE,1) GO TO 2

C SOMET TIMES S COMPTED TO ZERO WHEN B/R IS ENTERED FOR FIRST TIME.
SC=0.0
SCOMPL=0.0
RATIO=1./(1.+AMFS3D*C08P**2)
DO 4 N=1, INTL
1 SCTR(N)**0.0
SCI(N)**0.0
SICOMP(N)**0.0
SUMM(N)**0.0
4 CONTINUE

IST#0

C EVALUATE (LAMBDA)**2 = BASED ON MINIMUM KINETIC VISCOSITY COEFFICIENT.
C EITHER FREE STREAM OR EDGE VALUE
FACT=1./RATIO**1.5
IF (AMES3D, AMINF3D) FACT=1.
2 EMB=#AC*USM*THETA1**2/UTWO*FACT
WRITE(2,10)

ORIGINAL PAGE IS OF POOR QUALITY
10 FORMAT(1X,3SH*** TRANSITION TEST (GRANVILLE) ***)
   DO 11,N=1,NINRL
      WRITE(2,11)N,RNL(N)
   11 FORMAT(1H*** TRANSITION TEST (GRANVILLE)
      IF(BCTR(N),GT,0.1) GO TO 14

C SCALE REYNOLDS NUMBER TO STANDARD FORM.
C IF(IFR.EQ.1)RN=RNL(N) C IF(IFR.EQ.2)RN=RNL(N)/COSP
C IF(IFR.EQ.3)RN=RNL(N)/COSP**2

C EVALUATE R2
C REYNOLDS NUMBER IS BASED ON MINIMUM KINEMATIC VISCOSITY COEFFICIENT,
C EITHER FREE STREAM OR EDGE VALUE
R0=5ORT(RN**SC**UTWO**FACT)*THETA*FACT
   WRITE(2,22)RD
22 FORMAT(1H*** TEST(2,11)RN=(N)),(1X,2H1)**2)
   IF(BCTR(N),GT,0.1) GO TO 14

C HAS INSTABILITY BEEN PREDICTED UPSTREAM OF THIS POINT
C IF(SCI(N),GT,0.1) GO TO 140

C FIND CRITICAL VALUE OF R2 FROM STUARTS CURVE.
   DO 6,J=2,17
      IF(AM(J),GT,EM)GO TO 7
   CONTINUE
   J=17
5   7 AM(RO(J)-1)+ROB(J-1)*EM/J+AM(J-1))/AM(J-1)
   RTE=10.**A
   IF(RD,GTRTE)GO TO 9
      RTE=10.**A
   IF(RD,GT,RTE)GO TO 9

RTCL(N)*RTC
   RDL(N)=RD
   IF(JACKPOT,GT,3)GO TO 3
   WRITE(2,110)RTC,EM
110 FORMAT(1H***,F4.1,1H+RTHETA,F6.1)
   WRITE(2,110)RTC
   IF(SCI(N),GT,0.1) GO TO 140
   IF(TNC,EQ,0) GO TO 20
   SCI(SCI(N))=SCI(N)+SCC*(RTC-RDL(N))
   SUMM(N)=SUMM(N)+DIM
   RTMRTI=RTI(N)-RTCL(N)
   LAMFD=BAR
   AMB=SUMM(N)/(5COMP+8CICOMP(N))-SUMM(N)/DIM
   GO TO 10

C INTERPOLATE FOR VALUES AT POINT OF INSTABILITY.
   9 SCI(N)=SCL+((SC-BCL)**RTCL(N)-RD(N))/((RD+RTC-RDL(N)+RTCL(N))
   IF(INC,GT,0) GO TO 20
   SCI(FST(N))=SCI(N)
   GO TO 21
20 CALL C81(SXVINC,F8VINC,L,SCL(N),SICOMP(N),ROT)
21 RTI(N)=RTCL(N)+((RTC+RTCL(N))*5C(N)=SCL)/(5C=SCL)
   ENM+EML*(SCL)=SCL/(5C=SCL)
   SUMM(N)=SUM(N)-SUMM(N).DOM
   GO TO 8

140 DTM=0.5*(EM+RATIOL)**GAM1+EML+RATIOL**GAM1)**5C=SCL
   SUMM(N)=SUMM(N)-DTM
C EVALUATE (R2)T=(R2)1
   8 RTMRTI=RD-RTI(N)
C EVALUATE (LAMBDAL)2 BAR
   AMB=SUMM(N)/(5COMP+8CICOMP(N))
C FIND CRITICAL VALUE OF (R2)T=(R2)I FROM GRANVILLES CURVE.
DO 15 K=2,13
15 CONTINUE
16 RCMRTI = GRAN(K-1)+AMT*K(K-1)*GRAN(K-1)/
(AMT*K(K-1))
WRITE(2,13)$ICOMP(N)
FORMAT(1H+,72X,19HSINDABILITY AT 8/CW ,F6.4)
WRITE(2,19)SCTR(N),STK,RTMRTI
FORMAT(14H40,19HTRANSITION AT S/CW ,F6.4)
WRITE(2,101)RTMRTI
10 CONTINUE
3 CONTINUE
SCL=SC
SCOMP=SCOMPL
EM=EM
RATIO=RATIO
RETURN
END

BLOCK DATA

C STORE TABLES DERIVED FROM STUARTS AND GRANVILLES CURVES FOR USE IN
C SUB-Routine TRANS.

COMMON/SUBTRAN /ROS(17),AM(17),GRAN(13),AMT(13)
DATA ROS/1,392.1,564.1,573.1,77.1,84.2,2.0,6.2,2.224.2,456.2,713.2,956.2,
13.155.3,310.3,452.3,57.3,676.3,734.3,768/AM/=03,=05,=04,=03,
=2,=02,=01,=00,=01,=02,=03,=04,=05,=06,=07,=08,=09,=10/GRAN/456.2,
5460.5,540.5,50.7,70.6,356.1000.1199.1440.1720.2046/
AMT/=035,=030,=025,=02,=015,=01,=009,=005,=010,=015,=02,
5,025/
END

SURROUTINE VELOCITIES (INTV, CSOP)

C COMPUTES U FROM DATA

COMMON/X&NEW/U(365),THXV(365),THXV(365),PUTH(365),CPI(365),
18XV(365),8XVINC(365),PSVINC(365),L,3SAT,INT3,CH,ISP

ORIGINAH PAGE IS
OF POOR QUALITY
F. E

S

h t t-S

ftLt £ Q1 00

lilt iDV13H1)NID^S^'O^rHIaDO

MI - i4)XHlaDV13H1

O£Lt 2'S'	 (f1NI)dI

DLI fit	 01	 0:)r3'

p

3'tV3Nt't)3T 	 -

LILT o.^1I

9141 (UL^JtJOHtl'(ULi)L'(Ott)dW00Z°dWO^C°0I1'Vd'U£6^WV'hWb01

i	 S2LZ 'fNV9

2W^'J

172x618'

tWY"J'1

►

WN^fl

264x618'

'IDUO'dNiQ'

Jf

â

W^"C1£lNIw^I°ONI1D3ddW00

/NUWWU7

',

hLLS (fi9f)VI'(59t)1X/WU30/N0WWQ3

f2Lt

22LI 491'HO'f1N1'11VO'1'(69&)ONISAS4'( 59£)ONIAXS'(S9£),AXaT

OUT

((£D+j

201x440)

r((£D+j

270x440)

4Z4r

(2+

325x440)(Jf

336x440)â

342x440

W^"C1£lNIw^I°ONI1D3ddW00

90L1 _,

T --

LOLL

گHd 1v

+►

SStttin'•v

T

tdV) ^I'I- 

n0Lt 1	 Owt-

£OLS

f!NI

L691 Ndf113a

9691 Z^dD00w(1)wnd0

56
C. THETA(S) FOR ESTIMATED S
  2 TESTS+XV(1)/CH
  IF (TEST, GT, 1) GO TO 7
  THETAS=TH(THEST)
  GO TO 4
  7 THETAS=6.

C. FIND S AND DS/D(THETA) AT S
  6 CALL CSI(TH,STH,FSTH,INT4,THETAS,8X1,DSOTH)
  TST1=S+BATT-5X1
  IF (ABS(TST1),LT,0,000I) GO TO 3

C. IMPROVE ESTIMATE FOR S AND EVALUATE THETA(S).
  THETAS=THETAS+TST1/DSOTH
  ITC=ITC+1
  IF (ITC.LT.20) GO TO 17

WRITE(2,5)
  5 FORMAT(20MON-CONVERGENCE IN S TO THETA PROCEDURE)
  RETURN

C. FIND U AND DU/D(THETA) AT THETA(S)
  3 CALL CSI(THXV,UM,FUTH,UL,THETAS,U,DUDTH)

15 AME2D=AMINF3D*U
  AME3D=AME2D**2*(1.+AMFS3D)*(AMINF3D*8INP)**2/(1.+AMFS3D*COSP**2)
  AME3D=AMESORT(AME3D)
  RATIO=1.*5*(GAMMA-1.)*AME3D**2/(1.+AMFS3D)
  DSCOSI=RATIO**GAMM
  IF (LINEAR.EQ.1) GO TO 20
  U0DUDTH=DUDTH*DNSOTH*DSCOSI
  20 XMTH(THETAS)*CH

IF (ILP,EQ,1) RETURN
  CALL CSI(TH,ZA,FZH,INT4,THETAS,ROT,DZDTH)

DXDTH=ABS(SIN(THETAS))
  IF (DXDTH,GT,1.0E-05) GO TO 6
  ANGLE8=141592654/2.
  RETURN
  6 ASLOPE=DZDTH/DXDTH
  ANGLE=ATAN(ASLOPE)
  RETURN
  END

SUBROUTINE X8CPNT (INTV)

C. PRINTS OUT TABLE OF VELOCITY DATA.

COMMON/X&ANDU/VM(365),THXV(365),FUTH(365),XV(365),CPUM(365),
  18XV(365),8XVINC(365),FSVINC(365),L,BATT,TNT3,CH,ISP

DIMENSION S(365)

IF (INT3.EQ,0) GO TO 6
  DO 5 N=1,L
  S(N)=8XV(N)*CH
  5 CONTINUE

END
IF (INT3.EQ.0.AND.INTV.LE.2) WRITE (2,1)(XV(N),UM(N),N=1,L)
1 FORMAT (1H0,4X,2HXV,8X,1HU/(1H,3(F8.4,2X)))

IF (INT3.EQ.0.AND.INTV.EQ.3) WRITE (2,2)(XV(N),CPUM(N),UM(N),N=1,L)
2 FORMAT (1H0,4X,2HXV,7X,2HCP,9X,1HU/(1H,3(F8.4,2X)))

IF (INT3.EQ.1.AND.INTV.LE.2) WRITE (2,3)(XV(N),SXV(N),SXVINC(N),
1UM(N),THXV(N),FUTH(N),FSVINC(N),N=1,L)
3 FORMAT (1H0,7X2HXV,14X3HSXV,11X6HSXVINC,13X1HU,13X6THXV,12X4HFUTH, 
11X7HFSVINC/(1H,7E16.8))

IF (INT3.EQ.1.AND.INTV.EQ.3) WRITE (2,4)(XV(N),SXV(N),SXVINC(N),
1CPUM(N),UM(N),N=1,L)
4 FORMAT (1H0,6X2HXV,14X3HSXV,13X6HSXVINC,11X2HCP,14X1HU/
1(1H,5E16.8))

RETURN
END
APPENDIX E

SAMPLE CASE

The sample case consists of the computation of the boundary layer on
the upper surface of a wing swept at 35° with the airfoil section shown in
figure 2 subject to the suction distribution given in figure 1. This airfoil
which is nominally 13% thick was designed specifically for LFC use by Pfenninger, Allison, and Bobbitt using the inverse method in reference 6 to design the
airfoil and the analysis method in reference 7 to modify the lower surface.
The sample case free stream Reynolds number is $11 \times 10^6$, based on the chord
measured perpendicularly to the leading edge. The free stream Mach number
is 0.885 which gives a Mach number normal to the wing leading edge of 0.725,
the same as the design value. The suction distribution shown in figure 1
maintains laminar flow over the entire wing surface according to the criterions
which were previously discussed. It should be noted however that no attempt
was made to optimize this suction distribution; hence, it is expected that
these suction levels can be reduced thereby reducing the skin-friction drag.

The input for the sample case is listed below. The program prints
this input as well as some computed quantities and that information is also
listed below. A sample of the output is then shown with both the print out
at a typical boundary-layer station and the boundary-layer profiles given.
Figures 3 gives the distributions for this sample case of the x and y
skin-friction coefficients along the surface from the leading to trailing edge.
This sample case required a total of 18 seconds and 768 K storage for
execution on the CDC CYBER 175 computer.
Suction, transition analysis of tandem wing laminar boundary layer

<table>
<thead>
<tr>
<th>i</th>
<th>suction</th>
<th>transition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>1</td>
<td>0.1000</td>
<td>0.0000</td>
</tr>
<tr>
<td>2</td>
<td>0.2000</td>
<td>0.0000</td>
</tr>
<tr>
<td>3</td>
<td>0.3000</td>
<td>0.0000</td>
</tr>
<tr>
<td>4</td>
<td>0.4000</td>
<td>0.0000</td>
</tr>
<tr>
<td>5</td>
<td>0.5000</td>
<td>0.0000</td>
</tr>
<tr>
<td>6</td>
<td>0.6000</td>
<td>0.0000</td>
</tr>
<tr>
<td>7</td>
<td>0.7000</td>
<td>0.0000</td>
</tr>
<tr>
<td>8</td>
<td>0.8000</td>
<td>0.0000</td>
</tr>
<tr>
<td>9</td>
<td>0.9000</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

**Original Page is of Poor Quality**
<table>
<thead>
<tr>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.24729015E+00</td>
<td>7.0633822E+01</td>
</tr>
<tr>
<td>0.2639414E+00</td>
<td>7.1096477E+01</td>
</tr>
<tr>
<td>0.2666304E+00</td>
<td>7.2267380E+01</td>
</tr>
<tr>
<td>0.29823375E+00</td>
<td>7.2493377E+01</td>
</tr>
<tr>
<td>0.3166211E+00</td>
<td>7.3504914E+01</td>
</tr>
<tr>
<td>0.3366621E+00</td>
<td>7.3577507E+01</td>
</tr>
<tr>
<td>0.35174169E+00</td>
<td>7.4312806E+01</td>
</tr>
<tr>
<td>0.37001929E+00</td>
<td>7.4607337E+01</td>
</tr>
<tr>
<td>0.3884705E+00</td>
<td>7.4766077E+01</td>
</tr>
<tr>
<td>0.4076648E+00</td>
<td>7.4823216E+01</td>
</tr>
<tr>
<td>0.42577831E+00</td>
<td>7.4976607E+01</td>
</tr>
<tr>
<td>0.44457722E+00</td>
<td>7.4602365E+01</td>
</tr>
<tr>
<td>0.46343471E+00</td>
<td>7.4326132E+01</td>
</tr>
<tr>
<td>0.48232163E+00</td>
<td>7.3944521E+01</td>
</tr>
<tr>
<td>0.5012059E+00</td>
<td>7.3444124E+01</td>
</tr>
<tr>
<td>0.52006676E+00</td>
<td>7.2830944E+01</td>
</tr>
<tr>
<td>0.5386623E+00</td>
<td>7.2101315E+01</td>
</tr>
<tr>
<td>0.55758506E+00</td>
<td>7.1254024E+01</td>
</tr>
<tr>
<td>0.57618947E+00</td>
<td>7.0247556E+01</td>
</tr>
<tr>
<td>0.59465437E+00</td>
<td>6.9199941E+01</td>
</tr>
<tr>
<td>0.61295386E+00</td>
<td>6.7989380E+01</td>
</tr>
<tr>
<td>0.63106287E+00</td>
<td>6.6654304E+01</td>
</tr>
<tr>
<td>0.6489564E+00</td>
<td>6.5193370E+01</td>
</tr>
<tr>
<td>0.66661201E+00</td>
<td>6.3604700E+01</td>
</tr>
<tr>
<td>0.68400827E+00</td>
<td>6.1887390E+01</td>
</tr>
<tr>
<td>0.70112508E+00</td>
<td>6.0041747E+01</td>
</tr>
<tr>
<td>0.71794282E+00</td>
<td>5.8068930E+01</td>
</tr>
<tr>
<td>0.73444290E+00</td>
<td>5.5970045E+01</td>
</tr>
<tr>
<td>0.75040217E+00</td>
<td>5.3746808E+01</td>
</tr>
<tr>
<td>0.76642330E+00</td>
<td>5.1401958E+01</td>
</tr>
<tr>
<td>0.78187390E+00</td>
<td>4.9366602E+01</td>
</tr>
<tr>
<td>0.79608400E+00</td>
<td>4.6359081E+01</td>
</tr>
<tr>
<td>0.8116381E+00</td>
<td>4.3666760E+01</td>
</tr>
<tr>
<td>0.82594255E+00</td>
<td>4.0970923E+01</td>
</tr>
<tr>
<td>0.83986046E+00</td>
<td>3.7981682E+01</td>
</tr>
<tr>
<td>0.85361311E+00</td>
<td>3.5025549E+01</td>
</tr>
<tr>
<td>0.86658587E+00</td>
<td>3.2048020E+01</td>
</tr>
<tr>
<td>0.87957576E+00</td>
<td>2.9070466E+01</td>
</tr>
<tr>
<td>0.89179595E+00</td>
<td>2.6191555E+01</td>
</tr>
<tr>
<td>0.90369811E+00</td>
<td>2.3406008E+01</td>
</tr>
<tr>
<td>0.91513139E+00</td>
<td>2.0787979E+01</td>
</tr>
<tr>
<td>0.92601800E+00</td>
<td>1.8343501E+01</td>
</tr>
<tr>
<td>0.93630612E+00</td>
<td>1.6087736E+01</td>
</tr>
<tr>
<td>0.94595079E+00</td>
<td>1.4028140E+01</td>
</tr>
<tr>
<td>0.95491555E+00</td>
<td>1.1969778E+01</td>
</tr>
<tr>
<td>0.96314744E+00</td>
<td>1.0507215E+01</td>
</tr>
<tr>
<td>0.97062697E+00</td>
<td>9.0435138E+00</td>
</tr>
<tr>
<td>0.97731771E+00</td>
<td>7.7728876E+02</td>
</tr>
<tr>
<td>0.98319142E+00</td>
<td>6.6688130E+02</td>
</tr>
<tr>
<td>0.98822326E+00</td>
<td>5.7854336E+02</td>
</tr>
<tr>
<td>0.99239108E+00</td>
<td>4.9089986E+02</td>
</tr>
<tr>
<td>0.99567440E+00</td>
<td>4.0448413E+02</td>
</tr>
<tr>
<td>0.99805372E+00</td>
<td>3.4095701E+02</td>
</tr>
<tr>
<td>0.9990735E+00</td>
<td>3.3656210E+02</td>
</tr>
<tr>
<td>0.99999890E+00</td>
<td>3.3775884E+02</td>
</tr>
</tbody>
</table>

**UPPER SURFACE CALCULATION USING LFC 15.0 PERCENT THICK AIRFOIL DESIGNED BY ALLISON**

35°
<table>
<thead>
<tr>
<th>n</th>
<th>A3</th>
<th>A9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4503054E+03</td>
<td>2.347317E+00</td>
<td></td>
</tr>
<tr>
<td>0.1776235E+02</td>
<td>3.879075E+00</td>
<td></td>
</tr>
<tr>
<td>0.3423110E+02</td>
<td>5.203236E+00</td>
<td></td>
</tr>
<tr>
<td>0.5629872E+02</td>
<td>6.208344E+00</td>
<td></td>
</tr>
<tr>
<td>0.8553735E+02</td>
<td>7.261811E+00</td>
<td></td>
</tr>
<tr>
<td>0.1207106E+01</td>
<td>7.986545E+00</td>
<td></td>
</tr>
<tr>
<td>0.1621180E+01</td>
<td>8.657527E+00</td>
<td></td>
</tr>
<tr>
<td>0.2098330E+01</td>
<td>9.254157E+00</td>
<td></td>
</tr>
<tr>
<td>0.2640580E+01</td>
<td>9.771008E+00</td>
<td></td>
</tr>
<tr>
<td>0.3247192E+01</td>
<td>1.022894E+01</td>
<td></td>
</tr>
<tr>
<td>0.3919411E+01</td>
<td>1.059790E+01</td>
<td></td>
</tr>
<tr>
<td>0.4654525E+01</td>
<td>1.087273E+01</td>
<td></td>
</tr>
<tr>
<td>0.5460550E+01</td>
<td>1.106877E+01</td>
<td></td>
</tr>
<tr>
<td>0.6339039E+01</td>
<td>1.117121E+01</td>
<td></td>
</tr>
<tr>
<td>0.7280014E+01</td>
<td>1.121336E+01</td>
<td></td>
</tr>
<tr>
<td>0.8266350E+01</td>
<td>1.122085E+01</td>
<td></td>
</tr>
<tr>
<td>0.9356676E+01</td>
<td>1.119861E+01</td>
<td></td>
</tr>
<tr>
<td>1.0448595E+01</td>
<td>1.117211E+01</td>
<td></td>
</tr>
<tr>
<td>1.1668199E+01</td>
<td>1.112970E+01</td>
<td></td>
</tr>
<tr>
<td>1.2974599E+01</td>
<td>1.107919E+01</td>
<td></td>
</tr>
<tr>
<td>1.4234126E+01</td>
<td>1.104233E+01</td>
<td></td>
</tr>
<tr>
<td>1.5592027E+01</td>
<td>1.109999E+01</td>
<td></td>
</tr>
<tr>
<td>1.707092E+01</td>
<td>1.109568E+01</td>
<td></td>
</tr>
<tr>
<td>1.855855E+01</td>
<td>1.109153E+01</td>
<td></td>
</tr>
<tr>
<td>1.9962635E+01</td>
<td>1.108716E+01</td>
<td></td>
</tr>
<tr>
<td>2.1510730E+01</td>
<td>1.107369E+01</td>
<td></td>
</tr>
<tr>
<td>2.3100153E+01</td>
<td>1.106190E+01</td>
<td></td>
</tr>
<tr>
<td>2.4729015E+01</td>
<td>1.105056E+01</td>
<td></td>
</tr>
<tr>
<td>2.639414E+01</td>
<td>1.104895E+01</td>
<td></td>
</tr>
<tr>
<td>2.8093408E+01</td>
<td>1.104163E+01</td>
<td></td>
</tr>
<tr>
<td>2.982373E+01</td>
<td>1.103598E+01</td>
<td></td>
</tr>
<tr>
<td>3.155211E+01</td>
<td>1.103155E+01</td>
<td></td>
</tr>
<tr>
<td>3.335662E+01</td>
<td>1.102805E+01</td>
<td></td>
</tr>
<tr>
<td>3.517415E+01</td>
<td>1.102452E+01</td>
<td></td>
</tr>
<tr>
<td>3.700129E+01</td>
<td>1.102109E+01</td>
<td></td>
</tr>
<tr>
<td>3.884705E+01</td>
<td>1.101869E+01</td>
<td></td>
</tr>
<tr>
<td>4.070648E+01</td>
<td>1.101629E+01</td>
<td></td>
</tr>
<tr>
<td>4.257783E+01</td>
<td>1.101389E+01</td>
<td></td>
</tr>
<tr>
<td>4.444722E+01</td>
<td>1.101149E+01</td>
<td></td>
</tr>
<tr>
<td>4.633471E+01</td>
<td>1.100909E+01</td>
<td></td>
</tr>
<tr>
<td>4.823193E+01</td>
<td>1.100669E+01</td>
<td></td>
</tr>
<tr>
<td>5.012859E+01</td>
<td>1.100429E+01</td>
<td></td>
</tr>
<tr>
<td>5.200676E+01</td>
<td>1.100189E+01</td>
<td></td>
</tr>
<tr>
<td>5.388683E+01</td>
<td>1.100049E+01</td>
<td></td>
</tr>
<tr>
<td>5.575650E+01</td>
<td>1.100008E+01</td>
<td></td>
</tr>
<tr>
<td>5.761897E+01</td>
<td>1.100068E+01</td>
<td></td>
</tr>
<tr>
<td>5.946537E+01</td>
<td>1.100128E+01</td>
<td></td>
</tr>
<tr>
<td>6.129556E+01</td>
<td>1.100188E+01</td>
<td></td>
</tr>
<tr>
<td>6.310526E+01</td>
<td>1.100248E+01</td>
<td></td>
</tr>
<tr>
<td>6.490534E+01</td>
<td>1.100308E+01</td>
<td></td>
</tr>
<tr>
<td>6.666120E+01</td>
<td>1.100368E+01</td>
<td></td>
</tr>
<tr>
<td>6.840027E+01</td>
<td>1.100428E+01</td>
<td></td>
</tr>
<tr>
<td>7.012505E+01</td>
<td>1.100488E+01</td>
<td></td>
</tr>
<tr>
<td>7.174282E+01</td>
<td>1.100548E+01</td>
<td></td>
</tr>
<tr>
<td>7.336279E+01</td>
<td>1.100608E+01</td>
<td></td>
</tr>
<tr>
<td>7.506017E+01</td>
<td>1.100668E+01</td>
<td></td>
</tr>
<tr>
<td>7.664233E+01</td>
<td>1.100728E+01</td>
<td></td>
</tr>
<tr>
<td>78.18739E+00</td>
<td>9.0744695E+00</td>
<td></td>
</tr>
<tr>
<td>79.69649E+00</td>
<td>8.071752E+00</td>
<td></td>
</tr>
<tr>
<td>81.16391E+00</td>
<td>8.720836E+00</td>
<td></td>
</tr>
<tr>
<td>82.594255E+00</td>
<td>9.5100503E+00</td>
<td></td>
</tr>
<tr>
<td>83.96446E+00</td>
<td>8.2766929E+00</td>
<td></td>
</tr>
<tr>
<td>85.241131E+00</td>
<td>8.0254672E+00</td>
<td></td>
</tr>
<tr>
<td>86.54657E+00</td>
<td>7.7701671E+00</td>
<td></td>
</tr>
<tr>
<td>87.93776E+00</td>
<td>7.5258171E+00</td>
<td></td>
</tr>
<tr>
<td>89.17958E+00</td>
<td>7.3053494E+00</td>
<td></td>
</tr>
<tr>
<td>90.36941E+00</td>
<td>7.1130797E+00</td>
<td></td>
</tr>
<tr>
<td>91.51248E+00</td>
<td>6.9503462E+00</td>
<td></td>
</tr>
<tr>
<td>92.60180E+00</td>
<td>6.8070845E+00</td>
<td></td>
</tr>
<tr>
<td>93.63941E+00</td>
<td>6.6658051E+00</td>
<td></td>
</tr>
<tr>
<td>94.56079E+00</td>
<td>6.5260134E+00</td>
<td></td>
</tr>
<tr>
<td>95.491055E+00</td>
<td>6.3879166E+00</td>
<td></td>
</tr>
<tr>
<td>96.31474E+00</td>
<td>6.2385472E+00</td>
<td></td>
</tr>
<tr>
<td>97.06297E+00</td>
<td>6.071027E+00</td>
<td></td>
</tr>
<tr>
<td>97.731771E+00</td>
<td>5.8935388E+00</td>
<td></td>
</tr>
<tr>
<td>98.319142E+00</td>
<td>5.7176496E+00</td>
<td></td>
</tr>
<tr>
<td>98.82232E+00</td>
<td>5.5417832E+00</td>
<td></td>
</tr>
<tr>
<td>99.239108E+00</td>
<td>5.3666732E+00</td>
<td></td>
</tr>
<tr>
<td>99.56744E+00</td>
<td>5.1920023E+00</td>
<td></td>
</tr>
<tr>
<td>99.805372E+00</td>
<td>5.0181908E+00</td>
<td></td>
</tr>
<tr>
<td>99.950735E+00</td>
<td>4.8457992E+00</td>
<td></td>
</tr>
<tr>
<td>99.999989E+00</td>
<td>4.673208E+00</td>
<td></td>
</tr>
<tr>
<td>INPUT + SOME COMPUTED QUANTITIES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PECT** 50 **In** 100 **TOL** ,00001 **O2** ,50000 **O** ,010000 **USTEP** ,050000 **F** 1,00000

**IRLC** DISCONTINUOUS SUCTION OR INJECTION GIVEN RELC

**SUCTION OR INJECTION VELOCITY** | **S LOCATION** | **NB** | **AXES** | **7** |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WALL(N)</strong></td>
<td><strong>SDB(N)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-3,00000</td>
<td>40000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-3,50000</td>
<td>50000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-4,00000</td>
<td>40000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-5,00000</td>
<td>70000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-6,00000</td>
<td>80000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-7,00000</td>
<td>90000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-8,00000</td>
<td>10,00000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**INC** = AMINF30, 0530020000E+00 CANM 1,40000000E+01

COMPRESSIBLE FLOW (INC), STEWARTON TRANSFORMATION USED

**B** = SUCTION, TRANSITION ANALYSIS OF YAWING LAMINAR BOUNDARY LAYER

**INPUT** 1 **CHM** 1,00000

**IBY** = 0 **INT** = 161 **RHO** = 3,00000000E+03

<table>
<thead>
<tr>
<th><strong>IBPS</strong> 2</th>
<th><strong>N</strong></th>
<th><strong>X(N)</strong></th>
<th><strong>Z(N)</strong></th>
<th><strong>S(N)</strong></th>
<th><strong>TH(N)</strong></th>
<th><strong>STH(N)</strong></th>
<th><strong>F(N)</strong></th>
<th><strong>FSTH(N)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>01</td>
<td>1000000000E+01</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>2</td>
<td>00</td>
<td>05498510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>3</td>
<td>00</td>
<td>03498510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>4</td>
<td>00</td>
<td>04598510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>5</td>
<td>00</td>
<td>05698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>6</td>
<td>00</td>
<td>06698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>7</td>
<td>00</td>
<td>07698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>8</td>
<td>00</td>
<td>08698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>9</td>
<td>00</td>
<td>09698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>10</td>
<td>00</td>
<td>10698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>11</td>
<td>00</td>
<td>11698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>12</td>
<td>00</td>
<td>12698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>13</td>
<td>00</td>
<td>13698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>14</td>
<td>00</td>
<td>14698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>15</td>
<td>00</td>
<td>15698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>16</td>
<td>00</td>
<td>16698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>17</td>
<td>00</td>
<td>17698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>18</td>
<td>00</td>
<td>18698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>19</td>
<td>00</td>
<td>19698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>20</td>
<td>00</td>
<td>20698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>21</td>
<td>00</td>
<td>21698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>22</td>
<td>00</td>
<td>22698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>23</td>
<td>00</td>
<td>23698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>24</td>
<td>00</td>
<td>24698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>25</td>
<td>00</td>
<td>25698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>26</td>
<td>00</td>
<td>26698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>27</td>
<td>00</td>
<td>27698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>28</td>
<td>00</td>
<td>28698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>29</td>
<td>00</td>
<td>29698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>30</td>
<td>00</td>
<td>30698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>31</td>
<td>00</td>
<td>31698510E+00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
</tbody>
</table>
NON-DIMENSIONAL DISTANCE FROM LOWER SURFACE TRAILING EDGE (IF UPPER SURFACE IS TO BE COMPUTED, ISP=2), OR FROM UPPER SURFACE TRAILING EDGE (IF LOWER SURFACE IS TO BE COMPUTED, ISP=0) TO ATTACHMENT LINE = BATT/CH = .51022849E+01

SUCTION TRANSITION ANALYSIS OF YAWED WING LAMINAR BOUNDARY LAYER

UPPER SURFACE CALCULATION USING LFC 13.0 PCT THICK AIRFOIL DESIGNED BY ALLISON

REYNOLDS NUMBER DEFINED BY RNN/UL

VELOCITY GRADIENT AT ATTACHMENT LINE = 88.67

MGRAD  = .96100000E+02
VGRAD  = 88.6677  XVC(1) = -.15400000E+04
<table>
<thead>
<tr>
<th>U</th>
<th>U*</th>
<th>V</th>
<th>V*</th>
<th>W</th>
<th>W*</th>
<th>(\Delta T)</th>
<th>(\Delta T^*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000000</td>
<td>0.000000</td>
<td>-0.29171</td>
<td>0.000000</td>
<td>0.000000</td>
<td>1.15660</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>0.059000</td>
<td>0.036772</td>
<td>-0.20984</td>
<td>0.06470</td>
<td>0.03820</td>
<td>1.15649</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>0.109000</td>
<td>0.077539</td>
<td>-0.20942</td>
<td>0.13479</td>
<td>0.07508</td>
<td>1.15632</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>0.209000</td>
<td>0.195009</td>
<td>-0.31539</td>
<td>0.27998</td>
<td>0.14809</td>
<td>1.15622</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>0.330000</td>
<td>0.323167</td>
<td>-0.36216</td>
<td>0.36470</td>
<td>0.21029</td>
<td>1.15613</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>0.490000</td>
<td>0.457888</td>
<td>-0.38137</td>
<td>0.45949</td>
<td>0.28131</td>
<td>1.15606</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>0.580000</td>
<td>0.610975</td>
<td>-0.43979</td>
<td>0.59502</td>
<td>0.35422</td>
<td>1.15600</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>0.630000</td>
<td>0.617567</td>
<td>-0.44394</td>
<td>0.63533</td>
<td>0.36464</td>
<td>1.15596</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>0.790000</td>
<td>0.893972</td>
<td>-0.70506</td>
<td>0.77246</td>
<td>0.54731</td>
<td>1.15579</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>1.000000</td>
<td>1.20219</td>
<td>-0.77602</td>
<td>0.87379</td>
<td>0.74104</td>
<td>1.15567</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>1.100000</td>
<td>1.602855</td>
<td>-0.66395</td>
<td>0.95113</td>
<td>0.83675</td>
<td>1.15557</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>1.200000</td>
<td>2.42063</td>
<td>-0.54902</td>
<td>0.87900</td>
<td>0.72530</td>
<td>1.15547</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>1.300000</td>
<td>2.99710</td>
<td>-0.34177</td>
<td>0.90338</td>
<td>0.76415</td>
<td>1.15537</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>1.400000</td>
<td>3.99710</td>
<td>-0.34177</td>
<td>0.90338</td>
<td>0.76415</td>
<td>1.15528</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>1.500000</td>
<td>5.99710</td>
<td>-0.34177</td>
<td>0.90338</td>
<td>0.76415</td>
<td>1.15528</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>1.600000</td>
<td>1.223489</td>
<td>-0.32515</td>
<td>0.91700</td>
<td>0.75765</td>
<td>1.15528</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>1.700000</td>
<td>1.204062</td>
<td>-0.31874</td>
<td>0.91700</td>
<td>0.75765</td>
<td>1.15528</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>1.800000</td>
<td>1.373227</td>
<td>-0.51539</td>
<td>0.97703</td>
<td>0.81319</td>
<td>1.15528</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>1.900000</td>
<td>1.447910</td>
<td>-0.61209</td>
<td>0.97703</td>
<td>0.81319</td>
<td>1.15528</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>2.000000</td>
<td>1.623477</td>
<td>-0.71078</td>
<td>0.97703</td>
<td>0.81319</td>
<td>1.15528</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>2.100000</td>
<td>1.546495</td>
<td>-0.80449</td>
<td>0.94916</td>
<td>0.86709</td>
<td>1.15528</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>2.200000</td>
<td>1.671384</td>
<td>-0.90328</td>
<td>1.01405</td>
<td>0.95784</td>
<td>1.15528</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>2.300000</td>
<td>1.795253</td>
<td>-1.00477</td>
<td>0.9584</td>
<td>1.02875</td>
<td>1.15528</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>2.400000</td>
<td>1.820026</td>
<td>-1.10453</td>
<td>0.94837</td>
<td>1.07760</td>
<td>1.15528</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>2.500000</td>
<td>1.840276</td>
<td>-1.20536</td>
<td>0.92981</td>
<td>1.07760</td>
<td>1.15528</td>
<td>1.27716</td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>ZCOMP</td>
<td>U</td>
<td>V</td>
<td>STV</td>
<td>CFV</td>
<td>T</td>
<td>MHD</td>
</tr>
<tr>
<td>---</td>
<td>-------</td>
<td>---</td>
<td>---</td>
<td>-----</td>
<td>-----</td>
<td>---</td>
<td>-----</td>
</tr>
<tr>
<td>0</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>0.0500</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>0.1000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>0.2000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>0.3000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>0.5000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>2.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>3.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

**Additional Tables and Data**

- Reynolds Number: 11000000
- DeltaI = 0.000138
- ThetaI = 0.0551
- DeltaI/C = 4.26E-02
- Cross Flow Displacement Thickness = 0.075184
- Stream Flow Displacement Thickness = 1.475369
- Maximum Cross-Flow Velocity = 0.024473
<table>
<thead>
<tr>
<th>Reynolds Numbers</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensional 23/Chord</td>
<td>0.000912</td>
<td>0.007171</td>
<td>0.006572</td>
<td>0.006893</td>
<td>0.007298</td>
<td>0.007601</td>
<td>0.007904</td>
<td>0.008207</td>
<td>0.008510</td>
<td>0.008813</td>
</tr>
<tr>
<td>Delta/C</td>
<td>0.000140</td>
<td>0.000128</td>
<td>0.000117</td>
<td>0.000106</td>
<td>0.000095</td>
<td>0.000085</td>
<td>0.000075</td>
<td>0.000065</td>
<td>0.000055</td>
<td>0.000045</td>
</tr>
<tr>
<td>Theta/Ca</td>
<td>0.000043</td>
<td>0.000042</td>
<td>0.000041</td>
<td>0.000040</td>
<td>0.000039</td>
<td>0.000038</td>
<td>0.000037</td>
<td>0.000036</td>
<td>0.000035</td>
<td>0.000034</td>
</tr>
</tbody>
</table>

### Sweep Instability Test

<table>
<thead>
<tr>
<th>Reynolds Numbers</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
<th>11000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensional 23/Chord</td>
<td>0.000912</td>
<td>0.007171</td>
<td>0.006572</td>
<td>0.006893</td>
<td>0.007298</td>
<td>0.007601</td>
<td>0.007904</td>
<td>0.008207</td>
<td>0.008510</td>
<td>0.008813</td>
</tr>
<tr>
<td>Delta/C</td>
<td>0.000140</td>
<td>0.000128</td>
<td>0.000117</td>
<td>0.000106</td>
<td>0.000095</td>
<td>0.000085</td>
<td>0.000075</td>
<td>0.000065</td>
<td>0.000055</td>
<td>0.000045</td>
</tr>
<tr>
<td>Theta/Ca</td>
<td>0.000043</td>
<td>0.000042</td>
<td>0.000041</td>
<td>0.000040</td>
<td>0.000039</td>
<td>0.000038</td>
<td>0.000037</td>
<td>0.000036</td>
<td>0.000035</td>
<td>0.000034</td>
</tr>
</tbody>
</table>

**Reynolds Numbers**

- 11000000
- 11000000
- 11000000
- 11000000
- 11000000
- 11000000
- 11000000
- 11000000
- 11000000
- 11000000

**Sweep Instability Test**

- Reynolds Numbers: 11000000
- Reynolds Numbers: 11000000
- Reynolds Numbers: 11000000
- Reynolds Numbers: 11000000
- Reynolds Numbers: 11000000
- Reynolds Numbers: 11000000
- Reynolds Numbers: 11000000
- Reynolds Numbers: 11000000
- Reynolds Numbers: 11000000
- Reynolds Numbers: 11000000

**Transition Test**

- Granville
- Granville
- Granville
- Granville
- Granville
- Granville
- Granville
- Granville
- Granville
- Granville

**Instability**

- Transition:
- No Transition:
- No Transition:
- No Transition:
- No Transition:
- No Transition:
- No Transition:
- No Transition:
- No Transition:
- No Transition:

**Results**

- No Transition:
- No Transition:
- No Transition:
- No Transition:
- No Transition:
- No Transition:
- No Transition:
- No Transition:
- No Transition:
- No Transition:
REFERENCES


7. Bauer, Frances; Garabedian, Paul; Korn, David; and Jameson, Anthony: Supercritical Wing Sections II. Springer-Verlag, 1975.
Figure 1. Suction distribution for sample case.
Figure 2. Airfoil and pressure distribution for sample case, $M_\infty = 0.725$. 
SKIN FRICTION DISTRIBUTIONS

+ CFX
× CFY

Figure 3. Upper surface skin-friction distributions for sample case.

AMINF3D = .885  PSI = 35.0  RNL(1) = 1.10E+07
CDEX = .00168  CDFXINF = .00196
YADYOGI  77/01/27. 12.01.35.