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HADY-I, a FORTRAN Program for the Compressible Stability Analysis of Three-Dimensional Boundary Layers

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CONTENTS

I. SUMMARY AND INTRODUCTION

This report describes a computer program HADY-I for calculating the linear incompressible or compressible stability characteristics of the laminar boundary layer on swept and tapered wings. The stability analysis and computational procedures used in this program are outlined in details in references 1 and 2.

The eigenvalue problem and its adjoint arising from the linearized disturbance equations with the appropriate boundary conditions are solved numercially using a combination of Newton-Raphson iterative scheme and a variable step size integrator based on the Runge-kutta-Fehlburg fifth-order formulas. The integrator is used in conjunction with a modified Gram-Schmidt orthonormalization procedure. More details concerning the integrator is found in reference 3.

The computer program HADY-I calculates the growth rates of crossflow (CF) or streamwise Tollmien-Schlichting (TS) instabilities. It also calculates the group velocities of these disturbances. The program incorporates all methods of calculation outlined in reference 1, namely, they are:

(1) MMSGR, method of maximum spatial growth rates

(2) MFCWL, method of fixed spanwise component of wavelength

(3) MFWL, method of fixed wavelength

HADY-I is restricted to parallel stability calculations, where the boundary layer (meanflow) is assumed to be parallel. The meanflow solution is an input to the program, see Appendix I. A nonparallel stability computer program HADY-II is another part that is under preparation.

Figure 1 shows a definition of the coordinate system used in this analysis, x is the chordwise direction, z is the spanwise direction, and y is the normal to the x-z plane.

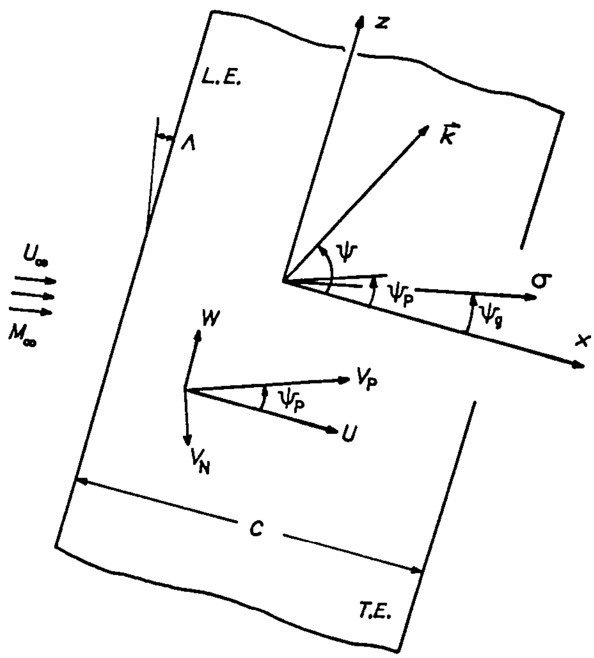

Figure 1.- Definition of the coordinate system.

II. PROGRAM STRUCTURE

A. FLOW CHART

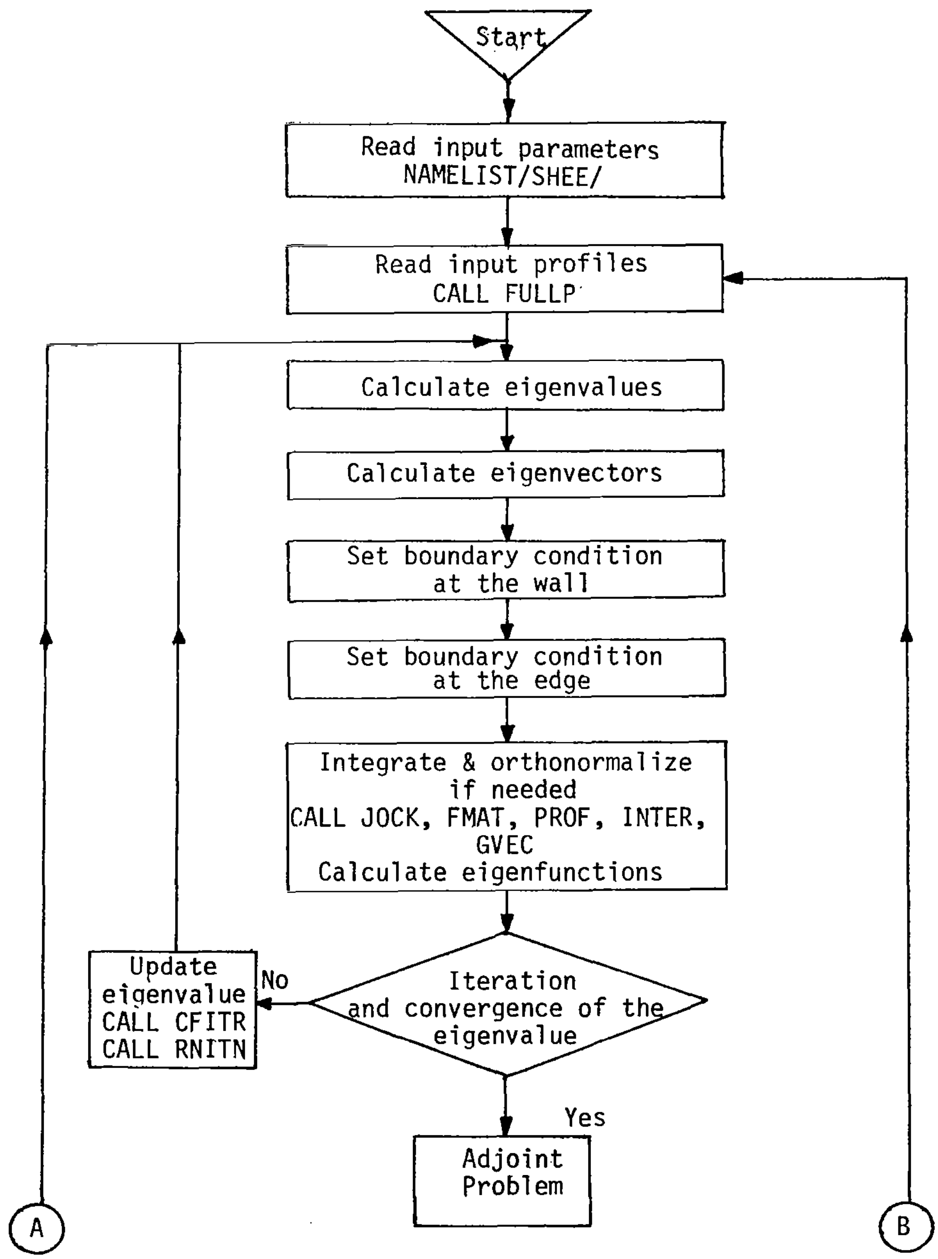

Figure 2.- Overall flow chart for HADY-I program.

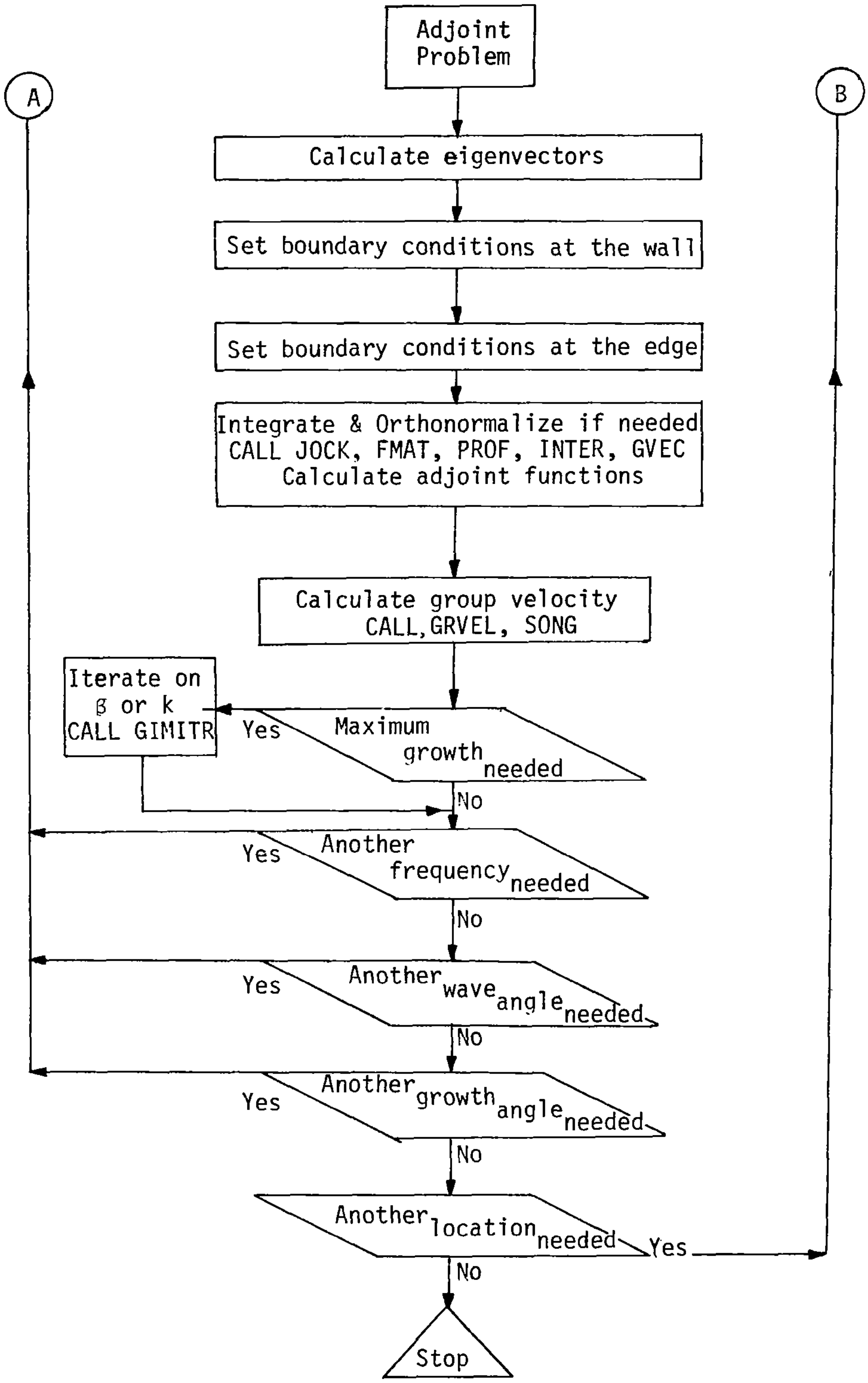

Figure 2.- (Cont.)

B. SUBROUTINES, PURPOSE AND OUTPUT

See Section C for the definition of the Fortran variable names.

SUBROUTINE FULLP

PURPOSE = To read from TAPE10, the compressible parallel meanflow profiles, and modify these profiles if incompressible stability calculations are needed.

OUTPUT = The variables NS, XC, MACH, R, CHL, UFS, ETA, PRA, ND, IE, and the arrays YI, U, UP, UPP, W, WP, WPP, T, TP, TPP, MU, MUP, MUPP, ALFA, ALFAP, PR

SUBROUTINE CFA

PURPOSE = To calculate the angle of the velocity vector with respect to x at the y-location of an inflection point of the crossflow velocity profile

OUTPUT = EPSICF

SUBROUTINE CDMINV

PURPOSE = To calculate the transpose of the eigenvector matrix

OUTPUT = The transpose matrix A

SUBROUTINE JOCK

PURPOSE = To integrate the disturbance equations and to orthonormalize the solution whenever needed

OUTPUT = IFLAG, the array PH

SUBROUTINE FMAT

PURPOSE = Provides the disturbance equations to be integrated in JOCK

SUBROUTINE RNITN

PURPOSE = To iterate on the complex eigenvalues KX. Used only when ICASE = 1 or ICASE = 3

OUTPUT = Updated value of KX

SUBROUTINE CFITN

PURPOSE = To iterate on the real eigenvalues ALFAR and EPSI. Used only when ICASE = 4 or ICASE = 5

OUTPUT = Updated values of ALFAR and EPSI

SUBROUTINE GIMIR

PURPOSE = Iteration to maximize the disturbance growth rate, at each chordwise location. The iteration is performed on BETAR when ICASE = 3, and on WN when ICASE = 4

OUTPUT = Updated values of BETAR or WN

SUBROUTINE SONG

PURPOSE = Numerical itegration of a complex quantity from $y = 0$ to $y = y_e$ (the edge of the boundary layer)

OUTPUT = The value of the integral at y_e

SUBROUTINE PROF

PURPOSE = During the integration of the disturbance equations, meanflow quantities are needed at a specific y-location. This subroutine uses the real function INTER to interpolate the meanflow profiles

OUTPUT = Meanflow values at the required y-location, they are U, UP, UPP, W, WP, WPP, T, TP, TPP, MU, MUP, MUPP, ALFA, ALFAP, PRANDL

SUBROUTINE GRVEL

PURPOSE = To calculate the ratio of the components of the group velocity and the group velocity angle

OUTPUT = VIG1, VIG2, TATA, EPGR

C. FORTRAN VARIABLE NAMES

Variable Name	Description
ALFA	d(MU)/dT, where MU and T are the viscosity and temperature of the meanflow
ALFAP	$\frac{d}{dy}\left(\frac{d(MU)}{dT}\right)$
ALFAR	α_r, wave number component in x-direction
ALFAI	α_i, growth rate component in x-direction
BETAR	β_r, wave number component in z-direction
BETAI	β_i, growth rate component in z-direction
CHL	L* dimensional characteristic length = $(U_e^* \, x^*/\nu_e^*)^{1/2}$
ETA	$(y^*/L^*)_{max}$
EPSI	$\Psi = \tan^{-1}(\beta_r/\alpha_r)$
EPSIP	$\bar{\Psi} = \tan^{-1}(\beta_i/\alpha_i)$
EPGR	$\Psi_{gr} = \tan^{-1}(\omega_\beta/\omega_\alpha)_r$, real part of the group velocity angle
EPSICF	Ψ, wave angle for the crossflow instabilities
IFLAG	Flag from the integrator to indicate the status of the solution
IE	Number of points in the boundary layer where the meanflow quantities is given
KX	$k_x = (\alpha_r, \alpha_i)$, complex wave number in x-direction
KZ	$k_z = (\beta_r, \beta_i)$, complex wave number in z-direction
MACH	M_∞, freestream Mach number
MU	Array of meanflow viscosity
MUP	d(MU)/dy
MUPP	$d^2(MU)/dy^2$
ND	$\tan\phi = W_e/U_e$

NS	Station number along the chord
PH	Array of solution vector from JOCK
PR	Array of Prandtl number
PRA	The boundary layer edge value of Prandtl number
R	Reynolds number = $U_e{}^*L^*/\nu_e{}^*$
T	Array of meanflow temperature
TATA	$\omega_\beta/\omega_\alpha$, group velocity ratio
TP	dT/dy
TPP	d^2T/dy^2
U	Array of meanflow velocity in x-direction
UFS	Dimensional freestream velocity
UP	dU/dy
UPP	d^2U/dy^2
W	Array of meanflow velocity in z-direction
WP	dW/dy
WPP	d^2W/dy^2
WN	wave number k or wavelength λ/c
XC	x location as percentage of the chord
YI	Array of y-location in the boundary layer
VIGI	Proportional to ω_α, group velocity in x-direction
VIGZ	Proportional to ω_β, group velocity in z-direction
PHI	ϕ, potential flow angle in degrees
OMEGA	Complex circular frequency
FREQ	Nondimensional frequency F (if f is input), or dimensional frequency f (if F is input)
CR	Wave speed

PGR	Parallel growth rate calculated as $-\alpha_i - \beta_i \tan(\omega_\beta/\omega_\alpha)_r$
D	The wall value of the eigenfunction which we iterate on after convergence (it should be zero)
DKX	Incremental variation of kx during the iteration
IW1	Number of performed orthonormalization
IW2	Maximum number of allowed orthonormalization
IFL	IFLAG
DEPSI	Incremental variation of EPSI during the iteration
DALFAI	Incremental variation of ALFAI during the iteration
NIT	Number of iteration

III. COMPUTER PROGRAM USAGE

The program calculates the stability characteristics at one or more chordwise locations.

A. Machine Requirements

HADY-I executes on a computer CDC CYBER 175

B. Storage Allocation

The program executes in 125000 octal words of central memory

C. Timing

Timing for the job depends on several different options available for running HADY-I. In a single execution, the CPU required depends on how near is the guessed eigenvalue to the exact value, number of chordwise locations where output is needed, . . . etc. . . . The CPU requirement for one chordwise location using a reasonable guess (not very far from the exact value) for one disturbance frequency and one wavelength is about 30 seconds.

D. Input/Output Files

The program card is

PROGRAM HADY (INPUT, OUTPUT, TAPE6 = INPUT, TAPE6 = OUTPUT, TAPE10)

TAPE10 is an input file that contains all meanflow profiles at different chordwise locations on the wing, starting from the leading edge to the trailing edge. At each location, meanflow quantities are stored from $y = y_e$ to $y = 0$.

E. Control Cards

The following control cards can be used to execute the program

```
JOBN, Tt, CM
USER, USERNO, PASSWRD.
CHARGE, CHARGNO, LRC.
GET, HADYI.
GET, TAPE10 = TAPEN.
REWIND, TAPE10.
GET, NBLHLIB/UN = 357811N.
LDSET, LIB = NBLHLIB, PRESET = INDEF.
```

HADYI
EXIT
7/8/9 end of record
Input Cards
6/7/8/9

NBLHLIB is a special file that contains the integrator

F. Program Input

All input variables are read inside the program in a NAMELIST statement

NAMELIST/SHEE/ISPTM, INCOMP, NSTATN, NSEND, NSTEP, ICASE, ICIZER, FR, IFR, NFR, DFR, EPSI, IEPSI, NEPSI, DEPSI, EPSIP, IEPSIP, NEPSIP, DEPSIP, ALFAR, ALFAI, BETAR, IBETAR, BETAI, WN, IWN, NWN, DWN, CHORD, IPRINT, RE, AE, EPS, ITR, OMEGAR, OMEGAI

A description of these variables follows

ISPTM	Flag for spatial or temporal stability calculations ISPTM = 1 spatial ISPTM = 2 temporal
INCOMP	Flag for incompressible or compressible stability calculations INCOMP = 1 incompressible INCOMP = 2 compressible
NSTATN	Chordwise station number where stability calculations start
NSEND	Chordwise station number where stability calculations end. NSEND = NSTATN if calculations is needed at one station
NSTEP	Stability calculations are performed every NSTEP chordwise stations
ICASE	Flag for the method of calculation ICASE = 1 TS calculations with MMSGR or MFWL ICASE = 3 TS calculations with MFCWL ICASE = 4 CF calculations with MMSGR or MFWL ICASE = 5 CF calculations with MFCWL
ICIZER	Flag for the method of calculation ICIZER = 1 iteration on the eigenvalue for maximum growth rate ICIZER = 2 no iteration to maximize the growth rate
FR	The disturbance frequency, dimensional (f) in CPS, or non-dimensional ($F = 2\pi f\nu_\infty/U^2_\infty$)
IFR	Flag for the input frequency FR IFR = 1 F is an input IFR = 2 f is an input

NFR Number of frequencies to be used in calculations at each chordwise station

DFR Incremental variation in FR if more than one frequency is used
FR (new) = FR (old) + DFR

EPSI The wave angle Ψ in degrees

IEPSI Flag to indicate how Ψ is calculated, IEPSI = 2 and IEPSI = 3 are used for CF calculations
IEPSI = 1 Ψ is an input
IEPSI = 2 $\Psi = \phi + 90^o$
IEPSI = 3 Ψ is calculated from subroutine CFA
IEPSI = 4 $\Psi = \phi$

NEPSI Number of wave angles to be used in calculations at each chordwise station

DEPSI Incremental variation in Ψ, if more than one wave length analyis needed
EPSI (new) = EPSI (old) + DEPSI

EPSIP Angle of the growth rate vector, $\bar{\Psi} = \tan^{-1} (\beta_i/\alpha_i)$

IEPSIP Flag to indicate how $\bar{\Psi}$ is calculated
IEPSIP = 1 $\bar{\Psi}$ is an input
IEPSIP = 2 $\bar{\Psi} = \phi$

NEPSIP Number of angles $\bar{\Psi}$ to be used in calculations at each chordwise station

DEPSIP Incremental variation in $\bar{\Psi}$, if more than one angle is needed
EPSIP (new) = EPSIP (old) + DEPSIP

ALFAR α_r, wavenumber component in chordwise direction

ALFAI $-\alpha_i$, growth rate component in chordwise direction

BETAR β_r wavenumber component, or λ_z*/C*, wavelength component in the spanwise direction. C is the chord length

IBETAR Flag for the input BETAR
IBETAR = 1 β_r is an input
IBETAR = 2 λ_z*/C* is an input

BETAI $-\beta_i$; growth rate component in spanwise direction

WN k, wave number or λ*/C* wavelength

IWN	Flag for the input WN IWN = 1 k is an input IWN = 2 λ^*/C^* is an input
NWN	Number of wavenumbers or wavelengths to be used in the calculations at each chordwise station
DWN	Incremental variation in WN if more than one is needed WN (new) = WN (old) + DWN
CHORD	The dimensional chord length normal to the leading edge
IPRINT	Flag to control output printing IPRINT = 1 long print IPRINT = 2 short print
RE	Relative error tolerance used by the integrator
AE	Absolute error tolerance used by the integrator
EPS	Relative error tolerance used in calculating the eigenvalue
ITR	Maximum number of iterations for the eigenvalue calculation
OMEGAR	Dimensionless circular frequency
OMEGAI	Temporal growth rate

G. PROGRAM OUTPUT

The output is controlled by IPRINT, see last section. The long print contains the short one added to it, the eigenvalues, eigenfunctions of the homogeneous problem, and adjoint eigenfunctions at different y-locations. The output contains

NS, XC, R, CHL
NIT, KX, D, DKX, IFL, IW1, IW2 (for TS calculations)
or NIT, KX, KZ, EPSI, DEPSI, DALFAI, IFL, IW1, IW2 (for CF calculations)
VIG1, VIG2, TATA, EPGR
KX, KZ, OMEGA, FR, FREQ
CR, MACH, ETA, IE, WN, PGR, D
PHI, EPSI, EPSIP

See section C for the definition of the FORTRAN variable names

IV. REFERENCES

1. El-Hady, N. M.: Nonparallel Stability of Three-Dimensional Compressible Boundary Layers. Part I - Stability Analysis, NASA CR-3245, 1980.

2. El-Hady, N. M.: On the Stability of Three-Dimensional, Compressible, Nonparallel Boundary Layers. AIAA Paper No. 80-1374, Snowmass, Colorado, 1980.

3. Scott, M. R.; and Watts, H. A.: Computational Solution of Linear Two-Point Boundary Value Problems Via Orthonormalization. SIAM J. Num. Anal. 14, 40, 1977.

4. Kaups, K.; and Cebeci, T.: Compressible Laminar Boundary Layers with Suction on Swept and Tapered Wings. J. Aircraft, V. 14, 1977.

V. SAMPLE CASES

The meanflow used for the following sample cases is the same as in reference 2.

The boundary layer with suction on a 23^{o} swept infinite span wing is calculated (see Appendix I). The airfoil section is supercritical with normal chord c = 1.98 m including a trailing edge flap. The freestream conditions are; Mach number = .82, total temperature = 393 K, and total pressure = .46 atm.

Figure 3 shows the geometry, the distribution of the pressure coefficient C_p, and the distribution of the suction coefficient $C_S = -\rho_0 V_0/\rho_\infty U_\infty$, where the subscript $_0$ denotes wall condition.

Variables needed to be input are marked in the following sample cases.

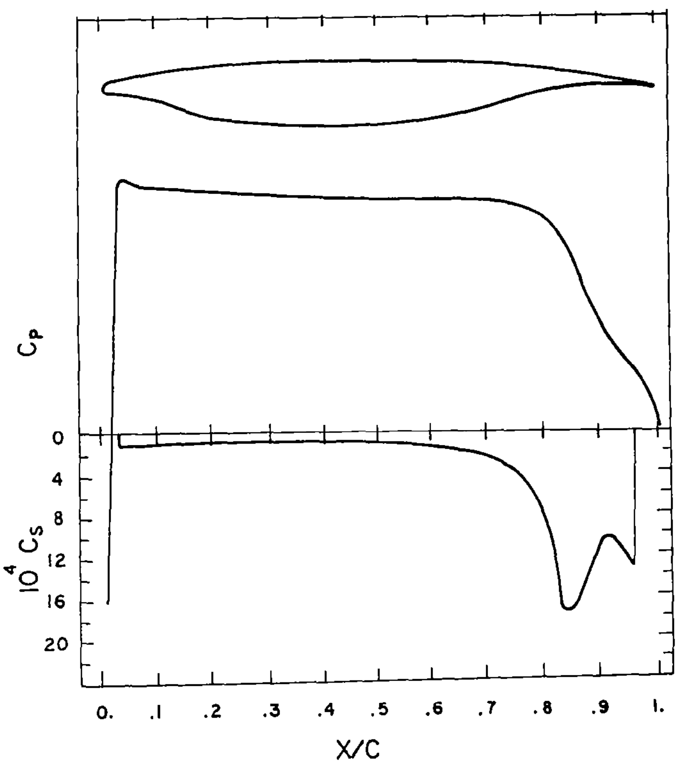

Figure 3.- Airfoil geometry, pressure coefficient and suction coefficient distributions on the upper surface.

Case 1.- Calculation of the spatial growth rate of TS disturbance of a specified wave angle and $\psi = \epsilon$ at the frequency f = 8000CPS.

```
$SHEE
 ISPTM  = 1,
 INCOMP = 2,
 NSTATN = 33,
 NSEND  = 33,
 NSTEP  = 2,
 ICASE  = 1,
 ICIZER = 2,
 FR     = .8E+04,
 IFR    = 2,
 NFR    = 1,
 DFR    = .3E-05,
 EPSI   = -.45E+02,
 IEPSI  = 1,
 NEPSI  = 1,
 DEPSI  = -.15E+02,
 EPSIP  = 0.0,
 IEPSIP = 2,
 NEPSIP = 1,
 DEPSIP = 0.0,
 ALFAR  = -.1382E+00,
 ALFAI  = -.152E-02,
 BETAR  = .33E-03,
 IBETAR = 2,
 BETAI  = -.7E-02,
```

```
WN     = .128E+00,
IWN    = 1,
NWN    = 1.
DWN    = .5E-01,
CHORD  = .644E+01,
IPRINT = 2,
RE     = .1E-03,
AE     = .1E-03,
EPS    = .1E-03,
ITP    = 10,
OMEGAR = .1636E-01,
OMEGAI = .1966E-02,
SEND
```

NS= 33 XC= .1100E+00 R= .1540E+04 CHL= .5097E-03

NIT	KX		D		DKX		IFL	IW1	IW2
1	.9096E-01	-.1528E-02	.6687E+00	.1501E+00	.1112E-01	.6106E-02	0	13	35
2	.1021E+00	.4578E-02	.2523E+00	-.8016E-01	.6723E-02	-.2160E-02	0	13	35
3	.1088F+00	.2418E-02	.1235E+00	-.1346E+00	.2973E-03	-.9221E-02	0	13	35
4	.1091E+00	-.6803E-02	-.4612E+00	-.1466E+00	-.2397E-02	.7248E-02	0	13	35
5	.1067E+00	.4444E-03	.7595E-01	-.6853E-01	-.7629E-03	-.1220E-02	0	13	35
6	.1059E+00	-.7754E-03	.3832E-01	-.2191E-01	-.1966E-03	-.1042E-02	0	13	35
7	.1058E+00	-.1817E-02	-.7740E-02	.1198E-01	.1380E-03	.2254E-03	0	13	35
8	.1059E+00	-.1592E-02	.7425E-03	.5055E-03	.1384F-04	-.9236E-05	0	13	35

INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

-.2426D+02 -.4848D+02 -.3321D+01 -.9808D+01 .1892D+00 .2617D-01 .1071D+02

KX= .10590E+00 -.16006E-02 KZ=-.10590E+00 -.50060E-03 OMEGA= .28586E-01 0. FR= .80000E+04 FREQ= .18561E-04

CP= .26993E+00 MACH= .82345E+00 ETA= .12429E+02 IE= 79 WN= .14977E+00 PGR= .16955E-02 D=-.26811E-04 .22323E-03

PHI= 17.3654 EPSI= -45.0000 EPSIP= 17.3654

Case 2.- Calculation of the spatial growth rate of TS disturbance of specified wave angle and specified ψ at the frequency $F = 21 \times 10^{-6}$. Eigenvalues are printed.

```
$SHEE
ISPTM   = 1,
INCOMP  = 2,
NSTATN  = 33,
NSEND   = 33,
NSTEP   = 2,
ICASE   = 1,
ICTZEP  = 2,
FR      = .21E-04,
IFR     = 1,
NFR     = 1,
DFR     = .3E-05,
EPSI    = -.2E+02,
IEPSI   = 1,
NEPSI   = 1,
DEPSI   = -.15E+02,
EPSIP   = .3E+02,
IEPSIP  = 1,
NEPSIP  = 1,
DEPSIP  = 0.0,
ALFAP   = -.1382E+00,
ALFAI   = -.25E-02,
BETAR   = .33E-03,
IBETAP  = 2,
BETAI   = -.2E-02,
```

```
WN       = .11E+00,
IWN      = 1,
NWN      = 1,
DWN      = .5E-01,
CHORD    = .644E+01,
IPRINT   = 1,
RE       = .1E-03,
AE       = .1E-03,
EPS      = .1E-03,
ITP      = 10,
OMEGAR   = .1636E-01,
OMEGAI   = .1966E-02,
$END

     NS=   33      XC=  .1100E+00      R=  .1540E+04      CHL=  .5097E-03

  NIT                KX                         D                           DKX                IFL IW1 IW2

    1    .1039E+00   -.2513E-02   -.1059E+00   -.2230E-01   -.1845E-02   -.1515E-04   0  13  35
    2    .1020E+00   -.2528E-02    .3399E-02   -.1341E-02    .5142E-04   -.3203E-04   0  13  35

  INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGP

       -.2436D+02  -.5385D+01  -.5317D+01  -.1276D+01   .2191D+00   .3964D-02   .1236D+02
      KX= .10209E+00 -.25597E-02 KZ=-.37158E-01 -.14778E-02 OMEGA= .32343E-01 0.            FR= .21000E-04 FREQ= .90513E+04

      CP= .31681E+00 MACH= .82346E+00 ETA= .12429E+02 IE=   79 WN= .10864E+00 PGR= .28834E-02 D=-.15587E-03  .62013E-03

      PHI=  17.3654 EPSI= -20.0000 EPSIP=  30.0000
  EIGEN VALUES

       -.6867D+01  -.6518D+01  -.5786D+01  -.5492D+01  -.9752D-01   .8945D-03  -.6867D+01  -.6518D+01
  EIGEN FUNCTIONS-REGULAR(Z1,Z2,Z3,Z5,Z6,Z7)
```

12.43	-.190D-01	-.252E-01	.243D-01	-.178E-01	.304D-02	.381E-02	.631D-02	.960E-02
9.79	-.247D-01	-.325E-01	.314D-01	-.230E-01	.394D-02	.492E-02	.819D-02	.124E-01
7.72	-.302D-01	-.397E-01	.384D-01	-.283E-01	.478D-02	.595E-02	.101D-01	.152E-01
6.09	-.346D-01	-.453E-01	.449D-01	-.332E-01	.418D-02	.496E-02	.123D-01	.185E-01
4.82	-.287D-01	-.360E-01	.502D-01	-.371E-01	-.323D-02	-.609E-02	.191D-01	.283E-01
3.80	.428D-02	.147E-01	.522D-01	-.387E-01	-.199D-01	-.315E-01	.361D-01	.537E-01
2.97	.585D-01	.999E-01	.491D-01	-.366E-01	-.377D-01	-.594E-01	.621D-01	.930E-01
2.30	.118D+00	.185E+00	.418D-01	-.318E-01	-.563D-01	-.787E-01	.107D+00	.137E+00
1.75	.171D+00	.311E+00	.326D-01	-.256E-01	-.592D-01	-.128E+00	.174D+00	.330E+00
1.31	.761D-01	.423E+00	.231D-01	-.197E-01	.168D-01	-.149E+00	-.126D+00	.545E+00
.96	-.272D-01	.346E+00	.148D-01	-.147E-01	.766D-01	-.675E-01	-.448D+00	.315E+00
.68	.243D-02	.218E+00	.839D-02	-.103E-01	.758D-01	-.228E-01	-.429D+00	.475E-02
.47	.765D-01	.133E+00	.397D-02	-.642E-02	.534D-01	.761E-02	-.277D+00	-.123E+00
.29	.116D+00	.760E-01	.139D-02	-.326E-02	.338D-01	.136E-01	-.157D+00	-.120E+00
.16	.102D+00	.317E-01	.249D-03	-.113E-02	.193D-01	.931E-02	-.829D-01	-.732E-01
.05	.458D-01	.469E-02	-.253D-04	-.116E-03	.705D-02	.305E-02	-.296D-01	-.233E-01
0.00	.482D-15	.264E-14	-.202D-16	-.508E-17	.165D-16	.276E-15	-.155D-03	.620E-03

EIGEN FUNCTIONS-ADJOINT(W1,W2,W3,W4,W6,W8)

12.43	-.264D-02	-.237E-02	.355D+01	-.383E+01	.217D-02	.184E-02	.903D-03	.923E-03
9.79	-.342D-02	-.306E-02	.458D+01	-.496E+01	.281D-02	.238E-02	.117D-02	.119E-02
7.72	-.420D-02	-.373E-02	.559D+01	-.608E+01	.345D-02	.291E-02	.144D-02	.146E-02
6.09	-.494D-02	-.439E-02	.654D+01	-.713E+01	.405D-02	.341E-02	.169D-02	.171E-02
4.82	-.586D-02	-.518E-02	.741D+01	-.811E+01	.469D-02	.393E-02	.201D-02	.202E-02
3.80	-.781D-02	-.685E-02	.828D+01	-.908E+01	.565D-02	.472E-02	.268D-02	.267E-02
2.97	-.122D-01	-.112E-01	.933D+01	-.103E+02	.731D-02	.612E-02	.417D-02	.436E-02
2.30	-.485D-01	-.187E-01	.105D+02	-.125E+02	.132D-01	.839E-02	.172D-01	.787E-02
1.75	-.105D-01	-.218E+00	.189D+02	-.181E+02	.188D-01	.293E-01	-.121D-02	.799E-01
1.31	.360D+00	-.988E-01	.340D+02	-.613E+01	-.782D-02	.498E-01	-.134D+00	.276E-01
.96	.255D+00	.316E+00	.278D+02	.134E+02	-.394D-01	.385E-01	-.854D-01	-.121E+00
.68	-.900D-01	.345E+00	.124D+02	.171E+02	-.497D-01	.153E-01	.410D-01	-.124E+00
.47	-.235D+00	.172E+00	.347D+01	.113E+02	-.440D-01	.240E-03	.897D-01	-.570E-01
.29	-.213D+00	.473E-01	.619D+00	.530E+01	-.324D-01	-.425E-02	.790D-01	-.121E-01
.16	-.136D+00	.359E-02	.939D-01	.168E+01	-.197D-01	-.303E-02	.497D-01	.190E-02
.05	-.498D-01	-.888E-03	.281D-01	.184E+00	-.721D-02	-.753E-03	.181D-01	.131E-02
0.00	-.134D-13	-.172E-13	.195D-12	-.939E-13	.166D-16	-.636E-14	-.948D-04	-.303E-03

<u>Case 3</u>.- Calculation of the spatial growth rates of TS disturbances at the frequency f = 5000 CPS with $\bar{y}' = q$ and for different wave angles.

```
$SHEE
ISPTM   = 1,
INCOMP  = 2,
NSTAIN  = 44,
NSEND   = 44,
NSTEP   = 2,
ICASE   = 1,
ICIZER  = 2,
FR      = .5E+04,
IFR     = 2,
NFR     = 1,
DFR     = .3E-05,
EPSI    = .4E+02,
IEPSI   = 1,
NEPSI   = 5,
DEPSI   = -.15E+02,
EPSIP   = 0.0,
IEPSIP  = 2,
NEPSIP  = 1,
DEPSIP  = 0.0,
ALFAR   = -.1362E+00,
ALFAI   = -.53E-03,
BETAR   = .33E-03,
IBETAR  = 2,
BETAI   = -.2E-02,
```

```
WN      = .65E-01,
IWN     = 1,
NWN     = 1,
DWN     = .5E-01,
CHORD   = .644E+01,
IPRINT  = 2,
RE      = .1E-03,
AE      = .1E-03,
EPS     = .1E-03,
ITP     = 10,
OMEGAR  = .1636E-01,
OMEGAI  = .1966E-02,
$END
```

NS= 44 XC= .2200E+00 R= .2125E+04 CHL= .7046E-03

NIT	KX		D		DKX		IFL	IW1	IW2
1	.5004E-01	-.5327E-03	-.8655E+00	.1158E+00	.7540E-02	.1141E-02	0	14	35
2	.5758E-01	.6085E-03	-.2089E+00	.9100E-01	.2579E-02	-.5844E-03	0	14	35
3	.6016E-01	.2409E-04	-.4351E-01	.7700E-01	.5175E-03	-.1311E-02	0	14	35
4	.6066E-01	-.1287E-02	.4002E-02	.1814E-01	-.1720E-03	-.3002E-03	0	14	35
5	.6051E-01	-.1587E-02	-.1701E-02	-.4766E-03	.3135E-04	.1575E-05	0	14	35

```
INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

-.3896D+02 -.1273D+02 -.1428D+02 -.4566D+01  .3656D+00 -.2272D-02  .2008D+02
KX= .60538E-01 -.15852E-02 KZ= .50798E-01 -.50016E-03 OMEGA= .24697E-01 0.    FP= .50000E+04 FREQ= .11622E-04

CR= .40796E+00 MACH= .82346E+00 ETA= .12078E+02 IE=  85 WN= .79027E-01 PGR= .17690E-02 D= .18567E-03  .18724E-03

PHI=  17.5116 EPSI=  40.0000 EPSIP=  17.5116
```

```
 NS=   44      XC=  .2200E+00     R=  .2125E+04     CHL=  .7046E-03

 NIT            KX                   D                      DKX                 IFL IW1 IW2

  1    .7198E-01   -.1593E-02    .2410E+00    .7166E-01   -.5491E-02    .6845E-03   0  14  35
  2    .6649E-01   -.9052E-03   -.5439E-01    .3749E-01    .6180E-03   -.9176E-03   0  14  35
  3    .6731E-01   -.1526E-02    .4952E-02   -.1159E-01   -.5018E-04    .1948E-03   0  14  35
  4    .6726E-01   -.1631E-02   -.2204E-03   -.4862E-03    .5019E-05    .7186E-05   0  14  35

 INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

      -.2520D+02  -.4440D+01  -.8312D+01  -.1404D+01   .3294D+00  -.2309D-02   .1623D+02
     KX= .67263E-01 -.16238E-02 KZ= .31365E-01 -.51236E-03 OMEGA= .24697E-01 0.        FP= .50000E+04 FREQ= .11622E-04

  CR= .36717E+00 MACH= .92346E+00 ETA= .12078E+02 IF=   85 WN= .74216E-01 PGR= .17926E-02 D= .21147E-04 -.49058E-05

  PHI=  17.5116 EPSI=  25.0000 FPSIP=  17.5116



  NS=   44      XC=  .2200E+00     R=  .2125E+04     CHL=  .7046E-03

 NIT            KX                   D                      DKX                 IFL IW1 IW2

  1    .7345E-01   -.1632E-02    .4057E-01    .1205E-01   -.3415E-03   -.4308E-04   0  14  35

 INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

      -.2063D+02  -.2943D+01  -.6272D+01  -.8358D+00   .3037D+00  -.2607D-02   .1689D+02
     KX= .73113E-01 -.16750E-02 KZ= .12892E-01 -.52851E-03 OMEGA= .24697E-01 0.        FP= .50000E+04 FREQ= .11622E-04

  CR= .33779E+00 MACH= .62346E+00 ETA= .12078E+02 IF=   85 WN= .74240E-01 PGR= .18355E-02 D= .62601E-04 -.35494E-03

  PHI=  17.5116 EPSI=  10.0000 FPSIP=  17.5116



  NS=   44      XC=  .2200E+00     R=  .2125E+04     CHL=  .7046E-03

 NIT            KX                   D                      DKX                 IFL IW1 IW2

  1    .7433E-01   -.1663E-02    .1190E+01   -.6825E-01    .3807E-02    .2881E-03   0  14  35
  2    .7813E-01   -.1395E-02    .1597E+00   -.6292E-01    .6096E-03   -.2704E-03   0  14  35
  3    .7674E-01   -.1666E-02    .1467E-01   -.1940E-01    .6137E-04   -.8202E-04   0  14  35
```

```
INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

    -.2064D+02  -.3446D+01  -.5577D+01  -.6268D+00   .2693D+00  -.4906D-02   .1507D+02
  KX= .78806E-01 -.17477E-02 KZ=-.68946E-02 -.55145E-03 OMEGA= .24697E-01 0.          FP= .50000E+04 FREQ= .11622E-04

  CR= .31339E+00 MACH= .82346E+00 ETA= .12078E+02 TF=   85 WN= .79107F-01 PGR= .18962E-02 D=-.53194F-03  .67663E-03

  PHI= 17.5116 EPSI= -5.0000 EPSIP=  17.5116

  NS=   44    XC=  .2200E+00     R=  .2125E+04    CHL=  .7046F-03

 NIT          KX                D                      DKX              IFL IW1 IW2

  1   .7471E-01  -.1756E-02   .8260E+00   .3739E-02   .7679E-02   .1280E-02   0  14  35
  2   .8239E-01  -.4764E-03   .1687E+00  -.7936E-01   .2017E-02  -.8535E-03   0  14  35
  3   .8440E-01  -.1330E-02   .2430E-01  -.3294E-01   .3071E-03  -.5051E-03   0  14  35
  4   .8471E-01  -.1835E-02  -.3853E-02   .5243E-03  -.5039E-04   .1494E-04   0  14  35

INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

    -.2542D+02  -.7101D+01  -.5645D+01  -.1538D+01   .2217D+00  -.1413D-02   .1250D+02
  KX= .84660E-01 -.18200E-02 KZ=-.30814E-01 -.57425E-03 OMEGA= .24697E-01 0.          FP= .50000E+04 FREQ= .11622E-04

  CR= .29172E+00 MACH= .82346E+00 ETA= .12078E+02 TF=   85 WN= .90093E-01 PGR= .19473E-02 D=-.34107E-03  .16560E-03

  PHI= 17.5116 EPSI= -20.0000 EPSIP=  17.5116
```

Case 4.- Calculation of the spatial growth rates of TS disturbance at the frequency f = 5000 CPS propagating downstream with $\Psi = 0$ and $\bar{\Psi} = \phi$.

```
$SHEE
ISPTM   = 1,            ✓
INCOMP  = 2,
NSTATN  = 42,           ✓
NSEND   = 72,           ✓
NSTEP   = 5,            ✓
ICASE   = 1,            ✓
ICIZER  = 2,            ✓
FR      = .5E+04,       ✓
IFR     = 2,            ✓
NFR     = 1,            ✓
DFR     = .3E-05,
EPSI    = 0.0,          ✓
IEPSI   = 1,            ✓
NEPSI   = 1,            ✓
DEPSI   = -.15E+02,
EPSIP   = 0.0,
IEPSIP  = 2,            ✓
NEPSIP  = 1,            ✓
DEPSIP  = 0.0,
ALFAR   = -.1382E+00,
ALFAI   = -.5E-03,      ✓
BETAR   = .33E-03,
IBETAR  = 2,
BETAI   = -.2E-02,
```

```
WN     = .7E-01,
IWN    = 1,
NWN    = 1,
DWN    = .5E-01,
CHORD  = .644E+01,
IPRINT = 2,
RE     = .1E-03,
AE     = .1E-03,
EPS    = .1E-03,
ITR    = 10,
OMEGAR = .1636E-01,
OMEGAI = .1966E-02,
SEND

   NS=   42      XC=  .2000E+00     R=  .2031E+04     CHL=  .6734E-03

 NIT             KX                      D                           DKX              IFL IW1 IW2

  1    .7035E-01   -.5025E-03   .3539E+01   -.2432E+02    .2835E-02   -.5281E-03   0  14  35
  2    .7319E-01   -.1031E-02  -.8681E+00   -.1381E+01    .1196E-03   -.1620E-03   0  14  35
  3    .733CE-01   -.1193E-02  -.3168E+00   -.5801E+00    .9216E-04   -.1012E-03   0  14  35
  4    .7340E-01   -.1294E-02  -.4099E-01   -.1186E+00    .2589E-04   -.1873E-04   0  14  35

 INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

     -.2120D+02  -.3650D+01  -.6001D+01  -.1104D+01   .2836D+00   .3243D-02   .1583D+02
    KX= .73423E-01 -.13126E-02 KZ=0.            -.41364E-03 OMEGA= .23604E-01 0.          FR= .50000E+04 FREQ= .11619E-04

     CR= .32148E+00 MACH= .82346E+00 ETA= .12622E+02 IE=   85 WN= .73423E-01 PGR= .14299E-02 D=-.27732E-02 -.12033E-01

     PHI=  17.4909 EPSI=   0.0000 EPSIP=  17.4909
```

```
NS=   47     XC=  .2500E+00     R=   .2258E+04     CHL=   .7489E-03

NIT            KX                  D                        DKX                  IFL IW1 IW2

 1    .8125E-01   -.1319E-02   -.2497E+01   -.1841E+01    .4145E-03   -.8355E-03   0  14  35
 2    .8166E-01   -.2155E-02    .8639E-01    .8913E-01   -.2086E-04    .2922E-04   0  14  35
 3    .8164E-01   -.2125E-02    .2823E-01    .3321E-01   -.1279E-04    .1458E-04   0  14  35

INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

     -.1912D+02  -.1908D+01  -.5432D+01  -.4681D+00   .2838D+00  -.3845D-02   .1584D+02
   KX= .81630E-01 -.21109E-02 KZ=0.          -.66743E-03 OMEGA= .26252E-01 0.          FR= .50000E+04 FREQ= .11628E-04

   CR= .32160E+00 MACH= .82346E+00 ETA= .11380E+02 IE=   85 WN= .81630E-01 PGR= .23003E-02 D=-.34651E-03 -.33141E-03

   PHI=  17.5462 EPSI=   0.0000 EPSIP=  17.5462
```

```
NS=   52     XC=  .3000E+00     R=   .2463E+04     CHL=   .8174E-03

NIT            KX                  D                        DKX                  IFL IW1 IW2

 1    .8865E-01   -.2121E-02    .7713E+00   -.2837E+00    .1644E-03    .3451E-03   0  14  35
 2    .8881E-01   -.1776E-02   -.5262E-01   -.1795E-01    .4787E-05   -.2407E-04   0  14  35

INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

     -.1699D+02   .1533D+00  -.4704D+01   .6020D-01   .2768D+00  -.1045D-02   .1547D+02
   KX= .88815E-01 -.18004E-02 KZ=0.          -.57025E-03 OMEGA= .28653E-01 0.          FR= .50000E+04 FREQ= .11633E-04

   CR= .32262E+00 MACH= .82346E+00 ETA= .12054E+02 IE=   88 WN= .88815E-01 PGR= .19583E-02 D= .95461E-02  .62265E-03

   PHI=  17.5750 EPSI=   0.0000 EPSIP=  17.5750
```

```
NS=   57     XC=  .3500E+00     R=   .2652E+04     CHL=   .8807E-03

NIT            KX                  D                        DKX                  IFL IW1 IW2

 1    .9520E-01   -.1809E-02    .5042E+00   -.1446E+01    .5835E-03    .2001E-03   0  14  35
 2    .9579E-01   -.1609E-02   -.4606E-01   -.6729E-01    .2698E-04   -.2049E-04   0  14  35

INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR
```

```
-.1546D+02  .1571D+01  -.4313D+01  .4857D+00  .2793D+00  -.3035D-02  .1560D+02
KX= .95813E-01 -.16298E-02 KZ=0.          -.51733E-03 OMEGA= .30870E-01 0.          FR= .50000E+04 FREQ= .11638E-04

CR= .32219E+00 MACH= .82346E+00 ETA= .11211E+02 IE=  88 WN= .95813E-01 PGR= .17742E-02 D= .93187E-02  .54255E-02

PHI=  17.6109 EPSI=   0.0000 EPSIP=  17.6109
```

```
NS=  62     XC= .4000E+00     R=  .2829E+04     CHL=  .9397E-03
```

NIT	KX		D		DKX		IFL	IW1	IW2
1	.1017E+00	-.1638E-02	.2360E+01	-.8932E+00	.3150E-03	.9037E-03	0	15	35
2	.1020E+00	-.7342E-03	-.1916E+00	-.2548E-01	.8536E-05	-.6812E-04	0	15	35
3	.1020E+00	-.8023E-03	.1480E+00	.4516E-01	-.6556E-05	.2991E-04	0	15	35

```
INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

-.1380D+02  .2982D+01  -.3901D+01  .8240D+00  .2825D+00  .1334D-02  .1577D+02
KX= .10203E+00 -.77243E-03 KZ=0.          -.24564E-03 OMEGA= .32938E-01 0.          FR= .50000E+04 FREQ= .11643E-04

CR= .32282E+00 MACH= .82346E+00 ETA= .12133E+02 IE=  91 WN= .10203E+00 PGR= .84181E-03 D= .51049E-02  .40354E-02

PHI=  17.6409 EPSI=   0.0000 EPSIP=  17.6409
```

```
NS=  67     XC= .4500E+00     R=  .2995E+04     CHL=  .9951E-03
```

NIT	KX		D		DKX		IFL	IW1	IW2
1	.1075E+00	-.7763E-03	.7285E+01	-.1934E+01	.5005E-03	.1540E-02	0	15	35
2	.1080E+00	.7639E-03	.9634E-01	-.2301E+00	.5200E-04	.1695E-04	0	15	35
3	.1081E+00	.7808E-03	-.4917E-01	-.5236E+00	-.6818E-04	-.5533E-04	0	15	35

```
INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

-.1174D+02  .4011D+01  -.3483D+01  .1277D+01  .2990D+00  -.6619D-02  .1665D+02
KX= .10799E+00  .72549E-03 KZ=0.          .23090E-03 OMEGA= .34880E-01 0.          FR= .50000E+04 FREQ= .11646E-04

CR= .32300E+00 MACH= .82346E+00 ETA= .11474E+02 IE=  91 WN= .10799E+00 PGR=-.79454E-03 D=-.11187E-01  .27567E-01

PHI=  17.6541 EPSI=   0.0000 EPSIP=  17.6541
```

Case 5.- Calculation of the spatial growth rate of stationary CF disturbance at a specified location and $\Psi = \phi$.

```
$SHEF
ISPTM   = 1,
INCOMP  = 2,
NSTATN  = 107,
NSEND   = 107,
NSTEP   = 5,
ICASE   = 4,
ICIZER  = 2,
FR      = .1E-01,
IFR     = 2,
NFR     = 1,
DFR     = .3E-05,
EPSI    = .1136E+03,
IEPSI   = 1,
NEPSI   = 1,
DEPSI   = -.15E+02,
EPSIP   = 0.0,
IEPSIP  = 2,
NEPSIP  = 1,
DEPSIP  = 0.0,
ALFAR   = -.1382E+00,
ALFAI   = -.2E-02,
BETAR   = .33E-03,
IBETAR  = 2,
BETAI   = -.2E-02,
```

```
WN     = .398E+00,
IWN    = 1,
NWN    = 1,
DWN    = .5E-01,
CHORD  = .644E+01,
IPRINT = 2,
RE     = .1E-03,
AE     = .1E-03,
EPS    = .1E-03,
ITR    = 10,
OMEGAR = .1636E-01,
OMEGAI = .1966E-02,
SEND
```

NS= 107 XC= .8500E+00 R= .4022E+04 CHL= .1384E-02

NIT	KX		KZ		EPSI	DEPSI	DALFAI	IFL	IWI	IW2
1	-.1593E+00	-.2001E-02	.3647E+00	-.7090E-03	.1136E+03	.1323E+00	.3779E-04	0	16	34
2	-.1602E+00	-.1964E-02	.3643E+00	-.6959E-03	.1137E+03	.1210E+00	-.1302E-03	0	16	34
3	-.1610E+00	-.2095E-02	.3640E+00	-.7424E-03	.1139E+03	.2884E-01	-.2161E-03	0	16	34
4	-.1611E+00	-.2313E-02	.3639E+00	-.8194E-03	.1139E+03	-.7008E-02	-.2494E-04	0	16	34
5	-.1611E+00	-.2339E-02	.3639E+00	-.8287E-03	.1139E+03	.1087E-02	.1612E-05	0	16	34

INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

-.2436D+02 .2776D+02 -.1073D+02 .1206D+02 .4369D+00 .3066D-02 .2360D+02

KX=-.16109E+00 -.23388E-02 KZ= .36394E+00 -.82866E-03 OMEGA= .97004E-07 0. FR= .10000E-01 FREQ= .24118E-10

CR=-.60217E-06 MACH= .82346E+00 ETA= .10542E+02 IE= 97 WN= .39800E+00 PGR= .27009E-02 D=-.40062E-04 .12230E-03

PHI= 19.5096 EPSI= 113.8752 EPSIP= 19.5096

Case 6.- Calculation of the maximum spatial growth rate of stationary CF disturbance at a specified location with $\bar{\Psi} = \psi$.

```
$SHEF
ISPTM   = 1,
INCOMP  = 2,
NSTATN  = 106,
NSEND   = 106,
NSTEP   = 5,
ICASE   = 4,
ICIZER  = 1,
FR      = .1E-01,
IFR     = 2,
NFR     = 1,
DFR     = .3E-05,
EPSI    = .1126E+03,
IEPSI   = 1,
NEPSI   = 1,
DEPSI   = -.15E+02,
EPSIP   = 0.0,
IEPSIP  = 2,
NEPSIP  = 1,
DEPSIP  = 0.0,
ALFAR   = -.1382E+00,
ALFAI   = -.26E-02,
BETAR   = .33E-03,
IBETAR  = 2,
BETAI   = -.2E-02,
```

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```
 WN       = .393E+00,
 IWN     = 1,
 NWN     = 1,
 DWN      = .5E-01,
 CHORD   = .644E+01,
 IPRINT  = 2,
 RE       = .1E-03,
 AE       = .1E-03,
 EPS      = .1E-03,
 ITR      = 10,
 OMEGAR  = .1636E-01,
 OMEGAI  = .1966E-02,
 $END

      NS=  106      XC=  .8400E+00     R=  .4016E+04     CHL=  .1369E-02

  NIT              KX                          KZ                        EPSI         DEPSI         DALFAI      IFL IW1 IW2

   1   -.1510E+00   -.2601E-02   .3628E+00   -.9005E-03   .1126E+03   -.3065E-01   -.8352E-04   0  16  34
   2   -.1508E+00   -.2686E-02   .3629E+00   -.9298E-03   .1126E+03    .6041E-02    .1564E-04   0  16  34
   3   -.1509E+00   -.2672E-02   .3629E+00   -.9249E-03   .1126E+03   -.9066E-03    .9552E-06   0  16  34

  INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

     -.2176D+02   .3715D+02   -.9025D+01   .1512D+02   .4090D+00   .3424D-02   .2224D+02
    KX=-.15087E+00 -.26719E-02 KZ= .36289E+00 -.92488E-03 OMEGA= .95995E-07 0.        FR= .10000E-01 FREQ= .23901E-10

     CP=-.63627E-06 MACH= .82346E+00 ETA= .10752E+02 IE=   97 WN= .39300E+00 PGR= .30501E-02 D= .96133E-04 -.62438E-04

    PHI=  19.0936 EPSI= 112.5754 EPSIP=  19.0936
   1   -.1509E+00   -.2673E-02   .3631E+00   -.9253E-03   .1126E+03   -.1099E-02    .1727E-05   0  16  34

  INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR
```

```
     -.2173D+02   .3714D+02  -.9015D+01   .1511D+02   .4090D+00   .3410D-02   .2224D+02
    KX=-.15095E+00 -.26732E-02 KZ= .36307E+00 -.92534E-03 OMEGA= .95995E-07 0.          FR= .10000E-01 FREQ= .23901E-10

    CR=-.63595E-06 MACH= .82346E+00 ETA= .10752E+02 IE=   97 WN= .39320E+00 PGR= .30516E-02 D= .12140E-03 -.72654E-04

    PHI=  19.0936 EPSI= 112.5754 EPSIP=  19.0936
  1    .3932E+00   .3410E-02  -.7144E-01   .4774E-01
  1   -.1693E+00  -.2675E-02   .4071E+00  -.9258E-03    .1126E+03   -.3712E-01   -.7596E-04   0  16  34
  2   -.1690E+00  -.2752E-02   .4073E+00  -.9526E-03    .1125E+03    .9218E-02    .2287E-04   0  16  34
  3   -.1691E+00  -.2730E-02   .4072E+00  -.9451E-03    .1125E+03   -.1598E-02    .3084E-06   0  16  34

 INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

     -.2335D+02   .3999D+02  -.9603D+01   .1648D+02   .4118D+00  -.2905D-03   .2238D+02
    KX=-.16908E+00 -.27304E-02 KZ= .40723E+00 -.94513E-03 OMEGA= .95995E-07 0.          FR= .10000E-01 FREQ= .23901E-10

    CR=-.56777E-06 MACH= .82346E+00 ETA= .10752E+02 IE=   97 WN= .44093E+00 PGR= .31196E-02 D= .14959E-03 -.16014E-03

    PHI=  19.0936 EPSI= 112.5475 EPSIP=  19.0936
  2    .4409E+00  -.2905E-03  -.7752E-01  -.3747E-02
  1   -.1676E+00  -.2732E-02   .4038E+00  -.9456E-03    .1125E+03    .1164E-03    .1516E-05   0  16  34

 INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

     -.2329D+02   .4010D+02  -.9585D+01   .1651D+02   .4116D+00  -.3312D-04   .2237D+02
    KX=-.16764E+00 -.27317E-02 KZ= .40377E+00 -.94560E-03 OMEGA= .95995E-07 0.          FR= .10000E-01 FREQ= .23901E-10

    CR=-.57263E-06 MACH= .82346E+00 ETA= .10752E+02 IE=   97 WN= .43719E+00 PGR= .31209E-02 D= .45496E-04  .45975E-04

    PHI=  19.0936 EPSI= 112.5475 EPSIP=  19.0936
  3    .4372E+00  -.3312E-04  -.6868E-01  -.4823E-03
  1   -.1675E+00  -.2733E-02   .4033E+00  -.9461E-03    .1125E+03    .3470E-03    .2920E-05   0  16  34

 INFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR

     -.2324D+02   .4013D+02  -.9566D+01   .1652D+02   .4116D+00   .6952D-06   .2237D+02
    KX=-.16745E+00 -.27331E-02 KZ= .40332E+00 -.94608E-03 OMEGA= .95995E-07 0.          FR= .10000E-01 FREQ= .23901E-10

    CR=-.57327E-06 MACH= .82346E+00 ETA= .10752E+02 IE=   97 WN= .43670E+00 PGR= .31225E-02 D= .55056E-04  .87678E-04

    PHI=  19.0936 EPSI= 112.5475 EPSIP=  19.0936
```

VI. THE CODE HADY-I

```
* T I D Y *
      PROGRAM HADY(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10)

      PROGRAM HADY(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10)
C
C
C        ************************************************************
C        *                                                          *
C        *                                                          *
C        *               HADY-I, STABILITY ANALYSIS FOR             *
C        *           THREE-DIMENSIONAL BOUNDARY LAYER FLOWS         *
C        *                                                          *
C        *                            BY                            *
C        *                                                          *
C        *                    NABIL M. EL-HADY                      *
C        *                                                          *
C        *      DEPARTMENT OF MECHANICAL ENGINEERING & MECHANICS    *
C        *         OLD DOMINION UNIVERSITY, NORFOLK, VIRGINIA       *
C        *                                                          *
C        *                                                          *
C        ************************************************************
C
C
      REAL MACH,KRR,MU,MUP,MUPP,KFF,ND
      COMPLEX XI,D,DTR,DF,COR,ALAM,TATA,A(8,8),B1(4,8),EV(8)
      COMPLEX KX,KXX,KZ,KZZ,QA,A37,A48,A84,A85,A87,EVV,OMEGA
      COMPLEX A21,A24,A25,A31,A34,A35,G,A42,A43,A46,A64,A65,H1,H2
      COMPLEX Z1(101),Z2(101),Z3(101),Z4(101),Z5(101),Z6(101),Z7(101),Z8
     1(101)
      COMPLEX W1(101),W2(101),W3(101),W4(101),W5(101),W6(101),W7(101),W8
     1(101)
      DIMENSION PH(16,101), BMI(8,16), BMF(8,16), BCIV(8), BCFV(8)
      DIMENSION WORK(17000), IWORK(300)
      COMMON /AAA/ XSAVE,KL,INDEX,NIT
      COMMON /BBB/ KX,KXX,KZ,KZZ,OMEGA,XI,P,Q,GAMMA,QB
      COMMON /BB1/ XC,CHL,UFS,R,MACH,ETA,PRANDL,ND,NS,NY
      COMMON /CCC/ Y(101),U(101),UP(101),UPP(101),W(101),WP(101),WPP(101
     1),T(101),TP(101),TPP(101),MU(101),MUP(101),MUPP(101),ALFA(101),ALF
     2AP(101),PR(101)
      COMMON /FFF/ Z1,Z2,Z3,Z4,Z5,Z6,Z7,Z8
      NAMELIST /SHEE/ ISPTM,INCOMP,NSTATN,NSEND,NSTEP,ICASE,ICIZER,FR,IF
     1R,NFR,DFR,EPSI,IEPSI,NEPSI,DEPSI,EPSIP,IEPSIP,NEPSIP,DEPSIP,ALFAR,
     2ALFAI,BETAR,IBETAR,BETAI,WN,IWN,NWN,DWN,CHORD,IPRINT,RE,AE,EPS,ITR
     3,OMEGAR,OMEGAI
      JL=1
      XI=(0.,1.)
      GAMMA=1.4
      F=0.8
```

```
      P=(1.+2.*E)/3.
      Q=2.*(E+2.)/3.
C     ****************************************************************
C     READING INPUT DATA AND PROFILES
C     ****************************************************************
      READ (5,SHEF)
      WRITE (6,SHEE)
      CALL FULLP (NSTATN,INCOMP)
      QB=GAMMA*MACH*MACH
      EPSI=EPSI/57.29577
      DEPSI=DEPSI/57.29577
      EPSIP=EPSIP/57.29577
      DEPSIP=DEPSIP/57.29577
      IF (ICASE.EQ.3.OR.ICASE.EQ.5) GO TO 1
      IF (IWN.EQ.2) WN=6.2831853*CHL/(WN*CHORD)
      GO TO 2
1     CONTINUE
      IF (IBETAR.EQ.2) BETAR=6.2831853*CHL/(BETAR*CHORD)
2     CONTINUE
      PHI=ATAN(NO)
      IF (IEPSIP.EQ.2) EPSIP=PHI
      GO TO (6,3,4,5), IEPSI
3     EPSI=PHI+1.57
      GO TO 6
4     CALL CFA (EPSI,NY)
      GO TO 6
5     EPSI=PHI
6     CONTINUE
      NIT=0
      NITB=0
      INDEX=1
      INDOX=1
      IF (ICASE.EQ.3.OR.ICASE.EQ.5) GO TO 7
      ALFAR=WN*COS(EPSI)
      BETAR=WN*SIN(EPSI)
      GO TO 8
7     CONTINUE
      IF (EPSI.EQ.0.) GO TO 8
C     IF EPSI=0. ALFAR IS INPUT
      ALFAR=BETAR/TAN(EPSI)
8     BETAI=ALFAI*TAN(EPSIP)
      KX=CMPLX(ALFAR,ALFAI)
      KZ=CMPLX(BETAR,BETAI)
C
      IF (ISPTM.EQ.2) GO TO 10
```

```
* T I D Y *
          PROGRAM HADY(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10)

      IF (IFR.EQ.1) GO TO 9
      OMEGAR=6.2831853*FR*CHL/UFS
      OMEGAI=0.
      OMEGA=CMPLX(OMEGAR,OMEGAI)
      FREQ=OMEGA/R
      GO TO 11
9     OMEGAR=FR*R
      FREQ=OMEGAR*UFS/(6.2831853*CHL)
      OMEGAI=0.
      OMEGA=CMPLX(OMEGAR,OMEGAI)
      GO TO 11
10    OMEGA=CMPLX(OMEGAR,OMEGAI)
C
11    WRITE (6,56) NS,XC,R,CHL
      IF (ICASE.EQ.1.OR.ICASE.EQ.3) WRITE (6,53)
      IF (ICASE.EQ.4.OR.ICASE.EQ.5) WRITE (6,54)
12    CONTINUE
      DO 13 I=1,8
      DO 13 J=1,16
      BMI(I,J)=0.
13    BMF(I,J)=0.
C     ****************************************************************
C     BOUNDARY CONDITIONS AT THE WALL,HOMOGENEOUS PROBLEM
C     ****************************************************************
      BMF(1,1)=1.
      BMF(2,2)=1.
      BMF(3,5)=1.
      BMF(4,6)=1.
      BMF(5,9)=1.
      BMF(6,10)=1.
      BMF(7,13)=1.
      BMF(8,14)=1.
C
      DO 14 I=1,8
      BCFV(I)=0.
14    BCIV(I)=0.
C     ****************************************************************
C     CALCULATION OF EIGEN VALUES
C     ****************************************************************
15    CONTINUE
      KXX=KX*KX
      KZZ=KZ*KZ
      QA=KX+ND*KZ-OMEGA
      A21=XI*R*QA+KXX+KZZ
      A24=XI*KX*R-P*QB*KX*QA
```

```
      A25=P*KX*QA
      A31=-XI*KX
      A34=-XI*QB*QA
      A35=XI*QA
      A37=-XI*KZ
      G=P+XI*QB*Q*QA
      A42=-XI*KX/G
      A43=(-KXX-KZZ-XI*R*QA)/G
      A46=XI*Q*QA/G
      A48=-XI*KZ/G
      A64=-XI*R*PRANDL*(GAMMA-1.)*MACH*MACH*QA
      A65=XI*R*PRANDL*QA+KXX+KZZ
      A84=XI*R*KZ-P*KZ*QB*QA
      A85=P*KZ*QA
      A87=A21
      H1=A42*A24+A43*A34+A46*A64+A48*A84
      H2=A42*A25+A43*A35+A46*A65+A48*A85
      EV(1)=-CSQRT(A21)
      EV(2)=-CSQRT(0.5*(H1+A65)+CSQRT(0.25*(H1-A65)**2+H2*A64))
      EV(3)=-CSQRT(0.5*(H1+A65)-CSQRT(0.25*(H1-A65)**2+H2*A64))
      EV(4)=EV(1)
      EV(5)=-EV(1)
      EV(6)=-EV(2)
      EV(7)=-EV(3)
      EV(8)=-EV(4)
C     ****************************************************************
C     CALCULATION OF EIGEN VECTORS,HOMOGENEOUS PROBLEM
C     ****************************************************************
      DO 21 J=1,8
      EVV=EV(J)*EV(J)
      GO TO (16,18,18,17,16,18,18,17), J
16    B1(1,J)=1.
      B1(2,J)=0.
      B1(3,J)=0.
      B1(4,J)=0.
      GO TO 19
17    B1(1,J)=0.
      B1(2,J)=0.
      B1(3,J)=0.
      B1(4,J)=1.
      GO TO 19
18    B1(1,J)=((EVV-A65)*A24+A25*A64)/(A21-EVV)
      B1(2,J)=A65-EVV
      B1(3,J)=-A64
      B1(4,J)=(A64*A85-A84*(A65-EVV))/(A21-EVV)
```

```
19    CONTINUE
      IF (J.EQ.4.OR.J.EQ.8) GO TO 20
      A(1,J)=1.
      A(2,J)=EV(J)
      A(3,J)=(A31*B1(1,J)+A34*B1(2,J)+A35*B1(3,J)+A37*B1(4,J))/(EV(J)*B1
     1(1,J))
      A(4,J)=B1(2,J)/B1(1,J)
      A(5,J)=B1(3,J)/B1(1,J)
      A(6,J)=EV(J)*B1(3,J)/B1(1,J)
      A(7,J)=B1(4,J)/B1(1,J)
      A(8,J)=(A84*B1(2,J)+A85*B1(3,J)+A87*B1(4,J))/(EV(J)*B1(1,J))
      GO TO 21
20    A(1,J)=B1(1,J)
      A(2,J)=EV(J)*B1(1,J)
      A(3,J)=(A31*B1(1,J)+A34*B1(2,J)+A35*B1(3,J)+A37*B1(4,J))/EV(J)
      A(4,J)=B1(2,J)
      A(5,J)=B1(3,J)
      A(6,J)=EV(J)*B1(3,J)
      A(7,J)=B1(4,J)
      A(8,J)=(A84*B1(2,J)+A85*B1(3,J)+A87*B1(4,J))/EV(J)
21    CONTINUE
      GO TO 29
22    CONTINUE
      DO 23 I=1,8
      DO 23 J=1,16
      BMI(I,J)=0.
23    BMF(I,J)=0.
C     ****************************************************************
C     BOUNDARY CONDITIONS AT THE WALL, ADJOINT PROBLEM
C     ****************************************************************
      BMF(1,3)=1.
      BMF(2,4)=1.
      BMF(3,7)=1.
      BMF(4,8)=1.
      BMF(5,11)=1.
      BMF(6,12)=1.
      BMF(7,15)=1.
      BMF(8,16)=1.
C     ***************************************************************
C     CALCULATION OF EIGEN VECTORS,ADJOINT PROBLEM
C     ***************************************************************
      DO 28 J=1,8
      EVV=EV(J)*EV(J)
      GO TO (24,25,25,26,24,25,25,26), J
24    B1(1,J)=1.
```

```
      B1(2,J)=(A24*(A65-EVV)-A64*A25)/(H2*A64-(H1-EVV)*(A65-EVV))
      B1(3,J)=(A25*(H1-EVV)-A24*H2)/(H2*A64-(H1-EVV)*(A65-EVV))
      B1(4,J)=0.
      GO TO 27
25    B1(1,J)=0.
      B1(2,J)=-A64
      B1(3,J)=H1-EVV
      B1(4,J)=0.
      GO TO 27
26    B1(1,J)=0.
      B1(2,J)=(A84*(A65-EVV)-A64*A85)/(H2*A64-(H1-EVV)*(A65-EVV))
      B1(3,J)=(A85*(H1-EVV)-A84*H2)/(H2*A64-(H1-EVV)*(A65-EVV))
      B1(4,J)=1.
27    CONTINUE
      A(1,J)=B1(1,J)
      A(2,J)=(-B1(1,J)-A42*B1(2,J))/EV(J)
      A(3,J)=-A43*B1(2,J)/EV(J)
      A(4,J)=B1(2,J)
      A(5,J)=B1(3,J)
      A(6,J)=(-A46*B1(2,J)-B1(3,J))/EV(J)
      A(7,J)=B1(4,J)
28    A(8,J)=(-A48*B1(2,J)-B1(4,J))/EV(J)
29    CONTINUE
C     ****************************************************************
C     BOUNDARY CONDITIONS AT THE EDGE OF THE BOUNDARY LAYER
C     ****************************************************************
      CALL CDMINV (A,8,DTR)
      M=4
      DO 30 I=1,7,2
      L=0
      M=M+1
      DO 30 J=1,15,2
      L=L+1
      BMI(I,J)=A(M,L)
30    BMI(I,J+1)=XI*A(M,L)
      DO 31 I=2,8,2
      DO 31 J=1,15,2
      BMI(I,J)=-BMI(I-1,J+1)
31    BMI(I,J+1)=BMI(I-1,J)
C
      IWORK(11)=1
      IWORK(1)=NY/6
      II=IWORK(1)
      DO 32 I=1,II
32    WORK(I)=Y(6*I-1)
```

```
* T I D Y *
          PROGRAM HADY(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10)

      XSAVE=0.
      KL=1
      IFLAG=0
C     ******************************************************************
C     INTEGRATION AND ORTHONORMALIZATION
C     ******************************************************************
      CALL JOCK (PH,16,16,Y,NY,BMI,8,BCIV,8,BMF,8,BCFV,8,0,RE,AE,IFLAG,W
     1ORK,17000,IWORK,300,0)
C
      DF=CMPLX(PH(3,NY),PH(4,NY))
      COR=1./DF
      D=CMPLX(PH(13,NY),PH(14,NY))*COR
      MNB=IWORK(1)
      MVC=IWORK(2)
      GO TO (33,33,37,50), INDEX
33    CONTINUE
      IF (ICASE.EQ.4.OR.ICASE.EQ.5) GO TO 34
      CALL RNITN (EPSI,EPSIP,IFLAG,MNB,MVC,D,ISPTM,ICASE,WN,EPS,ITR)
      GO TO 35
34    CALL CFITN (EPSI,EPSIP,IFLAG,MNB,MVC,D,WN,EPS,ICASE,BETAR,ITR)
35    IF (AIMAG(KX).GT.0.0010.AND.IEPSI.NE.1) GO TO 46
      IF (INDEX.EQ.1.OR.INDEX.EQ.2) GO TO 15
      CR=REAL(OMEGA)/REAL(KX)
      DO 36 I=1,NY
      Z1(I)=CMPLX(PH(1,I),PH(2,I))*COR
      Z2(I)=CMPLX(PH(3,I),PH(4,I))*COR
      Z3(I)=CMPLX(PH(5,I),PH(6,I))*COR
      Z4(I)=CMPLX(PH(7,I),PH(8,I))*COR
      Z5(I)=CMPLX(PH(9,I),PH(10,I))*COR
      Z6(I)=CMPLX(PH(11,I),PH(12,I))*COR
      Z7(I)=CMPLX(PH(13,I),PH(14,I))*COR
      Z8(I)=CMPLX(PH(15,I),PH(16,I))*COR
36    CONTINUE
C     ******************************************************************
C     START THE ADJOINT PROBLEM
C     ******************************************************************
      INDEX=3
      GO TO 22
37    CONTINUE
      DF=CMPLX(PH(1,NY),PH(2,NY))
      COR=1./DF
      DO 38 I=1,NY
      W1(I)=CMPLX(PH(1,I),PH(2,I))*COR
      W2(I)=CMPLX(PH(3,I),PH(4,I))*COR
      W3(I)=CMPLX(PH(5,I),PH(6,I))*COR
```

```
      W4(I)=CMPLX(PH(7,I),PH(8,I))*COR
      W5(I)=CMPLX(PH(9,I),PH(10,I))*COR
      W6(I)=CMPLX(PH(11,I),PH(12,I))*COR
      W7(I)=CMPLX(PH(13,I),PH(14,I))*COR
38    W8(I)=CMPLX(PH(15,I),PH(16,I))*COR
C
      ALFAI=-XI*KX
      BETAI=-XI*KZ
      ALFAR=KX
      BETAR=KZ
      WN=SQRT(ALFAR**2+BETAR**2)
      IF (ICASE.EQ.2) EPSIP=ATAN(BETAI/ALFAI)
      IF (ICASE.EQ.3) EPSI=ATAN(BETAR/ALFAR)
C     ******************************************************************
C     CALCULATION OF THE RATIO OF THE GROUP VELOCITY COMPONENTS
C     ******************************************************************
      IF (CABS(EV(2)).LT.CABS(EV(3))) GO TO 39
      ALAM=EV(3)
      IA=3
      GO TO 40
39    ALAM=EV(2)
      IA=2
40    CALL GRVEL (ALAM,W2,W3,W4,W6,W8,TATA,EPGR,SM)
      IF (ISPTM.EQ.2) GO TO 41
      PGR=-ALFAI-BETAI*SM
      GO TO 42
41    PGR=OMEGAI
      FR=OMEGA/R
      FREQ=OMEGAR*UFS/(6.2831853*CHL)
42    WRITE (6,55) KX,KZ,OMEGA,FR,FREQ,CR,MACH,ETA,NY,WN,PGR,Z7(NY),PHI*
     157.29577,EPSI*57.29577,EPSIP*57.29577
      GIM=-XI*TATA
C     ******************************************************************
C     ITERATION FOR MAXIMUM AMPLIFICATION RATE
C     ******************************************************************
      IF (ICIZER.NE.1) GO TO 43
      IF (ABS(GIM).LE.1.E-05) GO TO 43
      CALL GIMTR (GIM,EPSI,EPSIP,ICASE,NITB,INDOX,WN,EPS)
      NIT=0
      INDEX=1
      IF (INDOX.NE.10) GO TO 12
43    CONTINUE
      IF (IPRINT.EQ.2) GO TO 46
      WRITE (6,58)
      WRITE (6,60) EV(1),EV(2),EV(3),EV(4)
```

* T I D Y *

```
      PROGRAM HADY(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10)

      WRITE (6,61)
      DO 44 I=1,NY,5
   44 WRITE (6,57) Y(I),Z1(I),Z3(I),Z5(I),Z7(I)
      WRITE (6,57) Y(NY),Z1(NY),Z3(NY),Z5(NY),Z7(NY)
      WRITE (6,59)
      DO 45 I=1,NY,5
   45 WRITE (6,57) Y(I),W2(I),W4(I),W6(I),W8(I)
      WRITE (6,57) Y(NY),W2(NY),W4(NY),W6(NY),W8(NY)
   46 CONTINUE
C     ****************************************************************
C     ANOTHER FREQUENCY/WAVE ANGLE/WAVENUMBER/DOWNSTREAM STATION
C     ****************************************************************
      IF (NFR.GT.1) GO TO 47
      IF (NEPSI.GT.1) GO TO 48
      IF (NWN.GT.1) GO TO 49
      NSTATN=NSTATN+NSTEP
      IF (NSTATN.GT.NSEND) STOP
      KRR=WN/CHL
      RKR=BETAR/CHL
      CALL FULLP (NSTATN,INCOMP)
      WN=KRR*CHL*0.99
      IF (ICASE.EQ.4) WN=KRR*CHL
      IF (ICASE.EQ.3.OR.ICASE.EQ.5) BETAR=RKR*CHL
      GO TO 2
   47 CONTINUE
      JL=JL+1
      IF (JL.GT.NFR) STOP
      KFF=WN/FR
      FR=FR+DFR
      WN=KFF*FR*0.97
      GO TO 6
   48 CONTINUE
      JL=JL+1
      IF (JL.GT.NEPSI) STOP
      EPSI=EPSI+DEPSI
      GO TO 6
   49 CONTINUE
      JL=JL+1
      IF (JL.GT.NWN) STOP
      WN=WN+DWN
      GO TO 6
      WRITE (6,52)
      STOP
   50 WRITE (6,51)
      STOP
```

```
* T I D Y *
           PROGRAM HADY(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10)
C
51    FORMAT (1H ,10HHA  HA  HA)
52    FORMAT (1H ,26H                       NORM=2)
53    FORMAT (1H ,1X,3HNIT,13X,2HKX,24X,1HD,22X,3HDKX,12X,3HIFL,1X,3HIW1
     1,1X,3HIW2/)
54    FORMAT (1H ,1X,3HNIT,13X,2HKX,24X,2HKZ,17X,4HEPSI,8X,5HDEPSI,8X,6H
     1DALFAI,5X,3HIFL,1X,3HIW1,1X,3HIW2/)
55    FORMAT (1H ,5X,3HKX=,2(E11.5,1X),3HKZ=,2(E11.5,1X),6HOMEGA=,2(E11.
     15,1X),3HFR=,E11.5,1X,5HFREQ=,E11.5//,5X,3HCR=,E11.5,1X,5HMACH=,E11
     2.5,1X,4HETA=,E11.5,1X,3HIE=,I5,1X,3HWN=,E11.5,1X,4HPGR=,E11.5,1X,2
     3HD=,2(E11.5,1X)//,5X,4HPHI=,F9.4,1X,5HEPSI=,F9.4,1X,6HEPSIP=,F9.4)
56    FORMAT (1H ,////,5X,3HNS=,I5,5X,3HXC=,E11.4,5X,2HR=,E11.4,5X,4HCHL
     1=,F11.4/)
57    FORMAT (1H ,1X,F5.2,1X,6(D9.3,1X,E9.3,1X))
58    FORMAT (1H ,12HEIGEN VALUES/)
59    FORMAT (1H ,1X,42HEIGEN FUNCTIONS-ADJOINT(W1,W2,W3,W4,W6,W8))
60    FORMAT (1H ,5X,10(D11.4,1X)///)
61    FORMAT (1H ,42HEIGEN FUNCTIONS-REGULAR(Z1,Z2,Z3,Z5,Z6,Z7))
      END
```

SUBROUTINE FULLP (NW,INCOMP)

```
      SUBROUTINE FULLP (NW,INCOMP)
      REAL MACH,MU,MUP,MUPP,ND
      COMMON /BB1/ XC,CHL,UFS,R,MACH,ETA,PRA,ND,NS,IE
      COMMON /CCC/ YI(101),U(101),UP(101),UPP(101),W(101),WP(101),WPP(10
     11),T(101),TP(101),TPP(101),MU(101),MUP(101),MUPP(101),ALFA(101),AL
     2FAP(101),PR(101)
1     CONTINUE
      READ (10) NS,XC,MACH,R,CHL,UFS,ETA,PRA,ND,IE
      READ (10) (YI(I),I=1,IE)
      READ (10) (U(I),I=1,IE)
      READ (10) (UP(I),I=1,IE)
      READ (10) (UPP(I),I=1,IE)
      READ (10) (W(I),I=1,IE)
      READ (10) (WP(I),I=1,IE)
      READ (10) (WPP(I),I=1,IE)
      READ (10) (T(I),I=1,IE)
      READ (10) (TP(I),I=1,IE)
      READ (10) (TPP(I),I=1,IE)
      READ (10) (MU(I),I=1,IE)
      READ (10) (MUP(I),I=1,IE)
      READ (10) (MUPP(I),I=1,IE)
      READ (10) (ALFA(I),I=1,IE)
      READ (10) (ALFAP(I),I=1,IE)
      READ (10) (PR(I),I=1,IE)
      IF (NS.LT.NW) GO TO 1
      ND=W(1)
      IF (INCOMP.NE.1) RETURN
      MACH=0.0001
      DO 2 I=1,IE
      T(I)=1.
      TP(I)=0.
      TPP(I)=0.
      MU(I)=1.
      MUP(I)=0.
      MUPP(I)=0.
      ALFA(I)=0.8
2     ALFAP(I)=0.
      RETURN
      END
```

```
* T I D Y *
                    SUBROUTINE FMAT (X,Y,YP,IGOFX,S,SP)

      SUBROUTINE FMAT (X,Y,YP,IGOFX,S,SP)
      REAL MACH,MU,MUP,MUPP,ND
      COMPLEX G1,G2,G3,G4,G5,G6,G7,G8,Z1,Z2,Z3,Z4,Z5,Z6,XI,KX,KXX,KZ,KZZ
     1,QA,QC,OMEGA,Z7,Z8
      COMPLEX A21,A23,A24,A25,A31,A34,A35,G,A41,A42,A43,A44,A45,A46
      COMPLEX A63,A64,A65,A37,A48,A84,A85,A87,A47,A83
      DIMENSION Y(1), YP(1), S(1), SP(1)
      COMMON /AAA/ XSAVE,KL,INDEX,NIT
      COMMON /BBB/ KX,KXX,KZ,KZZ,OMEGA,XI,P,Q,GAMMA,QB
      COMMON /BB1/ XC,CHL,UFS,R,MACH,ETA,PRA,ND,NS,N
C
      IF (XSAVE.EQ.X) GO TO 1
      IF (XSAVE.LT.X) KL=1
      XSAVE=X
      CALL PROF (X,U1,U1P,UPP,W1,W1P,WPP,T,TP,TPP,MU,MUP,MUPP,ALFA,ALFAP
     1,PRANDL,KL,INDEX)
      QA=KX*U1+KZ*W1-OMEGA
      QC=KX*U1P+KZ*W1P
      QD=PRANDL*(GAMMA-1.)*MACH*MACH
      A21=XI*R*QA/(T*MU)+KXX+KZZ
      A22=-MUP/MU
      A23=R*U1P/(T*MU)-XI*KX*(MUP/MU+P*TP/T)
      A24=XI*R*KX/MU-P*QB*KX*QA
      A25=P*KX*QA/T-(ALFA*UPP+U1P*ALFAP)/MU
      A26=-ALFA*U1P/MU
      A31=-XI*KX
      A33=TP/T
      A34=-XI*QB*QA
      A35=XI*QA/T
      A37=-XI*KZ
      G=R/MU+XI*QB*Q*QA
      A41=-XI*KX*(2.*MUP/MU+Q*TP/T)/G
      A42=-XI*KX/G
      A43=(-KXX-KZZ+(Q*MUP*TP/MU+Q*TPP-XI*R*QA/MU)/T)/G
      A44=-XI*Q*QB*(QA*(MUP/MU+TP/T)+QC)/G
      A45=XI*((ALFA/MU+Q/T)*QC+Q*MUP*QA/(T*MU))/G
      A46=XI*Q*QA/(T*G)
      A47=-XI*KZ*(2.*MUP/MU+Q*TP/T)/G
      A48=-XI*KZ/G
      A62=-2.*QD*U1P
      A63=R*PRANDL*TP/(T*MU)-2.*XI*QD*QC
      A64=-XI*R*QD*QA/MU
      A65=XI*R*PRANDL*QA/(T*MU)-ALFA*QD*(U1P*U1P+W1P*W1P)/MU+KXX+KZZ-MUP
     1P/MU
      A66=-2.*MUP/MU
```

```
      SUBROUTINE FMAT (X,Y,YP,IGOFX,S,SP)
      A68=-2.*QD*W1P
      A83=P*W1P/(T*MU)-XI*(MUP/MU+P*TP/T)*KZ
      A84=KZ*(XI*R/MU-P*QB*QA)
      A85=-(ALFA*WPP+W1P*ALFAP)/MU+P*KZ*QA/T
      A86=-ALFA*W1P/MU
      A87=A21
      A88=-MUP/MU
1     CONTINUE
      G1=CMPLX(Y(1),Y(2))
      G2=CMPLX(Y(3),Y(4))
      G3=CMPLX(Y(5),Y(6))
      G4=CMPLX(Y(7),Y(8))
      G5=CMPLX(Y(9),Y(10))
      G6=CMPLX(Y(11),Y(12))
      G7=CMPLX(Y(13),Y(14))
      G8=CMPLX(Y(15),Y(16))
      IF (INDEX.EQ.3.OR.INDEX.EQ.4) GO TO 2
      YP(1)=Y(3)
      YP(2)=Y(4)
      Z1=A21*G1+A22*G2+A23*G3+A24*G4+A25*G5+A26*G6
      YP(3)=Z1
      YP(4)=-XI*Z1
      Z2=A31*G1+A33*G3+A34*G4+A35*G5+A37*G7
      YP(5)=Z2
      YP(6)=-XI*Z2
      Z3=A41*G1+A42*G2+A43*G3+A44*G4+A45*G5+A46*G6+A47*G7+A48*G8
      YP(7)=Z3
      YP(8)=-XI*Z3
      YP(9)=Y(11)
      YP(10)=Y(12)
      Z4=A62*G2+A63*G3+A64*G4+A65*G5+A66*G6+A68*G8
      YP(11)=Z4
      YP(12)=-XI*Z4
      YP(13)=Y(15)
      YP(14)=Y(16)
      Z5=A83*G3+A84*G4+A85*G5+A86*G6+A87*G7+A88*G8
      YP(15)=Z5
      YP(16)=-XI*Z5
      RETURN
C
2     CONTINUE
      Z1=-A21*G2-A31*G3-A41*G4
      YP(1)=Z1
      YP(2)=-XI*Z1
      Z2=-G1-A22*G2-A42*G4-A62*G6
```

```
* T I D Y *
                    SUBROUTINE FMAT (X,Y,YP,IGOFX,S,SP)

      YP(3)=Z2
      YP(4)=-XI*Z2
      Z3=-A23*G2-A33*G3-A43*G4-A63*G6-A83*G8
      YP(5)=Z3
      YP(6)=-XI*Z3
      Z4=-A24*G2-A34*G3-A44*G4-A64*G6-A84*G8
      YP(7)=Z4
      YP(8)=-XI*Z4
      Z5=-A25*G2-A35*G3-A45*G4-A55*G6-A85*G8
      YP(9)=Z5
      YP(10)=-XI*Z5
      Z6=-A26*G2-A46*G4-G5-A66*G6-A86*G8
      YP(11)=Z6
      YP(12)=-XI*Z6
      Z7=-A37*G3-A47*G4-A87*G8
      YP(13)=Z7
      YP(14)=-XI*Z7
      Z8=-A48*G4-A68*G6-G7-A88*G8
      YP(15)=Z8
      YP(16)=-XI*Z8
      RETURN
      END
```

```
* T I D Y *
      SUBROUTINE CFITN (EPSI,EPSIP,IFLAG,MNB,MVC,D,WN,EPS,ICASE,BETAR,IT

      SUBROUTINE CFITN (EPSI,EPSIP,IFLAG,MNB,MVC,D,WN,EPS,ICASE,BETAR,IT
     1R)
      COMPLEX KX,KZ,OMEGA,D,KXX,KZZ,XI
      COMMON /AAA/ XSAVE,KL,INDEX,NIT
      COMMON /BBB/ KX,KXX,KZ,KZZ,OMEGA,XI,P,Q,GAMMA,QB
      DEL=.0005
      GO TO (1,3,1,3), INDEX
1     DAR=D
      DAI=-XI*D
      EPSIA=EPSI
      ALFAIA=-XI*KX
      DEPSI=EPSI*DEL
      IF (DEPSI.EQ.0.) DEPSI=DEL
      EPSI=EPSI+DEPSI
      IF (ICASE.EQ.5) GO TO 2
      BETAR=WN*SIN(EPSI)
2     ALFAR=BETAR/TAN(EPSI)
      BETAI=ALFAIA*TAN(EPSIP)
      KX=CMPLX(ALFAR,ALFAIA)
      KZ=CMPLX(BETAR,BETAI)
      INDEX=2
      INDOX=1
      RETURN
3     CONTINUE
      IF (INDOX.EQ.2) GO TO 5
      DFRS=(REAL(D)-DAR)/DEPSI
      DFIS=(AIMAG(D)-DAI)/DEPSI
      EPSI=EPSIA
      DALFAI=ALFAIA*DEL
      ALFAI=ALFAIA+DALFAI
      IF (ICASE.EQ.5) GO TO 4
      BETAR=WN*SIN(EPSI)
4     ALFAR=BETAR/TAN(EPSI)
      BETAI=ALFAI*TAN(EPSIP)
      KX=CMPLX(ALFAR,ALFAI)
      KZ=CMPLX(BETAR,BETAI)
      NIT=NIT+1
      IF (NIT.GE.ITR) GO TO 11
      INDEX=2
      INDOX=2
      RETURN
5     DFRAI=(REAL(D)-DAR)/DALFAI
      DFIAI=(AIMAG(D)-DAI)/DALFAI
      SAL=DFRS*DFIAI-DFRAI*DFIS
      IF (SAL.EQ.0.) GO TO 8
```

```
* T I D Y *
      SUBROUTINE CFITN (EPSI,EPSIP,IFLAG,MNB,MVC,D,WN,EPS,ICASE,BETAR,IT

      DEPSI=(-DAR*DFIAI+DAI*DFRAI)/SAL
      DALFAI=(DAR*DFIS-DAI*DFRS)/SAL
      WRITE (6,13) NIT,KX,KZ,EPSI*57.29577,DEPSI*57.29577,DALFAI,IFLAG,M
     1NB,MVC
      IF (ABS(DEPSI).LE.EPS.AND.ABS(DALFAI).LE.EPS) GO TO 10
6     IF (ABS(DEPSI).LE.(.02*ABS(EPSI))) GO TO 7
      DEPSI=.5*DEPSI
      GO TO 6
7     IF (ABS(DALFAI).LE.(.5*ABS(ALFAI))) GO TO 8
      DALFAI=.5*DALFAI
      GO TO 7
8     CONTINUE
      EPSI=EPSI+DEPSI
      ALFAI=ALFAI+DALFAI
      IF (NIT.EQ.ITR) GO TO 11
      IF (ICASE.EQ.5) GO TO 9
      BETAR=WN*SIN(EPSI)
9     ALFAR=BETAR/TAN(EPSI)
      BETAI=ALFAI*TAN(EPSIP)
      KX=CMPLX(ALFAR,ALFAI)
      KZ=CMPLX(BETAR,BETAI)
      INDEX=1
      RETURN
10    INDEX=10
      GO TO 12
11    WRITE (6,14)
      STOP
12    RETURN
C
13    FORMAT (1H ,1X,I2,7E13.4,1X,3(I3,1X))
14    FORMAT (1H ,27HEXESSIVE NO. OF ITTERATIONS)
      END
```

```
* T I D Y *
      SUBROUTINE RNITN (EPSI,EPSIP,IFLAG,MNB,MVC,D,ISPTM,ICASE,WN,EPS,IT

      SUBROUTINE RNITN (EPSI,EPSIP,IFLAG,MNB,MVC,D,ISPTM,ICASE,WN,EPS,IT
     1R)
      COMPLEX D,DA,DK,KX,KZ,OMEGA,DPHDK,K,XI,KXX,KZZ
      COMMON /AAA/ XSAVE,KL,INDEX,NIT
      COMMON /BBB/ KX,KXX,KZ,KZZ,OMEGA,XI,P,Q,GAMMA,QB
C
      DEL=.005
      GO TO (1,7,1,7), INDEX
1     DA=D
      IF (ISPTM.EQ.2) GO TO 6
      DK=KX*DEL
      KX=KX+DK
      ALFAR=KX
      ALFAI=-XI*KX
      BETAR=KZ
      BETAI=-XI*KZ
      GO TO (4,3,2), ICASE
2     BETAI=ALFAI*TAN(EPSIP)
      EPSI=ATAN(BETAR/ALFAR)
      GO TO 5
3     BETAR=ALFAR*TAN(EPSI)
      GO TO 5
4     BETAR=ALFAR*TAN(EPSI)
      BETAI=ALFAI*TAN(EPSIP)
5     KZ=CMPLX(BETAR,BETAI)
      NIT=NIT+1
      INDEX=2
      RETURN
6     CONTINUE
      DK=OMEGA*DEL
      OMEGA=OMEGA+DK
      NIT=NIT+1
      INDEX=2
      RETURN
C
7     CONTINUE
      DPHDK=(D-DA)/DK
      DK=-D/DPHDK
      IF (ISPTM.EQ.1) K=KX
      IF (ISPTM.EQ.2) K=OMEGA
      IF (CABS(DK/K).LE.EPS) GO TO 15
8     IF (CABS(DK).LE.(0.2*CABS(K))) GO TO 9
      DK=0.5*DK
      GO TO 8
9     CONTINUE
```

```
* T I D Y *
      SUBROUTINE PNITN (EPSI,EPSIP,IFLAG,MNB,MVC,D,ISPTM,ICASE,WN,EPS,IT

      WRITE (6,18) NIT,K,D,DK,IFLAG,MNB,MVC
      IF (ISPTM.EQ.2) GO TO 14
      KX=KX+DK
      ALFAR=KX
      ALFAI=-XI*KX
      BETAR=KZ
      BETAI=-XI*KZ
      GO TO (12,11,10), ICASE
10    BETAI=ALFAI*TAN(EPSIP)
      EPSI=ATAN(BETAR/ALFAR)
      GO TO 13
11    BETAR=ALFAR*TAN(EPSI)
      GO TO 13
12    BETAR=ALFAR*TAN(EPSI)
      BETAI=ALFAI*TAN(EPSIP)
13    CONTINUE
      KZ=CMPLX(BETAR,BETAI)
      DA=D
      IF (NIT.EQ.ITR) GO TO 16
      NIT=NIT+1
      INDEX=2
      RETURN
14    CONTINUE
      OMEGA=OMEGA+DK
      DA=D
      IF (NIT.EQ.ITR) GO TO 16
      NIT=NIT+1
      INDEX=2
      RETURN
C
C
15    CONTINUE
      INDEX=10
      GO TO 17
16    WRITE (6,19)
      STOP
17    RETURN
C
18    FORMAT (1H,1X,I2,6E13.4,1X,3(I3,1X))
19    FORMAT (1H,27HEXESSIVENO.OFITTERATIONS)
      END
```

```
* T I D Y *
            SUBROUTINE GIMTR (GIM,EPSI,EPSIP,ICASE,NITB,INDOX,WN,EPS)

      SUBROUTINE GIMTR (GIM,EPSI,EPSIP,ICASE,NITB,INDOX,WN,EPS)
      COMPLEX KZ,KX,XI,OMEGA,KXX,KZZ
      COMMON /BBB/ KX,KXX,KZ,KZZ,OMEGA,XI,P,Q,GAMMA,QB
C
      DELX=.0005
      ITR=10
      GO TO (1,6), INDOX
1     GIMA=GIM
      BETAR=KZ
      BETAI=-XI*KZ
      ALFAI=-XI*KX
      GO TO (13,4,3,2), ICASE
2     DWN=WN*DELX
      IF (DWN.EQ.0.) DWN=DELX
      WN=WN+DWN
      ALFAR=WN*COS(EPSI)
      BETAR=WN*SIN(EPSI)
      KX=CMPLX(ALFAR,ALFAI)
      GO TO 5
      DEPSI=EPSI*DELX
      IF (DEPSI.EQ.0.) DEPSI=DELX
      EPSI=EPSI+DEPSI
      ALFAR=WN*COS(EPSI)
      BETAR=WN*SIN(EPSI)
      KX=CMPLX(ALFAR,ALFAI)
      GO TO 5
3     DBETR=BETAR*DELX
      IF (DBETR.EQ.0.) DBETR=DELX
      BETAR=BETAR+DBETR
      GO TO 5
4     DBETI=BETAI*DELX
      IF (DBETI.EQ.0.) DBETI=DELX
      BETAI=BETAI+DBETI
5     KZ=CMPLX(BETAR,BETAI)
      NITB=NITB+1
      INDOX=2
      RETURN
6     CONTINUE
      GO TO (13,8,9,7), ICASE
7     DPHDK=(GIM-GIMA)/DWN
      DWN=-GIM/DPHDK
      IF (ABS(DWN/WN).LE.EPS) GO TO 11
      WRITE (6,16) NITB,WN,GIM,DPHDK,DWN
      WN=WN+DWN
      ALFAR=WN*COS(EPSI)
```

```
* T I D Y *
           SUBROUTINE GIMTR (GIM,EPSI,EPSIP,ICASE,NITB,INDOX,WN,EPS)

      BETAR=WN*SIN(EPSI)
      ALFAI=-XI*KX
      BETAI=-XI*KZ
      KX=CMPLX(ALFAR,ALFAI)
      GO TO 10
      DPHDK=(GIM-GIMA)/DEPSI
      DEPSI=-GIM/DPHDK
      IF (ABS(DEPSI/EPSI).LE.EPS) GO TO 11
      WRITE (6,16) NITB,EPSI*57.29577,GIM,DPHDK,DEPSI*57.29577
      EPSI=EPSI+DEPSI
      ALFAR=WN*COS(EPSI)
      BETAR=WN*SIN(EPSI)
      ALFAI=-XI*KX
      BETAI=-XI*KZ
      KX=CMPLX(ALFAR,ALFAI)
      GO TO 10
8     DPHDK=(GIM-GIMA)/DBETI
      DBETI=-GIM/DPHDK
      IF (ABS(DBETI/BETAI).LE.EPS) GO TO 11
      WRITE (6,16) NITB,KZ,GIM,DPHDK,DBETI
      BETAR=KZ
      BETAI=BETAI+DBETI
      GO TO 10
9     DPHDK=(GIM-GIMA)/DBETR
      DBETR=-GIM/DPHDK
      IF (ABS(DBETR/BETAR).LE.EPS) GO TO 11
      WRITE (6,16) NITB,KZ,GIM,DPHDK,DBETR
      BETAI=-XI*KZ
      BETAR=BETAR+DBETR
10    KZ=CMPLX(BETAR,BETAI)
      GIMA=GIM
      NITB=NITB+1
      IF (NITB.EQ.ITR) GO TO 12
      INDOX=2
      RETURN
11    CONTINUE
      INDOX=10
      GO TO 14
12    WRITE (6,15)
13    STOP
14    RETURN
C
15    FORMAT (1H ,26HEXESSIVE NO. OF ITERATIONS)
16    FORMAT (1H,1X,I2,2E13.4,E13.4,4E13.4)
      END
```

* T I D Y *

SUBROUTINE SONG (N,X,YM,Z)

```
      SUBROUTINE SONG (N,X,YM,Z)
      COMPLEX X(N),Z
      DIMENSION GM1(101), GM2(101), YM(101), Y(101)
      DO 1 I=1,N
      Y(I)=YM(N+1-I)
      GM1(I)=REAL(X(N+1-I))
1     GM2(I)=AIMAG(X(N+1-I))
      VRI=0.
      VII=0.
      DO 2 I=2,N
      VRI=VRI+(GM1(I)+GM1(I-1))*(Y(I)-Y(I-1))/2.
      VII=VII+(GM2(I)+GM2(I-1))*(Y(I)-Y(I-1))/2.
2     CONTINUE
      Z=CMPLX(VRI,VII)
      RETURN
      END
```

* T I D Y *

SUBROUTINE CFA (EPSICF,N)

```
      SUBROUTINE CFA (EPSICF,N)
      REAL MU,MUP,MUPP
      DIMENSION U(101), W(101), UPP(101), WPP(101)
      COMMON /CCC/ Y(101),U1(101),UP(101),U1PP(101),W1(101),WP(101),W1PP
     1(101),T(101),TP(101),TPP(101),MU(101),MUP(101),MUPP(101),DVDT(101)
     2,DVDTP(101),PR(101)
      DO 1 J=1,N
      I=N-J+1
      U(I)=U1(J)
      W(I)=W1(J)
      UPP(I)=U1PP(J)
      WPP(I)=W1PP(J)
1     CONTINUE
      B1=1.E+06
      DO 2 I=2,N
      IF (U(I).GT.0.999) GO TO 3
      A1=U(I)/W(I)
      A2=UPP(I)/WPP(I)
      B2=A1-A2
      IF ((B2.GE.0..AND.B1.LE.0.).OR.(B2.LE.0..AND.B1.GE.0.)) ISAVE=I
      B1=B2
2     CONTINUE
3     CONTINUE
      EPSICF=-ATAN(U(ISAVE)/W(ISAVE))+3.1415977
      WRITE (6,4) EPSICF*57.29577
      RETURN
C
4     FORMAT (1H ,7HEPSICF=,E12.5)
      END
```

* T I D Y *

```
      SUBROUTINE PROF (YARG,UL,UP,UPP,WL,WP,WPP,TL,TP,TPP,MU,MUP,MUPP,AL

      SUBROUTINE PROF (YARG,UL,UP,UPP,WL,WP,WPP,TL,TP,TPP,MU,MUP,MUPP,AL
     1FA,ALFAP,PRANDL,KL,INDEX)
      REAL INTER
      REAL MU,MUP,MUPP,MACH,ND
      COMPLEX KX,KZ,OMEGA,KXX,KZZ,XI
      COMMON /BBB/ KX,KXX,KZ,KZZ,OMEGA,XI,P,Q,GAMMA,QB
      COMMON /BB1/ XC,CHL,UFS,R,MACH,ETA,PRA,ND,NS,IE
      COMMON /CCC/ Y(101),U(101),DU(101),DDU(101),W(101),DW(101),DDW(101
     1),T(101),DT(101),DDT(101),VS(101),VSP(101),VSPP(101),DVDT(101),DVD
     2TP(101),PR(101)
C
      DO 1 J=KL,IF
      I=J
      IF (YARG.GT.Y(J)) GO TO 2
      IF (YARG.EQ.Y(J)) GO TO 3
1     CONTINUE
2     MIN=I-3
      IF (I.LE.3) MIN=1
      IF (I.GE.(IE-2)) MIN=IE-6
      UL=INTER(Y,U,YARG,6,MIN)
      UP=INTER(Y,DU,YARG,6,MIN)
      UPP=INTER(Y,DDU,YARG,6,MIN)
      WL=INTER(Y,W,YARG,6,MIN)
      WP=INTER(Y,DW,YARG,6,MIN)
      WPP=INTER(Y,DDW,YARG,6,MIN)
      TL=INTER(Y,T,YARG,6,MIN)
      TP=INTER(Y,DT,YARG,6,MIN)
      TPP=INTER(Y,DDT,YARG,6,MIN)
      PPANDL=PRA
      MU=INTER(Y,VS,YARG,6,MIN)
      MUP=INTER(Y,VSP,YARG,6,MIN)
      MUPP=INTER(Y,VSPP,YARG,6,MIN)
      ALFA=INTER(Y,DVDT,YARG,6,MIN)
      ALFAP=INTER(Y,DVDTP,YARG,6,MIN)
      KL=I
      RETURN
3     UL=U(I)
      UP=DU(I)
      UPP=DDU(I)
      WL=W(I)
      WP=DW(I)
      WPP=DDW(I)
      TL=T(I)
      TP=DT(I)
      TPP=DDT(I)
```

```
* T I D Y *
      SUBROUTINE PROF (YARG,UL,UP,UPP,WL,WP,WPP,TL,TP,TPP,MU,MUP,MUPP,AL

      PRANDL=PRA
      MU=VS(I)
      MUP=VSP(I)
      MUPP=VSPP(I)
      ALFA=DVDT(I)
      ALFAP=DVDTP(I)
      KL=I
      RETURN
      END
```

* T I D Y *

REAL FUNCTIONINTER(X,Y,XARG,IDEG,MIN)

```
      REAL FUNCTIONINTER(X,Y,XARG,IDEG,MIN)
      DIMENSION X(101), Y(101)
1     FACTOR=1.0
      MAX=MIN+IDEG
      DO 2 J=MIN,MAX
      IF (XARG.NE.X(J)) GO TO 2
      INTER=Y(J)
      RETURN
2     FACTOR=FACTOR*(XARG-X(J))
      YEST=0.0
      DO 4 I=MIN,MAX
      TERM=Y(I)*FACTOR/(XARG-X(I))
      DO 3 J=MIN,MAX
3     IF (I.NE.J) TERM=TERM/(X(I)-X(J))
4     YEST=TERM+YEST
      INTER=YEST
      RETURN
      END
```

```
      SUBROUTINE GVEC (X,C,S)                                           K   1
      DIMENSION C(1), S(1)                                              K   2
      RETURN                                                            K   3
      END                                                               K   4-
```

* T I D Y *

SUBROUTINE COMINV (A,N,D)

```
      SUBROUTINE COMINV (A,N,D)
      COMPLEX A(N,N),D,BIGA,HOLD
      DIMENSION L(8), M(8)
      D=(1.E0,0.F0)
      DO 18 K=1,N
      L(K)=K
      M(K)=K
      BIGA=A(K,K)
      DO 2 J=K,N
      DO 2 I=K,N
      IF (CABS(BIGA)-CABS(A(I,J))) 1,2,2
1     BIGA=A(I,J)
      L(K)=I
      M(K)=J
2     CONTINUE
      J=L(K)
      IF (J-K) 5,5,3
3     DO 4 I=1.N
      HOLD=-A(K,I)
      A(K,I)=A(J,I)
4     A(J,I)=HOLD
5     I=M(K)
      IF (I-K) 8,8,6
6     DO 7 J=1,N
      HOLD=-A(J,K)
      A(J,K)=A(J,I)
7     A(J,I)=HOLD
8     IF (CABS(BIGA)) 10,9,10
9     D=(0.E0,0.F0)
      RETURN
10    DO 12 I=1,N
      IF (I-K) 11,12,11
11    A(I,K)=A(I,K)/(-BIGA)
12    CONTINUE
      DO 15 I=1,N
      HOLD=A(I,K)
      DO 15 J=1,N
      IF (I-K) 13,15,13
13    IF (J-K) 14,15,14
14    A(I,J)=HOLD*A(K,J)+A(I,J)
15    CONTINUE
      DO 17 J=1,N
      IF (J-K) 16,17,16
16    A(K,J)=A(K,J)/BIGA
17    CONTINUE
```

```
* T I D Y *
                              SUBROUTINE CDMINV (A,N,D)
          D=D*BIGA
          A(K,K)=1.E0/BIGA
   18     CONTINUE
          K=N
   19     K=(K-1)
          IF (K) 26,26,20
   20     I=L(K)
          IF (I-K) 23,23,21
   21     DO 22 J=1,N
          HOLD=A(J,K)
          A(J,K)=-A(J,I)
   22     A(J,I)=HOLD
   23     J=M(K)
          IF (J-K) 19,19,24
   24     DO 25 I=1,N
          HOLD=A(K,I)
          A(K,I)=-A(J,I)
   25     A(J,I)=HOLD
          GO TO 19
   26     RETURN
          END
```

* T I D Y *
SUBROUTINE GRVEL (ALAM,W2,W3,W4,W6,W8,TATA,EPGR,SM)

```
      SUBROUTINE GRVEL (ALAM,W2,W3,W4,W6,W8,TATA,EPGR,SM)
      REAL MACH,MU,MUP,MUPP,ND
      COMPLEX Z1(101),Z2(101),Z3(101),Z4(101),Z5(101),Z6(101),Z7(101),Z8
     1(101)
      COMPLEX W2(101),W3(101),W4(101),W6(101),W8(101)
      COMPLEX G1(101),G2(101)
      COMPLEX GZ1,GZ2,GZ3,GZ4,GZ5,GZ6,GZ7,GZ8,GW2,GW3,GW4,GW6,GW8
      COMPLEX VIG1,VIG2,VIG10,VIG20,TATA,VIHX,VIHZ
      COMPLEX XI,KX,KXX,KZ,KZZ,A111,A15,A102,A10
      COMPLEX A12,G,ALAM,OMEGA
      COMMON /BBB/ KX,KXX,KZ,KZZ,OMEGA,XI,P,Q,GAMMA,QB
      COMMON /BB1/ XC,CHL,UFS,R,MACH,ETA,PRA,ND,NS,N
      COMMON /CCC/ Y(101),U(101),UP(101),UPP(101),W(101),WP(101),WPP(101
     1),T(101),TP(101),TPP(101),MU(101),MUP(101),MUPP(101),ALFA(101),ALF
     2AP(101),PR(101)
      COMMON /FFF/ Z1,Z2,Z3,Z4,Z5,Z6,Z7,Z8
C
      DO 1 J=1,N
      I=J
      A111=KX*U(I)+KZ*W(I)-OMEGA
      A15=-KXX-KZZ+Q*MUP(I)*TP(I)/(MU(I)*T(I))+Q*TPP(I)/T(I)-XI*R*A111/(
     1MU(I)*T(I))
      A9=MUP(I)/MU(I)+TP(I)/T(I)
      A102=KX*UP(I)+KZ*WP(I)
      A10=A9*A111+A102
      A121=Q/T(I)+ALFA(I)/MU(I)
      A12=A121*A102+Q*MUP(I)*A111/(MU(I)*T(I))
      A13=2.*MUP(I)/MU(I)+Q*TP(I)/T(I)
      A8=PR(I)*(GAMMA-1.)*MACH*MACH
      G=P/MU(I)+XI*Q*QB*A111
      GZ1=(XI*R*U(I)/(T(I)*MU(I))+2.*KX)*Z1(J)
      GZ3=-XI*(MUP(I)/MU(I)+P*TP(I)/T(I))*Z3(J)
      GZ4=(XI*R/MU(I)-P*QB*(2.*KX*U(I)+KZ*W(I)-OMEGA))*Z4(J)
      GZ5=P*(2.*KX*U(I)+KZ*W(I)-OMEGA)*Z5(J)/T(I)
      GW2=(GZ1+GZ3+GZ4+GZ5)*W2(J)
      GZ1=-XI*Z1(J)
      GZ4=-XI*QB*U(I)*Z4(J)
      GZ5=XI*U(I)*Z5(J)/T(I)
      GW3=(GZ1+GZ4+GZ5)*W3(J)
      GZ1=-XI*(1.-XI*KX*QB*Q*U(I)/G)*A13*Z1(J)/G
      GZ2=XI*(XI*KX*QB*Q*U(I)/G-1.)*Z2(J)/G
      GZ3=(-2.*KX-XI*R*U(I)/(MU(I)*T(I))-XI*Q*QB*U(I)*A15/G)*Z3(J)/G
      GZ4=-XI*Q*QB*(A9*U(I)+UP(I)-XI*Q*QB*U(I)*A10/G)*Z4(J)/G
      GZ5=(XI*(A121*UP(I)+Q*MUP(I)*U(I)/(MU(I)*T(I)))/G+Q*QB*U(I)*A12/(G
     1*G))*Z5(J)
```

```
* T I D Y *
                SUBROUTINE GRVEL (ALAM,W2,W3,W4,W6,W8,TATA,EPGR,SM)

      GZ6=Q*U(I)*(XI+Q*QB*A111/G)*Z6(J)/(G*T(I))
      GZ7=-A13*KZ*Q*QB*U(I)*Z7(J)/(G*G)
      GZ8=-KZ*Q*QB*U(I)*Z8(J)/(G*G)
      GW4=(GZ1+GZ2+GZ3+GZ4+GZ5+GZ6+GZ7+GZ8)*W4(J)
      GZ3=-2.*XI*A8*UP(I)*Z3(J)
      GZ4=-XI*R*A8*U(I)*Z4(J)/MU(I)
      GZ5=(XI*R*PR(I)*U(I)/(MU(I)*T(I))+2.*KX)*Z5(J)
      GW6=(GZ3+GZ4+GZ5)*W6(J)
      GZ4=-P*KZ*QB*U(I)*Z4(J)
      GZ5=P*KZ*U(I)*Z5(J)/T(I)
      GZ7=(XI*R*U(I)/(MU(I)*T(I))+2.*KX)*Z7(J)
      GW8=(GZ4+GZ5+GZ7)*W8(J)
      G1(J)=GW2+GW3+GW4+GW6+GW8
      GZ1=(XI*R*W(I)/(MU(I)*T(I))+2.*KZ)*Z1(J)
      GZ4=-P*QB*KX*W(I)*Z4(J)
      GZ5=P*KX*W(I)*Z5(J)/T(I)
      GW2=(GZ1+GZ4+GZ5)*W2(J)
      GZ4=-XI*QB*W(I)*Z4(J)
      GZ5=XI*W(I)*Z5(J)/T(I)
      GZ7=-XI*Z7(J)
      GW3=(GZ4+GZ5+GZ7)*W3(J)
      GZ1=-Q*QB*W(I)*KX*A13*Z1(J)/(G*G)
      GZ2=-Q*QB*KX*W(I)*Z2(J)/(G*G)
      GZ3=(-2.*KZ-XI*R*W(I)/(MU(I)*T(I))-XI*Q*QB*W(I)*A15/G)*Z3(J)/G
      GZ4=-XI*Q*QB*(A9*W(I)+WP(I)-XI*Q*QB*W(I)*A10/G)*Z4(J)/G
      GZ5=(XI*(A121*WP(I)+Q*MUP(I)*W(I)/(MU(I)*T(I)))/G+Q*QB*W(I)*A12/(G
     1*G))*Z5(J)
      GZ6=Q*W(I)*(XI+Q*QB*A111/G)*Z6(J)/(G*T(I))
      GZ7=-A13*(KZ*Q*QB*W(I)/(G*G)+XI/G)*Z7(J)
      GZ8=-(KZ*Q*QB*W(I)/G+XI)*Z8(J)/G
      GW4=(GZ1+GZ2+GZ3+GZ4+GZ5+GZ6+GZ7+GZ8)*W4(J)
      GZ3=-2.*XI*A8*WP(I)*Z3(J)
      GZ4=-XI*R*A8*W(I)*Z4(J)/MU(I)
      GZ5=(XI*R*PR(I)*W(I)/(MU(I)*T(I))+2.*KZ)*Z5(J)
      GW6=(GZ3+GZ4+GZ5)*W6(J)
      GZ3=-XI*(MUP(I)/MU(I)+P*TP(I)/T(I))*Z3(J)
      GZ4=(XI*R/MU(I)-P*QB*(KZ*W(I)+A111))*Z4(J)
      GZ5=P*(KZ*W(I)+A111)*Z5(J)/T(I)
      GZ7=(XI*R*W(I)/(MU(I)*T(I))+2.*KZ)*Z7(J)
      GW8=(GZ3+GZ4+GZ5+GZ7)*W8(J)
      G2(J)=GW2+GW3+GW4+GW6+GW8
1     CONTINUE
C
      CALL SONG (N,G1,Y,VIG1)
      CALL SONG (N,G2,Y,VIG2)
```

```
* T I D Y *
              SUBROUTINE GRVEL (ALAM,W2,W3,W4,W6,W8,TATA,EPGR,SM)

      A111=KX+ND*KZ-OMEGA
      A15=-KXX-KZZ-XI*R*A111
      A121=Q+ALFA(1)
      A8=PR(1)*(GAMMA-1.)*MACH*MACH
      G=R+XI*Q*QB*A111
      GW2=((XI*R+2.*KX)*Z1(1)+(XI*R-P*QB*(2.*KX+ND*KZ-OMEGA))*Z4(1)+P*(2
     1.*KX+ND*KZ-OMEGA)*Z5(1))*W2(1)
      GW3=XI*(-Z1(1)-QB*Z4(1)+Z5(1))*W3(1)
      GW4=(XI*(XI*KX*QB*Q/G-1.)*Z2(1)/G+(-2.*KX-XI*R-XI*Q*QB*A15/G)*Z3(1
     1)/G+Q*(XI+Q*QB*A111/G)*Z6(1)/G-KZ*Q*QB*Z8(1)/(G*G))*W4(1)
      GW6=(-XI*R*A8*Z4(1)+(XI*R*PR(1)+2.*KX)*Z5(1))*W6(1)
      GW8=(-P*KZ*QB*Z4(1)+P*KZ*Z5(1)+(XI*R+2.*KX)*Z7(1))*W8(1)
      VIG1D=-(GW2+GW3+GW4+GW6+GW8)/(2.*ALAM)
      GW2=((XI*R*ND+2.*KZ)*Z1(1)-P*QB*ND*KX*Z4(1)+P*KX*ND*Z5(1))*W2(1)
      GW3=(-XI*QB*ND*Z4(1)+XI*ND*Z5(1)-XI*Z7(1))*W3(1)
      GW4=(-KX*Q*QB*ND*Z2(1)/(G*G)+(-2.*KZ-XI*R*ND-XI*Q*QB*ND*A15/G)*Z3(
     11)/G+Q*ND*(XI+Q*QB*A111/G)*Z6(1)/G-(KZ*Q*QB*ND/G+XI)*Z8(1)/G)*W4(1
     2)
      GW6=(-XI*R*A8*ND*Z4(1)+(XI*R*PR(1)*ND+2.*KZ)*Z5(1))*W6(1)
      GW8=((XI*R-P*KZ*QB*ND-P*QB*A111)*Z4(1)+P*(KZ*ND+A111)*Z5(1)+(XI*R*
     1ND+2.*KZ)*Z7(1))*W8(1)
      VIG2D=-(GW2+GW3+GW4+GW6+GW8)/(2.*ALAM)
      VIG1=VIG1+VIG1D
      VIG2=VIG2+VIG2D
      TATA=VIG2/VIG1
      SM=TATA
      EPGR=ATAN(SM)*57.29577
      WRITE (6,2)
      WRITE (6,3) VIG1,VIG2,TATA,EPGR
      RETURN
C
2     FORMAT (1H ,/,2X,43HINFORMATIONS FROM GRVEL VIG1,VIG2,TATA,EPGR/)
3     FORMAT (1H ,5X,10(D11.4,1X),F5.2//)
      END
```

APPENDIX I

THE MEAN FLOW

The meanflow solution is an input to HADY-I. The boundary layer solution is calculated using as input the airfoil geometry, pressure coefficient distribution, and suction requirements.

The boundary layer program used here was adapted from the program of Kaups and Cebeci[4] for laminar, compressible boundary layers with adiabatic wall and wall suction boundary conditions. Extensive modifications and additions was necessary to this program[4], to suit the need of HADY-I stability program.

A. Input/Output Files

The program card is

```
PROGRAM MFLOW (INPUT, OUTPUT, TAPE5 = INPUT, TAPE6 = OUTPUT, TAPE9,
TAPE10, TAPE11)
```

TAPE9 A file for internal use
TAPE10 An output file that contains boundary layer profiles, used for parallel stability calculations
TAPE11 An output file that is used with TAPE10 for nonparallel stability calculations

B. Control Cards

The following control cards can be used to execute the program

```
JOBS, Tt, CM.
USER, USERNO, PASSWRD.
CHARGE, CHARNO, LRC.
GET, MFLOW.
ATTACH (FTNMLIB/UN = LIBRARY)
NOEXIT.
LDSET (LIB = FTNMLIB, PRESET = ZERO)
MFLOW.
REPLACE, TAPE10 = TAPEN.
EXIT.
7/8/9 end of record
Input Cards
6/7/8/9
```

C. Program Input

The input is through data cards

Card 1 — 8A10

TITLE	Description of the case

Card 2 — 4I1, 3I, 2X, 2F15.1

IPRINT	Define type of output printed = 1 Long print = 2 Short print
IPANPA	Define type of analysis desired = 1 Parallel flow = 2 Nonparallel flow
MK	Number of input stations before minimum x/c (not including the minimum)
NK	Number of input stations before x/c = .001 (not including x/c = .001)
NM	Number of output stations starting from x/c = .001 (NM = 118)
RCR	Streamwise chord Reynolds number where input is given (tunnel conditions and suction distribution)
RCU	Streamwise chord Reynolds number where solution is needed

Card 3 — 2I3, 3F10.0

NI	Number of input stations for the streamwise airfoil
NZT	Number of input stations where suction coefficient C_S is specified
ETAE	Estimated value of maximum η at the first station
DETA1	First $\Delta\eta$ - step size
VGP	Variable grid parameter

Card 4 — 8F10.0

X	Chord length in feet for the streamwise airfoil
SWLE	Leading-edge sweep in degrees
SWTE	Trailing-edge sweep in degrees

CMACH Freestream Mach number

UREF Freestream velocity in ft/sec (only if $M_\infty = 0$)

TPRES Freestream static pressure, in lb/ft^2

TT Freestream static temperature, in degrees Rankin

PR Prandtl number

Card 5 2F15.10

XLE x/c of the leading edge

YLE y/c of the leading edge

Card 6 4F15.10

Total of NI cards, one per station. These cards contain informations of the normal to the leading edge airfoil, (airfoil data output from Garabedian program is used directly).

XA x/c value

YA y/c value

CM local Mach number

CP2 Input C_p values (two-dimensional)

Card 7 8F10.0

BLP Input suction coefficient values, defined as $C_S = (\rho V)_0/(\rho U)_\infty$
Total of NZT points

D. The Program MFLOW

```
* T I D Y *
      PROGRAM MFLOW(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE9,TAPE10,T

      PROGRAM MFLOW(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE9,TAPE10,T
     1APE11)
      COMMON /BLCO/ NZT,NZ,NP,IT,X,ROFS,CMACH,TT,ETA(151),DETA(151),A(15
     11),Y(151),IPANPA
      COMMON /BLC1/ HE,PR,CMUFS,UFS,CEL(151),BETA1(151),UE(151),WE(151),
     1Z(151),PE(151),PHI(151),RHOE(151),XC(151),CMUE(151),P1(151),P3(151
     2),P4(151),RR(151),BLP(151),DDW(151)
      COMMON /PROF/ DELV(151),F(101,2),U(101,2),V(101,2),G(101,2),W(101,
     12),T(101,2),B(101,2),C(151),BG(101,2),E(101,2),DENR(101,2),CA1(101
     2,2),CA2(101,2)
      COMMON /PAR/ A1,A2,A3,VGP,NNN,IPRINT
      COMMON /BAB/ H
C
      CALL INTIAL
      NZ=1
      ISOLV2=0
      ITMAX=20
1     IGROW=0
2     IT=0
3     IT=IT+1
      IF (IT.LE.ITMAX) GO TO 4
      WRITE (6,10)
      GO TO 9
4     IF (ISOLV2.EQ.1) CALL FLUID
      IF (H.LT.0.0) GO TO 9
      CALL COEF
      CALL SOLV6
      IF (ABS(DELV(1)).LE.0.0001) GO TO 5
      IF (ISOLV2.EQ.1) CALL SOLV2
      GO TO 3
5     IF (ISOLV2.EQ.0) GO TO 6
      CALL SOLV2
      GO TO 7
6     IF (CMACH.EQ.0.0) GO TO 7
      ISOLV2=1
      GO TO 2
7     IF (ABS(T(NP,2)).LE.1.E-8) GO TO 8
      IF (NP.EQ.101) GO TO 8
      IGROW=IGROW+1
      IF (IGROW.GT.1) GO TO 8
      LL=1
      CALL PROFIL (LL)
      GO TO 2
8     CALL OUTPUT
      IF (NZ.LE.NZT) GO TO 1
```

```
* T I D Y *
      PROGRAM MFLOW(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE9,TAPE10,T

9     CONTINUE
      IF (IPANPA.EQ.1) STOP
      CALL XZDER
      STOP
C
C
10    FORMAT (1H0,23HITERATIONS EXCEED ITMAX)
      END
```

* T I D Y *

SUBROUTINE INTIAL

```
      SUBROUTINE INTIAL
      COMMON /BLCO/ NZT,NZ,NP,IT,X,ROFS,CMACH,TT,ETA(151),DETA(151),A(15
     11),Y(151),IPANPA
      COMMON /BLC1/ HE,PR,CMUFS,UFS,CEL(151),BETA1(151),UE(151),WE(151),
     1Z(151),PE(151),PHI(151),RHOE(151),XC(151),CMUE(151),P1(151),P3(151
     2),P4(151),RR(151),BLP(151),DDW(151)
      COMMON /PROF/ DELV(151),F(101,2),U(101,2),V(101,2),G(101,2),W(101,
     12),T(101,2),B(101,2),C(151),BG(101,2),E(101,2),DENR(101,2),CA1(101
     2,2),CA2(101,2)
      COMMON /PAR/ A1,A2,A3,VGP,NNN,IPRINT
      DIMENSION DUE(151), DWE(151), DPR(151), TITLE(8)
      DIMENSION XA(151), YA(151), CM(151), CP2(151), CP3(151)
      DIMENSION DUM1(151), DUM2(151)
      DIMENSION SARA(151,3), SARB(151), SARBN(151), SARAO(151,3), WK(200
     10), YO(3)
C
      READ (5,35) TITLE
      READ (5,43) IPRINT,IPANPA,MK,NK,NM,RCR,RCU
      READ (5,36) NI,NZT,ETAE,DETA1,VGP
      READ (5,37) X,SWLE,SWTE,CMACH,UREF,TPRES,TT,PR
      READ (5,34) XLE,YLE
      READ (5,34) (XA(I),YA(I),CM(I),CP2(I),I=1,NI)
      READ (5,37) (BLP(I),I=1,NZT)
      SARBN(1)=0.0010
      DO 1 I=2,10
1     SARBN(I)=SARBN(I-1)+.0010
      DO 2 I=11,28
2     SARBN(I)=SARBN(I-1)+.005
      DO 3 I=29,NM
3     SARBN(I)=SARBN(I-1)+.01
      MK1=MK+1
      DO 4 I=MK1,NI
      M=I-MK1+1
      SARA(M,1)=YA(I)
      SARA(M,2)=CP2(I)
4     SARB(M)=XA(I)
      MKK=MK-2
      DO 5 I=MKK,NZT
      M=I-MKK+1
5     SARA(M,3)=BLP(I)
      IW=-1
      N=NI-MK1+1
      DO 7 I=1,NM
      XO=SARBN(I)
      CALL IUNI (151,N,SARB,3,SARA,2,XO,YO,IW,IERR)
```

SUBROUTINE INTIAL

```
      IF (IERR.EQ.0) GO TO 6
      WRITE (6,33) IERR
      STOP
6     SARAO(I,1)=YO(1)
      SARAO(I,2)=YO(2)
      SARAO(I,3)=YO(3)
7     CONTINUE
      NK1=NK+1
      DO 8 I=1,NM
      M=NK1+I-1
      XA(M)=SARBN(I)
      YA(M)=SARAO(I,1)
8     CP2(M)=SARAO(I,2)
      DO 9 I=1,NM
      M=MK1+I-1
9     BLP(M)=SARAO(I,3)
      NI=NM+NK
      NZT=NI-3
      PI=4.*ATAN(1.)
      CD=COS(PI*SWLE/180.)
      DO 10 I=1,NI
      XA(I)=XA(I)-XLE
      YA(I)=(YA(I)-YLE)*CD
10    CP3(I)=CP2(I)*CD*CD
      DO 11 I=1,NI
      A(I)=XA(I)
11    Y(I)=YA(I)
      DO 12 I=1,NZT
      XC(I)=XA(I+3)
12    P4(I)=CP3(I+3)
      SQRCR=SQRT(RCR)
      SQRCU=SQRT(RCU)
      DO 13 I=1,NZT
13    BLP(I)=BLP(I)*SQRCR/SQRCU
      TPRES=TPRES*RCU/RCR
C
      WRITE (6,39) TITLE
      WRITE (6,41) (I,A(I),Y(I),I=1,NI)
C
      XINPUT=X
      CMSQ=CMACH**2
      ROFS=TPRES/(1716.*TT)
      UFS=CMACH*SQRT(1.4*1716.*TT)
      IF (CMACH.EQ.0.0) UFS=UREF
      CMUFS=2.27E-08*TT**1.5/(TT+198.6)
```

```
      TTT=TT*(1.0+0.2*CMSQ)
      HE=TTT*6006.0
      REY=UFS*ROFS*XINPUT/CMUFS
      A1=1.+VGP
      A2=A1+VGP**2
      A3=A2+VGP**3
C
      DEL=ACOS(1.0-A(1))
      ETA(1)=DEL
      IF (A(1).GT.A(2)) ETA(1)=-DEL
      DO 16 I=2,NI
      PHANG=ACOS(1.0-A(I))
      IF (A(I).LT.A(I-1)) GO TO 14
      ETA(I)=PHANG
      GO TO 15
14    ETA(I)=-PHANG
15    IF (A(I).EQ.0.0) ETA(I)=0.0
16    CONTINUE
      CALL SPLINE (Y,ETA,NI,DELV)
      TLE=TAN(0.0174533*SWLE)
      TTE=TAN(0.0174533*SWTE)
      CB=TLE-TTE
      X=X*SQRT(1.0+TLE**2)/CB
      DO 17 I=1,NI
      SF=SIN(ETA(I))
      TCS=TLE-CB*A(I)
      FF=1.0+(CB*Y(I))**2+TCS*TCS
      DF=2.0*CB*(-TCS*SF+CB*Y(I)*DELV(I))
      XF=(CB*SF+TCS*DF/FF/2.0)**2
      YF=0.25*(DF/FF)**2
      ZF=(CB*(DELV(I)-Y(I)*DF/FF/2.0))**2
      DETA(I)=SQRT((XF+YF+ZF)/FF)
17    CONTINUE
      CALL INTEG (ETA,DETA,C,NI)
C
      DO 23 I=1,NZT
      IF (CMACH.EQ.0.0) GO TO 18
      DPR(I)=1.0+0.7*P4(I)*CMSQ
      PE(I)=1.0+(1.0-DPR(I)**0.285714)/(0.2*CMSQ)
      GO TO 19
18    PE(I)=1.0-P4(I)
      DPR(I)=1.0+UREF*UREF*P4(I)/TT/3432.0
19    IF (I.GT.1) GO TO 20
      DEL=ACOS(1.0-XC(I))
      P3(1)=DEL
```

```
      IF (XC(1).GT.XC(2)) P3(1)=-DEL
      GO TO 23
20    PHANG=ACOS(1.0-XC(I))
      IF (XC(I).LT.XC(I-1)) GO TO 21
      P3(I)=PHANG
      GO TO 22
21    P3(I)=-PHANG
22    IF (XC(I).EQ.0.0) P3(I)=0.0
23    CONTINUE
      CALL CUBIC (C,ETA,NI,P3,NZT,Z)
      DUE(1)=SQRT(PE(1))
      DWE(1)=0.0
      NUM=1
      DZ1=Z(1)
      Z(1)=0.0
      CR=CB*CB/(1.0+TLE**2)
      CC=2.0*TLE/CB
      RR(1)=0.0
      DO 24 I=2,NZT
      Z(I)=Z(I)-DZ1
      DZ=Z(I)-Z(I-1)
      RR(I)=RR(I-1)+DZ*X
      G1=-DWE(I-1)*DZ
      P1(1)=Z(I-1)+0.5*DZ
      CALL CUBIC (PE,Z,NZT,P1,NUM,UE)
      G2TRM=-(DUE(I-1)+G1/2.0)**2+UE(1)
      IF (G2TRM.LT.0.0) G2TRM=0.0
      G2=-SQRT(G2TRM)*DZ
      G3TRM=-(DUE(I-1)+G2/2.0)**2+UE(1)
      IF (G3TRM.LT.0.0) G3TRM=0.0
      G3=-SQRT(G3TRM)*DZ
      G4TRM=PE(I)-(DUE(I-1)+G3)**2
      IF (G4TRM.LT.0.0) G4TRM=0.0
      G4=-SQRT(G4TRM)*DZ
      DUE(I)=DUE(I-1)+(G1+2.0*G2+2.0*G3+G4)/6.0
      ALA=PE(I)-DUE(I)**2
      IF (ALA.LT.0.0) ALA=0.0
      DWE(I)=SQRT(ALA)
24    CONTINUE
      CALL SPLINE (DWE,Z,NZT,DDW)
      DDW(1)=-2.0*(DUE(2)-DUE(1))/Z(2)/Z(2)
C
      DO 25 I=1,NZT
      DUM1(I)=DUE(I)*UFS
      DUM2(I)=DWE(I)*UFS
```

```
25    CONTINUE
      WRITE (6,40) CMACH,UFS,TPRES,TT,PR,ROFS,CMUFS,REY,XINPUT,X,SWLE,SW
     1TE,NI,NZT,ETAE,DETA1,VGP
      WRITE (6,42) (I,XC(I),Z(I),RR(I),P4(I),BLP(I),DUE(I),DWE(I),DDW(I)
     1,DPR(I),I=1,NZT)
      UFS2=UFS**2
      DO 28 J=1,NZT
      UE(J)=UFS*DUE(J)
      WE(J)=UFS*DWE(J)
      BETA1(J)=DWE(J)/DUE(J)
      PE(J)=DPR(J)*TPRES
      IF (CMACH.EQ.0.0) GO TO 26
      TE=TT*(1.0-0.2*CMSQ*(DUE(J)**2+DWE(J)**2-1.0))
      S=(-DWE(J)*(DDW(J)-DUE(J))*(UFS2/(1716.*TE))*(1.0+(198.6-TE)/(7.0*
     1(198.6+TE))))
      RHOE(J)=PE(J)/(1716.*TE)
      GO TO 27
26    TE=TT
      S=0.0
      RHOE(J)=ROFS
27    CMUE(J)=2.27E-08*(TE**1.5/(TE+198.6))
      P1(J)=DDW(J)/DUE(J)
      P4(J)=BETA1(J)**2
      P3(J)=0.5*(2.0*DDW(J)/DUE(J)+P4(J)+S*BETA1(J))
      BLP(J)=SQRT(UE(J)*RHOE(J)*X/CMUE(J))*BLP(J)*UFS*ROFS/RHOE(J)/UE(J)
      IF (J.EQ.1) GO TO 28
      BETA1B=0.5*(BETA1(J)+BETA1(J-1))
      CEL(J)=BETA1B/(Z(J)-Z(J-1))
28    CONTINUE
      CEL(1)=0.0
C
      DETA(1)=DETA1
      ETA(1)=0.0
      IF ((VGP-1.0).LE.0.001) GO TO 29
      NP=ALOG((ETAE/DETA(1))*(VGP-1.0)+1.0)/ALOG(VGP)+1.001
      GO TO 30
29    NP=ETAE/DETA(1)+1.001
30    IF (NP.LE.101) GO TO 31
      WRITE (6,38)
      NP=101
31    DO 32 J=2,101
      DETA(J)=DETA(J-1)*VGP
      ETA(J)=ETA(J-1)+DETA(J-1)
32    A(J)=0.5*DETA(J-1)
      LL=0
```

* T I D Y *

SUBROUTINE INTIAL

```
      CALL PROFIL (LL)
      RETURN
C
C
C
33    FORMAT (1H1,10X,11HIERR NE 0  ,5X,I5)
34    FORMAT (4F15.10)
35    FORMAT (8A10)
36    FORMAT (2I3,3F10.0)
37    FORMAT (8F10.0)
38    FORMAT (1H0,36HNP EXCEEDED DIMENSIONS -- SET TO 101)
39    FORMAT (1H1,8A10)
40    FORMAT (1H0,7HMACHN =,E14.6,3X,7HUFS   =,E14.6,3X,7HPFS   =,E14.6,
     13X,7HTFS   =,E14.6,3X,7HPR    =,E14.6/1H0,7HROFS  =,E14.6,3X,7HMUF
     2S  =,E14.6,3X,7HREC   =,E14.6/1H0,7HCHORD =,F14.6,3X,7HRADIUS=,E14
     3.6,3X,7HLESW  =,E14.6,3X,7HTESW  =,E14.6/1H0,7HNI    =,I3,14X,7HNZ
     4    =,I3,14X,7HETAE  =,E14.6,3X,7HDETA1 =,E14.6,3X,7HVGP   =,E14.6
     5/)
41    FORMAT (//1H0,4X,30HSTREAMWISE AIRFOIL COORDINATES/1H0,3H NI,8X,3H
     1X/C,16X,3HZ/C/(1H ,I3,3X,E14.6,5X,E14.6))
42    FORMAT (1H0,58X,12HSTATION DATA/1H0,1X,2HNZ,5X,3HX/C,10X,5HTHETA,1
     11X,1HS,13X,2HCP,11X,3HCQL,10X,5HUEUFS,9X,5HWEUFS,9X,6HDWEUFS,8X,5H
     2PEPFS/(1H ,I3,9E14.6))
43    FORMAT (4I1,I3,2X,2F15.1)
      END
```

* T I D Y *

SUBROUTINE PROFIL (L)

```
      SUBROUTINE PROFIL (L)
      COMMON /BLCO/ NZT,NZ,NP,IT,X,ROFS,CMACH,TT,ETA(151),DETA(151),A(15
     11),Y(151),IPANPA
      COMMON /BLC1/ HE,PR,CMUFS,UFS,CEL(151),BETA1(151),UE(151),WE(151),
     1Z(151),PE(151),PHI(151),RHOE(151),XC(151),CMUE(151),P1(151),P3(151
     2),P4(151),RR(151),BLP(151),DDW(151)
      COMMON /PROF/ DELV(151),F(101,2),U(101,2),V(101,2),G(101,2),W(101,
     12),T(101,2),B(101,2),C(151),BG(101,2),F(101,2),DENR(101,2),CA1(101
     2,2),CA2(101,2)
      IF (L.EQ.1) GO TO 2
C
      E(1,2)=0.0
      BG(1,2)=1.0
      BG1=4.0*(BG(1,2)-1.0)
      BG2=4.0*(1.0-BG(1,2))
      DO 1 J=1,NP
      ETAB=ETA(J)/ETA(NP)
      F(J,2)=0.5*ETAB*ETA(J)
      U(J,2)=ETAB
      V(J,2)=1.0/ETA(NP)
      G(J,2)=F(J,2)
      W(J,2)=U(J,2)
      T(J,2)=V(J,2)
      DENR(J,2)=1.0
      B(J,2)=1.0
      C(J)=1.0
      BG(J,2)=1.0
1     CONTINUE
      RETURN
C
2     NP1=NP+1
      NP11=NP1-1
      NP=NP+3
      IF (NP.GT.101) NP=101
      KK=1
      IF (NZ.EQ.1) KK=2
      DO 4 K=KK,2
      DO 3 J=NP1,NP
      DENR(J,K)=DENR(NP11,K)
      C(J)=1.0
      F(J,K)=ETA(J)+F(NP11,K)-ETA(NP11)
      U(J,K)=1.0
      V(J,K)=V(NP11,K)
      G(J,K)=ETA(J)+G(NP11,K)-ETA(NP11)
      W(J,K)=1.0
```

```
      T(J,K)=T(NP11,K)
      B(J,K)=B(NP11,K)
      IF (CMACH.EQ.0.0) GO TO 3
      BG(J,K)=1.0
      E(J,K)=E(NP11,K)
      CA1(J,K)=CA1(NP11,K)
      CA2(J,K)=CA2(NP11,K)
3     CONTINUE
4     CONTINUE
      RETURN
      END
```

* T I D Y *

SUBROUTINE CUBIC (YL,XL,IN,FI,NR,PR)

```
      SUBROUTINE CUBIC (YL,XL,IN,FI,NR,PR)
      DIMENSION YL(1), XL(1), FI(1), PR(1)
      COMMON /BLCO/ NZT,NZ,NP,IT,X,POFS,CMACH,TT,ETA(151),DETA(151),AS(1
     151),Y1(151),IPANPA
      DO 8 I=1,NR
      DO 2 J=1,IN
      IF ((FI(I)-XL(J)).LE.0.0) GO TO 1
      GO TO 2
1     K2=J
      GO TO 3
2     CONTINUE
      K2=IN
3     IF (I.EQ.1) K1=100
      IF (K2.EQ.K1) GO TO 7
      IF (K2.GT.2.AND.K2.LT.IN) GO TO 5
      IF (K2.EQ.IN) GO TO 4
      L=3
      GO TO 6
4     L=IN-1
      GO TO 6
5     L=K2
6     CONTINUE
      A=-(XL(L-1)-XL(L-2))*(XL(L)-XL(L-2))*(XL(L+1)-XL(L-2))
      B=(XL(L-1)-XL(L-2))*(XL(L)-XL(L-1))*(XL(L+1)-XL(L-1))
      C=-(XL(L)-XL(L-2))*(XL(L)-XL(L-1))*(XL(L+1)-XL(L))
      D=(XL(L+1)-XL(L-2))*(XL(L+1)-XL(L-1))*(XL(L+1)-XL(L))
7     A1=(FI(I)-XL(L))*(FI(I)-XL(L+1))
      A6=(FI(I)-XL(L-2))*(FI(I)-XL(L-1))
C     IF(IHNA.EQ.4)  WRITE(6,15) A,B,C,D,A1,A6
C15   FORMAT(1H ,8X,6(E11.4,2X))
      PR(I)=(FI(I)-XL(L-1))*A1*YL(L-2)/A+(FI(I)-XL(L-2))*A1*YL(L-1)/B+(F
     1I(I)-XL(L+1))*A6*YL(L)/C+(FI(I)-XL(L))*YL(L+1)*A6/D
      K1=K2
8     CONTINUE
      RETURN
      END
```

```
* T I D Y *
                            SUBROUTINE SPLINE (X,FI,IN,XP)

      SUBROUTINE SPLINE (X,FI,IN,XP)
      DIMENSION X(1), FI(1), XP(1), QJ(131), UJ(131)
      QJ(1)=-1.0
      UJ(1)=2.0*(X(2)-X(1))/(FI(2)-FI(1))
      DO 3 I=2,IN
      AJ=FI(I)-FI(I-1)
      IF (I.EQ.IN) GO TO 1
      BJ=FI(I+1)-FI(I)
      CJ=AJ/(AJ+BJ)
      DJ=3.0*(CJ*(X(I+1)-X(I))/BJ+(1.0-CJ)*(X(I)-X(I-1))/AJ)
      GO TO 2
1     DJ=2.0*(X(I)-X(I-1))/AJ
      CJ=0.0
2     PJ=(1.0-CJ)*QJ(I-1)+2.0
      IF (I.EQ.IN) PJ=PJ-1.0
      QJ(I)=-CJ/PJ
      UJ(I)=(DJ-(1.0-CJ)*UJ(I-1))/PJ
3     CONTINUE
      XP(IN)=UJ(IN)
      INM1=IN-1
      DO 4 I=1,INM1
      NR=IN-I
      XP(NR)=QJ(NR)*XP(NR+1)+UJ(NR)
4     CONTINUE
      RETURN
      END
```

```
* T I D Y *
                          SUBROUTINE INTEG (X,Y,TAB,NPT)

      SUBROUTINE INTEG (X,Y,TAB,NPT)
      DIMENSION X(1), Y(1), TAB(1)
      IF (NPT.LT.4) GO TO 6
      DO 5 I=1,NPT
      TAB(I)=0.0
      K=I-1
      IF (I-2) 5,3,1
1     IF (I.LT.NPT) GO TO 2
      K=K-1
2     K=K-1
3     A=X(I)
      B=X(I-1)
      L=K+1
      M=K+2
      N=K+3
      DO 4 J=1,4
      XL=X(L)
      XN=X(N)
      XM=X(M)
      XK=X(K)
      YK=Y(K)
      SUM=YK/((XK-XM)*(XK-XN)*(XK-XL))
      SUM1=((A**4)-(B**4))/4.0
      SUM2=(XL+XM+XN)*((A**3)-(B**3))/3.0
      SUM3=(XM*XN+XM*XL+XL*XN)*(A**2-B**2)/2.0
      SUM4=(XM*XN*XL)*(A-B)
      SUM=SUM*(SUM1-SUM2+SUM3-SUM4)
      TAB(I)=TAB(I)+SUM
      ITEMP=K
      K=N
      N=M
      M=L
4     L=ITEMP
      TAB(I)=TAB(I)+TAB(I-1)
5     CONTINUE
6     RETURN
      END
```

* T I D Y *

SUBROUTINE FLUID

```
      SUBROUTINE FLUID
      COMMON /BLCO/ NZT,NZ,NP,IT,X,ROFS,CMACH,TT,ETA(151),DETA(151),A(15
     11),Y(151),IPANPA
      COMMON /BLC1/ HE,PR,CMUFS,UFS,CEL(151),BETA1(151),UE(151),WE(151),
     1Z(151),PE(151),PHI(151),RHOE(151),XC(151),CMUE(151),P1(151),P3(151
     2),P4(151),RR(151),BLP(151),DDW(151)
      COMMON /PROF/ DELV(151),F(101,2),U(101,2),V(101,2),G(101,2),W(101,
     12),T(101,2),B(101,2),C(151),BG(101,2),E(101,2),DENR(101,2),CA1(101
     2,2),CA2(101,2)
      COMMON /BOX/ VIS(101),DMUDT(101)
      COMMON /BAB/ H
      WW=0.0
      IF (IT.GT.1) GO TO 1
      PE35=3.5*PE(NZ)
      UE2H=0.5*UE(NZ)**2
C
1     DO 2 J=1,NP
      IF (NZ.GT.1) WW=W(J,2)
      H=HE*BG(J,2)-UE2H*(U(J,2)**2+P4(NZ)*WW**2)
      IF (H.LT.0.0) RETURN
      TTT=H/6006.0
      CMU=2.27E-08*TTT**1.5/(TTT+198.6)
      VIS(J)=CMU
      SP=1.5/TTT-1./(TTT+198.6)
      DMUDT(J)=CMU*SP
      DENR(J,2)=RHOE(NZ)*H/PE35
      C(J)=CMU/(CMUE(NZ)*DENR(J,2))
2     CONTINUE
C
      UE2HE=UE(NZ)**2/HE
      RPR=1.0-1.0/PR
      DO 3 J=1,NP
      CA1(J,2)=C(J)/PR
      CA2(J,2)=(C(J)*UE2HE)*RPR*(U(J,2)*V(J,2)+P4(NZ)*W(J,2)*T(J,2))
      B(J,2)=C(J)
3     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE COEF
      COMMON /BLCO/ NZT,NZ,NP,IT,X,ROFS,CMACH,TT,ETA(151),DETA(151),A(15
     11),Y(151),IPANPA
      COMMON /BLC1/ HE,PR,CMUFS,UFS,CEL(151),BETA1(151),UE(151),WE(151),
     1Z(151),PE(151),PHI(151),RHOE(151),XC(151),CMUE(151),P1(151),P3(151
     2),P4(151),RR(151),BLP(151),DDW(151)
      COMMON /PROF/ DELV(151),F(101,2),U(101,2),V(101,2),G(101,2),W(101,
     12),T(101,2),B(101,2),C(151),BG(101,2),E(101,2),DENR(101,2),CA1(101
     2,2),CA2(101,2)
      COMMON /BLC8/ B1(101),B2(101),B3(101),B4(101),B5(101),B6(101),B7(1
     101),B8(101),B9(101),B10(101),R1(101),R2(101),R3(101),R4(101),R5(10
     21),R6(101),S1(101),S2(101),S3(101),S4(101),S5(101),S6(101),S7(101)
     3,S8(101),S9(101),S10(101)
      P1P=P1(NZ)+CEL(NZ)
      P3P=P3(NZ)+CEL(NZ)
      P4P=P4(NZ)-CEL(NZ)
      P1T2=2.0*P1(NZ)
      P4T2=2.0*P4(NZ)
      P1P2=2.0*P1P
      DO 4 J=2,NP
      UB=0.5*(U(J,2)+U(J-1,2))
      VB=0.5*(V(J,2)+V(J-1,2))
      GB=0.5*(G(J,2)+G(J-1,2))
      WB=0.5*(W(J,2)+W(J-1,2))
      TB=0.5*(T(J,2)+T(J-1,2))
      DENRB=0.5*(DENR(J,2)+DENR(J-1,2))
      FVB=0.5*(F(J,2)*V(J,2)+F(J-1,2)*V(J-1,2))
      FTB=0.5*(F(J,2)*T(J,2)+F(J-1,2)*T(J-1,2))
      UWB=0.5*(U(J,2)*W(J,2)+U(J-1,2)*W(J-1,2))
      GVB=0.5*(G(J,2)*V(J,2)+G(J-1,2)*V(J-1,2))
      GTB=0.5*(G(J,2)*T(J,2)+G(J-1,2)*T(J-1,2))
      WSB=0.5*(W(J,2)**2+W(J-1,2)**2)
      IF (NZ.GT.1) GO TO 1
C
      CUB=0.0
      CVB=0.0
      CGB=0.0
      CWB=0.0
      CTB=0.0
      CFTB=0.0
      CUWB=0.0
      CGVB=0.0
      CGTB=0.0
      CWSB=0.0
      CDENRB=0.0
```

```
* T I D Y *
                                   SUBROUTINE COEF

C
C     - ATTACHMENT-LINE FLOW
C     DEFINITIONS OF COEFFICIENTS IN DIFFERENCED X-MOM EQ.
      S1(J)=B(J,2)+A(J)*(-1.5*F(J,2)+P1(NZ)*G(J,2)-BLP(NZ))
      S2(J)=-B(J-1,2)+A(J)*(-1.5*F(J-1,2)+P1(NZ)*G(J-1,2)-BLP(NZ))
      S3(J)=-1.5*A(J)*V(J,2)
      S4(J)=-1.5*A(J)*V(J-1,2)
      S5(J)=0.0
      S6(J)=0.0
      S7(J)=A(J)*P1(NZ)*V(J,2)
      S8(J)=A(J)*P1(NZ)*V(J-1,2)
      S9(J)=0.0
      S10(J)=0.0
C     DEFINITIONS OF COEFFICIENTS IN DIFFERENCED Z-MOM EQ.
      B1(J)=S1(J)
      B2(J)=S2(J)
      B3(J)=-1.5*A(J)*T(J,2)
      B4(J)=-1.5*A(J)*T(J-1,2)
      B5(J)=-A(J)*(-U(J,2)+P1T2*W(J,2))
      B6(J)=-A(J)*(-U(J-1,2)+P1T2*W(J-1,2))
      B7(J)=A(J)*W(J,2)
      B8(J)=A(J)*W(J-1,2)
      B9(J)=A(J)*P1(NZ)*T(J,2)
      B10(J)=A(J)*P1(NZ)*T(J-1,2)
      GO TO 2
C
C     GENERAL FLOW
1     CUB=0.5*(U(J,1)+U(J-1,1))
      CVB=0.5*(V(J,1)+V(J-1,1))
      CGB=0.5*(G(J,1)+G(J-1,1))
      CWB=0.5*(W(J,1)+W(J-1,1))
      CTB=0.5*(T(J,1)+T(J-1,1))
      CFTB=0.5*(F(J,1)*T(J,1)+F(J-1,1)*T(J-1,1))
      CFVB=0.5*(F(J,1)*V(J,1)+F(J-1,1)*V(J-1,1))
      CUWB=0.5*(U(J,1)*W(J,1)+U(J-1,1)*W(J-1,1))
      CGVB=0.5*(G(J,1)*V(J,1)+G(J-1,1)*V(J-1,1))
      CGTB=0.5*(G(J,1)*T(J,1)+G(J-1,1)*T(J-1,1))
      CWSB=0.5*(W(J,1)**2+W(J-1,1)**2)
      CDENRB=0.5*(DENR(J,1)+DENR(J-1,1))
C
C     DEFINITIONS OF COEFFICIENTS IN DIFFERENCED X-MOM EQ.
      S1(J)=B(J,2)+A(J)*(-1.5*F(J,2)+P3P*G(J,2)-CEL(NZ)*CGB-BLP(NZ))
      S2(J)=-B(J-1,2)+A(J)*(-1.5*F(J-1,2)+P3P*G(J-1,2)-CEL(NZ)*CGB-BLP(N
     1Z))
      S3(J)=-1.5*A(J)*V(J,2)
```

```
      S4(J)=-1.5*A(J)*V(J-1,2)
      S5(J)=A(J)*(P4P*W(J,2)-CEL(NZ)*CWB)
      S6(J)=A(J)*(P4P*W(J-1,2)-CEL(NZ)*CWB)
      S7(J)=A(J)*(P3P*V(J,2)+CEL(NZ)*CVB)
      S8(J)=A(J)*(P3P*V(J-1,2)+CEL(NZ)*CVB)
      S9(J)=A(J)*(P4P*U(J,2)-P4T2*W(J,2)+CEL(NZ)*CUB)
      S10(J)=A(J)*(P4P*U(J-1,2)-P4T2*W(J-1,2)+CEL(NZ)*CUB)
C
C     DEFINITIONS OF COEFFICIENTS IN DIFFEPENCED Z-MOM EQ.
      B1(J)=S1(J)
      B2(J)=S2(J)
      B3(J)=-1.5*A(J)*T(J,2)
      B4(J)=-1.5*A(J)*T(J-1,2)
      B5(J)=-A(J)*(P1P2*W(J,2)-U(J,2))
      B6(J)=-A(J)*(P1P2*W(J-1,2)-U(J-1,2))
      B7(J)=A(J)*W(J,2)
      B8(J)=A(J)*W(J-1,2)
      B9(J)=A(J)*(P3P*T(J,2)+CEL(NZ)*CTB)
      B10(J)=A(J)*(P3P*T(J-1,2)+CEL(NZ)*CTB)
C
C     DEFINITION OF RJ
2     R1(J)=F(J-1,2)-F(J,2)+DETA(J-1)*UB
      R2(J)=U(J-1,2)-U(J,2)+DETA(J-1)*VB
      R3(J)=G(J-1,2)-G(J,2)+DETA(J-1)*WB
      R4(J)=W(J-1,2)-W(J,2)+DETA(J-1)*TB
      IF (NZ.GT.1) GO TO 3
      R5(J)=-(B(J,2)*V(J,2)-B(J-1,2)*V(J-1,2)+DETA(J-1)*(-1.5*FVB+P1(NZ)
     1*GVB-BLP(NZ)*VB))
      R6(J)=-DETA(J-1)*DENRB*(-1.0+P1(NZ))-(B(J,2)*T(J,2)-B(J-1,2)*T(J-1
     1,2)+DETA(J-1)*(-1.5*FTB+P1(NZ)*GTB+UWB-P1(NZ)*WSB-BLP(NZ)*TB))
      GO TO 4
3     DERBV=(B(J,1)*V(J,1)-B(J-1,1)*V(J-1,1))/DETA(J-1)
      CL5B=DERBV-1.5*CFVB+P3(NZ-1)*CGVB+P4(NZ-1)*(CUWB-CWSB)-BLP(NZ-1)*C
     1VB
      CR5B=-CL5B+CEL(NZ)*(CGVB-CUWB)
      R5(J)=DETA(J-1)*CR5B-(B(J,2)*V(J,2)-B(J-1,2)*V(J-1,2)+DETA(J-1)*(-
     11.5*FVB+P3P*GVB+P4P*UWB-P4(NZ)*WSB-CEL(NZ)*(CWB*UB-CUB*WB-CVB*GB+C
     2GB*VB)-BLP(NZ)*VB))
      DERBT=(B(J,1)*T(J,1)-B(J-1,1)*T(J-1,1))/DETA(J-1)
      CL6B=DERBT-1.5*CFTB+P3(NZ-1)*CGTB+P1(NZ-1)*(CDENRB-CWSB)+CUWB-CDEN
     1RB-BLP(NZ-1)*CTB
      CR6B=-DENRB*(P1(NZ)-1.0)+CEL(NZ)*(CGTB-CWSB)-CL6B
      R6(J)=DETA(J-1)*CR6B-(B(J,2)*T(J,2)-B(J-1,2)*T(J-1,2)+DETA(J-1)*(-
     11.5*FTB+P3P*GTB-P1P*WSB+UWB-CEL(NZ)*(CGB*TB-CTB*GB)-BLP(NZ)*TB))
4     CONTINUE
```

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* T I D Y *
                    SUBROUTINE COEF

      RETURN                                          H 136
      END                                             H 137-
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SUBROUTINE SOLV6

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      SUBROUTINE SOLV6
      COMMON /BLC0/ NZT,NZ,NP,IT,X,ROFS,CMACH,TT,ETA(151),DETA(151),A(15
     11),Y(151),IPANPA
      COMMON /BLC1/ HE,PR,CMUFS,UFS,CEL(151),BETA1(151),UE(151),WE(151),
     1Z(151),PE(151),PHI(151),RHOE(151),XC(151),CMUE(151),P1(151),P3(151
     2),P4(151),RR(151),BLP(151),DDW(151)
      COMMON /PROF/ DELV(151),F(101,2),U(101,2),V(101,2),G(101,2),W(101,
     12),T(101,2),B(101,2),C(151),BG(101,2),E(101,2),DENR(101,2),CA1(101
     2,2),CA2(101,2)
      COMMON /BLC8/ B1(101),B2(101),B3(101),B4(101),B5(101),B6(101),B7(1
     101),B8(101),B9(101),B10(101),R1(101),R2(101),R3(101),R4(101),R5(10
     21),R6(101),S1(101),S2(101),S3(101),S4(101),S5(101),S6(101),S7(101)
     3,S8(101),S9(101),S10(101)
      DIMENSION A11(101), A21(101), A31(101), A41(101), A51(101), A61(10
     11), A12(101), A22(101), A32(101), A42(101), A52(101), A62(101), B1
     21(101), B21(101), B31(101), B41(101), B51(101), B61(101), B12(101)
     3, B22(101), B32(101), B42(101), B52(101), B62(101), DELF(101), DEL
     4U(101), DELT(101), DELG(101), DELW(101), W1(101), W2(101), W3(101)
     5, W4(101), W5(101), W6(101)
C     CALCULATION OF GAMMA (AI1,AI2 I=1,6) VECTOR FOR J=2
C     FIRST  AI1
      A11(2)=(S5(2)+S1(2)/A(2)+S3(2)*A(2))/(S2(2)-S1(2))
      A21(2)=(B7(2)+B3(2)*A(2))/(B2(2)-B1(2))
      A31(2)=-A(2)
      A41(2)=-A11(2)-1./A(2)
      A51(2)=0.0
      A61(2)=-A21(2)
C     THEN  AI2
      A12(2)=(S7(2)*A(2)+S9(2))/(S2(2)-S1(2))
      A22(2)=(B5(2)+A(2)*B9(2)+B1(2)/A(2))/(B2(2)-B1(2))
      A32(2)=0.0
      A42(2)=-A12(2)
      A52(2)=-A(2)
      A62(2)=-A22(2)-1./A(2)
C
C     CALCULATION OF WI(I=1,6) A1(VECTOR)*W(VECTOR)=R(VECTOR), AT J=2
      W1(2)=(R5(2)+(R2(2)*S1(2))/A(2)-S7(2)*R3(2)-S3(2)*R1(2))/(S2(2)-S1
     1(2))
      W3(2)=R1(2)
      W4(2)=-W1(2)-R2(2)/A(2)
      W5(2)=R3(2)
      W2(2)=(R6(2)-B1(2)*R4(2)/A(2)-B9(2)*R3(2)-B3(2)*R1(2))/(B2(2)-B1(2
     1))
      W6(2)=-W2(2)-R4(2)/A(2)
C
```

```
*TIDY*
                              SUBROUTINE SOLV6
C     CALCULATION OF ALFA COEFFICIENTS  BI1,BI2 WITH I=1,6
C     NOTE-THE SUBSCRIPT FOR THESE COEF. START FROM 11.
      DO 1 J=3,NP
      B11(J)=-A(J)+A31(J-1)
      B21(J)=-1.0+A(J)*A41(J-1)
      B31(J)=A51(J-1)
      B41(J)=A(J)*A61(J-1)
      B51(J)=S6(J)-S4(J)*A31(J-1)-S2(J)*A41(J-1)-S8(J)*A51(J-1)
      B61(J)=B8(J)-B4(J)*A31(J-1)-B10(J)*A51(J-1)-B2(J)*A61(J-1)
      B12(J)=A32(J-1)
      B22(J)=A42(J-1)*A(J)
      B32(J)=A52(J-1)-A(J)
      B42(J)=A62(J-1)*A(J)-1.0
      B52(J)=-(S4(J)*A32(J-1)+S2(J)*A42(J-1)+S8(J)*A52(J-1))+S10(J)
      B62(J)=B6(J)-B4(J)*A32(J-1)-B10(J)*A52(J-1)-B2(J)*A62(J-1)
C
C     CALCULATION OF AI1,AI2 WITH I=1,6
      CCA1=B51(J)-S3(J)*B11(J)+S1(J)*B21(J)/A(J)-S7(J)*B31(J)
      CB1=B52(J)+S1(J)*B22(J)/A(J)-S7(J)*B32(J)-S3(J)*B12(J)
      CCA2=B61(J)-B3(J)*B11(J)-B9(J)*B31(J)+B1(J)*B41(J)/A(J)
      CB2=B62(J)-B3(J)*B12(J)-B9(J)*B32(J)+B1(J)*B42(J)/A(J)
      CC1=S5(J)+S3(J)*A(J)+S1(J)/A(J)
      CC2=B7(J)+B3(J)*A(J)
      DEN=CCA1*CB2-CB1*CCA2
      A11(J)=(CC1*CB2-CB1*CC2)/DEN
      A21(J)=(CCA1*CC2-CC1*CCA2)/DEN
      A31(J)=-A(J)-B11(J)*A11(J)-B12(J)*A21(J)
      A41(J)=(-1.0+B21(J)*A11(J)+B22(J)*A21(J))/A(J)
      A51(J)=-B31(J)*A11(J)-B32(J)*A21(J)
      A61(J)=(B41(J)*A11(J)+B42(J)*A21(J))/A(J)
      CC1=S7(J)*A(J)+S9(J)
      CC2=B5(J)+B9(J)*A(J)+B1(J)/A(J)
      A12(J)=(CC1*CB2-CB1*CC2)/DEN
      A22(J)=(CCA1*CC2-CC1*CCA2)/DEN
      A32(J)=-B11(J)*A12(J)-B12(J)*A22(J)
      A42(J)=(B21(J)*A12(J)+B22(J)*A22(J))/A(J)
      A52(J)=-A(J)-B31(J)*A12(J)-B32(J)*A22(J)
      A62(J)=(-1.0+B41(J)*A12(J)+B42(J)*A22(J))/A(J)
      D1=R1(J)+W3(J-1)
      D2=R2(J)+A(J)*W4(J-1)
      D3=R3(J)+W5(J-1)
      D4=R4(J)+A(J)*W6(J-1)
      D5=R5(J)-(S4(J)*W3(J-1)+S2(J)*W4(J-1)+S8(J)*W5(J-1))
      D6=R6(J)-(B4(J)*W3(J-1)+B10(J)*W5(J-1)+B2(J)*W6(J-1))
      CC1=D5-D1*S3(J)+(S1(J)*D2)/A(J)-S7(J)*D3
```

```
      CC2=D6-D1*B3(J)+(B1(J)*D4)/A(J)-B9(J)*D3
      W1(J)=(CC1*CB2-CB1*CC2)/DEN
      W2(J)=(CCA1*CC2-CC1*CCA2)/DEN
      W3(J)=D1-B11(J)*W1(J)-B12(J)*W2(J)
      W4(J)=(-D2+B21(J)*W1(J)+B22(J)*W2(J))/A(J)
      W5(J)=D3-B31(J)*W1(J)-B32(J)*W2(J)
      W6(J)=(-D4+B41(J)*W1(J)+B42(J)*W2(J))/A(J)
1     CONTINUE
C
C     CALCULATION OF PERTURBATION QUANTITIES
      DELU(NP)=0.0
      DELW(NP)=0.0
      DELF(NP)=W3(NP)
      DELV(NP)=W4(NP)
      DELG(NP)=W5(NP)
      DELT(NP)=W6(NP)
      DELU(NP-1)=W1(NP)
      DELW(NP-1)=W2(NP)
      J=NP
2     J=J-1
      DELU(J-1)=W1(J)-A11(J)*DELU(J)-A12(J)*DELW(J)
      DELW(J-1)=W2(J)-A21(J)*DELU(J)-A22(J)*DELW(J)
      DELF(J)=W3(J)-A31(J)*DELU(J)-A32(J)*DELW(J)
      DELV(J)=W4(J)-A41(J)*DELU(J)-A42(J)*DELW(J)
      DELG(J)=W5(J)-A51(J)*DELU(J)-A52(J)*DELW(J)
      DELT(J)=W6(J)-A61(J)*DELU(J)-A62(J)*DELW(J)
      IF (J.GT.3) GO TO 2
      DELF(2)=W3(2)-A31(2)*DELU(2)-A32(2)*DELW(2)
      DELV(2)=W4(2)-A41(2)*DELU(2)-A42(2)*DELW(2)
      DELG(2)=W5(2)-A52(2)*DELW(2)-A51(2)*DELU(2)
      DELT(2)=W6(2)-A61(2)*DELU(2)-A62(2)*DELW(2)
      DELV(1)=W1(2)-A11(2)*DELU(2)-A12(2)*DELW(2)
      DELT(1)=W2(2)-A21(2)*DELU(2)-A22(2)*DELW(2)
      DELF(1)=0.0
      DELG(1)=0.0
      DELU(1)=0.0
      DELW(1)=0.0
C     IF(IT.EQ.1)  WRITE(6,4)
C     WRITE(6,5) IT,V(1,2),DELV(1),T(1,2),DELT(1)
      DO 3 J=1,NP
      F(J,2)=F(J,2)+DELF(J)
      U(J,2)=U(J,2)+DELU(J)
      V(J,2)=V(J,2)+DELV(J)
      G(J,2)=G(J,2)+DELG(J)
      W(J,2)=W(J,2)+DELW(J)
```

```
* T I D Y *
                              SUBROUTINE SOLV6

      T(J,2)=T(J,2)+DELT(J)
3     CONTINUE
      RETURN
C
C
      END
```

* T I D Y *

SUBROUTINE SOLV2

```
      SUBROUTINE SOLV2
      COMMON /BLC0/ NZT,NZ,NP,IT,X,ROFS,CMACH,TT,ETA(151),DETA(151),A(15
     11),Y(151),IPANPA
      COMMON /BLC1/ HE,PR,CMUFS,UFS,CEL(151),BETA1(151),UE(151),WE(151),
     1Z(151),PE(151),PHI(151),RHOE(151),XC(151),CMUE(151),P1(151),P3(151
     2),P4(151),RR(151),BLP(151),DDW(151)
      COMMON /PROF/ DELV(151),F(101,2),U(101,2),V(101,2),G(101,2),W(101,
     12),T(101,2),B(101,2),C(151),BG(101,2),E(101,2),DENR(101,2),CA1(101
     2,2),CA2(101,2)
      DIMENSION S1(101), S2(101), S3(101), R1(101), R2(101), Y1(101), Y2
     1(101), B11(101), B12(101), A11(101), A12(101)
      BG(NP,2)=1.0
      ALFA0=0.0
      ALFA1=1.0
      GAMMA0=0.0
      BETA0=1.0
      BTA1=0.0
C
      DO 2 J=2,NP
      FB=0.5*(F(J,2)+F(J-1,2))
      GB=0.5*(G(J,2)+G(J-1,2))
      WB=0.5*(W(J,2)+W(J-1,2))
      IF (NZ.GT.1) GO TO 1
C
      CFB=0.0
      CGB=0.0
      CWB=0.0
      CEB=0.0
C     - ATTACHMENT-LINE FLOW
      S1(J)=CA1(J,2)+A(J)*(-1.5*FB+P1(NZ)*GB-BLP(NZ))
      S2(J)=-CA1(J-1,2)-CA1(J,2)+S1(J)
      S3(J)=0.0
      R1(J)=CA2(J-1,2)-CA2(J,2)
      R2(J)=0.0
      GO TO 2
C
1     CFB=0.5*(F(J,1)+F(J-1,1))
      CGB=0.5*(G(J,1)+G(J-1,1))
      CWB=0.5*(W(J,1)+W(J-1,1))
      CEB=0.5*(E(J,1)+E(J-1,1))
      CBGB=0.5*(BG(J,1)+BG(J-1,1))
C
      S1(J)=CA1(J,2)+A(J)*(-1.5*FB+P3(NZ)*GB+CEL(NZ)*(GB-CGB)-BLP(NZ))
      S2(J)=-CA1(J-1,2)-CA1(J,2)+S1(J)
      S3(J)=-A(J)*CEL(NZ)*(WB+CWB)
```

```
* T I D Y *
                              SUBROUTINE SOLV2

C
      DERCA1=(CA1(J,1)*E(J,1)-CA1(J-1,1)*E(J-1,1))/DETA(J-1)
      DERCA2=((CA2(J,2)-CA2(J-1,2))/DETA(J-1))+((CA2(J,1)-CA2(J-1,1))/DE
     1TA(J-1))
      CLBE=DERCA1-1.5*CFB*CEB+P3(NZ-1)*CGB*CEB-BLP(NZ-1)*CEB
      R1(J)=DETA(J-1)*(-CLBE+CEL(NZ)*(-CBGB*(WB+CWB)-(GB-CGB)*CEB)-DERCA
     12)
      R2(J)=0.0
2     CONTINUE
      R2(NP)=1.0
C
      R1(1)=GAMMAO
      R2(1)=0.0
      B11(1)=ALFAO
      B12(1)=ALFA1
      Y1(1)=R1(1)
      Y2(1)=R2(1)
      DO 3 J=2,NP
      A11(J)=(S2(J)-A(J)*S3(J))/(B12(J-1)-A(J)*B11(J-1))
      A12(J)=B11(J-1)*A11(J)-S3(J)
C     CALCULATION OF ALFA COEFFICIENTS
      B11(J)=S3(J)-A12(J)
      B12(J)=S1(J)+A12(J)*A(J)
      Y1(J)=R1(J)-A11(J)*Y1(J-1)-A12(J)*Y2(J-1)
      Y2(J)=R2(J)
3     CONTINUE
      BG(NP,2)=R2(NP)
      E(NP,2)=(Y1(NP)*BETAO-B11(NP)*Y2(NP))/(B12(NP)*BETAO-B11(NP)*BTA1)
      J=NP
4     J=J-1
      PAR1=Y2(J)-BG(J+1,2)+A(J+1)*E(J+1,2)
      E(J,2)=(Y1(J)+B11(J)*PAR1)/(-A(J+1)*B11(J)+B12(J))
      BG(J,2)=-A(J+1)*E(J,2)-PAR1
      IF (J.GT.1) GO TO 4
      RETURN
      END
```

* T I D Y *

SUBROUTINE OUTPUT

```
      SUBROUTINE OUTPUT
      DIMENSION UP(101), UPP(101), WP(101), WPP(101), TP(101), TPP(101),
     1 CMUP(101), CMUPP(101), ALFAP(101)
      COMMON /BLC0/ NZT,NZ,NP,IT,X,ROFS,CMACH,TT,ETA(151),DETA(151),A(15
     11),Y(151),IPANPA
      COMMON /BLC1/ HE,PR,CMUFS,UFS,CEL(151),BETA1(151),UE(151),WE(151),
     1Z(151),PE(151),PHI(151),RHOE(151),XC(151),CMUE(151),P1(151),P3(151
     2),P4(151),RR(151),BLP(151),DDW(151)
      COMMON /PROF/ DELV(151),F(101,2),U(101,2),V(101,2),G(101,2),W(101,
     12),T(101,2),B(101,2),C(151),BG(101,2),E(101,2),DENR(101,2),CA1(101
     2,2),CA2(101,2)
      DIMENSION Y1(101), U1(101), W1(101), T1(101), CMU1(101), ALFA(101)
      DIMENSION A1(101), A2(101), A3(101), A4(101), A5(101), A6(101), A7
     1(101), A8(101), A9(101), A10(101), A11(101), A12(101), A13(101), A
     214(101), A15(101), A16(101), RAA(101)
      COMMON /PAR/ A111,A21,A31,VGP,NNN,IPRINT
      COMMON /BOX/ VIS(101),DMUDT(101)
      COMMON /WAW/ R,XO,CO,ZST,CHLENTH,THETA,WEEA,SO,NEDGE,TEEA,CMUEEA
C
      RX=RHOE(NZ)*UE(NZ)*X/CMUE(NZ)
      SQRX=SQRT(RX)
      PAR3=X/SQRX
      SUM=0.0
      F1=DENR(1,2)
      Y(1)=0.0
      DO 1 J=2,NP
      F2=DENR(J,2)
      SUM=SUM+(F1+F2)*A(J)
      F1=F2
      Y(J)=SUM*PAR3
1     CONTINUE
      DUM1=0.
      DUM2=0.
      DUM3=0.
      RES=0.
      DO 2 J=2,NP
      DUM1=1.-W(J-1,2)
      DUM2=1.-W(J,2)
      RES=RES+(DUM1+DUM2)/2.*(Y(J)-Y(J-1))
2     CONTINUE
      DSTZINC=RES
      RDSTZ=RHOE(NZ)*WE(NZ)*DSTZINC/CMUE(NZ)
      CID=SUM
      DELSTX=PAR3*(-F(NP,2)+CID)
      DELSTZ=PAR3*(-G(NP,2)+CID)
```

* T I D Y *

SUBROUTINE OUTPUT

```
      SUM=0.0
      SUM2=0.0
      F1=U(1,2)*U(1,2)
      F11=W(1,2)*W(1,2)
      DO 3 J=2,NP
      F2=U(J,2)*U(J,2)
      F22=W(J,2)*W(J,2)
      SUM=SUM+(F1+F2)*A(J)
      SUM2=SUM2+(F11+F22)*A(J)
      F1=F2
      F11=F22
3     CONTINUE
      THETAX=PAR3*(F(NP,2)-SUM)
      THETAZ=PAR3*(G(NP,2)-SUM2)
      CFX=2.0*C(1)*V(1,2)/SQRX
      HX=DELSTX/THETAX
      HZ=DELSTZ/THETAZ
      IF (CMACH.EQ.0.0) GO TO 4
      TE=PE(NZ)/RHOE(NZ)/1716.0
      TW=TE*DENR(1,2)
      RHOW=RHOE(NZ)/DENR(1,2)
      GO TO 5
4     TE=TT
      TW=TT
      RHOW=ROFS
5     VW=BLP(NZ)*SQRT(UE(NZ)*CMUE(NZ)*RHOE(NZ)/X)/RHOW
      IF (NZ.GT.1) GO TO 6
      CFZ=0.0
      SQUIG=BLP(1)/SQRT(P1(1))
      GO TO 7
6     CFZ=2.0*C(1)*T(1,2)*UE(NZ)/WE(NZ)/SQRX
      SQUIG=BLP(NZ)*SQRT(RR(NZ)*UE(NZ)/WE(NZ)/X)
7     IF (NZ.EQ.1) GO TO 14
      R=SQRT(RHOE(NZ)*WE(NZ)*RR(NZ)/CMUE(NZ))
      CHLENTH=SQRT(CMUE(NZ)*RR(NZ)/(RHOE(NZ)*WE(NZ)))
      DO 8 J=1,NP
      Y1(J)=Y(J)/CHLENTH
C     Y1(J)=Y(J)/DSTZINC
      U1(J)=W(J,2)
      W1(J)=U(J,2)*UE(NZ)/WE(NZ)
      T1(J)=DENR(J,2)
      CMU1(J)=VIS(J)/CMUE(NZ)
      ALFA(J)=DMUDT(J)*TE/CMUE(NZ)
8     CONTINUE
C
```

```
      DO 9 I=1,NP
      A16(I)=PR
9     CONTINUE
      IF (IPANPA.EQ.2) GO TO 12
      NPM1=NP-1
      DO 10 J=2,NPM1
      DY1=Y1(J)-Y1(J-1)
      DY2=Y1(J+1)-Y1(J)
      UP(J)=(DY1*U1(J+1)/DY2-DY2*U1(J-1)/DY1)/(DY1+DY2)-U1(J)*(DY1-DY2)/
     1(DY1*DY2)
      WP(J)=(DY1*W1(J+1)/DY2-DY2*W1(J-1)/DY1)/(DY1+DY2)-W1(J)*(DY1-DY2)/
     1(DY1*DY2)
      TP(J)=(DY1*T1(J+1)/DY2-DY2*T1(J-1)/DY1)/(DY1+DY2)-T1(J)*(DY1-DY2)/
     1(DY1*DY2)
      CMUP(J)=(DY1*CMU1(J+1)/DY2-DY2*CMU1(J-1)/DY1)/(DY1+DY2)-CMU1(J)*(D
     1Y1-DY2)/(DY1*DY2)
      ALFAP(J)=(DY1*ALFA(J+1)/DY2-DY2*ALFA(J-1)/DY1)/(DY1+DY2)-ALFA(J)*(
     1DY1-DY2)/(DY1*DY2)
C
      UPP(J)=(DY1*U1(J+1)+DY2*U1(J-1)-U1(J)*(DY1+DY2))/(.5*DY1*DY2*(DY1+
     1DY2))
      WPP(J)=(DY1*W1(J+1)+DY2*W1(J-1)-W1(J)*(DY1+DY2))/(.5*DY1*DY2*(DY1+
     1DY2))
      TPP(J)=(DY1*T1(J+1)+DY2*T1(J-1)-T1(J)*(DY1+DY2))/(.5*DY1*DY2*(DY1+
     1DY2))
      CMUPP(J)=(DY1*CMU1(J+1)+DY2*CMU1(J-1)-CMU1(J)*(DY1+DY2))/(.5*DY1*D
     1Y2*(DY1+DY2))
10    CONTINUE
C
      UP(NP)=(U1(NP)-U1(NP-1))/DY2
      WP(NP)=(W1(NP)-W1(NP-1))/DY2
      TP(NP)=(T1(NP)-T1(NP-1))/DY2
      CMUP(NP)=(CMU1(NP)-CMU1(NP-1))/DY2
      ALFAP(NP)=(ALFA(NP)-ALFA(NP-1))/DY2
C
      UPP(NP)=(U1(NP-1)-U1(NP))/DY2**2
      WPP(NP)=(W1(NP-1)-W1(NP))/DY2**2
      TPP(NP)=(T1(NP-1)-T1(NP))/DY2**2
      CMUPP(NP)=(CMU1(NP-1)-CMU1(NP))/DY2**2
C
      DY1=Y1(2)-Y1(1)
      DY2=Y1(3)-Y1(1)
      UP(1)=(DY2*U1(2)/DY1-DY1*U1(3)/DY2)/(DY2-DY1)-U1(1)*(DY1+DY2)/(DY1
     1*DY2)
      WP(1)=(DY2*W1(2)/DY1-DY1*W1(3)/DY2)/(DY2-DY1)-W1(1)*(DY1+DY2)/(DY1
```

```
     1*DY2)
      TP(1)=(DY2*T1(2)/DY1-DY1*T1(3)/DY2)/(DY2-DY1)-T1(1)*(DY1+DY2)/(DY1
     1*DY2)
      CMUP(1)=(DY2*CMU1(2)/DY1-DY1*CMU1(3)/DY2)/(DY2-DY1)-CMU1(1)*(DY1+D
     1Y2)/(DY1*DY2)
      ALFAP(1)=(DY2*ALFA(2)/DY1-DY1*ALFA(3)/DY2)/(DY2-DY1)-ALFA(1)*(DY1+
     1DY2)/(DY1*DY2)
C
      X1=Y1(2)
      X2=Y1(3)
      X3=Y1(4)
      X4=Y1(5)
      B2=X2*X3+X2*X4+X3*X4
      DL1=X1*(X1-X2)*(X1-X3)*(X1-X4)
      C2=X1*X3+X1*X4+X3*X4
      DL2=X2*(X2-X1)*(X2-X3)*(X2-X4)
      D2=X1*X2+X1*X4+X2*X4
      DL3=X3*(X3-X1)*(X3-X2)*(X3-X4)
      E2=X1*X2+X1*X3+X2*X3
      DL4=X4*(X4-X1)*(X4-X2)*(X4-X3)
      UPP(1)=2.*B2*U1(2)/DL1+2.*C2*U1(3)/DL2+2.*D2*U1(4)/DL3+2.*E2*U1(5)
     1/DL4
      WPP(1)=2.*B2*W1(2)/DL1+2.*C2*W1(3)/DL2+2.*D2*W1(4)/DL3+2.*E2*W1(5)
     1/DL4
      TPP(1)=2.*B2*T1(2)/DL1+2.*C2*T1(3)/DL2+2.*D2*T1(4)/DL3+2.*E2*T1(5)
     1/DL4
      CMUPP(1)=2.*B2*CMU1(2)/DL1+2.*C2*CMU1(3)/DL2+2.*D2*CMU1(4)/DL3+2.*
     1E2*CMU1(5)/DL4
C
      TPP(1)=TPP(2)
      CMUPP(1)=CMUPP(2)
C
      DO 11 J=1,NP
      I=NP-J+1
      A1(I)=Y1(J)
      A2(I)=U1(J)
      A3(I)=UP(J)
      A4(I)=UPP(J)
      A5(I)=W1(J)
      A6(I)=WP(J)
      A7(I)=WPP(J)
      A8(I)=T1(J)
      A9(I)=TP(J)
      A10(I)=TPP(J)
      A11(I)=CMU1(J)
```

```
      A12(I)=CMUP(J)
      A13(I)=CMUPP(J)
      A14(I)=ALFA(J)
      A15(I)=ALFAP(J)
   11 CONTINUE
      CALL CFA (A2,A4,A5,A7,EPSICF,NP)
C
C
      WRITE (10) NZ,XC(NZ),CMACH,R,CHLENTH,WE(NZ),A1(1),PR,A5(1),NP
      WRITE (10) (A1(I),I=1,NP)
      WRITE (10) (A2(I),I=1,NP)
      WRITE (10) (A3(I),I=1,NP)
      WRITE (10) (A4(I),I=1,NP)
      WRITE (10) (A5(I),I=1,NP)
      WRITE (10) (A6(I),I=1,NP)
      WRITE (10) (A7(I),I=1,NP)
      WRITE (10) (A8(I),I=1,NP)
      WRITE (10) (A9(I),I=1,NP)
      WRITE (10) (A10(I),I=1,NP)
      WRITE (10) (A11(I),I=1,NP)
      WRITE (10) (A12(I),I=1,NP)
      WRITE (10) (A13(I),I=1,NP)
      WRITE (10) (A14(I),I=1,NP)
      WRITE (10) (A15(I),I=1,NP)
      WRITE (10) (A16(I),I=1,NP)
C
      IF (IPRINT.EQ.2) GO TO 14
      WRITE (6,16) NZ,XC(NZ),NP,CHLENTH,R,EPSICF*57.29577
      WRITE (6,17)
      WRITE (6,19) (I,A1(I),A2(I),A3(I),A4(I),A5(I),A6(I),A7(I),A8(I),A9
     1(I),A10(I),I=1,NP,5)
      WRITE (6,19) NP,A1(NP),A2(NP),A3(NP),A4(NP),A5(NP),A6(NP),A7(NP),A
     18(NP),A9(NP),A10(NP)
      WRITE (6,18)
      WRITE (6,20) (I,A1(I),A11(I),A12(I),A13(I),A14(I),A15(I),A16(I),I=
     11,NP,5)
      WRITE (6,20) NP,A1(NP),A11(NP),A12(NP),A13(NP),A14(NP),A15(NP),A16
     1(NP)
      GO TO 14
   12 CONTINUE
      RA=SQRT(RHOE(NZ)*CMUE(NZ)/UE(NZ))
      DO 13 I=1,NP
   13 RAA(I)=RA*G(I,2)
      WRITE (9) NZ,XC(NZ),RR(NZ),Z(NZ),RHOE(NZ),CMUE(NZ),UE(NZ),WE(NZ),P
     1E(NZ),DDW(NZ),R,CHLENTH,RHOW,VW,TE,X,UFS,PR,CMACH,NP
```

SUBROUTINE OUTPUT

```
      WRITE (9) (Y1(I),I=1,NP)
      WRITE (9) (U1(I),I=1,NP)
      WRITE (9) (W1(I),I=1,NP)
      WRITE (9) (T1(I),I=1,NP)
      WRITE (9) (CMU1(I),I=1,NP)
      WRITE (9) (ALFA(I),I=1,NP)
      WRITE (9) (F(I,2),I=1,NP)
      WRITE (9) (U(I,2),I=1,NP)
      WRITE (9) (RAA(I),I=1,NP)
      WRITE (9) (DENR(I,2),I=1,NP)
C
14    CONTINUE
      DO 15 J=1,NP
      F(J,1)=F(J,2)
      U(J,1)=U(J,2)
      V(J,1)=V(J,2)
      G(J,1)=G(J,2)
      W(J,1)=W(J,2)
      T(J,1)=T(J,2)
      B(J,1)=B(J,2)
      DENR(J,1)=DENR(J,2)
      IF (CMACH.EQ.0.0) GO TO 15
      E(J,1)=E(J,2)
      BG(J,1)=BG(J,2)
      CA1(J,1)=CA1(J,2)
      CA2(J,1)=CA2(J,2)
15    CONTINUE
C
      NZ=NZ+1
      RETURN
C
C
C
16    FORMAT (///1X,3HNZ=,I5,3X,4HX/C=,E13.6,3X,3HNP=,I5,3X,8HCHLENTH=,E
     116.6,3X,2HR=,E16.6,3X,4HCFA=,E16.6)
17    FORMAT (1H ,5X,30H(Y,U,UP,UPP,W,WP,WPP,T,TP,TPP)/)
18    FORMAT (1H ,/,5X,31H(MU,MUP,MUPP,ALFA,ALFAP,PRANDL)/)
19    FORMAT (1H ,2X,I4,2X,F6.3,9E12.4)
20    FORMAT (1H ,2X,I4,2X,F6.3,6E12.4)
      END
```

* T I D Y *

SUBROUTINE XZDER

```
      SUBROUTINE XZDER
      REAL LST
      DIMENSION X(3), X1(3), S(3), LST(4), R(3), THETA(3), NSA(4), RHOE(
     13), CMUE(3), UE(3), WE(3), PE(3), DDW(3), RHOW(3), VW(3), TE(3), X
     2I(3), UFS(3), NZN(3)
      COMMON /BXT/ DGTH(101),DEN(101),YSTS(101),YS(101),F(101),U(101),G(
     1101),V(101),VP(101),VPP(101),N
      COMMON /BLCO/ NZT,NA,NB,IT,C,D,CMACH,TT,ETA(151),DETA(151),A(151),
     1YI(151),IPANPA
      DIMENSION A1(101), A2(101), A3(101), A4(101), A5(101), A6(101), A7
     1(101), A8(101), A9(101), A10(101), A11(101), A12(101), A13(101), A
     214(101), A15(101), A16(101), A17(101), A18(101), A19(101), A20(101
     3), A21(101), A22(101), A23(101), A24(101), A25(101), A26(101), A27
     4(101), A28(101), A29(101), A30(101), A31(101), A32(101), A33(101)
      DIMENSION DUX(101), DUPX(101), DUPPX(101), DWX(101), DWPX(101), DW
     1PPX(101), DTX(101), DTPX(101), DTPPX(101), DMUX(101), DMUPX(101),
     2DMUPPX(101), DALFX(101), DALFPX(101), PRANDL(101)
      DIMENSION UPO(3,101), UPPO(3,101), WPO(3,101), WPPO(3,101), TPO(3,
     1101), TPPO(3,101), CMUPO(3,101), CMUPPO(3,101), ALFAPO(3,101), YST
     2(4,101)
      DIMENSION Y(4,101), UO(4,101), WO(4,101), TO(4,101), CMUO(4,101),
     1ALFAO(4,101), FAO(4,101), GAO(4,101), UAO(4,101), DENRAO(4,101)
      COMMON /TAXI/ D1,DN,D3,D4,D5,D6,D7,D8,D9,D10,D11,D12
      COMMON /PAR/ AA1,AA2,AA3,VGP,NNN,IPRINT
C
      REWIND 9
      DO 1 I=1,3
      READ (9) NZN(I),X(I),S(I),THETA(I),RHOE(I),CMUE(I),UE(I),WE(I),PE(
     1I),DDW(I),R(I),LST(I),RHOW(I),VW(I),TE(I),XI(I),UFS(I),PR,CMACH,NS
     2A(I)
      NP=NSA(I)
      READ (9) (Y(I,J),J=1,NP)
      READ (9) (UO(I,J),J=1,NP)
      READ (9) (WO(I,J),J=1,NP)
      READ (9) (TO(I,J),J=1,NP)
      READ (9) (CMUO(I,J),J=1,NP)
      READ (9) (ALFAO(I,J),J=1,NP)
      READ (9) (FAO(I,J),J=1,NP)
      READ (9) (UAO(I,J),J=1,NP)
      READ (9) (GAO(I,J),J=1,NP)
      READ (9) (DENRAO(I,J),J=1,NP)
C     WRITE(6,31)(Y(I,J),FAO(I,J),UAO(I,J),GAO(I,J),J=1,NP)
C     WRITE(6,13)NZN(I),X(I),S(I),THETA(I),RHOE(I),CMUE(I),UE(I),
C    *WE(I),PE(I),DDW(I),R(I),LST(I),RHOW(I),VW(I),TE(I),XI(I),
C    *UFS(I),PR,CMACH,NSA(I)
```

SUBROUTINE XZDER

```
C       WRITE(6,12)(Y(I,J),UO(I,J),WO(I,J),TO(I,J),CMUO(I,J),ALFAO(I,J),
C      *FAO(I,J),UAO(I,J),GAO(I,J),DENRAO(I,J),J=1,NP)
1       CONTINUE
        K=4
2       CONTINUE
        NP=NSA(3)
        NSA(4)=NSA(3)
        LST(4)=LST(3)
        DO 3 J=1,NP
        Y(4,J)=Y(3,J)
        UO(4,J)=UO(3,J)
        WO(4,J)=WO(3,J)
        TO(4,J)=TO(3,J)
        CMUO(4,J)=CMUO(3,J)
        ALFAO(4,J)=ALFAO(3,J)
        FAO(4,J)=FAO(3,J)
        UAO(4,J)=UAO(3,J)
        GAO(4,J)=GAO(3,J)
3       DENRAO(4,J)=DENRAO(3,J)
        DO 4 I=1,4
        NP=NSA(I)
        DO 4 J=1,NP
4       YST(I,J)=Y(I,J)*LST(I)
        N=NSA(2)
        DO 5 I=1,3,2
        M=NSA(I)
        CALL PROFO (YST,UO,I,2,N,M)
        CALL PROFO (YST,WO,I,2,N,M)
        CALL PROFO (YST,TO,I,2,N,M)
        CALL PROFO (YST,CMUO,I,2,N,M)
        CALL PROFO (YST,ALFAO,I,2,N,M)
        CALL PROFO (YST,FAO,I,2,N,M)
        CALL PROFO (YST,UAO,I,2,N,M)
        CALL PROFO (YST,GAO,I,2,N,M)
        CALL PROFO (YST,DENRAO,I,2,N,M)
5       CONTINUE
C
        DO 6 I=1,N
        YSTS(I)=YST(2,I)
        YS(I)=Y(2,I)
        DEN(I)=DENRAO(2,I)
        F(I)=FAO(2,I)
        U(I)=UAO(2,I)
6       G(I)=GAO(2,I)
        DO 8 I=1,3
```

```
      NPM1=N-1
      DO 7 J=2,NPM1
      DY1=Y(2,J)-Y(2,J-1)
      DY2=Y(2,J+1)-Y(2,J)
      UPO(I,J)=(DY1*UO(I,J+1)/DY2-DY2*UO(I,J-1)/DY1)/(DY1+DY2)-UO(I,J)*(
     1DY1-DY2)/(DY1*DY2)
      WPO(I,J)=(DY1*WO(I,J+1)/DY2-DY2*WO(I,J-1)/DY1)/(DY1+DY2)-WO(I,J)*(
     1DY1-DY2)/(DY1*DY2)
      TPO(I,J)=(DY1*TO(I,J+1)/DY2-DY2*TO(I,J-1)/DY1)/(DY1+DY2)-TO(I,J)*(
     1DY1-DY2)/(DY1*DY2)
      CMUPO(I,J)=(DY1*CMUO(I,J+1)/DY2-DY2*CMUO(I,J-1)/DY1)/(DY1+DY2)-CMU
     1O(I,J)*(DY1-DY2)/(DY1*DY2)
      ALFAPO(I,J)=(DY1*ALFAO(I,J+1)/DY2-DY2*ALFAO(I,J-1)/DY1)/(DY1+DY2)-
     1ALFAO(I,J)*(DY1-DY2)/(DY1*DY2)
C
      UPPO(I,J)=(DY1*UO(I,J+1)+DY2*UO(I,J-1)-UO(I,J)*(DY1+DY2))/(.5*DY1*
     1DY2*(DY1+DY2))
      WPPO(I,J)=(DY1*WO(I,J+1)+DY2*WO(I,J-1)-WO(I,J)*(DY1+DY2))/(.5*DY1*
     1DY2*(DY1+DY2))
      TPPO(I,J)=(DY1*TO(I,J+1)+DY2*TO(I,J-1)-TO(I,J)*(DY1+DY2))/(.5*DY1*
     1DY2*(DY1+DY2))
      CMUPPO(I,J)=(DY1*CMUO(I,J+1)+DY2*CMUO(I,J-1)-CMUO(I,J)*(DY1+DY2))/
     1(.5*DY1*DY2*(DY1+DY2))
7     CONTINUE
C
      UPO(I,N)=(UO(I,N)-UO(I,N-1))/DY2
      WPO(I,N)=(WO(I,N)-WO(I,N-1))/DY2
      TPO(I,N)=(TO(I,N)-TO(I,N-1))/DY2
      CMUPO(I,N)=(CMUO(I,N)-CMUO(I,N-1))/DY2
      ALFAPO(I,N)=(ALFAO(I,N)-ALFAO(I,N-1))/DY2
C
      UPPO(I,N)=(UO(I,N-1)-UO(I,N))/DY2**2
      WPPO(I,N)=(WO(I,N-1)-WO(I,N))/DY2**2
      TPPO(I,N)=(TO(I,N-1)-TO(I,N))/DY2**2
      CMUPPO(I,N)=(CMUO(I,N-1)-CMUO(I,N))/DY2**2
C
      DY1=Y(2,2)-Y(2,1)
      DY2=Y(2,3)-Y(2,1)
      UPO(I,1)=(DY2*UO(I,2)/DY1-DY1*UO(I,3)/DY2)/(DY2-DY1)-UO(I,1)*(DY1+
     1DY2)/(DY1*DY2)
      WPO(I,1)=(DY2*WO(I,2)/DY1-DY1*WO(I,3)/DY2)/(DY2-DY1)-WO(I,1)*(DY1+
     1DY2)/(DY1*DY2)
      TPO(I,1)=(DY2*TO(I,2)/DY1-DY1*TO(I,3)/DY2)/(DY2-DY1)-TO(I,1)*(DY1+
     1DY2)/(DY1*DY2)
      CMUPO(I,1)=(DY2*CMUO(I,2)/DY1-DY1*CMUO(I,3)/DY2)/(DY2-DY1)-CMUO(I,
```

```
      11)*(DY1+DY2)/(DY1*DY2)
       ALFAPO(I,1)=(DY2*ALFAO(I,2)/DY1-DY1*ALFAO(I,3)/DY2)/(DY2-DY1)-ALFA
      1O(I,1)*(DY1+DY2)/(DY1*DY2)
C
       X11=Y(2,2)
       X2=Y(2,3)
       X3=Y(2,4)
       X4=Y(2,5)
       B2=X2*X3+X2*X4+X3*X4
       DL1=X11*(X11-X2)*(X11-X3)*(X11-X4)
       C2=X11*X3+X11*X4+X3*X4
       DL2=X2*(X2-X11)*(X2-X3)*(X2-X4)
       D2=X11*X2+X11*X4+X2*X4
       DL3=X3*(X3-X11)*(X3-X2)*(X3-X4)
       E2=X11*X2+X11*X3+X2*X3
       DL4=X4*(X4-X11)*(X4-X2)*(X4-X3)
       UPPO(I,1)=2.*B2*UO(I,2)/DL1+2.*C2*UO(I,3)/DL2+2.*D2*UO(I,4)/DL3+2.
      1*E2*UO(I,5)/DL4
       WPPO(I,1)=2.*B2*WO(I,2)/DL1+2.*C2*WO(I,3)/DL2+2.*D2*WO(I,4)/DL3+2.
      1*E2*WO(I,5)/DL4
       TPPO(I,1)=2.*B2*TO(I,2)/DL1+2.*C2*TO(I,3)/DL2+2.*D2*TO(I,4)/DL3+2.
      1*E2*TO(I,5)/DL4
       CMUPPO(I,1)=2.*B2*CMUO(I,2)/DL1+2.*C2*CMUO(I,3)/DL2+2.*D2*CMUO(I,4
      1)/DL3+2.*E2*CMUO(I,5)/DL4
C
       TPPO(I,1)=TPPO(I,2)
       CMUPPO(I,1)=CMUPPO(I,2)
C
8      CONTINUE
C      WRITE(6,130)(Y(1,I),UO(1,I),UO(2,I),UPO(1,I),
C     *UPO(2,I),I=1,N)
C
       DO 9 I=1,3
9      X1(I)=S(I)/(LST(2)*R(2))
       DX1=X1(2)-X1(1)
       DX2=X1(3)-X1(2)
       DTH1=THETA(2)-THETA(1)
       DTH2=THETA(3)-THETA(2)
       DELX=DX1/DX2
       DELTH=DTH1/DTH2
       DELX1=DX1+DX2
       DELTH1=DTH1+DTH2
       DELX2=(DX1-DX2)/(DX1*DX2)
       DELTH2=(DTH1-DTH2)/(DTH1*DTH2)
       DO 10 I=1,N
```

SUBROUTINE XZDER

```
      DUX(I)=((DELX*UO(3,I)-UO(1,I)/DELX)/DELX1-DELX2*UO(2,I))
      DUPX(I)=((DELX*UPO(3,I)-UPO(1,I)/DELX)/DELX1-DELX2*UPO(2,I))
      DUPPX(I)=((DELX*UPPO(3,I)-UPPO(1,I)/DELX)/DELX1-DELX2*UPPO(2,I))
      DWX(I)=((DELX*WO(3,I)-WO(1,I)/DELX)/DELX1-DELX2*WO(2,I))
      DWPX(I)=((DELX*WPO(3,I)-WPO(1,I)/DELX)/DELX1-DELX2*WPO(2,I))
      DWPPX(I)=((DELX*WPPO(3,I)-WPPO(1,I)/DELX)/DELX1-DELX2*WPPO(2,I))
      DTX(I)=((DELX*TO(3,I)-TO(1,I)/DELX)/DELX1-DELX2*TO(2,I))
      DTPX(I)=((DELX*TPO(3,I)-TPO(1,I)/DELX)/DELX1-DELX2*TPO(2,I))
      DTPPX(I)=((DELX*TPPO(3,I)-TPPO(1,I)/DELX)/DELX1-DELX2*TPPO(2,I))
      DMUX(I)=((DELX*CMUO(3,I)-CMUO(1,I)/DELX)/DELX1-DELX2*CMUO(2,I))
      DMUPX(I)=((DELX*CMUPO(3,I)-CMUPO(1,I)/DELX)/DELX1-DELX2*CMUPO(2,I)
     1)
      DMUPPX(I)=((DELX*CMUPPO(3,I)-CMUPPO(1,I)/DELX)/DELX1-DELX2*CMUPPO(
     12,I))
      DALFX(I)=((DELX*ALFAO(3,I)-ALFAO(1,I)/DELX)/DELX1-DELX2*ALFAO(2,I)
     1)
      DALFPX(I)=((DELX*ALFAPO(3,I)-ALFAPO(1,I)/DFLX)/DELX1-DELX2*ALFAPO(
     12,I))
10    CONTINUE
C
      DO 11 I=1,N
      DGTH(I)=(DELTH*GAO(3,I)-GAO(1,I)/DELTH)/DELTH1-DELTH2*GAO(2,I)
C     WRITE(6,31) F(I),U(I),G(I),DGTH(I)
11    CONTINUE
C
      D1=RHOW(2)
      DN=VW(2)
      D3=UE(2)
      D4=PE(2)
      D5=XI(2)
      D6=WE(2)
      D7=DDW(2)
      D8=TE(2)
      D9=CMUE(2)
      D10=RHOE(2)
      D11=UFS(2)
      D12=R(2)
      CALL VVEL
      DO 12 I=1,N
12    PRANDL(I)=PR
      DO 13 J=1,N
      I=N-J+1
      A1(I)=Y(2,J)
      A2(I)=UO(2,J)
      A3(I)=UPO(2,J)
```

```
      A4(I)=UPPO(2,J)
      A5(I)=WO(2,J)
      A6(I)=WPO(2,J)
      A7(I)=WPPO(2,J)
      A8(I)=TO(2,J)
      A9(I)=TPO(2,J)
      A10(I)=TPPO(2,J)
      A11(I)=CMUO(2,J)
      A12(I)=CMUPO(2,J)
      A13(I)=CMUPPO(2,J)
      A14(I)=ALFAO(2,J)
      A15(I)=ALFAPO(2,J)
      A16(I)=PRANDL(J)
      A17(I)=DUX(J)
      A18(I)=DUPX(J)
      A19(I)=DUPPX(J)
      A20(I)=DWX(J)
      A21(I)=DWPX(J)
      A22(I)=DWPPX(J)
      A23(I)=DTX(J)
      A24(I)=DTPX(J)
      A25(I)=DTPPX(J)
      A26(I)=DMUX(J)
      A27(I)=DMUPX(J)
      A28(I)=DMUPPX(J)
      A29(I)=DALFX(J)
      A30(I)=DALFPX(J)
      A31(I)=V(J)
      A32(I)=VP(J)
      A33(I)=VPP(J)
   13 CONTINUE
      CALL CFA (A2,A4,A5,A7,EPSICF,N)
      WRITE (10) NZN(2),X(2),CMACH,R(2),LST(2),UFS(2),Y(2,N),PR,WO(2,N),
     1N
      WRITE (10) (A1(I),I=1,N)
      WRITE (10) (A2(I),I=1,N)
      WRITE (10) (A3(I),I=1,N)
      WRITE (10) (A4(I),I=1,N)
      WRITE (10) (A5(I),I=1,N)
      WRITE (10) (A6(I),I=1,N)
      WRITE (10) (A7(I),I=1,N)
      WRITE (10) (A8(I),I=1,N)
      WRITE (10) (A9(I),I=1,N)
      WRITE (10) (A10(I),I=1,N)
      WRITE (10) (A11(I),I=1,N)
```

```
      WRITE (10) (A12(I),I=1,N)
      WRITE (10) (A13(I),I=1,N)
      WRITE (10) (A14(I),I=1,N)
      WRITE (10) (A15(I),I=1,N)
      WRITE (10) (A16(I),I=1,N)
C
      WRITE (11) NZN(2),X(2),N
      WRITE (11) (A17(I),I=1,N)
      WRITE (11) (A18(I),I=1,N)
      WRITE (11) (A19(I),I=1,N)
      WRITE (11) (A20(I),I=1,N)
      WRITE (11) (A21(I),I=1,N)
      WRITE (11) (A22(I),I=1,N)
      WRITE (11) (A23(I),I=1,N)
      WRITE (11) (A24(I),I=1,N)
      WRITE (11) (A25(I),I=1,N)
      WRITE (11) (A26(I),I=1,N)
      WRITE (11) (A27(I),I=1,N)
      WRITE (11) (A28(I),I=1,N)
      WRITE (11) (A29(I),I=1,N)
      WRITE (11) (A30(I),I=1,N)
      WRITE (11) (A31(I),I=1,N)
      WRITE (11) (A32(I),I=1,N)
      WRITE (11) (A33(I),I=1,N)
C
      IF (IPRINT.EQ.2) GO TO 14
      WRITE (6,20) NZN(2),X(2),N,LST(2),R(2),EPSICF
      WRITE (6,21)
      WRITE (6,25) (I,Y(2,I),UO(2,I),UPO(2,I),UPPO(2,I),WO(2,I),WPO(2,I)
     1,WPPO(2,I),TO(2,I),TPO(2,I),TPPO(2,I),I=1,N,5)
      WRITE (6,25) N,Y(2,N),UO(2,N),UPO(2,N),UPPO(2,N),WO(2,N),WPO(2,N),
     1WPPO(2,N),TO(2,N),TPO(2,N),TPPO(2,N)
      WRITE (6,22)
      WRITE (6,25) (I,Y(2,I),CMUO(2,I),CMUPO(2,I),CMUPPO(2,I),ALFAO(2,I)
     1,ALFAPO(2,I),PRANDL(I),DUX(I),DUPX(I),DUPPX(I),I=1,N,5)
      WRITE (6,25) N,Y(2,N),CMUO(2,N),CMUPO(2,N),CMUPPO(2,N),ALFAO(2,N),
     1ALFAPO(2,N),PRANDL(N),DUX(N),DUPX(N),DUPPX(N)
      WRITE (6,23)
      WRITE (6,25) (I,Y(2,I),DWX(I),DWPX(I),DWPPX(I),DTX(I),DTPX(I),DTPP
     1X(I),DMUX(I),DMUPX(I),DMUPPX(I),I=1,N,5)
      WRITE (6,25) N,Y(2,N),DWX(N),DWPX(N),DWPPX(N),DTX(N),DTPX(N),DTPPX
     1(N),DMUX(N),DMUPX(N),DMUPPX(N)
      WRITE (6,24)
      WRITE (6,26) (I,Y(2,I),DALFX(I),DALFPX(I),V(I),VP(I),VPP(I),I=1,N,
     15)
```

```
      WRITE (6,26) N,Y(2,N),DALFX(N),DALFPX(N),V(N),VP(N),VPP(N)
14    CONTINUE
C
      DO 15 I=1,2
      M=I+1
      NZN(I)=NZN(M)
      X(I)=X(M)
      S(I)=S(M)
      THETA(I)=THETA(M)
      RHOE(I)=RHOE(M)
      CMUE(I)=CMUE(M)
      UE(I)=UE(M)
      WE(I)=WE(M)
      PE(I)=PE(M)
      DDW(I)=DDW(M)
      R(I)=R(M)
      LST(I)=LST(M)
      RHOW(I)=RHOW(M)
      VW(I)=VW(M)
      TE(I)=TE(M)
      XI(I)=XI(M)
15    UFS(I)=UFS(M)
C
      DO 18 I=1,2
      IF (I.EQ.2) GO TO 16
      M=I+1
      GO TO 17
16    M=I+2
17    CONTINUE
      NSA(I)=NSA(M)
      NP=NSA(M)
      DO 18 J=1,NP
      Y(I,J)=Y(M,J)
      UO(I,J)=UO(M,J)
      WO(I,J)=WO(M,J)
      TO(I,J)=TO(M,J)
      CMUO(I,J)=CMUO(M,J)
      ALFAO(I,J)=ALFAO(M,J)
      FAO(I,J)=FAO(M,J)
      UAO(I,J)=UAO(M,J)
      GAO(I,J)=GAO(M,J)
18    DENRAO(I,J)=DENRAO(M,J)
C
      I=3
      K=K+1
```

```
      IF (K.GT.NZT) GO TO 19
      READ (9) NZN(I),X(I),S(I),THETA(I),RHOE(I),CMUE(I),UE(I),WE(I),PE(
     1I),DDW(I),R(I),LST(I),RHOW(I),VW(I),TE(I),XI(I),UFS(I),PR,CMACH,NS
     2A(I)
      NP=NSA(I)
      READ (9) (Y(I,J),J=1,NP)
      READ (9) (UO(I,J),J=1,NP)
      READ (9) (WO(I,J),J=1,NP)
      READ (9) (TO(I,J),J=1,NP)
      READ (9) (CMUO(I,J),J=1,NP)
      READ (9) (ALFAO(I,J),J=1,NP)
      READ (9) (FAO(I,J),J=1,NP)
      READ (9) (UAO(I,J),J=1,NP)
      READ (9) (GAO(I,J),J=1,NP)
      READ (9) (DENRAO(I,J),J=1,NP)
C     DO 11 I=1,3
C     NP=NSA(I)
C11   WRITE(6,31)(Y(I,J),FAO(I,J),UAO(I,J),GAO(I,J),J=1,NP)
C     WRITE(6,13)NZN(I),X(I),S(I),THETA(I),RHOE(I),CMUE(I),UE(I),
C    *WE(I),PE(I),DDW(I),R(I),LST(I),RHOW(I),VW(I),TE(I),XI(I),
C    *UFS(I),PR,CMACH,NSA(I)
C     WRITE(6,12)(Y(I,J),UO(I,J),WO(I,J),TO(I,J),CMUO(I,J),ALFAO(I,J),
C    *FAO(I,J),UAO(I,J),GAO(I,J),DENRAO(I,J),J=1,NP)
      GO TO 2
19    RETURN
C
C
20    FORMAT (///1X,3HNZ=,I5,3X,4HX/C=,E16.6,3X,3HNP=,I5,3X,8HCHLENTH=,E
     116.6,3X,2HR=,E16.6,3X,4HCFA=,E16.6)
21    FORMAT (1H ,5X,28HY,U,UP,UPP,W,WP,WPP,T,TP,TPP/)
22    FORMAT (1H ,5X,42HY,MU,MUP,MUPP,ALFA,ALFAP,PR,DUX,DUPX,DUPPX/)
23    FORMAT (1H ,5X,47HY,DWX,DWPX,DWPPX,DTX,DTPX,DTPPX,DMUX,DMPX,DMPPX/
     1)
24    FORMAT (1H ,5X,23HY,ALFAX,ALFAPX,V,VP,VPP/)
25    FORMAT (1H ,2X,I4,2X,F6.3,9E12.4)
26    FORMAT (1H ,2X,I4,2X,F6.3,5E12.4)
      END
```

```
* T I D Y *
                        SUBROUTINE PROFO (Y,U,I,K,N,M)

      SUBROUTINE PROFO (Y,U,I,K,N,M)
      REAL INTER
      DIMENSION Y(4,101), U(4,101), Y1(101), Y2(101), U2(101), U3(101)
      DO 1 J=1,M
      U2(J)=U(I,J)
      Y2(J)=Y(I,J)
1     CONTINUE
      DO 2 J=1,N
2     Y1(J)=Y(K,J)
      IF (Y2(M).GE.Y1(N)) GO TO 3
      L=M+1
      Y2(L)=Y1(N)
      U2(L)=U2(M)
      GO TO 4
3     CONTINUE
      L=M
4     CONTINUE
      DO 8 JJJ=1,N
      YARG=Y1(JJJ)
      DO 5 J=1,L
      JJ=J
      IF (YARG.LT.Y2(J)) GO TO 6
      IF (YARG.EQ.Y2(J)) GO TO 7
5     CONTINUE
6     MIN=JJ-3
      IF (JJ.LE.3) MIN=1
      IF (JJ.GE.(L-2)) MIN=L-6
      U3(JJJ)=INTER(Y2,U2,YARG,6,MIN)
      GO TO 8
7     U3(JJJ)=U2(JJ)
8     CONTINUE
      DO 9 J=1,N
      U(I,J)=U3(J)
9     CONTINUE
      RETURN
      END
```

* T I D Y *

REAL FUNCTIONINTER(X,Y,XARG,IDEG,MIN)

```
      REAL FUNCTIONINTER(X,Y,XARG,IDEG,MIN)
      DIMENSION X(101), Y(101)
1     FACTOR=1.
      MAX=MIN+IDEG
      DO 2 J=MIN,MAX
      IF (XARG.NE.X(J)) GO TO 2
      INTER=Y(J)
      RETURN
2     FACTOR=FACTOR*(XARG-X(J))
      YEST=0.
      DO 4 I=MIN,MAX
      TERM=Y(I)*FACTOR/(XARG-X(I))
      DO 3 J=MIN,MAX
3     IF (I.NE.J) TERM=TERM/(X(I)-X(J))
4     YEST=TERM+YEST
      INTER=YEST
      RETURN
      END
```

```
* T I D Y *
                      SUBROUTINE CFA (U1,U1PP,W1,W1PP,EPSICF,N)

      SUBROUTINE CFA (U1,U1PP,W1,W1PP,EPSICF,N)
      DIMENSION U(101), W(101), UPP(101), WPP(101), U1(101), W1(101), U1
     1PP(101), W1PP(101)
      DO 1 J=1,N
      I=N-J+1
      U(I)=U1(J)
      W(I)=W1(J)
      UPP(I)=U1PP(J)
      WPP(I)=W1PP(J)
1     CONTINUE
      B1=1.E+06
      DO 2 I=2,N
      IF (U(I).GT.0.999) GO TO 3
      A1=U(I)/W(I)
      A2=UPP(I)/WPP(I)
      B2=A1-A2
      IF ((B2.GE.0..AND.B1.LE.0.).OR.(B2.LE.0..AND.B1.GE.0.)) ISAVE=I
      B1=B2
2     CONTINUE
3     CONTINUE
      EPSICF=-ATAN(U(ISAVE)/W(ISAVE))+3.1415977
C     WRITE (6,4) EPSICF*57.29577
      RETURN
C
C
      END
```

* T I D Y *

SUBROUTINE VVEL

```
      SUBROUTINE VVEL
      DIMENSION ETA(101)
      COMMON /TAXI/ RHOW,VW,UE,PE,X,WE,DDW,TE,CMUE,RHOE,UFS,R
      COMMON /BXT/ DGTH(101),DEN(101),YST(101),Y(101),FA(101),UA(101),GA
     1(101),V(101),VP(101),VPP(101),N
C
C     WRITE(6,30) RHOW,VW,UE,PE,X,WE,DDW,TE,CMUE,RHOE,UFS
C30   FORMAT(1H ,5X,11(E10.4,1X))
C
      SQRX=SQRT(RHOE*UE*X/CMUE)
      PAR3=SQRX/X
      SUM=0.
      F1=1/DEN(1)
      ETA(1)=0.
      DO 1 J=2,N
      F2=1/DEN(J)
      SUM=SUM+(F1+F2)*(YST(J)-YST(J-1))/2.
      F1=F2
      ETA(J)=SUM*PAR3
1     CONTINUE
      CON=RHOW*VW/WE
      DO 2 I=1,N
      RHO=PE/(1716.*TE*DEN(I))
      DPSIX=(CMUE*SQRX/2.)*(3.*FA(I)-ETA(I)*UA(I))
      DPHITH=SQRT(X**3)*(WE*DGTH(I)+GA(I)*DDW*UFS)
      V(I)=CON/RHO+(1./(RHO*X*WE))*(DPSIX-DPHITH/X)
      V(I)=V(I)*R
C     WRITE(6,31)Y(I),FA(I),UA(I),GA(I),DGTH(I),DPSIX,DPHITH,
C    *V(I),X
2     CONTINUE
C
      N1=N-1
      DO 3 I=2,N1
      DY1=Y(I)-Y(I-1)
      DY2=Y(I+1)-Y(I)
      VP(I)=(DY1*V(I+1)/DY2-DY2*V(I-1)/DY1)/(DY1+DY2)-V(I)*(DY1-DY2)/(DY
     11*DY2)
      VPP(I)=(DY1*V(I+1)+DY2*V(I-1)-V(I)*(DY1+DY2))/(.5*DY1*DY2*(DY1+DY2
     1))
3     CONTINUE
      VP(N)=(V(N)-V(N-1))/DY2
      VPP(N)=(V(N-1)-V(N))/DY2**2
      DY1=Y(2)-Y(1)
      DY2=Y(3)-Y(1)
      VP(1)=(DY2*V(2)/DY1-DY1*V(3)/DY2)/(DY2-DY1)-V(1)*(DY1+DY2)/(DY1*DY
```

* T I D Y *

SUBROUTINE VVEL

```
     12)
      X1=Y(2)
      X2=Y(3)
      X3=Y(4)
      X4=Y(5)
      B2=X2*X3+X2*X4+X3*X4
      DL1=X1*(X1-X2)*(X1-X3)*(X1-X4)
      C2=X1*X3+X1*X4+X3*X4
      DL2=X2*(X2-X1)*(X2-X3)*(X2-X4)
      D2=X1*X2+X1*X4+X2*X4
      DL3=X3*(X3-X1)*(X3-X2)*(X3-X4)
      E2=X1*X2+X1*X3+X2*X3
      DL4=X4*(X4-X1)*(X4-X2)*(X4-X3)
      VPP(1)=2.*B2*V(2)/DL1+2.*C2*V(3)/DL2+2.*D2*V(4)/DL3+2.*E2*V(5)/DL4
C
      VPP(1)=VPP(2)
      VPP(N)=VPP(N-1)
      RETURN
C700  FORMAT(1H ,1X,8E13.4)
C
      END
```

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16. Abstract

This report describes a computer program HADY-I for calculating the linear incompressible or compressible stability characteristics of the laminar boundary layer on swept and tapered wings.

The eigenvalue problem and its adjoint arising from the linearized disturbance equations with the appropriate boundary conditions are solved numerically using a combination of Newton-Raphson interative scheme and a variable step size integrator based on the Runge-kutta-Fehlburg fifth-order formulas. The integrator is used in conjunction with a modified Gram-Schmidt orthonormalization procedure.

The computer program HADY-I calculates the growth rates of crossflow (CF) or streamwise Tollmien-Schlichting (TS) instabilities. It also calculates the group velocities of these disturbances. It is restricted to parallel stability calculations, where the boundary layer (meanflow) is assumed to be parallel. The meanflow solution is an input to the program.

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