SEMI-ANNUAL REPORT

DEVELOPMENT OF COMPUTERIZED ANALYSIS FOR SOLID PROPELLANT COMBUSTION (ISAP-2)

NAG8-627

by

T. J. Chung and Raymond Hallit

Department of Mechanical Engineering
The University of Alabama in Huntsville

prepared for

NASA/MSFC

(NASA-CR-181399) DEVELOPMENT OF COMPUTERIZED ANALYSIS FOR SOLID PROPELLANT COMBUSTION (ISAP-2) Semiannual Report (Alabama Univ.) 78 p Avail: NTIS HC A05/MF A01 CSCL 21B G3/25

N87-29634

Unclas
0102767

November, 1987

ABSTRACT

This report is an improvement to ISAP-1, "SRB Vorticity-Acoustic Coupled Instability Analysis", September, 1986. Included in this report are the automatic generation of all input data for grid configuration, boundary conditions for coupled acoustic and vortical field calculations, transformation of all dimensions to a parametric form, resulting in flexibility for the user to define the size of the problem (geometric configurations) with reduction in storage (15-65%) and computer time (50-75%). Additional research is required for the following areas: (1) effects of turbulence, (2) nonlinear wave oscillations, and (3) chemistry upon combustion instability.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Tables

I. INTRODUCTION

This report represents an improved version of "SRB Vorticity-Acoustic Coupled Instability Analysis - ISAP-1, September, 1986. The many basic changes to the original code include the automatic generation of all the input data for grid structure, boundary conditions, and coupling between the flow field and the acoustic/vortical field. In addition, all the dimensions in the program were transformed into a parametric form. These new parameters will enable the user to control the computer memory storage and the program execution time by specifying different sets of parameters and different geometric configurations. Also presented is the comparison between the results of the original program and those of the new one, along with recommendations to the user and additional research requirements.

As noted in the earlier report (ISAP-1), unstable waves may occur as a result of acoustic and/or vortical (hydrodynamic) oscillations. If these two different types of waves are coupled together, their physical interactions lead to extremely complicated phenomena. Theoretically, there exists an infinite number of frequencies for both acoustic and vortical oscillations. Realistically, however, only a limited number of combined frequencies are excited. Our objective is to determine the combined nature of acoustic and vortical frequencies at which instabilities may arise. This subject is important in rocket motor combustion chambers when the vortical field is coupled with acoustic pressure oscillations. In the past, the acoustic combustion instability was studied independently of the vortical instability induced by vortex motions. This report is intended to combine the two different sources of energy everywhere within the spatial domain and to determine the effect of one upon the other. This can be achieved by calculating the mean flow velocities and vorticities and their fluctuating parts of velocities and vortices, as well as the fluctuating pressure.

To elucidate this coupling mechanism, the acoustic wave equation and the perturbed vortical transport equation are solved, being combined with the results of mean flow calculations from the Navier-Stokes system by means of finite elements. With these data, growth constants are calculated and stability boundaries determined. Contributions to stability and/or instability from various sources such as combustion, convection (flow turning), and viscous damping on propellant surfaces and energy convection, momentum convection, momentum viscous damping, and dissipative energy from the interior domain are separately identified. It is also found that stability boundaries for coupled acoustic and vortical oscillations are somewhat similar to the classical hydrodynamic stability boundaries, but they occur in the form of multiple islands.

II. MESH GENERATION

In the original version of the program, the input data was read externally, and this procedure required extensive preparation for any changes in the input constants and/or the configuration of the field. This process is complex and time consuming. Consequently, a mesh generation routine is added to the program.

The program has two major parts: (1) the flow field calculations and (2) the acoustic and vortical calculations from which the stability integrals and growth constants are derived. Therefore, a complete set of input data is required for each part.

A. Flow Field

The flow field calculations include velocities and pressure with grid configurations coarser than those in ISAP-1. Figure 1a shows the original grid in ISAP-1. It is apparent that the element sizes are smaller near boundaries (4), (5), and (6) in Fig. 2, but these reductions were set arbitrarily. The mesh generation routine has a much better approach. It reduces the grid size logarithmically near the same boundaries. This will enhance the flexibility of the program. The generated arrays are the following:

(a) NENN - the element connectivity matrix; it sets the global nodal values of the nodes of each element.

(b) XX, YY - the coordinates of each global node.

(c) NU, NV, and ND - the global nodes for the Dirichlet boundary condition adjustment for the U, V velocities and pressure, respectively.

(d) UB, VB, and PB - the boundary values associated with NU, NV, and ND, respectively.

(e) UU, VV, PP - the velocities in the x-direction, y-direction, and the pressure, respectively.

B. <u>Acoustic and Vortical Field</u>

This is the smaller grid shown in Fig. 2b,d. The two grids are interconnected through the ICON matrix. Again this connectivity was previously set arbitrarily. While in the mesh generation routine, the new grid is set through ICON, such that the distances between the nodes at each boundary are as equal as possible. The arrays for this field are:

(a) NENL - the element connectivity matrix for the smaller grid.

(b) ICON - the interconnectivity matrix between the flow field and the acoustic/vortical field.

(c) NODE - the adjustment matrix for the boundary conditions in the computation of vortical modes.

(d) FFNX, FFNY - the direction cosines at the boundaries in the x and y directions, respectively.

(e) NBQ - the number of elements at each boundary.

(f) ABN, ANN - the admittance at the burning surface and nozzle, respectively.

(g) NC - the connectivity matrix of the boundary elements.

C. Initial and Flow Constants

For each problem, there are some basic constants that are needed to define it. They deal with the geometry, flow properties, error, time-step, and convergence parameters. Many of these constants, such as REN, GAMMA, DT, ERROR, ITMAX, and NPT, have already been defined in the original report. In order to enhance the flexibility of the program, a few additional constants dealing with the geometry of the problem were utilized in the mesh generation routine. They are the following:

(a) XMIN, XMAX, YMIN, YMAX - the limiting values of the domain.

(b) X0, Y0 - the coordinates of the corner node (see Fig. 1).

These geometric values must be redefined by the user every time the configuration of the problem changes.

III. PARAMETRIC DIMENSIONS

The original program was bounded by a set of fixed parameters which controls the memory storage requirements. For the flow field, the program used 832 grid points and 767 elements; for the acoustic/vortical field, it used 40 grid points and 27 elements.

In order to make the programs more flexible, parametric dimensions were added. This addition will allow the user to choose the memory storage needed for different executions. This procedure requires the definition of the parameters and the respective arrays.

A. Parameters

A total of 10 parameters is needed to maximize the flexibility of the program. All but two of these parameters are geometric; they will generate both grids. Of the remaining two parameters, one is fixed and the other is floating (not fixed).

(a) Geometric Parameters:

Four parameters are needed for each grid.

1. Flow field:

The four parameters, shown in Fig. 2, are defined as follows:

NELF1 - the number of boundary elements above the corner node in the y-direction.

NELF2 - the number of boundary elements below the corner node in the y-direction.

NETP1 - the number of boundary elements left of the corner node in the x-direction.

NETP2 - the number of boundary elements right of the corner node in the x-direction.

2. Acoustic/vortical field:

The four parameters associated with this field are similar to those of the flow field with their respective positions. NALF1, NALF2, NATP1, and NATP2 are the number of elements on boundaries (5), (1), (6), and (4), respectively (see Fig. 2).

(b) Floating Parameter:

The parameter MI is affected by other parameters and constants and is a direct result of the calculations. In the original code, the value of MI was set at 65. However, this value can be much lower (see Table 3).

From the program, the needed value of MI is augmented for each St (Strouhal number) $\geq .01$. Those values of St $< .01$ will produce oscillations which are negligible relative to the acoustic oscillations and, therefore, are eliminated to avoid unnecessary calculations. As the Reynolds number increases, the vortical oscillations expand further in the field, resulting in higher values of St at additional nodes; therefore, the needed value of MI will increase.

However, in order to limit the memory storage requirements, MI must be minimized. This procedure will be achieved by changing MI relative to the changes in REN and the geometric parameters (see Section V for the recommended values of MI).

(c) Fixed Parameter:

The parameter NBP, which is always equal to 6, represents the 6 boundaries of the domain. It must be noted that the remaining parameters are derived directly from the 10 preset parameters already defined.

B. Arrays

The size of all the different arrays can be set either by a DIMENSION statement or by a COMMON block. When the parameters were added to the program, two other steps had to be taken:

(1) All the COMMON blocks were eliminated from the code. This step required a change in the way the subroutines are called, by including all the variable arrays that were otherwise included in the COMMON statements.

(2) All the arrays must be referenced in the MAIN program. This step was required because the dimensions of all the arrays are generated in the PARAMETER statements in the MAIN program.

IV. COMPARISON OF RESULTS

The computer memory storage and the execution time are the important outcome of this study. Therefore, to compare these effects, the results will be displayed in two ways: (1) by comparing the original code and the revised code and (2) by comparing the original grids' results with those of the reduced ones.

First of all, the basic assumptions and flow constants are presented:

1. The Reynolds number, REN = 10^3, 10^4, 10^5 for different runs.
2. The specific heat ratio, GAMMA = 1.2.
3. The time step for the calculation of the mean flow field, DT = 1.
4. The convergence error for mean flow, ERROR = .001.
5. The maximum number of iterations for flow field calculations, ITMAX = 30.
6. The domain of calculations: XMIN = 0, XMAX = 10, YMIN = 0, YMAX = 1.5.
7. The corner node coordinates: X0 = 2, Y0 = 1.
8. Boundary and initial conditions: With reference to Fig. 1, burning takes place only on boundary (6); therefore, an instantaneous flux normal to this boundary appears at time T = 0. Then, the velocity in the negative y-direction is set at a dimensionless value of v = -.01, only at the nodes of boundary (6), and excluding the end points of this boundary. All other flow variables are set equal to zero

everywhere in the domain. (The value of -.01 was taken from the original code and is a function of the burning rate at the surface of the solid fuel).

9. The normal vectors at the boundaries: At boundaries (1) - (6), the values of the normal vectors are FFNX = 1., 0., 1., 0., 1., 0.; FFNY = 0., 1., 0., 1., 0., 1., respectively.

10. Admittance: Only at the burning surface (boundary 6), ABN = 1.; otherwise, it is equal to zero. Only at the nozzle (boundary 3), AAN = 1.; otherwise, it is equal to zero.

These assumptions and flow constants were kept fixed (except for REN) throughout the calculations. Now, we can proceed to the comparison of the results.

A. Original Grids

It is clear that with the original grids (ISAP-1), the storage required to generate the data in the revised code will exceed the storage needed to read the data from an outside source. Therefore, the total memory requirements for the revised code exceed that of the original code by about 2%.

Concerning the run time requirements, on the other hand, the revised code used about 2% less time than that of the original code, even though it went through 5 additional values of Strouhal numbers, i.e., vortical calculations (see Table 1).

NOTE: The value of MI has been defined earlier, but this value is also dependent on the systems on which these programs are running. The original code gave a value of MI = 15 on the IBM

3084 and a value of MI = 16 on the UNIVAC. This phenomenon is a result of the eigenvalue solver routine. This routine is very sensitive to any small variations in its input data. To eliminate the sensitivity problem, these codes should be transformed to operate in double-precision, while reducing the ERROR value and increasing ITMAX. These new additions will increase the storage requirements and run time by over 50%.

The flow field results, as shown in Fig. 3, prove that the revised code presents the same exact flow field as that of the original code. In the figure, the original code results are displayed in the upper half of each section for (a) the pressure, (b) the velocity in the x-direction, and (c) the velocity in the y-direction. These results were expected because of the linearity of the solution. However, the difference between the values of MI was not expected to be as large.

Even though the revised version of the program made it more flexible and easy to operate, it still has not made any major contribution to reduce the memory requirements nor the necessary run time. Therefore, we will present the other aspects of possible improvements which reduce the memory storage and run time. But, as we will see, they will slightly affect the computational results.

B. Reduced Grids

As a part of the flexibility of the revised code, the user has the option of changing the number of nodes and elements used in the program. Figure 1 shows the different grids used for comparison purposes. The number of nodes and elements are tabulated in Table 2. As seen in Table 2, if the number of elements at the boundaries is reduced by 1/4, the total number of nodes and elements is reduced by about 1/2. As a result of the reduced grids, the required memory storage and run time will definitely be reduced. Then, there is a need to find what percentage reduction is achieved and how it will affect the results.

Table 3 shows the different reductions achieved for required memory and run time at different Reynolds numbers. The storage requirement is reduced by 14% and 66% with coarser grids for the flow field and the flow and A/V fields, respectively, while the execution time is reduced between 56% and 76%. From these values, we can conclude that the flow field calculations affect mostly the run time required, while the acoustic/vortical (A/V) field affects the storage size of the program. On the other hand, the computational results of such reductions are slightly affected. Figures 4-6 show the flow field variables for the reduced grid (the lower part of each section), as comapred to the original grid, for Re = 10^3, 10^4, and 10^5, respectively. The difference between the results becomes more obvious as Re gets larger. Consequently, at high values of the Reynolds number (Re), the coarse mesh does not produce accurate results.

V. RECOMMENDATIONS

Two types of recommendations are necessary to conclude this report: (1) those directed towards the users of the program and (2) those needed for a more realistic modeling of the problem at hand.

A. To the user:

(1) Grids: This program does not contain a turbulent flow model to accommodate for the higher values of Re. Also, there is a limit, in reducing the grids, at which the results would become insignificant. Therefore, a coarse mesh, such as (6, 9, 13, 20), may be used at Re $\leq 10^3$; but, at higher values of Re, a more refined mesh is needed. Recommended values for the parameters: NELF1 $\geq$ 6, NELF2 $\geq$ 9, NETP1 $\geq$ 13, NETP2 $\geq$ 20, 2 $\leq$ NALF1, NALF2, NATP1, NATP2 $\leq$ 4. It is imperative that the last 4 parameters be $\geq$ 2; otherwise, the calculations will become senseless.

(2) The value of MI: As stated earlier, the needed value of MI is calculated within the program. The maximum allowable value of MI is equal to the number of A/V modes: MI_{max} = NT. In order to control the memory storage requirements, MI can be specified smaller than NT. As shown in Table 3, the needed values of MI increase as the Reynolds number increases.

Therefore, it is recommended that the user adjust the value of MI, as needed, to correspond with the values of the Reynolds number and the appropriate geometric parameters. The recommended values of MI are: $MI_{(needed)} < MI \le NT$, where $MI_{(needed)}$ are the values listed in Table 3.

B. Additional Recommendations:

There are many areas where this program can be improved, some of which can be done in the near future, others will be the topics of further study and research.

(1) Double precision, smaller DT, smaller ERROR, and larger ITMAX: these extra steps are needed for accuracy and to avoid the sensitivity in the eigenvalue solver.

(2) Turbulent model: this model will be used for the relatively high values of Re.

(3) Higher order approximations of the pressure and the vorticity.

(4) The study of the effect of compressibility.

(5) The addition of chemistry to the model by adding the species and energy equations.

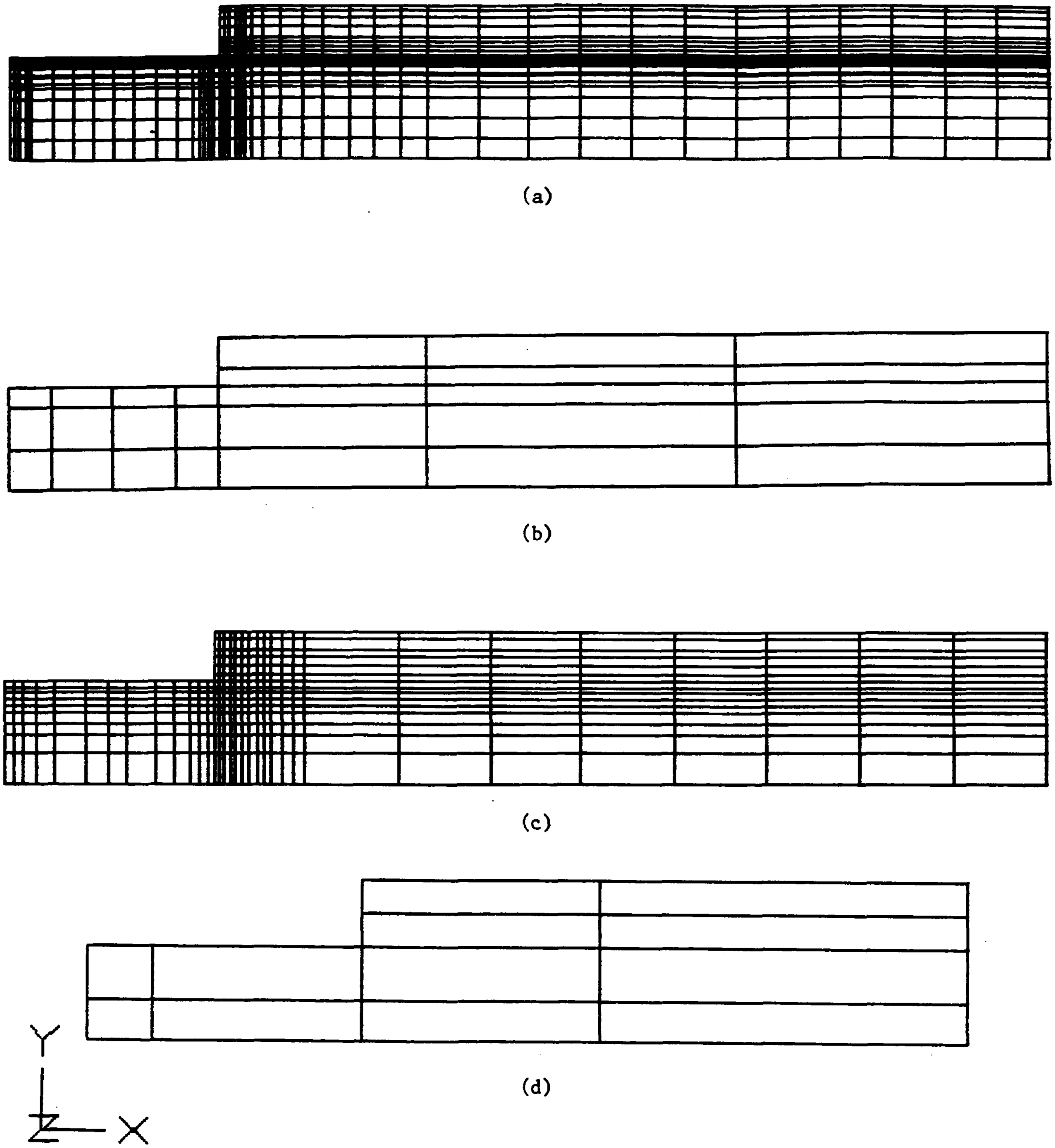


Fig 1. The grids: a) for the original flow calculations, b) for the original A/V calculations, c) for the reduced flow calculations, and d) for the reduced A/V calculations.

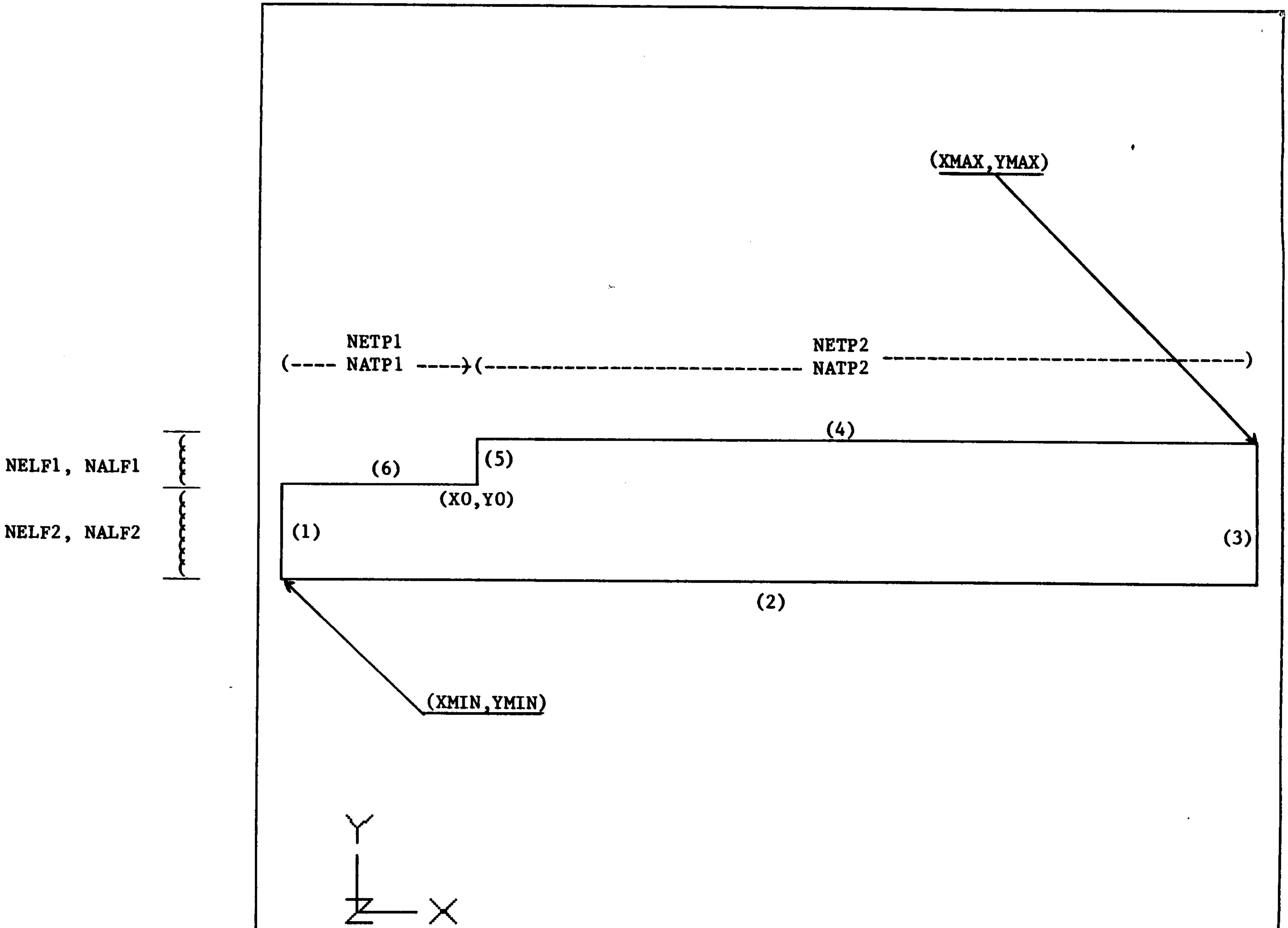
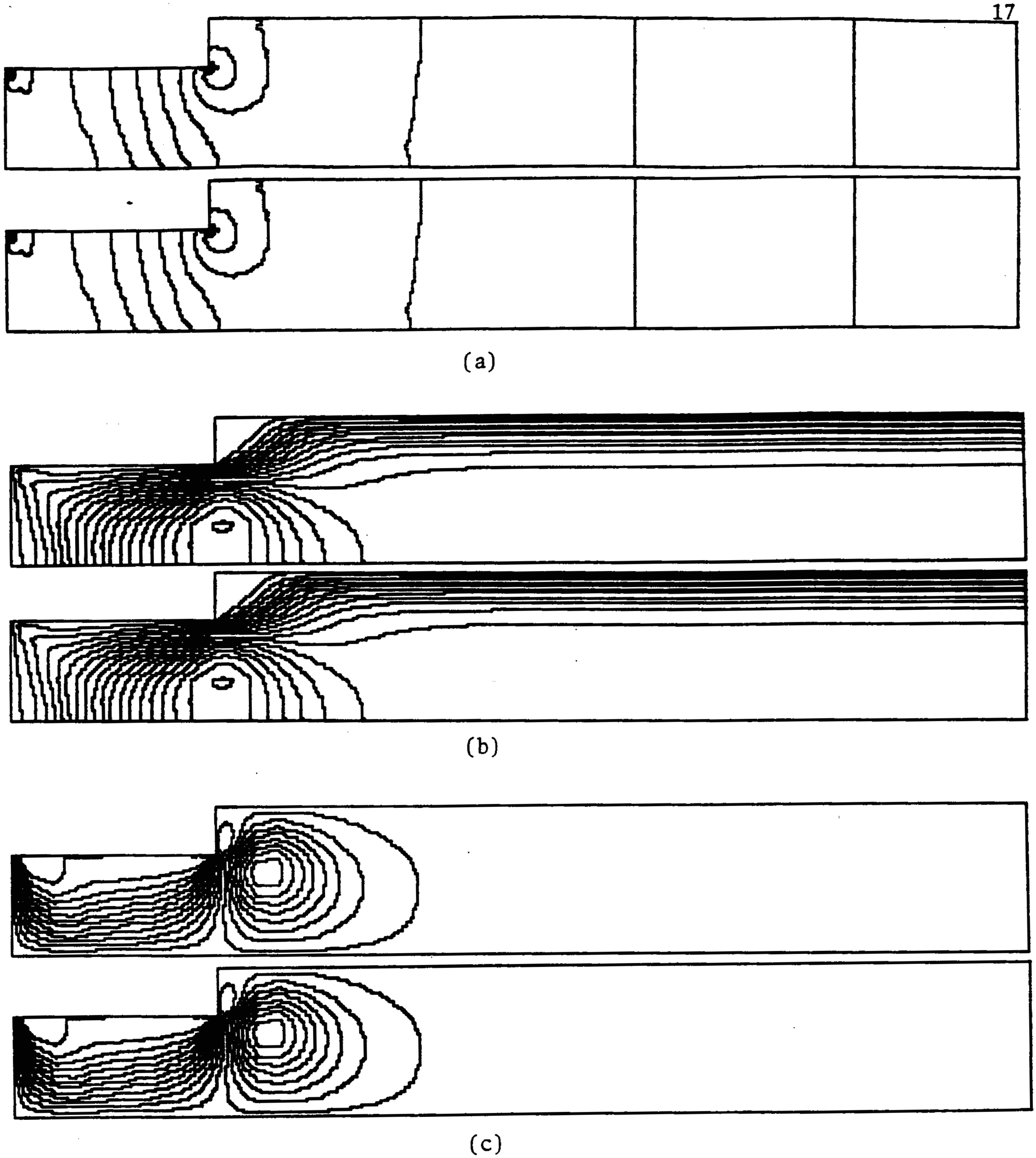


Fig 2. Parameters, boundaries, and domain of calculations.



Fif 3. Comparison between the flow field results of the original code (upper part) and those of the revised code (lower part), for (a) the pressure, (b) the U-velocity, and (c) the V-velocity. (Re=1000.)

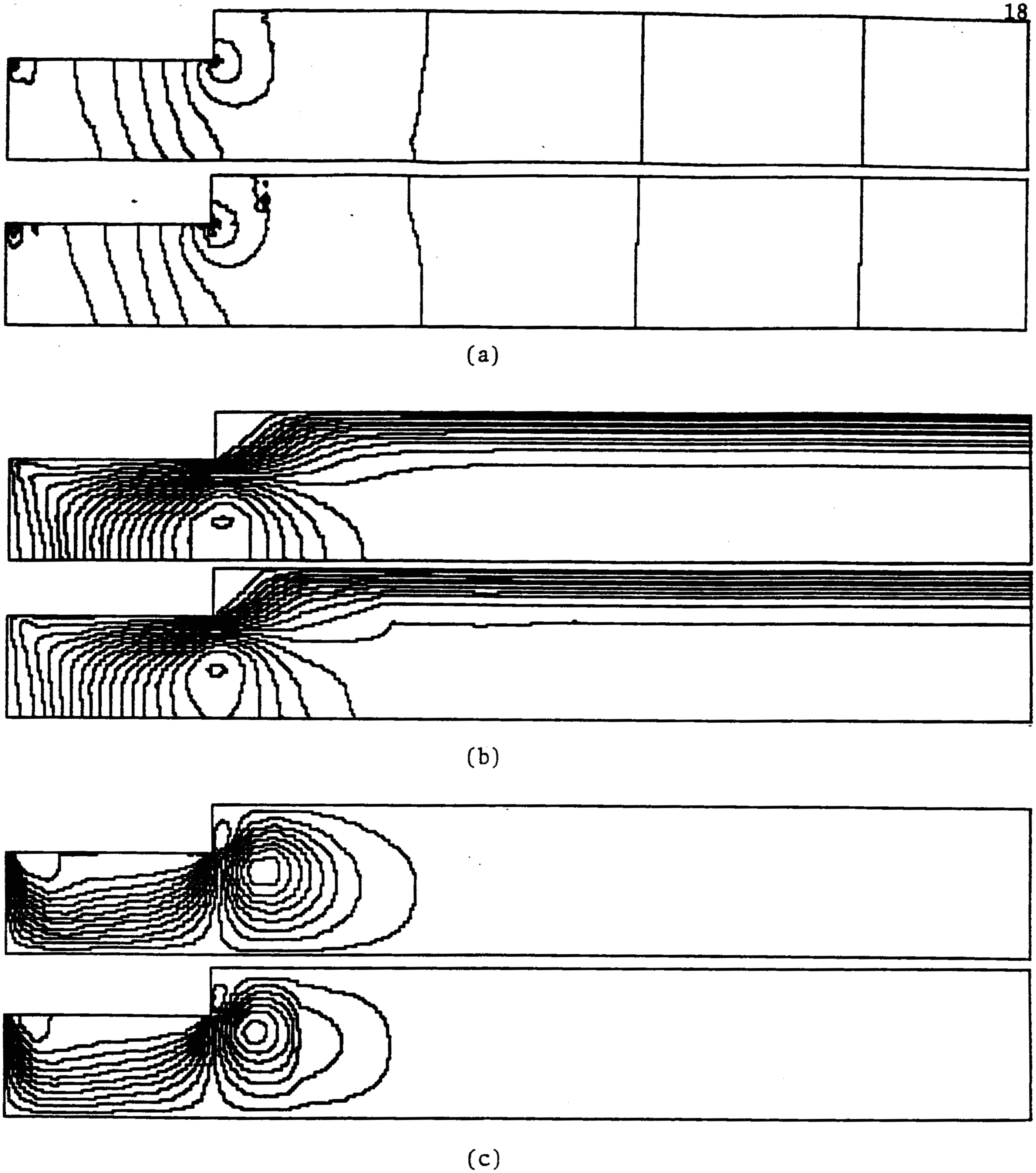
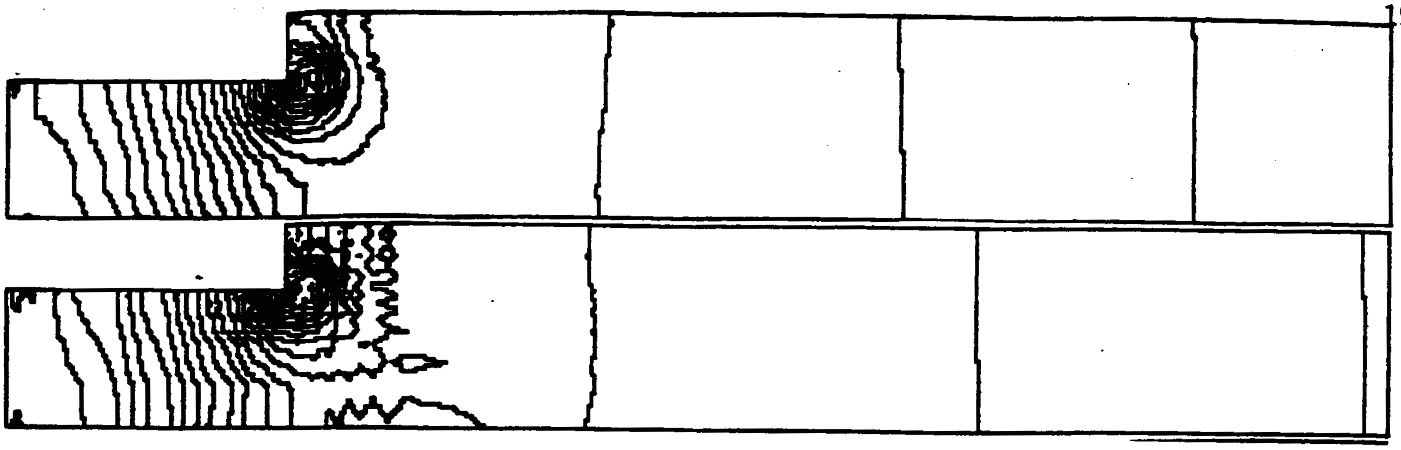
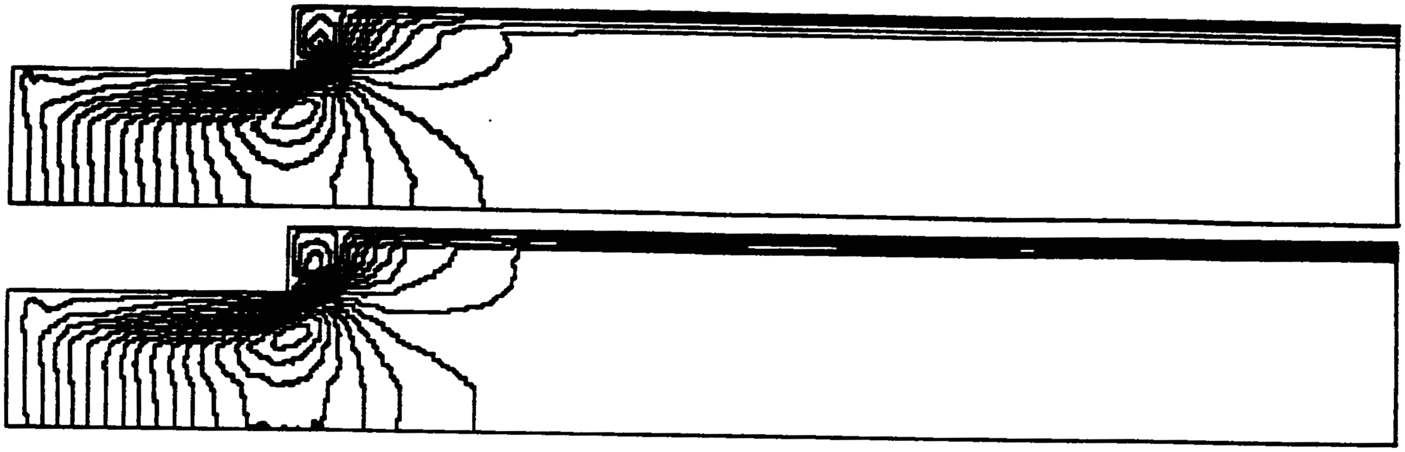


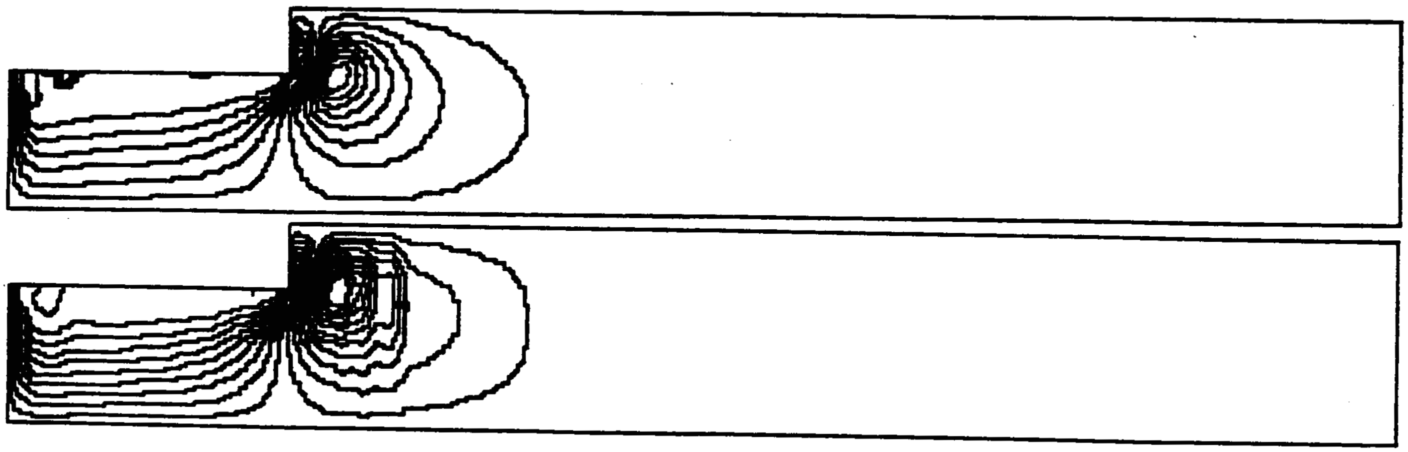
Fig 4. Comparison of the flow field variables between the original mesh (upper part) and the reduced mesh (lower part) : (a) the pressure, (b) the U-velocity, (c) the V-velocity; Re= 1000.



(a)

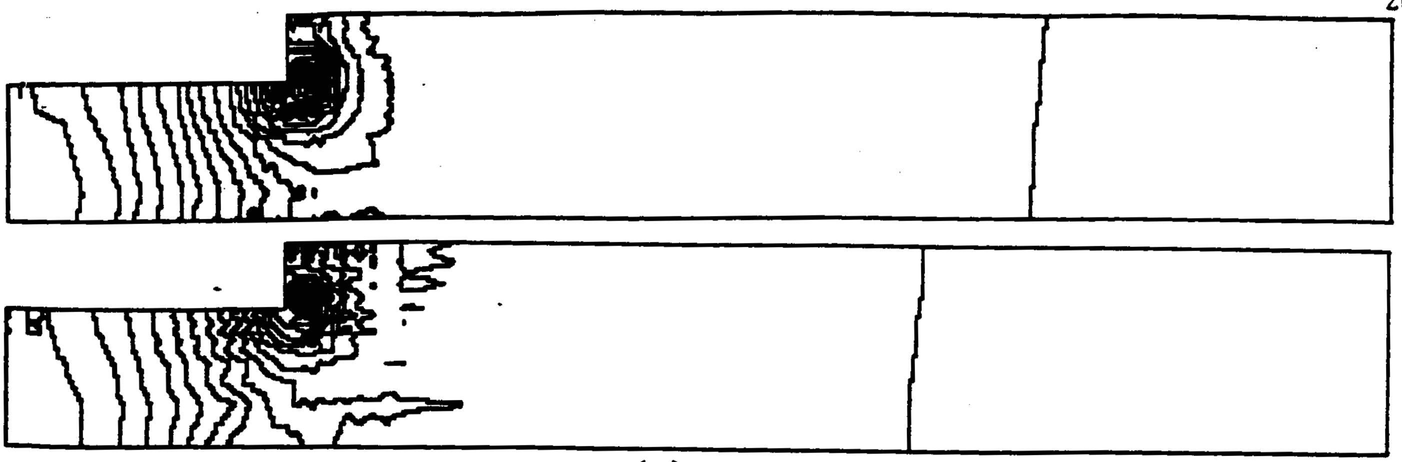


(b)

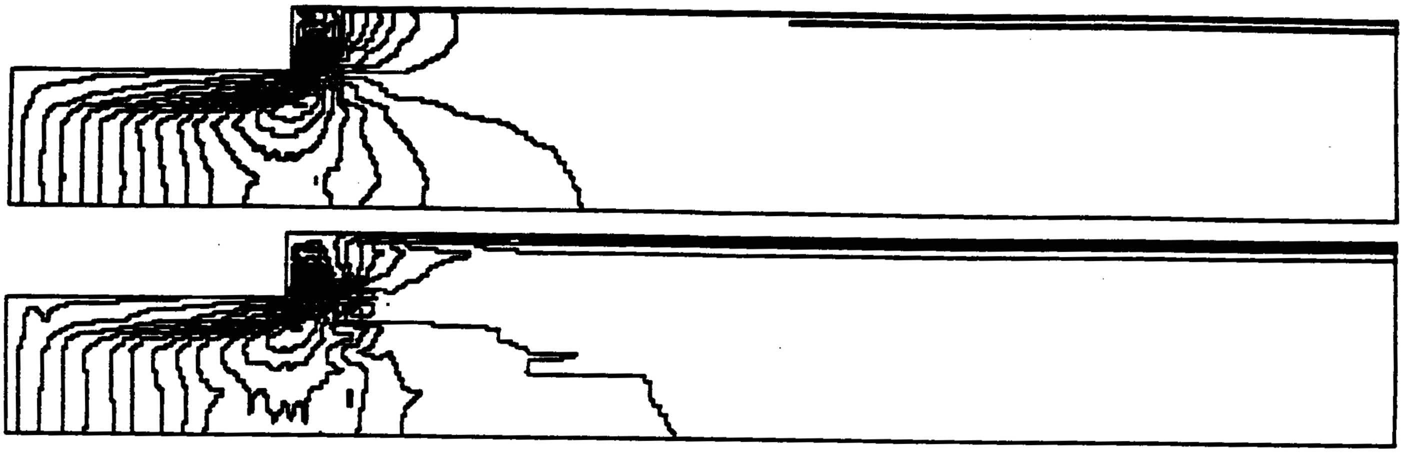


(c)

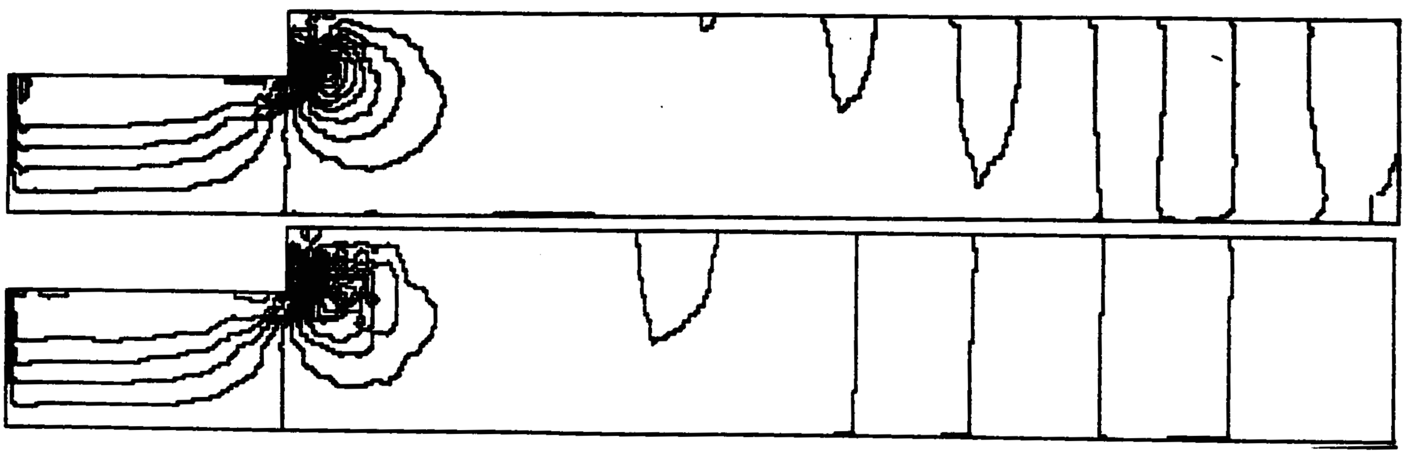
Fig 5. Comparison of the flow field variables between the original mesh (upper part) and the reduced mesh (lower part) : (a) the pressure, (b) the U-velocity, (c) the V-velocity; Re= 10000.



(a)



(b)



(c)

Fig 6. Comparison of the flow field variables between the original mesh (upper part) and the reduced mesh (lower part) : (a) the pressure, (b) the U-velocity, (c) the V-velocity; Re= 100000.

Table 1. Comparison between the storage and runtime of the original code and the revised one, at Re= 10^3. (original grids)

	Memory Requirement Bytes	Fraction of the original	Run-time (UNIVAC) min	Fraction of the original	MI (needed)
ORIGINAL	3023004	1	226	1	16
REVISED	3109452	1.02	223	.98	21

Table 2. The reduced grids.

		Parameters	No. of Nodes	No. of Elements
Flow Field	Original	(8,13,17,26)	832	767
	Reduced	(6,9,13,20)	466	417
A/V Field	Original	(2,3,4,3)	40	27
	Reduced	(2,2,2,2)	21	12

Table 3. Storage and run-time comparison between the original grids and the reduced ones. (MI was set at 65 as an initial assumption).

	Re	Memory Requirement Bytes	Fraction of the Original	Run-time (UNIVAC) min	Fraction of the Original	MI (needed)
Original GRID	10^3	3109452	1.	223	1.	21
	10^4	3109452	1.	240	1.	30
	10^5	3109452	1.	242	1.	33
Flow field reduced (only)	10^3	2682808	.86	80	.358	19
	10^4	2682808	.86	100	.420	27
	10^5	2682808	.86	105	.434	33
Flow & A/V fields reduced	10^3	1077816	.34	52	.233	7
	10^4	1077816	.34	64	.267	12
	10^5	1077816	.34	65	.270	14

APPENDIX

Listing of the Revised Code.

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  1  C
 11            PROGRAM ISAP1
  1  C         VIRTUAL A,A2,B,B2,C,CZZ2,D,SI,SR
  1  C     VIRTUAL PAA,PAH,PAT,UUI,UUR,VVI,VVR
  1  C
  1  C         PPROGRAM FOR SRB VORTICALLY-COUPLED COMBUSTION INSTABILITY
  1  C         ANALYSIS BY FINITE ELEMENTS
  1  C
  7        PARAMETER (NELF1=6,NELF2=9,NETP1=13,NETP2=20)
  1  C     PARAMETER (NELF1=8,NELF2=13,NETP1=17,NETP2=26)
  1  C     PARAMETER (NALF1=2,NALF2=3,NATP1=4,NATP2=3)
  7        PARAMETER (NALF1=2,NALF2=2,NATP1=2,NATP2=2)
  1  C
  7        PARAMETER (MI=65,NC1=20,NBP=6,
  6       &NERGT=NELF1+NELF2,NEBOT=NETP1+NETP2,
  6       &NEL=NETP2*NERGT+NETP1*NELF2,NBO=2*NERGT+7,
  6       &NARGT=NALF1+NALF2,NABOT=NATP1+NATP2,
  6       &NPT1A=(NALF2+1)*NATP1,NPT2A=(NATP2+1)*(NARGT+1),
  6       &NL=NATP2*NARGT+NATP1*NALF2,NT=NPT1A+NPT2A,MII=4*NT,
  6       &NT1=NT-NALF1-NALF2-NATP2-2,NTT=3*NT1+NT,
  6       &NPT1=(NELF2+1)*NETP1,NPT2=(NETP2+1)*(NERGT+1),
  6       &NGPT=NPT1+NPT2,NDP=NERGT+1,
  6       &NUX=NELF1+NELF2+NETP1+NETP2+3,NVY=NUX+NDP+NEBOT+1)
  1  C
  7        DIMENSION NENN(NEL,4),NENL(NL,4),ICON(NT),NC(NBP,NC1,2),FRE(NT),
  6       &PRESS(NT,NT),FVE(MI),UUR(NT,MI),UUI(NT,MI),VVR(NT,MI),
  6       &VVI(NT,MI)
  7        DIMENSION NBN1(NELF2+1),NBN2(NELF1+NETP1+1),NBN3(NETP2+1),
  6       &NBN4(NERGT+1),NBN5(NEBOT+1)
  1  C
  7        DIMENSION NODE(NTT),NBQ(NBP),FFNX(NBP),FFNY(NBP),ABN(NBP)
  7        DIMENSION ANN(NBP)
  7        DIMENSION XT(NT),YT(NT),UT(NT),VT(NT)
 11            DIMENSION NU(NUX),NV(NVY),ND(NDP),UB(NUX),VB(NVY),PB(NDP)
 11            DIMENSION XX(NGPT),YY(NGPT),UU(NGPT),VV(NGPT),PP(NGPT)
 11            DIMENSION PFR(NT),PFV(MI),PAA(NT,MI),PAH(NT,MI),PAT(NT,MI)
  7        DIMENSION US(NGPT),VS(NGPT),DPP(NGPT),DELU(NGPT),DELV(NGPT),
  6       *A(NGPT,NBO),B(NGPT,NBO),FU(NGPT),FV(NGPT),TARR1(NT),
  6       *ITER(NT),SR(MII,NTT),SI(MII,NTT),FV1(MII),ITER2(NTT)
  7        COMPLEX A1(NT,NT),B1(NT,NT),CZZ1(NT,NT),EIGAV(NT),EIGBV(NT),
  6       *EIGV(NT),A2(MII,MII),B2(MII,MII),C(NTT,NTT),D(NTT,NTT),
  6       *CZZ2(NTT,NTT),EIGAV2(NTT),EIGBV2(NTT),EIGV2(NTT)
  1  C
  7        DATA XMIN,XMAX,YMIN,YMAX/0.,10.,0.,1.5/
  7        DATA XO,YO/2.,1./
  1  C
  7        REN=1000.
  7        GAMMA=1.2
  7        DT=1.
  7        ERROR=.001
  7        ITMAX=30
  7        NPT=4
  1  C
  1  C
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  1  C         CT=SPEED OF SOUND(IN/SEC)/CHARACTERISTIC LENGTH(IN)
  1  C
 11            CT=40000.0/24.0
  1  C
  1  C         INPUT DATA
  1  C
  7          CALL DINPUT(NELF1,NELF2,NETP1,NETP2,NALF1,NALF2,
  6         &NATP1,NATP2,NERGT,NEBOT,NARGT,NABOT,NPT1A,NPT1,
  6         &NEL,NGPT,NPT,NBW1,NBWT,NUX,NVY,NDP,NBP,NTT,NODE,
  6         &NENN,NENL,ICON,NC,NBN1,NBN2,NBN3,NBN4,NBN5,NT1,NC1,
  6         *                  XMIN,XMAX,YMIN,YMAX,XO,YO,
  6         *                 NBQ,XX,YY,UU,VV,PP,NU,NV,ND,UB,VB,PB,FFNX,
  6         *                 FFNY,ABN,ANN,REN,GAMMA,DT,ERROR,ITMAX,NL,NT)
  1  C
  1  C         COMPUTATION OF MEAN FLOW FIELDS
  1  C
 11            CALL VELOT(NEL,NGPT,NPT,NBW1,NBWT,XX,YY,UU,VV,PP,REN,DT,ERROR,
  6         * NENN,ICON,XT,YT,UT,VT,NBO,US,VS,DPP,DELU,DELV,FU,FV,
  6         *          A,B,NUX,NVY,NDP,NU,NV,ND,UB,VB,PB,NT,ITMAX)
  1  C
  1  C         COMPUTATION OF ACOUSTIC MODES
  1  C
 11            CALL EIPRE(NL,NT,NPT,NENL,FRE,PRESS,
  6         * XT,YT,TARR1,A1,B1,CZZ1,EIGAV,EIGBV,EIGV,ITER)
  1  C
  1  C       IF(NELF1.GT.1)GOTO 100
  1  C
  1  C         COMPUTATION OF VORTICAL MODES
  1  C
 11            CALL EIVOR(NL,NT,NPT,REN,NTT,NODE,MVP,MI,MII,
  6         * SR,SI,FV1,A2,B2,C,D,CZZ2,EIGAV2,EIGBV2,EIGV2,ITER2,
  6         * NENL,FVE,UUR,UUI,VVR,VVI,XT,YT,UT,VT)
  1  C
 11            WRITE(6,1000)
  1  C
  1  C         DO LOOP FOR EACH ACOUSTIC MODE
  1  C
 11            DO 1 IK=2,NT
  1  C
 11            FR=CT*FRE(IK)
 11            PFR(IK)=FR
  1  C
  1  C         DO LOOP FOR EACH VORTICAL MODE
  1  C
 11            DO 1 IG=1,MVP
  1  C
  1  C         STABILITY INTEGRAL AT THE BOUNDARY
  1  C
 11            CALL SURFCE(IK,IG,NBP,FFNX,FFNY,ABN,ANN,NC1,
  6         *          NC,FRE,PRESS,FVE,UUR,UUI,VVR,VVI,
  6         *           NT,AAA,AAB,AHB,AHC,REN,GAMMA,NBQ,MI,
  6         *            XT,YT,UT,VT)
  1  C
  1  C         STABILITY INTEGRAL IN THE VOLUME
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  1   C
 11             CALL VOLUME(IK,IG,NPT,NL,NT,EN,AAD,AAE,AAF,
  6        *            NENL,FRE,PRESS,UUR,UUI,VVR,VVI,
  6        *                  AHE,AHF,AHG,REN,GAMMA,MI,XT,YT,UT,VT)
  1   C
  1   C         DIMENSIONALIZATIONS OF GROWTH CONSTANTS
  1   C
 11             FV2 =FVE(IG)
 11             PFV(IG)=FV2
  9           CTOEN=CT/EN
 11             AAA=CTOEN*AAA
 11             AAB=CTOEN*AAB
 11             AAC=CTOEN*AAC
 11             AAD=CTOEN*AAD
 11             AAE=CTOEN*AAE
 11             AAF=CTOEN*AAF
  1   C
 11             AHB=CTOEN*AHB
 11             AHC=CTOEN*AHC
 11             AHE=CTOEN*AHE
 11             AHF=CTOEN*AHF
 11             AHG=CTOEN*AHG
  1   C
 11             AA=AAA+AAB+AAC+AAD+AAE+AAF
 11             AH=AHB+AHC+AHE+AHF+AHG
 11             AT=AA+AH
  1   C
 11             PAA(IK,IG)=AA
 11             PAH(IK,IG)=AH
 11             PAT(IK,IG)=AT
  1   C
 11             WRITE(6,1001) FR,FV2
 11             WRITE(6,1002) AT,AA,AH
 11             WRITE(6,1012)
 11             WRITE(6,1003) AAA,AAB,AAC,AAD,AAE,AAF
 11             WRITE(6,1004) AHB,AHC,AHE,AHF,AHG
  1   C
  1   1         CONTINUE
  1   C
 11             WRITE(6,1006)
 11             DO 100 IK=1,NT
 11             DO 100 IG=1,MVP
 11             WRITE(6,1005) PFR(IK),PFV(IG),PAA(IK,IG),PAH(IK,IG),
  6        *                  PAT(IK,IG)
  1   100       CONTINUE
  1   C
  1   C
 11             STOP
  1   1000      FORMAT(/////,5X,'STABILITY INTEGRALS',//)
  1   1001      FORMAT(//,10X,'ACOUSTIC FREQ =',E10.5,'HZ',5X,
  6        *            'STRAUHAL NO. =',E10.5,/)
  1   1002      FORMAT(5X,'TOTAL ALP =',E15.5,3X,'ACOUSTIC ALP =',
  6        *            E15.5,3X,'VORTICAL ALP =',E15.5)
  1   1012      FORMAT(20X,'A',14X,'B',14X,'C',14X,'D',14X,'E',
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 6        *         14X,'F',14X,'G')
 1   1003      FORMAT(6X,'ALPA',6E15.5)
 1   1004      FORMAT(6X,'ALPH',15X,2E15.5,15X,3E15.5)
 1   1005      FORMAT(5X,5E12.3)
 1   1006      FORMAT(/////)
11             END
 1   C
 1   C
 1   C
 7          SUBROUTINE DINPUT(NELF1,NELF2,NETP1,NETP2,NALF1,NALF2,
 6         &NATP1,NATP2,NERGT,NEBOT,NARGT,NABOT,NPT1A,NPT1,
 6         &NEL,NGPT,NPT,NBW1,NBWT,NUX,NVY,NDP,NBP,NTT,NODE,
 6         &NENN,NENL,ICON,NC,NBN1,NBN2,NBN3,NBN4,NBN5,NT1,NC1,
 6         *                 XMIN,XMAX,YMIN,YMAX,XO,YO,
 6         *                NBQ,XX,YY,UU,VV,PP,NU,NV,ND,UB,VB,PB,FFNX,
 6         *                FFNY,ABN,ANN,REN,GAMMA,DT,ERROR,ITMAX,NL,NT)
 1   C
 1   C                 GENERATION OF INPUT DATA
 1   C
 1   C            NEL             : NUMBER OF FINITE ELEMENTS
 1   C            NGPT            : NUMBER OF GLOBAL NODES
 1   C            NPT             : NUMBER OF LOCAL NODES IN EACH FINITE
 1   C                              ELEMENT
 1   C            NBW1            : HALF BAND WIDTH + 1 OF THE STIFFNESS
 1   C                              MATRIX
 1   C            NBWT            : TOTAL BAND WIDTH OF THE STIFFNESS
 1   C                              MATRIX
 1   C            NUX             : NUMBER OF BOUNDARY CONDITIONS OF
 1   C                              U-VELOCITY
 1   C            NVY             : NUMBER OF BOUNDARY CONDITIONS OF
 1   C                              V-VELOCITY
 1   C            NDP             : NUMBER OF BOUNDARY CONDITIONS OF
 1   C                              PRESSURE
 1   C            NTT             : NUMBER OF TITAL EQUATIONS FOR THE
 1   C                              COMPUTATION OF VORTICAL MODE
 1   C            NODE(NTT)       : ADJUSTMENT MATRIX FOR THE BOUNDARY
 1   C                              CONDITIONS OF THE COMPUTATION OF VIRTICAL
 1   C                              MODES
 1   C            NBP             : NUMBER OF BOUNDARY FACES OF DOMAIN
 1   C            NBQ(NBP)        : BOUNDARY ELEMENT MATRIX
 1   C            XX(NGPT)        : X-COORDINATE
 1   C            YY(NGPT)        : Y-COORDINATE
 1   C            UU(NGPT)        : INITIAL CONDITIONS OF U-VELOCITY
 1   C            VV(NGPT)        : INITIAL CONDITIONS OF V-VELOCITY
 1   C            PP(NGPT)        : INITIAL CONDITIONS OF PRESSURE
 1   C            NU(NUX)         : GLOBAL NODES OF BOUNDARY CONDITIONS OF
 1   C                              U-VELOCITY
 1   C            NV(NVY)         : GLOBAL NODES OF BOUNDARY CONDITIONS OF
 1   C                              V-VELOCITY
 1   C            ND(NDP)         : GLOBAL NODES OF BOUNDARY CONDITIONS OF
 1   C                              PRESSURE
 1   C            FFNX(NBP)       : X-DIRECTION NORMAL VECTORS AT EACH BOUNDARY
 1   C            FFNY(NBP)       : Y-DIRECTION NORMAL VRCTORS AT EACH BOUNDARY
 1   C            ABN(NBP)        : ADMITTANCE AT THE BURNING SURFACE
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

   1  C           ANN(NBP)          : ADMITTANCE AT THE NOZZLE
   1  C           REN               : REYNOLDS NUMBER
   1  C           GAMMA             : SPECIFIC HEAT RATIO
   1  C           DT                : TIME STEP FOR THE COMPUTATION OF MEAN FLOW
   1  C           ERROR             : CONVERGENCE ERROR CRITERIA OF THE
   1  C                               COMPUTATION OF MEAN FLOW
   1  C           ITMAX             : MAXIMUM NUMBER OF ITERATIONS OF THE
   1  C                               COMPUTATION OF MEAN FLOW
   1  C
   7        DIMENSION NENN(NEL,4),NENL(NL,4),ICON(NT),NC(NBP,NC1,2)
  11            DIMENSION XX(NGPT),YY(NGPT),NU(NUX),NV(NVY),ND(NDP),
   6       *              UB(NUX),VB(NVY),PB(NDP)
  11            DIMENSION UU(NGPT),VV(NGPT),PP(NGPT)
  11            DIMENSION NODE(NTT),NBQ(NBP),FFNX(NBP),FFNY(NBP),ABN(NBP),
   6       *              ANN(NBP)
   7        DIMENSION NBN1(NELF2+1),NBN2(NELF1+NETP1+1),NBN3(NETP2+1),
   6       &NBN4(NERGT+1),NBN5(NEBOT+1)
   1  C
   1  C
   1  C          CONSTANTS FOR BAND MATRIX
   1  C
   7        NBW=NERGT+3
  11            NBW1=NBW+1
  11            NBWT=NBW*2+1
   1  C
   7        DO 10 J=1,NETP1
   7        DO 10 I=1,NELF2
   7        K=(J-1)*NELF2+I
   7        NNZ=0
   7        IF(J.EQ.NETP1)NNZ=NELF1
   7        NENN(K,1)=(J-1)*(NELF2+1)+I+1
   7        NENN(K,2)=J*(NELF2+1)+I+1+NNZ
   7        NENN(K,3)=NENN(K,2)-1
   7        NENN(K,4)=NENN(K,1)-1
   1  10    CONTINUE
   1  C
   7        NEL1=NETP1*NELF2
   7        DO 20 J=1,NETP2
   7        DO 20 I=1,NERGT
   7        K=(J-1)*NERGT+I+NEL1
   7        NENN(K,1)=(J-1)*(NERGT+1)+I+1+NPT1
   7        NENN(K,2)=J*(NERGT+1)+I+1+NPT1
   7        NENN(K,3)=NENN(K,2)-1
   7        NENN(K,4)=NENN(K,1)-1
   1  20    CONTINUE
   1  C
   7        DO 40 I=1,NETP1
   7        K=(I-1)*(NELF2+1)
   7        YY(K+1)=YO
   7        DO 40 J=1,NELF2-1
   7        YY(K+J+1)=(YO-YMIN)*ALOG10(10.*(1.-FLOAT(J)/FLOAT(NELF2+1)))
   7        YY(K+J+2)=YMIN
   1  40    CONTINUE
   1  C
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
START
 COL   ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  7          DY11=(YMAX-YO)/FLOAT(NELF1)
  7          DO 50 I=1,NETP2+1
  7          K=(I-1)*(NERGT+1)
  7          YY(NPT1+K+1)=YMAX
  7          DO 45 I1=1,NELF1-1
  7          YY(NPT1+K+I1+1)=YMAX-DY11*FLOAT(I1)
  1    45    CONTINUE
  7          DO 50 J=1,NELF2+1
  7          YY(NPT1+K+NELF1+J)=YY(J)
  1    50    CONTINUE
  1    C
  7          DO 60 I=1,NELF2+1
  7          XX(I)=XMIN
  1    60    CONTINUE
  1    C
  7          NO=NELF2+1
  1    C
 11              DX12=(XO-XMIN)*.5
 11              NTP22=INT(.5*FLOAT(NETP1-1)+.1)
 11              PINV22=1./FLOAT(NTP22)
 11              PINV33=1./FLOAT(NETP1-NTP22)
  1    C
 11              DO 75 J=2,NETP1
 11              N1=NO
  7          IF(J.EQ.NTP22+1)GOTO 72
 11              IF(J.GT.NTP22)GOTO 73
 11              DUMMY=1.-PINV22*FLOAT(J-1)
 11              DX22=DX12*(1.-ALOG10(10.*DUMMY))
 11              XXOO=XMIN
 11              GOTO 74
  1    72    XXOO=XMIN
  7          DX22=DX12
  7          GOTO 74
  1    73        DUMMY=PINV33*FLOAT(J-1-NTP22)
 11              DX22=DX12*ALOG10(10.*DUMMY)
 11              XXOO=XMIN+DX12
  1    74        DO 75 I=1,NELF2+1
 11              NO=NO+1
 11              XX(N1+I)=XXOO+DX22
  1    75        CONTINUE
  1    C
 11              DX33=XO-XMIN
 11              PINV44=1./FLOAT(NETP1+NTP22)
 11              DO 77 J=1,NETP1
 11              N1=NO
 11              DUMMY=1.-PINV44*FLOAT(J-1)
 11              DX34=DX33*(1.-ALOG10(10.*DUMMY))
 11              DO 77 I=1,NERGT+1
 11              NO=NO+1
 11              XX(N1+I)=XO+DX34
  1    77        CONTINUE
  1    C
 11              NTP44=NETP2-NETP1
 11              DX44=(XMAX-XX(NO))/FLOAT(NTP44+1)
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11              DO 79 J=1,NTP44+1
 11              N1=NO
 11              DO 79 I=1,NERGT+1
 11              NO=NO+1
 11              XX(N1+I)=XX(N1)+DX44
  1   79         CONTINUE
  1   C
 11              DO 80 I=1,NGPT
 11              PP(I)=0.
 11              UU(I)=0.
 11              VV(I)=0.
  1   80         CONTINUE
 11              DO 90 I=2,NETP1
 11              J=(I-1)*(NELF2+1)
 11              VV(J+1)=-0.01
  1   90         CONTINUE
  1   C
  7         DO 101 I=1,NELF2+1
  7         NBN1(I)=I
  1   101   CONTINUE
  7         DO 102 I=1,NELF1+1
  7         NBN2(I)=NPT1+I
  1   102   CONTINUE
  7         DO 103 I=1,NETP1
  7         J=I+NELF1+1
  7         NBN2(J)=NPT1+1-I*(NELF2+1)
  1   103   CONTINUE
  7         DO 104 I=1,NETP2+1
  7         NBN3(I)=NGPT+1-I*(NERGT+1)
  1   104   CONTINUE
  7         DO 105 I=1,NERGT+1
  7         NBN4(I)=NGPT-I+1
  1   105   CONTINUE
  7         NN=NELF2+1
  7         NBN5(1)=NN
  7         DO 106 I=2,NEBOT+1
  7         IF(I.GT.NETP1)NN=NERGT+1
  7         NBN5(I)=NBN5(I-1)+NN
  1   106   CONTINUE
  1   C
  7         N2=0
  7         N3=0
  7         DO 110 I=1,NELF2+1
  7         N2=N2+1
  7         N3=N3+1
  7         NU(I)=NBN1(I)
  7         NV(I)=NBN1(I)
  1   110   CONTINUE
  1   C
  7         N4=N2
  7         DO 111 I=1,NEBOT+1
  7         N2=N2+1
  7         NV(N4+I)=NBN5(I)
  1   111   CONTINUE
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  1   C
  7         N4=N2
  7         DO 112 I=1,NERGT+1
  7         N2=N2+1
  7         NV(N4+I)=NBN4(I)
  7         ND(I)=NBN4(I)
  1    112  CONTINUE
  1   C
  7         N4=N2
  7         N5=N3
  7         DO 113 I=1,NETP2+1
  7         N2=N2+1
  7         N3=N3+1
  7         NV(N4+I)=NBN3(I)
  7         NU(N5+I)=NBN3(I)
  1    113  CONTINUE
  1   C
  7         N6=NELF1+NETP1+1
  7         DO 114 I=1,N6
  7         NV(N2+I)=NBN2(I)
  7         NU(N3+I)=NBN2(I)
  1    114  CONTINUE
  1   C
  7         DO 116 I=1,NUX
  7         J=NU(I)
  7         UB(I)=UU(J)
  1    116  CONTINUE
  1   C
  7         DO 117 I=1,NVY
  7         J=NV(I)
  7         VB(I)=VV(J)
  1    117  CONTINUE
  1   C
  7         DO 118 I=1,NDP
  7         J=ND(I)
  7         PB(I)=PP(J)
  1    118  CONTINUE
  1   C
  7         DO 120 J=1,NATP1
  7         DO 120 I=1,NALF2
  7         K=(J-1)*NALF2+I
  7         NNZ=0
  7         IF(J.EQ.NATP1)NNZ=NALF1
  7         NENL(K,1)=(J-1)*(NALF2+1)+I+1
  7         NENL(K,2)=J*(NALF2+1)+I+1+NNZ
  7         NENL(K,3)=NENL(K,2)-1
  7         NENL(K,4)=NENL(K,1)-1
  1    120   CONTINUE
  1   C
  7         NAL1=NATP1*NALF2
  7         DO 121 J=1,NATP2
  7         DO 121 I=1,NARGT
  7         K=(J-1)*NARGT+I+NAL1
  7         NENL(K,1)=(J-1)*(NARGT+1)+I+1+NPT1A
```

```
START
 COL   ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  7          NENL(K,2)=J*(NARGT+1)+I+1+NPT1A
  7          NENL(K,3)=NENL(K,2)-1
  7          NENL(K,4)=NENL(K,1)-1
  1    121    CONTINUE
  1    C
  1    C :::::::::::::::::::::::::::::::::::::::::::::::
  7          YDY=(YO-YMIN)/FLOAT(NALF2)
  7          ICON(1)=1
  7          ICON(NALF2+1)=NELF2+1
  7          DO 525 I=2,NALF2
  7          YDY1=(NALF2+1-I)*YDY
  7          DO 520 J=2,NELF2
  7          YINC1=YDY1-YY(J)+YMIN
  7          YINC2=YDY1-YY(J+1)+YMIN
  7          IF(YINC2.LT.O.)GOTO 520
  7          IF(ABS(YINC2).GE.ABS(YINC1))GOTO 521
  7          IF(ABS(YINC2).LT.ABS(YINC1))GOTO 522
  1    520   CONTINUE
  1    521   ICON(I)=J
  7          GOTO 525
  1    522   ICON(I)=J+1
  1    525   CONTINUE
  7          IF(NALF2.LE.2)GOTO 526
  7          DO 526 I=3,NALF2
  7          IF(ICON(I).EQ.ICON(I+1))ICON(I)=ICON(I)-1
  1    526   CONTINUE
  1    C
  7          XMID=(XO-XMIN)/2.
  7          XDX=(XO-XMIN)/FLOAT(NATP1)
  7          DO 535 I=2,NATP1
  7          XDX1=(I-1)*XDX
  7          DO 530 J=1,NETP1-1
  7          JJ1=J*(NELF2+1)+1
  7          JJ2=(J+1)*(NELF2+1)+1
  7          XINC1=XX(JJ1)-XDX1-XMIN
  7          XINC2=XX(JJ2)-XDX1-XMIN
  7          IF(XINC2.LT.O.)GOTO 530
  7          IF(ABS(XINC2).GE.ABS(XINC1))GOTO 531
  7          IF(ABS(XINC2).LT.ABS(XINC1))GOTO 532
  1    530   CONTINUE
  1    531   JJ=JJ1
  7          GOTO 533
  1    532   JJ=JJ2
  1    533   IF(NATP1.LE.2)GOTO 534
  7          LL=-1
  7          IF(XX(JJ).GT.XMID)LL=1
  7          JK=(I-2)*(NALF2+1)+1
  7          IF(ICON(JK).EQ.JJ)JJ=JJ+LL*(NELF2+1)
  1    534   ICON((I-1)*(NALF2+1)+1)=JJ
  7          DO 535 K=2,NALF2+1
  7          KK=(I-1)*(NALF2+1)+K
  7          ICON(KK)=ICON(K)+JJ-1
  1    535   CONTINUE
  1    C
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 7          ICON(NPT1A+1)=NPT1+1
 7          ICON(NPT1A+NALF1+1)=NPT1+NELF1+1
 7          YDY2=(YMAX-YO)/FLOAT(NALF1)
 7          DO 545 I=2,NALF1
 7          YDY3=(NALF1+1-I)*YDY2
 7          DO 540 J=1,NELF1-1
 7          YINC3=YDY3-YY(NPT1+J)+YO
 7          YINC4=YDY3-YY(NPT1+J+1)+YO
 7          IF(YINC4.LT.O.)GOTO 540
 7          IF(ABS(YINC4).GE.ABS(YINC3))GOTO 541
 7          IF(ABS(YINC4).LT.ABS(YINC3))GOTO 542
 1    540   CONTINUE
 1    541   ICON(NPT1A+I)=NPT1+J
 7          GOTO 545
 1    542   ICON(NPT1A+I)=NPT1+J+1
 1    545   CONTINUE
 7          IF(NALF1.LE.2)GOTO 546
 7          DO 546 I=2,NALF1
 7          J=NPT1A+I
 7          IF(ICON(J).EQ.ICON(J+1))ICON(J)=ICON(J)-1
 1    546   CONTINUE
 7          DO 547 I=2,NALF2+1
 7          ICON(NPT1A+NALF1+I)=NPT1+NELF1+ICON(I)
 1    547   CONTINUE
 1    C
 7          XDX2=(XMAX-XO)/FLOAT(NATP2)
 7          DO 555 I=2,NATP2
 7          XDX3=(I-1)*XDX2
 7          DO 550 J=2,NETP2
 7          JJ3=NPT1+J*(NERGT+1)+1
 7          JJ4=NPT1+(J+1)*(NERGT+1)+1
 7          XINC3=XX(JJ3)-XDX3-XO
 7          XINC4=XX(JJ4)-XDX3-XO
 7          IF(XINC4.LT.O.)GOTO 550
 7          IF(ABS(XINC4).GE.ABS(XINC3))GOTO 551
 7          IF(ABS(XINC4).LT.ABS(XINC3))GOTO 552
 1    550   CONTINUE
 1    551   JJ=JJ3
 7          GOTO 553
 1    552   JJ=JJ4
 1    553   IF(NATP2.LE.2)GOTO 554
 7          JK=NPT1A+(I-1)*(NARGT+1)
 7          IF(ICON(JK).EQ.JJ)JJ=JJ-(NERGT+1)
 1    554   ICON(NPT1A+(I-1)*(NARGT+1)+1)=JJ
 7          DO 555 K=2,NARGT+1
 7          KK=NPT1A+(I-1)*(NARGT+1)+K
 7          ICON(KK)=ICON(NPT1A+K)+JJ-NPT1-1
 1    555   CONTINUE
 1    C
 7          ICON(NT)=NGPT
 7          ICON(NT-NARGT)=NGPT-NERGT
 7          DO 556 I=2,NARGT
 7          J=NT-(NARGT+1)+I
 7          JDD=ICON(NPT1A+I)-ICON(NPT1A+I-1)
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  7           ICON(J)=ICON(J-1)+JDD
  1     556   CONTINUE
  1     C
  1     C ::::::::::::::::::::::::::::::::::::::::::::::::::
  7           J1=0
  7           DO 320 J=2,NATP1
  7           DO 320 I=1,NALF2+1
  7           J1=J1+1
  7           NODE(J1)=(J-1)*(NALF2+1)+I
  1     320   CONTINUE
  7           DO 321 I=1,NALF2
  7           J1=J1+1
  7           NODE(J1)=NPT1A+NALF1+1+I
  1     321   CONTINUE
  7           DO 322 J=2,NATP2+1
  7           DO 322 I=2,NARGT+1
  7           J1=J1+1
  7           J2=0
  7           IF(I.EQ.2)J2=1
  7           NODE(J1)=NODE(J1-1)+1+J2
  1     322   CONTINUE
  7           DO 323 I=1,2
  7           DO 323 J=1,NT1
  7           K=I*NT1+J
  7           NODE(K)=NODE(J)+I*NT
  1     323   CONTINUE
  7           DO 324 I=1,NT
  7           J=3*NT1+I
  7           NODE(J)=NODE(J-1)+1
  1     324   CONTINUE
  1     C
  1     C
  7           DO 350 I=1,6
  7           FFNX(I)=0.
  7           FFNY(I)=0.
  7           ABN(I)=0.
  7           ANN(I)=0.
  1     350   CONTINUE
  7           NBQ(1)=NALF2
  7           NBQ(2)=NABOT
  7           NBQ(3)=NARGT
  7           NBQ(4)=NATP2
  7           NBQ(5)=NALF1
  7           NBQ(6)=NATP1
  7           DO 360 I=1,6,2
  7           FFNX(I)=1.
  7           FFNY(I+1)=1.
  1     360   CONTINUE
  7           ABN(6)=1.
  7           ANN(3)=1.
  1     C
  1     C
  7           DO 371 J=1,NBQ(1)
  7           NC(1,J,1)=J
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  7          NC(1,J,2)=J+1
  1   371    CONTINUE
  1   C
  7          K=0
  7          NBDQ2=NALF2+1
  7          DO 372 J=1,NBQ(2)
  7          K=K+NBDQ2
  7          IF(J.GE.NATP1)NBDQ2=NARGT+1
  7          NC(2,J,1)=K
  7          NC(2,J,2)=K+NBDQ2
  1   372    CONTINUE
  1   C
  7          DO 373 J=1,NBQ(3)
  7          NC(3,J,1)=NT+1-J
  7          NC(3,J,2)=NT-J
  1   373    CONTINUE
  1   C
  7          DO 374 J=1,NBQ(4)
  7          NC(4,J,1)=NT-J*(NARGT+1)+1
  7          NC(4,J,2)=NC(4,J,1)-(NARGT+1)
  1   374    CONTINUE
  1   C
  7          DO 375 J=1,NBQ(5)
  7          NC(5,J,1)=NPT1A+J
  7          NC(5,J,2)=NPT1A+J+1
  1   375    CONTINUE
  1   C
  7          DO 376 J=1,NBQ(6)
  7          NBDQ6=0
  7          IF(J.EQ.1)NBDQ6=NALF1
  7          NC(6,J,1)=NPT1A+1-(J-1)*(NALF2+1)+NBDQ6
  7          NC(6,J,2)=NPT1A+1-J*(NALF2+1)
  1   376    CONTINUE
  1   C          PRINT INPUT DATA
  1   C
 11              WRITE(6,2000)
 11              WRITE(6,2001) REN,GAMMA
 11              WRITE(6,2002) DT,ERROR,ITMAX
 11              WRITE(6,2003) NEL,NGPT,NPT,NBW,NBW1,NBWT
  1   C
 11              WRITE(6,2004)
 11              DO 1  I=1,NEL
 11              WRITE(6,1003) (NENN(I,J),J=1,NPT)
  1   1          CONTINUE
  1   C
 11              WRITE(6,2005)
 11              WRITE(6,2006)
 11              DO 11 I=1,NGPT
 11              WRITE(6,1004) I,XX(I),YY(I),UU(I),VV(I),PP(I)
  1   11         CONTINUE
  1   C
 11              WRITE(6,2007)
 11              DO 12 I=1,NUX
 11              WRITE(6,1005) NU(I),UB(I)
```

```
  1   12          CONTINUE
 11               WRITE(6,2008)
 11               DO 13 I=1,NVY
 11               WRITE(6,1005) NV(I),VB(I)
  1   13          CONTINUE
 11               WRITE(6,2009)
 11               DO 14 I=1,NDP
 11               WRITE(6,1005) ND(I),PB(I)
  1   14          CONTINUE
  1   C
 11               WRITE(6,2010)
 11               DO 15 I=1,NTT
 11               WRITE(6,1006) I,NODE(I)
  1   15          CONTINUE
  1   C
 11               WRITE(6,2011)
 11               WRITE(6,2012)
 11               DO 16 I=1,NBP
 11               WRITE(6,1007) I,NBQ(I),FFNX(I),FFNY(I),ABN(I),ANN(I)
  1   16          CONTINUE
  1   C
 11               WRITE(6,2013)
 11               DO 17 I=1,NBP
 11               NB=NBQ(I)
 11               DO 17 J=1,NB
 11               WRITE(6,1008) (NC(I,J,K),K=1,2)
  1   17          CONTINUE
  1   C
  1   1003        FORMAT(4I5)
  1   1004        FORMAT(I5,5F10.5)
  1   1005        FORMAT(I5,F10.5)
  1   1006        FORMAT(2I5)
  1   1007        FORMAT(2I5,4F10.5)
  1   1008        FORMAT(2I5)
 11               RETURN
  1   2000        FORMAT(///,10X,'INPUT DATA',///)
  1   2001        FORMAT(5X,'REN=',E10.5,5X,'GAMMA=',F10.5)
  1   2002        FORMAT(5X,'DT=',F10.5,2X,'ERROR=',F10.5,2X,'ITMAX=',I5)
  1   2003        FORMAT(5X,'NEL=',I5,2X,'NGPT=',I5,2X,'NPT=',I5,2X,
  6        *              'NBW=',I5,2X,'NBW1=',I5,2X,'NBWT=',I5)
  1   2004        FORMAT(//,10X,'ELEMENT CONNECTIVITY MATRIX',/)
  1   2005        FORMAT(//,10X,'COORDINATE VALUE AT EACH GLOBAL NODE',/)
  1   2006        FORMAT(1X,'NO',7X,'XX',7X,'YY',7X,'UU',7X,'VV',7X,'PP',/)
  1   2007        FORMAT(//,10X,'BOUNDARY CONDITIONS FOR MEAN FLOW FIELDS',/)
  1   2008        FORMAT(/)
  1   2009        FORMAT(/)
  1   2010        FORMAT(//,10X,'ADJUSTMENT FOR BOUNDARY CONDITIONS',/)
  1   2011        FORMAT(//,10X,'NORMAL VELCTORS AND ADMITTANCES',/)
  1   2012        FORMAT(1X,'NO',3X,'NEQ',6X,'FFNX',6X,'FFNY',7X,'ABN',
  6        *              7X,'ANN',/)
  1   2013        FORMAT(//,10X,'BOUNDARY ELEMENT CONNECTIVITY MATRIX',/)
 11               END
  1   C
  1   C
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  1   C
 11         SUBROUTINE VELOT(NEL,NGPT,NPT,NBW1,NBWT,XX,YY,
  6        *                  UU,VV,PP,REN,DT,ERROR,
  6        * NENN,ICON,XT,YT,UT,VT,NBO,US,VS,DPP,DELU,DELV,FU,FV,
  6        *        A,B,NUX,NVY,NDP,NU,NV,ND,UB,VB,PB,NT,ITMAX)
  1   C
  1   C     VIRTUAL
  1   C
  1   C     SUBROUTINE FOR MEAN VELOCITY CALCULATIONS
  1   C
  1   C     A(NGPT,NBWT)     : GLOBAL BAND STIFFNESS MATRIX
  1   C     B(NGPT,NBWT)     : GLOBAL BAND STIFFNESS MATRIX
  1   C     FN(NGPT)         : GLOBAL FORCE MATRIX
  1   C     FV(NGPT)         : GLOBAL FORCE MATRIX
  1   C     US(NGPT)         : ESTIMATED U-VELOCITY
  1   C     VS(NGPT)         : ESTIMATED V-VELOCITY
  1   C     DPP(NGPT)        : PRESSURE CORRECTIONS
  1   C     DELU(NGPT)       : ACCELERATIONS IN X-DIRECTION
  1   C     DELV(NGPT)       : ACCELERATIONS IN Y-DIRECTION
  1   C     ST(4)            : GAUSSIAN POINTS OF GAUSSIAN QUADRTURE
  1   C     WS(4)            : WEIGHTING FUNCTIONS OF GAUSSIAN QUADRATURE
  1   C     ANM(NPT,NPT)     : LOCAL STIFFNESS MATRIX
  1   C     BNM(NPT,NPT)     : LOCAL STIFFNESS MATRIX
  1   C     CNM(NPT,NPT)     : LOCAL STIFFNESS MATRIX
  1   C     FNU(NPT)         : LOCAL FORCE MATRIX
  1   C     FNV(NPT)         : LOCAL FORCE MATRIX
  1   C     GN(NPT)          : LOCAL FORCE MATRIX
  1   C     HNU(NPT)         : LOCAL FORCE MATRIX
  1   C     HNV(NPT)         : LOCAL FORCE MATRIX
  1   C     SUM              : CONVERGENCE ERROR IN EACH ITERATION
  1   C     ITER             : COUNTER OF ITERATION
  1   C
 11         DIMENSION XX(NGPT),YY(NGPT),UU(NGPT),VV(NGPT),PP(NGPT)
 11         DIMENSION UB(NUX),VB(NVY),PB(NDP),WS(4),ST(4)
 11         DIMENSION NU(NUX),NV(NVY),ND(NDP)
  7     DIMENSION XT(NT),YT(NT),UT(NT),VT(NT)
 11         DIMENSION US(NGPT),VS(NGPT),DPP(NGPT),DELU(NGPT),DELV(NGPT)
 11         DIMENSION ANM(4,4),BNM(4,4),CNM(4,4),FNU(4),FNV(4),GN(4),
  6        *          HNU(4),HNV(4),A(NGPT,NBO),B(NGPT,NBO),
  6        *          FU(NGPT),FV(NGPT),NENN(NEL,4),ICON(NT)
  1   C
  1   C     CALL THE VALUES FOR GAUSSIAN QUADRATURE INTEGRATIONS
  1   C
 11         CALL GAUSS(4,WS,ST)
  1   C
 11         ITER=0
  1   C
  1   2000  CONTINUE
  1   C
 11         ITER=ITER+1
  1   C
  1   C     ESTIMATED VELOCITIES
  1   C
 11         DO 100 I=1,NGPT
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11             FU(I)=0.0
 11             FV(I)=0.0
 11             DO 100 J=1,NBWT
 11             A(I,J)=0.0
 11             B(I,J)=0.0
  1   100       CONTINUE
  1   C
 11             DO 200 I=1,NEL
 11             CALL ELEUV(I,NPT,NGPT,XX,YY,UU,VV,PP,REN,DT,NENN,
  6        *               ANM,FNU,FNV,WS,ST,NEL)
 11             DO 200 J=1,NPT
 11             JJ=NENN(I,J)
 11             FU(JJ)=FU(JJ)+FNU(J)
 11             FV(JJ)=FV(JJ)+FNV(J)
 11             DO 200 K=1,NPT
 11             KK=NENN(I,K)
 11             KKJJ=KK-JJ+NBW1
 11             A(JJ,KKJJ)=A(JJ,KKJJ)+ANM(J,K)
 11             B(JJ,KKJJ)=A(JJ,KKJJ)
  1   200       CONTINUE
  1   C
 11             CALL ADJUST(NUX,NGPT,NU,A,UB,FU,NBW1,NBWT)
 11             CALL ADJUST(NVY,NGPT,NV,B,VB,FV,NBW1,NBWT)
  1   C
 11             CALL GAUSU(A,FU,US,NGPT,NBW1,NBWT)
 11             CALL GAUSU(B,FV,VS,NGPT,NBW1,NBWT)
  1   C
  1   C         PRESSURE CORRECTIONS
  1   C
 11             DO 300 I=1,NGPT
 11             FU(I)=0.0
 11             DO 300 J=1,NBWT
 11             A(I,J)=0.0
  1   300       CONTINUE
  1   C
 11             DO 400 I=1,NEL
 11             CALL ELEPR(I,NPT,NGPT,XX,YY,US,VS,DT,BNM,GN,
  6        *               WS,ST,NEL,NENN)
 11             DO 400 J=1,NPT
 11             JJ=NENN(I,J)
 11             FU(JJ)=FU(JJ)+GN(J)
 11             DO 400 K=1,NPT
 11             KK=NENN(I,K)
 11             KKJJ=KK-JJ+NBW1
 11             A(JJ,KKJJ)=A(JJ,KKJJ)+BNM(J,K)
  1   400       CONTINUE
  1   C
 11             CALL ADJUST(NDP,NGPT,ND,A,PB,FU,NBW1,NBWT)
  1   C
 11             CALL GAUSU(A,FU,DPP,NGPT,NBW1,NBWT)
  1   C
  1   C         ACCELERATIONS
  1   C
 11             DO 500 I=1,NGPT
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11              FU(I)=0.0
 11              FV(I)=0.0
 11              DO 500 J=1,NBWT
 11              A(I,J)=0.0
 11              B(I,J)=0.0
  1   500        CONTINUE
  1   C
 11              DO 600 I=1,NEL
 11              CALL ELEAC(I,NPT,NGPT,XX,YY,DPP,CNM,HNU,HNV,
  6                        WS,ST,NEL,NENN)
 11              DO 600 J=1,NPT
 11              JJ=NENN(I,J)
 11              FU(JJ)=FU(JJ)+HNU(J)
 11              FV(JJ)=FV(JJ)+HNV(J)
 11              DO 600 K=1,NPT
 11              KK=NENN(I,K)
 11              KKJJ=KK-JJ+NBW1
 11              A(JJ,KKJJ)=A(JJ,KKJJ)+CNM(J,K)
 11              B(JJ,KKJJ)=A(JJ,KKJJ)
  1   600        CONTINUE
  1   C
 11              CALL GAUSU(A,FU,DELU,NGPT,NBW1,NBWT)
 11              CALL GAUSU(B,FV,DELV,NGPT,NBW1,NBWT)
  1   C
  1   C          CORRECTIONS OF PRESSURE AND VELOCITIES
  1   C
 11              DO 700 I=1,NGPT
 11              PP(I)=PP(I)+DPP(I)
 11              UU(I)=US(I)+DELU(I)*DT
 11              VV(I)=VS(I)+DELV(I)*DT
  1   700        CONTINUE
  1   C
  1   C          CALCULATOINS OF CONVERGENCE ERROR
  1   C
 11              SUM1=0.0
 11              SUM2=0.0
 11              DO 800 I=1,NGPT
 11              SUM1=SUM1+(DELU(I)*DT)**2
 11              SUM2=SUM2+UU(I)**2
  1   800        CONTINUE
 11              SUM=SQRT(SUM1/SUM2)
  1   C
 11              IF(ITER.GT.ITMAX) GO TO 3000
 11              IF(SUM.GT.ERROR) GO TO 2000
  1   C
  1   3000       CONTINUE
  1   C
 11              DO 900 I=1,NGPT
 11              UU(I)=US(I)
 11              VV(I)=VS(I)
  1   900        CONTINUE
  1   C
 11              DO 910 I=1,NT
 11              K=ICON(I)
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11              XT(I)=XX(K)
 11              YT(I)=YY(K)
 11              UT(I)=UU(K)
 11              VT(I)=VV(K)
  1   910        CONTINUE
  1   C
  1   C          OUTPUT FOR CONVERGED MEAN VELOCITY FIELDS
  1   C
 11              WRITE(6,5000) ITER,SUM
 11              WRITE(6,5010)
 11              DO 1200 I=1,NGPT
 11              WRITE(6,5020) I, XX(I),YY(I),UU(I),VV(I),PP(I)
  1   1200       CONTINUE
  1   C
 11              RETURN
  1   5000       FORMAT(/////,10X,'ITER=',2X,I5,5X,'ERROR=',2X,E15.8,//)
  1   5010       FORMAT(8X,'NO',4X,'XX',8X,'YY',14X,'UU',13X,'VV',
  6        *            13X,'PP')
  1   5020       FORMAT(5X,I5,2F10.5,3E15.5)
 11              END
  1   C
  1   C
 11              SUBROUTINE EIPRE(NL,NT,NPT,NENL,FRE,PRESS,
  6        * XT,YT,TARR1,A1,B1,CZZ1,EIGAV,EIGBV,EIGV,ITER)
  1   C          VIRTUAL
  1   C
  1   C          SUBROUTINE FOR ACOUSTIC MODES
  1   C
  1   C          FRE(NGPT)         : ACOUSTIC FREQUENCIES
  1   C          PRESS(NGPT,NGPT): ACOUSTIC MODES
  1   C          A1(NGPT,NGPT)      : LEFT-HAND-SIDE GLOBAL EIGENMATRIX
  1   C          B1(NGPT,NGPT)      : RIGHT-HAND-SIDE GLOBAL EIGENMATRIX
  1   C          CZZ1(NGPT,NGPT) : SOLUTIONS OF EIGENVECTORS
  1   C          EIGAV(NGPT)       : SOLUTIONS OF EIGENVECTORS
  1   C          EIGBV(NGPT)       : SOLUTIONS OF EIGENVECTORS
  1   C          EIGV(NGPT)        : EIGAV(NGPT)/EIGBV(NGPT)
  1   C          ANM(NPT,NPT)       : LEFT-HAND-SIDE LOCAL EIGENMATRIX
  1   C          BNM(NPT,NPT)       : RIGHT-HAND-SIDE LOCAL EIGENMATRIX
  1   C
  7         DIMENSION XT(NT),YT(NT)
 11              DIMENSION TARR1(NT),WS(4),ST(4),ANM(4,4),BNM(4,4)
  6        *,     NENL(NL,4),FRE(NT),PRESS(NT,NT)
 11              COMPLEX    A1(NT,NT),B1(NT,NT),CZZ1(NT,NT),EIGAV(NT),
  6        *                EIGBV(NT),EIGV(NT)
 11              INTEGER    ITER(NT)
  1   C
 11              CALL GAUSS(4,WS,ST)
  1   C
  1   C          INITIALIZATION OF ALL GLOBAL MATRICES
  1   C
 11              DO 190 I=1,NT
 11              DO 190 J=1,NT
 11              A1(I,J)=(0.0,0.0)
 11              B1(I,J)=(0.0,0.0)
```

```
START
 COL   ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

   1  190        CONTINUE
   1  C
   1  C          ASSEMBLY OF GLOBAL MATRICES
   1  C
  11             DO 200 I=1,NL
  11             CALL ELEMP(I,NPT,ANM,BNM,WS,ST,NL,NT,NENL,
   6       *               XT,YT)
   1  C
  11             DO 200 J=1,NPT
  11             JJ=NENL(I,J)
  11             DO 200 K=1,NPT
  11             KK=NENL(I,K)
  11             A1(JJ,KK)=A1(JJ,KK)+CMPLX(ANM(J,K),0.0)
  11             B1(JJ,KK)=B1(JJ,KK)+CMPLX(BNM(J,K),0.0)
   1  200        CONTINUE
   1  C
   1  C          APPLY EIGENVALUE SUBROUTINE IN IMSL
   1  C
  11             CALL CONVRT(NT,A1,NT,B1,NT,CZZ1,NT)
  11             CALL SOLVE(NT,A1,NT,B1,NT,CZZ1,NT,ITER,EIGAV,EIGBV)
   1  C
   1  C          OBTAIN EIVENVALUES AND EIGENVECTORS
   1  C
  11             DO 220 IEG=1,NT
  11             IF(EIGBV(IEG).EQ.0.0) GO TO 220
  11             EIGV(IEG)=EIGAV(IEG)/EIGBV(IEG)
  11             FRE(IEG)=SQRT(ABS(REAL(EIGV(IEG))))
  11             DO 221 IEF=1,NT
  11             PRESS(IEF,IEG)=REAL(CZZ1(IEF,IEG))
   1  221        CONTINUE
   1  220        CONTINUE
   1  C
   1  C          SORTING PROCESS
   1  C
  11             NN=NT-1
  11             DO 4000 K=1,NN
  11             JJ=NT-K
  11             DO 410 L=1,JJ
  11             IF(FRE(L).LE.FRE(L+1)) GO TO 410
  11             TEMP=FRE(L)
  11             FRE(L)=FRE(L+1)
  11             FRE(L+1)=TEMP
  11             DO 420 NP=1,NT
  11             TARR1(NP)=PRESS(NP,L)
  11             PRESS(NP,L)=PRESS(NP,L+1)
  11             PRESS(NP,L+1)=TARR1(NP)
   1  420        CONTINUE
   1  410        CONTINUE
   1  4000       CONTINUE
   1  C
   1  C          OUTPUT FOR ACOUSTIC FREQUENCIES AND THEIR MODES
   1  C
  11             WRITE(6,1000)
  11             DO 500 I=1,NT
```

```
START
 COL   ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11              WRITE(6,1001) I,FRE(I)
  1   500        CONTINUE
 11              WRITE(6,1002)
 11              DO 501 I=1,NT
 11              WRITE(6,1003) I-1,FRE(I)
 11              WRITE(6,1013)
 11              DO 502 J=1,NT
 11              WRITE(6,1004) J,XT(J),YT(J),PRESS(J,I)
  1   502        CONTINUE
 11              WRITE(6,1005)
  1   501        CONTINUE
  1   C
 11              RETURN
  1   1000       FORMAT(//,10X,'ACOUSTIC FREQUENCIES',/)
  1   1001       FORMAT(15X,I5,E15.5)
  1   1002       FORMAT(//,10X,'LOWEST TWENTY ACOUSTIC MODES',/)
  1   1003       FORMAT(10X,I5,'-TH ACOUSTIC MODE',5X,'FRE = ',E15.5)
  1   1013       FORMAT(8X,'NO',4X,'XX',8X,'YY',14X,'PRESS')
  1   1004       FORMAT(5X,I5,2F10.5,E15.5)
  1   1005       FORMAT(//)
 11              END
  1   C
  1   C
  1   C
 11              SUBROUTINE EIVOR(NL,NT,NPT,REN,NTT,NODE,MVP,MI,MII,'
  6         * SR,SI,FV1,A2,B2,C,D,CZZ2,EIGAV2,EIGBV2,EIGV2,ITER2,
  6         * NENL,FVE,UUR,UUI,VVR,VVI,XT,YT,UT,VT)
  1   C          VIRTUAL
  1   C
  1   C          SUBROUTINE FOR VORTICAL MODES
  1   C
  1   C          MVP              : NUMBER OF USEFUL VORTICAL EIGENMODES
  1   C          FVE(MVP)         : VORTICAL  FREQUENCIES
  1   C          UUR(NT,MVP)      : REAL PART OF VORTICAL DISTURBANCES OF
  1   C                             U-VELOCITY
  1   C          VVR(NT,MVP)      : REAL PART OF VORTICAL DISTURBANCES OF
  1   C                             V-VELOCITY
  1   C          UUI(NT,MVP)      : IMAGINARY PART OF VORTICAL DISTURBANCES OF
  1   C                             U-VELOCITY
  1   C          VVI(NT,MVP)      : IMAGINARY PART OF VIRTICAL DISTURBANCES OF
  1   C                             V-VELOCITY
  1   C          C(NTT,NTT)       : LEFT-HAND-SIDE GLOBAL EIGENMATRIX
  1   C          D(NTT,NTT)       : RIGHT-HAND-SIDE GLOBAL EIGENMATRIX
  1   C          CZZ2(NTT,NTT)    : SOLUTIONS OF EIGENVECTORS
  1   C          EIGAV2(NTT)       : SOLUTIONS OF EIGENVALUES
  1   C          EIGBV2(NTT)       : SOLUTIONS OF EIGENVALUES
  1   C          EIGV2(NTT)        : EIGAV2(NTT)/EIGBV2(NTT)
  1   C          SR(4*NT,4*NT)    : REAL PART OF CZZ2(NTT,NTT)
  1   C          SI(4*NT,4*NT)    : IMAGINARY PART OF CZZ2(NTT,NTT)
  1   C          ANM(4,4,4,4)     : LEFT-HAND-SIDE OF LOCAL EIGENMATRIX
  1   C          BNM(4,4,4,4)     : RIGHT-HAND-SIDE OF LOCAL EIGENMATRIX
  1   C
  7         DIMENSION XT(NT),YT(NT),UT(NT),VT(NT)
 11              DIMENSION SR(MII,NTT),SI(MII,NTT),NODE(NTT)
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11          DIMENSION ANM(4,4,4,4),BNM(4,4,4,4),FV1(MII),NENL(NL,4),
  6        * FVE(MI),UUR(NT,MI),UUI(NT,MI),VVR(NT,MI),VVI(NT,MI)
 11          COMPLEX A2(MII,MII),B2(MII,MII),C(NTT,NTT),D(NTT,NTT),
  6        *         CZZ2(NTT,NTT),EIGAV2(NTT),EIGBV2(NTT),EIGV2(NTT)
 11          INTEGER   ITER2(NTT)
  1   C
 11          CALL GAUSS(4,WS,ST)
  1   C
  1   C      INITIALIZATION OF GLOBAL MATRICES
  1   C
  7        NT4=NT*4
  7        NT2=NT*2
 11          DO 1 I=1,NT4
 11          DO 1 J=1,NT4
 11          A2(I,J)=(0.0,0.0)
 11          B2(I,J)=(0.0,0.0)
  1   1      CONTINUE
  1   C
 11          DO 111 I=1,NTT
 11          DO 111 J=1,NT
 11          C(I,J)=(0.0,0.0)
 11          D(I,J)=(0.0,0.0)
  1   111    CONTINUE
  1   C
 11          DO 112 I=1,NT4
 11          DO 112 J=1,NTT
 11          SR(I,J)=0.0
 11          SI(I,J)=0.0
  1   112    CONTINUE
  1   C
  1   C      ASSEMBLY OF GLOBAL MATRICES
  1   C
 11          DO 2 I=1,NL
 11          CALL ELEVR(I,NPT,ANM,BNM,WS,ST,REN,NL,NT,NENL,
  6        *           XT,YT,UT,VT)
 11          DO 2 L=1,4
  7        LNT=(L-1)*NT
 11          DO 2 J=1,NPT
 11          JJ=NENL(I,J)+LNT
 11          DO 2 LL=1,4
  7        LLNT=(LL-1)*NT
 11          DO 2 K=1,NPT
 11          KK=NENL(I,K)+LLNT
 11          A2(JJ,KK)=A2(JJ,KK)+CMPLX(ANM(L,LL,J,K),0.0)
 11          B2(JJ,KK)=B2(JJ,KK)+CMPLX(BNM(L,LL,J,K),0.0)
  1   2      CONTINUE
  1   C
  1   C      APPLY BOUNDARY CONDITIONS
  1   C
 11          DO 20 I=1,NTT
 11          DO 20 J=1,NTT
 11          C(I,J)=A2(NODE(I),NODE(J))
 11          D(I,J)=B2(NODE(I),NODE(J))
  1   20     CONTINUE
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  1   C
 11              CALL CONVRT(NTT,C,NTT,D,NTT,CZZ2,NTT)
 11              CALL SOLVE(NTT,C,NTT,D,NTT,CZZ2,NTT,ITER2,EIGAV2,EIGBV2)
  1   C
  1   C          OBTAIN EIGENVALUES AND CORRESPONDING EIGENMODES
  1   C
 11              DO 3 IEG=1,NTT
 11              IF(EIGBV2(IEG) .EQ. 0.0) GO TO 3
 11              EIGV2(IEG)=EIGAV2(IEG)/EIGBV2(IEG)
 11              FV1(IEG)=AIMAG(EIGV2(IEG))
 11              DO 4 IEF=1,NTT
 11              SR(NODE(IEF),IEG)=REAL(CZZ2(IEF,IEG))
 11              SI(NODE(IEF),IEG)=AIMAG(CZZ2(IEF,IEG))
  1   4          CONTINUE
  1   3          CONTINUE
  1   C
  1   C          SORTING PROCESS
  1   C
 11              NN=NTT-1
 11              DO 5 K=1,NN
 11              JJ=NTT-K
 11              DO 6 L=1,JJ
 11              IF(FV1(L).LT.FV1(L+1)) GO TO 6
 11              TEMP=FV1(L)
 11              FV1(L)=FV1(L+1)
 11              FV1(L+1)=TEMP
 11              DO 7 NP=1,NT4
 11              TR=SR(NP,L)
 11              TI=SI(NP,L)
 11              SR(NP,L)=SR(NP,L+1)
 11              SI(NP,L)=SI(NP,L+1)
 11              SR(NP,L+1)=TR
 11              SI(NP,L+1)=TI
  1   7          CONTINUE
  1   6          CONTINUE
  1   5          CONTINUE
  1   C
 11              IP=0
 11              DO 8 I=1,NTT
 11              IF(FV1(I).LT.0.01) GO TO 8
 11              IP=IP+1
 11              FVE(IP)=FV1(I)
 11              DO 9 J=1,NT
 11              UUR(J,IP)=SR(NT2+J,I)
 11              UUI(J,IP)=SI(NT2+J,I)
 11              VVR(J,IP)=-SR(NT+J,I)
 11              VVI(J,IP)=-SI(NT+J,I)
  1   9          CONTINUE
  1   8          CONTINUE
  1   C
 11              MVP=IP
  1   C
  1   C          OUTPUT FOR VORTICAL MODES
  1   C
```

```
START
 COL   ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11              WRITE(6,999)
 11              DO 10 I=1,20
 11              WRITE(6,1000) I,FVE(I)
 11              WRITE(6,1010)
 11              DO 11 J=1,NT
 11              WRITE(6,1001) J,XT(J),YT(J),UUR(J,I),UUI(J,I),
  6          *                VVR(J,I),VVI(J,I)
  1   11         CONTINUE
  1   10         CONTINUE
  1   C
 11              RETURN
  1   999        FORMAT(/////,10X,'LOWEST TWENTY VORTICAL MODES',/)
  1   1000       FORMAT(/////,I5,'-TH VORTICAL MODE',5X,
  6          *          'STROUHAL NO. =',E10.5,/)
  1   1010       FORMAT(3X,'NO',5X,'XT',8X,'YT',9X,'UUR',12X,'UUI',
  6          *          12X,'VVR',12X,'VVI')
  1   1001       FORMAT(I5,2F9.5,4E14.5)
 11              END
  1   C
  1   C
  1   C
 11              SUBROUTINE SURFCE(IK,IG,NBP,FFNX,FFNY,ABN,ANN,NC1,
  6          *           NC,FRE,PRESS,FVE,UUR,UUI,VVR,VVI,
  6          *                     NT,AAA,AAB,
  6          *                     AHB,AHC,REN,GAMMA,NBQ,MI,
  6          *             XT,YT,UT,VT)
  1   C      VIRTUAL
  1   C
  1   C
  1   C          STABILITY INTEGRALS AT THE SURFACES
  1   C
  1   C          IK                : COUNTER OF ACOUSTIC MODES
  1   C          IG                : COUNTER OF VIRTICAL MODES
  1   C          AAA               : (A)-TERM OF ACOUSTIC GROWTH CONSTANT
  1   C          AAB               : (B)-TERM OF ACOUSTIC GROWTH CONSTANT
  1   C          AHB               : (B)-TERM OF VORTICALLY COUPLED ACOUSTIC
  1   C                              GROWTH CONSTANT
  1   C          AHC               : (C)-TERM OF VORTICALLY COUPLED ACOUSTIC
  1   C                              GROWTH CONSTANT
  1   C          X(2)              : LOCAL BOUNDARY X-COORDINATES
  1   C          Y(2)              : LOCAL BOUNDARY Y-COORDINATES
  1   C          U(2)              : LOCAL BOUNDARY MEAN VELOCITY IN X-DIRECTION
  1   C          V(2)              : LOCAL BOUNDARY MEAN VELOCITY IN Y-DIRECTION
  1   C          P(2)              : LOCAL BOUNDARY ACOUSTIC MODES
  1   C          UR(2)             : LOCAL BOUNDARY VALUE OF REAL PART OF VORTICAL
  1   C                              DISTURBANCES IN X-DIRECTION
  1   C          VR(2)             : LOCAL BOUNDARY VALUE OF REAL PART OF VORTICAL
  1   C                              DISTURBANCES IN Y-DIRECTION
  1   C          UI(2)             : LOCAL BOUNDARY VALUE OF IMAGINARY PART OF
  1   C                              VORTICAL DISTURBANCES IN X-DIRECTION
  1   C          VI(2)             : LOCAL BOUNDARY VALUE OF IMAGINARY PART OF
  1   C                              VORTICAL DISTURBANCES IN Y-DIRECTION
  1   C          FI(2)             : INTERPOLATION FUNCTIONS IN BOUNDARY ELEMENT
  1   C          DS(2)             : FIRST DERIVATIVES OF INTERPOLATION FUNCTIONS
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8
  1   C                          IN BOUNDARY ELEMENT
  1   C
  7         DIMENSION XT(NT),YT(NT),UT(NT),VT(NT)
 11             DIMENSION FFNX(NBP),FFNY(NBP),ABN(NBP),ANN(NBP),NBQ(NBP)
 11             DIMENSION U(2),V(2),
  6        *             WS(4),ST(4),X(2),Y(2),P(2),UI(2),VI(2),FI(2),DS(2)
 11             DIMENSION UR(2),VR(2),NC(NBP,NC1,2),FRE(NT),PRESS(NT,NT),
  6        * FVE(MI),UUR(NT,MI),UUI(NT,MI),VVR(NT,MI),VVI(NT,MI)
  1   C
 11             CALL GAUSS(4,WS,ST)
  1   C
 11             FR=FRE(IK)
  7         FRINV=1./FR
  7         FR2INV=FRINV*FRINV
  7         RFRINV=FRINV/REN
 11             FV3=FVE(IG)
  1   C
  1   C         INITIALIZATIONS
  1   C
 11             AAA=0.0
 11             AAB=0.0
 11             AHB=0.0
 11             AHC=0.0
  1   C
  1   C         REPEAT INTEGRATION IN EACH BOUNDARY AREA
  1   C
 11             DO 1 IB=1,NBP
  1   C
 11             IF(IB.EQ.2) GO TO 1
  1   C
  1   C         NECESSARY INFORMATION IN EACH BOUNDARY AREA
  1   C
 11             FNX=FFNX(IB)
 11             FNY=FFNY(IB)
 11             NB = NBQ(IB)
 11             AB = ABN(IB)
 11             AN = ANN(IB)
  1   C
 11             DO 2 IC=1,NB
  1   C
 11             DO 10 N=1,2
 11             NN=NC(IB,IC,N)
 11             X(N)=XT(NN)
 11             Y(N)=YT(NN)
 11             U(N)=UT(NN)
 11             V(N)=VT(NN)
 11             P(N)=PRESS(NN,IK)
 11             UR(N)=UUR(NN,IG)
 11             VR(N)=VVR(NN,IG)
 11             UI(N)=UUI(NN,IG)
 11             VI(N)=VVI(NN,IG)
  1   10        CONTINUE
  1   C
 11             IF(FNX .EQ. 0.0) DTA=0.5*ABS(X(2)-X(1))
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11             IF(FNY .EQ. 0.0) DTA=0.5*ABS(Y(2)-Y(1))
  7         DTINV5=-.5/DTA
  1   C
 11             DO 100 K=1,4
 11             XI=ST(K)
 11             ACOF=WS(K)
  1   C
  1   C         INTERPOLATION FUNCTIONS AT THE BOUNDARY ELEMENT
  1   C
 11             FI(1)=0.5*(1.0-XI)
 11             FI(2)=0.5*(1.0+XI)
  1   C
 11             DS(1)=DTINV5
 11             DS(2)=-DS(1)
  1   C
 11             YP=0.0
 11             SU=0.0
 11             SV=0.0
 11             PN=0.0
 11             PS=0.0
 11             SUI=0.0
 11             SUIS=0.0
 11             SVIS=0.0
  1   C
 11             DO 110 N=1,2
 11             YP=YP+FI(N)*Y(N)
 11             SU=SU+FI(N)*U(N)
 11             SV=SV+FI(N)*V(N)
 11             PN=PN+FI(N)*P(N)
 11             PS=PS+DS(N)*P(N)
 11             SUI=SUI+FI(N)*UI(N)
 11             SVI=SVI+FI(N)*VI(N)
 11             SUIS=SUIS+DS(N)*UI(N)
 11             SVIS=SVIS+DS(N)*VI(N)
  1   110       CONTINUE
  1   C
 11             C=3.14159*YP*ACOF*DTA
  1   C
 11             AAA=AAA+C*((AB-AN)*PN*PN+(GAMMA+1.0)*(SU*FNX+SV*FNY)*PN*PN)
 11             AAB=AAB-C*(SU*FNX+SV*FNY)*PS*PS*FR2INV
 11             AHB=AHB+C*GAMMA*(2.0*(SU*SUI*PS*FNX+SV*SVI*PS*FNY)
  6        *                +(SU*SVI+SV*SUI)*PS*(FNX+FNY))*FRINV
 11             AHC=AHC+C*(SVIS*PS*FNX+SUIS*PS*FNY)*RFRINV
  1   100       CONTINUE
  1   C
  1   2         CONTINUE
  1   1         CONTINUE
  1   C
 11             RETURN
 11             END
  1   C
  1   C
  1   C
 11             SUBROUTINE VOLUME(IK,IG,NPT,NL,NT,EN,AAD,AAE,AAF,
```

```
  6        *           NENL,FRE,PRESS,UUR,UUI,VVR,VVI,
  6        *                  AHE,AHF,AHG,REN,GAMMA,MI,XT,YT,UT,VT)
  1   C         VIRTUAL
  1   C
  1   C         STABILITY INTEGRALS IN THE VOLUME
  1   C
  1   C         IK                : COUNTER OF ACOUSTIC MODES
  1   C         IG                : COUNTER OF VORTICAL MODES
  1   C         EN                : DENOMINATOR OF EACH STABILITY INTEGRAL TERM
  1   C         AAD               : (D)-TERM OF ACOUSTIC GROWTH CONSTANT
  1   C         AAE               : (E)-TERM OF ACOUSTIC GROWTH CONSTANT
  1   C         AAF               : (F)-TERM OF ACOUSTIC GROWTH CONSTANT
  1   C         AHE               : (E)-TERM OF VORTICALLY COUPLED ACOUSTIC
  1   C                             GROWTH CONSTANT
  1   C         AHF               : (F)-TERM OF VORTICALLY COUPLED ACOUSTIC
  1   C                             GROWTH CONSTANT
  1   C         AHG               : (G)-TERM OF VORTICALLY COUPLED ACOUSTIC
  1   C                             GROWTH CONSTANT
  1   C         X(NPT)            : LOCAL X-COORDINATES
  1   C         Y(NPT)            : LOCAL Y-COORDINATES
  1   C         U(NPT)            : LOCAL VALUES OF MEAN VELOCITIES IN
  1   C                             X-DIRECTION
  1   C         V(NPT)            : LOCAL VALUES OF MEAN VELOCITIES IN
  1   C                             Y-DIRECTION
  1   C         P(NPT)            : LOCAL VALUES OF ACOUSTIC MODES
  1   C         UR(NPT)           : LOCAL VALUES OF REAL PART OF VORTICAL
  1   C                             DISTURBANCES IN X-DIRECTION
  1   C         VR(NPT)           : LOCAL VALUES OF REAL PART OF VORTICAL
  1   C                             DISTURBANCES IN Y-DIRECTION
  1   C         UI(NPT)           : LOCAL VALUES OF IMAGINARY PART OF
  1   C                             VORTICAL DISTURBANCES IN X-DIRECTION
  1   C         VI(NPT)           : LOCAL VALUES OF IMAGINARY PART OF
  1   C                             VORTICAL DISTURBANCES IN Y-DIRECTION
  1   C         FI(NPT)           : INTERPOLATION FUNCTIONS
  1   C         DX(NPT)           : FIRST DERIVATIVES OF INIERPOLATION
  1   C                             FUNCTIONS IN X-DIRECTION
  1   C         DY(NPT)           : FIRST DERIVATIVES OF INTERPOLATION
  1   C                             FUNCTIONS IN Y-DIRECTION
  1   C         DXX(NPT)          : SECOND DERIVATIVES OF INTERPOLATION
  1   C                             FUNCTIONS IN X-DIRECTION
  1   C         DXY(NPT)          : SECOND DERIVATIVES OF INTERPOLATION
  1   C                             FUNCTIONS IN X- AND Y-DIRECTION
  1   C         DYY(NPT)          : SECOND DERIVATIVES OF INTERPOALTION
  1   C                             FUNCTIONS IN Y-DIRECTION
  1   C
  7         DIMENSION XT(NT),YT(NT),UT(NT),VT(NT)
 11             DIMENSION X(4),Y(4),U(4),V(4),P(4),UR(4),VR(4),UI(4),VI(4),
  6        *             FI(4),DX(4),DY(4),AA(4),AB(4),DXX(4),DXY(4),
  6        *             DYY(4),WS(4),ST(4),NENL(NL,4),FRE(NT),PRESS(NT,NT),
  6        * UUR(NT,MI),UUI(NT,MI),VVR(NT,MI),VVI(NT,MI)
  1   C
 11             CALL GAUSS(4,WS,ST)
  1   C
 11             FR=FRE(IK)
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  7         RENINV=1./REN
  7         FRINV=1./FR
  7         FR2INV=FRINV*FRINV
  7         RFRINV=FRINV*RENINV
  7         RF2INV=RENINV*FR2INV
  7         RN3INV=RENINV/3.
  1   C
  1   C         INITAILIZATIONS
  1   C
 11             EN=0.0
 11             AAD=0.0
 11             AAE=0.0
 11             AAF=0.0
 11             AHE=0.0
 11             AHF=0.0
 11             AHG=0.0
  1   C
  1   C         VOLUME INTEGRATIONS
  1   C
 11             DO 1 MMM=1,NL
  1   C
 11             DO 10 N=1,NPT
 11             NN=NENL(MMM,N)
 11             X(N)=XT(NN)
 11             Y(N)=YT(NN)
 11             U(N)=UT(NN)
 11             V(N)=VT(NN)
 11             P(N)=PRESS(NN,IK)
 11             UR(N)=UUR(NN,IG)
 11             VR(N)=VVR(NN,IG)
 11             UI(N)=UUI(NN,IG)
 11             VI(N)=VVI(NN,IG)
  1   10        CONTINUE
  1   C
 11             DO 20 K=1,4
 11             DO 20 L=1,4
 11             XI=ST(K)
 11             ETA=ST(L)
 11             ACOF=WS(K)*WS(L)
  1   C
 11             CALL INTER(XI,ETA,NPT,X,Y,DX,DY,FI,DTA,AA,AB)
  1   C
 11             CALL QUADR(AA,AB,X,Y,DX,DY,DXX,DXY,DYY,NPT)
  1   C
 11             YP=0.0
 11             PRN=0.0
 11             PRX=0.0
 11             PRY=0.0
 11             PRXX=0.0
 11             PRXY=0.0
 11             PRYY=0.0
 11             UNN=0.0
 11             UNX=0.0
 11             UNY=0.0
```

```
START
 COL   ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  11            VNN=0.0
  11            VNX=0.0
  11            VNY=0.0
  11            URN=0.0
  11            URX=0.0
  11            URY=0.0
  11            VRN=0.0
  11            VRX=0.0
  11            VRY=0.0
  11            UIN=0.0
  11            UIX=0.0
  11            UIY=0.0
  11            VIN=0.0
  11            VIX=0.0
  11            VIY=0.0
   1    C
  11            DO 30 N=1,NPT
  11            YP=YP+FI(N)*Y(N)
  11            PRN=PRN+FI(N)*P(N)
  11            PRX=PRX+DX(N)*P(N)
  11            PRY=PRY+DY(N)*P(N)
  11            PRXX=PRXX+DXX(N)*P(N)
  11            PRXY=PRXY+DXY(N)*P(N)
  11            PRYY=PRYY+DYY(N)*P(N)
  11            UNN=UNN+FI(N)*U(N)
  11            UNX=UNX+DX(N)*U(N)
  11            UNY=UNY+DY(N)*U(N)
  11            VNN=VNN+FI(N)*V(N)
  11            VNX=VNX+DX(N)*V(N)
  11            VNY=VNY+DY(N)*V(N)
  11            URN=URN+FI(N)*UR(N)
  11            URX=URX+DX(N)*UR(N)
  11            URY=URY+DY(N)*UR(N)
  11            VRN=VRN+FI(N)*VR(N)
  11            VRX=VRX+DX(N)*VR(N)
  11            VRY=VRY+DY(N)*VR(N)
  11            UIN=UIN+FI(N)*UI(N)
  11            UIX=UIX+DX(N)*UI(N)
  11            UIY=UIY+DY(N)*UI(N)
  11            VIN=VIN+FI(N)*VI(N)
  11            VIX=VIX+DX(N)*VI(N)
  11            VIY=VIY+DY(N)*VI(N)
   1    30      CONTINUE
   1    C
  11            C=3.14159*YP*ACOF*DTA
   1    C
  11            EN=EN+C*2.0*PRN*PRN
  11            AAD=AAD-C*(2.0*GAMMA+1.0)*PRN*(UNN*PRX+VNN*PRY)
  11            AAE=AAE+C*(-(UNN*PRX+VNN*PRY)*PRN
   6       *              +2.0*(UNN*PRX*PRXX+VNN*PRY*PRYY
   6       *                   +(UNN*PRX+VNN*PRY)*PRXY)*FR2INV)
  11            AAF=AAF-C*((PRXX*PRXX+2.0*PRXY*PRXY+PRYY*PRYY)*RF2INV
   6       *              +FR*FR*PRN*PRN*RN3INV)
  11            AHE=AHE+2.0*C*GAMMA*(UNN*UIN*PRXX+VNN*VIN*PRYY
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  6        *                +(UNN*VIN+VNN*UIN)*PRXY)*FRINV
 11              AHF=AHF-C*GAMMA*(UIX*PRXX+VIX*PRYY+(UIY+VIX)*PRXY)*RFRINV
 11              AHG=AHG+2.0*C*GAMMA*(GAMMA-1.0)
  6        *                *(2.0*(UNX*URX+VNY*VRY)
  6        *                 +(UNY+VNX)*(URY+VRX))*RENINV
  1   20         CONTINUE
  1   C
  1   1          CONTINUE
  1   C
 11              RETURN
 11              END
  1   C
  1   C
  1   C
 11              SUBROUTINE ELEUV(MMM,NPT,NGPT,XX,YY,UU,VV,PP,
  6        *                    REN,DT,NENN,ANM,FNU,FNV,WS,ST,NEL)
  1   C
  1   C          LOCAL MATRICES FOR VELOCITIES
  1   C
 11              DIMENSION XX(NGPT),YY(NGPT),UU(NGPT),VV(NGPT),PP(NGPT)
 11              DIMENSION ANM(4,4),FNU(4),FNV(4),WS(4),ST(4)
 11              DIMENSION X(4),Y(4),FI(4),DX(4),DY(4),AA(4),AB(4),
  6        *               U(4),V(4),P(4),NENN(NEL,4)
  1   C
  7         RENINV=1./REN
  7         DTINV=1./DT
  1   C
 11              DO 1 N=1,NPT
 11              NN=NENN(MMM,N)
 11              X(N)=XX(NN)
 11              Y(N)=YY(NN)
 11              U(N)=UU(NN)
 11              V(N)=VV(NN)
 11              P(N)=PP(NN)
  1   1          CONTINUE
  1   C
 11              DO 2 N=1,NPT
 11              FNU(N)=0.0
 11              FNV(N)=0.0
 11              DO 2 M=1,NPT
 11              ANM(N,M)=0.0
  1   2          CONTINUE
  1   C
 11              DO 300 K=1,4
 11              DO 300 L=1,4
 11              XI=ST(K)
 11              ETA=ST(L)
 11              ACOF=WS(K)*WS(L)
  1   C
 11              CALL INTER(XI,ETA,NPT,X,Y,DX,DY,FI,DTA,AA,AB)
  1   C
 11              SSU=0.0
 11              SSV=0.0
 11              SXP=0.0
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11            SYP=0.0
 11            YP=0.0
  1   C
 11            DO 301 N=1,NPT
 11            SSU=SSU+FI(N)*U(N)
 11            SSV=SSV+FI(N)*V(N)
 11            SXP=SXP+DX(N)*P(N)
 11            SYP=SYP+DY(N)*P(N)
 11            YP =YP +FI(N)*Y(N)
  1   301      CONTINUE
  1   C
 11            C=ACOF*DTA*YP
  1   C
 11            DO 500 N=1,NPT
  7         CFIN=C*FI(N)
 11            FNU(N)=FNU(N)+CFIN*(SSU*DTINV-SXP)
 11            FNV(N)=FNV(N)+CFIN*(SSV*DTINV-SYP)
 11            DO 500 M=1,NPT
 11            ANM(N,M)=ANM(N,M)+CFIN*(FI(M)*DTINV+SSU*DX(M)+SSV*DY(M))
  6        *                     +C*(DX(N)*DX(M)+DY(N)*DY(M))*RENINV
  1   500      CONTINUE
  1   300      CONTINUE
  1   C
 11            RETURN
 11            END
  1   C
  1   C
 11            SUBROUTINE ELEPR(MMM,NPT,NGPT,XX,YY,US,VS,
  6        *                     DT,BNM,GN,WS,ST,NEL,NENN)
  1   C
  1   C        LOCAL MATRICES FOR PRESSURE CORRECTIONS
  1   C
 11            DIMENSION XX(NGPT),YY(NGPT),US(NGPT),VS(NGPT)
 11            DIMENSION BNM(4,4),GN(4),WS(4),ST(4),NENN(NEL,4)
 11            DIMENSION X(4),Y(4),FI(4),DX(4),DY(4),AA(4),AB(4),U(4),V(4)
  1   C
  7         DTINV=1./DT
 11            DO 1 N=1,NPT
 11            NN=NENN(MMM,N)
 11            X(N)=XX(NN)
 11            Y(N)=YY(NN)
 11            U(N)=US(NN)
 11            V(N)=VS(NN)
  1   1        CONTINUE
  1   C
 11            DO 2 N=1,NPT
 11            GN(N)=0.0
 11            DO 2 M=1,NPT
 11            BNM(N,M)=0.0
  1   2        CONTINUE
  1   C
 11            DO 300 K=1,4
 11            DO 300 L=1,4
 11            XI=ST(K)
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11             ETA=ST(L)
 11             ACOF=WS(K)*WS(L)
  1   C
 11             CALL INTER(XI,ETA,NPT,X,Y,DX,DY,FI,DTA,AA,AB)
  1   C
 11             SXU=0.0
 11             SYV=0.0
 11             YP =0.0
  1   C
 11             DO 301 N=1,NPT
 11             SXU=SXU+DX(N)*U(N)
 11             SYV=SYV+DY(N)*V(N)
 11             YP =YP +FI(N)*Y(N)
  1   301       CONTINUE
  1   C
 11             C=ACOF*DTA*YP
  1   C
 11             DO 500 N=1,NPT
 11             GN(N)=GN(N)-C*FI(N)*(SXU+SYV)*DTINV
 11             DO 500 M=1,NPT
 11             BNM(N,M)=BNM(N,M)+C*(DX(N)*DX(M)+DY(N)*DY(M))
  1   500       CONTINUE
  1   300       CONTINUE
  1   C
 11             RETURN
 11             END
  1   C
  1   C
 11             SUBROUTINE ELEAC(MMM,NPT,NGPT,XX,YY,DPP,CNM,
  6        *                     HNU,HNV,WS,ST,NEL,NENN)
  1   C
  1   C         LOCAL MATRICES FOR ACCELERATIONS
  1   C
 11             DIMENSION XX(NGPT),YY(NGPT),DPP(NGPT),NENN(NEL,4)
 11             DIMENSION CNM(4,4),HNU(4),HNV(4),WS(4),ST(4)
 11             DIMENSION X(4),Y(4),DP(4),FI(4),DX(4),DY(4),AA(4),AB(4)
  1   C
 11             DO 1 N=1,NPT
 11             NN=NENN(MMM,N)
 11             X(N)=XX(NN)
 11             Y(N)=YY(NN)
 11             DP(N)=DPP(NN)
  1   1         CONTINUE
  1   C
 11             DO 2 N=1,NPT
 11             HNU(N)=0.0
 11             HNV(N)=0.0
 11             DO 2 M=1,NPT
 11             CNM(N,M)=0.0
  1   2         CONTINUE
  1   C
 11             DO 300 K=1,4
 11             DO 300 L=1,4
 11             XI=ST(K)
```

```
 11              ETA=ST(L)
 11              ACOF=WS(K)*WS(L)
  1   C
 11              CALL INTER(XI,ETA,NPT,X,Y,DX,DY,FI,DTA,AA,AB)
  1   C
 11              SDPX=0.0
 11              SDPY=0.0
 11              YP  =0.0
  1   C
 11              DO 310 N=1,NPT
 11              SDPX=SDPX+DX(N)*DP(N)
 11              SDPY=SDPY+DY(N)*DP(N)
 11              YP  =YP  +FI(N)*Y(N)
  1   310        CONTINUE
  1   C
 11              C=ACOF*DTA*YP
  1   C
 11              DO 500 N=1,NPT
  7         CFIN=C*FI(N)
 11              HNU(N)=HNU(N)-CFIN*SDPX
 11              HNV(N)=HNV(N)-CFIN*SDPY
 11              DO 500 M=1,NPT
 11              CNM(N,M)=CNM(N,M)+CFIN*FI(M)
  1   500        CONTINUE
  1   300        CONTINUE
  1   C
 11              RETURN
 11              END
  1   C
  1   C
 11              SUBROUTINE ELEMP(MMM,NPT,ANM,BNM,WS,ST,NL,NT,NENL,
  6        *                XT,YT)
  1   C
  7         DIMENSION XT(NT),YT(NT)
 11              DIMENSION ANM(4,4),BNM(4,4),WS(4),ST(4),NENL(NL,4)
 11              DIMENSION X(4),Y(4),FI(4),DX(4),DY(4),AA(4),AB(4)
  1   C
 11              DO 100 N=1,NPT
 11              NN=NENL(MMM,N)
 11              X(N)=XT(NN)
 11              Y(N)=YT(NN)
  1   100        CONTINUE
  1   C
 11              DO 110 I=1,NPT
 11              DO 110 J=1,NPT
 11              ANM(I,J)=0.0
 11              BNM(I,J)=0.0
  1   110        CONTINUE
  1   C
 11              DO 300 K=1,4
 11              DO 300 L=1,4
 11              XI=ST(K)
 11              ETA=ST(L)
 11              ACOF=WS(K)*WS(L)
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  1   C
 11             CALL INTER(XI,ETA,NPT,X,Y,DX,DY,FI,DTA,AA,AB)
  1   C
 11             YP=0.0
 11             DO 310 N=1,NPT
 11             YP=YP+FI(N)*Y(N)
  1   310       CONTINUE
  1   C
 11             C=•COF*DTA*YP
  1   C
 11             DO 500 N=1,NPT
  7         CFIN=C*FI(N)
 11             DO 500 M=1,NPT
 11             ANM(N,M)=ANM(N,M)+C*(DX(N)*DX(M)+DY(N)*DY(M))
 11             BNM(N,M)=BNM(N,M)+CFIN*FI(M)
  1   500       CONTINUE
  1   300       CONTINUE
  1   C
 11             RETURN
 11             END
  1   C
  1   C
  1   C
 11             SUBROUTINE ELEVR(MMM,NPT,ANM,BNM,WS,ST,REN,NL,NT,NENL,
  6        *              XT,YT,UT,VT)
  1   C
  1   C         LOCAL ELEMENT FOR VORTICAL EIGENMODES
  1   C
  7         DIMENSION XT(NT),YT(NT),UT(NT),VT(NT)
 11             DIMENSION X(4),Y(4),U(4),V(4),ANM(4,4,4,4),BNM(4,4,4,4),
  6        *             WS(4),ST(4),PI(4,4),DPX(4,4),DPY(4,4),
  6        *             DPXX(4,4),DPXY(4,4),DPYY(4,4),NENL(NL,4)
  1   C
  7         RENINV=1./REN
  1   C
 11             DO 100 N=1,NPT
 11             NN=NENL(MMM,N)
 11             X(N)=XT(NN)
 11             Y(N)=YT(NN)
 11             U(N)=UT(NN)
 11             V(N)=VT(NN)
  1   100       CONTINUE
  1   C
 11             DO 110 L=1,4
 11             DO 110 N=1,NPT
 11             DO 110 LL=1,4
 11             DO 110 M=1,NPT
 11             ANM(L,LL,N,M)=0.0
 11             BNM(L,LL,N,M)=0.0
  1   110       CONTINUE
  1   C
 11             DA=ABS(X(2)-X(1))*.5
 11             DB=ABS(Y(4)-Y(1))*.5
  1   C
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11              DO 300 K=1,4
 11              DO 300 L=1,4
 11              XI=ST(K)
 11              ETA=ST(L)
 11              ACOF=WS(K)*WS(L)
  1   C
 11              CALL HERMT(XI,ETA,DA,DB,PI,DPX,DPY,DPXX,DPXY,DPYY)
  1   C
 11              SU=0.0
 11              SV=0.0
 11              SUX=0.0
 11              SUY=0.0
 11              SVX=0.0
 11              SVY=0.0
 11              SUXX=0.0
 11              SUXY=0.0
 11              SUYY=0.0
 11              SVXX=0.0
 11              SVXY=0.0
 11              SVYY=0.0
 11              YP=0.0
  1   C
 11              DO 310 N=1,NPT
 11              SU=SU+PI(1,N)*U(N)
 11              SV=SV+PI(1,N)*V(N)
 11              SUX=SUX+DPX(1,N)*U(N)
 11              SUY=SUY+DPY(1,N)*U(N)
 11              SVX=SVX+DPX(1,N)*V(N)
 11              SVY=SVY+DPY(1,N)*V(N)
 11              SUXX=SUXX+DPXX(1,N)*U(N)
 11              SUXY=SUXY+DPXY(1,N)*U(N)
 11              SUYY=SUYY+DPYY(1,N)*U(N)
 11              SVXX=SVXX+DPXX(1,N)*V(N)
 11              SVXY=SVXY+DPXY(1,N)*V(N)
 11              SVYY=SVYY+DPYY(1,N)*V(N)
 11              YP=YP+PI(1,N)*Y(N)
  1   310        CONTINUE
  1   C
 11              C=ACOF*DA*DB*YP
  1   C
 11              DO 500 IL=1,4
 11              DO 500 N=1,NPT
 11              DO 500 JL=1,4
 11              DO 500 M=1,NPT
 11              ANM(IL,JL,N,M)=ANM(IL,JL,N,M)+C*(
  6        *            PI(IL,N)*(SVXX*DPY(JL,M)-SVXY*DPX(JL,M)
  6        *                     -SUXY*DPY(JL,M)+SUYY*DPX(JL,M))
  6        *          +(SU*DPX(IL,N)+SV*DPY(IL,N))*(DPXX(JL,M)+DPYY(JL,M))
  6        *          -(DPXX(IL,N)*DPXX(JL,M)+2.0*DPXY(IL,N)*DPXY(JL,M)
  6        *           +DPYY(IL,N)*DPYY(JL,M))*RENINV)
 11              BNM(IL,JL,N,M)=BNM(IL,JL,N,M)+C*(
  6        *           DPX(IL,N)*DPX(JL,M)+DPY(IL,N)*DPY(JL,M))
  1   500        CONTINUE
  1   300        CONTINUE
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

   1  C
  11            RETURN
  11            END
   1  C
   1  C
   1  C
  11            SUBROUTINE ADJUST(NB,NT,NBX,A,UNB,F,NBW1,NBWT)
   1  C
   1  C          ADJUSTMENT OF BOUNDARY CONDITIONS FOR MEAN VELOCITY FIELDS
   1  C
  11            DIMENSION NBX(NB),UNB(NB)
  11            DIMENSION A(NT,NBWT),F(NT)
   1  C
  11            DO 1 I=1,NB
  11            ND=NBX(I)
  11            DO 2 J=1,NBWT
   1  2         A(ND,J)=0.0
  11            DO 3 J=1,NT
  11            NX1=(ND-1)+NBWT
  11            IF(NX1.LE.0.OR.NX1.GT.NBWT) GO TO 3
  11            F(J)=F(J)-A(J,NX1)*UNB(I)
  11            A(J,NX1)=0.0
   1  3         CONTINUE
  11            A(ND,NBW1)=1.0
  11            F(ND)=UNB(I)
   1  1         CONTINUE
   1  C
  11            RETURN
  11            END
   1  C
   1  C
  11            SUBROUTINE GAUSU(A,B,X,N,NBW1,NBWT)
   1  C
   1  C          SOLVER OF LINEAR EQUATIONS WITH BAND MATRIX
   1  C
  11            DIMENSION A(N,NBWT),B(N),X(N)
   1  C
  11            NM1=N-1
   1  C
  11            DO 5 I=1,NM1
  11            IP1=I+1
  11            DO 6 K=IP1,N
  11            II=I-K+NBW1
  11            IF(II.LE.0 .OR. II.GT.NBWT) GO TO 6
  11            FACT=-A(K,II)/A(I,NBW1)
  11            IF(FACT.EQ.0.0) GO TO 6
  11            A(K,II)=0.0
  11            DO 7 J=IP1,N
  11            JI=J-I+NBW1
  11            IF(JI.LE.0 .OR. JI.GT.NBWT) GO TO 7
  11            JJ=J-K+NBW1
  11            IF(JJ.LE.0 .OR. JJ.GT.NBWT) GO TO 7
  11            A(K,JJ)=A(K,JJ)+FACT*A(I,JI)
   1  7         CONTINUE
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11             B(K)=B(K)+FACT*B(I)
  1   6         CONTINUE
  1   5         CONTINUE
  1   C
  1   C
 11             X(N)=B(N)/A(N,NBW1)
 11             NP1=N+1
 11             DO 2 K=1,NM1
 11             SUM=0.0
 11             NMK=N-K
 11             DO 3 J=1,K
 11             JJ=(NP1-J)-NMK+NBW1
 11             IF(JJ.LE.0 .OR.JJ.GT.NBWT) GO TO 3
 11             SUM=SUM+A(NMK,JJ)*X(NP1-J)
  1   3         CONTINUE
 11             X(NMK)=(B(NMK)-SUM)/A(NMK,NBW1)
  1   2         CONTINUE
  1   C
 11             RETURN
 11             END
  1   C
  1   C
  1   C
  7       SUBROUTINE GAUSS(NGG,W,ST)
  1   C
  7       DIMENSION W(NGG),ST(NGG)
  1   C
  7       IF(NGG.EQ.1) GO TO 10
  7       IF(NGG.EQ.2) GO TO 20
  7       IF(NGG.EQ.3) GO TO 30
  7       IF(NGG.EQ.4) GO TO 40
  7       IF(NGG.EQ.5) GO TO 50
  7       IF(NGG.EQ.6) GO TO 60
  1   C
  2    10 W(1)=2.0
  7       ST(1)=0.0
  7       GO TO 70
  1   C
  2    20 W(1)   =  1.0
  7       W(2)   =  W(1)
  7       ST(1)  = -0.577350269
  7       ST(2)  = -ST(1)
  7       GO TO 70
  1   C
  2    30 W(1)   =  0.5555555555
  7       W(2)   =  0.8888888888
  7       W(3)   =  W(1)
  7       ST(1)  = -0.7745966692
  7       ST(2)  =  0.0
  7       ST(3)  = -ST(1)
  7       GO TO 70
  1   C
  2    40 W(1)   =  0.3478548451
  7       W(2)   =  0.6521451548
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  7           W(3)    =  W(2)
  7           W(4)    =  W(1)
  7           ST(1)   = -0.8611363115
  7           ST(2)   = -0.3399810435
  7           ST(3)   = -ST(2)
  7           ST(4)   = -ST(1)
  7           GO TO 70
  1   C
  2    50     W(1)    =  0.2369268850
  7           W(2)    =  0.478628674
  7           W(3)    =  0.5688888888
  7           W(4)    =  W(2)
  7           W(5)    =  W(1)
  7           ST(1)   = -0.9061798459
  7           ST(2)   = -0.5384693101
  7           ST(3)   =  0.0
  7           ST(4)   = -ST(2)
  7           ST(5)   = -ST(1)
  7           GO TO 70
  1   C
  2    60     W(1)    =  0.1713244923
  7           W(2)    =  0.3607615730
  7           W(3)    =  0.4679139345
  7           W(4)    =  W(3)
  7           W(5)    =  W(2)
  7           W(6)    =  W(1)
  7           ST(1)   = -0.9324695142
  7           ST(2)   = -0.6612093864
  7           ST(3)   = -0.2386191860
  7           ST(4)   = -ST(3)
  7           ST(5)   = -ST(2)
  7           ST(6)   = -ST(1)
  1   C
  2    70     CONTINUE
  1   C
  7           RETURN
  7           END
  1   C
  1   C
  1   C
 11               SUBROUTINE INTER(XX,YY,NPT,X,Y,DX,DY,FT,DTA,AA,AB)
  1   C
  1   C           LINEAR INTERPOLATION FUNCTIONS AND THEIR FIRST DERIVATIVES
  1   C
 11               DIMENSION X(NPT),Y(NPT),DX(NPT),DY(NPT),FT(NPT)
 11               DIMENSION AA(NPT),AB(NPT),DTJ(2,2)
  1   C
  1   C           FT(1)=0.25*(1.0-XX)*(1.0-YY)
  1   C           FT(2)=0.25*(1.0+XX)*(1.0-YY)
  1   C           FT(3)=0.25*(1.0+XX)*(1.0+YY)
  1   C           FT(4)=0.25*(1.0-XX)*(1.0+YY)
  1   C
  1   C           AA(1)=0.25*(-1.0+YY)
  1   C           AA(2)=0.25*( 1.0-YY)
```

```
   1 C          AA(3)=0.25*( 1.0+YY)
   1 C          AA(4)=0.25*(-1.0-YY)
   1 C
   1 C          AB(1)=0.25*(-1.0+XX)
   1 C          AB(2)=0.25*(-1.0-XX)
   1 C          AB(3)=0.25*( 1.0+XX)
   1 C          AB(4)=0.25*( 1.0-XX)
   1 C
   7      XXP1=XX+1.
   7      XXM1=XX-1.
   7      YYP1=YY+1.
   7      YYM1=YY-1.
   1 C
   7      AA(1)=.25*YYM1
   7      AA(2)=-AA(1)
   7      AA(3)=.25*YYP1
   7      AA(4)=-AA(3)
   1 C
   7      AB(1)=.25*XXM1
   7      AB(3)=.25*XXP1
   7      AB(2)=-AB(3)
   7      AB(4)=-AB(1)
   1 C
   7      FT(1)=AB(1)*YYM1
   7      FT(2)=AB(2)*YYM1
   7      FT(3)=AB(3)*YYP1
   7      FT(4)=AB(4)*YYP1
   1 C
  11          DO 4 I=1,2
  11          DO 4 J=1,2
   1 4        DTJ(I,J)=0.0
   1 C
  11          DO 5 N=1,NPT
  11          DTJ(1,1)=DTJ(1,1)+AA(N)*X(N)
  11          DTJ(1,2)=DTJ(1,2)+AA(N)*Y(N)
  11          DTJ(2,1)=DTJ(2,1)+AB(N)*X(N)
   1 5        DTJ(2,2)=DTJ(2,2)+AB(N)*Y(N)
   1 C
  11          DTA=DTJ(1,1)*DTJ(2,2)-DTJ(1,2)*DTJ(2,1)
   7      DTAINV=1./DTA
   1 C
  11          DO 7 N=1,NPT
  11          DX(N)=( DTJ(2,2)*AA(N)-DTJ(1,2)*AB(N))*DTAINV
  11          DY(N)=(-DTJ(2,1)*AA(N)+DTJ(1,1)*AB(N))*DTAINV
   1 7        CONTINUE
   1 C
  11          RETURN
  11          END
   1 C
   1 C
   1 C
  11          SUBROUTINE QUADR(AA,AB,X,Y,DX,DY,DXX,DXY,DYY,NPT)
   1 C
   1 C        SECOND DERIVATIVES OF INTERPOLATION FUNCTIONS
```

```
START
 COL' ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  1  C
 11          DIMENSION AA(NPT),AB(NPT),X(NPT),Y(NPT),DX(NPT),DY(NPT),
  6      *             DXX(NPT),DXY(NPT),DYY(NPT)
 11          DIMENSION DUMXX(4),DUMXY(4),DUMYY(4),AXX(4),AXY(4),AYY(4)
  1  C
 11          AXX(1)=0.0
 11          AXX(2)=0.0
 11          AXX(3)=0.0
 11          AXX(4)=0.0
 11          AXY(1)=0.25
 11          AXY(2)=-0.25
 11          AXY(3)=0.25
 11          AXY(4)=-0.25
 11          AYY(1)=0.0
 11          AYY(2)=0.0
 11          AYY(3)=0.0
 11          AYY(4)=0.0
  1  C
 11          DXX1=0.0
 11          DXY1=0.0
 11          DYX1=0.0
 11          DYY1=0.0
 11          DXXXX=0.0
 11          DXYXX=0.0
 11          DYYXX=0.0
 11          DXXYY=0.0
 11          DXYYY=0.0
 11          DYYYY=0.0
  1  C
 11          DO 5 N=1,NPT
 11          DXX1=DXX1+AA(N)*X(N)
 11          DXY1=DXY1+AA(N)*Y(N)
 11          DYX1=DYX1+AB(N)*X(N)
 11          DYY1=DYY1+AB(N)*Y(N)
 11          DXXXX=DXXXX+AXX(N)*X(N)
 11          DXYXX=DXYXX+AXY(N)*X(N)
 11          DYYXX=DYYXX+AYY(N)*X(N)
 11          DXXYY=DXXYY+AXX(N)*Y(N)
 11          DXYYY=DXYYY+AXY(N)*Y(N)
 11          DYYYY=DYYYY+AYY(N)*Y(N)
  2   5    CONTINUE
  1  C
 11          DDD=DXX1*DXX1*DYY1*DYY1*(DXX1*DYY1+DXY1*DYX1)
  6      *      +2.*DXX1*DYX1*DYX1*DYY1*DXY1*DXY1
  6      *      +2.*DYX1*DYX1*DXY1*DYY1*DXX1*DXY1
  6      *      -DYX1*DYX1*DXY1*DXY1*(DXX1*DYY1+DYX1*DXY1)
  6      *      -2.*DXX1*DYX1*DXX1*DXY1*DYY1*DYY1
  6      *      -2.*DXX1*DXX1*DXY1*DYY1*DYX1*DYY1
 13            DDDINV=1./DDD
  1  C
 11          DO 8 N=1,NPT
 11          DUMXX(N)=AXX(N)-DXXXX*DX(N)-DXXYY*DY(N)
 11          DUMXY(N)=AXY(N)-DXYXX*DX(N)-DXYYY*DY(N)
 11          DUMYY(N)=AYY(N)-DYYXX*DX(N)-DYYYY*DY(N)
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  2    8   CONTINUE
  1   C
 11          D11=(DXX1*DYY1+DXY1*DYX1)*DYY1*DYY1-2.*DYX1*DYY1*DXY1*DYY1
 11          D12=2.*DYX1*DYY1*DYY1*DYY1-2.*DXX1*DXY1*DYY1*DYY1
 11          D13=2.*DXX1*DXY1*DXY1*DYY1-DXY1*DXY1*(DXX1*DYY1+DYX1*DXY1)
 11          D21=DXY1*DXY1*DYX1*DYX1-DXX1*DXX1*DYY1*DYY1
 11          D22=DXX1*DXX1*DYY1*DYY1-DXY1*DXY1*DYX1*DYX1
 11          D23=DXY1*DXY1*DXX1*DYX1-DXY1*DXY1*DYX1*DYX1
 11          D31=2.*DXX1*DXY1*DXY1*DYY1-DXY1*DXY1*(DXX1*DYY1+DYX1*DXY1)
 11          D32=DXY1*DXY1*DXX1*DYX1-DXX1*DXX1*DXY1*DYY1
 11          D33=DXX1*DXX1*(DXX1*DYY1+DYX1*DXX1)-2.*DXX1*DXY1*DXX1*DYX1
  1   C
  1   C
 11          DO 9 N=1,NPT
 11          DXX(N)=(D11*DUMXX(N)+D12*DUMXY(N)+D13*DUMYY(N))*DDDINV
 11          DXY(N)=(D21*DUMXX(N)+D22*DUMXY(N)+D23*DUMYY(N))*DDDINV
 11          DYY(N)=(D31*DUMXX(N)+D32*DUMXY(N)+D33*DUMYY(N))*DDDINV
  2    9   CONTINUE
  1   C
 11          RETURN
 11          END
 11          SUBROUTINE HERMT(XI,ETA,DA,DB,PI,DPX,DPY,DPXX,DPXY,DPYY)
  1   C
  1   C      HERMITE POLYNOMIAL INTERPOLATION FUNCTIONS
  1   C
 11          DIMENSION PI(4,4),DPX(4,4),DPY(4,4),DPXX(4,4),DPXY(4,4),
  6       *            DPYY(4,4)
  1   C
  7        DAINV4=.25/DA
  7        DBINV4=.25/DB
  7        DA2IN4=DAINV4/DA
  7        DB2IN4=DBINV4/DB
  1   C
 11          F1X=(2.-3.*XI+XI*XI*XI)*.25
 11          F2X=(2.+3.*XI-XI*XI*XI)*.25
 11          G1X=DA*(1.-XI-XI*XI+XI*XI*XI)*.25
 11          G2X=DA*(-1.-XI+XI*XI+XI*XI*XI)*.25
  1   C
 11          F1Y=(2.-3.*ETA+ETA*ETA*ETA)*.25
 11          F2Y=(2.+3.*ETA-ETA*ETA*ETA)*.25
 11          G1Y=DB*(1.-ETA-ETA*ETA+ETA*ETA*ETA)*.25
 11          G2Y=DB*(-1.-ETA+ETA*ETA+ETA*ETA*ETA)*.25
  1   C
 11          DF1X=(-3.+3.*XI*XI)*DAINV4
 11          DF2X=( 3.-3.*XI*XI)*DAINV4
 11          DG1X=(-1.-2.*XI+3.*XI*XI)*.25
 11          DG2X=(-1.+2.*XI+3.*XI*XI)*.25
  1   C
 11          DF1Y=(-3.+3.*ETA*ETA)*DBINV4
 11          DF2Y=( 3.-3.*ETA*ETA)*DBINV4
 11          DG1Y=(-1.-2.*ETA+3.*ETA*ETA)*.25
 11          DG2Y=(-1.+2.*ETA+3.*ETA*ETA)*.25
  1   C
 11          DDF1X=6.*XI*DA2IN4
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11             DDF2X=-6.*XI*DA2IN4
 11             DDG1X=(-2.+6.*XI)*DAINV4
 11             DDG2X=( 2.+6.*XI)*DAINV4
  1   C
 11             DDF1Y=6.*ETA*DB2IN4
 11             DDF2Y=-6.*ETA*DB2IN4
 11             DDG1Y=(-2.+6.*ETA)*DBINV4
 11             DDG2Y=( 2.+6.*ETA)*DBINV4
  1   C
 11             PI(1,1)=F1X*F1Y
 11             PI(1,2)=F2X*F1Y
 11             PI(1,3)=F2X*F2Y
 11             PI(1,4)=F1X*F2Y
 11             PI(2,1)=G1X*F1Y
 11             PI(2,2)=G2X*F1Y
 11             PI(2,3)=G2X*F2Y
 11             PI(2,4)=G1X*F2Y
 11             PI(3,1)=F1X*G1Y
 11             PI(3,2)=F2X*G1Y
 11             PI(3,3)=F2X*G2Y
 11             PI(3,4)=F1X*G2Y
 11             PI(4,1)=G1X*G1Y
 11             PI(4,2)=G2X*G1Y
 11             PI(4,3)=G2X*G2Y
 11             PI(4,4)=G1X*G2Y
  1   C
 11             DPX(1,1)=DF1X*F1Y
 11             DPX(1,2)=DF2X*F1Y
 11             DPX(1,3)=DF2X*F2Y
 11             DPX(1,4)=DF1X*F2Y
 11             DPX(2,1)=DG1X*F1Y
 11             DPX(2,2)=DG2X*F1Y
 11             DPX(2,3)=DG2X*F2Y
 11             DPX(2,4)=DG1X*F2Y
 11             DPX(3,1)=DF1X*G1Y
 11             DPX(3,2)=DF2X*G1Y
 11             DPX(3,3)=DF2X*G2Y
 11             DPX(3,4)=DF1X*G2Y
 11             DPX(4,1)=DG1X*G1Y
 11             DPX(4,2)=DG2X*G1Y
 11             DPX(4,3)=DG2X*G2Y
 11             DPX(4,4)=DG1X*G2Y
  1   C
 11             DPY(1,1)=F1X*DF1Y
 11             DPY(1,2)=F2X*DF1Y
 11             DPY(1,3)=F2X*DF2Y
 11             DPY(1,4)=F1X*DF2Y
 11             DPY(2,1)=G1X*DF1Y
 11             DPY(2,2)=G2X*DF1Y
 11             DPY(2,3)=G2X*DF2Y
 11             DPY(2,4)=G1X*DF2Y
 11             DPY(3,1)=F1X*DG1Y
 11             DPY(3,2)=F2X*DG1Y
 11             DPY(3,3)=F2X*DG2Y
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11            DPY(3,4)=F1X*DG2Y
 11            DPY(4,1)=G1X*DG1Y
 11            DPY(4,2)=G2X*DG1Y
 11            DPY(4,3)=G2X*DG2Y
 11            DPY(4,4)=G1X*DG2Y
  1   C
 11            DPXX(1,1)=DDF1X*F1Y
 11            DPXX(1,2)=DDF2X*F1Y
 11            DPXX(1,3)=DDF2X*F2Y
 11            DPXX(1,4)=DDF1X*F2Y
 11            DPXX(2,1)=DDG1X*F1Y
 11            DPXX(2,2)=DDG2X*F1Y
 11            DPXX(2,3)=DDG2X*F2Y
 11            DPXX(2,4)=DDG1X*F2Y
 11            DPXX(3,1)=DDF1X*G1Y
 11            DPXX(3,2)=DDF2X*G1Y
 11            DPXX(3,3)=DDF2X*G2Y
 11            DPXX(3,4)=DDF1X*G2Y
 11            DPXX(4,1)=DDG1X*G1Y
 11            DPXX(4,2)=DDG2X*G1Y
 11            DPXX(4,3)=DDG2X*G2Y
 11            DPXX(4,4)=DDG1X*G2Y
  1   C
 11            DPYY(1,1)=F1X*DDF1Y
 11            DPYY(1,2)=F2X*DDF1Y
 11            DPYY(1,3)=F2X*DDF2Y
 11            DPYY(1,4)=F1X*DDF2Y
 11            DPYY(2,1)=G1X*DDF1Y
 11            DPYY(2,2)=G2X*DDF1Y
 11            DPYY(2,3)=G2X*DDF2Y
 11            DPYY(2,4)=G1X*DDF2Y
 11            DPYY(3,1)=F1X*DDG1Y
 11            DPYY(3,2)=F2X*DDG1Y
 11            DPYY(3,3)=F2X*DDG2Y
 11            DPYY(3,4)=F1X*DDG2Y
 11            DPYY(4,1)=G1X*DDG1Y
 11            DPYY(4,2)=G2X*DDG1Y
 11            DPYY(4,3)=G2X*DDG2Y
 11            DPYY(4,4)=G1X*DDG2Y
  1   C
 11            DPXY(1,1)=DF1X*DF1Y
 11            DPXY(1,2)=DF2X*DF1Y
 11            DPXY(1,3)=DF2X*DF2Y
 11            DPXY(1,4)=DF1X*DF2Y
 11            DPXY(2,1)=DG1X*DF1Y
 11            DPXY(2,2)=DG2X*DF1Y
 11            DPXY(2,3)=DG2X*DF2Y
 11            DPXY(2,4)=DG1X*DF2Y
 11            DPXY(3,1)=DF1X*DG1Y
 11            DPXY(3,2)=DF2X*DG1Y
 11            DPXY(3,3)=DF2X*DG2Y
 11            DPXY(3,4)=DF1X*DG2Y
 11            DPXY(4,1)=DG1X*DG1Y
 11            DPXY(4,2)=DG2X*DG1Y
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 11             DPXY(4,3)=DG2X*DG2Y
 11             DPXY(4,4)=DG1X*DG2Y
  1   C
 11             RETURN
 11             END
  7         SUBROUTINE CONVRT                                                   530970
  6        $( N, A, NA, B, NB, X, NX )                                          530980
  1   C                                                                         530990
  7         COMPLEX A(NA,N)                                                     531000
  7         COMPLEX B(NB,N)                                                     531010
  7         COMPLEX W                                                           531020
  7         COMPLEX X(NX,N)                                                     531030
  7         COMPLEX Y                                                           531040
  7         COMPLEX Z                                                           531050
  1   C                                                                         531060
  7         REAL C                                                              531070
  7         REAL D                                                              531080
  1   C                                                                         531090
  7         INTEGER I                                                           531100
  7         INTEGER II                                                          531110
  7         INTEGER IMJ                                                         531120
  7         INIfGER IM1                                                         531130
  7         INTEGER IP1                                                         531140
  7         INTEGER J                                                           531150
  7         INTEGER JM2                                                         531160
  7         INTEGER JP1                                                         531170
  7         INTEGER K                                                           531180
  7         INTEGER N                                                           531190
  7         INTEGER NA                                                          531200
  7         INTEGER NB                                                          531210
  7         INTEGER NM1                                                         531220
  7         INTEGER NM2                                                         531230
  7         INTEGER NX                                                          531240
  1   C                                                                         531250
  7         LUWT = 6                                                            531260
  7         NM1 = N - 1                                                         531270
  7         DO  80 I=1,NM1                                                      531280
  7         D = 0.0                                                             531290
  7         IP1 = I + 1                                                         531300
  7         DO  10 K=IP1,N                                                      531310
  7         Y = B(K,I)                                                          531320
  7         C = ABS(REAL(Y)) + ABS(AIMAG(Y))                                    531330
  7         IF( C.LE.D )      GO TO   9                                         531340
  7         D = C                                                               531350
  7         II = K                                                              531360
  5       9 CONTINUE                                                            531370
  4      10 CONTINUE                                                            531380
  7         IF( D.EQ.0.0 )      GO TO  78                                       531390
  7         Y = B(I,I)                                                          531400
  7         IF( D.LE.ABS(REAL(Y)) + ABS(AIMAG(Y)) )      GO TO  40              531410
  7         DO 20 J=1,N                                                         531420
  7         Y = A(I,J)                                                          531430
  7         A(I,J) = A(II,J)                                                    531440
  7         A(II,J) = Y                                                         531450
```

```
      PROJECT: CTJC197            MEMBER: MAIN2           DATE: 87/09/24
      GROUP:   STB1               LEVEL:  01.00           TIME: 12:02
      TYPE:    FORT               USERID: CTJC197         PAGE: 43 OF 50
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  4      20 CONTINUE                                                      531460
  7         DO 30  J=I,N                                                  531470
  7         Y = B(I,J)                                                    531480
  7         B(I,J) = B(II,J)                                              531490
  7         B(II,J) = Y                                                   531500
  4      30 CONTINUE                                                      531510
  4      40 CONTINUE                                                      531520
  7         DO  70 J=IP1,N                                                531530
  7         Y = B(J,I)/B(I,I)                                             531540
  7         IF( REAL(Y).EQ.0.0  .AND.  AIMAG(Y).EQ.0.0 )     GO TO  68    531550
  7         DO  50 K=1,N                                                  531560
  7         A(J,K) = A(J,K) - Y*A(I,K)                                    531570
  4      50 CONTINUE                                                      531580
  7         DO  60 K=IP1,N                                                531590
  7         B(J,K) = B(J,K) - Y*B(I,K)                                    531600
  4      60 CONTINUE                                                      531610
  4      68 CONTINUE                                                      531620
  4      70 CONTINUE                                                      531630
  7         B(IP1,I) = CMPLX(0.0,0.0)                                     531640
  4      78 CONTINUE                                                      531650
  4      80 CONTINUE                                                      531660
  1   C                                                                   53167
  7         DO 100 I=1,N                                                  531680
  7         DO  90 J=1,N                                                  531690
  7         X(I,J) = CMPLX(0.0,0.0)                                       531700
  4      90 CONTINUE                                                      531710
  7         X(I,I) = CMPLX(1.0,0.0)                                       531720
  3     100 CONTINUE                                                      531730
  1   C                                                                   531740
  7         NM2 = N - 2                                                   531750
  7         IF( NM2.LT.1 )     GO TO 270                                  531760
  7         DO 260 J=1,NM2                                                531770
  7         JM2 = NM1 - J                                                 531780
  7         JP1 = J + 1                                                   531790
  7         DO 250 II=1,JM2                                               531800
  7         I = N + 1 - II                                                531810
  7         IM1 = I - 1                                                   531820
  7         IMJ = I - J                                                   531830
  1   C                                                                   531840
  7         W = A(I,J)                                                    531850
  7         Z = A(IM1,J)                                                  531860
  7         IF( ABS(REAL(W)) + ABS(AIMAG(W)).LE.                          531870
  6        $    ABS(REAL(Z)) + ABS(AIMAG(Z)) )     GO TO 140              531880
  7         DO 120 K=J,N                                                  531890
  7         Y = A(I,K)                                                    531900
  7         A(I,K) = A(IM1,K)                                             531910
  7         A(IM1,K) = Y                                                  531920
  3     120 CONTINUE                                                      531930
  7         DO 130 K=IM1,N                                                531940
  7         Y = B(I,K)                                                    531950
  7         B(I,K) = B(IM1,K)                                             531960
  7         B(IM1,K) = Y                                                  531970
  3     130 CONTINUE                                                      531980
  3     140 CONTINUE                                                      531990
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  1   C                                                                    532000
  7         Z = A(I,J)                                                     532010
  7         IF( REAL(Z).EQ.0.0  .AND.  AIMAG(Z).EQ.0.0 )     GO TO 170     532020
  7         Y = Z/A(IM1,J)                                                 532030
  7         DO 150 K=JP1,N                                                 532040
  7         A(I,K) = A(I,K) - Y*A(IM1,K)                                   532050
  3     150 CONTINUE                                                       53767
  7         DO 160 K=IM1,N                                                 532070
  7         B(I,K) = B(I,K) - Y*B(IM1,K)                                   532080
  3     160 CONTINUE                                                       532090
  3     170 CONTINUE                                                       532100
  1   C                                                                    532110
  7         W = B(I,IM1)                                                   532120
  7         Z = B(I,I)                                                     532130
  7         IF( ABS(REAL(W)) + ABS(AIMAG(W)).LE.                           532140
  6        $    ABS(REAL(Z)) + ABS(AIMAG(Z)) )     GO TO 210               532150
  7         DO 180 K=1,I                                                   532160
  7         Y = B(K,I)                                                     532170
  7         B(K,I) = B(K,IM1)                                              532180
  7         B(K,IM1) = Y                                                   532190
  3     180 CONTINUE                                                       532200
  7         DO 190 K=1,N                                                   532210
  7         Y = A(K,I)                                                     532220
  7         A(K,I) = A(K,IM1)                                              532230
  7         A(K,IM1) = Y                                                   532240
  3     190 CONTINUE                                                       532250
  7         DO 200 K=IMJ,N                                                 532260
  7         Y = X(K,I)                                                     532270
  7         X(K,I) = X(K,IM1)                                              532280
  7         X(K,IM1) = Y                                                   532290
  3     200 CONTINUE                                                       532300
  3     210 CONTINUE                                                       532310
  1   C                                                                    532320
  7         Z = B(I,IM1)                                                   532330
  7         IF( REAL(Z).EQ.0.0  .AND.  AIMAG(Z).EQ.0.0 )     GO TO 249     532340
  7         Y = Z/B(I,I)                                                   532350
  7         DO 220 K=1,IM1                                                 532360
  7         B(K,IM1) = B(K,IM1) - Y*B(K,I)                                 532370
  3     220 CONTINUE                                                       532380
  7         B(I,IM1) = CMPLX(0.0,0.0)                                      538320
  7         DO 230 K=1,N                                                   532400
  7         A(K,IM1) = A(K,IM1) - Y*A(K,I)                                 532410
  3     230 CONTINUE                                                       532420
  7         DO 240 K=IMJ,N                                                 532430
  7         X(K,IM1) = X(K,IM1) - Y*X(K,I)                                 532440
  3     240 CONTINUE                                                       532450
  3     249 CONTINUE                                                       532460
  1   C                                                                    532470
  3     250 CONTINUE                                                       532480
  7         A(JP1+1,J) = CMPLX(0.0,0.0)                                    532490
  3     260 CONTINUE                                                       532500
  3     270 CONTINUE                                                       532510
  1   C                                                                    532520
  7         RETURN                                                         532530
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  7          END                                                                  532540
  7          SUBROUTINE SOLVE                                                     532550
  6         $( N, A, NA, B, NB, X, NX, ITER, EIGA, EIGB )                         532560
  1     C                                                                         532570
  7          COMPLEX S                                                            532580
  7          COMPLEX W                                                            532590
  7          COMPLEX Y                                                            532600
  7          COMPLEX Z                                                            532610
  7          COMPLEX A(NA,N)                                                      532620
  7          COMPLEX B(NB,N)                                                      532630
  7          COMPLEX X(NX,N)                                                      532640
  7          COMPLEX EIGA(N)                                                      532650
  7          COMPLEX EIGB(N)                                                      532660
  7          COMPLEX ANNM1                                                        53267
  7          COMPLEX ALFM                                                         532680
  7          COMPLEX BETM                                                         532690
  7          COMPLEX D                                                            532700
  7          COMPLEX SL                                                           532710
  7          COMPLEX DEN                                                          532720
  7          COMPLEX NUM                                                          532730
  7          COMPLEX ANM1M1                                                       532740
  1     C                                                                         532750
  7          REAL DO                                                              532760
  7          REAL D1                                                              532770
  7          REAL D2                                                              532780
  7          REAL EO                                                              532790
  7          REAL E1                                                              532800
  7          REAL C                                                               532810
  7          REAL EPSA                                                            532820
  7          REAL EPSB                                                            532830
  7          REAL SS                                                              532840
  7          REAL R                                                               532850
  7          REAL ANORM                                                           532860
  7          REAL BNORM                                                           532870
  7          REAL ANI                                                             532880
  7          REAL BNI                                                             532890
  1     C                                                                         532900
  7          INTEGER ITER(N)                                                      532910
  1     C                                                                         532920
  7          NN = N                                                               532930
  7          ANORM = 0.0                                                          532940
  7          BNORM = 0.0                                                          532950
  7          DO 30 I=1,N                                                          532960
  7          ANI = 0.0                                                            532970
  7          IF( I.EQ.1 )      GO TO 10                                           532980
  7          Y = A(I,I-1)                                                         532990
  7          ANI = ANI + ABS(REAL(Y)) + ABS(AIMAG(Y))                             533000
  4       10 CONTINUE                                                             533010
  7          BNI = 0.0                                                            533020
  7          DO 20 J=I,N                                                          533030
  7          ANI = ANI + ABS(REAL(A(I,J))) + ABS(AIMAG(A(I,J)))                   533040
  7          BNI = BNI + ABS(REAL(B(I,J))) + ABS(AIMAG(B(I,J)))                   533050
  4       20 CONTINUE                                                             533060
  7          IF( ANI.GT.ANORM )     ANORM = ANI                                   533070
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  7          IF( BNI.GT.BNORM )      BNORM = BNI                              533080
  4       30 CONTINUE                                                         533090
  1     C                                                                     533100
  7          IF( ANORM.EQ.0.0 )      ANORM = 1.0                              533110
  7          IF( BNORM.EQ.0.0 )      BNORM = 1.0                              533120
  7          EPSA = ANORM                                                     533130
  7          EPSB = BNORM                                                     533140
  4       40 CONTINUE                                                         533150
  7          EPSA = EPSA/2.0                                                  533160
  7          EPSB = EPSB/2.0                                                  533170
  7          C = ANORM + EPSA                                                 533180
  7          IF( C.GT.ANORM )      GO TO 40                                   533190
  7          IF( N.LE.1 )      GO TO 320                                      533200
  4       50 CONTINUE                                                         533210
  7          ITS = 0                                                          533220
  7          NM1 = NN - 1                                                     533230
  4       60 CONTINUE                                                         533240
  7          D2 = ABS(REAL(A(NN,NN))) + ABS(AIMAG(A(NN,NN)))                  533250
  7          DO 70 LB=2,NN                                                    533260
  7          L = NN + 2 - LB                                                  533270
  7          SS = D2                                                          533280
  7          Y = A(L-1,L-1)                                                   533290
  7          D2 = ABS(REAL(Y)) + ABS(AIMAG(Y))                                533300
  7          SS = SS + D2                                                     533310
  7          Y = A(L,L-1)                                                     533320
  7          R = SS + ABS(REAL(Y)) + ABS(AIMAG(Y))                            533330
  7          IF( R.EQ.SS )      GO TO 80                                      533340
  4       70 CONTINUE                                                         533350
  7          L = 1                                                            533360
  4       80 CONTINUE                                                         533370
  7          IF( L.EQ.NN )      GO TO 320                                     533380
  7          IF( ITS.LT.30 )      GO TO 90                                    533390
  7          ITER(NN) = -1                                                    533400
  7          IF( ABS(REAL(A(NN,NM1))) + ABS(AIMAG(A(NN,NM1))).GT.             533410
  6         $0.8*ABS(REAL(ANNM1)) +     ABS(AIMAG(ANNM1))     )     GO TO 999 533420
  4       90 CONTINUE                                                         533430
  7          IF( ITS.EQ.10  .OR.  ITS.EQ.20 )      GO TO 110                  533440
  1     C                                                                     533450
  7          ANNM1 = A(NN,NM1)                                                533460
  7          ANM1M1 = A(NM1,NM1)                                              533470
  7          S = A(NN,NN)*B(NM1,NM1) - ANNM1*B(NM1,NN)                        533480
  7          W = ANNM1*B(NN,NN)*                                              533490
  6         $    (A(NM1,NN)*B(NM1,NM1) - ANM1M1*B(NM1,NN))                    533500
  7          Y = (ANM1M1*B(NN,NN) - S)/2.0                                    533510
  7          Z = CSQRT(Y*Y + W)                                               533520
  7          IF( REAL(Z).EQ.0.0  .AND.  AIMAG(Z).EQ.0.0 )     GO TO 100       533530
  7          DO = REAL(Y/Z)                                                   533540
  7          IF( DO.LT.0.0 )      Z = -Z                                      533550
  3      100 CONTINUE                                                         533560
  7          DEN = (Y + Z)*B(NM1,NM1)*B(NN,NN)                                533570
  7          IF(  REAL(DEN).EQ.0.0   .AND.                                    533580
  6         $    AIMAG(DEN).EQ.0.0 )                                          533590
  6         $DEN = CMPLX(EPSA,0.0)                                            533600
  7          NUM = (Y + Z)*S - W                                              533610
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  7         GO TO 120
  3     110 CONTINUE
  7         Y = A(NM1,NN-2)
  7         NUM = CMPLX(ABS(REAL(ANNM1)) + ABS(AIMAG(ANNM1)),
  6        $            ABS(REAL(Y))      + ABS(AIMAG(Y))     )
  7         DEN = CMPLX(1.0,0.0)
  3     120 CONTINUE
  7         IF( NN.EQ.L+1 )      GO TO 140
  7         D1 = ABS(REAL(A(NN,NN))) + ABS(AIMAG(A(NN,NN)))
  7         D2 = ABS(REAL(A(NM1,NM1))) + ABS(AIMAG(A(NM1,NM1)))
  7         E1 = ABS(REAL(ANNM1)) + ABS(AIMAG(ANNM1))
  7         NL = NN - (L + 1)
  7         DO 130 MB=1,NL
  7         M = NN - MB
  7         EO = E1
  7         Y = A(M,M-1)
  7         E1 = ABS(REAL(Y)) + ABS(AIMAG(Y))
  7         DO = D1
  7         D1 = D2
  7         Y = A(M-1,M-1)
  7         D2 = ABS(REAL(Y)) + ABS(AIMAG(Y))
  7         Y = A(M,M)*DEN - B(M,M)*NUM
  7         DO = (DO + D1 + D2)*( ABS(REAL(Y)) + ABS(AIMAG(Y)) )
  7         EO = EO*E1*( ABS(REAL(DEN)) + ABS(AIMAG(DEN)) ) + DO
  7         IF( EO.EQ.DO )      GO TO 150
  3     130 CONTINUE
  3     140 CONTINUE
  7         M = L
  3     150 CONTINUE
  7         ITS = ITS + 1
  7         W = A(M,M)*DEN - B(M,M)*NUM
  7         Z = A(M+1,M)*DEN
  7         D1 = ABS(REAL(Z)) + ABS(AIMAG(Z))
  7         D2 = ABS(REAL(W)) + ABS(AIMAG(W))
  7         LOR1 = 1
  7         NNORN = N
  7         DO 310 I=M,NM1
  7         J = I + 1
  7         IF( I.EQ.M )      GO TO 170
  7         W = A(I,I-1)
  7         Z = A(J,I-1)
  7         D1 = ABS(REAL(Z)) + ABS(AIMAG(Z))
  7         D2 = ABS(REAL(W)) + ABS(AIMAG(W))
  7         IF( D1.EQ.0.0 )      GO TO 60
  3     170 CONTINUE
  7         IF( D2.GT.D1 )      GO TO 190
  7         DO 180 K=I,NNORN
  7         Y = A(I,K)
  7         A(I,K) = A(J,K)
  7         A(J,K) = Y
  7'        Y = B(I,K)
  7         B(I,K) = B(J,K)
  7         B(J,K) = Y
  3     180 CONTINUE
```

```
START
 COL   ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  7          IF( I.GT.M )      A(I,I-1) = A(J,I-1)                          534160
  7          IF( D2.EQ.0.0 )      GO TO 220                                 534170
  7          Y = CMPLX( REAL(W)/D1, AIMAG(W)/D1 )/                          534180
  6         $    CMPLX( REAL(Z)/D1, AIMAG(Z)/D1 )                           534190
  7          GO TO 200                                                      534200
  3      190 CONTINUE                                                       534210
  7          Y = CMPLX( REAL(Z)/D2, AIMAG(Z)/D2 )/                          534220
  6         $    CMPLX( REAL(W)/D2, AIMAG(W)/D2 )                           534230
  3      200 CONTINUE                                                       534240
  7          DO 210 K=I,NNORN                                               534250
  7          A(J,K) = A(J,K) - Y*A(I,K)                                     534260
  7          B(J,K) = B(J,K) - Y*B(I,K)                                     534270
  3      210 CONTINUE                                                       534280
  3      220 CONTINUE                                                       534290
  7          IF( I.GT.M )      A(J,I-1) = CMPLX(0.0,0.0)                    534300
  7          Z = B(J,I)                                                     534310
  7          W = B(J,J)                                                     534320
  7          D1 = ABS(REAL(Z)) + ABS(AIMAG(Z))                              534330
  7          D2 = ABS(REAL(W)) + ABS(AIMAG(W))                              534340
  7          IF( D1.EQ.0.0 )      GO TO 60                                  534350
  7          IF( D2.GT.D1 )      GO TO 270                                  534360
  7          DO 230 K=LOR1,J                                                534370
  7          Y = A(K,J)                                                     534380
  7          A(K,J) = A(K,I)                                                534390
  7          A(K,I) = Y                                                     534400
  7          Y = B(K,J)                                                     534410
  7          B(K,J) = B(K,I)                                                534420
  7          B(K,I) = Y                                                     534430
  3      230 CONTINUE                                                       534440
  7          IF( I.EQ.NM1 )      GO TO 240                                  534450
  7          Y = A(J+1,J)                                                   534460
  7          A(J+1,J) = A(J+1,I)                                            534470
  7          A(J+1,I) = Y                                                   534480
  3      240 CONTINUE                                                       534490
  7          DO 250 K=1,N                                                   534500
  7          Y = X(K,J)                                                     534510
  7          X(K,J) = X(K,I)                                                534520
  7          X(K,I) = Y                                                     534530
  3      250 CONTINUE                                                       534540
  7          B(J,I) = CMPLX(0.0,0.0)                                        534550
  7          IF( D2.EQ.0.0 )      GO TO 310                                 534560
  7          Z = CMPLX( REAL(W)/D1, AIMAG(W)/D1 )/                          534570
  6         $    CMPLX( REAL(Z)/D1, AIMAG(Z)/D1 )                           534580
  7          GO TO 280                                                      534590
  3      270 CONTINUE                                                       534600
  7          Z = CMPLX( REAL(Z)/D2, AIMAG(Z)/D2 )/                          534610
  6         $    CMPLX( REAL(W)/D2, AIMAG(W)/D2 )                           534620
  3      280 CONTINUE                                                       534630
  7          DO 290 K=LOR1,J                                                534640
  7          A(K,I) = A(K,I) - Z*A(K,J)                                     534650
  7          B(K,I) = B(K,I) - Z*B(K,J)                                     534660
  3      290 CONTINUE                                                       53467
  7          B(J,I) = CMPLX(0.0,0.0)                                        534680
  7          IF( I.LT.NM1 )      A(I+2,I) = A(I+2,I) - Z*A(I+2,J)           534690
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

 7        DO 300 K=1,N                                                   534700
 7        X(K,I) = X(K,I) - Z*X(K,J)                                     534710
 3    300 CONTINUE                                                       534720
 3    310 CONTINUE                                                       534730
 7        GO TO 60                                                       534740
 3    320 CONTINUE                                                       534750
 7        EIGA(NN) = A(NN,NN)                                            534760
 7        EIGB(NN) = B(NN,NN)                                            534770
 7        IF( NN.EQ.1 )      GO TO 330                                   534780
 7        ITER(NN) = ITS                                                 534790
 7        NN = NM1                                                       534800
 7        IF( NN.GT.1 )      GO TO 50                                    534810
 7        ITER(1) = 0                                                    534820
 7        GO TO 320                                                      534830
 3    330 CONTINUE                                                       534840
 7        M = N                                                          534850
 3    340 CONTINUE                                                       534860
 7        ALFM = A(M,M)                                                  534870
 7        BETM = B(M,M)                                                  534880
 7        B(M,M) = CMPLX(1.0,0.0)                                        534890
 7        L = M - 1                                                      534900
 7        IF( L.EQ.0 )      GO TO 370                                    534910
 3    350 CONTINUE                                                       534920
 7        L1 = L + 1                                                     534930
 7        SL = CMPLX(0.0,0.0)                                            534940
 7        DO 360 J=L1,M                                                  534950
 7        SL = SL + B(J,M)*(BETM*A(L,J) - ALFM*B(L,J))                   534960
 3    360 CONTINUE                                                       534970
 7        Y = BETM*A(L,L) - ALFM*B(L,L)                                  534980
 7        IF(  REAL(Y).EQ.0.0    .AND.                                   534990
 6       $    AIMAG(Y).EQ.0.0 )                                          535000
 6       $Y = CMPLX( (EPSA+EPSB)/2.0, 0.0 )                              535010
 7        B(L,M) = -SL/Y                                                 535020
 7        L = L - 1                                                      535030
 3    370 CONTINUE                                                       535040
 7        IF( L.GT.0 )      GO TO 350                                    535050
 7        M = M - 1                                                      535060
 7        IF( M.GT.0 )      GO TO 340                                    535070
 7        M = N                                                          535080
 3    380 CONTINUE                                                       535090
 7        DO 400 I=1,N                                                   535100
 7        S = CMPLX(0.0,0.0)                                             535110
 7        DO 390 J=1,M                                                   535120
 7        S = S + X(I,J)*B(J,M)                                          535130
 3    390 CONTINUE                                                       535140
 7        X(I,M) = S                                                     535150
 3    400 CONTINUE                                                       535160
 7        M = M - 1                                                      535170
 7        IF( M.GT.0 )      GO TO 380                                    535180
 7        M = N                                                          535190
 3    410 CONTINUE                                                       535200
 7        SS = 0.0                                                       535210
 7        DO 420 I=1,N                                                   535220
 7        R = ABS(REAL(X(I,M))) + ABS(AIMAG(X(I,M)))                     535230
```

```
START
 COL  ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8

  7         IF( R.LT.SS )     GO TO 418                                  535240
  7         SS = R                                                       535250
  7         D = X(I,M)                                                   535260
  3     418 CONTINUE                                                     535270
  3     420 CONTINUE                                                     535280
  7         IF( SS.EQ.0.0 )     GO TO 440                                535290
  7         DO 430 I=1,N                                                 535300
  7         X(I,M) = X(I,M)/D                                            535310
  3     430 CONTINUE                                                     535320
  3     440 CONTINUE                                                     535330
  7         M = M - 1                                                    535340
  7         IF( M.GT.0 )     GO TO 410                                   535350
  3     999 CONTINUE                                                     535360
  7         RETURN                                                       535370
  7         END                                                          535380
```