NASA CR-145165

COMOC II: TWO-DIMENSIONAL AERODYNAMICS SEQUENCE, COMPUTER PROGRAM USER'S GUIDE

BY

P. D. MANHARDT
J. A. ORZECHOWSKI
A. J. BAKER

FEBRUARY, 1977

PREPARED UNDER CONTRACT NAS1-14307

BY

COMPUTATIONAL MECHANICS CONSULTANTS, INC.
3601A CHAPMAN HIGHWAY
KNOXVILLE, TENNESSEE 37920

FOR

National Aeronautics and Space Administration

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-145165		
4. Title and Subtitle COMOC II: TWO-DIMENSIONAL AERODYNAMICS SEQUENCE COMPUTER PROGRAM USER'S GUIDE		5. Report Date February 1977
		6. Performing Organization Code
7. Author(s) P.D. Manhardt, J.A. Orzechowski and A.J. Baker		8. Performing Organization Report No. CoMoC 77TR-3
9. Performing Organization Name and Address Computational Mechanics Consultants, Inc. 3601A Chapman Highway Knoxville, TN 37920		10. Work Unit No.
		11. Contract or Grant No. NAS1-14024 & 14307
12. Sponsoring Agency Name and Address National Aeronautics & Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Contractor Report
		14. Sponsoring Agency Code

15. Supplementary Notes

Final Report: Technical Monitor, Mr. H.L. Morgan, Jr.
Langley Research Center

16. Abstract

The COMOC finite element fluid mechanics computer program system is applicable to diverse problem classes. The two-dimensional aerodynamics sequence has been established for solution of the potential and/or viscous and turbulent flowfields associated with subsonic flight of elementary two-dimensional isolated airfoils. The sequence is constituted of three specific flowfield options in COMOC for two-dimensional flows. These include the potential flow option (2DPF), the boundary layer option (2DBL), and the parabolic Navier-Stokes option (2DPNS). By sequencing through these options, it is possible to computationally construct a weak-interaction model of the aerodynamic flowfield. This report is the user's guide to operation of COMOC for the aerodynamics sequence.

17. Key Words (Selected by Author(s))	18. Distribution Statement
Aerodynamics Turbulent Flow Finite Element Method Computer Program	Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	79	

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

TABLE OF CONTENTS

ILLUSTRATIONS

COMOC II: TWO-DIMENSIONAL AERODYNAMICS SEQUENCE,

COMPUTER PROGRAM USER'S GUIDE

By

P.D. Manhardt, J.A. Orzechowski

And

A.J. Baker

COMPUTATIONAL MECHANICS CONSULTANTS
Knoxville, TN

SUMMARY

The COMOC finite element fluid mechanics computer program system is applicable to diverse problem classes. The two-dimensional aerodynamics sequence has been established for solution of the potential and/or viscous and turbulent flowfields associated with subsonic flight of elementary two-dimensional isolated airfoils. The sequence consists of three specific flowfield options in COMOC for two-dimensional flows. These include the potential flow, option (2DPF), the boundary layer option (2DBL), and the parabolic Navier-Stokes option (2DPNS). By sequencing through these options, it is possible to computationally construct a weak-interaction model of the aerodynamic flowfield. This report is the user's guide to operation of COMOC for the aerodynamics sequence.

INTRODUCTION

The COMOC finite element computer program can solve various differential equation descriptions for fluid flows of practical interest. The two-dimensional aerodynamics sequence has been established to allow determination of the inviscid and irrotational flow about an isolated airfoil, and the resultant pressure distribution including the trailing edge wake trajectory. The potential flow shape may be the actual airfoil, or an "effective" inviscid shape established by inclusion of viscous and turbulent flow effects in the potential solution. These corrections are determined by solution of the boundary layer equations for the viscous attached flow, and the parabolic Navier-Stokes equations for the merging of upper and lower surface turbulent boundary layers into the trailing edge wake. Under the assumption of weak-interaction, the viscous flow computations are executed within the axial pressure (gradient) field established from the inviscid flow solution. The program outputs all viscous flow parameters of interest. The computed distribution of displacement thickness can be employed to augment the inviscid airfoil shape, and a new potential flow pressure distribution then established. Therefore, by cycling through the various flowfield options in COMOC, it is possible to build a weak-interaction solution for the aerodynamic shape of interest.

The two-dimensional aerodynamics sequence in COMOC is constructed upon three distinct program options. Each option is basically a computational sequence that allows solution of the differential equation(s) governing specific classes of fluid flow. The potential flow option (2DPF) establishes the distribution of velocity perturbation function for inviscid irrotational flow about an isolated two-dimensional airfoil. It can be instructed to call the pressure coefficient routine which computes C_p from the potential distribution on the airfoil and on the trailing edge wake. The boundary layer flow option (2DBL) establishes solution for turbulent two-dimensional attached flow in a given C_p distribution. It can run two (opposed) boundary layer solutions with distinct C_p as well, as occurs with upper and lower surface flows on the airfoil. In both cases, closure for turbulence can be accomplished using mixing length theory (MLT), or a second order model built on turbulent kinetic energy (TKE) and solution of additional differential equations. Upon special input specification, an economical integral boundary layer solution can be computed as well, for the entire airfoil including transition from laminar to turbulent.

The merging of the upper and lower surface boundary layers at the trailing edge into a turbulent downstream wake is an important part of the interaction flowfield. Solution for the wake flow is accomplished using the parabolic Navier-Stokes (2DPNS) option in COMOC. The lateral boundaries for this flow are the extended upper and lower surface inviscid flows and the solution is marched down the wake. Closure for turbulence must now be the TKE model; initializing levels are obtained from the boundary layer solutions. Both the 2DBL and 2DPNS options provide detailed downstream distributions of important integral parameters, e.g., skin friction (if appropriate), displacement thickness, shape factor, etc. In the wake region, these parameters are referenced to the downstream projection of the trailing edge included angle bisector. The displacement thickness is usually interpreted to define the effective boundary of an inviscid flow. Therefore, the computed distribution of displacement thickness on the airfoil surface and wake can be employed to define a new effective inviscid shape, and the sequential solution procedure repeated. This constitutes the weak-interaction solution algorithm, which the aerodynamics sequence in COMOC is capable of executing.

COMOC is undergoing a rapid rate of growth and the features of the program discussed herein are newly developed. The theoretical foundation for the finite element solution algorithm, applied to the components of the weak interaction solution, and detailed analysis of accuracy, convergence, and verified capabilities are presented in reference 1. This report is intended to guide the program user in correct problem specification and data deck preparation. It contains a discussion of the organization of COMOC, including a complete description of all real and integer arrays and all FORTRAN variables. Brief mathematical descriptions of the problem statements are given in the next section, including boundary condition constraints. An overview of the finite element algorithm form is presented. The next section discusses data deck preparation, including detailed output for comparison standard test cases. The final section presents the organizational and logical structure for the program.

PROBLEM DEFINITION

Aerodynamic Potential Flow

The 2DPF option in COMOC solves the elliptic boundary value statement for the perturbation potential function, which is the Laplacian, i.e.,

$$L(\phi) = \frac{\partial^2 \phi}{\partial x_i \partial x_i} = 0 \tag{1}$$

The definition for ϕ, in terms of the reference freestream velocity at angle of attack and the local velocity vector u_j is

$$u_j \equiv U_\infty \left[\hat{\varepsilon}_j - \frac{\partial \phi}{\partial x_j} \right] \tag{2}$$

Equation (2) provides the flow tangency boundary condition used for solution of equation (1). Denoting $\hat{n}_j$ as the unit normal vector defining any impervious surface, the boundary condition is

$$\frac{\partial \phi}{\partial x_j} \hat{n}_j = \hat{\varepsilon}_j \hat{n}_j \tag{3}$$

In the freestream, sufficiently remote from the airfoil surface, the flow is undisturbed. Hence, equation (3) vanishing identically can account for this as well as the Kutta condition to admit angle of attack.

Turbulent Boundary Layer Flow

COMOC can execute this option using a coordinate stretching transformation to economically account for boundary layer growth (see ref. 1, equation 94). Denoting $\tilde{u}_i$ as the time-averaged mean flow velocity vector, and assuming constant density, the 2DBL option solves the differential equation system

$$L(\tilde{u}_2) = \left[\frac{\partial}{\partial \xi} - (h_2 + \eta h_3) \frac{\partial}{\partial \eta} \right] \tilde{u}_1 + \frac{\partial \tilde{u}_2}{\partial \eta} = 0 \tag{4}$$

$$L(\tilde{u}_1) = \tilde{u}_1\left[\frac{\partial}{\partial\xi} - (h_2 + \eta h_3)\frac{\partial}{\partial\eta}\right]\tilde{u}_1 + \tilde{u}_2\frac{\partial\tilde{u}_1}{\partial\eta}$$

$$- \frac{\partial}{\partial\eta}\left[\nu^e h_1 \frac{\partial\tilde{u}_1}{\partial\eta}\right] - \frac{1}{\bar{\rho}}\frac{dp_e}{d\xi} = 0 \tag{5}$$

$$L(k) = \tilde{u}_1\left[\frac{\partial}{\partial\xi} - (h_2 + \eta h_3)\frac{\partial}{\partial\eta}\right]k + \tilde{u}_2\frac{\partial k}{\partial\eta}$$

$$- \frac{\partial}{\partial\eta}\left[\frac{\nu^e h_1}{Pr_k}\frac{\partial k}{\partial\eta}\right] - \nu^e\left(\frac{\partial\tilde{u}_1}{\partial\eta}\right)^2 + \varepsilon = 0 \tag{6}$$

$$L(\varepsilon) = \tilde{u}_1\left[\frac{\partial}{\partial\xi} - (h_2 + \eta h_3)\frac{\partial}{\partial\eta}\right]\varepsilon + \tilde{u}_2\frac{\partial\varepsilon}{\partial\eta}$$

$$- \frac{\partial}{\partial\eta}\left[\frac{\nu^e h_1}{Pr_\varepsilon}\frac{\partial\varepsilon}{\partial\eta}\right] - C_\varepsilon^1\varepsilon k^{-1}\nu^e\left(\frac{\partial\tilde{u}_1}{\partial\eta}\right)^2 + C_\varepsilon^2\varepsilon^2 k^{-1} = 0 \tag{7}$$

In equations (4)-(7), ν^e is the effective kinematic viscosity defined as

$$\nu^e = Re^{-1}\nu + \nu_t \tag{8}$$

Here, Re is flow Reynolds number and ν_t is the turbulent eddy viscosity, defined as

$$\nu_t \equiv \begin{cases} \omega^2\ell^2\left|\dfrac{\partial\tilde{u}_1}{\partial x_2}\right| & \text{(MLT)} \quad (9) \\ C_\nu k^2\varepsilon^{-1} & \text{(TKE)} \quad (10) \end{cases}$$

In the MLT specification, ω is the VanDriest damping and ℓ is the mixing length.

Boundary conditions are required for all four variables, equations (4)-(7), at the wall and all except $\tilde{u}_2$ at freestream. The freestream condition is simply vanishing gradient. The no-slip constraint is used for $\tilde{u}_1$ and $\tilde{u}_2$ may have a specified value at the wall. The TKE closure is invalid at a no-slip wall, since the local flow is not fully turbulent. COMOC employs a sub-layer model to internally evaluate appropriate boundary values for both k and ε, at a user-specified value of $y+$ (see ref. 1).

Turbulent Wake Flow

The 2DPNS option in COMOC can be entered directly under a restart from the 2DBL option. The 2DPNS equation system is.

$$L(\bar{\rho}) = \frac{\partial}{\partial x_i}(\bar{\rho}\tilde{u}_i) = 0 \tag{11}$$

$$L(\rho\tilde{u}_i) = \bar{\rho}\tilde{u}_j\frac{\partial\tilde{u}_i}{\partial x_j} + \frac{\partial\bar{p}}{\partial x_i} - \frac{\partial}{\partial x_\ell}\left[\mu^e\left(\frac{\partial\tilde{u}_i}{\partial x_\ell} + \frac{\partial\tilde{u}_\ell}{\partial x_i}\right)\right] = 0 \tag{12}$$

$$L(k) = \frac{\partial}{\partial x_j}(\tilde{u}_j k) - \frac{\partial}{\partial x_\ell}\left[\frac{\nu^e}{Pr_k}\frac{\partial k}{\partial x_\ell}\right] - \nu^e\frac{\partial\tilde{u}_1}{\partial x_\ell}\frac{\partial\tilde{u}_1}{\partial x_\ell} + \varepsilon = 0 \tag{13}$$

$$L(\varepsilon) = \frac{\partial}{\partial x_j}(\tilde{u}_j\varepsilon) - \frac{\partial}{\partial x_\ell}\left[\frac{\nu^e}{Pr_\varepsilon}\frac{\partial\varepsilon}{\partial x_\ell}\right] - C_\varepsilon^1\varepsilon k^{-1}\nu^e\frac{\partial\tilde{u}_1}{\partial x_\ell}\frac{\partial\tilde{u}_1}{\partial x_\ell} + C_\varepsilon^2\varepsilon^2 k^{-1} = 0 \tag{14}$$

where $1 \leq i,j \leq 2$ and $\ell = 2$ only. The second of equations (12) is now solved for $\bar{\tilde{u}}_2$, with equation (11) providing the freestream boundary conditions in terms of C_p, top and bottom. Since the wake is an unbounded flow, the slip surface has vanished and the solution domain for all variables is closed by vanishing freestream normal gradient. Further, the TKE equation system is everywhere valid.

Finite Element Solution Algorithm

The appropriate differential equation systems are established. Each is a special case of the general, second order elliptic boundary value specification

$$L(q) = \frac{\partial}{\partial x_\ell}\left[K\frac{\partial q}{\partial x_\ell}\right] + f_1\left(q,\frac{\partial q}{\partial x_\ell},p,x_i\right) + f_2\left(\tilde{u}_1,\frac{\partial q}{\partial x_1}\right) = 0 \tag{15}$$

where q is interpreted as a generalized dependent variable, i.e., $q \equiv \{\phi, \tilde{u}_1, \tilde{u}_2, k, \varepsilon\}$. The boundary condition statement applicable for all numbers of the set q is

$$\ell(q) = a^{(1)} q + a^{(2)} K \frac{\partial q}{\partial x_\ell} \hat{n}_\ell + a^{(3)} = 0 \qquad (16)$$

The finite element algorithm for equations (15)-(16) is established using the method of weighted residuals. It is

$$\underset{m}{S}\left[\int_{R_m} \{\phi(x_\ell)\}\, L(q_m^*) d\tau - \lambda \int_{\partial R_m \cap \partial R} \{\phi(x_\ell)\} \ell(q_m^*) d\tau\right] \equiv \{0\} \qquad (17)$$

where $\underset{m}{S}$ is the finite element assembly operator, and within the finite element domain R_m, the finite element approximation q_m^* to the solution q is

$$q_m^*(x_i) \equiv \{f(x_\ell)\}^T \{Q(x)\}_m \qquad (18)$$

where $\{f(x_\ell)\}$ are polynomials written on coordinates spanning R_m. Upon application of a Green-Gauss theorem, the globally assembled algorithm for the representative differential equation system (15)-(16) is

$$\underset{m}{S}\left[-\int_{R_m} \frac{\partial}{\partial x_\ell}\{\phi\}\, K \frac{\partial q^*}{\partial x_\ell} d\tau + \int_{R_m} \{\phi\}\, (f_1^* + f_2^*)\, d\tau - \int_{\partial R_m \cap \partial R} \{\phi\} \left[a^{(1)} q^* + a^{(3)}\right] d\tau\right] \equiv \{0\} \qquad (19)$$

In equation (19), the $a^{(i)}$ are coefficients in the boundary condition statements. Of particular interest, note that for $q \equiv \phi$,

$$a^{(3)} \equiv \hat{n}_j\, \hat{\varepsilon}_j \qquad (20)$$

which introduces the non-homogeneous boundary condition constraint directly into the algorithm.

DATA DECK PREPARATION

The input facilities in the COMOC weak interaction viscous-inviscid interaction flow program are highly sophisticated and greatly simplify data deck preparation and modification. The program sequentially scans the data deck and operates on command data cards as they are encountered. Numerical data required for each command operation is input in free format on cards directly following the command card. Command operations can cause vectors to be filled, initiate a series of solution operations or specify output formats and titles. Command card sequence is quite flexible and care has been taken to ensure that most operations which must be performed sequentially are specifiable under one command name. Guidelines for numerical data preparation, command card sequencing and utilization of the output are described in this section. Copies of actual data decks used for solution of the test cases are given in the appendices for reference.

Structure and Guidelines

The COMOC data deck for weak interaction flow solution is divided into six sections for description. Exclusive of machine related job control cards, the six sections consist of a Fortran main routine and accompanying subroutines (if any), namelist data, geometric description, output format specification, boundary and initial condition data and solution command cards (Fig. 1). Each of these data and its subset is preceded by a command card which directs a program activity which when completed returns control to the next data card. The program operates in a dynamic storage mode and the function of Main is to allocate sufficient storage for the IZ array which is internally sized as a function of the number of finite elements requested for a specific problem. The namelist section of the deck is used to specify scalar integer and floating point data utilizing the Fortran namelist option. The data is read in namelists NAME01 and NAME02, respectively, and stored in the arrays IARRAY and RARRAY. Execution of the namelist read is initiated via commands FENAME or NAMELIST.

The geometric description section contains the data required to generate a finite element grid suitable for solution. Command FEDIMN dynamically dimensions the arrays required by the analysis according to the number of nodes (NODE) specified in namelist NAME01. The finite elements are generated via command card LINK2 (14) for viscous flow and LINK1 (09) for potential flow. Finite element numerical data follows these cards as noted in the data deck description.

COMOC employs a highly adaptive output routine which allows for data specification of the scalar and array variables to be printed, scale factors to be applied to each variable and titling information to head each variable list. Each is specified under a command name in the output section (Section IV, Fig. 1) of the data deck. The program operates in non-dimensional units and the data specified scale factors are utilized to present the results in

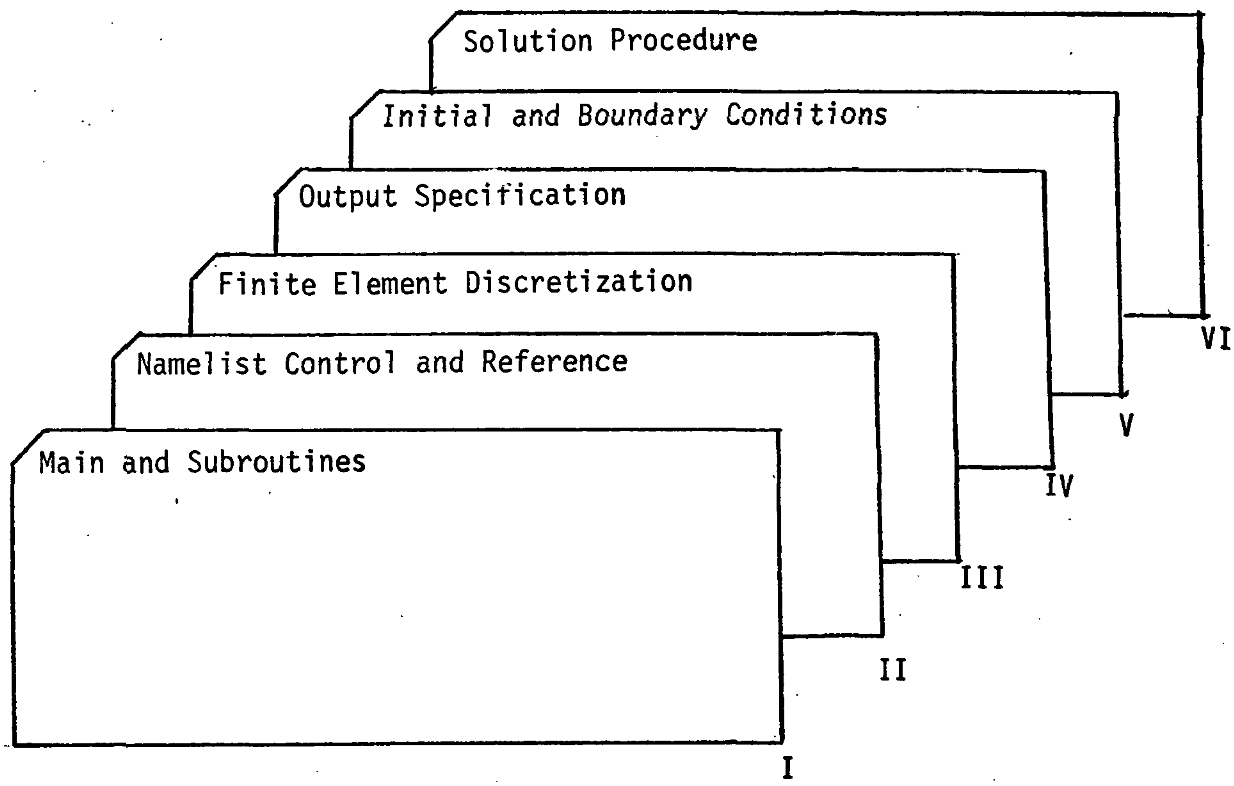

Fig. 1 COMOC Data Deck Major Sections

a consistent set of units. A reference length parameter (REFL in NAME02) is also available to scale all output to a problem reference length, i.e., airfoil chord length. In addition, command names are available for specification of problem identifying titles to be printed at various strategic locations such as the beginning of each set of printed output.

The fifth section of the data deck contains the required boundary and initial condition data which are specified at the solution nodes. The finite element method easily handles mixed boundary conditions, hence, both fixed and Neumann type are allowed. Parameter tables such as C_p vs x may also be specified in this section. Initial conditions are required only for the viscous flow calculations. The inviscid (Cp) solution boundary conditions are automatically generated in subroutine ARFOIL, hence, need not be specified.

Section VI contains the commands for the solution proper. For potential flow, the Laplacian elliptic boundary value problem is solved on the perturbation potential function. Pressure coefficient C_p is subsequently evaluated over the airfoil and in the wake region by differentiating ϕ. For viscous flow solutions, the generated C_p curve is differentiated in DPDXTB. Upon command QKNINT in the solution section, integration of the 2DBL equation system over the airfoil or integration of 2DPNS in the wake region is performed subject to the applied pressure gradient.

A complete listing of the allowed command names and a brief description of their use is given in Table 1. During the progression from sections one to five in the data deck, various execution and data management commands are required in addition to numerical data specifications. These are more fully explained for particular sample test cases which follow.

Free Format

Most of the numerical data other than command data specified in the COMOC input deck may be input in free format. Data delimiters may be blanks or commas. The end of a data set is indicated by a T or blank card for numerical data and a DONE beginning in card column 1 for literal data. Exceptions to the rule are namelist data which utilizes the standard Fortran Namelist option and certain special card types which combine literal and numerical data. Command cards are an example of this type and the restrictions imposed are that the command name begin in column 1 and numerical data begins beyond column 10.

Several features which greatly simplify sequential and repetitive data specifications are available in free format. For example:

Repetitive Numbers	12. 5*7.
Fills Array	12. 7. 7. 7. 7. 7.
Repetitive Sequence (one per card only)	2(5. 2. 4.
Fills Array	5. 2. 4. 5. 2. 4
Skip P locations	10. 12. 3*P 22. T
Fills Array	10. 12. Δ Δ Δ 22.
Increment by a constant	5* 50 10 T
Fills Array	10 60 110 160 210
Exponential Notation	6. 10.E-2 14.E-4 T
Fills Array.	6. .1 .0014

Restart

The airfoil viscous solution proceeds in marching fashion along the upper and lower airfoil surfaces toward the trailing edge and into the wake region. If the solution fails to reach the final station in the allotted Cpu time, it is desirable to restart the solution where it ended rather than begin again. The RESTART and SAVETAPE commands permit this by writing the entire stored array on a user specified file at each requested print interval.

Sample Test Cases

Three test cases were selected for checkout of the COMOC solution options which are coupled under a weak interaction assumption. Test case results are presented in the accompanying theoretical report (ref. 1). Potential flow and pressure coefficient (C_p) were calculated for flow over a NACA-0015 airfoil with modified leading edge region as noted in Ref. 2. Secondly, a viscous boundary layer solution was obtained for the geometry of Bradshaw as reported in the Stanford Conference Proceedings (ref. 3). The wake region was analyzed for a Joukowski 12% thick airfoil at 6° angle of attack. Data deck setup for these cases is described in detail in the following sections and a copy of the complete data deck for each is presented in the appendices.

TABLE 1

Command Name Input

A CONTROL CARD WITH THE FOLLOWING PARAMETERS IS READ IN -

PARAMETER	FORMAT	CARD COLS	DESCRIPTION
V1	A8	1 - 8	CONTROL VARIABLE.
NMUL	FREE	AFTER 8	NMUL(1) = NX NMUL(2) = NPCD NMUL(3) = NREPET NMUL(4) = NRTAPE - - - NMUL(N)
		TO	

IF KOUMP = 1 IN NAME01, THEN THE ENTIRE INPUT CARD IS PRINTED IMMEDIATELY AFTER BEING READ FOLLOWED BY THE DATA THAT IS BEING STORED ALONG WITH THE DATA'S ENTRY POSITION IN THE IZ ARRAY (SEE IPLACE AND NPLACE)

THIS ROUTINE LOOKS FIRST FOR A MATCH OF V1 WITH CERTAIN KEY WORDS WHICH WILL EITHER CAUSE A SUBROUTINE TO BE CALLED OR PROGRAM FLOW TO OCCUR.

- -

THE KEY WORDS THAT ARE SCANNED ARE -

- -

```
ABSVAL N1 N2 N3-   SET RZ(IZ(N2)) = ABS(RZ(IZ(N3))), I = 1, N1
      (BLANK)  -   RETURN TO SCAN ANOTHER CARD.
COMOC          -   PRINT THE COMOC TITLE PAGE TWO TIMES.
COMTITLE       -   READ A TITLE CARD WHICH WILL APPEAR ON COMOC.
DESCRIPT NX    -   CALL DSCRPT AND PROCESS ACCORDING TO NX.
                      NX
                   BLANK - READ AND WRITE INFORMATION CARDS.
                     203 - READ TITLES FOR DEP. VAR. OUTPUT HEADINGS.
                     204 - READ DESCRIPTIVE TITLE FOR HEADING
                           AT BEGINNING OF OUTPUT HEADER.
                     332 - READ TITLES FOR PARAMETERS PRINTED IN
                           THE OUTPUT HEADER.
END            -   RETURN CONTROL TO MAIN PROGRAM, RESET ARRAYS
                   AND RETURN TO BDINPT.
EXIT           -   CALL EXIT.
2DPF           -   SET IBL = 0 AND IPHI = 1.
3DBR           -   SET IBL = 1.
3DPNS          -   SET IBL = 1 AND N3DPNS = 1.
2DNS           -   SET IBL = 0.
FEDIMN         -   CALL DIMENSIONALIZATION ROUTINE FEDIMN.
FENAME         -   CALL FENAME TO SET DEFAULT SCALARS AND THEN
                   CALL NMELST TO READ IN NAME01 AND NAME02
                   NAMELISTS.

IARRAY   N1, N2, N3, N4, ETC.
         SET IARRAY(N1) = N2, IARRAY(N3) = N4, ETC.
```

TABLE 1 Contd.

```
ICCND               -  CALL ICCND TO PRINT REAL AND INTEGER SCALARS.
INPUT N1            -  SET INPUT UNIT TO N1.
INTEGER             -  ALLOWS NEW VALUES TO READ INTO A SEQUENCE
                       OF LOCATIONS IN THE BORDER, IPLACE AND NLOC
                       VECTORS.
KBND      NX        -  ENTER FIXED NODES FOR DEP. VARIABLE NX.
                         CALL GETBND
KBND      NX   1    -  ENTER FIXED NODES AND/OR BOUNDARY
                       CONDITIONS FOR DEP. VARIABLE NX.
                         CALL GETBCC
LINK1     NX        -  CALL LINK1(NX)
LINK2     NX        -  CALL LINK2(NX)
LINK3     NX        -  CALL LINK3(NX,DUMMY1,DUMMY2)
LINK4     NX        -  CALL LINK4(NX,K)
LINK5     NX        -  CALL LINK5(NX)
MATSUM  N1, N2, N3, N4, N5
                    - CALL MATSUM ( RZ(IZ(N2)), RZ(IZ(N3)), RARRAY(N4),
                          RZ(IZ(N5)), N1 )
NAMELIST            -  CALL NMELST TO READ IN NAME01 AND NAME02
                       NAMELISTS.
PDUMP N1 N2 N3 -  CALL PDUMP ( IZ(IZ(N2)), IZ(IZ(N3)), N1 )
PLUS N1 N2 N3 . . . ETC.
READ   N1 N2 N3 N4
                        READ ( N1 ) RZ(IZ(N3)+N4) , I = 1, N2
SAVETAPE N1 N2   - SAVE OUTPUT ON UNIT N1, REWIND AFTER
                             MOD ( KOUNT, N2 ) = 0.
SETVAL N1 N2 N3 N4 N5
                    -  CALL SETVAL ( RZ(IZ(N2)), RZ(IZ(N3)),
                              RARRAY(N4), RARRAY(N5), N1 )
SQRT N1 N2 ... -  RARRAY(N1) = SQRT(RARRAY(N2)
                       RARRAY(N3) = SQRT(RARRAY(N4))
                         . . . ETC.
SQRT N1 N2 N3   -  RZ(IZ(N2) = SQRT(RZ(IZ(N3))), I = 1, N1
VYYEND    NX        -  DENOTES END OF INPUT FOR DEP. VAR. NX.
WRITE N1 N2 N3 N4
                       WRITE ( N1 ) RZ(IZ(N3)+N4) , I = 1, N2
```

```
IF NONE OF THE ABOVE SITUATIONS OCCUR,
THE VECTORS BORDER AND VALUE ARE SCANNED UNTIL A MATCH IS FOUND
  AND THE LOCATION IS STORED IN THE PARAMETER 'K'.
```

TABLE 1 Contd.

DESCRIPTION OF INTEGER TYPE INPUT

- -

BORDER IS A VECTOR OF CONTROL NAMES WHICH IS SCANNED WITH THE USER INPUT CONTROL FOR INTEGER INPUT.

- -

IZ(IPLACE(K)) = LOCATION IN THE IZ ARRAY AT WHICH TO BEGIN STORING INTEGER ENTRIES.

IARRAY(NLOC(K)) = NUMBER OF ENTRIES STORED STARTING AT IZ(IPLACE(K)).

IF NX .NE. -1, CALL GETBND TO ENTER INTEGER DATA.
IF NX .EQ. -1, CALL ADDCEL TO ENTER INTEGER DATA.

SEE GETBND FOR INPUT DESCRIPTION.

K	BORDER	IPLACE(K)	NLOC(K)	DEFINITION
3	THICK	68	93	ELEMENT THICKNESS VECTOR.
7	IPINT	5	31	SOLUTION SEQUENCE VECTOR.
12	LINKCALL	121	125	LINK NOS. TO BE CALLED AT END OF QKNUIN.
13	SPECIES	31	121	VARIABLE NOS. FOR SPECIES TO BE RUN.
14	IOMULT	123	67	OUTPUT VARIABLE MULTIPLIER FROM RARRAY.
15	IOSAVE	124	60	VARIABLE LIST TO BE DISPLAYED AT OUTPUT.
16	CNTPTS	127	47	CONTOUR NODES TO BE USED IN CONTES, DFCFBL, TRBTHK, WLFLXS, ETC.
17	CNTNDS	128	128	NO. OF NODES IN EACH CONTOUR LINE.
18	IBCRC	38	131	COUNTER-CLOCKWISE LIST OF BOUNDARY.
21	IONUMB	131	142	LIST OF ENTRIES IN RARRAY TO BE DISPLAYED AT START OF EACH OUTPUT.
22	MPARA	135	67	LIST OF MULTIPLIERS IN RARRAY USED TO MULTIPLY IONUMB ENTRIES.
26	NX	117	67	NO. OF SUBDIVISIONS / SUPER ELEMENT ALONG DIRECTION 1.
27	NY	118	67	NO. OF SUBDIVISIONS / SUPER ELEMENT ALONG DIRECTION 2.
28	ELEMENTS	26	14	READ IN ELEMENT NODE CONNECTIONS.

NOTE -
NLOC(K) OR NVOC(K) = 67 IMPLIES PRESET LENGTH IS NOT CHANGED.

TABLE 1 Contd.

DESCRIPTION OF REAL TYPE INPUT

- -

VALUE IS A VECTOR OF CONTROL NAMES WHICH IS SCANNED WITH THE USER INPUT CONTROL FOR REAL INPUT.

- -

IZ(NPLACE(K)) = LOCATION IN THE IZ ARRAY AT WHICH TO BEGIN STORING REAL ENTRIES.

IARRAY(NVOC(K)) = NUMBER OF ENTRIES STORED STARTING AT IZ(NPLACE(K)).

ROUTINE REDREL IS CALLED AT THIS TIME TO ENTER DATA.

THESE CONTROL CARDS CAN CONTAIN A GROUP OF MULTIPLIERS FOR THE ENTERED DATA.

```
E. G.
VYY          3  -100.0  -27
    1.2  0.9    3.7  T   VORTICITY INPUT

      THE PROGRAM SETS  AMULT = -100.0 * RARRAY(3) / RARRAY(27)
      THEN VYY(1) = AMULT * 1.2
           VYY(2) = AMULT * 0.9
           VYY(3) = AMULT * 3.7
```

K	VALUE	NPLACE(K)	NVOC(K)	DEFINITION
3	VU3POS	65	178	X STATION FOR VARIABLE GRID CHANGE.
4	VU3VAL	66	67	SCALE FACTOR FOR VARIABLE GRID CHANGE.
5	VTHICK	70	67	VALUE OF ELEMENT THICKNESSES. DEFAULT = 1.0 / ALC
6	VRHO	84	67	DENSITY AT NODE POINTS. DEFAULT = RHOINF
7	VTTAB	19	59	TABLE LOOK-UP TEMPERATURES. DEFAULT = TOFINF
8	VCPTAB	18	67	TABLE LOOK-UP SPECIFIC HEATS. DEFAULT = CPOINF
9	VX1COR	89	16	X1-COORDINATES AT NODE POINTS.
10	VX2COR	90	16	X2-COORDINATES AT NODE POINTS.
11	VH	79	67	ENTHALPY DISTRIBUTION AT NODE POINTS. DEFAULT = 1.0
16	VPRESS	91	67	PRESSURE VALUES AT NODE POINTS. DEFAULT = PINF
17	VSCHMIDT	114	67	SCHMIDT NO. DIST. AT NODE POINTS. DEFAULT = SCT
18	VYY	82	67	DEPENDENT VAR. DIST. AT NODE POINTS.
19	VTEMP	85	67	TEMPERATURE DIST. AT NODE POINTS. DEFAULT = TOFINF
22	VTK	88	67	THICKNESS OF ELEMENTS IN THICK VECTOR. DEFAULT = 1.0 / ALC

TABLE 1 Contd.

23	VSUTHLD	133	67	STLDVR, STLDTR, STLDCR, STLDEX, STLCON ENTRIES FOR SUTHERLANDS LAW. DEF. .1163E-4, 494.0, 204.0, 1.5, 0.0
24	VPRANDTL	134	67	PRANDTL NO. DIST. AT NODE POINTS. DEFAULT = PR
25	VX3ST	139	161	DOWNSTREAM STATIONS AT WHICH PRESSURE IS DEFINED.
26	VPVSX	140	67	DOWNSTREAM PRESSURES AT VX3ST.
27	VEPSILON	136	67	TURBULENT VISCOSITY AT NODE POINTS. DEFAULT = XMUINF
29	RARRAY	0	67	RARRAY(NX) = AMULT, WHERE AMULT = COMBINATION OF REMAINING ENTRIES.
31	VWALLSTA	67	82	DOWNSTREAM POS. AT WHICH TO INJECT TRANSVERSE VELOCITY.
32	VWALLVAL	68	81	VALUE OF INJECTED TRANSVERSE VELOCITY.

NACA 0015 (Modified) Potential Flow

Data specifications for finite element potential flow analysis over single element airfoils has been greatly simplified through use of the COMOC grid generator and automated evaluation of the airfoil normal gradient (a_3) boundary conditions. The basic data requirements therefore, consist of an accurate description of the airfoil or viscous boundary shape. The airfoil shape is left as a subroutine specification since certain classes such as Karman-Trefftz may be generated rather than data specified. Subroutine SHAPE is keyed to call various subroutines which generate airfoil shapes. An example of data specification for a modified NACA 0015 airfoil is shown in Fig. 2. The airfoil is point specified and the subroutine is called from SHAPE when JSHP is set equal to 2 in Namelist NAME01. Other airfoil shapes may be similarly input by substituting the Fortran subroutine AFSHP in Figure 2 and specifying JSHP = 2 in NAME01. The Fortran deck is placed behind MAIN in section one of the data deck. If the airfoil shape is of a class which may be generated from general parameters such as maximum thickness ratio, chord length, etc, such as the Karmann-Trefftz class of airfoils, shape changes are effected by merely changing the shape generating parameters. The required parameters for the Karmann-Trefftz class are trailing edge angle, maximum thickness ratio (t/c), angle of attack (α) and camber angle (β). These data are input in the Namelist NAME02 and maximum thickness ratio and angle of attack are always required since they are used to scale the solution domain. Given an airfoil shape, thickness ratio and angle of attack, therefore, the appropriate finite element grid for an external flow domain is automatically generated and the gradient (a_3) boundary conditions are evaluated and applied at the appropriate finite element boundaries.

The following list presents the major sections of the potential flow data deck and a brief description of the command and data cards required.

Section I Fortran Main and Subroutines

The function of Main is to allocate space for the data arrays. The amount of space required is problem dependent and the size of the data arrays must be initially guessed at for each different discretization refinement. The actual size of the "IZ" array utilized by the program is printed (IARRAY (100) = IREND) as illustrated in the output section and the dimensions in MAIN can be reduced accordingly on subsequent runs. A list of MAIN for the potential flow test case is illustrated in Figure 2.

Airfoil shapes are input by subroutine AFSHP which directly follows MAIN in the data deck. The maximum airfoil thickness (t/C) must be specified in namelist NAME02 to provide the discretizer with the proper domain size scale factors. Data requirements consist of the airfoil coordinates along each surface non-dimensionalized by chord length and in the order upper, lower proceeding from the leading to trailing edge, and the number of points along one surface.

```
C             - - - C - O - M - O - C - - -
         COMMON / ARRAYS / IZ(40000)
         COMMON / VARBLE / IARRAY(00500), RARRAY(00500)
         EQUIVALENCE ( IARRAY(00092), IZSIZE )
         CALL ERRSET ( 207, 500, -1, 1, 0, 217 )
     100 CONTINUE
C
         CALL ZEROTK
         CALL RESET ( 00500, IARRAY, 0 )
         CALL RESET ( 00500, RARRAY, 0.0 )
         IZSIZE = 40000
         CALL RESET  ( IZSIZE, IZ, 0 )
         CALL BDINPT
         GO TO 100
         END
```

2a MAIN Program

```
      SUBROUTINE AFSHP(D,X1AF,X2AF,NPTS)
C
C --- PURPOSE -- POINT SPECIFICATION OF AN AIRFOIL SHAPE
C
C ---             COORDINATES IN CHORD LENGTHS, UPPER SURFACE FOLLOWED
C                 BY LOWER SURFACE, LEADING EDGE TO TRAILING EDGE,
C                 100 TOTAL POINTS (MAX.)
C                 SAME NUMBER OF POINTS UPPER AND LOWER
C                 MAXIMUM THICK. RATIO (T/C) MUST BE SPEC. IN NAME01
      DIMENSION D(1), X1AF(1), X2AF(1)
      DIMENSION X10015(050), X20015(050)
      DATA  X10015/
     *            0., .0023, .0057, .0114, .0173, .0229, .0343, .0458,
     *            .0572, .0687, .0801,  .103, .1259, .1488, .1717, .206,
     *            .2518, .3, .3433, .3891, .4349, .4807, .5265, .5722,
     *            .6295, .6867, .7439, .8011, .8584, .9156, .9614, 1.,
     *            18*0./
      DATA  X20015/
     *            0., .0145, .022, .0287, .0336, .0376, .0433, .0473,
     *            .05, .0532, .0545, .059, .0632, .0664, .0693, .0721,
     *            .0746, .075, .0744, .0729, .0704, .0672, .0633, .059,
     *            .0538, .0478, .0408, .0335, .0252, .016, .0077, .0,
     *            18*0./
      NPTS = 32
      DO 100 I=1,NPTS
      X1AF(I) = X10015(I)
  100 X2AF(I) = X20015(I)
      WRITE(6,600)(X1AF(I),I=1,NPTS)
      WRITE(6,610)(X2AF(I),I=1,NPTS)
      RETURN
  600 FORMAT(//,10X,37HDATA SPECIFIED AIRFOIL X1-COORDINATES,
     *       (/,47X,5E12.5))
  610 FORMAT(/,33X,14HX2COORDINATES, (/,47X,5E12.5))
      END
```

2b Subroutine AFSHP

Figure 2 MAIN Program and Subroutine AFSHP

Section II NAMELIST Specified Control and Reference Parameters

Command	Name	Code	Function
2DPF			Initiates COMOC execution
FENAME &NAME01			Read NAMELIST & set default values Fortran NAMELIST integer data
	JSHP	1	Karman-Trefftz class airfoil
		2	Calls user supplied subroutine AFSHP to obtain airfoil shape
	NAFPT		Number of data points specified along one airfoil surface.
	NODE		Greater than or equal to the number of solution nodes expected.
	NVRHS	5	Dependent variable to be used in STRF
	NVP	5	Variable vector extracted from dependent variable array.
	NIZS	250	Data starting point in the IZ array
	KDUMP	1	Prints data reflection and IZ array entry points.
	NMBOUT	1	Number of output variables
	NC		Number of digits to right of decimal in print + 3
	LCOL		Maximum number of columns in discretization
	KROW		Maximum number of rows in discretization
	NMOUT	2	Prints dependent variable ϕ solution in node number ascending order.

Command	Name	Code	Function
NMOUT		3	Geometric form print
&NAME02			
	THKAF		Airfoil maximum thickness
	ALPHA		Angle of attack
	BETA		Karman Trefftz camber angle
	TEANG		Trailing edge angle
	RNB		Flow Reynolds number
	COMPX		Geometric form print compression factor (rows). Required if NMOUT = 3.
	COMPY		Geometric form print compression factor (columns)
ICOND			Prints NAMELIST data stored in arrays IARRAY, RARRAY.
FEDIMN			Dimension Arrays

Section III Finite Element Discretization 2DPF

Command		Function
NX		Specifies grid refinement normal to the airfoil surface for each super element
NY		Specifies grid refinement along airfoil surface for each super element
LINK1	9	Generates airfoil flow domain discretization sized and scaled for airfoil in subroutine AFSHP
LINK2	14	Generate vectors for output control

Section IV Output Specification

Sample output is listed in the next section

Command	Function
COMTITLE	Reads title which is printed below the COMOC symbol
DONE	Terminates literal data
DESCRIPT 204	Solution print heading
DONE	Same as above

The next three commands are inter-related and should be fully understood prior to changing them. See subroutine BDINPT under subroutines and variables.

Command	Function
DESCRIPT 332	Solution print parameter titles Starting location at RZ(L(32))
MPARA -1	RARRAY locations of multiplier to be applied to parameter print
IONUMB -1	RARRAY locations of parameters to be printed
DESCRIPT 203	Titles to head dependent variable (ϕ) print
IOSAVE -1	List of dependent variables to be printed.
IOMULT -1	List of locations in RARRAY of multipliers to be applied to each dependent variable for print

Section V Dependent Variable Boundary and Initial Condition Specifications

The potential flow solution is strictly a boundary value problem, therefore, no initial conditions are required. Gradient boundary conditions are internally computed from the specified geometry, and internally applied as in equation 16, hence, no boundary condition specification is required.

Command		Function
IPINT	-1	Numbers of the Dependent and Parameter Variables in the Solution

Section VI Solution Procedure 2DPF

Command		Function
Link 3	4	Non-dimensionalize coordinates
LINK 1	3	Finite element matrices
LINK 2	5	Print node numbers
LINK 2	7	Potential Flow Solution ($\nabla^2\phi = 0$)
LINK 2	6	Print potential field
COMOC		Print COMOC symbol and title specified under command COMTITLE
EXIT		End of execution

Bradshaw Boundary Layer

The finite element discretization for 2D boundary layer solutions is one dimensional and essentially consists of a column of one dimensional finite elements normal to the airfoil surface. Explicit integration of the boundary layer equations is performed over the column of elements as it marches in the major flow direction. Specification of the finite element geometry has been greatly simplified thru the use of geometric progression super elements where each element size is a geometric function of the one preceeding it according to the equation

$$z_{i+1} = z_0 + s \sum_{j=2}^{M+1} p^{j-2} \tag{21}$$

In equation (21) p is the specified geometric progression ratio and M is the number of finite elements to be generated and scaled by S. For airfoil flows, therefore, two super elements are required. The progression for the lower surface should be less than unity, while for the upper surface, greater than unity to provide discretization refinement in the vicinity of the airfoil.

The following list presents a description of the Bradshaw data deck. Parameters previously described are omitted to avoid redundancy. A complete listing of the actual data deck is given in Appendix B.

Command	Name	Code	Function
FENAME &NAME01			
	IPTSPL	1	τ(wall), Patanker & Spaulding
		0	τ(wall), Ludwig Tillman
	ITWALL	1	τ(wall), du/dy wall
		0	Use one of the above
	NEQKNN		Number of variables being integrated (must not be greater than NEQ)
	NM	2	One dimensional Finite Elements
		3	Two-dimensional Finite Elements
	NPRNT		Print page size, in columns
	NTKS		Number of integral parameters printed
	NTPRNT	99999	Suppress integral parameter print
	KNTPAS		Maximum number of integration steps between prints
&NAME02			
	RNULOC	0.	Laminar viscosity for Van Driest coef. in DFCFBL
		1.	Turbulent viscosity for Van Driest coef. in DFCFBL
	REFL		Reference length applied to output
	UINF		Mean Flow Velocity (ft/sec.)
	TOFINF		Reference temperature (Rankine)
	PINF		Reference pressure (PSF)
	TO		Initial station for explicit integration in direction of flow (ft.)
	TD		Distance to final integration station (ft.)
	DELP		Print interval (% of TD)

Command	Function
LINK2 14	Forms discretization
VX2SCL	
Z0, NINT1, Z1, ZPR1, NINT2, Z2, ZPR2	Sample discretization card. Z0 - first Z coordinate NINT1,2 number of finite elements, ZPR1,2 - geometric progression ratio
NDECRD	
NODZ, NOZ, 1, 1, 0, T	Sample node selection card NODZ first node in discretization NOZ number of nodes in Z direction
ELEM	Finite element connection table
DONE	Ends finite element generation sequence

Section V Dependent Variable, Boundary and Initial Condition Specifications

In this section, initial values of all dependent variables being integrated must be specified at each solution node. An exception to this occurs when integrating the TKE and DISS equations, since a program option exists which allows these variables to be internally initialized from an MLT turbulence model. Boundary conditions (eqn. 16) are specified in this section in two forms, together with a vector of nodes along which each is to be applied. Dependent variable values are held constant by simply specifying the dependent variable number on the KBNO command card and listing the node numbers in free format on cards following. (see subroutine GETBND in the next section). Gradient boundary conditions are applied in a special format as described under subroutine GETBCD. Other solution parameters may also be input in this section in the form of tables to be interpolated as solution progresses (i.e., pressure coefficient for dp/dx_1 evaluation). Table 1 lists and describes the allowed command names and the function of each.

Command	Function
KBNO 1	Nodes where values of the variable 1 are to be fixed
BOTTOM	Special command card which fixes all nodes along one surface. Other options are Top, Right and Left.
VX3ST	Tabular input of x_1 locations for pressure table (ft.)
VPVSX	Tabular input of edge velocity (U_1/U_∞)
VYY	U_1 velocity initialization
VYYEND 1	(Non-dimensional input) may be input dimensionally if non-dimensionalizing factor is specified on the VYY card beginning in column 11. A convenient method of nondimensionalization is to specify the integer location of UINF in the RARRAY array.

Section VI Solution Procedure 2DBL

Command			Function
LINK2 4			Calls the continuity equation solver
LINK2 20			Bradshaw data initialization
LINKCALL -1			Subroutines called during the integration phase
	1	5	Obtain P&P from table
	2	3	Evaluate gradients at airfoil boundary

	5	6	Evaluate effective viscosity
	2	15	Evaluate the integral parameters
QKNINT			Initiates explicit integration phase to march the solution from TO to TO+TD. At each integration station, calls are placed to the LINKCALL subroutines specified under the command (Linkcall).

Joukowski Wake

A viscous turbulent solution was performed in the wake of a 12% thick Joukowski airfoil at 6° angle of attack. The parabolic Navier Stokes option (2DPNS) was utilized and initial velocity profiles at the trailing edge were experimentally derived (ref. 4). The solution was initialized .01 chord lengths upstream of the trailing edge and marched downstream and into the wake region. A method of incorporating problem specification changes in COMOC such as the sudden ending of the airfoil at the trailing edge is to issue a RESTART command which is activated following return from QKNINT. Upon restart program variables may be respecified and integration continued. For the Joukowski airfoil test case the solution was begun at .99 chord using the 2DBL option with TD set at .01. The restart deck following the QKNINT command contained boundary condition information which effectively removed the surface gradient. U_2 boundary conditions were applied and LINKCALL was modified to perform a 2DPNS solution. The data deck sequence required to perform this sequence is described below. Again, duplication of previously defined parameters is avoided. A complete listing of the data deck required to perform this solution is given in Appendix C.

Section II Namelist Specified Control and Reference Parameters 2DBL

Command	Name	Code	Function
3DBR			Initiates COMOC executions
FENAME & NAME01			Reads namelist data
	NEQ		Number of variable vectors in the solution
	LG		≥ Number of values in array CNTPTS.
	NU2POS		Number of values in tables VU2POS And VU2VAL

Command	Name	Code	Function 2DBL
	NU3POS		Number of values in tables VU3POS And VU3VAL
	NEQADD		Number of variables in IPINT not integrated until VSTART or C4EDSW values of x_1 are reached.
	NC		Number of characters in a print word
	NBC		Number of a_1 , a_3 boundary conditions to be applied.
&NAME02			
	VSTART		% of TD where U_2 is to be ~~initiated when using CONTES.~~
	XMUINF		Mean viscosity
	HSINIT		Initial integration step size
	C4EDSW		X_1 location where TKE and dissipation become dependent variables and begin integrating (see NEQADD in NAME01)
	PRTKE		TKE from Prandtl mixing length
	PRDIS		Dissipation from Prandtl mixing length
	C1TKE		Dissipation production coefficient
	C2TKE		Dissipation dissipation coefficient
	CKTKE		TKE production coefficient
	CD		Constant in dissipation equation.
	YLTKE		Constant for Diss. length calculation for MLT.
	ESCF		Diss. with scale factor from MLT
	YPLUS		Non-dimensional Y wall

Command	Index	Function
VU3POS		Tabular specification of x_1 coordinate describing geometric boundary variation in the Z direction.
VU3VAL		Values of Z at each VU3POS x_1 coordinate The 2DBL and 2DPNS equations are scaled to allow for grid growth as the solution proceeds
KBNO	I	Nodes where variable is to be fixed
	I = 1	Variable No. 1 - U_1 velocity
	I = 2	Variable No. 2 - U_2 velocity
	I = 5	Variable No. 5 - Turbulent Kinetic Energy
	I = 6	Variable No. 6 - Dissipation Function
VYY		
VYYEND	1	Only U_1 need be initially specified.For boundary layers U_2 is computed from the continuity equation. The continuity equation is initiated by setting VSTART in NAME02, and U_2 is counted as a variable in NEQ but not in NEQKNN in NAME01.

TKE and DISS, variables 5 and 6 respectively, are initialized from the MLT model. Setting NE1E2 equal to 2 and E1E2SW to a small increment of TO will initiate a laminar-turbulent (MLT) sequence and NEQADD = -2 will maintain TKE + DISS as solution parameters to be evaluated from MLT results. C4EDSW in NAME02 is the X_1 location where variables 5-6 become solution dependent variables utilizing the values stored during their parameter status as initial conditions.

Command	Index	Function
LINK2	21	Obtain pressure from the C_p table.
SAVETAPE	10 2	Store the entire data arrays set on unit specified at each print station. The second integer indicates the number of back-up writes to retain for restart.
RESTART	0 1	To initiate a restart and allow changes in the data deck. Change equations to 2DPNS

The following explains the restart deck in Appendix C as used specifically for the Joukowski test case.

Section II Namelist Specified Control And Reference Parameters 2DPNS

Command	Name	Code	Function
NAMELIST & NAME01			Reads Namelist data
	KDUMP	0	No print of input
		1	Print input as encountered.
	NEQADD	0	All equations integrated immediately upon restart
	NE1E2	0	Do not evaluate MLT anywhere

Command	Index	Function
IBORD		Set up vector of boundary-nodes for boundary condition input.
RIGHT		Freestream node along upper surfaces
DONE		Ends literal data
KBNO	1	All nodes in solution for Variable 1 (u_1)
DONE		Terminates Literal Data.
KBNO	2 1	Dep. Var. 2 boundary conditions
BOTTOM	0,0,0, 0.0, 2, 4.321, 2	0.0,2 sets a_1= 0.0 4.321,2 sets $\frac{dv}{dy} = - \frac{du}{dx}$
TOP	0,0,0, 0.0 2, -4.321, 2	Same as for bottom. These cards set the boundary conditions required to integrate U_2' to form 2DPNS equation system. ±4.321 is a code indicating that the a_3 freestream boundary condition is to be obtained from du/dx.
DONE		Ends literal data
KBNO	5	Removes fixed restrictions on TKE new airfoil surface
DONE		Terminates Literal Data
KBNO	6	Removes fixed restriction on dissipation near airfoil surface.
DONE		
IARRAY	145 0	IMIN = 0
RARRAY	15 7 -1	H = (non-dimensional)
RARRAY	22 1.001 -1	Reset final station (non-dimensional)

Command	Index	Function
LINKCALL	-1 T	Calls routines to solve the 2DPNS equations
	1 5	Evaluate dp/dx
	2 15	Evaluate integral parameters
	5 6	Evaluate diffusion coefficients
3DPNS		Flags 2DPNS solution
SAVETAPE	10 2	Saves data on unit 10 modulo 2.
QKN1NT		Initiates 2DPNS equation integration.
EXIT		End of job

Selected Print Samples

The output package in COMOC is quite versatile and allows the user substantial print format control. The standard print may be described in the three distinct classes of problem identifying titles, data reflection print and solution print. Each of these operates under control of the user as described in the previous section. Three different titles may be input under different command names for print below the COMOC symbol on command COMOC, print at the beginning of the data reflection or as a descriptive heading at the beginning of each solution print.

Data reflection print is accessed by setting KDUMP = 1 in NAME01 and the print format is illustrated in Figure 3. Each card in the deck is printed as it is encountered. In addition, vectors filled by array data are printed directly following the data reflection, thus providing a positive verification of proper input. Common data errors such as not specifying "T" or blank card delimiters are easily detected since the reader will continue to read cards until it encounters one of these. The print subsequently appears as continuous data reflection of all the cards under the original command name, thus providing a quick and positive data check. Scalar data is stored in the arrays RARRAY and IARRAY. Print of these data is accessed by inserting the command ICOND. Figure 4 illustrates the print format. This provides a quick check of the namelist data specification and program computed scalars which are stored in these arrays.

```
 200 38 200 2*38,  999,  39  4*36,  200 154  98 135 122,
  11  12  14  85  47   T

     IONUMB      58 ENTRIES.
 8743-   999  8744-   200  8745-   200  8746-   200  8747-   200  8748-   200  8749-   999  8750-   200  8751-    43  8752-    43
 8753-    43  8754-    43  8755-   200  8756-    27  8757-   200  8758-    27  8759-    27  8760-   200  8761-    10  8762-   200
 8763-    10  8764-    10  8765-   200  8766-    58  8767-   200  8768-    58  8769-   200  8770-   200  8771-    97  8772-   200
 8773-    97  8774-   200  8775-   200  8776-    30  8777-   200  8778-    30  8779-   200  8780-   200  8781-    38  8782-   200
 8783-    38  8784-    38  8785-   999  8786-    39  8787-    36  8788-    36  8789-    36  8790-    36  8791-   200  8792-   154
 8793-    98  8794-   135  8795-   122  8796-    11  8797-    12  8798-    14  8799-    85  8800-    47

  DESCRIPT  203        T  IFMTHD TITLES FOR OUTPUT DEPENDENT VARIABLES.
 U1 / UREF        U2 / UREF        TKE / TKEREF     DISS / DISSREF  MU / MUREF
 U1 PRIME         U2 PRIME         TKE PRIME        DISS PRIME      DPDX
 DONE

  IOSAVE   -1
 1248 2248 5248 6248 1247 1249 2249 5249 6249   305   T

     IOSAVE      10 ENTRIES.
 8111-  1248  8112-  2248  8113-  5248  8114-  6248  8115-  1247  8116-  1249  8117-  2249  8118-  5249  8119-  6249  8120-   305

  IOMULT   -1
  10*2   T

     IOMULT      10 ENTRIES.
 8096-     2  8097-     2  8098-     2  8099-     2  8100-     2  8101-     2  8102-     2  8103-     2  8104-     2  8105-     2

  CNTPTS       -1
      21     21    T

     CNTPTS       2 ENTRIES.
 8654-    21  8685-    21

  CNTNDS        -1
      21*I-1     21     25*11     22       T

     CNTNDS      46 ENTRIES.
 8686-    21  8687-    20  8688-    19  8689-    18  8690-    17  8691-    16  8692-    15  8693-    14  8694-    13  8695-    12
 8696-    11  8697-    10  8698-     9  8699-     8  8700-     7  8701-     6  8702-     5  8703-     4  8704-     3  8705-     2
 8706-     1  8707-    22  8708-    23  8709-    24  8710-    25  8711-    26  8712-    27  8713-    28  8714-    29  8715-    30
 8716-    31  8717-    32  8718-    33  8719-    34  8720-    35  8721-    36  8722-    37  8723-    38  8724-    39  8725-    40
 8726-    41  8727-    42  8728-    43  8729-    44  8730-    45  8731-    46

  IPINT    -1
     1   5   6   2    T

     IPINT        4 ENTRIES.
  558-     1   559-     5   560-     6   561-     2

  LINK3     4     T    DIMEN        COMPUTE NON-DIM. PARAMETERS.

      LOCATION OF INDEPENDENT VAR.

     1-     1     2-     4     3-     0     4-     0     5-     2     6-     3     7-     0     8-     0     9-     0    10-     0
    11-     0    12-     0    13-     0    14-     0    15-     0    16-     0    17-     0    18-     0

  LINK1     3     T    GEOMFL       GENERATE GEOMETRY VECTORS AND MATRICES.

  KBND      1
```

Figure 3 Sample Data Reflection Print (KDUMP = 1 in NAME01)

INITIAL CONDITIONS :

1	ND =	1	2	MLTDIF =	0	3	IROW =	1	4	KEYMTD =	1	5	NOMEGB =	0
6	KODG =	0	7	KOD5 =	0	8	KPRINT =	0	9	NRSTRT =	0	10	NV =	0
11	NPTDOF =	1	12	NCC =	0	13	NCOORD =	0	14	NELEM =	45	15	NN =	3
16	NNODE =	46	17	NNS =	6	18	NPART =	2	19	NOE =	46	20	NPRNT =	60
21	NROW =	2	22	NC =	10	23	NB =	4	24	NPTEL =	3	25	KIND =	4
26	KOUNT =	1	27	NSKIP =	30	28	IPASS =	0	29	IRUN =	0	30	NP =	4
31	NEQ =	4	32	=	0	33	NBUG =	0	34	LPRINT =	100	35	NPSICC =	0
36	NPRSCC =	0	37	IS200 =	0	38	IS3000 =	0	39	=	0	40	=	0
41	=	0	42	=	5	43	NEQADD =	-3	44	NSTORE =	0	45	NEXP =	0
46	NF =	4	47	LG =	2	48	NDOF =	0	49	NQEL =	3	50	LCOL =	1
51	NDBL =	0	52	KROW =	45	53	NH2 =	0	54	NHHALF =	0	55	NODE =	55
56	NDOUTZ =	0	57	IASVEC =	0	58	NEWKNN =	4	59	NCPTAB =	1	60	NMBOUT =	10
61	KOUMP =	1	62	NTITL =	3	63	NIND =	110	64	NSM =	5	65	NJ =	0
66	NRHOSS =	0	67	NS =	14	68	NI =	331	69	NBSET =	0	70	NVP =	9
71	NVU =	1	72	NVV =	2	73	NVW =	3	74	NVH =	4	75	NVK =	5
76	NVE =	6	77	NPR =	16	78	=	0	79	NPT =	0	80	=	0
81	IVWVAL =	0	82	IVSTA =	0	83	IFSLT =	0	84	NVARD =	0	85	NVAR1 =	0
86	KPNT =	0	87	NRTAPE =	10	88	KLINE =	60	89	NEMD =	55	90	NYY =	2
91	NZZ =	2	92	IZSIZE =	15000	93	NTK =	2	94	NIZS =	200	95	NVELTB =	0
96	IBASE =	200	97	ITKS =	0	98	IMAT =	1	99	IBL =	1	100	IREND =	9950
101	NPRESS =	0	102	KCUT =	0	103	NTM =	0	104	NFLIP =	1	105	IPTSPL =	1
106	KK =	2	107	NE1E2 =	2	108	NUQ3 =	0	109	NTAPER =	4	110	NPRESH =	0
111	IMAX =	3	112	=	0	113	KPLVAR =	0	114	MSSD =	0	115	IFORCE =	0
116	IGINIT =	0	117	IBUG1 =	0	118	IBUG2 =	0	119	NGBUG =	0	120	IFR =	0
121	NSPEC =	9	122	IWRIT =	0	123	IGAS =	0	124	NDERIV =	2	125	NCALLS =	10
126	ISPEED =	0	127	IDIFRT =	0	128	ICNTND =	55	129	IMATAB =	2	130	NGETH =	1
131	NBORD =	0	132	IPWRIT =	0	133	ITOP =	0	134	NPSIBD =	0	135	NPSBDL =	0
136	KSAV =	0	137	LPSIA1 =	0	138	LPSIAM =	0	139	INGAS =	0	140	NTCNTS =	1
141	=	0	142	NOUTPR =	58	143	=	45	144	ITRAN =	0	145	IMIN =	0
146	NSFDBE =	0	147	NPAST =	0	148	NONC =	0	149	IT =	0	150	NODNG =	0
151	NSCX =	0	152	NSCY =	135	153	NPUNCH =	0	154	NELDEL =	0	155	NELADD =	0
156	LFIL =	1	157	LRS =	44	158	INITCN =	0	159	NSORCE =	1	160	NSPRSC =	0
161	NPVSX =	14	162	NDPVSX =	26	163	NPSIST =	0	164	NPSIND =	0	165	=	0
166	N3DPNS =	0	167	KNTPAS =	99	168	NOPRES =	0	169	KCOC =	0	170	NBC =	2
171	NBCND =	148	172	LOWD =	2	173	NCOMOC =	0	174	NCOMTD =	1	175	IFSL =	0
176	NTKS =	10	177	NU2POS =	0	178	NU3POS =	0	179	LJC =	1	180	NSTRT =	7
181	NVELP =	0	182	LOGS =	0	183	IXST =	24	184	IXEND =	50	185	IP =	7
186	ITDA =	16	187	ITDB =	15	188	NBUF =	0	189	NSTD =	8	190	NMOUT =	3
191	NM =	2	192	N2M =	4	193	NM2 =	4	194	NDP =	8	195	KFXGND =	0
196	ITWALL =	0	197	NTPRNT =	0	198	NPGRDT =	4	199	NPGRDV =	4	200	INTPSI =	0

Figure 4a Scalar Integer Data Contained in IARRAY and Passed Through COMMON/VARBLE/, (First 200 Locations)

INITIAL CONDITIONS

1	FACT	= 1.1664E-04	2	ONE	= 1.0000E 00	3	ALC	= 1.1664E-04	4	THK	= 8.5732E 03	5	AJ	= 7.7828E 02
6	SOUND	= 0.0	7	HSINIT	= 1.0000E-07	8	RMINS1	= -1.0000E 00	9	PINF	= 2.1168E 03	10	RHOINF	= 7.4471E-02
11	XT	= 0.0	12	HT	= 0.0	13	DELP	= 1.7661E 02	14	EPS	= 1.0000E-02	15	H	= 8.5732E-04
16	HMAX	= 8.8304E 00	17	HMIN	= 0.0	18	OUTEPS	= 0.0	19	PNTEPS	= 0.0	20	PTIM	= 0.0
21	RE	= 2.8066E 01	22	TF	= 9.4305E 03	23	TIME	= 8.5475E 03	24	TO	= 8.5475E 03	25	TRNC	= 0.0
26	TWOPI	= 6.2832E 00	27	UINF	= 4.0000E 01	28	FUNIV	= 1.5453E 03	29	ZT	= 0.0	30	CPOINF	= 2.4000E-01
31	G	= 3.2174E 01	32	RTCON1	= 5.0081E 04	33	RTCON2	= 7.0000E-01	34	RTCON3	= 5.3342E 01	35	TD	= 8.8304E 02
36	PEDDIM	= 2.1170E 03	37	XLE	= 1.0000E 00	38	XMUINF	= 1.2360E-05	39	PEDGE	= 5.7162E 02	40	TRATIO	= 1.0002E 00
41	XSHFT	= 0.0	42	YSHFT	= 0.0	43	REFL	= 1.0000E 00	44	SQ2	= 1.4142E 00	45	HS	= 0.0
46	XMDXR	= 0.0	47	REFLRE	= 2.4062E 05	48	TIMESV	= 0.0	49	RTEST	= 1.0000E-02	50	SSINIT	= 8.5732E-04
51	VELU	= -7.5065E 09	52	XSCALE	= 1.0000E 00	53	YSCALE	= 4.4812E-03	54	TURB	= 0.0	55	RTCON4	= 8.7455E-04
56	RTCON5	= 2.4975E-04	57	RTCON6	= 1.7491E-03	58	TOFINF	= 5.3300E 02	59	FACTMU	= 3.4746E-04	60	GAMMAF	= 1.4000E 00
61	XMACHO	= 3.5346E-02	62	CONV	= 1.0000E 00	63	XSAVE	= 1.0000E 00	64	YSAVE	= 4.4812E-03	65	ZTEST	= 1.0000E-05
66	XMF	= 2.9400E 01	67	PR	= 1.0000E 00	68	EP4MD	= 1.0000E-01	69	DISS	= 0.0	70	CONRHO	= 0.0
71	STLDVR	= 1.1630E-05	72	STLDTR	= 4.9200E 02	73	STLDCR	= 2.0400E 02	74	STLDEX	= 1.5000E 00	75	STLCON	= 0.0
76	YTT	= 0.0	77	CON1	= 1.3988E 00	78	CON2	= 2.6243E-03	79	FACTP	= 2.6780E 03	80	FACTH	= 7.8174E-03
81	XI	= 0.0	82	YI	= 0.0	83	COMPX	= 0.0	84	COMPY	= 0.0	85	HMIND	= 0.0
86	AVD	= 2.5300E 01	87	ARNEW	= 0.0	88	HHMIN	= 0.0	89	EPSINF	= 5.4868E 08	90	EKNINF	= 1.6000E 03
91	RVEL	= 0.0	92	PFSLL	= 1.0000E-01	93	PFSLH	= 9.0000E-01	94	RATO2	= 0.0	95	EPTEST	= 1.8225E-09
96	PSISTR	= 0.0	97	HINF	= 1.0000E 00	98	XPRIME	= 1.7301E-05	99	PPRCON	= 3.1750E 04	100	PPRIME	= 5.4931E-01
101	YUP	= 0.0	102	VSTART	= 8.8304E 00	103	DEPLT	= 8.9187E 02	104	VELCST	= 2.4975E-04	105	RCCST	= 1.3370E 01
106		= 0.0	107	VELD	= 0.0	108	ENMULT	= 4.7661E 03	109	XMA	= 2.8970E 01	110	XMH	= 2.0160E 00
111	DELX3	= 8.5475E 03	112	X3LAST	= 0.0	113	DLAST	= 0.0	114	DLXML	= 0.0	115	ARSCAL	= 0.0
116	RR	= 1.4354E 01	117	RTOHM1	= 1.3004E 01	118	XMSDF	= 0.0	119	ROUALC	= 4.0529E-08	120	SCAL	= 0.0
121	HDOT	= 0.0	122	HKSDOT	= 0.0	123	QR	= 1.0000E 00	124	CON	= 4.3500E-01	125	XLAM	= 9.0000E-02
126	XMUAIR	= 1.1500E-05	127	XMUNRM	= 1.0000E 00	128	XMUCRS	= 1.0000E 00	129	SCT	= 1.0000E 00	130	C4ED	= 7.0000E-04
131	SPLIT	= 2.8350E-02	132	HRCON	= 2.9126E-02	133	PCNT	= 1.0000E-02	134	Q3MAX	= 0.0	135	ENERGY	= 0.0
136	OSMAX	= 9.2070E 02	137	AVDP	= -4.1000E-01	138	RUESQ	= 1.0776E 02	139	VH	= 0.0	140	VK	= 2.0000E 00
141	VA	= 1.5100E 00	142	VB	= 6.7500E-01	143	C4EDSW	= 9.9720E-01	144	C4FACT	= 1.0000E 00	145	E1E2SW	= 9.9710E-01
146	TOA	= 5.3300E 02	147	TOH	= 5.2000E 02	148	CVH	= 1.0000E 00	149	CVU	= 3.0480E-01	150	CVT	= 1.0000E 00
151	CVP	= 4.7250E-04	152	CVRHO	= 1.6020E 01	153	CVCP	= 4.1860E 03	154	XMACHS	= 3.5346E-02	155	TSINF	= 5.3287E 02
156	AINF	= 1.1315E 03	157	RHOUIN	= 2.9788E 00	158	CPA	= 2.4000E-01	159	CPH	= 3.4450E 00	160	CPINF	= 2.4000E-01
161	RO161	= 3.1416E 00	162	FTTOIN	= 1.2000E 01	163	FTTOCM	= 3.0480E 01	164	FTTOMT	= 3.0480E-01	165	DKTODK	= 5.5556E-01
166	PSFTOA	= 4.7250E-04	167	PSFTOT	= 3.5910E-01	168	PSFTCN	= 4.7880E 01	169	PSFTOI	= 6.9440E-03	170	PDFTOK	= 1.6020E 01
171	PRSCON	= 3.7034E 00	172	XMFACT	= 3.5608E-02	173	ZMAX	= 0.0	174	PDFTOC	= 1.6020E-02	175	EBTOKJ	= 2.3244E 00
176	CBTOKJ	= 4.1840E 00	177	VLBTON	= 1.4880E 00	178	VLBTOP	= 1.4880E 01	179	RADCCN	= 1.7453E-02	180	PMSKGS	= 4.5455E-01
181	PRTKE	= 1.0000E 00	182	C1TKE	= 1.4500E 00	183	C2TKE	= 1.8000E-01	184	CKTKE	= 9.0000E-02	185	PRDIS	= 1.3000E 00
186	H1	= 1.0000E 00	187	H2	= 0.0	188	H3	= 0.0	189	H4	= 0.0	190	SLOPE	= 2.6238E 01
191	ADUCT	= 1.0000E 00	192	XLAST	= 0.0	193	XNWGEO	= 0.0	194	XTTT	= 0.0	195	YTT	= 0.0
196	THETA	= 0.0	197	YF3SF1	= 0.0	198	YPLUS	= 3.0000E 01	199	RNULOC	= 0.0	200		= 0.0

Figure 4b Scalar Real Data Contained in RARRAY and Passed Through COMMON/VARBLE/, (First 200 Locations)

Solution print may be subdivided into two parts for purposes of discussion. The first contains header information which includes narrative titles specifying the option being executed. This is followed by a titled table of parameters as specified in Section IV of the data deck. Figure 5 illustrates one of the more elaborate tables which includes mean values of various flow and thermodynamic parameters in four different sets of units. Integration parameters such as x_1 station, current integration step size, cumulative number of passes through the derivative evaluation routine, and number of print stations are also given to provide information on integration status.

The header section is followed by print of the solution variables at their current computed values. The variables specified under the IOSAVE and IOMULT commands in Section IV of the data are printed according to the digit format specified in NAMEOI parameter NC. Titles for each variable printed are specifiable under command DESCRIPT-203 and appear as illustrated in Figure 6. All dependent variables and their derivatives and node specified solution parameters may be printed in this form.

Geometric form print of solution variables is the default option for print at each solution print station. This form of print is illustrated in Figure 6 where the airfoil surface is envisioned at the center of the geometry and the discretization proceeds above and below the surface. A more graphic example of the usefulness of this option occurs in the potential flow solution where a two-dimensional finite element grid is required. Figure 7 illustrates that by geometrically ordering the print, values of potential function at points of interest with respect to the airfoil are readily identified. In order to keep this print form within a few pages, however, compression factors must be applied to the data. These are specified as COMPX and COMPY in NAMEO2, and higher numbers provide the most compression. Unfortunately, compression causes some of the data to be eliminated from the print. The region of maximum loss is in the highly refined and more interesting portion of the flowfield. This problem can be overcome, however, by resorting to the more standard columnar form of print which is accessed by setting NMOUT = 2 in NAMEO1.

In addition to standard print of discrete variables at selected print intervals, the option exists to print integral solution parameters in the 2DBL and 2DPNS COMOC options at each integration station. This print, as illustrated in Figure 8, provides an indication of solution progress between print stations. Solution of these parameters must be requested (2-15) under the LINKCALL command in Section VI of the data deck.

Upon call to QKNINT, a series of prints is initiated. The first, illustrated in Figure 9, prints the variable numbers and types in the solution. If a restart unit is requested, the unit number is printed. The order of calls for solution process is listed and identified, followed by the variables and multipliers to appear following the header page at each DELP.

```
                                          C O M O C
                                 2-DIMENSIONAL BOUNDARY LAYER OPTION

                     AIRFOIL SOLUTION
X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -
 REFERENCE          ENGLISH-FT       ENGLISH-IN          M-K-S            C-G-S

X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -
 LENGTH              ...FEET...       ....IN....        ....M.....       ....CM....
                    0.10000E+01      0.12000E+02       0.30480E+00      0.30480E+02
 VELOCITY            ..FT/SEC..                         ...M/S....       ...CM/S...
                    0.40000E+02                        0.12192E+02      0.12192E+04
 DENSITY             .LBM/FT3..                         ..KG/M3...       ...G/CC...
                    0.74471E-01                        0.11930E+01      0.11930E-02
 TEMPERATURE         .RANKINE..                         ..KELVIN..
                    0.53300E+03                        0.29611E+03
 ENTHALPY            .BTU/LBM..                         ..KJ/KG...
                    0.43022E+00                        0.10000E+01
 FROZ. SPEC.HEAT     .BTU/LBM-R                         .KJ/KG-K..
                    0.24000E+00                        0.10042E+01
 VISCOSITY           .LBM/FT-S.                         .NT-S/M2..       ..POISE...
                    0.12380E-04                        0.18421E-04      0.16421E-03
X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -
 LOCAL PRESSURE      ...PSF....       ...PSI....        ..NT/M2...       ...TORR...
    0.57162E+03     0.21170E+04      0.14700E+02       0.10136E+06      0.76020E+03
 LOCAL SOLUTION      .MACH. NO.       ..DPDX1...        ..ENERGY..       .MIX. EFF.
                    0.35346E-01      0.17301E-04       0.67591E+01      0.0     E+00
 X1/LREF             .DX1/LREF.       .EPSILON..        .DX1M/LREF REFL REYNOLDS NO
    0.99700E+00     0.0     E+00     0.10000E-01       0.0     E+00     0.24062E+06
 - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -
                                                                                N-   .N+   PASSES    PRINT    OF
                                                                                0     0      1         1      100
```

Figure 5 Typical Solution Header Print

	UI / UREF	E 0 UI PRIME	E -1
E 0			
0.1073923	0.9509999		0.0
0.1005452	0.9509999		0.0
0.0936981	0.9509999		0.0
0.0868510	0.9509999		-.0000303
0.0800039	0.9509999		-.0001516
0.0731569	0.9509999		-.0001907
0.0674524	0.8999999		-.0001985
0.0626980	0.8299999		-.0002044
0.0587368	0.7799999		-.0002313
0.0554355	0.7199999		-.0002306
0.0526846	0.6799999		-.0002751
0.0503920	0.6299999		-.0002504
0.0484817	0.5999999		-.0002433
0.0468896	0.5899999		-.0004307
0.0455627	0.5499999		-.0002583
0.0444573	0.5249999		-.0002706
0.0435359	0.5099999		-.0004495
0.0427683	0.4899999		-.0004257
0.0421284	0.4699999		-.0018185
0.0415952	0.4099999		-.0020625
0.0411509	0.3299999		-.0109676
0.0407806	0.1599999		0.0198502
0.0404721	0.0999999		0.0109147
0.0402150	0.0699999		-.0693190
0.0400007	0.0		0.0
0.0398841	0.0300000		0.1675854
0.0397383	0.0899999		-.1000563
0.0395561	0.1099999		0.0425826
0.0393283	0.1799999		0.0101792
0.0390435	0.2899999		-.0054481
0.0386876	0.3799999		-.0033594
0.0382426	0.4299999		0.0032377
0.0376865	0.5499999		0.0007832
0.0369915	0.6999999		-.0008970
0.0361226	0.7399999		0.0006494
0.0350364	0.7999999		0.0004917
0.0336786	0.8599999		0.0004551
0.0319811	0.9099999		0.0004520
0.0298593	0.9499999		0.0004244
0.0272074	0.9509999		0.0004603
0.0238922	0.9509999		0.0004609
0.0197485	0.9509999		0.0004609
0.0145683	0.9509999		0.0004609
0.0080930	0.9509999		0.0004609
0.0	0.9509999		0.0004609
E 0	0.0		0.0

Figure 6 Typical Dependent Variable and Derivative Print

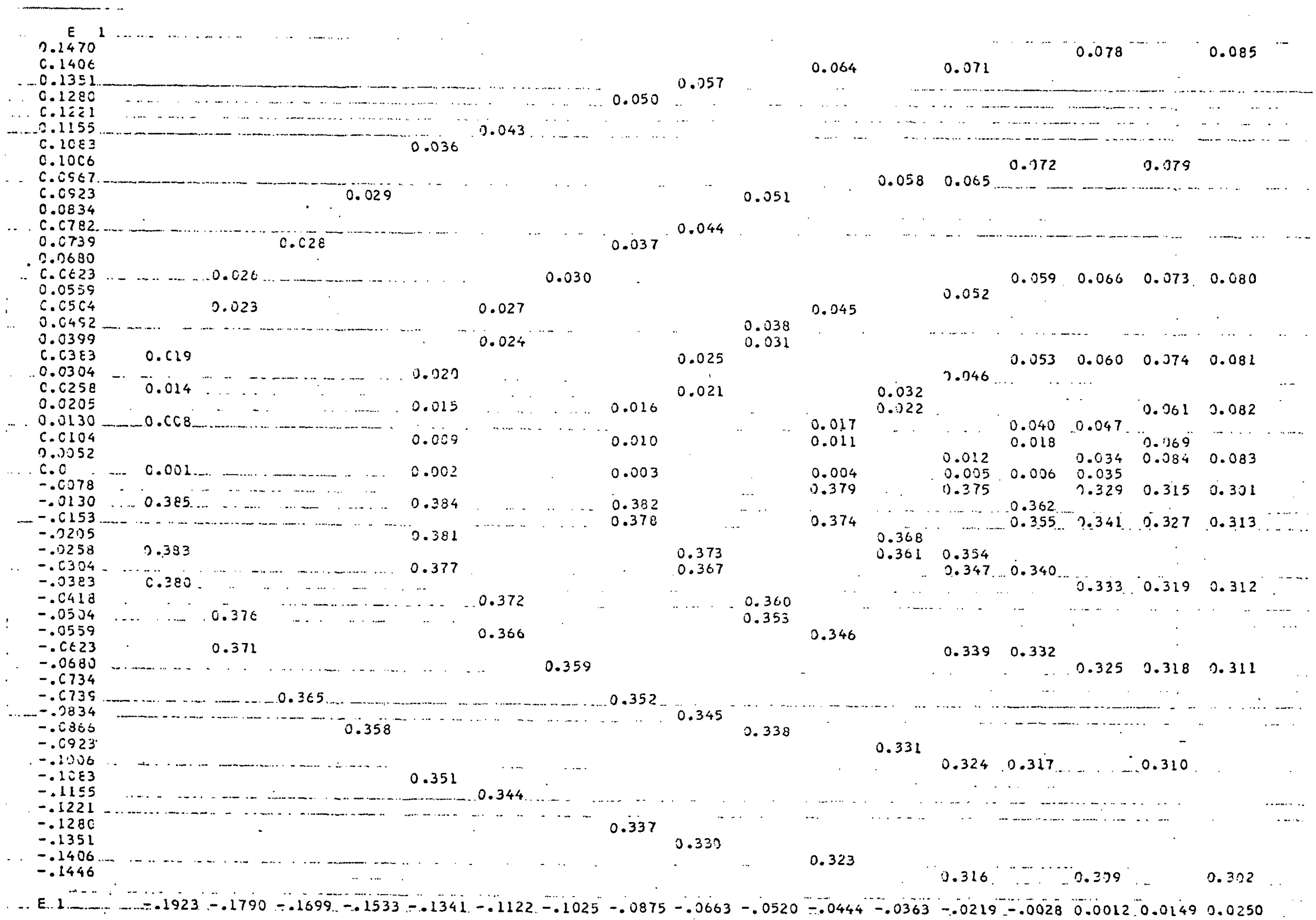

Figure 7 Node Map of Potential Flow Solution Domain
NACA-0015 (Mod.),First Quarter Chord

CURRENT XI/LREF	VELOCITY U1/UINF WALL	EDGE	ENERGY E	DISP. THK. DEL STAR	MOM. THK. THETA	EN. DIS.THK DELTA 3	THETA REYNL. NO.	BNDY THK. DELTA	SHAPE FCT. H	SKIN FRIC. CF/2
1.0049E 00	2.1097E-01	9.4747E-01	2.1758E 01	2.1498E-03	1.2628E-03	2.1152E-03	2.8779E 02	9.7246E-03	1.7024E 00	8.0953E-03
1.0049E 00	1.4819E-01	9.4726E-01	2.1758E 01	8.4406E-03	5.0964E-03	8.5300E-03	1.1612E 03	3.2282E-02	1.6562E 00	3.1032E-03
1.0049E 00	2.1131E-01	9.4747E-01	2.1753E 01	2.1492E-03	1.2628E-03	2.1153E-03	2.8779E 02	9.7246E-03	1.7020E 00	8.1082E-03
1.0049E 00	1.4843E-01	9.4727E-01	2.1753E 01	8.4403E-03	5.0964E-03	8.5300E-03	1.1612E 03	3.2282E-02	1.6561E 00	3.1082E-03
1.0049E 00	2.1164E-01	9.4748E-01	2.1749E 01	2.1486E-03	1.2628E-03	2.1153E-03	2.8779E 02	9.7247E-03	1.7015E 00	8.1211E-03
1.0049E 00	1.4866E-01	9.4727E-01	2.1749E 01	8.4400E-03	5.0964E-03	8.5300E-03	1.1612E 03	3.2282E-02	1.6561E 00	3.1132E-03
1.0049E 00	2.1197E-01	9.4748E-01	2.1744E 01	2.1480E-03	1.2628E-03	2.1154E-03	2.8779E 02	9.7248E-03	1.7010E 00	8.1339E-03
1.0049E 00	1.4890E-01	9.4728E-01	2.1744E 01	8.4397E-03	5.0963E-03	8.5300E-03	1.1612E 03	3.2282E-02	1.6560E 00	3.1181E-03
1.0050E 00	2.1231E-01	9.4748E-01	2.1746E 01	2.1474E-03	1.2627E-03	2.1154E-03	2.8778E 02	9.7248E-03	1.7006E 00	8.1467E-03
1.0050E 00	1.4913E-01	9.4728E-01	2.1746E 01	8.4394E-03	5.0963E-03	8.5300E-03	1.1612E 03	3.2282E-02	1.6560E 00	3.1231E-03
1.0050E 00	2.1264E-01	9.4749E-01	2.1740E 01	2.1468E-03	1.2627E-03	2.1155E-03	2.8778E 02	9.7249E-03	1.7001E 00	8.1594E-03
1.0050E 00	1.4936E-01	9.4728E-01	2.1740E 01	8.4391E-03	5.0963E-03	8.5300E-03	1.1612E 03	3.2283E-02	1.6559E 00	3.1280E-03
1.0050E 00	2.1297E-01	9.4749E-01	2.1735E 01	2.1462E-03	1.2627E-03	2.1155E-03	2.8778E 02	9.7249E-03	1.6996E 00	8.1722E-03
1.0050E 00	1.4960E-01	9.4729E-01	2.1735E 01	8.4388E-03	5.0963E-03	8.5300E-03	1.1612E 03	3.2283E-02	1.6559E 00	3.1329E-03
1.0050E 00	2.1330E-01	9.4750E-01	2.1731E 01	2.1455E-03	1.2627E-03	2.1156E-03	2.8778E 02	9.7250E-03	1.6992E 00	8.1849E-03
1.0050E 00	1.4983E-01	9.4729E-01	2.1731E 01	8.4385E-03	5.0963E-03	8.5300E-03	1.1613E 03	3.2283E-02	1.6558E 00	3.1378E-03
1.0050E 00	2.1363E-01	9.4750E-01	2.1726E 01	2.1449E-03	1.2627E-03	2.1156E-03	2.8778E 02	9.7251E-03	1.6987E 00	8.1975E-03
1.0050E 00	1.5007E-01	9.4730E-01	2.1726E 01	8.4383E-03	5.0963E-03	8.5300E-03	1.1613E 03	3.2283E-02	1.6558E 00	3.1427E-03
1.0051E 00	2.1397E-01	9.4750E-01	2.1726E 01	2.1443E-03	1.2627E-03	2.1157E-03	2.8778E 02	9.7251E-03	1.6982E 00	8.2104E-03
1.0051E 00	1.5030E-01	9.4730E-01	2.1726E 01	8.4380E-03	5.0963E-03	8.5300E-03	1.1613E 03	3.2283E-02	1.6557E 00	3.1477E-03
1.0051E 00	2.1430E-01	9.4751E-01	2.1720E 01	2.1437E-03	1.2627E-03	2.1157E-03	2.8777E 02	9.7252E-03	1.6978E 00	8.2232E-03
1.0051E 00	1.5054E-01	9.4731E-01	2.1720E 01	8.4377E-03	5.0963E-03	8.5300E-03	1.1613E 03	3.2283E-02	1.6556E 00	3.1527E-03
1.0051E 00	2.1463E-01	9.4751E-01	2.1722E 01	2.1431E-03	1.2626E-03	2.1158E-03	2.8777E 02	9.7253E-03	1.6973E 00	8.2361E-03
1.0051E 00	1.5077E-01	9.4731E-01	2.1722E 01	8.4374E-03	5.0963E-03	8.5300E-03	1.1613E 03	3.2284E-02	1.6556E 00	3.1576E-03
1.0051E 00	2.1497E-01	9.4752E-01	2.1715E 01	2.1425E-03	1.2626E-03	2.1159E-03	2.8777E 02	9.7253E-03	1.6968E 00	8.2488E-03
1.0051E 00	1.5100E-01	9.4732E-01	2.1715E 01	8.4371E-03	5.0963E-03	8.5299E-03	1.1613E 03	3.2284E-02	1.6555E 00	3.1625E-03
1.0051E 00	2.1530E-01	9.4752E-01	2.1711E 01	2.1419E-03	1.2626E-03	2.1159E-03	2.8777E 02	9.7254E-03	1.6964E 00	8.2616E-03
1.0051E 00	1.5123E-01	9.4732E-01	2.1711E 01	8.4368E-03	5.0963E-03	8.5300E-03	1.1613E 03	3.2284E-02	1.6555E 00	3.1674E-03
1.0052E 00	2.1563E-01	9.4752E-01	2.1706E 01	2.1413E-03	1.2626E-03	2.1160E-03	2.8777E 02	9.7255E-03	1.6959E 00	8.2743E-03
1.0052E 00	1.5147E-01	9.4733E-01	2.1706E 01	8.4365E-03	5.0963E-03	8.5299E-03	1.1613E 03	3.2284E-02	1.6554E 00	3.1723E-03
1.0052E 00	2.1596E-01	9.4753E-01	2.1702E 01	2.1407E-03	1.2626E-03	2.1160E-03	2.8776E 02	9.7255E-03	1.6955E 00	8.2870E-03
1.0052E 00	1.5170E-01	9.4733E-01	2.1702E 01	8.4363E-03	5.0963E-03	8.5299E-03	1.1613E 03	3.2284E-02	1.6554E 00	3.1772E-03
1.0052E 00	2.1629E-01	9.4753E-01	2.1704E 01	2.1401E-03	1.2626E-03	2.1161E-03	2.8776E 02	9.7256E-03	1.6950E 00	8.2996E-03
1.0052E 00	1.5193E-01	9.4734E-01	2.1704E 01	8.4360E-03	5.0963E-03	8.5299E-03	1.1613E 03	3.2285E-02	1.6553E 00	3.1821E-03
1.0052E 00	2.1661E-01	9.4754E-01	2.1697E 01	2.1395E-03	1.2626E-03	2.1161E-03	2.8776E 02	9.7257E-03	1.6946E 00	8.3123E-03
1.0052E 00	1.5216E-01	9.4734E-01	2.1697E 01	8.4357E-03	5.0963E-03	8.5299E-03	1.1613E 03	3.2285E-02	1.6553E 00	3.1870E-03
1.0052E 00	2.1694E-01	9.4754E-01	2.1693E 01	2.1389E-03	1.2625E-03	2.1162E-03	2.8776E 02	9.7257E-03	1.6941E 00	8.3248E-03
1.0052E 00	1.5239E-01	9.4735E-01	2.1693E 01	8.4354E-03	5.0962E-03	8.5299E-03	1.1613E 03	3.2285E-02	1.6552E 00	3.1918E-03
1.0053E 00	2.1727E-01	9.4755E-01	2.1686E 01	2.1383E-03	1.2625E-03	2.1162E-03	2.8776E 02	9.7258E-03	1.6937E 00	8.3374E-03
1.0053E 00	1.5262E-01	9.4735E-01	2.1688E 01	8.4351E-03	5.0962E-03	8.5299E-03	1.1613E 03	3.2285E-02	1.6552E 00	3.1966E-03
1.0053E 00	2.1760E-01	9.4755E-01	2.1689E 01	2.1377E-03	1.2625E-03	2.1163E-03	2.8776E 02	9.7259E-03	1.6932E 00	8.3502E-03
1.0053E 00	1.5285E-01	9.4735E-01	2.1689E 01	8.4348E-03	5.0962E-03	8.5299E-03	1.1613E 03	3.2285E-02	1.6551E 00	3.2015E-03
1.0053E 00	2.1793E-01	9.4755E-01	2.1683E 01	2.1371E-03	1.2625E-03	2.1164E-03	2.8775E 02	9.7259E-03	1.6928E 00	8.3629E-03
1.0053E 00	1.5308E-01	9.4736E-01	2.1683E 01	8.4345E-03	5.0962E-03	8.5299E-03	1.1613E 03	3.2285E-02	1.6551E 00	3.2064E-03
1.0053E 00	2.1826E-01	9.4756E-01	2.1678E 01	2.1366E-03	1.2625E-03	2.1164E-03	2.8775E 02	9.7260E-03	1.6923E 00	8.3756E-03
1.0053E 00	1.5331E-01	9.4736E-01	2.1678E 01	8.4343E-03	5.0962E-03	8.5299E-03	1.1613E 03	3.2286E-02	1.6550E 00	3.2113E-03
1.0053E 00	2.1859E-01	9.4756E-01	2.1680E 01	2.1360E-03	1.2625E-03	2.1165E-03	2.8775E 02	9.7261E-03	1.6919E 00	8.3883E-03
1.0053E 00	1.5354E-01	9.4737E-01	2.1680E 01	8.4340E-03	5.0962E-03	8.5299E-03	1.1613E 03	3.2286E-02	1.6550E 00	3.2162E-03
1.0054E 00	2.1892E-01	9.4757E-01	2.1674E 01	2.1354E-03	1.2625E-03	2.1165E-03	2.8775E 02	9.7261E-03	1.6914E 00	8.4009E-03
1.0054E 00	1.5377E-01	9.4737E-01	2.1674E 01	8.4337E-03	5.0962E-03	8.5299E-03	1.1613E 03	3.2286E-02	1.6549E 00	3.2210E-03

Figure 8 Integral Parameter Print

solution print interval. Following this print, a call to ICOND is initiated to print the RARRAY and IARRAY scalar lists. This is followed by a node map print which matches node numbers with their coordinates. A subsequent standard solution print, as described above, is output which lists the specified initial conditions.

```
             4 VARIABLES BEING INTEGRATED.
 1    5    6    2

             4 VARIABLES IN SOLUTION.
 1    5    6    2

           SAVE OUTPUT ON UNIT 10

ORDER OF CALLS AT END OF QKNUIN

     LINK1( 5) - DPDX

     LINK2( 4) - CONTES

     LINK2(15) - TRBTHK

     LINK2( 3) - WLFLXS

     LINK5( 6) - SETDIF

     PRINTOUT VARIABLES

 1248   2248   5248   6248   1247
 1249   2249   5249   6249    305

     PRINTOUT VARIABLE MULTIPLIERS.

     2      2      2      2      2
     2      2      2      2      2
```

Figure 9 Solution Sequence Print, Obtained Upon Entering QKNINT

COMOC COMPUTER PROGRAM SYSTEM

General Overview

The COMOC computer program system is rapidly developing into its intended design state as a general purpose differential equation solver. Present capabilities include various fluid mechanics solution options (2DBL, 3DBR, 2DNS, 2DPNS, and 2DPF) including various turbulence modeling and thermodynamics evaluation. The most recent capability combines (2DPF, 2DBL and 2DPNS) into a coupled weak interaction aerodynamic iterative flow solution sequence. The program I/O is highly developed and approaching a state of data specified mathematical operations. The finite element method is utilized as the basic numerical algorithm, thus providing the ability to easily model general geometric boundaries and allows for simplified boundary condition specification.

The program is written entirely in Fortran and presently consists of approximately 19000 cards. Array storage is dynamically allocated according to problem size, making problem size limitation strictly dependent upon the computer size on which it is run. This section gives a brief description of the program flow followed by a list defining the subroutines and some of the more important variables in the program. Finally, some examples of diagnostic print obrainable by code in Namelist NAME01 are illustrated.

The COMOC macro-structure is illustrated in the flow diagram of figure 10. Main allocates core for the data arrays. The input module consists of the sub-routines used to control the program flow and read unformatted data. All data is read by subroutine REDREL controlled by READER. Command data are interpreted by BDINPT which is the program director. Interpretation includes the three categories of program control, integer data and real data. Command data, therefore, controls the program sequence and directs the filling of arrays. The LINK name is utilized to perform a sequence of operations which require several subroutines. This manipulation helps insure that certain internal operations are performed in the proper sequence at the expense of some user control. Vector initialization and discretization are user controlled, but must be performed prior to the integration phase. Integration is initiated by calling subroutine QKNINT and integration progresses via the integrator QKNUIN. Derivative vectors to be integrated are formed in DERVBL. The user has control over the equations evaluated through specification of dependent variables in the IPINT array and NEQKNN in NAME01. User control of the subroutines to be invoked each integration step is exercised under the LINKCALL command. Output is controlled by sub-routines REOUTP (prints node map) and FEOUTP (prints data array) which are accessed through calls to LINK2-5 and LINK2-6 respectively. Execution proceeds until T = TF whence control is returned BDINPT. Command END is used to terminate a data case and EXIT terminates execution.

The following pages list and give a brief description of the subroutines and some of the more pertinent variables in the program.

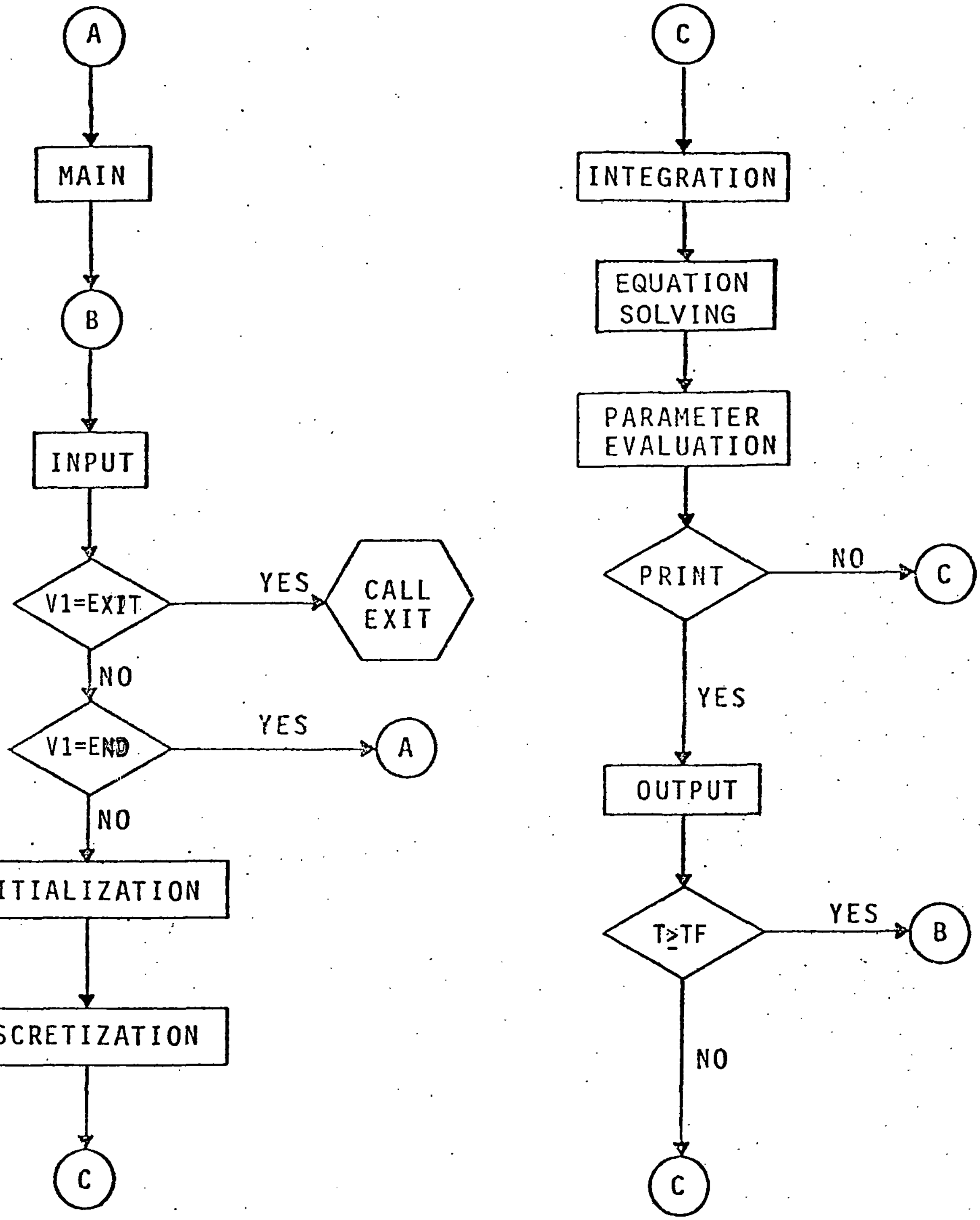

Figure 10 COMOC Macro-Structure

SUBROUTINE DESCRIPTIONS.

THE FOLLOWING PAGES CONTAIN A BRIEF DESCRIPTION OF THE SUBROUTINES IN THE CCMCC COMPUTER PROGRAM.

NAMES IN PARENTHESES INDICATE CALLING ROUTINES.
IF NO NAME IS ENTERED THEN SEVERAL ROUTINES PLACE CALL.

MAIN

THIS IS THE MAIN CONTROL PROGRAM WHICH INITIALIZES THE RARRAY, IAPRAY AND THE IZ ARRAYS TO ZERO.

TO CHANGE THE VARIABLE SOTRAGE CAPACITY OF THE IZ ARRAY, RESET THE DIMENSION OF 'IZ' AND, ACCORDINGLY, THE VALUE OF 'IZSIZE'.

AFTER INITIALIZATION THE CONTROL ROUTINE BDINPT IS CALLED.

BDINPT (MAIN)

THIS IS THE CONTROL ROUTINE WHICH INITIALIZES VECTORS AND CONTROLS THE FLOW OF THE PROGRAM ACCORDING TO USER INPUT.

(SEE TABLE 1 FOR INPUT DESCRIPTION.)

LINK1

PLACE CALLS TO THE FOLLOWING ROUTINES.

2. NODELM
3. GEOMFL
4. GETPPR, GTUEDG
5. GETPPR, PRSGRD
7. BCONDT
8. DERVBL

LINK2

PLACE CALLS TO THE FOLLOWING ROUTINES.

1. DFCFNS
2. CFCFBL
3. WLFLXS
4. CONTES
5. RECUTP
6. FECUTP

IF 'ITDB' .GT. 0, WRITE 'PLOTS' DATA ON UNIT 'ITDB'.
IF RESTART CODE 'NRTAPE' IS .GT. 0, WRITE RESTART DATA ON TAPE 'NRTAPE'.

7. STRF
9. CRFCBL, CRFCNS, CRFOGS
10. TBLINP
11. CFFPFI
12. H2MIX
13. XYCROM
14. DSCRTZ
15. TRBTHK
21. PFRMCP
22. ARFOIL
23. SYMELM
25. BLTINT

```
LINK3
     PLACE CALLS TO THE FOLLOWING ROUTINES.
          1. NBNDRY
          2. RITE
          4. DPCXTB, DIMEN AND STORE DEP. VAR. LOCATION LIST IN IZ(INPINT)
          5. L7H

LINK4
     PLACE CALLS TO THE FOLLOWING ROUTINES.
          2. QKNUIN
          9. PCTENT
LINK5
     PLACE CALLS TO THE FOLLOWING ROUTINES.
          1. NWGECM
          2. CALL ROUTINES FROM LINKCALL LIST AT END OF QKNUIN.
          3. CPINIT
          5. SCHPRN
          6. SETDIF

AESAVE
     COMPUTE THE SUM OF ABSOLUTE VALUES OF A SEQUENCE OF NUMBERS.
ADDDEL ( ELEM, GETBCD, GETBND, SETUP )
     ADD OR DELETE ENTRIES IN AN INTEGER ARRAY DEPENDING ON THE
     VALUE OF 'KTYP'.
     KTYP = 1, DELETE
     KTYP = 2, ADD
ASMSQ (STRF)
     BOOLEAN ASSEMBLY OF SQUARE SYMMETRIC MATRIX.
ASMVEC
     BOOLEAN ASSEMBLY OF COLUMN MATRIX.
AVRG
     COMPUTE THE ARITHMETIC AVERAGE OF 'NUMB' ENTRIES IN AN ARRAY.
BANCHO (STRF)
     SYMMETRIC BANDED CHOLESKY LINEAR ALGEBRAIC EQUATION SOLVER.
BCCNDT ( LINK1(7))
     GRADIENT BOUNDARY CONDITION SPECIFICATION (A1,A3) FOR DEP. VARIABLE.
                                            -1.234 = USE DUDY FOR A3.
                                       + OR -4.321 = SET DVDY = - DUDX
BNDSET (GETBCD,GETBND)
     DETERMINE NODES TO BE INSERTED INTO BOUNDARY ARRAY.
CALORD  (BDINPT)
     PRINT CALL ORDER OF ROUTINES USED FOR VARIABLE PARAMETERS.
     PRINT INTEGRATION VARIABLE NOS. AND DEPENDENT VARIABLE NOS.
     PRINT LIST OF PARAMETERS TO BE PRINTED IN OUTPUT ROUTINE.
CCLS (DSCRTZ)
     COMPUTE THE NUMBER OF COLUMNS, 'LCCL', IN THE OUTPUT DISPLAY
     AND SET UP THE FOLLOWING ARRAY,
       INCCL(J)  - NO. OF NODES IN COLUMN J.
CCMCC (BDINPT)
     PRINT THE CCMCC SYMBOL ON TWO PAGES ALONG WITH ASSOC. TITLE CARDS.
CONTES (LINK2(4))
     RUNNING SMOOTH CONTINUITY EQUATION SOLVER TO COMPUTE U2 UP COLUMNS
     OF NODES AFTER VSTART HAS BEEN REACHED.
CPINIT (DIMEN)
     COMPUTE CPINF AT TSINF.
```

```
DELADD (ADDDEL)
     ADD ENTRIES TO AN INTEGER ARRAY 'NSIDE' AT A TIME.
DELELM (DELNOD)
     DELETE ENTRIES IN AN INTEGER ARRAY 'NSIDE' AT A TIME.
DELETE (DSCRTZ)
     DELETE NODES THAT ARE NOT CONNECTED TO ANY ELEMENTS.
DELNOD (ADDDEL)
     SET UP CALL TO DELELM AND SUPPRESS ZERO ENTRIES IN A VECTOR.
DERVBL (LINK1(8))
     FORM THE DERIVATIVE OF THE ORDINARY DIFFERENTIAL EQUATION FIRST
       ON U1-VELOCITY (GLOBAL CONTINUITY) AND OTHER DEPENDENT
       VARIABLES INCLUDING SPECIES CONTINUITY, ENERGY, LONGITUDINAL
       AND LATERAL MOMENTUM, IF REQUIRED.
DERVDX (CONTES)
     3-POINT FORWARD DIFF. FORMULA TO COMPUTE DERIVATIVE IN DOWNSTREAM DIR.
DESCRP(KA) (BDINPT)
DPDXTB
     COMPUTE DPDX FROM PRESSURE TABLE. DPDX IS CONSTANT OVER INTERVALS.
DFCFBL (LINK2(2))
     COMPUTE TURBULENT VISCOSITIES  FOR DEPENDENT VARIABLES FROM
     1. TKE - DISSIPATION EQUATIONS OR
     2. MIXING LENGTH THEORY, OR
     3. COMBINATION OF BOTH TKE - DISS. AND MLT.
DFCFNS (LINK2(1))
     COMPUTE LAMINAR VISCOSITY ACCORDING TO TEMP. AT NODES
       USING SUTHERLAND'S LAW.
DIMEN (LINK3(4))
     COMPUTE NON-DIMENSIONALIZING FACTORS USED IN PROGRAM.
DRHOBL (LINK2(9))
     CALL IF IGAS = 0 IN NAME01
     COMPUTES THE TEMPERATURE AND DENSITY USING A SIMPLIFIED
       ENERGY EQUATION. ISOENERGETIC MIXING FLOW WITH 2 SPECIES.
DRHOGS (LINK2(9))
      CALLED IF IGAS = 1 IN NAME01
      COMPUTES THE TEMPERATURE, DENSITY AND SPECIFIC HEAT ON A NODAL
       BASIS AS A FUNCTION OF PRESS., ENTH., VEL. AND SPECIES COMPOSITION.
       IF NGETH = 1 IN NAME01, THE FIRST PASS THROUGH THIS ROUTINE
       WILL RETURN ENTHALPY WHEN GIVEN THE TOTAL TEMPERATURE AT THE NODES.
```

DSCRTZ (LINK2(14))

SET UP SOLUTION DOMAIN DISCRETIZATION.

SET UP SCALE FACTORS, GENERATE NODES AND ELEMENTS, COMPUTE ROW AND COLUMN KEYS FOR SOLUTION AND PRINTOUT, AND SCALE INPUT COORDINATES BY REFL.

THE FOLLOWING KEYWORDS ARE USED TO TRANSFER FLOW -

KEYWORD	FORMAT	BLOCK COLS.	DESCRIPTION
VX1SCL	A8	1 - 8	READ THE FOLLOWING IN FREE FORMAT X0 - START OF X1 GEOMETRY. NDIV1 - NO. OF DIVISIONS IN FIRST INT. X1 - X1 POS. AT END OF INTERVAL. PR1 - PROGRESSION RATIO FOR SPACING. NDIV2 - NO. OF DIV. IN 2ND INTERVAL. X2 - X2 POS. AT END OF 2ND INTERVAL. PR2 - PROG. RATIO FOR SPACING. . . . CONTINUE WITH NDIV3 X3 PR3, ETC. UNTIL A SCAN DELIMETER 'T' OR A BLANK CARD IS ENCOUNTERRED.
VX2SCL	A8	1 - 8	SAME AS VX1SCL BUT FOR DIRECTION 2.
NDECRD	A8	1 - 8	
N1	FREE AFTER COL. 8 ON NDECRD CARD.		FOR N1 EQ -1, A RECTANGULAR GRID IS FORMED FROM THE VX1SCL AND VX2SCL INPUT. FOR N1 NE -1, READ IN RECTANGULAR MESHES, 4 PER CARD IN FREE FORMAT. TERMINATE READ WITH A BLANK CARD. NRL, NRU, NCL, NCU NRL - LOWER ROW NUMBER NRU - UPPER ROW NUMBER. NCL - LOWER COLUMN NUMBER. NCU - UPPER COLUMN NUMBER. E. G. 3 8, 1 6 PRODUCES A MESH OF NODES FROM ROW 3 THRU ROW 8 AND FROM COLUMNS 1 THRU 6 WITH SCALE FACTORS GENERATED ACCORDINGLY.
ELEM	A8	1 - 8	GENERATE ELEMENTS FROM RECTANGULAR MESH.
N1	FREE	AFTER COL. 8 ON ELEM CARD	+1 = ADD ELEMENTS IN ELEM.
N2	FREE	AFTER N1	-1 = DELETE ELEMENTS IN ELEM.
N3	FREE	AFTER N2	TURN DIAGONALS BELOW ROW N3.
DONE	A8	1 - 8	SCALE X1COR BY XSCALE SCALE X2COR BY YSCALE AND RETURN.

ANY OTHER KEYWORD ENCOUNTERRED WILL CAUSE A RETURN FROM DSCRTZ.

* * * NOTE * * * VX1SCL IS OPTIONAL FOR 1D ELEMENTS.

DUDY (WLFLXS)
THREE POINT INTEGRATION FORMULA FOR COMPUTING DUDY.
ELEM (DSCRTZ)
GENERATE ELEMENTS AS A FUNCTION OF NODE COORDINATE INPUT.
USED PRIMARILY FOR A RECTANGUALR DOMAIN.
ELKEY2 (L7H)
GENERATE KEYS CORRELATING ELEMENT DOF TO SYSTEM DOF.
FEDIMN (BDINPT)
SET UP DIMENSIONS OF VARIABLE LENGTH ARRAYS USED IN THE SYSTEM. FINDS LOCATIONS OF OUTPUT ARRAYS FOR 'FEOUTP'.
IF 'KDUMP' = 1, PRINT LOCATION OF ENTRY POINTS IN 'IZ' ARRAY.

FENAME (BDINPT)
THIS ROUTINE CONTAINS A LIST OF ALL EQUIVALENCED VARIABLES IN THE IARRAY AND RARRAY VECTORS.
MOST DEFAULT VALUES ARE ALSO SET IN THIS ROUTINE.
CALL NMELST TO READ IN NAME01 AND NAME02 NAMELISTS.
FEPLOT (STOUT1)
GENERATE DATA TO BE USED FOR PLOT PACKAGES.
FINDBE (BDINPT)
DETERMINE A SERIES OF BOUNDARY ELEMENTS AS A FUNCTION OF INPUTING BOUNDARY NODES IN COUNTER-CLOCKWISE ORDER.
ON FIRST PASS, IF IBORD IS READ, FIND BORDER ELEMENTS AND REORDER NODES SO THAT FIRST TWO ARE ON THE BOUNDARY.
GENDA
EXTRACT AN ELEMENT VECTOR FROM A GLOBAL VECTOR USING THE ELEMENT CONNECTION TABLE 'INODE'.
GEOMDR (GEOMFL)
COMPUTE ENTRIES FOR B112 AND B113 MATRICES.
GEOMFL (LINK1(3))
GENERATE THE UNIQUE ELEMENT MATRICES AND VECTORS.
SET UP THICKNESS VECTOR ITK.
GENERATE LENGTH * THICKNESS ARRAY IX1P2.
GENERATE AREA * THICKNESS ARRAY IAREA.
GENERATE B112 MATRIX.
GENERATE B113 MATRIX.
IF KOOG .GT. 0, PRINT ELEMENT NO., NODES OF ELEMENT AND COORDINATES OF NODES FOR ELEMENTS FROM 'IBOT' TO 'ITOP'.
AFTER THE ELEMENT LOOP IS COMPLETED, PRINT THE VECTORS AND MATRICES THAT WERE GENERATED IN THE ELEMENT LOOP.
GETADD (FEDIMN)
IBM 360 ASSEMBLER LANGUAGE ROUTINE TO GET MACHINE ADDRESS OF VARIABLE.
GETALC (XYCRDM)
COMPUTE 'ALC' AS THE SHORTEST SIDE OF ALL THE ELEMENTS IF IT IS NOT READ IN NAME02.

GETBCD (BDINPT)

INPUT IS SIMILAR TO GETBND EXCEPT THERE IS ONLY ONE BLOCK PER CARD -

KEYWORD	FORMAT	BLOCK COLS.	DESCRIPTION
(SAME) KEYWORD	A8 FORMAT	1 - 8 BLOCK COLS.	SAME DEF. AS IN GETBND. DESCRIPTION
KODE1	FREE	AFTER 8	SAME AS KODE1 IN GETBND.
KODE2	FREE	AFTER KODE1	SAME AS KODE2 IN GETBND.
KODE3	FREE	AFTER KODE2	SAME AS KODE3 IN GETBND.
A1	FREE	AFTER KODE3	VALUE OF A1 FOR THIS BOUNDARY.
MA1	FREE	AFTER A1	RARRAY MULT. FOR A1.
A3	FREE	AFTER MA1	VALUE FOR A3 BOUNDARY CONDITION.
MA3	FREE	AFTER A3	RARRAY MULT. FOR A3.
			+MA1 = MULTIPLY BY RARRAY(MA1)
			-MA1 = DIVIDE BY RARRAY(MA1)

GETBCM (GETBCD)

EXTRACT BOUNDARY CONDITION VECTORS FROM INPUT DATA.

GETBND (BDINPT)

ESTABLISHES THE BOUNDARY NODE VECTOR FOR EACH DEP. VAR. USING EITHER THE WORD 'ADD' OR SIMPLE GEOMETRY OF THE PROBLEM WITH THE FOLLOWING KEYWORDS AND CODES -

EACH CARD IS DIVIDED INTO FOUR IDENTICAL BLOCKS OF 20 COLUMNS EACH. ALL BLOCKS ARE OF THE SAME FROMAT SO THAT A DESCRIPTION OF ONE BLOCK ONLY WILL BE GIVEN. THE BLOCKS START IN COL. 1, 21, 41 AND 61.

KEYWORD	FORMAT	BLOCK COLS.	DESCRIPTION
TOP	A8	1 - 8	ACROSS TOP FROM LEFT TO RIGHT.
-TOP	A8	1 - 8	ACROSS TOP FROM RIGHT TO LEFT.
BOTTOM	A8	1 - 8	ACROSS BOTTOM FROM LEFT TO RIGHT.
-BOTTOM	A8	1 - 8	ACROSS BOTTOM FROM RIGHT TO LEFT.
RIGHT	A8	1 - 8	UP RIGHT HAND SIDE.
-RIGHT	A8	1 - 8	DOWN RIGHT HAND SIDE.
LEFT	A8	1 - 8	UP LEFT HAND SIDE.
-LEFT	A8	1 - 8	DOWN LEFT HAND SIDE.
(BLANK)	A8	1 - 8	IGNORE BLOCK.
ADD	A8	1 - 8	CALL ADDDEL TO INSERT ENTRIES.
			IGNORE BLOCK COLS. 9 - 20.
DELETE	A8	1 - 8	CALL ADDDEL TO DELETE ENTRIES.
			IGNORE BLOCK COLS. 9 - 20.
DONE	A8	1 - 8	LEAVE ROUTINE.

FOR THE FOLLOWING KEYWORDS, THE THREE CODES (WE'LL CALL THEM KODE1, KODE2 AND KODE3 FOR CONVENIENCE) WILL DETERMINE WHICH NODES WILL BE SELECTED.

KEYWORD	FORMAT	BLOCK COLS.	DESCRIPTION
KODE1	I4	9 - 12	ROW OR COLUMN DISPLACEMENT FROM EDGE BEING DESCRIBED (DEF. = 0).
KODE2	I4	13 - 16	POS. IN LINE TO START (DEF. = FIRST).
KODE3	I4	17 - 20	POS. IN LINE TO END (DEF. = LAST).

GETFSL (DFCFBL,TRBTHK)
FIND BOUNDARY LAYER THICKNESS, DELTA, AND NODE AT WHICH IT OCCURS.
GETIND (GEOMFL)
EXTRACT NODE INDICES FOR ELEMENT BEING PROCESSED.
GETPPR (LINK1(5))
TABLE LOOK-UP OF PRESSURE AND DPDX AS FUNCTION OF DOWNSTREAM STATION.
GMADD
GENERAL MATRIX ADDITION. C = A + B
GPAHFT (THERMO)
MULTIPLE SPECIES THERMODYNAMICS.
IF NGETH .GT. 0, COMPUTE ENTHALPY DISTRIBUTION FROM TOTAL TEMP.
IF NGETH .LE. 0, COMPUTE TEMPERATURE, DENSITY, SPECIFIC HEAT AND MACH NO. AS FUNCTION OF PRESSURE, ENTHALPY AND SPECIES COMP.
H2MIX (LINK2(12))
COMPUTE THE MIXING EFFICIENCY HRSDOT AND THE MASS FLOW HDOT.
ICOND (BDINPT)
PRINT INTEGER AND REAL INITIAL CONDITIONS.
IARRAY(1) - IARRAY(400)
RARRAY(1) - RARRAY(400)
LOC (MPRD)
COMPUTE VECTOR SUBSCRIPT FOR AN ELEMENT IN A MATRIX OF SPECIFIED STORAGE MODE.
LOCATE
FIND THE LOCATION OF 'M' IN THE ARRAY 'NA' AND STORE IT IN 'N'.
LOOK
LINEAR INTERPOLATION ROUTINE.
LSFT (MISDIV)
GENERATE A LEAST SQUARES FIT THRU A SERIES OF POINTS.
L7H (LINK3(5))
COMPUTE ELEMENT LINKING KEYS FOR SOLVER ROUTINE BANCHO.
MATSUM
COMPUTE A(I) = B(I) + COEF * C(I), I = 1, N
MINMAX (DSCRTZ,ORDER,SETSCL)
COMPUTE THE MINIMUM 'MN' AND MAXIMUM 'MX' ENTRIES IN AN ARRAY AT LOCATIONS 'IMN' AND 'IMX' IN THE ARRAY.
MISDIV (CONTES)
POLYNOMIAL FIT THRU 'NPT' POINTS OF THE M-TH ORDER.
NPT MUST BE AN ODD NUMBER.
MNMX (ELEM)
FROM AN INTEGER VECTOR INA CONTAINING NN ENTRIES, STORE THE FOLLOWING -
LOW - POSITION IN 'INA' OF MINIMUM.
LHI - POSITION IN 'INA' OF MAXIMUM.
MN - MINIMUM VALUE IN 'INA'.
MX - MAXIMUM VALUE IN 'INA'
MPRD
MULTIPLY TWO MATRICES AND STORE IN RESULTANT MATRIX.
C = A * B
MTRA (GEOMFL)
FIND THE TRANSPOSE OF A GENERAL MATRIX. T = A TRANSPOSE.
NBNDRY (LINK3(1))
THE VALUE OF 'NBSET' DETERMINES THE OPERATION OF THIS ROUTINE,
NBSET = 1, SET UP INTEGRATION NODES AND STORE DEPENDENT VARIABLE INTO 'YY' VECTOR.
NBSET = 0, SET UP INTEGRATION NODES AND RETRIEVE DEPENDENT VARIABLE FROM 'YY' VECTOR.

```
NDECRD (DSCRTZ)
      GENERATE NODE COORDINATES FROM SUPER ELEMENT INPUT DATA.
NMELST (FENAME, BDINPT)
      READ NAMELISTS NAME01 AND NAME02.
       NAME01 = INTEGER INPUT.
       NAME02 = REAL INPUT.
NODELM (LINK1(2))
     SET UP THE ARRAYS 'IELS' AND 'IELEM' TO STORE THE NUMBER OF
       ELEMENTS PER NODE AND A LIST OF ELEMENTS CONNECTED TO EACH NODE.
     ALSO AVTHK AND AVAREA
NWGEOM (LINK5(1))
      COMPUTE H21, G22, G23 AND F1 FOR VARIABLE GEOMETRY PROBLEM.
ORDER (COLS,ROWS,XYSCAL)
     ORDER 3 ARRAYS ACCORDING TO THEIR X1 AND X2 COORDINATES.
       THE THIRD ARRAY WILL CONTAIN THEIR ARRAY LOCATIONS.
OUTNOD
     PRINT AN INTEGER ARRAY ALONG WITH A 32 CHARACTER TITLE.
OUTPG (GEOMFL)
     PRINT THE ELEMENT NO. AND NODE CONNECTIONS AND NODE
       COORDINATES FROM THE GEOMETRY ROUTINE 'GEOMFL'.
OUTVEC
     PRINT A REAL ARRAY ALONG WITH A 32 CHARACTER TITLE.
PBLANK (REOUTP)
     INSERT BLANKS IN THE OUTPUT VECTOR 'P'.
PFRMCP (LINK2(21))
     COMPUTE PRESSURE TABLE AND DPDX TABLE FROM CP INPUT.
PLILNK (REOUTP)
     CONVERT A FLOATING POINT NUMBER INTO 'A' FORMAT.
POLY (MISDIV)
     FUNCTION TO GENERATE COEFFICIENTS C(I) IN Y = C(I) * X**M
PRINTA
     PRINT A LIST OF REAL NUMBERS IN 'A' FORMAT.
PRATIO (DSCRTZ)
     COMPUTE NODES USING PROGRESSION RATIO AND END POINTS.
PRSGRD
     COMPUTE AXIAL PRESSURE GRADIENT.
QKNINT (BDINPT)
      INTEGRATION CONTROL ROUTINE TO TRANSFER CALL TO OUTPUT
      PACKAGE AT PRINT STATIONS.
QKNUIN (LINK4(2))
     INITIALIZE INTEGRATION CONSTANTS DURING FIRST PASS.
     COMPUTE STEP SIZE AND NEW VALUE OF DEPENDENT VARIABLES.
     COMPUTE UPDATED PARAMETERS BASED ON UPDATED VALUES OF DEP. VAR.
QMCONC
     COMPUTE A ROUGH APPROXIMATION OF THE AREA OF SPECIES
       CONCENTRATION AND THE MASS DEFECT XMSDF = ROUALC * (AREA-XSUM),
       WHERE XSUM = AMOUNT OF SPECIES PRESENT.
READER
     READ INFORMATION FROM SPECIFIED INPUT UNIT.


READV1
     READ FROM INPUT UNIT ACCORDING TO THE FOLLOWING FORMAT,
      COL. 1 - 8, A8
      COL. 9 AND FOLL.  FREE FORMAT INTEGER OR REAL.
```

```
RECIP (STOUT1)
     INVERT INPUT VECTOR.
REDREL (BDINPT,ADDDEL)
     SCAN AN 80 CHARACTER CARD IMAGE AND CONVERT THE INFORMATION THEREON
       INTO REAL OR INTEGER NUMBERS ACCORDING TO THE FOLLOWING FORMAT,
         DELIMETERS ARE BLANKS, COMMAS OR COLUMN 80.
         INTEGERS CONTAIN NO DECIMAL POINTS
         REALS CONTAIN DECIMAL POINT AND MAY BE 'E' FORMAT
         IF A 'C' APPEARS ON A CARD, THE FOLLOWING CARD IS CONSIDERED A
           CONTINUATION CARD
         SCAN TERMINATES WITH A 'T' OR A BLANK CARD.

         A VALUE MAY BE REPEATED, SUCH AS 20*5.0 MEANS A SERIES OF 20 5.0
         AN ARITHMETIC PROGRESSION MAY BE INPUT,
           5*I-2.0 3.0 MEANS   3.0  1.0  -1.0  -3.0  -5.0

         A GROUP OF NUMBERS MAY BE REPEATED
           4(     2.5  5   1.02  -1.2E-5 MEANS
               2.5  5  1.02 -1.2E-5, 2.5 5 1.02 -1.2E-5,
               2.5  5  1.02 -1.2E-5, 2.5 5 1.02 -1.2E-5,

REORDR (FINDBE)
     REORDER THE NODES OF AN ELEMENT SO THAT THE FIRST TWO WILL BE
      BOUNDARY NODE SPECIFICATION IN THE 'IBORD' VECTOR MUST BE
         COUNTER-CLOCKWISE.
REOUTP (LINK2(5))
     PRINT THE ARRAY GEOMETRY AND NODE NUMBERS IN A PATTERN THAT
       RESEMBLES PROBLEM GEOMETRY.
(FEOUTP) (LINK2(6)) FEOUTP IS AN ENTRY POINT IN REOUTP.
     PRINT OUTPUT PARAMETERS IN A PATTERN THAT RESEMBLES PROBLEM GEOMETRY.
       IF MAX. SCALE FACTOR EXCEEDS 'NSM' (DEF. = 10), TERMINATE THE PROBLEM.
       IF OUTPUT PRINT NO. 'KOUNT', EXCEEDS PRINT LIMIT 'LPRINT' (DEF. = 100)
       TERMINATE THE PROBLEM.
RESET
     RESET 'NN' ENTRIES OF ARRAY 'A' TO THE VALUE 'V'.
RESTOR
     REDEFINE A DEP. VARIABLE IF SOME ENTRIES ARE CHANGED
       WITHOUT INTEGRATION OR ITERATION.
RITE (LINK3(2))
     COMPUTE ' NUMBER = (KEY-1)*10 + NMB ',
       GO TO STATEMENT ACCORDING TO VALUE OF 'NUMBER'.
       IF 'NUMBER' IS OUT OF RANGE, WRITE TITLE INFORMATION.
ROWS (DSCRTZ)
     COMPUTE THE NUMBER OF ROWS, 'KROW', IN THE OUTPUT DISPLAY
       AND SET UP THE FOLLOWING ARRAYS,
       INROW(I) - NO. OF NODES IN ROW I.
       INDRW(I) - COLUMN NUMBERS OF NODES IN ROW I.
       INDEX(J) - ROW NUMBERS OF NODES IN COLUMN J.
       NOCOL(I) - STARTING COLUMN NO. FOR ROW I.

RSTRHS (DERVBL)
     FOR 3DBR U1 VELOCITY WITH FIXED WALL, ALLOW FOR TRIANGULAR
       NODES WITH ONLY 1 OR 2 ELEMENTS ATTACHED.
SCALEV (FEOUTP)
     CALL SCALE ROUTINE FOR UP TO 10 OUTPUT VARIABLES AT A TIME.
```

```
SCHPRN (LINK5(5))
     COMPUTE THE SCHMIDT AND PRANDTL NUMBERS ON A NODE BASIS.
SETDER (DERVBL)
     COMPUTE Q' = RHS / LHS, I = 1, NNODE
SETDIF (LINK5(6))
     COMPUTE EFFECTIVE VISCOSITY FOR DEP. VAR. USING DFCFNS AND DFCFBL.
SETSCL (SCALEV)
     SET SCALE FACTOR FOR AN ARRAY OF REAL NUMBERS AND NORMALIZE THE ARRAY.
SETVAL
     COMPUTE A(I) = B(I) * C + D
SORT (LINK5(8))
     SORT A VECTOR IN ASCENDING OR DESCENDING ORDER.
         +NN = SORT IN ASCENDING ORDER.
         -NN = SORT IN DESCENDING ORDER.
STOUT1 (FEOUTP)
     DIMENSIONALIZE OUTPUT VARIABLES FOR DISPLAY PURPOSES.
STRF (LINK2(7))
     IMPLICIT EQUATION SOLVER SETUP ROUTINE.
SUMKEY (L7H)
     SET UP NODE KEYS FOR EQUATION SOLVER BANCHO.
SUTHLD (DIMEN)
     COMPUTE VISCOSITY USING SUTHERLAND'S VISCOSITY LAW FOR AIR.
TAUW (WLFLXS)
     COMPUTE SKIN FRICTION USING PATANKER AND SPALDING OR LUDWIEG - TILLMAN.
THERMO (DRHOGS)
     INITIATE CALL TO GPAHFT.
TRBTHK (LINK2(15))
      COMPUTE AND PRINT INTEGRAL PARAMETERS.
      IF 'ITDA' .GT. 0, WRITE PLOT TAPE FOR INTEGRAL PARAMETERS.
VARMAX (FEDIMN,FEPLOT)
     FOR +NN, FIND MAXIMUM VALUE IN VECTOR,
     FOR -NN, FIND MINIMUM VALUE IN VECTOR.
VECFUL (DERVBL)
     MULTIPLY A FULL HYPERMATRIX BY A VECTOR OF LENGTH NN.
VECMAT (DERVBL)
     MULTIPLY A XYMMETRIC HYPERMATRIX BY A VECTOR OF LENGTH NN.
VECTA
     BOOLEAN ASSEMBLY OF AN ELEMENT VECTOR INTO A GLOBAL VECTOR
       USING INTEGRATION NODE SEQUENCE.
VHOLES (LINK2(24))
     TRANSVERSE VELOCITY AND/OR SPECIES INJECTION THROUGH A POROUS WALL.
         (TRANSIENT BOUNDARY CONDITION).
WLFLXS (LINK2(3))
      COMPUTE THE SKIN FRICTION DISTRIBUTION AND HEAT TRANSFER
       DISTRIBUTION ALONG THE WALL.
XYCRDM (LINK2(13))
     GENERATE VECTORS FOR GRID OUTPUT ROWS AND COLUMNS,
       SCALE COORDINATES WHEN RUNNING VARIABLE GEOMETRY.
XYSCAL (DSCRTZ)
      COMPRESS A VECTOR OF NUMBERS 'X1' BY SCALE FACTOR 'SCFT'.
     FIND ' XYD = MAX(X1) - MIN(X1) * SCFT '
     IF TWO ADJACENT POINTS OF ARRAY 'X1' ARE WITHIN 'XYD' OF EACH
       OTHER, SET THE UPPER VALUE EQUAL TO THE LOWER VALUE.
```

AIRFOIL GENERATOR AND INITIALIZER.

THE FOLLOWING SUBROUTINES ARE USED TO GENERATE AIRFOIL DISCRETIZATION AND INITIALIZATION FOR POTENTIAL SOLUTION.

AFSHP (SHAPE)
USER SUBROUTINE TO DEFINE AIRFOIL COORDINATES. (JSHP = 1 IN NAME01) AIRFOIL THICKNESS AND ANGLE OF ATTACK MUST BE SPECIFIED IN NAME02.

ARFOIL (SYMELM)
DEFINES SUBREGION DATA FOR POTENTIAL FLOW CALCULATION AND MODIFIES GRADIENT BOUNDARY CONDITIONS ALONG THE AIRFOIL SURFACE FOR ANGLE OF ATTACK.

BND (REFINE)
APPLIES BOUNDARY CONDITIONS TO REFINED GRID BOUNDARIES.

CAPPY (REFINE)
EXTRACTS COORDINATE AND PARAMETER DATA FOR A PARTICULAR SUBREGION FROM SUBREGION DATA.

CPFPHI (LINK2(11))
COMPUTES PRESSURE COEFFICIENT ALONG VISCOUS BOUNDARY FROM A GIVEN POTENTIAL SOLUTION.

ELKEY (REFINE)
GENERATES REFINED GRID FINITE ELEMENT CONNECTION DATA.

ELLIPS (ARFOIL)
GENERATES SUBREGION DATA OVER REGULAR AND DEFORMED ELLIPTICAL SHAPES.

EXTRCT (REFINE)
EXTRACTS REFINED GRID FINITE ELEMENT DATA FROM REFINED NODAL DATA.

EXT1D (BND)
SAME AS EXTRCT BUT FOR BOUNDARY FINITE ELEMENTS.

GRDPHI (ARFOIL)
COMPUTES GRADIENT BOUNDARY CONDITIONS ALONG AN AIRFOIL SURFACE.

MAXARA (ELKEY)
DETERMINES MAXIMUM AREA OF A TRIANGULAR FINITE ELEMENT PAIR.

POTENT (LINK1(9))
SETS UP TEMPORARY STORAGE LOCATIONS IN IZ ARRAY FOR POTENTIAL FLOW.

QUADR (REFINE)
PERFORMS BI-QUADRATIC TRANSFORMATION OF QUADRILATERAL SUBREGION DATA AND GENERATES REFINED GRID DATA.

REFINE (ARFOIL)
PERFORMS GRID REFINEMENT OVER TWO-DIMENSIONAL SOLUTION DOMAIN.

SELBND (REFINE)
RENUMBERS THE SUBREGION GENERATED BOUNDARY GRIDPOINTS.

SELINK (REFINE)
FORMS SUBREGION CONNECTION TABLE.

SETOSN (REFINE)
PERFORMS SUBREGION ELEMENT TO SUBREGION NODE DATA TRANSFER.

SHAPE (ARFOIL)
GENERATES SUBREGION COORDINATES FOR SELECTED AIRFOIL SHAPE.

SYMELM (POTENT)
SETS UP CALL TO AIRFOIL DISCRETIZER 'ARFOIL' AND STORES OUTPUT TO BE USED FOR POTENTIAL SOLUTION.

TRIANG (REFINE)
PERFORMS QUADRATIC TRANSFORMATION OF TRIANGULAR SUBREGION DATA AND GENERATES REFINED GRID DATA.

XCOORD (REFINE)
TRANSFORMS SUBREGION COORDINATES TO RECTANGULAR CARTESIAN.

TURBULENT INTEGRAL BOUNDARY LAYER SOLUTION.

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    THE FOLLOWING SUBROUTINES ARE USED TO COMPUTE UPPER AND LOWER
      AIRFOIL BOUNDARY LAYER INTEGRAL PARAMETERS.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

ACOE (FMAT)
ARC (INPUT)
BLTINT (LINK1(10))
     COMPUTES TURBULENT INTEGRAL PARAMETERS TO BE USED FOR POTENTIAL SOLUTION.
BOUND (BLTINT)
CPOLY (ACOE,FAT)
DRAG (BLTINT)
FAT (ACOE,TURB)
   ENTRY - INFAT
FMAT (INTBL)
INIT (BOUND)
INPUT (BLTINT)
INSERT (TBLU1)
INSTAB (TRNSIT)
INTBL (TURB)
   ENTRY - SETUPS
LAMNAR (BOUND)
MERSON (INTBL)
OUTPUT (TURB)
PRNTER (BLTINT)
SCHCRC (INPUT)
SMLN (FMAT)
SMOOTH (INPUT)
   ENTRY - SDERV
STAG (BLTINT)
TBLU1 (BOUND,FAT,INIT,INPUT,LAMNAR,SMOOTH,TRCALC)
TRCALC (TRNSIT)
TRNSIT (BOUND)
TURB (BOUND)
XSTEP (FAT,TURB)
   ENTRY - ISTEP
```

Program Variables

IARRAY

THE FOLLOWING IS A PARTIAL LIST OF ENTRIES IN THE IARRAY VECTOR WHICH CONTAINS INTEGER PARAMETERS THAT ARE USED TO CONTROL PROGRAM FLOW. NOT ALL ENTRIES ARE LISTED SINCE SOME OF THEM DO NOT PERTAIN TO THE PROBLEM CLASS IN THIS DOCUMENT.

IARRAY ENTRY	NAME	DEFINITION	NON-0 DEF.
492	IARRST	- STARTING LOCATION IN IARRAY CONTAINING LENGTHS OF VECTORS TO BE ADDED.	
96	IBASE	- BASE NO. FOR IZ ENTRIES.	200
261	IBC	- NUMBER OF BOUNDARY CONDITION TYPES.	
211	IBIDRV	- CODE TO ALLOCATE STORAGE FOR BI-DIRECTIONAL DERIVATIVE.	
99	IBL	- 1 = BOUNDARY LAYER PROGRAM, 0 = 2-D NAVIER STOKES PROGRAM.	1
208	IBOT	- STARTING ELEMENT NO. FOR DEBUG PRINT IN DERVBL, GEOMFL AND STRF.	
255	IDIAGL	- 1 = REMOVE DIAGONALS FROM DISCRETIZATION PLOT.	
127	IDIFRT	- NO. OF TIMES TO PRINT INTER. OUTPUT IN WLFLXS AND PRSGRD.	
491	IEXT	- NO. OF EXTRA VECTORS TO BE ADDED TO IZ ARRAY.	
115	IFORCE	- 1 = READ XCOR AND YCOR IN 2E15.5 FORMAT IN SETUP.	
120	IFR	- 1 = FROZEN CALCULATION IN THERMO. 0 = NON-FROZEN CALC. IN THERMO.	
175	IFSL	- WHEN ITKE = 1, THE FOLLOWING CONDITIONS APPLY, 0 = INTEGRATE TKE AND DISSIPATION. 1 = INTEGRATE TKE AND USE MIXING LENGTH FOR LENGTH CONSTANT. 2 = INTEGRATE TKE AND USE FREE SHEAR LAYER FOR DISS. LENGTH.	
83	IFSLT	- TEMPORARY STORAGE OF IFSL FOR CALL TO GETFSL.	
123	IGAS	- 1 = CALL DRHOGS. 0 = CALL DRHOBL.	
111	IMAX	- NODE AT WHICH BOUNDARY LAYER THICKNESS IS FOUND.	
145	IMIN	- SWITCH IN QKNLIN WHEN HMIN IS SET.	
158	INITCN	- INITIALIZER IN CONTES.	
28	IPASS	- NO. OF CALLS TO DERIV.	
250	IPHI	- 1 = EXECUTE POTENTIAL SOLUTION.	
213	IPHIR	-	
271	IPRINT	- 1 = PRINT CROSS FLOW THICKNESSES IN BLTINT.	
105	IPTSPL	- 1 = USE PATANKER AND SPALDING'S FOR TAU WALL. 0 = USE LUDWIEG - TILLMAN FOR TAU WALL.	
132	IPWRIT	- CODE IN STRF FOR INTERMEDIATE OUTPUT.	
100	IREND	- END POSITION IN 'IZ' ARRAY.	
3	IROW	- 1 OR 2 = INDEX FOR PRESENT OR PAST VALUE OF DEP. VAR.	1
29	IRUN	- PROBLEM NO. BEING RUN. (USUALLY ONLY 1)	
259	ISIDE	- NUMBER OF SIDES / SUPER ELEMENT.	
186	ITDA	- UNIT NO. ON WHICH TO STORE INT. PAR. DATA FOR PLOTTING.	
187	ITDB	- UNIT NO. ON WHICH TO STORE 'PLOTS' DATA FOR PLOTTING.	
133	ITOP	- UPPER PRINT LIMIT COUNTER FOR ELEMENTS.	
97	ITKE	- 0 = DO NOT INTEGRATE TKE - DISS. EQNS. 1 = USE TKE - DISS. TO COMPUTE TURBULENT VISCOSITY.	
196	ITWALL	- 1 = USE DUCY FOR TAU WALL.	
281	IVYY	- DEPENDENT VAR. FOR WHICH TO CALL DPSISQ.	
122	IWRIT	- DEBUG PRINT FLAG IN DFCFBL, CONTES AND WLFLXS.	

```
494 IZEROC  - STARTING LOCATION OF ADDRESSES IN IZ ARRAY TO BE ZEROED OUT.
495 IZEROS  - NUMBER OF IZ ADDRESSES TO BE ZEROED OUT.
 92 IZSIZE  - MAXIMUM DIMENSION OF IZ VECTOR.
492 IZSTRT  - STARTING LOCATION IN IZ ARRAY WHERE NEW VECTORS
                ARE TO BE ADDED.
253 JCOORD  - KEYS FOR INPUT COORDINATE SYSTEM.
254 JSHP    - 1 = KARMAN-TREFFTZ CLASS AIRFOIL.
              2 = CALL AFSHP ( USER SUPPLIED SUBROUTINE TO SPECITY
                     AIRFOIL COORDINATES.

169 KCDC    - 1 = RESET NLINE TO 50 AND DUMP KODE TO 2.
 61 KDUMP   - PRINT INPUT CARDS AND DATA GENERATED IN BDINPT.

  4 KEYMTD  - INTEGRATION TECHNIQUE.                          1
              1 = MAXIMUM ABSOLUTE STABILITY.
              2 = MAXIMUM RELATIVE STABILITY.
              3 = EULER INTEGRATION.
195 KFXBND  - FLUX BOUNDARY CODE USED IN WLFLXS.
 25 KIND    - KIND OF ELEMENT. ( USED IN L7H).                4
167 KNTPAS  - IF NO PRINT IN KNTPAS TIMES THRU QKNUIN, THEN FORCE PRINT.   99
  6 KODG    - PRINT GEOMETRY OUTPUT IF .NE. 0.
  7 KOD5    - PRINT INTER. DERIV OUTPUT KOD5 TIMES.
 26 KOUNT   - RUNNING COUNT OF OUTPUT. ( LIMITED BY LPRINT.)
102 KOUT    - LOGICAL UNIT NUMBER ON WHICH TO STORE PLOT DATA.
113 KPLVAR  - NO. OF VARIABLES TO BE PLOTTED OR PUNCHED.    10
 86 KPNT    - PRINT OPTION ( SET DURING EXECUTION.)
              0 = NO CALL TO FEOUTP FROM QKNINT.
              1 = CALL FEOUTP FROM QKNINT.
 52 KROW    - NO. OF ROWS IN DISCRETIZATION.                 100
136 KSAV    - PLOT TAPE NO. SAVED IN QKNINT.
272 KSKIP   - N = PRINT EVERY N-TH INTEGRATION STEP IN BLTINT.

 50 LCOL    - NO. OF COLUMNS IN DISCRETIZATION.              20
            -   IF .NE. 0 ON INPUT, THEN CNTPTS AND CNTNDS ARE
            -   TO BE READ IN.
 47 LG      - NO. OF COLS.  IN SOLUTION FIELD.
213 LMLT    - NO. OF CONTOURS FOR WHICH TO COMPUTE MIX. LENGTH TURB. VISC.
179 LOC     - INTERVAL NO. FOUND IN LOCK SUBROUTINE.
182 LOGS    - PRINTOUT VAR. KODE USED IN STOUTL.
172 LOWD    - USE LAMINAR VISCOSITY BELOW LOWD AND MLT FROM LOWD ON.       2
 34 LPRINT  - LIMIT ON OUTPUT COUNT.                         100

212 MLTRHS  - NUMBER OF RIGHT HAND SIDES TO SOLVE FOR IN STRF.        1
212 MLTRHS  - CODE TO ALLOCATE CORE FOR MULTIPLE RIGHT HAND SIDES IN STRF.
114 MSSC    - CONVERGENCE SWITCH USED IN QKNUIN.
103 MTM     - NO. OF PASSES TO USE IN FEOUTP.    (PROGRAM SET)

256 NAFTP   - NUMBER OF DATA POINTS SPECIFIED ALONG ONE AIRFOIL SURFACE.
 23 NB      - NO. OF CHAR. IN EACH WORD OF OUTPUT VAR. TITLE.    4
170 NBC     - MAX. NO. OF BOUNDARY COND. FOR ANY ONE DEP. VAR.
131 NBORD   - NO. OF NODES AROUND BORDER OF DISCRETIZATION.
 69 NBSET   - 1 = STORE DEP. VARIABLE INTO YY ARRAY.
              0 = STORE YY ENTRY INTO DEP. VARIABLE VECTOR.
 33 NBUG    - 1 THRU 5, PRINT DEBUG OUTPUT FROM L7H AND POTENTIAL FLOW
                DATA GENERATOR.
```

```
 22 NC      - NO. OF CHARACTERS IN OUTPUT FORMAT.              8
125 NCALLS - NO. OF ROUTINES TO CALL AT END OF QKNUIN.        10
173 NCCMCC - NO. OF CARD READ IN FOR COMOC TITLE PAGE.
174 NCCMTD - NO. OF CARDS READ IN FOR TITLE INFORMATION.
 59 NCPTAB - NO. OF ENTRIES IN SPECIFIC HEAT TABLE.            1
  1 ND      - INITIALIZATION PARAMETER IN DFCFNS.
 51 NDBL    - QKNUIN CODE TO DETERMINE MINIMUM STEP SIZE.
124 NDERIV - 2 = CALL DERVEL.                                  1
279 NDIM    - CORE ALLOCATION FOR DELTA STAR SUBROUTINES.
 48 NDOF    - NO. OF DEGREES OF FREEDOM. ( USED IN L7H)        1
194 NDP     - SPACE ALLOCATION IN INPINT VECTOR.               7
168 NDPRES - 1 = PRINT OUTPUT FROM PRSGRD BUT DO NOT USE IT IN SOLUTION.
162 NDPVSX - NO. OF DPDX'S IN PPRIME TABLE.                    4
 14 NELEM   - NUMBER OF ELEMENTS IN SOLUTION.
 89 NEMD    - STARTING LOC. PAR. IN FEDIMN.
 31 NEQ     - NO. OF VARIABLES TO BE SOLVED.                   5
 43 NEQADD - NO. OF EQNS. TO ADD AFTER TKE - DISS. STARTUP.
            - E.G. -2 = DELAY INT. TKE AND DISS. UNTIL C4EDSW IS SATISFIED.
 58 NEQKNN - NO. OF DEP. VAR. TO BE INTEG. IN QKNUIN.      1
 45 NEXP    - NO. OF BOUNDAR NODES IN JBOUND VECTOR.  ( FROM L7H)
107 NELE2   - 0 = DO NOT USE MIXING LENGTH THEORY FOR DIFF. COEF.
              1 = USE MLT FOR SOLUTION OF DIFF. COEF.
              2 = DELAY USING MLT UNTIL FLE2SW IS SATISFIED.
 46 NF      - NO. OF 'NB' BYTE WORDS IN TITLE FOR EACH DEP. VAR.       4
257 NFLUX   - NUMBER OF FLUX (A3) BOUNDARY CONDITIONS.
258 NFX     - NUMBER OF FIXED NODES.
130 NGETH   - COUNTER IN ORHOGS TO INIT. VARIABLES IN GAS.         1
 54 NHHALF - NO. OF DECREASES IN STEP SIZE IN QKNUIN.
 53 NH2     - NO. OF INCREASES IN STEP SIZE IN QKNUIN.
 68 NI      - STARTING LOC. IN DEP. VAR. MATRIX FOR THIS VARIABLE.
 63 NIND    - FEDIMN DISPLACEMENT COUNTER.
 94 NIZS    - NO. OF IZ ENTRY POINTS THAT CAN BE STORED.   400
 65 NJ      - STARTING LOC. IN YY MATRIX FOR DEP. VAR.
275 NL      - NO. OF X, Z COORDINATES DESCRIBING LOWER SURFACE IN BLTINT.
 88 NLINE   - LINE COUNT OUTPUT CONTROL.                       60
191 NM      - TYPE OF ELEMENTS IN SOLUTION.                    3
            - 2 = LINE (ONE-DIMENSIONAL).
            - 3 = TRIANGLE (TWO-DIMENSIONAL).
 60 NMBOUT - NO. OF VARIABLES TO BE PRINTED.                   30
206 NMDL    - ALLOW EXTRA STORAGE IN IZ(71) AND IZ(72)
              LENGTH OF IZ(71) = MAXIMUM ( NODE, NEQ*NM*NMDL )
              LENGTH OF IZ(72) = MAXIMUM ( NODE, NEQ*NMDL)
190 NMOUT   - 3 = PRINT OUTPUT IN GEOMETRY FORM.               1
              2 = PRINT OUTPUT IN NODE NO. SEQUENCE.
 16 NNODE   - NUMBER OF NODES IN SOLUTION.
278 NNPT    -
 55 NODE    - VARIABLE DIMENSIONING PARAMETER IN FEDIMN.           100
150 NODNO   - NODE NO. AT WHICH DRHOGS IS COMPUTING.
 19 NOE     - NO. OF EQUATION BEING SOLVED FOR DEP. VAR. 'NP'.
148 NONC    - NON-CONVERGENCE CODE IN GAS.
142 NOUTPR - NO. OF SCALARS TO PRINT IN OUTPUT.                60
283 NO1     - VECTOR FOR STORAGE OF D/DX IN DPSISQ.
284 NO2     - VECTOR FOR STORAGE OF D/DY IN DPSISQ.
 30 NP      - DEP. VARIABLE BEING SOLVED AT THIS TIME.
 18 NPART   - NO. OF PARTITIONS ( USED IN 'L7H')               2
```

```
198 NPGRCT - STARTUP COUNTER USED IN PRSGRD.                      4
199 NPGRDV - STARTUP COUNTER USED IN PRSGRD.                      4
 20 NPRNT  - NO. OF PRINT POSITIONS ON A LINE OF OUTPUT.  132
 35 NPSICC - NO. OF BOUNDARY NODES FOR VAR. ENTERING STRF.
 11 NPTDOF - NO. OF POINTS DEG. OF FREEDOM. ( JBOUND PAR.)          1
 24 NPTEL  - NO. OF POINTS ELEMENT. (L7H)                         3
153 NPUNCH - SET = 7 IF ELEMENTS AND NODES ARE TO BE PUNCHED IN DIMEN.
161 NPVSX  - NO. OF PRESSURES IN P VS X TABLE.                    2
 49 NQEL   - NO. OF POINTS / ELEMENT. (L7H)                       3
 21 NROW   - DEP. VAR. AND DERIVATIVE ALTERNATOR IN QKNINT.     2
  9 NRSTRT - LOGICAL TAPE NO. TO READ RESTART COND. IN 'BDINPT'.
 87 NRTAPE - LOGICAL TAPE NO. TO STORE RESTART COND. IN 'LINK2'
 67 NS     - GENERAL DUMMY PARAMETER.
252 NSELEM - NO. OF SUPER ELEMENTS IN AIRFOI.
146 NSFDBE - RESET CONDITION FLAG IN 'FINDBE'.
 27 NSKIP  - NO. OF BOUNDARY LOC. / DEP. VAR.                     NODE
 64 NSM    - STOP PROGRAM IF OUTPUT EXP. IS .GT. NSM.             10
251 NSNODE - NO. OF SUPER NODES IN AIRFOIL.
121 NSPEC  - NO. OF SPECIES IN SOLUTION.                          9
273 NSTAG  - 1 = INPUT GEOMETRY AND PRESSURE DO NOT BEGIN AT STAGNATION
               POINT AND END AT TRAILING EDGE.
180 NSTRT  - STARTING LOCATION IOF DEP. VAR. NOS. FOR SPECIES.
276 NUS    - NUMBER OF POINTS TO USE FOR COMPUTING DELTA STAR IN BLTINT.
109 NTAPER - LOGICAL UNIT NO. OF RESTART TAPE.
140 NTCNTS - STARTUP PARAMETER IN CONTES.
 62 NTITL  - NO. OF TITLE CARDS TO BE READ IN AND PRINTED AT THE
                 BEGINNING OF EACH OUTPUT SET.                    10
197 NTPRNT - 99999 = DO NOT PRINT INTEGRAL PARAMETERS IN TRBTHK.
176 NTKS   - NO. OF INTEGRAL PARAMETERS TO BE COMPUTED.    5
             ONLY 5 INT. PARAMETERS ARE COMPUTED, BUT OTHER PARAMETERS
                ARE SET, SUCH AND THETA REYNOLD'S NO., SHAPE FACTOR, ETC.
             IF = 99999, DO NOT PRINT INTEGRAL PARAMETERS BETWEEN OUTPUTS.
274 NU     - NO. OF X, Z COORDINATES DESCRIBING UPPER SURFACE IN BLTINT.
282 NV     - ARRAY FOR TEMPORARY STORAGE OF DEP. VAR. IN DPSISQ.
260 NVAR   - NUMBER OF VARIABLES TO BE DISTRIBUTED OVER REFINED GRID.
 84 NVARO  - COUNTER USED IN STRF.
 85 NVAR1  - COUNTER USED IN STRF.
 74 NVH    - DEP. VAR. NO. FOR ENTHALPY.         DEF. = 4
 70 NVP    - DEP. VAR. NO. FOR PSI.              DEF. = 5
 71 NVU    - DEP. VAR. NO. FOR U1 VELOCITY.      DEF. = 1
 72 NVV    - DEP. VAR. NO. FOR U2 VELOCITY.      DEF. = 2
 73 NVW    - DEP. VAR. NO. FOR U3 VELOCITY.      DEF. = 3
 90 NYY    - NO. OF TIME PERIODS TO STORE YY.   MUST = 2
 91 NZZ    - NO. OF TIME PERIODS TO STORE ZZ.   MUST = 2
193 NM2    - NM**2. USED FOR STORING FULL MATRICES.
192 N2M    - NM * 2.  USED FOR STORING SYMMETRIC MATRICES.
166 N3DPNS - 1 = CALL PRSGRD FOR DPDX COMPUTATION.
```

RARRAY

THE FOLLOWING IS A PARTIAL LIST OF ENTRIES IN THE RARRAY VECTOR WHICH CONTAINS REAL PARAMETERS THAT ARE USED TO CONTROL PROGRAM FLOW. NOT ALL ENTRIES ARE LISTED SINCE SOME OF THEM DO NOT PERTAIN TO THE PROBLEM CLASS IN THIS DOCUMENT.

RARRAY ENTRY	NAME	DEFINITION	NON-D DEF.
156	AINF	- REFERENCE SPEED OF SOUND.	
5	AJ	- JOULES CONSTANT.	778.28
3	ALC	- CHARACTERISTIC ELEMENT SIZE. DEF. = MIN. SIDE	
251	ALPHA	- ANGLE OF ATTACK.	
87	ARNEW	- NEW AREA COMPUTATION IN PRSGRD.	
86	AVD	- DAMPING FACTOR IN DFCFBL.	25.3
252	BETA	- KARMAN-TREFFTZ CAMBER ANGLE.	
209	BLTH	- BOUNDARY LAYER THICKNESS, DELTA.	
176	CBTCKJ	- SPECIFIC HEAT BRITISH TO MKS	4.184
365	CD	- TKE - DISS. COEF.	0.09
364	CK	- TKE - DISS. COEF.	1.0
211	CFOV2	- SKIN FRICTION	
184	CKTKE	- TKE - DISS. COEF.	0.09
83	COMPX	- COMPRESSION FACTOR FOR OUTPUT COL. VECTOR INDICATES PERCENT OF X1 AXIS TO BE USED TO SHORTEN SPACING INTERVALS.	
84	COMPY	- COMPRESSION FACTOR FOR OUTPUT ROW VECTOR. SAME AS COMPX, BUT FOR X2 AXIS.	
124	CON	- KARMANN'S CONSTANT USED IN MLT IN DFCFBL.	.435
70	CONRHO	- IF .GT. 0.0, SET ALL RHO = CONRHO.	
62	CONV	- OUTPUT SCALE FACTOR = 1.0 / REFL.	
77	CON1	- ALC / (RE*CPOINF*XMUINF)	
78	CON2	- CON1 / TOFINF	
158	CPA	- SPECIFIC HEAT OF AIR.	0.24
159	CPH	- SPECIFIC HEAT OF HYDROGEN.	3.445
160	CPINF	- SPECIFIC HEAT COMPUTED IN CPINIT.	
30	CPOINF	- REFERENCE SPECIFIC HEAT.	0.24
153	CVCP	- SPEC. HEAT CONV.USED IN THERMO.	4186.0
148	CVH	- ENTHALPY CONV. USED IN THERMO.	1.0
151	CVP	- PRESSURE CONV. USED IN THERMO.	.4725E-3
152	CVRHO	- DENSITY CONV. USED IN THERMO.	16.02
150	CVT	- TEMPERATURE CONV. USED IN THERMO.	1.0
149	CVU	- VELOCITY CONV. USED IN THERMO.	0.3048
182	C1TKE	- TKE - DISS. COEF.	1.45
183	C2TKE	- TKE - DISS. COEF.	0.18
130	C4ED	- MIXING LENGTH MULTIPLIER.	0.0007
143	C4EDSW	- TKE - DISS. STARTUP POSITION IN DFCFBL.	30000.0
13	DELP	- PERCENT INTERVAL FOR PRINTOUT. DEF. = 2.0	
205	DELSTR	- DISPLACEMENT THICKNESS.	
207	DELTA3	- ENERGY DISSIPATION THICKNESS.	

```
103 DEPLT  - PERCENT OF TC TO BE USED FOR PLOTTING STATIONS.    101.0
165 DRTCDK - DEGREES RANKINE TO DEGREES KELVIN                 5.0 / 9.0

175 EBTCKJ - ENTHALPY BRITISH TO MKS                           2.3244
 90 EKNINF - TKE NON-D FACTOR - UINF**2
204 ENER   - ENERGY FOR VELOCITY.
108 ENMULT - DIMENSIONALIZING FACTOR FOR ENERGY.
 14 EPS    - ACCURACY TEST BETWEEN PREDICTOR-CORRECTOR FORMULAS.    0.01
 89 EPSINF - DISSL. NON-D FACTOR - UINF**3 / ALC
 95 EPTEST - ZERO TEST FOR DISSIPATION USED IN DERVBL.
 68 EP4MD  - MULTIPLIER FOR XMDOT IN PRSGRD.                   1.0
368 ESCF   - SCALE FACTOR IN DISS. LENGTH .                    .435
145 E1E2SW - STATION AT WHICH TC CHANGE NE1E2 FROM 2 TO 1.      30000.0

  1 FACT   - NON-DIM. FACTOR. ( BL = ALC,  2DNS = ALC / UINF )
 80 FACTH  - 1.0 / ( CPCINF*TOFINF)
 59 FACTMU - RHOINF * UINF * ALC
 79 FACTP  - 1.0 / FACTMU
370 FRCUDM - SCALE FACTOR USED ON FROUDE NO. IN DERVBL.
163 FTTOCM - FEET TO CENTIMETERS.                              30.48
162 FTTOIN - FEET TO INCHES.                                   12.0
164 FTTOMT - FEET TO METERS.                                   0.3048
189 F1     - Y-COORDINATE OF F1 CURVE.
329 F10    - LAST VALUE OF F1 CURVE.

 31 G      - GRAVITIATION CONSTANT.                            32.174
 60 GAMMAF - FACTOR USED IN GAS LAWS.                          1.4
142 G1     - Z-COORDINATE OF G1 CURVE.
381 G10    - LAST VALUE OF G1.
187 G22    - VARIABLE GEOMETRY FACTOR.
188 G23    - VARIABLE GEOMETRY SCALE FACTOR.
140 G32    - VARIABLE FACTOR.
141 G33    - VARIABLE FACTOR.

 15 H      - CURRENT TRIAL STEP SIZE.
121 HDOT   - Q MASS FLOW COMPUTED IN H2MIX.
 88 HHMIN  - USED IN GKNUIN FOR TIME STEP DETERMINATION.
 97 HINF   - REF. ENTHALPY. COMPUTED IN DRHCGS.                1.0
 16 HMAX   - MAX. STEP SIZE ALLOWED.               DEF. = 0.02 * TD
 17 HMIN   - MINIMUM INTEGRATION STEP SIZE.
132 HRCON  - CONSTANT USED IN H2MIX.                           0.029126
122 HRSDOT - MIXING EFFICIENCY COMPUTED IN H2MIX.
 45 HS     - CURRENT STEP SIZE.
  7 HSINIT - START INTEGRATION STEP SIZE AT THIS VALUE.    1.0 E-7
 12 HT     - OUTPUT VAR. FOR TIME STEP = HS * FACT / REFL
186 H21    - GRID GROWTH SCALE FACTOR.                         1.0
139 H31    - GRID GROWTH SCALE FACTOR.                         1.0

  2 ONE    - PROGRAM CONSTANT.                                 1.0
 18 OOTEPS - ACCURACY TEST PARAMETER IN 'QKNUIN'.
375 OSH1SQ - 1.0 / H21**2
362 OS12   - 1.0 / FACTORIAL(NM+1)
361 OS6    - 1.0 / FACTORIAL(NM)
```

```
174 PDFTOC  - POUNDS/FT**3 TO GRAMS/CM**3                       0.01602
170 PDFTCK  - POUNDS/FT**3 TO KG/M**3                           16.02
 36 PEDDIM  - DIMENSIONAL PRESSURE = PEDGE * PRSCON.
 39 PEDGE   - NON-DIM. PRESSURE AT PRESENT STATION.
  9 PINF    - FREESTREAM PRESSURE.     DEF. = 1ST VALUE IN P VS X TABLE.
180 PMSKGS  - POUNDS / KG.                                      1.0 / 2.2
 19 PNTEPS  - ACCURACY TEST PARAMETER IN ' QKNUIN'.
 99 PPRCON  - PRSCON / ALC
100 PPRIME  - PRSSURE GRADIENT COMPUTED IN PRESSURE ROUTINE.
 67 PR      - PRANDTL NUMBER.                                   1.0
185 PRDIS   - DISSIPATION PRANDTL NUMBER.                       1.3
171 PRSCON  - RHOINF * UINF**2 / G
181 PRTKE   - TKE PRANDTL NUMBER.                               1.0
166 PSFTOA  - POUNDS/FT**2 TO PSIA                              0.4725E-3
169 PSFTOI  - POUNDS/FT**2 TO POUNDS/IN**2                      0.006924
168 PSFTON  - POUNDS/FT**2 TO NEWTONS/M**2                      47.88
167 PSFTOT  - POUNDS/FT**2 TO TORR                              0.3591
 20 PTIM    - PRINT TIME PARAMETER IN 'QKNUIN'.
106 PTPL    - PLOT POINT DEFINITION WHEN STATION PASSES PTPL.

123 QR      - DYNAMIC PRESSURE RATIO.                           1.0
134 Q3MAX   - MAXIMUM Q CONC. FOUND AT PRESENT STATION.

179 RADCON  - CONVERSION FACTOR RADIANS TO DEGREES.             57.3
 94 RATO2   - RATIO OF TWO REMAINING GASES WHEN RUNNING H2, O2 AND N2.
 21 RE      - REYNOLD'S NO.     RHOINF*UINF*ALC/XMUINF
 43 REFL    - REFERENCE LENGTH.                       UINF      1.0
 47 REFLRE  - REYNOLD'S NO. BASED ON REFL.
 10 RHOINF  - FREESTREAM DENSITY.
157 RHOUIN  - RHOINF * UINF
  8 RMINS1  - PROGRAM CONSTANT.                                 -1.0
255 RNB     - REYNOLD'S NUMBER FOR AIRFOIL.
199 RNULOC  - 1.0 USED LOCAL VISCOSITY FOR VAN DRIEST DAMPING FACTOR.
105 ROCST   - XMA / XMH - 1.0
119 ROUALC  - RHOINF * UINF * ALC**2
116 RR      - CPH / CPA
208 RT      - THETA REYNOLD'S NUMBER.
 32 RTCON1  - 2.0 * G * AJ
 33 RTCON2  - GAMMAF / 2.0
 34 RTCON3  - RUNIV / XMA
 55 RTCON4  - RTCON2 * XMACHO**2
 56 RTCON5  - UINF**2 / (RTCON1*CPOINF*TOFINF)
 57 RTCON6  - 2.0 * RTCON4
117 RTOHM1  - RR * ( TOH/TOA - 1.0 )
 28 RUNIV   - UNIVERSAL GAS CONSTANT.                           1545.33

256 SANGLE  - SWEEP ANGLE (DEGREES).
129 SCT     - CONSTANT SCHMIDT NUMBER.                          1.0
210 SHAPEF  - SHAPE FACTOR.
190 SLOPE   - SLOPE OF VARIABLES COMPUTED IN LOOK.
  6 SOUND   - SPEED OF SOUND FOR NODE BEING PROCESSED.
131 SPLIT   - CUTOFF USED IN H2MIX.                             0.02835
 44 SQ2     - SQRT(2.0)
 73 STLDCR  - REF. CON. TEMP. IN SUTHERLAND.                    204.0
 74 STLDEX  - EXPONENT USED IN SUTHERLAND.                      1.5
```

```
 72 STLDTR - REF. TEMP. USED IN SUTHERLAND.                     492.0
 71 STLDVR - VISCOSITY USED IN SUTHERLAND.                      .1163E-4
 50 SSINIT - HSINIT / FACT

374 TAREA  - TOTAL COMPUTATIONAL AREA.
372 TBAR   - MASS WEIGHTED AVERAGE TEMPERATURE.
 35 TD     - TOTAL SOLUTION TIME ( DISTANCE ) FROM TO.     1.0
 22 TF     - FINAL TIME (DISTANCE),   TF = TO + TD
253 TEANG  - TRAILING EDGE ANGLE.
206 THETA  - MOMENTUM THICKNESS.
196 THETAP - SCALE FACTOR USED IN PRSGRD.
  4 THK    - DEF. NON-DIM. THICKNESS OF ELEMENTS.          1.0
254 THKAF  - AIRFOIL MAXIMUM THICKNESS.
 23 TIME   - CURRENT TIME (DISTANCE).
 48 TIMESV - SAVED TIME LOCATION FOR IMPLICIT INTEGRATION.
 24 TO     - STARTING TIME (DISTANCE).
146 TOA    - AIR REFERENCE TEMP. FOR COMPUTATIONS IN DIMEN.     533.0
 58 TOFINF - REFERENCE TEMPERATURE.                         533.0
147 TOH    - H2 REF. TEMPERATURE FOR COMPUTATIONS IN DIMEN.     520.0
 40 TRATIO - 1.0 + (GAMMAF-1.0) * XMACHS**2 / 2.0
257 TRIFOP - 1.0 = DO NOT SET TRIP LOCATION UNTIL RTHETA .GT. 200.0
258 TRIPUP - X/C VALUE OF TRIP LOCATION IN BLTINT.
155 TSINF  - STATIC TEMPERATURE COMP. IN CPINIT.
 26 TWOPI  - PI * 2.0

371 UBAR   - MASS WEIGHTED AVERAGE VELOCITY.
203 UED    - EDGE VELOCITY.
 63 UEDGE  - UINF / UINFX USED IN BROSHW.
 27 UINF   - FREESTREAM VELOCITY.
202 UWALL  - VELOCITY JUST OF WALL .

104 VELCST - UINF**2 / ( 2.0 * G * AJ * CPA * TOA )
177 VLBTCN - VISCOSITY BRITISH TO MKS.                      1.488
178 VLBTOP - VISCOSITY BRITISH TO CGS.                      14.88
102 VSTART - PERCENT OF TD AT WHICH TO START U2 COMP. IN CONTES.

383 WSMAX  - WIDTH OF DOMAIN AT INITIAL STATION.

366 XEM    - EXPONENT FACTOR USED IN VAN-DRIEST DAMP. FACTOR.  1.0
125 XLAM   - CONSTANT USED IN DFCFBL.                       0.09
 37 XLE    - LEWIS NUMBER.                                  1.0
109 XMA    - MOLELAR WEIGHT OF AIR.                         28.97
 61 XMACHO - MACH NUMBER.
154 XMACHS - LOCAL MACH NUMBER.
373 XMDOTC - AVERAGE MAS FLOW.
 66 XMF    - MOLECULAR WEIGHT OF FLUID.                     29.4
172 XMFACT - UINF * SQRT ( XMA / ( TOFINF * GAMMAF * G * RUNIV ) )
110 XMH    - MOLECULAR WEIGHT OF HYDROGEN.                  2.016
118 XMSDF  - MASS DEFECT COMPUTED IN QMCONC.
 38 XMUINF - FREESTREAM VISCOSITY.
 46 XMXDF  - RATE OF CHANCE OF DPDX. (USED IN PRSGRD).
193 XNWGEO - 1.0 = RUNNING NWGEOM.
 98 XPRIME - NON-DIM. PRESUURE GRADIENT AT PRESENT STATION.
 52 XSCALE - XICOR SCALE FACTOR.                            1.0
 41 XSHFT  - SHIFT X-COORDINATE.
```

```
201 XTC     - PRESENT STATION FOR INTEGRAL PARAMETER PRINT.
112 X3LAST - LAST TIME STEP USED IN DERVCX.

367 YLTKE   - SCALE FACTOR IN DISS. LENGTH.                  4.5
330 YMULT   - SCALE FACTOR FOR GRID MULTIPLIER.
198 YPLUS   - Y+ VALUE AT WHICH TO SWITCH FROM MLT TO TKE.        30.0
 53 YSCALE - X2COR SCALE FACTOR.                             1.0
 42 YSHFT   - SHIFT Y-COORDINATE.
 76 YTT     - SCALE FACTOR FOR PLOTTING.

382 ZMULT   - SCALE FACTOR FOR GRID MULTIPLIER.
 29 ZT      - DIMENSIONAL CURRENT STEPIZE (DISTANCE).
```

IZ ARRAY

- -

THE FOLLOWING IS A LIST OF ENTRIES AT THE BEGINNING OF THE IZ ARRAY WHICH CONTAIN ENTRY POINTS IN THE REMAINDER OF THE IZ ARRAY WHICH ARE THE STARTING LOCATION FOR THE VARIABLE LENGTH VECTORS USED IN THE PROGRAM.

- -

IZ ENTRY	NAME	DEFINITION
1	ICOL	- DISCRETIZATION COLUMN LOCATIONS.
2	IROW	- DISCRETIZATION ROW LOCATIONS.
3	IFMTHD	- HEADINGS FOR OUTPUT VARIABLES.
4	ITITLE	- TITLE FOR START OF EACH OUTPUT PHASE.
5	IIPINT	- LIST OF DEP. VARIABLE NUMBERS.
6	IKBND	- NO. OF BOUNDARY NODES / DEP. VARIABLE.
10	IINCOL	- NO. OF NODES PER COLUMN.
11	IINROW	- NO. OF NODES PER ROW.
18	ICPTAB	- SPECIFIC HEAT TABLE ENTRIES.
19	ITTAB	- TEMPERATURE TABLE ENTRIES.
20	IILSEC	- COUNTER USED IN FEOUTPUT.
21	INPINT	- DEP. VAR. POSITIONS IN IIPINT VECTOR.
25	IIBND	- RE-ORDERED NODES / DEP. VAR. TO ACCOUNT FOR BOUNDARY COND.
26	IINODE	- ARRAY OF ELEMENT CONNECTIONS (NM/ELEMENT).
27	IJBCND	- NODE SOLUTION ORDER USED IN BANCHC.
28	IKEYCL	- COLUMN KEYS FOR BANCHO.
29	IKEYDG	- DIAGONAL KEYS FOR BANCHO.
30	IKEYRW	- ROW KEYS FOR BNACHC.
31	IKIN	- LIST OF DEP. VAR. NOS. FOR SPECIES.
32	INWN	- TEMPORARY STORAGE FOR RE-ORDERED NODES.
33	IINDEX	- ORDER OF NODES BY COLUMNS FROM LEFT TO RIGHT.
34	IINDRW	- ORDER OF NODES BY ROWS FROM TOP TO BOTTOM.
35	INCCOL	- OUTPUT COLUMN POSITION OF NODES BY ROWS.
36	IIELS	- NO. OF ELEMENTS CONNECTED TO NODES.
37	IIELEM	- LIST OF ELEMENTS CONNECTED TO NODES.
38	IIBORD	- LIST OF BORDER NODES IN COUNTER-CLOCKWISE ORDER.
39	IA211A	- A211A ANTI-SYMMETRIC MATRIX.
40	IB11	- B11 MATRIX STORAGE.
41	IB211	- B211 MATRIX COMPUTED IN GEOMFL.
42	IB211S	- B211S MATRIX COMPUTED IN GEOMFL.
43	IC200	- B200 MATRIX STORAGE.
45	ISMSTR	- ENTRY POINTS IN IZ FOR STANDARD MATRICES.
46	IBCNST	- STORAGE FOR BOUNDARY CONDITIONS.
47	IDIF	- DIFFUSION COEFFICIENTS / DEP. VARIABLE.
48	IYY	- 2 SETS OF VALUES / DEP. VARIABLE.
49	IZZ	- 2 SETS OF VALUES OF DERIV. / DEP. VARIABLE.
50	IXIP2	- ELEMENT LENGTHS COMPUTED IN GEOMFL.
52	IYDIM	- NON-DIMENSIONAL TRANSVERSE COORDINATES.
53	IPCOL	- COLUMN COORDINATES FOR OUTPUT PAGE.
54	IPROW	- ROW COORDINATES FOR OUTPUT PAGE.
55	IASUM	- SUM OF AREAS OF ELEMENTS AROUND EACH NODE.
56	IAMXLT	- MIXING LENGTHS.
57	IWW	- TEMPORARY STORAGE FOR CROSS VELOCITY.

```
 58 IVV    - TEMPORARY STORAGE FOR TRANSVERSE VELOCITY.
 59 IVV    - TEMPORARY STORAGE FOR DOWNSTREAM VELOCITY.
 61 ITBRTK - STORAGE FOR INTEGRAL PARAMETERS.
 65 IU3POS - DOWNSTREAM POS. FOR TRANSVERSE COORDINATE CHANGE.
 66 IU3VAL - SCALE FACTOR FOR TRANSVERSE COORDINATE CHANGE.
 67 IVWALL - WALL VALUE OF INJECTED TRANSVERSE VELOCITY.
 68 IVWSTA - DOWNSTREAM STATION AT WHICH TO INSERT TRANSVERSE VELOCITY.

 71 IOUT1  - TEMPORARY STORAGE.
 TO          - - - -
 76 IOUT6  - TEMPORARY STORAGE.
 77 IAREA  - AREA OF ELEMENTS COMPUTED IN GEOMFL.
 78 ICP    - NODAL VALUES OF SPECIFIC HEAT.
 79 IH     - NODAL VALUES OF ENTHALPY.
 80 IPSI   - TEMPORARY STORAGE FOR VARIABLE TO BE SOLVED IMPLICITLY.
 82 IQ     - TEMPORARY STORAGE FOR DEPENDENT VARIABLE.
 83 IQP    - TEM-ORARY STORAGE.
 84 IRHO   - NODAL VALUES OF DENSITY.
 85 ITEMP  - NODAL VALUES OF TEM-ERATURE.
 86 IRHSP  - RIGHT HAND SIDE OF IMPLICIT EQUATION TO BE SOLVED.
 88 ITK    - ELEMENT THICKNESS DISTRIBUTION.
 89 IX1COR - NODAL VALUES OF TRANSVERSE COORDINATES.
 90 IX2COR - NODAL VALUES OF NORMAL COORDINATES.
 91 IPRESS - NODAL VALUES OF -RESSURE.
 92 IAMU   - NODAL VALUES OF LAMINAR VISCOSITY.
 95 INORMY - NORMALIZED TRANSVERSE COORDINATES.
 96 INORMZ - NORMALIZED VALUE OF CROSS COORDINATES.
 97 IUSQ   - NODAL VALUES OF PSI * B211S * PSI. (UIUI)
 98 IAVTHK - AVE. THICKNESS OF ELEMENTS AROUND EACH NODE.
 99 NJST   - STORAGE FOR RHS IN IMPLICIT EQN. SOLVER.
100 IPRVAL - STORAGE FOR RESTARTING 'PRSGRD'.
101 IQL    - STORAGE FOR DERVDX ROUTINE.
102 IQPL   - STORAGE FOR DERVDX ROUTINE.
103 IVEL   - NODAL VALUES OF U2 COM-UTED IN CONTES.
104 IW     - NODAL VALUES OF U3.
105 IPRGRD - NODAL VALUES OF DPDX.
108 IYNOD  - TRANSVERSE COORD. USED IN CONTES, DFCFBL, TRBTHK, WLFLXS, ETC.
109 IB112  - NATURAL COORDINATE DERIVATIVE COMP. IN GEOMFL.
110 IB113  - NATURAL COORDINATE DERIVATIVE COMP. IN GEOMFL.
111 IPLOTS - LIST OF VARIABLES TO BE -LOTTED.
112 IPLTYP - TYPE OF PLOT TO BE GENERATED.
114 ISCHMT - NODAL VALUES OF SCHMIDT NUMBERS.
117 INX    - NUMBER OF DIVISIONS ALONG X1 DIRECTION / SUPER ELEMENT.
118 INY    - NUMBER OF DIVISIONS ALONG X2 DIRECTION / SUPER ELEMENT.
119 IMACH  - NODAL VALUES OF MACH NUMBER.
120 IHSTAT - NODAL VALUES OF STATIC ENTHAL-Y.
121 ICALL  - LIST OF LINK NOS. AND ENTRIES TO CALL AT END OF QKNUIN.
123 IOMULT - LIST OF MULTI-LIERS FOR OUT-UT VARIABLES.
124 IOSAVE - LIST OF VARIABLES TO BE PRINTED IN OUTPUT.
125 INOUT  - TEM-ORARY STORAGE FOR OUT-UT VAR. AND SOURCE DATA.
127 IICNCL - NO. OF NODES / COL. USED IN CONTES, DFCFBL, TRBTHK, ETC.
128 IICNDX - LIST OF NODES / COL. USED IN CONTES, DFCFBL, TRBTHK, ETC.
129 IWCOS  - COSINE OF ANGLE / COL. USED IN CONTES.
130 IVSIN  - SINE OF ANGLE / COL. USED IN CONTES.
131 IIPAR  - LIST OF -ARAMETERS TO -RINT AT START OF OUTPUT.
```

132	IOPAR	- TITLE INFORMATION FOR PARAMETERS AT BEGINNING OF OUTPUT.
133	ISLTLC	- LIST OF CONSTANTS USED IN SUTHLD.
134	IPR	- NODAL VALUES OF PRANDTL NUMBER.
135	IMPAR	- LIST OF MULT. FOR PARAM. AT START OF OUTPUT.
136	IEPS	- NODAL VALUES OF TURB. VISC. COMPUTED IN DFCFBL.
137	ISKNFR	- SKIN FRICTION DIST. BY COLUMN.
138	ISTN	- STANTON NO. DIST. BY COLUMN.
139	IX3ST	- LIST OF DOWNSTREAM STATIONS IN PRESSURE TABLE.
140	IPVSO	- LIST OF DOWN PRESSURES IN PRESSURE TABLE.
141	IDPX3	- LIST OF DOWNSTREAM STATIONS IN PRESS. GRAD. TABLE.
142	IDPVX	- LIST OF DOWNSTREAM PRESS. GRAD. IN DPDX TABLE.
145	IADIF	- NODAL VALUES OF TURBULENT VISCOSITY.
146	IMXLT	- MIXING LENGTH USED IN DFCFBL.
147	IXYCP	- AIRFOIL BOUNDARY COORDINATES, CP'S, PHI AND NODE NUMBERS.
197	IDOUTP	- MATRIX STORAGE FOR BNACHC SOLVER IN STRF.
201	NZONE	- SUPER ELEMENT NUMBERS.
202	ISHAPE	- ORDER OF GENERATED ELEMENTS IN REFINE.
203	ICLZ	- TUPE OF ELEMENTS DESIRED / SUPER ELEMENT.
206	NZ	- NUMBER OF ELEMENTS ALONG COORDIANTE 3.
207	ITYPE	- TYPE OF SUPER ELEMENT 1 = TRIANGLE.
		2 = QUADRILATERAL.
208	NCOL	- NUMBER OF COLUMNS IN SUPER ELEMENT.
209	MELEM	- SUPER ELEMENT TO ELEMENT.
210	NELK	- TYPE OF SUPER ELEMENT LINK.
211	Q	- SUPER NODE TO ELEMENT.
212	KQ	- Q KEY.
213	KF	- F KEY.
214	KTK	- THK KEY.
215	IBCTYP	- BOUNDARY TYPE KEY.
216	BCUND	- BOUNDARY COEFFICIENTS.
217	IDUM	- DUMMY NODE COUNTER IN REFINE.
218	BC	- GENERATED BOUNDARY CONDITION ARRAY.
219	NODF	- VECTOR OF BOUNDARY NODES.
220	KTFIX	- FIXED DEP. VAR. NODE KEYS.
222	JELF	- VECOTR OF BOUNDARY ELEMENTS.
223	KBND	- SUPER ELEMENT BOUNDARY KEYS.
225	AA	- NON-RECTANGULAR CARTESIAN COORDINATES DIRECTION 1.
226	BB	- NON-RECTANGULAR CARTESIAN COORDINATES DIRECTION 2.
227	SNODE	- SUPER NODE NUMBER VECTOR.
228	SGRID	- VARIABLE ARRAYS RETURNED FROM REFINE.
229	DUM	- DUMMY STORAGE IN REFINE.
230	ELNK	- SUPER NODE CONNECTION TABLE.
231	MATL	- GENERATED SUPER ELEMENT TO ELELENT DATA.

201 - 240 ARE TEMPORARY LOCATIONS FOR POTENTIAL AND DELTA * SOLUTIONS.

Diagnostic Print

Aside from the previously described standard problem oriented print, various forms of debug type print are accessible to aid in checking out program changes and size limitations. These print are accessed via keys specified in namelist NAME01* This section describes the more useful of these and illustrates the print to be expected for each.

KDUMP	As previously noted, the KDUMP flag presents a data reflection together with a print of the array filled by the data. In addition, it provides a print of the starting location of each variable in the IZ array as dimensioned in FEDIMN. This print is valuable for determining the array sizes when adding new vectors to the IZ array. A sample print of this output is illustrated in Figure 11.
KODG	This flag prints finite element intermediate data formed in GEOMFL. The print can become quite cumbersome if there are many elements in the solution, and the flags IBOT and ITOP are utilized to define the range of element numbers to be printed.
KOD5	During the integration process the derivatives are formed by assembly over the finite elements. A print of the assembled and reduced vectors is obtained by setting KOD5 equal to the number of prints desired. The flag is decremented by one for each pass through the derivative routine. Flags IBOT and ITOP also apply to this print. An example of this print is illustrated in Figure 13.
IPWRIT	Equation solving is performed in subroutine STRF and this flag set to 1 causes the global system vectors and matrix to be printed during equation assembly and solution. Flags IBOT and ITOP indicate the span of elements over which print is desired.

* KPNT must also be set equal to 1 in NAME01 to obtain any debug print. KPNT will be automatically set equal to 0 in LINK2-6.

2145A0	000000C9											
21DDF4	002148C4	002148CC	002149A8	00214AE8	00214E58	00214E68	002145A0	002145A0	00214E78	00214E78	00214E80	00214F5C
21DE24	00214F5C	00214F5C	00214F5C	00214F5C	00214F5C	00214F5C	00214F60	00214F64	00215040	002145A0	002150AC	00215188
21DE54	00215264	002155D4	0021578C	00215868	00215944	00215A20	00215AFC	00215B20	00215BFC	00215CD8	00215DB4	00215E90
21DE84	00216048	00216570	002145A0	0021664C	0021698C	00216D2C	0021709C	002145A0	002171E4	00217218	002174A0	00217B80
21DEB4	00218260	00218940	00218A1C	00218A1C	00218AF8	00218B00	00218BDC	00218CB8	00218D94	00218E70	002145A0	00218F4C
21DEE4	00219028	00219080	0021915C	002191AC	002191FC	0021924C	0021929C	00219378	00219454	00219464	0021946C	002196EC
21DF14	0021982C	0021996C	00219AAC	00219BEC	00219D2C	00219E08	00219EE4	00219FC0	0021A09C	0021A178	0021A254	0021A330
21DF44	0021A40C	0021A4E8	0021A5C4	0021A6A0	0021A77C	0021A858	0021A934	0021AA10	0021AAEC	0021ABC8	0021ACA4	0021AD80
21DF74	0021AE5C	0021AF38	0021B014	0021B0F0	0021B0F0	0021B384	0021B53C	0021B618	0021B6F4	0021B938	0021B988	0021B968
21DFA4	0021BA64	0021BC1C	0021BDD4	0021BE24	0021BE74	0021C004	0021C0E0	0021C0E4	0021C1C0	0021C1CC	0021C1C0	0021C29C
21DFD4	0021C378	0021C420	0021C420	0021C45C	0021C4A8	002145A0	0021CD50	0021CD58	0021CD40	0021CD48	0021CE3C	0021CF2C
21E004	0021D33C	0021D364	0021D440	0021D530	0021D60C	0021D654	0021D65C	0021D774	0021D88C	0021DAC4	0021DCFC	0021DCFC
21E034	0021D530	0021DDD8	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0
21E064	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0
21E094	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0
21E0C4	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0	002145A0
21E0F4	002145A0	002145A0	002145A0	002145A0	0021DDF8	0021DDF8	002145A0	002145A0	00000000			

IZ ENTRY POINTS FOR VECTORS

1- 201	2- 203	3- 258	4- 338	5- 558	6- 562	7- 0	8- 0	9- 566	10- 566
11- 568	12- 623	13- 623	14- 623	15- 623	16- 623	17- 623	18- 623	19- 624	20- 625
21- 680	22- 0	23- 707	24- 762	25- 817	26- 1037	27- 1147	28- 1202	29- 1257	30- 1312
31- 1367	32- 1376	33- 1431	34- 1486	35- 1541	36- 1596	37- 1706	38- 2036	39- 0	40- 2091
41- 2311	42- 2531	43- 2751	44- 0	45- 2833	46- 2846	47- 3008	48- 3448	49- 3888	50- 4328
51- 4383	52- 4383	53- 4438	54- 4440	55- 4495	56- 4550	57- 4605	58- 4660	59- 0	60- 4715
61- 4770	62- 4792	63- 4847	64- 4867	65- 4887	66- 4907	67- 4927	68- 4982	69- 5037	70- 5041
71- 5043	72- 5203	73- 5283	74- 5363	75- 5443	76- 5523	77- 5603	78- 5658	79- 5713	80- 5768
81- 5823	82- 5878	83- 5933	84- 5988	85- 6043	86- 6098	87- 6153	88- 6208	89- 6263	90- 6318
91- 6373	92- 6428	93- 6483	94- 6538	95- 6593	96- 6648	97- 6703	98- 6758	99- 6813	100- 6868
101- 6868	102- 7033	103- 7143	104- 7198	105- 7253	106- 7418	107- 7418	108- 7418	109- 7473	110- 7583
111- 7693	112- 7713	113- 7733	114- 7833	115- 7883	116- 7889	117- 7944	118- 7944	119- 7944	120- 7999
121- 8054	122- 8096	123- 8096	124- 8111	125- 8130	126- 0	127- 8684	128- 8686	129- 8680	130- 8682
131- 8743	132- 8803	133- 9063	134- 9073	135- 9128	136- 9188	137- 9243	138- 9261	139- 9263	140- 9333
141- 9403	142- 9545	143- 9687	144- 9687	145- 9188	146- 9742	147- 0	148- 0	149- 0	150- 0
151- 0	152- 0	153- 0	154- 0	155- 0	156- 0	157- 0	158- 0	159- 0	160- 0
161- 0	162- 0	163- 0	164- 0	165- 0	166- 0	167- 0	168- 0	169- 0	170- 0
171- 0	172- 0	173- 0	174- 0	175- 0	176- 0	177- 0	178- 0	179- 0	180- 0
181- 0	182- 0	183- 0	184- 0	185- 0	186- 0	187- 0	188- 0	189- 0	190- 0
191- 0	192- 0	193- 0	194- 0	195- 0	196- 0	197- 9750	198- 9750	199- 0	200- 0

Figure 11 IZ ARRAY Vector Starting Locations in Hexadecimal and Decimal Form

```
ELEMENT    1     NODE   1        NODE   2        NODE
                 X1     0.0                0.0
                 X2     0.82079E 01        0.11260E 02
    AL
    1    -3.27645E-01        2    3.27645E-01         3    0.0                4    0.0
    AK TRAN
    1     1.00000E 00        2    0.0                 3    0.0                4    1.00000E 00
    B11
    1    -3.27645E-01        2    3.27645E-01         3    0.0                4    0.0
    B211
    1     1.07351E-01        2   -1.07351E-01         3    4.59916E-30        4    0.0

ELEMENT    2     NODE   2        NODE   3        NODE
                 X1     0.0                0.0
                 X2     0.11260E 02        0.15075E 02
    AL
    1    -2.62117E-01        2    2.62117E-01         3    0.0                4    0.0
    AK TRAN
    1     1.00000E 00        2    0.0                 3    0.0                4    1.00000E 00
    B11
    1    -2.62117E-01        2    2.62117E-01         3    0.0                4    0.0
    B211
    1     6.87053E-02        2   -6.87053E-02         3    4.59916E-30        4    0.0
```

Figure 12 Finite Element Intermediate Print (GEOMFL)

```
*-*-*-*-*-ELEMENT      3 NODES      3      4

       AREA           ANLHS          RHM2           PMULT          RHOAV        HIH3ML
  1.56250E 00     2.60416E-01   -1.66667E-01   -2.60416E-01    1.00000E 00    0.0

  DIFMUL( 1) = -3.1451E-01  DIFMUL( 2) = -3.1451E-01  DIFMUL( 3) = -2.4193E-01

  CNVMUL( 1) = -9.2792E-06  CNVMUL( 2) = -1.0015E-05  CNVMUL( 3) = -5.8625E-07

      AVECIF          AVEC           AVEK          DELUSQ         TKEDIS         DISDIS        TKEPRO
  0.10062E-03    0.10062E-03    0.70023E-02    0.15066E-03   -0.15000E-01   -0.43108E-03   0.22215E-07

    B211 MATRIX FOR DIFFUSION.

   1   1.00000E 00     2  -1.00000E 00     3  -1.00000E 00     4   1.00000E 00

     SA CONTRIBUTION TO LHS

   1   1.37275E 00     2   1.38502E 00

     DEPENDENT VARIABLE.

   1   4.53492E-01     2   4.65766E-01

     VISCOSITY.

   1   3.95555E 02     2   4.01457E 02

     DIFFUSION CONTRIBUTION.

   1  -1.22741E-02     2   1.22741E-02

     CONVECTION CONTRIBUTION.

   1  -9.27923E-06     2  -1.00154E-05

     DEPENDENT VARIABLE.

   1   6.61462E-03     2   7.39009E-03

     VISCOSITY.

   1   3.95555E 02     2   4.01457E 02

     DIFFUSION CONTRIBUTION.

   1  -7.75468E-04     2   7.75468E-04

     CONVECTION CONTRIBUTION.

   1  -5.36252E-07     2  -6.22783E-07

     DEPENDENT VARIABLE.

   1   1.02581E-04     2   9.86577E-05

     VISCOSITY.

   1   3.95555E 02     2   4.01457E 02

     DIFFUSION CONTRIBUTION.

   1   3.92283E-06     2  -3.92283E-06

     CONVECTION CONTRIBUTION.

   1   2.96569E-09     2   3.20102E-09
```

Figure 13 Debug Print From the derivative Routine

IWRIT

The IWRIT key is used to flag debug print in three subroutines. In CONTES it is used to print column vectors of density-velocity data which is integrated to obtain u_2. In DFCFBL, various turbulence parameters are printed depending upon the turbulence model used. Debug print from WLFLXS lists various intermediate data calculated in the boundary region of the discretization and used in wall shear stress calculations.

REFERENCES

1. Baker, A.J. and Manhardt, P.D., "Finite Element Analysis of Low Speed Viscous and Inviscid Aerodynamic Flows," NASA CR- , 1977.

2. Goradia, S.H., and Lilley, D.E., "Theoretical and Experimental Study of A New Method for Prediction of Profile Drag of Airfoil Sections," NASA CR-2539, 1975.

3. Proceedings, AFOSR-IFP Stanford Conference on Computation of Turbulent Boundary Layers - 1968, Vol. I., Eds. S.J. Kline, G. Sovran, M.V. Morkovan, D.J. 1ockrell, Vol. II, Eds. D.A. Coles, E.A. Hirst, pub. by Thermosciences Div., Dept. Mech. Engr., Stanford University 1969.

4. Preston, J.H. and Sweeting, N.E., "The Experimental Determination of the Boundary Layer and Wake Characteristics of A Simple Joukowski Airfoil With Particular Reference to the Trailing Edge Region," Reports and Memoranda No. 1998, N.P.L., 1943.

APPENDIX A

Potential Flow

Standard Check Case Data Deck

Goradia NACA0015 (Mod.)

```
POTENTIAL FLOW SOLUTION
DPF
FENAME
&NAME01
             NODE = 390,     LCOL = 100,     KROW = 100,     NIZS = 250,
             NPVSX = 2,      NBC = 60,       NEQ = 2,        IBL = 0,
             NVP = 5,        NPRNT = 132,    IDIFRT = 0,     NOUTPR = 70,
             NC = 7,         NMBOUT = 1,     KUDG = 0,       IWRIT = 0,
             NBUG = 1,       NSPEC = 3,      KDUMP = 1,      KNTPAS = 10,
             IARRAY(271)=1,10
             IARRAY(201) = 5, IARRAY(205) = 100, IARRAY(208) = 5,
             IARRAY(250) = 1, 57, 12, 0, 0, 0, 10, 54, 1, 4, 4, 1,
             IARRAY(271) = 1, 10, 1,
             IARRAY(241) = 1, 10, 1,          IARRAY(263) = 100,
             IARRAY(276) = 200),              IARRAY(279) = 200,
&END
&NAME02
             TOFINF=533.,    UINF = 1.,      RHOINF = 1.,    PINF = 1.,
             XMUINF=533.,
             XMUINF=533.,    ALC = .001,     THK = .001,     CONRHO = 1.,
             THKAF = .118,   ALPHA = 6.,     COMPX = 2.,     COMPY =2.,
             ALPHA = 8.,     BETA = 0.,      THKAF = .15,    RNB = 1.4E07,
&END
EEDIMN
LINK4      9          T  GENE-ATE G-60 FO- POTENTIAL FLOW SOLUTION
NX        -1          T  NO. OF DIV. PER SUPER ELEMENT NORMAL TO AIRFOIL
                         12*3      T
NY        -1          T  NO. OF DIV. PER SUPER ELEMENT TANGENT TO AIRFOIL
                         6 4 5 5 7 6 7 5 5 4 6          T
LINK2     14          T  (DSCRTZ)
DONE                  T  END OF LITERAL DATA
COMTITLE              T  TITLE PRINTED BELOW COMOC SYMBOL
             PERTURBATION POTENTIAL FLOW OVER NACA 0015 (MOD.) AIRFOIL
DONE
DESCRIPT  204         T  DESCRIPTIVE TITLE AT BEGINNING OF HEADER OUTPUT.
             NACA 0015 (MOD.) AIRFOIL, 8 DEGREE ANGLE OF ATTACK.
DONE                  T  END OF LITERAL DATA
DESCRIPT  332         T  TOPAR  PARAMETER TITLES FOR HEADER OUTPUT.
REFERENCE             ENGLISH-FT      ENGLISH-IN        M-K-S           C-G-S
LENGTH                ...FEET...      ....IN....        ....M.....      ....CM....
DONE                  T  END OF LITERAL DATA
MPARA     -1          T  MULTIPLIERS APPLIED TO HEADER OUTPUT. (LOC. IN RARRAY)
                         5*2, 2*2 162  164  163      T
IONUMB    -1          T  LOCATION IN RARRAY OF SCALARS TO BE PRINTED IN HEADER
                         999,  5*200,  999,  200  4*43    T
DESCRIPT  203         T  TITLES  FOR OUTPUT OF DEPENDENT AND PARAMETER VARIABLES.
PERTURBATION POTENTIAL
DONE                  T  END OF LITERAL DATA
IOSAVE    -1          T  DEPENDENT VARIABLE AND PARAMETER ARRAYS TO BE PRINTED
                         5248        T
IOMULT    -1          T  MULTIPLIERS APPLIED TO IOSAVE ARRAYS (LOC. IN ARRAY).
                         2    T
IPINT     -1          T  DEPENDENT VARIABLE NUMBERS
                         5      T
KBNO       5     1    T  POTENTIAL FIXED AT THESE NODES
ADD
                         1  T
DONE                  T  END OF LITERAL DATA
VYY
                         192*0.    T
VYYEND     5
LINK3      4          T  NON - DIMENSIONALIZE DATA  (DIMEN)
LINK1      3          T  FINITE ELEMENT MATRICIES  (GEOMFL)
COMOC                 T  PRINTS COMOC SYMBOL.
EXIT                  T  END OF JOB
```

APPENDIX B

Boundary Layer

Standard Check Case Data Deck

Bradshaw Relaxing Flow

```
 4BRADSHAW
 53DBR
 6FENAME            T  READS NAMELIST DATA
 7 &NAME01
 8          NODE = 40,      NM = 2,        NEQKNN = 1,     NMOUT = 3,
 9          NPRNT = 60,     KDUMP = 1,     IWRIT = 10,     KROW = 28,
10          KNTPAS = 99,
11 &END
12 &NAME02
13          TOFINF = 533., UINF = 110.,    UINFX = 112.2, PINF = 2272.,
14          TU = 3.917,     TD = .5,       DELP = 20.      VSTART = 8.,
15          REFL = 8.3333, KNULOC = 1.,
16 &END
17FEDIMN            T  DIMENSIONS ARRAYS
18LINK1     1    T   SETUP       NODE - ELEMENT GENERATION * OUTPUT TITLE.
19LINK2    14        T
20VX2SCL
21                    0. 30 .1 1.2     T
22NDECRD
23                     1  28,  1  1,  0    T  NODES 1 - 28   IN SOLUTION
24ELEM
25DONE               T  END OF LITERAL SEQUENCE
26COMTITLE           T  TITLE PRINTED BELOW COMOC SYMBOL
27BRADSHAW SOLUTION - IDENT 2400, (REF. 3)
28DONE               T  END OF LITERAL DATA
29COMOC              T  PRINTS COMOC SYMBOL.
30DESCRIPT  204      T  DESCRIPTIVE TITLE AT BEGINNING OF HEADER OUTPUT.
31
32BRADSHAW SOLUTION  MLT
33DONE               T  END OF LITERAL DATA
34DESCRIPT  332       T  IOPAR  PARAMETER TITLES FOR HEADER OUTPUT.
35 REFERENCE           ENGLISH-FT       ENGLISH-IN        M-K-S          C-G-S
36 LENGTH              ...FEET...       ....IN....        ....M.....     ....CM....
37 VELOCITY            ..FT/SEC..                         ...M/S....     ...CM/S...
38 DENSITY             .LBM/FT3..                         ..KG/M3...     ...G/CC...
39 TEMPERATURE         .RANKINE..                         ..KELVIN..
40 ENTHALPY            .BTU/LBM..                         ..KJ/KG...
41 FROZ. SPEC.HEAT     .BTU/LBM-R                         .KJ/KG-K..
42 VISCOSITY           .LBM/FT-S.                         .NT-S/M2..     ..POISE...
43 LOCAL PRESSURE      ...PSF....       ...PSI....        ..NT/M2...     ...TORR...
44 LOCAL SOLUTION      .MACH. NO.       ..DPDX1...        ..ENERGY..     .MIX. EFF.
45 X1/LREF             .DX1/LREF.       .EPSILON..        .DX1M/LREF REFL REYNOLDS NO
46DONE               T  END OF LITERAL DATA
47MPARA    -1        T  MULTIPLIERS APPLIED TO HEADER OUTPUT. (LOC. IN RARRAY)
48                    5*2, 2*2 162  164  163,  3*2  164  163,  3*2  170  174,
49                     3*2  165  2,  2  -175  3*2,  3*2  176  2,  3*2  177  178,
50                     2 2 169 168 167, 3*2 108 2,   5*2    T
51IONUMB   -1        T  LOCATION IN RARRAY OF SCALARS TO BE PRINTED IN HEADER
52                     999,  5*200,  999,  200  4*43,  200  27  200  2*27,  200
53                    10 200 2*10,   200  58  200  58  200,  200  97  200  97
54                    200, 200 30 200 30 200, 200 38 200 2*38,
55                    999,  39  4*36,  200 154  98 135 122,
56                          11  12  14  85  47    T
57DESCRIPT  203      T  IFMTHD TITLES FOR OUTPUT DEPENDENT VARIABLES.
58U1/UREF         U2/UREF          U1 PRIME          EFF. MU/MUREF
59DONE               T  END OF LITERAL SEQUENCE
60IOSAVE   -1        T  DEPENDENT VARIABLE AND PARAMETER ARRAYS TO BE PRINTED
61                        1248  2248  1249  1247  T
62IOMULT   -1        T  MULTIPLIERS APPLIED TO IOSAVE ARRAYS (LOC. IN ARRAY).
63                        6*2          T
64IPINT    -1        T  DEPENDENT VARIABLE NUMBERS
65                      1  2  T
66KBNO       1       T  U1 FIXED AT THESE NODES
67BOTTOM              DONE
68LINK3      4       T  NON - DIMENSIONALIZE DATA  (DIMEN)
69LINK1      3       T  FINITE ELEMENT MATRICIES  (GEOMFL)
70LINK2       4      T  CONTINUITY EQUATION SOLVER  (CONTES)
71VX3ST               0.08333333,       T  X1 COORDINATES FOR PRESSURE TABLE.
72                        47.0  53.0  59.0  65.0  200.0     T
73VPVSX              T  PRESSURE DATA FOR PRESS. TABLE  (CP)
74                      1.04  1.02  1.00  1.00  1.00   T
75LINK2       20     T  GENERATES U1 INITIAL PROFILE FOR BRADSHAW CASE
76LINK2      6       T  PRINTS GENERATED NODE MAP
77LINKCALL  -1       T  PLACES CALLS TO LINKI J AT END OF OKNUIN.
78                        2 4,  1 5,  2 3,  5 6,  2 15,  T
79OKNINT             T  INITIATES INTEGRATION RETURNS CONTROL TO BDINPT AT TF
80EXIT               T  END OF JOB
81CASE END
```

APPENDIX C

Boundary Layer and Wake Flow

Standard Check Case Data Deck

Joukowski, 12% Thick, 6° Angle of Attack

```
2DBL
FENAME              T  READS NAMELIST DATA
&NAME01
            NODE = 55,     KROW = 55,     LCOL = 2,      NIZS = 200,
            NEQ = 4,       NEQKNN = 4,    NE1E2  = 1,    NEQADD = -3,
            NDERIV = 2,    NM    = 2,     ITKE   = 0,    NTKS   = 10,
            NPVSX  = 70,   NBC     = 2,   NOUTPR=80.,    KDUMP  = 1,
            NMOUT  = 3,    KNTPAS=49,     IFSL = 0,      LG     = 2,
            NSCY = 1,      IPTSPL = 1,    IARRAY(206)=20,NC     = 10,
            KPNT = 1,      IWRIT = 1,     ITDA = 0,      ITDB = 0,
            NU2POS=20,     NU3POS=20,     NPRNT=60,
&END
&NAME02
            TOFINF = 533., PINF = 2116.8, UINF = 40.,    XMUINF=.1238E-4,
            REFL = 1.,     ADUCT = 1.,    RARRAY(391)=.88,RARRAY(392)=1.6667,
            PRTKE=1.,      PRDIS = 1.3,   C1TKE = 1.45,  C2TKE = .18,
            CKTKE = .09,   CD = .09,      YLTKE = .435,  ESCF = 1.,     CK=1.,
            C4EDSW = .999, E1E2SW=5.,     YPLUS = 8.,    VSTART = 10.,
            TO = .99,      TD = .01,      DELP = 20.,    HMAX = 10000.,
            HSINIT = 1.0E-07,
&END
FEDIMN              T  DIMENSIONS ARRAYS

LINK2   14          T  GENERATE GRID FOR VISCOUS SOLUTION - 2D  (DSCRTZ)
VX2SCL              T   INTERPRET SCALE FACTORS AND LIMITS.
                        .97,  15 1.0 0.840,  1 1.0 1.0, 20  1.06  1.13  T
NDECRD              T  SPECIFY NO. OF NODES TO BE GENERATED IN EACH DIR.
                       1   37,  1  1,  0  T
ELEM                T   CONSTRUCT F. E. CONNECTION TABLE.
DONE                T  END OF LITERAL SEQUENCE
CNTPTS    -1        T  NUMBER OF NODES IN EACH SUPER ELEMENT
                        21  16  T
CNTNOS    -1        T  RENUMBERS THE NODES TO INCREASE FROM BND. OUT.
                        21*I1  17,  16*I-1  16  T
COMTITLE            T  TITLE PRINTED BELOW COMOC SYMBOL
     AIRFOIL TRAILING EDGE AND WAKE SOLUTION
DONE                T  END OF LITERAL DATA
DESCRIPT  204       T  DESCRIPTIVE TITLE AT BEGINNING OF HEADER OUTPUT.

      JOUKOWSKI  T/C=.118,  6 DEG. ANGLE OF ATTACK,  BND.-WAKE SOLN.
DONE                T  END OF LITERAL DATA
DESCRIPT  332       T  IOPAR  PARAMETER TITLES FOR HEADER OUTPUT.
 REFERENCE             ENGLISH-FT        ENGLISH-IN       M-K-S          C-G-S
 LENGTH                ...FEET...        ....IN....       ....M.....     ....CM....
 VELOCITY              ..FT/SEC..                         ...M/S....     ...CM/S...
 DENSITY               .LBM/FT3..                         ..KG/M3...     ...G/CC...
 TEMPERATURE           .RANKINE..                         ..KELVIN..
 ENTHALPY              .BTU/LBM..                         ..KJ/KG...
 FROZ. SPEC.HEAT       .BTU/LBM-R                         .KJ/KG-K..
 VISCOSITY             .LBM/FT-S.                         .NT-S/M2..     ..POISE...
 LOCAL PRESSURE        ...PSF....        ...PSI....       ..NT/M2...     ...TORR...
 LOCAL SOLUTION        .MACH. NO.        ..DPDX1...       ..ENERGY..     .MIX. EFF.
 NWGEOM H'S            ...H21....        ...G22....       ...G23....     ....F1....
 X1/LREF               .DX1/LREF.        .EPSILON..       .DX1M/LREF REFL REYNOLDS NO
DONE                T  END OF LITERAL DATA
```

```
RESTART    9     1    T  RESTART AT TRAILING EDGE (PARABOLIC NAV. STOKES)
NAMELIST
 &NAME01
                NEQKNN = 4,     NEQADD = 0,     NDBL = 0,       NE1E2 = 0,
                KDUMP = 1,
 &END
 &NAME02
                HMIN = 0.,
 &END
IARRAY    145  0          T  RESET IMIN TO ZERO
RARRAY     13  0.1  -3    T  RESET PRINT INTERVAL (NON-D)
RARRAY     15   7   -1    T  RESET STEP SIZE           (NON-D)
RARRAY     22  1.001 -1 T  RESET FINAL STATION  (NON-D)
ELEMENTS  -1           T  RESET FINITE ELEMENT CONNECTION TABLE
                         1 2 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9 10 10 11 11 12 12
                         13 13 14 14 15 15 16 16 17 16 18 18 19 19 20 20
                         21 21 22 22 23 23 24 24 25 25 26 26 27 27
                         28 28  29 29 30 30 31 31 32 32 33 33 34 34
                         35 35 36 36 37    T REN. 17 18, 16 18
DESCRIPT   203         T  TITLES  FOR OUTPUT OF DEPENDENT AND PARAMETER VARIABLES.
U1 / UREF        U2 / UREF          TKE / TKEREF     DISS / DISSREF  MU / MUREF
U1 PRIME         U2 PRIME           TKE PRIME        DISS PRIME      DPDX
DONE                   T  END OF LITERAL DATA
IOSAVE     -1          T  DEPENDENT VARIABLE AND PARAMETER ARRAYS TO BE PRINTED
                         1248 2248 5248 6248 1247 1249 2249 5249 6249  305, T
IOMULT     -1          T  MULTIPLIERS APPLIED TO IOSAVE ARRAYS (LOC. IN ARRAY).
                         10*2  T
KBNO       1           T  U1 FIXED AT THESE NODES
DONE                   T  END OF LITERAL DATA
IBORD                  T  REORDERS BOUNDARY ELEMENT NODE PAIRS
RIGHT                  DONE
KBNO       2     1     T  DU/DX BOUNDARY CONDITION ON U2
TOP        0     0     0     0.   2    -4.321     2    T
BOTTOM     0     0     0     0.   2     4.321     2    T
DONE                   T  END OF LITERAL DATA
KBNO       5           T  TKE FIXED AT THESE NODES
DONE                   T  END OF LITERAL DATA
KBNO       6           T  DISSIPATION FIXED AT THESE NODES
DONE                   T  END OF LITERAL DATA
LINKCALL  -1           T  PLACES CALLS TO LINKI J AT END OF QKNUIN.
                          5 1,  1 4,  2 15,  5 6,  T
OPNS
QKNINT                 T  INITIATES INTEGRATION,RETURNS CONTROL TO BDINPT AT TF
RESTART    0     1     T  RESTART TO INCREASE STEP SIZE INCREMENT
NAMELIST
 &NAME01
                NDBL = 0,
 &END
 &NAME02
                HMIN  = 0.0,
 &END
IARRAY    145  0          T  RESET IMIN IN NOME01
RARRAY    115   7   -1    T  RESET HMIN NON-DIMENSIONALIZED BY FACT
RARRAY     20  23         T  RESET NEXT PRINT TIME
RARRAY      1   35   0.1  T  RESET PRINT INTERVAL (NON-D)
RARRAY     22  1.25  -1   T  RESET FINAL STATION -TF- (NON-D)
RARRAY     35  0.25  -3   T  RESET SOLUTION INTERVAL -TD- (NON-D)
SAVETAPE    9    4
QKNINT                 T  INITIATES INTEGRATION,RETURNS CONTROL TO BDINPT AT TF
EXIT                   T  END OF JOB
```