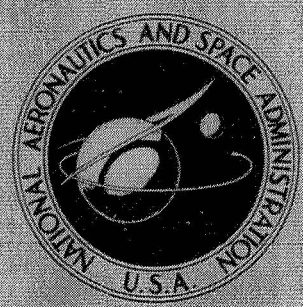N70-42196

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AN INVESTIGATION OF THE HIGH SPEED TURBULENT BOUNDARY LAYER WITH HEAT TRANSFER AND ARBITRARY PRESSURE GRADIENT

Part III - Computer Program Manual

by Jesse Schneider and John Boccio

CASE FILE COPY

Prepared by
GENERAL APPLIED SCIENCE LABORATORIES, INC.
Westbury, L. I., N. Y.
for Langley Research Center

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15. Supplementary Notes

A description of the problem formulation and development of the governing differential equations is presented in Part I of this report.

16. Abstract

This manual describes a new computer program capable of determining the properties of a compressible turbulent boundary layer with pressure gradient and heat transfer without imposing a Crocco integral to solve the energy equation. The program treats either the two-dimensional or axisymmetric problem with either a perfect gas or real gas equilibrium chemistry model for the thermodynamics. Coles' transformation is applied to the equations for the conservation of mass and momentum. In the transformed plane, these are linked with Baronti's incompressible solution and a solution is achieved by numerically solving the resulting system of six ordinary differential equations and one partial differential operation: The partial differential energy equation is written in von Mises coordinates and is essentially solved in the real plane using an implicit first order finite-difference technique.

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FOREWORD

The present report is one of a series of three reports which describe analyses and computational procedures developed for describing the behavior of high speed-turbulent boundary layers under conditions involving both heat transfer and arbitrary pressure gradient. Part I,serves as a summary report and describes the analysis which is utilized in the numerical calculation scheme. In Part II, the fundamental properties of of the compressibility transformation used in the analysis are examined in detail. Part III, describes the numerical and computational procedures involved and serves as a computer program manual.

The titles in the series are:

Part I   Summary Report - "An Investigation of the High Speed Turbulent Boundary Layer with Heat Transfer and Arbitrary Pressure Gradient," by C. Economos and J. Boccio.

Part II- "The Compressibility Transformation - General Considerations," by C. Economos.

Part III- "Computer Program Manual," by J. Schneider and J. Boccio.

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BOUNDARY LAYER WITH HEAT TRANSFER AND
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Part III - Computer Program Manual

by Jesse Schneider and John Boccio
General Applied Science Laboratories, Inc.

I. INTRODUCTION

This manual is the third part of a three-volume report
describing a new computer program capable of determining the
properties of a compressible turbulent boundary layer with
pressure gradient and heat transfer. The program treats either
the two-dimensional or axisymmetric problem with either a perfect
gas or real gas equilibrium chemistry model for the thermodynamics.
The description of the fluid dynamics is obtained by applying a
compressibility transformation to the equations for conservation
of mass and momentum, and coupling these to the low speed formula-
tion of Reference 1. The thermodynamic behavior is described by
simultaneous solution of the partial differential equation for
conservation of total enthalpy written in von Mises coordinates.
This solution is obtained by an implicit first order finite dif-
ference technique.

A detailed description of the problem formulation along
with the development of the working differential equations and
the necessary auxiliary conditions is presented in Part I of this
report (c.f., Ref. 2). This part is intended primarily to serve
as a program user's manual and contains:

a)   A description of the general program features and
     a flow diagram describing the overall logical flow
     of the program.

b)   A detailed description of program options and
     their use.

c) Detailed instructions for the preparation of
input data with samples for a few cases.

d) A description of built-in default options (i.e.,
the modes of operation or pre-set data items the
progam will use if it receives no other instructions
to the contrary).

e) A complete description of the program built-in
error messages and halts.

f) A description of the program output and some
sample cases.

g) A description and flow chart of each major
subroutine.

h) A description of program use, operation, accuracy,
and present limitations.

i) Table of program symbols.

II. GENERAL PROGRAM FEATURES

The program provides the user with the ability to generate the properties of a compressible turbulent boundary layer with or without pressure gradient using a perfect gas or real gas equilibrium thermodynamics. Either adiabatic or isothermal wall conditions may be prescribed on either a two-dimensional or axisymmetric body. The viscosity of the fluid is calculated from either a $\mu \sim T^n$ law, Sutherland's law or from fits which are functions of pressure and temperature. Both the laminar and turbulent Prandtl numbers may be input constants or generated from appropriate subroutines.

The user may specify the conditions external to the boundary layer in terms of pressure, velocity or Mach number as a function of axial distance along the body. The last of these (i.e., $M_e = f(x)$) is only available with the perfect-gas option.

Boundary-layer profiles will be calculated at user specified values of the axial distance, x, the Reynolds number based on momentum thickness, Re_θ, or the local Reynolds number based on distance along the body, Re_x. In addition, the user may present the program with input data in either English system engineering units or International (S.I.) units.

The general flow of program computation is to:

a) Evaluate all external conditions and their derivatives with the prescribed input information before any integration is performed.

b) Initially determine the solution to the energy equation, analytically, via a Crocco integral and then use this result to evaluate the initial derivatives.

c) Integrate the system of equations, solving the energy equation by finite differences.

d) Store the results of a complete integration step in an output array whose size is determined by the user. The output array is then separated into five units which are always printed as a group and consist of:

3

1) dependent variables in the transformed plane,
2) boundary layer properties in the transformed plane,
3) derivatives of the dependent variables, and
4) two sets of boundary layer properties in the corresponding physical plane.

After the output blocks are printed, the program then searches through the input values of x, R_θ, or Re_x at which profiles are desired, to see if any are within the present bounds of the output array. If some values are within the present output-array range, additional computation is performed; profiles are generated; and the results are printed.

If no profile values fall within the present output-array range, or if no profiles are desired, the program continues with the integration and begins to generate a new output array.

III. PROGRAM OPTIONS AND THEIR SELECTION.

CARD 1 - Control Card

All program users' options are selected with one control card which appears as the first member of the input data pack. In addition, this control card may be used to output the details of the computation of selected portions of the program during selected steps in the computation. All selections on the control card are made in integer format as follows:

Columns

1 - 3   NOXPTS   The number of axial points along which the external pressure, velocity or Mach number will be specified. This number must be right adjusted in the first three columns on the card. At present, program dimensions are set up to handle up to and including 50 points.

4 - 6   NPRFPT   The number of points at which profiles are desired. This number must be right adjusted in columns 4-6. At present, provision has been made for requesting profiles at up to and including 20 values of x, Re_θ or Re_x.

7 - 9   NINTPT   The number of integrations steps between adjacent lines of printout. Since the integration package is a variable step-size routine, this parameter provides the user with some control over the amount of computed information which is actually printed. As above, this number must be right adjusted in columns 7-9 and may be as large as 999.

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<u>Columns</u>

10-12	KTEST	The number which determines the size of the output print blocks and must be right adjusted in columns 10-12. At present, program dimensions provide for output blocks of up to and including 50 lines. Experience with the program has indicated that a value of KTEST $\leq$ 50 is a good choice.
13-14	UNITS SELECTION	Provision has been made in the program for specifying either input, output, or both in either English system engineering units (i.e., the pound-force, slug-mass system) or the International System(S.I.)which is basically the MKS system. Column 13 controls the units of the information to be input. If column 13 is other than zero, the program expects the input information to be in S.I. units. Column 14 controls the units of the information to be output. As above, if column 14 is other than zero, the program assumes the user desires the output information in S.I. units. If columns 13 and 14 are left blank, the default options (i.e., English system units are expected for input and will be used for output) are used.

Two additional items must be mentioned: (1) the units of input quantities may <u>not</u> be mixed between the systems, and (2) all internal calculations of dimensional quantities are performed using English system engineering units and the details of the computation of some selected portion of the program will be output in this system.

15	GEOMETRY	This switch is used to select either the two-dimensional or axisymmetric options of the program. A zero or blank (the default option) selects the two-dimensional case. If an axisymmetric problem is to be done, the user has two additional sub-options regarding the form in which the input data for the geometry may be supplied. If the user chooses to supply the body geometry as a table of r vs x, he merely puts a 9 in column 15. If the user finds it preferable to specify the geometry using curve fits, the number of regions into which the body has been divided is input in column 15. (A maximum of 8 regions are permitted.) For the case below, a 4 would be inserted in column 15, in which case the program expects to have available four sets of at most fourth order polynomials to describe the body geometry.
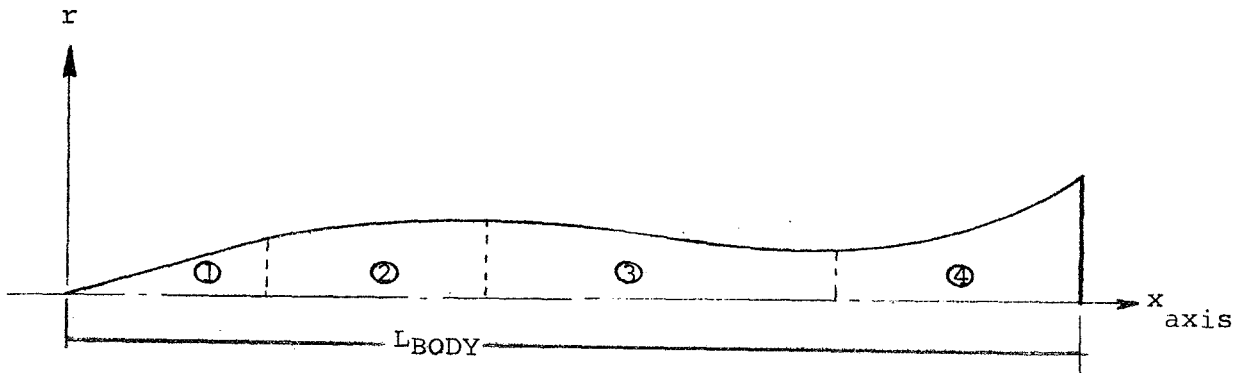
16	PROFILES	Column 16 is used to specify the parameter which is to serve as the independent variable at which profiles are desired.

If the integer in column 16 is:	Profiles will be calculated at user specified values of:
0	x
1	R_θ
2	Re_x

(A blank in column 16 is assumed to be zero.) If no profiles are desired (i.e., columns 4-6 are zero) column 16 is ignored.

17	PRINT CONTROL	Future plans call for providing an additional mode for generating the contents of the output array based on selected increments in the independent variable. At present, output array contents are governed by NINTPT (Columns 7-9) which is the print control default option and should always be used. Column 17 should therefore always be left blank in the present version of the program
18	SPECIAL S.I. INPUT	This switch is used only for the special cases in which S.I. units are being input (i.e., Column 13 $\neq$ 0), the Sutherland-viscosity option has been selected (i.e., column 24 = 0) and the user desires to change the constant K'*.(see formulation, Part I, Section F.1). This special switch is required since a default value of K' (which is dimensional with the units of a temperature) is stored in the block data routine of the program. For all

---

*in the Sutherland law relationship $\tilde{\mu} = \dfrac{1 + K\tilde{H}_e}{(1/\tilde{\rho}) + K\tilde{H}_e} (\tilde{\rho})^{-3/2}$ where $K = K'\, C_p/H_e$.

18 (contd)		other situations but the one mentioned above, column 18 may be left blank.
19	PRESSURE OPTION	With this switch the user may bypass a portion of the program logic to do a case which does not involve pressure gradient and in so doing make some small saving in computer time. If the user inserts a number other than zero in column 19, the program assumes no axial pressure gradient exits. (Note: the default option, column 19 left blank, assumes an axial pressure gradient exists and may be used in all cases.)
20	EXTERNAL CONDITIONS	Column 20 is used to select the form in which external conditions are supplied to the program.

If the integer in column 20 is:	The input option selected is:
0	Pressure as a function of x
1	Velocity as a function of x
2	Mach number as a function of x

Note that the default option assumes the user will normally input pressure information. It should also be remembered that Mach number input may be used only with the perfect gas option.

21	THERMODYNAMIC AND TRANSPORT PROPERTY CHANGES

This switch provides the user with the capability to change any of the thermodynamic and/or transport properties which

21(Contd)		have been built into the program. Changes in thermodynamic properties could include the molecular weight and ratio of specific heats of the gas, its laminar and/or turbulent Prandtl numbers, if they are constants, K'(the constant in Sutherland's Law), and the mole fractions of the species present if the chemistry option is being used. Transport properties which could be changed include the reference values of temperature and viscosity in both Sutherland's Law and $\mu \sim T^n$ and the exponent of the temperature in the latter. If any such changes are desired the user inserts a number other than zero in column 21. The default option (column 21 left blank) assumes no changes are desired.
22	CHEMISTRY MODEL	Two chemistry options are available to the user. If a zero is inserted in column 22 or it is left blank, it is assumed the user desires to do a perfect gas calculation. If no fluid properties are changed the gas is further assumed to be air. Any other perfect gas may be accommodated by using a number other than zero in column 21 and prescribing new values for the molecular weight and ratio of specific heats of the gas and different transport properties. The input of this information is described in detail in Section IV of this volume. A number other than zero in column 22 selects the equilibrium chemistry option. At present, the chemistry package has been set up to do calculations for 8 species air. The mole fractions at some reference condition which are required by the chemistry package, are built into the program as pre-set data. These may be

22(contd)		changed by the user in the same manner as any other chemistry or transport property changes are made. For further information regarding this chemistry package the user is referred to Section VIII of this volume which briefly describes the pertinent routines.
23	SPECIAL HALT	Before making a lengthy computation the user might like to examine the results of the first few integration steps. By selecting a small number, n, (i.e., 2 or 3) for KTEST in column 12, inserting a 1 in column 9 for NINTPT, the number of integration steps between adjacent lines of printout, and inserting a number other than zero in column 23 the program will halt after printing an output array of n lines corresponding to n integration steps. In all other cases column 23 should be left blank.
24	VISCOSITY OPTIONS	Three viscosity options are available to the user.

If the integer in Column 24 is: The option selected is:

     0   Sutherland's Law

This option is available with either the perfect gas or equilibrium chemistry option.

     1   μ from fits as functions of pressure & temperature

available only with equilibrium chemistry option.

     2       $\mu \sim T^n$

available only with perfect gas option.

24(contd)		The reference conditions used in both the $\mu \sim T^n$ and the Sutherland Law options and the temperature exponent of the former are for air and are stored as pre-set information in the block data section of the program. They may be changed as described above by inserting a number other than zero in column 21 and prescribing the desired new values in the input data section.
· 25	WALL CONDITIONS	The program has been set up to handle either an adiabatic or isothermal wall condition. For the former, a zero is inserted in column 25 or it is left blank. Any number other than zero in column 25 selects the isothermal option. In either case, a wall temperature must be input in the input data section, with it being considered as the initial value for the adiabatic option.
26	PRANDTL NUMBER OPTIONS	This switch provides the user with the choice of having the laminar and turbulent Prandtl numbers generated by a sub-routine (c.f. Sect. VIII) or using constants for both. A zero or blank in column 26 selects the latter. Note that if constants are to be used they may be either the pre-set values stored in the block-data routine or new ones which the user prescribes in the input-data section after inserting a number other than zero in column 21.
27	SPECIAL S.I. INPUT	This switch is similar to the one used in column 18 and is for the special cases in which S.I. units are being input (i.e., column 13 $\neq$ 0) and either the Sutherland Law or $\mu \sim T^n$ viscosity options have been selected (column 24 = 0

27(contd)   or 2) and the user desires to change
            the reference temperature, reference
            viscosity or both. As in the previous
            case, this special switch is required
            since these quantities are dimensional
            and default values of them are stored
            in the block data routine of the pro-
            gram. For all other situations but the
            ones mentioned above, column 27 may be
            left blank.

28   DATA DUMP FOR CHEMISTRY PACKAGE

            When a number other than zero is inserted
            in column 28 the program will print the
            value of selected members of the data
            arrays used in the chemistry package.
            This switch is used only as a check to
            insure that curve fit data has been
            stored properly in the chemistry routines.
            Under normal program operation column 28
            should be left blank.

29   SPECIAL HALT FOR EDGE CONDITIONS

            Before performing any integration the user
            may desire to examine the input and
            default data the program will actually
            use in the calculations as well as the
            wall conditions, edge conditions and
            particularly, the derivatives of the
            latter. This may be accomplished by
            merely inserting a number other than
            zero in column 29. The program will
            then print the above information and halt.
            During normal program operation, column
            29 may be left blank.

30   ITEXT (Integration Package Test)

            When a number other than zero is inserted
            in column 30, the integration package

Column

30(contd)   will print out a time history of the
                   computing interval and the reasons for
                   its variation. For normal program
                   operating, column 30 should be left
                   blank.

31 - 38   ORDER   These switches may be used to change
          CHANGES the order of the interpolation which is
                   used in various parts of the program or
                   change the number of points being used to
                   calculate derivatives in certain routines.
                   (Note a Lagrangian interpolation and de-
                   rivative scheme is presently being used.)
                   If these columns are left blank, the de-
                   fault values of these order parameter,
                   which are stored in the block data routine,
                   are used. A number, n, other than zero
                   inserted in any of the above columns will
                   change the order to n. The user is
                   advised to use the default values unless
                   there is a strong reason for changing them.
                   The table below indicates the control:

Column	Order Parameter	Service Routine which uses it	Subroutine which calls for the Service Routine
31	LORDR1	LGRANG	PRFILE
32	LORDR2	LGRANG	XTERNL
33	MORDR1	LAGR	DEFINT
34	MORDR2	LAGR	FUNCT
35	MORDR3	LAGR	FUNCT
36	MORDR4	LAGR	AXISYM
37	NORDR1	LAGDER	INITL1
38	NORDR2	LAGDER	AXISYM

<u>Column</u>

39 - 59   DUMP   The 21 switches represented by columns
           SWITCHES   39-59 may be used to examine the details
of the computation being made by a
particular subroutine of the program.
Each switch controls one subroutine
and all switches are independent of one
another. If a number other than a zero
or a blank is inserted in any member of
this group, the important parameters
and some of the quantities used to
compute them will be printed each time
the routine associated with them is
called. For some routines with many
branches, a sequence of tracing numbers
is also printed. These switches were
originally intended to aid in debugging
portions of the program and have been left
intact from that time. The user is warned
that the use of these switches can generate
a large quantity of output. Control is
as indicated below:

Column	Subroutine Dumped	Column	Subroutine Dumped
39	HSITER	51	COEFF
40	THERMO	52	FPRIM
41	AXISYM	53	GETFS
42	PRFILE	54	MATRX
43	STDM	55	GETPHI
44	DERSUB	56	INIT2
45	MAIN	57	DEFINT
46	BLPROP	58	INIT3
47	XTERNL	59	NERIT
48	CONV		
49	PROFIL		
50	FUNCT		

| 60 | PI CORRE-LATION | This switch is available if the user wishes to correct the outer region of the velocity profile by means of the correlation law discussed in Parts I and II and written here as $(PI)_{corr} = PI + 0.53 \ln P$ where $P = P(\tilde{H}_e, G_w)$ In this connection two points are noteworthy. If the initial value of the parameter PI, namely PIO, is generated from an experimental velocity profile and the PI CORRELATION is desired, then the proper input value of PI will be that which has been generated from the profile with the correlation term subtracted from it, i.e.,

$$(PI)_{input} = (PI)_{profile} - 0.53 \ln P$$

where

$$P = P(HTILDA, \ GWALL) = P(\tilde{H}, G_w)$$

This procedure is required so that when the correlation is applied initially the working value of PI will be that generated from the profile, i.e, $(PI)_{profile}$

The second noteworthy point is that if the input value of PI has been obtained from other than a profile, e.g., from some equilibrium incompressible turbulent boundary layer analysis then the input value will be corrected forthwith. A more detailed description of this correlation and its intended ramifications are presented in Section III.C.1 and 2 of Part I.

Finally, the normal default option (zero or blank) is understood to mean that this correlation is not to be applied. |

Column		
61 - 64	DUMP	
65 - 68	SWITCH	
69 - 72	VALUES	

These columns may be used to turn on or off the tracing sequence selected in columns 39-59 by specifying the integration steps (as integers) at which the user would like the changes to occur. Three such changes are permitted and the integration step at which each is to occur should be right adjusted in columns 61-64 for the first, 65-68 for the second, and 69-72 for the third. The on-off mechanism is keyed to the switch for MAIN (column 45). The following example will illustrate the use of the above. The user desires to trace the routine called "DEFINT" for the first three integration steps, then trace the program between the 52 and 153 integration steps, and then continue the calculation in the normal mode. The switch settings would be:

Column	Integer
45	1
57	1
64	3
67	5
68	2
70	1
71	5
72	3

This would result in MAIN and DEFINT being traced for the first three integration steps. The tracing sequence would be shut off after the third integration step and would be turned on again for all routines at integration step number 52. The tracing would continue through step 153 at which time it would be turned off and the computation would proceed normally.

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<u>Column</u>

61-64

65-68 (contd)   Note that for normal program operation,

69-72   columns 61-72 may be left blank.

To illustrate the preparation of the control card a
sample is presented below.

`12 2 1 251 51   21 211

```
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 2 3 4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 6
```

For this case, the user will prescribe 12 points along an
axisymmetric body where the external Mach number distribution
will be prescribed. The user has broken the body down into 5
regions and is specifying the geometry in terms of 4th order
polynomials. Recall, that at present the program can only handle
polynomial representation for the body geometry with a fourth
order fit as the highest order possible. The calculation will
assume a perfect-gas-thermodynamic-model and will be done
with pressure gradient for an isothermal wall. The user has
also selected the $\mu \sim T^n$ viscosity option and intends to change
some values of thermodynamic or transport property data.

The output information will be in blocks of 25 lines, each
line representing 1 integration step. Profiles will be generated
at two values of Re_θ to be specified by the user and the output
will be in English system engineering units (the input is in S.I.
units).

A table of the control card parameters is provided at the
end of this report for quick reference in preparing program
input.

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IV. PREPARATION OF PROGRAM INPUT DATA
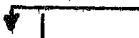
As previously mentioned, the first card of any set of input data must be a control card and its preparation is described in Section III. This section will discuss the remaining input data and its preparation.

Information input to this program is facilitated by combining the use of two standard FORTRAN features; a) block-data storage of a large number of data items which are not changed often or which are standard for a particular input option and b) namelist which provides greater flexibility by (1) permitting only the information actually required to run a given problem to be input in any order, and in any format, (2) by providing for the input of array information in a simple, compact form, and (3) by providing a permanent, easily identifiable record of the input information.

Four separate categories of namelist information can be supplied to the program as input; two of which are always required. They are discussed below in the order in which they appear in the input-data pack.

(A) OVRIDE - This namelist array is always required and is used for input of all free-stream or reference conditions, initial values of the dependent and independent variables, wall temperature, program constants, mesh sizes, reference lengths, initial and maximum permitted integration step sizes, truncation error tolerances and points at which profiles are desired.

Consequently, the second card of the input data pack must always begin with the following format:

$ OVRIDE| ⍦ |————at least one space

Column   2 3   8 9

Any or all of the above mentioned items may then be loaded beyond Column 9, free field, in any order, in any format, and in as many cards as are required to complete the input data requirements for the particular case of interest. The data is input by punching its program variable name, an equal sign, and the value of that variable, in any format. Each data item

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must be separated by a comma and no attention need be paid to spacing between data items, between the variable name and equal sign or between the equal sign and the actual value of the parameter.

A few additional simple rules must be observed:

1) all data continuation cards must start in column 3 or beyond,

2) no unnecessary blanks are permitted in the middle of an input number,

3) the last item on each card, except for the last item on the last card, must be a comma,

4) input must be terminated by a $ somewhere after the last data item.

A sample of a typical program input is shown below:

CARD 2
$OVRIDE , UEO = 2390., PEO = 15.0, HTOTE = 3.675E6,

CARD 3
TW=550.,BETA=.080,DPSI=5.,ALPHA=1.3,CHIMAX=0.1E9,DCHIBR=5000.,CHIO=0.,

CARD 4
PHIO =-.202335,PHIBRO=18.4,ETLDAO=1.0, UEBARO= 1.0,

FORTRAN STATEMENT

CARD 5
CHIBAR=0., XO=0.$

FORTRAN STATEMENT

Note that cards 3 and 4 could have been switched with no change in the input data received by the program.

The following list of variables may be input to the program via OVRIDE. Only the first 6 must always be specified. Default values for the remaining are stored in block data and may be changed, if desired, by merely including the desired values anywhere on the OVRIDE input cards before the last $ (Note: no numeric zeros are ever used in any variable name in this program.) For a complete description of all program symbols the user is referred to the table of symbols in Section X.

These are required input in OVRIDE

UEO	— the free stream or reference velocity – ft/sec or meters/sec
PEO	— the free-stream or reference static pressure – lbf/in^2 or $Newtons/m^2$
HTOTE	— the free-stream or reference total enthalpy – ft^2/sec^2 or Joules/kg
PIO	— initial value of the Coles wake parameter – dimensionless
PHIBRO	— initial value of the skin-friction parameter – dimensionless
TW	— the wall temperature – $^{\circ}R$ or $^{\circ}K$

Input of these is at the choice of the user

CHIBAR
ETLDAO
UEBARO
CHIO

— initial value of the independent variable and other dependent variables, are preset in block data. For definitions, see table of symbols

ACONST
B
BETA
ETASTR
YBPLUS

Program constants preset in block data. For a complete description, see table of symbols

	DPSI	Mesh variables preset in block data.
	ALPHA	For a complete description see table of symbols.

Input of these is at the choice of the user

PHIMAX	
CHIMAX	Integration package parameters (i.e.,
DCHIBR	step sizes, cutoff points, truncation
DCIMAX	error tolerance) preset in block data.
ELE1	See table of symbols for their
ELE2	description

LREF	Reference lengths preset in block data.
XO	See table of symbols.

XPROFL	Points at which profiles are desired. These are preset to zero in subroutine MAIN.

(B)   PRESSR/SPEED/MACH — One of these name list names is always required and follows immediately after OVRIDE. The one to be used depends upon the selection made in column 20 on the control card. In any case, 50 values of x and either PE, UE, or EME, the external pressure, velocity or Mach number, respectively, may be input. A sample of the input is presented below:

$PRESSR X(1)=0.,1.0,1.5,2.0,3.0,4., PE(1) = 14.7, 2*15.4,

```
8 8 8 8 0 ] J 8 0 _ 0 0 0 _ 0 _ 0 0 _ 0 0 0 _ 0 0 _ 8 0 _ 0 0 _ 0 0 0 0 _ 0 0 0 0 0 0 0 0. 0 0 0 0 0 0 0 _ 0 0 0 0 0 0
1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67
```

15.8,16.5,   17.2 $

```
8 8 8 8 0 8 8 8 8 0 0 0 8 0 0 0 0 8 0 0 0 0 0 0 0 8 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0.
1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67
```

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In this case, the control card would show

Column 20 ---- 0 (or blank)

3 ---- 6 (for 6 input points)

The program would then expect to be given 6 sets of external conditions in terms of the pressure, as above. The one-dimensional arrays of information which represent the coordinate x, and the pressure, PE, are loaded sequentially by merely identifying the array position of the first member in the group. Any repetitive information may be handled using a repetition factor (an integer and a multiplication sign) as it would be in a data statement or in standard FORTRAN arithmetic. Note that the PE array could have appeared before the x array.

For the case above, the x coordinates at which pressure information is specified are 0., 1.0, 1.5, 2.0, 3.0, and 4.0. The corresponding values of pressure would be 14.7, 15.4, 15.4, 15.8, 16.5 and 17.2.

If external velocity or Mach number had been the input choice, column 20 would have been set to 1 or 2, respectively; the name list name used would have been SPEED or MACH, respectively, (e.g., $ SPEED $x(1) = 0.$, 1.0, etc.) and in place of 6 values of the pressure there would have appeared 6 values of the velocity, $UE(1) = n_1, \ldots n_6$ $ or 6 values of the Mach number, $EME(1) = m_1, \ldots m_6$ $.

The only variables which can be input with PRESSR, SPEED or MACH are:

X   - the running coordinate along the body for the 2-D case or the non-dimensionalized axial coordinate for the axi-symmetric case   ft or meters and one of the following:

PE   - the external pressure distribution - lbs/in^2 or
                                            $Newton/m^2$
UE   - the external velocity distribution - ft/sec or
                                            meters/sec.
EME - the external Mach number distribution - dimensionless.

The remaining two namelist arrays are FLUID and RBODY and are required, respectively, only when the user desires to change the thermodynamic and/or transport properties of the fluid or use the axisymmetric option.

If FLUID is used (i.e., column 21 is set to a number other than zero) the input data associated with it is read immediately after the PRESSR, SPEED or MACH input data is read. There are 9 variables which have default values stored in the block data routine and only those that are to be changed need be input in this section. A sample of this input is presented below:

$FLUID   PRNLAM=1.0; PRNTUR=1.0;   VEX=1.0;   XMOLE(3)= 16.001,14.08 $

```
0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 7.
```

In this case, the user elected to change the values of the laminar and turbulent Prandtl numbers from their default values to 1.0. It is assumed that the user also has set column 26 on the control card to a number other than zero (i.e., has chosen to use an input or block data value of these parameters rather than have them generated by a subroutine as a function of temperature). In addition, the user also wished to change the exponent in the viscosity law from the default value preset in the block data routine to the value 1.0. (It is assumed that column 24 on the control card has been set to 2 to select the $\mu \sim T^n$ viscosity option). Finally, the values of the third and fourth numbers in the mole fraction array have been changed from their preset values to 16.001 and 14.08, respectively.

The parameters which may be changed under the control of FLUID are:

GAMA   - the ratio of specific heats - dimensionless

WGT   - the molecular weight of the fluid in lbm/lb-mole
            or kg/kg-mole

PRNLAM   - the laminar Prandtl number   ⎫
                                           ⎬ dimensionless
PRNTUR   - the turbulent Prandtl number ⎭

CAYPRM   - the Sutherland Law constant - $^\circ$R or $^\circ$K
            (Note: see column 18 instructions for input
            in S.I. units)

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XMOLE — the species mole fractions for 8-species air at some prescribed reference conditions- dimensionless

VEX — the temperature exponent in the $\mu \sim T^n$ viscosity law — dimensionless

TEMPR — the reference temperature for both the Sutherland or $\mu \sim T^n$ viscosity laws — $^\circ R$ or $^\circ K$

VISTR — the reference viscosity (μ at T = TEMPR) used in both Sutherland Law and $\mu \sim T^n$ — $lbf\text{-}sec/ft^2$ or $Newton\text{-}sec/meter^2$

(Note: see column 27 instructions for input of these last two parameters in S.I. units)

If RBODY is used, (i.e., column 15 is set to a number other than zero) the user has requested the axisymmetric option. As mentioned earlier in Section I, the axisymmetric geometry may be input in either of two modes, determined by the number, n, (n > 0) which has been inserted in column 15.

(a) if 1 ≤ n ≤ 8 — the program expects to find n sets of numbers, one set for each of n regions of the body, where n is determined by the user. Each set of numbers consists of 5 polynomial coefficients and a terminating value (i.e., the last value of X for which the particular curve fit is applicable). The fits in each region must be of the form

$$r^* = a_1 + a_2 x^* + a_3 x^{*2} + a_4 x^{*3} + a_5 x^{*4}$$

(Note that r* and x* are non-dimensional quantities and are the body radius and distance measured along the axis, respectively, both normalized with respect to the body length.)

These are loaded into the 6 x 8 array, AAXI. one region at a time, with the polynomial coefficients in ascending order followed by the terminating value. A sample of this input format is shown below:

$RBODY AAKI(1,1)=0.,0.36937,0.,0.,0.,0,14158,-0.00461,0.33498,1.22668,

WORD 1	WORD 2	WORD 3	WORD 4	WORD 5	WORD 6	WORD 7	W

```
0 0 0 0 0 0   0 0 0   0  0   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73
```

-6.49221,6.34730,0.45752$

WORD 1	WORD 2	WORD 3	WORD 4	WORD 5	WORD 6	WORD 7

```
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
```

For this case, the user divided the body up into two regions (n in column 15 is 2). The curve fit valid in the first region is

$$r* = 0.36937x*$$

and is applicable up to and including $x* = \dfrac{x_{axis}}{L_{BODY}} = .14158$

The curve fit valid in the second region is

$$r* = -.00461 + .33498x* + 1.22668x*^2 - 6.49221x*^3$$

$$+ 6.3473x*^4$$

and is applicable up to and including

$$x* = x_{axis}/LBODY = .45752$$

(b) if n = 9 — the program expects to find the body geometry prescribed as a table of r* vs x*. For this case, x* should have already been input with either the external pressure, velocity or Mach number in PRESSR, SPEED, or MACH, respectively. Noteworthy here is that for the 2-D option the dimensioned array name, x, is understood to be the dimensional running length along the body whereas for the axisymmetric option it is understood to mean the axial distance which has been non-dimensionalized with respect to LBODY.

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The corresponding r* information (a maximum of 50 values
permitted) is now loaded under control of the namelist
RBODY, as illustrated below:

$RBODY RSTAR(1) = 0., .2,.35,.38,.42,.55 $

```
0 0 0 0 0 1 0 0 0   0 0  8 0 0 0 0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67
```

In this case, the control card would indicate

Column 3 --- 6   (for 6 input points)
       15 --- 9

and 6 values of the body radius, normalized with respect to the
body length, LBODY, would be loaded into the program. These
6 values of r* would correspond to the 6 values of x* previously
loaded with the pressure, velocity or Mach number.

The last items of the input data pack are three cards which
may be used for case identification. Up to 72 hollerith characters
may be punched on each card and their contents are printed on
the first page of the output. If less than three cards are
required for identification purposes, blank cards must be
inserted to make up the difference.

V. BUILT-IN DEFAULT DATA

This section contains a description of the pre-set information in the block-data routine and presents the stored values and their associated units. The first group of these are dimensionless program constants which are typically used in turbulent flows:

ACONST   = 2.43 - a universal constant w.r.t. incompressible turbulent flows

B   = 7.5 - a universal constant w.r.t. incompressible turbulent flows

BETA   = 0.016 - a parameter used in the description of the incompressible eddy viscosity (c.f., Part II Equations (42a) the subsequent discussion in Section III.C.1 with regard to its implementation for wake correlation results.)

ETASTR   = 0.5 - a percentage value of the incompressible boundary layer height where the Clauser eddy-viscosity model is assumed to apply.

YBPLUS   = 10.6 - the value of incompressible Reynolds number based on shear velocity and sublayer weight (i.e., $\overline{\rho}\overline{u}_\tau\overline{y}_s/\overline{\mu}$)

The next group are commonly-used values of some thermo-dynamic and transport properties. These include

VEX   = 0.76 - the exponent of the temperature in the viscosity law of the form $\mu/\mu_R = (T/T_R)^n$

PRNLAM   = 0.72 - the laminar Prandtl number $\Big\}$ taken to
PRNTUR   = 0.72 - the turbulent Prandtl number   be constants

CAYPRM   = 198.6°R - the constant in Sutherland's Law formulation for the viscosity

GAMA   = 1.40 - the ratio of specific heats for "perfect" air

XMOLE = the one-dimensional array of 8 values for the species mole fractions of air at a specific reference condition (taken to be ρ = .0807 lbm/ft^3 and 1330°K, (c.f., Reference 3)

$$XMOLE \quad (1) \equiv x_{O_2} = .209727$$
$$(2) \equiv x_{N_2} = .778987$$
$$(3) \equiv x_{e^-} = .25 \times 10^{-6}$$
$$(4) \equiv x_{AR} = .009288$$
$$(5) \equiv x_{N} = .25 \times 10^{-6}$$
$$(6) \equiv x_{NO} = .00197$$
$$(7) \equiv x_{NO^+} = .25 \times 10^{-6}$$
$$(8) \equiv x_{O} = .25 \times 10^{-6}$$

TEMPR = 500°R – the reference temperature used in the $\mu \sim T^n$ and in the Sutherland Law formulation

VISTR = 3.58475 × 10^{-7} $\dfrac{lbf\text{-}sec}{ft^2}$ – the reference viscosity associated with the above reference temperature, TEMPR

Another portion of the block-data routine contains pre-set values for the order of the interpolations which are done in various portions of the program and the number of points used to numerically calculate the derivatives in certain routines. These data are:

LORDR1
LORDR2 } = 2 – used in call to LGRANG by subroutines PRFILE and XTERNL, respectively. (Note: LGRANG requires the number of points used in the interpolation (i.e., the order +1). If the order is to be changed, columns 31 and/or 32 on the control card should contain the order not the number of points.)

MORDR1
MORDR2
MORDR3
MORDR4 } = 1 – used in the call to another version of the interpolation routine called LAGR. This service routine is called by DEFINT, twice by FUNCT and by AXISYM, respectively.

NORDR1 ⎱
NORDR2 ⎰ = 1 – used in the call to LAGDER which calculates
numerically, the derivatives of certain
quantities in subroutines INITL1 and AXISYM,
respectively.

The next section of pre-set data values contains usual values of certain of the dependent variables and pre-sets to zero the initial value of the independent variable and the reference lengths.

ETLDAO   = 1.– initial value of a modified Coles
scaling parameter

UEBARO   = 1.– initial value of the edge velocity
ratio in the transformed plane.

CHIO   = 0.– the initial value of the streamwise
Reynolds number – $\rho_{e_0} U_{e_0} (x-x_0)/\mu_{e_0}$

CHIBAR   = 0.– the independent variable which is the
Reynolds number in the transformed plane,
i.e., $\overline{\rho u}_{e_0} (x-x_0)/\overline{\mu}$

XO   ⎱
LREF ⎰ = 0.ft.   reference lengths for the axi-
symmetric option LREF is equi-
valenced to LBODY

Pre-set values are also included for the mesh parameters

DPSI   = 5.0   variable grid-system parameters
ALPHA = 1.3   (c.f., Part I, Figure 4)

The last set of pre-set data in the block-data routine contains the default values of parameters associated with the integration.

PHIMAX   =100. – the maximum permitted value of the
skin friction parameter (PHI is one of the
dependent variables). Should this value be
exceeded, the program prints an error
message, the output array is dumped, and
any profiles requested are printed. The
program then proceeds with the next case.

CHIMAX   = 0.1×10^9 - the maximum permitted value of the
             streamwise Reynolds number, a dependent
             variable. Should this value be reached in the
             course of the computation, the output array
             is printed, any profiles requested up to that
             point are printed and the program returns to
             the input section to get the next case. This
             mode of case termination is the standard one.

DCHIBR   = 5000. - the initial integration step size for
             the independent variable, CHIBAR

DCIMAX   = 1.0×10^6 - the absolute value of the maximum
             step size that the integrator is permitted
             to use

ELE1   - the one-dimensional array of 7 values, one
             corresponding to each of the 7 dependent
             variables, which is the upper bound of the
             local relative truncation error for the
             respective dependent variables. If the error
             for any variable exceeds its respective ELE1
             value, the computing integral is halved and
             the integration restarted at the beginning
             of the present interval. If the error for
             all the variables is less than 1/128 of
             their respective ELE1 values, the computing
             interval is doubled for the next integration
             step. The pre-set values of the ELE1 array
             are shown below.

ELE2   - the one-dimensional array of 7 values which
             represent a "relative zero" for the
             respective dependent variable. If the
             absolute value of any of the dependent
             variables is less than its respective ELE2
             value, the relative error criterion for the
             variable will not be applied. The pre-set
             values for the ELE2 array are also shown
             below.

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INDEPENDENT VARIABLES	ELE1 MEMBER	VALUE	ELE2 MEMBER	VALUE
PHI (φ)	(1)	.0001	(1)	1.0×10^{-9}
RBAR $(\widetilde{R})$	(2)	.0001	(2)	1.0×10^{-9}
PI (π)	(3)	.0001	(3)	1.0×10^{-9}
UEBAR $(\overline{U}e)$	(4)	.0001	(4)	1.0×10^{-9}
CHI (χ)	(5)	.01	(5)	1.0×10^{2}
ETILDA $(\widetilde{\eta})$	(6)	.0001	(6)	1.0×10^{-9}
STILDA $(\widetilde{\sigma})$	(7)	.0001	(7)	1.0×10^{-9}

A summary of the pre-set data and default values are presented in a separate table for quick reference at the end of this report.

VI. BUILT-IN ERROR MESSAGES

This program has been constructed with a subroutine called "ERROR" which prints informative messages should trouble develop in the normal course of a computation. This subroutine may be called by any program routine and has a separate set of program termination logic.

Not all error messages are fatal (i.e., terminate the calculation). Some are merely informative and might possibly warn the user that some parameter has exceeded its table range or fallen outside the limits of applicability of some curve fit. In these cases, the informative message is printed and control is returned to the routine which called ERROR.

In most cases, however, the error message indicates that the program has had some serious trouble with a particular portion of the calculation. In these cases, the program is terminated by the error routine after the error message has been printed. The termination procedure is to:

(1) call the output routine which prints the present contents of the output array. This array will contain the results of all the calculations for all the integration steps since the last printed block.

(2) call the profile-generating-routine. The first of these, PRFILE, checks to see if any of the points at which profiles have been requested lie within the present output array range (i.e., are there any remaining profile values which fall within the present output array range for x, Re_θ, or Re_x). If there are, profiles for these remaining points are generated along with profiles at the very last complete integration step and all are printed. The program then returns to MAIN where internal switches are reset and new input data is sought.

The following text describes these error messages, indicates what routines call them and discusses the information they contain:

Error Number	Description

3   Error detected in subroutine 'STICKY' - the temperature at which the species enthalpy and species entropy are to be evaluated from curve fits is higher than the upper bound of temperature over which the fit is valid. The temperature and particular species are printed; the upper bound values are used and the program returns to the calling routine and continues.

4   Called from subroutine 'STICKY' - an attempt at computing the temperature given the mixture enthalpy and the pressure has failed to satisfy the prescribed value of enthalpy within a relative error of 10^{-6} after 10 iterations. ERROR prints the last iterate for the temperature and the species number. The program uses this last iterate, returns to the calling routine and continues.

5   Called from subroutine 'STICKY' - the temperature has become negative during some iteration in solving for the temperature given the pressure and the mixture enthalpy. ERROR prints the value of the temperature and the number of iterations performed to this point. The program terminates using the procedure described above.

6   Called from 'STICKY' - attempt at computing the temperature given the pressure and the mixture enthalpy fails. (A relative error of 10^{-6} on the enthalpy is exceeded.) Error prints the initial guess at the temperature and the value of the temperature as computed after the last iteration (this latter temperature is printed in integer format). The program uses this last value of temperature, returns to the calling routine and continues.

Error Number	Description
7	Called from entry point 'PERFCT' in subroutine 'STICKY' - the temperature is outside the range of validity of Sutherland's Law ($180°R$ to $3400°R$). ERROR prints the temperature and viscosity computed from it, the latter multiplied by 1×10^{10}, and returns to the calling routine (Note: this error message will be printed a maximum of 5 times in any one case).
8	Called from entry point 'PERFCT' in subroutine 'STICKY' - the temperature is outside the range of validity of a simple power law, $\mu \sim T^n$, variation for the viscosity ($300°R$ to $900°R$). ERROR prints the temperature and viscosity, the latter multiplied by 1×10^{10} and returns to the calling routine. (Note: this error message will be printed a maximum of 5 times in any one case).
9	Called from subroutine INITL1 - an enthalpy computation in the external-velocity input option has not converged in 30 iterations. The last values of the enthalpy and the number of iterations are printed by ERROR and the program is terminated as described above.
10	Called from subroutine 'GENL7X' - the temperature has exceeded the maximum range of some fit for the species enthalpy or entropy. ERROR prints both the temperature and species number. The program returns to the calling routine and continues using the upper bound values.
11	Called from subroutine - 'GENL7X' - prescribed values of the mixture enthalpy or entropy have not been satisfied to a relative tolerance of 10^{-6} after 10 iterations in attempting to

Error	
Number	Description

11(contd)   compute the temperature given the pressure and one of the above. The input value of the enthalpy or entropy and the last iterate, the latter in integer format, are printed. This last iterate is returned to the calling program and is used to continue the computation.

12   Called from 'GENL7X' - a pressure, temperature input problem has not converged in 30 iterations. The pressure and the temperature, the latter in integer format, are printed by ERROR, the program returns to the calling routine and continues the computation using the last iterates for the mixture enthalpy and entropy.

13   Called from 'GENL7X' - if between two successive iterations for a pressure - temperature problem, the residual vector used in the chemistry formulation has not decreased, the value of the relaxation factor used to find a solution to the chemical system will be reduced. This relaxation factor is reduced until the residual vector begins to decrease from iteration to iteration. This error message indicates that the relaxation factor has been reduced for 10 consecutive pressure-temperature iterations and the residual vector has not decreased. The program terminates using the above described procedure. New guesses for the mole fractions should be made and the run resubmitted.

14   Called from subroutine 'INITL1' - the perfect gas option section - the static enthalpy is negative. The velocity from which it was computed is printed by ERROR along with the array position of the X table value. The calculation is then terminated.

Error Number	Description

15   Same as error message (14) but called from the equilibrium chemistry section of INITL1 and associated with the static enthalpy at the initial point. The calculation is terminated after the error message is printed.

16   Same as error message (14) but called from general locations in the equilibrium chemistry option section of INITL1. As above, the calculation is terminated after the error message is printed.

17   Called from subroutine 'THERMO' – the static enthalpy has become negative – ERROR now prints the total enthalpy and the velocity (the latter in integer format) used in this calculation and the program terminates.

18   Called from subroutine 'CONV' – the Newton-Raphson iteration technique used in CONV to determine ETABAR as a function of PSI in the wake region has not converged in 50 iterations. ERROR prints the initial guess for the root, i.e., the last value of ETABAR obtained, and the error indicator, KE. The program then terminates.

19   Called from 'FUNCT' – the interpolation to find the integral I3ETA via subroutine LAGR has not succeeded. ERROR prints the last value of the answer from LAGR and the error indicator, KE, which is either 1, 2 or 3 depending upon whether the argument was below the lowest table value, above the largest table value or the number points were insufficient for interpolation, respectively. The program then terminates in the prescribed manner.

20 - 24   Called from various locations in subroutine
            'DEFINT' - the service routine, LAGR, which
            performs Lagrangian interpolation to determine
            the quantities MUTLDA, RTILDA and I3ETA
            at the edge of the laminar sublayer, has failed
            to interpolate successfully. The same message
            information is printed in this case as is
            printed in error message (19) above, and the
            program is terminated. The quantities associated
            with the particular error numbers are indicated
            below.

Quantity being sought	Program option
20 MUTLDS	
21 I3ETAS	$\mu \sim T^n$
22 RTLDAS	
23 I3ETAS	Sutherland's Law
24 RTLDAS	

25   Called from subroutine 'PROFIL' - to evaluate
            the integral I3ETA the service routine 'TRAPIN'
            is called upon to perform the integration by
            quadrature using the trapezoidal rule. If
            some reasonable number of iterations (50) are
            exceeded in the attempt to perform this inte-
            gration, this error message is printed along
            with the last value of the integral and the
            number of iterations performed. The program
            then terminates.

26   Called from subroutine 'MAIN' - PHIMAX, the
            maximum value of the skin friction parameter,
            has been exceeded. ERROR now prints the last
            value of IETMAX, an indicator of the boundary
            layer growth, and IINTRL which indicates
            the integration step. The program then
            terminates in the standard error mode.

Error Number	Description

27   Called from subroutine 'DERSUB' – the matrix
      which has been presented to the service
      routine SIMQ to invert, is singular. The
      error routine prints the values of the skin
      friction parameter, PHI and the integration
      step, IINTRL. ERROR now prints the contents
      of the coefficient array, AA, and the solution
      vector, COLD, before the inversion was attempted.
      The program then terminates in the standard
      error mode.

28   Called from 'MAIN' by the integration package
      'INT1A'. ERROR prints the integration package
      error indicator, IERR, which indicates that the
      ELT table was not monotonic if IERR=2 or that
      INT1A has run into truncation error problems
      (i.e., IERR=3 or 4). In addition, ERROR prints the
      last value of the independent variable, CHIBAR.
      The program is then terminated.

29   Called from subroutine 'DEFINT' – the service
      routine, LAGR, has tried to find I3EDGE from a
      table of I3ETA vs ETABAR by Lagrangian inter-
      polation and has failed. The same message in-
      formation is printed in this case as is printed
      in error message (19) above and the program is
      then terminated.

30   Called from subroutine 'THERMO' – in this case,
      THERMO is required to evaluate the integral
      I3ETA via the service routine TRAPIN (c.f.,
      error message (25)). The error message printed
      in this case is the same as is printed in error
      message (25). The computation is then terminated.

Error Number	Description

31

Called from subroutine 'MAIN' – the skin friction parameter, $\overline{\varphi}$ has exceeded the maximum value permitted, i.e., PHI > PHIMAX. The error routine prints the values of CHI, the streamwise Reynolds number and IETMAX, a mesh size parameter, and terminates the calculation.

32

Called from subroutine 'INITL1' – the Mach number input option has been mistakenly selected with the option for equilibrium chemistry. This input option does not provide enough information to do an equilibrium chemistry calculation. The user is advised to check the input data and his control card selections.

33

Called from 'FUNCT' – interpolation to find RSTARI via the service routine, LAGR, has not succeeded. ERROR prints the last value of the answer from LAGR and the error indicator, KE, which is either 1, 2 or 3 depending upon whether the argument was below the lowest table value, above the largest table value or the number of table points were insufficient for interpolation, respectively. The program then terminates in the standard error mode.

34

Called from 'FUNCT' – interpolation to find DRSDXI via the LAGR interpolation routine has failed. The same error message is printed in this case as in error (33) above. The program then terminates as indicated above.

35 - 39   Called from various locations in subroutine
               'AXISYM', the service routine, LAGR, which
               performs a Lagrangian interpolation to determine
               the quantities RSTARO, XO, XL, RSAXI, and XSAXI
               which are required in the axisymmetric option
               to make the transformation to two-dimensional
               coordinates, has failed to interpolate
               successfully. The same error message informa-
               tion is printed in this case as is printed in
               error messages (33) and (34) above and the
               program is terminated. The quantities associated
               with particular error numbers are

               Quantity being sought

35   RSTARO

36   XO

37   XL

38   RSAXI

39   XSAXI

40   Called from 'AXISYM' - in this case, AXISYM
               is required to calculate the transformed 2-D
               coordinate using the service routine TRAPIN.
               (c.f., error message (25)). The error
               message printed in this case is the same as is
               printed in error message (25). The computation
               is then terminated in the standard error mode.

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VII. PROGRAM OUTPUT

This section describes the format of the program output for the various program options that may be selected, defines the notation used in the output format and presents some samples of the output for illustration.

The first page of output specifies the system of units that will be used for all output quantities (note: a different system of units may have been selected for input) and the major options that have been chosen. In addition, the identifying information which has been punched on the three comment cards used to terminate the input data for each case, are printed.

The second page prints the values of the input and computed free stream or reference conditions, specifically the velocity, pressure, temperature, Reynolds number per foot, stagnation enthalpy, and reference length. Below this are printed the maximum number of mesh points in the $\tilde{\psi}$-direction being used, the number of integration steps between adjacent lines of printout and the values of the mesh parameters, ALPHA and DPSI. In addition, the program prints the particular variable name (x, Re_θ or Re_x) that has been chosen for profile generation, and the values of that variable at which profiles will be printed. If no profiles are requested, a message to that effect is also printed. The last item on this page is a printout of the control card indicators that have been selected.

The next page is a printout of namelist OVRIDE and contains:

a) all the values of the quantities that have been selected by the user along with

b) all the default options and pre-set data that the program will use in the course of the computation.

Following OVRIDE, namelist FLUID is printed and lists all the thermodynamic and transport properties the program will

use in the course of the calculation. This output is made
of user-changed-values and remaining default or pre-set values.

The following two pages contain all the wall and edge
condition information which has been input or generated by the
initialization portions of the program output in a variable
namelist-type format. These quantities are printed with their
program variable names and are, in the order in which they
are printed :

x (ft or meters)
    — the axial coordinate along the
body at which external pressure,
velocity, or Mach number
distributions are prescribed.
For the axisymmetric case, x
will be the dimensional values
of the transformed 2-D coordinates
and will not compare with the
non-dimensionalized input values
of axial distance.

PE (lbf/ft^2 or Newtons/m^2)
DPEDX (lbf/ft^2/ft or Newtons/ m^2/m)
    — the external pressure distribution
and its derivative w.r.t. axial
distance, respectively.

UE (ft/sec or meters/sec)
DUEDX (ft/sec/ft or meters/ sec/meter)
    — the external velocity distribution
and its derivative w.r.t. axial
distance, respectively.

RHOE (Slugs/ft^3 or kilograms/ m^3)
DROEDX (Slugs/ft^3/ft or kg/m^3/m)
    — the external density distribution
and its derivative w.r.t. axial
distance, respectively.

EMUE (lbf-sec/ft^2 or Newton- sec/m^2)
DMUEDX (lbf-sec/ft^2 or Newton-sec/m^2/m)
    — the external viscosity distribution and its derivative w.r.t.
axial distance, respectively.

HE (ft^2/sec^2 or Joules/kg)
    — the static enthalpy distribution
of the external stream.

CPE (ft^2/sec^2 $^\circ$R or Joules/Kg $^\circ$K)
    — the constant pressure specific
heat capacity of the external
stream.

TRMLKE (lbf/sec$^\circ$R or   — the thermal conductivity distri-
    Joules/meters sec $^\circ$K)   bution of the external fluid.

EME-dimensionless   — the external Mach number distri-
DEMEDX- (ft^{-1} or meter^{-1})   bution and its derivative w.r.t.
                                           axial distance.

TE ($^\circ$R or $^\circ$K)   — the external static temperature
DTEDX ($^\circ$R/ft or $^\circ$K/meter)   distribution and its derivative
                                           w.r.t. the axial distance.

RHOWO (slugs/ft^3 or kgs/m^3)   — the density, viscosity and
EMUWO (lbf-sec/ft^2 or   thermal conductivity, respectively
    Newton-sec/m^2)   of the fluid at the wall at
TMLKWO (lbf/sec$^\circ$R or   the free stream or reference
    Joules/meter sec $^\circ$K)   conditions.

RHOW (slugs/ft^3 or kgs/m^3)   — the density, viscosity and
EMUW (lbf-sec/ft^2 or   thermal conductivity distributions,
    Newtons-sec/m^2)   respectively of the fluid at
TRMLKW (lbf/sec $^\circ$R or   the wall.
    Joules/meter-sec $^\circ$K)

The results of the integration of the governing equations are stored in an array the length of which (i.e., the number of rows) is specified by the user. (c.f., columns 10-12 on the control card by the parameter KTEST.) The output of this information is separated into five categories, each of which is printed every time the output array is printed. This printing normally takes place when the output array is filled to the user specified length. The exception to this occurs when the program is prematurely terminated at which time the present contents of the output array are printed regardless of its present length.

The five blocks of information printed in the order in which they appear are:

Properties in the Transformed Plane

  A. Dependent Variables - The independent variable
CHIBAR, is printed followed by the 7 dependent variables,
PHIBAR , the skin friction parameter, PI,Coles wake parameter,·
RBAR, the transformed Reynolds number based on boundary layer
height, UEBAR, normalized edge velocity, ETATILDA and SGMATLDA,
Coles scaling parameters, and CHI, the streamwise Reynolds
number.

  B. Boundary Layer Properties - The independent variable
CHIBAR, is printed followed by 7 boundary layer parameters which
include CFBAR, the skin friction coefficient in the incompress-
ible plane, HBAR, the incompressible form factor, RDLTBAR, the
transformed Reynolds number based upon the transformed boundary
layer height, RBRDLSTR, the transformed Reynolds number based
upon the incompressible displacement thickness, RTHETABR, the
transformed Reynolds number based upon the incompressible
momentum thickness, CFRTHT/2, (1/2) the product of skin friction
coefficient and momentum thickness Reynolds number, and
TAULAW, the residual value of Coles skin friction law (Eq.(38)
Part I); ideally this parameter should be identically zero.

  C. Derivatives of the Dependent Variables - the
independent variable CHIBAR is printed followed by the de-
rivatives of the 7 dependent variables listed in (A) above.
These are PHIBARP, PIP, RBARP, UEBARP, ETATLDAP, SGMATLDP,
CHIP, respectively.

Properties in the Corresponding Physical Planes

  The output of this information is contained in two print
blocks. The first contains the distance along the body, DELTAX,
followed by CF, the skin friction coefficient in the compressible
plane, H, the compressible form factor, RDELTA, the Reynolds
number based upon boundary layer height, RDLTSTR, the Reynolds
number based upon boundary layer displacement thickness, RTHETA,
the Reynolds number based upon momentum thickness, DLTASTR, the
boundary layer displacement thickness and THETA, the boundary
layer momentum thickness.

  The second group of these starts again with the displacement
along the body, DELTAX, and is followed by the wall conditions

TTILDAW, GWALL, ROTLDAW, and MUTLDAW which are the wall values
of the temperature, total enthalpy, density and viscosity
of the fluid normalized to their respective edge values. The
last three columns of this block contain the heat transfer,
QDOTW, the Stanton number, ST, and the parameter 2ST/CF.

If profiles are obtained, their output is presented in
two print blocks. The first is headed by a statement indicating
at which station the profiles were generated and what the
independent profile variable was (i.e., x, Re_θ, Re_x). The
remaining two parameters are printed directly below.

Preceeding this first profile block are two smaller
blocks of information representing the interpolated values
of the dependent variables, their derivatives, the boundary
layer properties and the external quantities corresponding to
the x, Re_θ or Re_x value which has been selected by the user.
This information is immediately followed by the profiles.

The output format for the profiles presents the
transformed coordinate, ETABAR; the physical height, normalized
w.r.t boundary layer height ETA; the corresponding
stream-function coordinate, PSI; the normalized total enthalpy
G, and the normalized velocity, density, viscosity and static
temperature, UTILDA, RTILDA, MUTLDA, and TTILDA, respectively
in the first profile block. The second block, repeats the
normalized physical height, ETA; and then presents a Reynolds no.
based on transformed local external conditions and a transformed
height, RYBAR; the boundary layer physical height, Y; the Reynolds
number based on external conditions and the normal coordinate,
RSUBY; and the shear stress function, eddy viscosities, and mixing
length, TAUFCT, EDDY1, EDDY2, and LMIX, respectively.

A sample of the output of a complete two-dimensional case
is presented on the following pages including a sample of the
profile output at one particular point. Note the error message
printed at the end of the output of the edge condition infor-
mation warning the user that the temperature range for the
$\mu \sim T^n$ law has been violated.

For the case of an axisymmetric problem two additions to
the output format should be noted. Following the output of all

the thermodynamic and transport properties under the control
of namelist, FLUID, another namelist, RBODY, is printed which
contains either the table of input values of the normalized
radial coordinate, RSTAR(r*), or the table of polynomial
coefficients which were input for use with the curve fit
geometry option.

After the normal printing of the five block output array,
two additional blocks are printed. These contain the axi-
symmetric counterparts of the properties in the corresponding
physical planes. An example is included at the end of the
sample output.

COMPRESSIBLE TURBULENT BOUNDARY LAYER WITH PRESSURE GRADIENT
(VIA COLES TRANSFORMATION AND BARONTIS COMPRESSIBLE SOLUTION)
(ENERGY EQUATION VIA IMPLICIT FINITE DIFFERENCES)

DIMENSIONAL UNITS
------------- -----

VELOCITY   FT/SEC
DISTANCE   FFET
PRESSURE   LBS/SQ FT
TEMPERATURE   DEGREES-RANKINE
DENSITY   SLUGS/CU FT
FNTHALPY   FT SQ/SEC SQ
VISCOSITY   LBS-SEC/FT SQ
CONDUCTIVITY   LBS/SEC-DEG.R
SPECIFIC HEAT   FT SQ/SEC SQ-DEG.R
HEAT TRANS. RATE   BTU/FT SQ/SEC

OPTIONS SELECTED

EXTERNAL PRESSURE DISTRIBUTION-PE(X)-INPUT

PERFECT GAS OPTION WITH CONSTANT SPECIFIC HEATS

PERFECT GAS PROPERTY CHANGES
        GAMA = 1.400
        WGT =   29.000

VISCOSITY MODEL TAKEN IS MU PROPORTIONAL TO T**N

TEMPERATURE EXPONENT IN VISCOSITY LAW IS 1.0000

WALL CONDITION----NON-ADIABATIC, TWALL =   550.000

PRANDTL NO.(LAMINAR)- CONSTANT - =   .7200

PROGRAM TEST CASE -4A- BERTRAM AND NEAL-NO PRESSURE GRADIENT
FLAT PLATE OPTION USED- VISCOSITY FROM MU PROP. TO T
NON-ADIABATIC WALL -

FREE STREAM OR REFERENCE CONDITIONS

VELOCITY =   3453.09   PRESSURE =   5.7182   TEMPERATURE =   107.42
REYNOLDS NO./FT = 1.289347E+06 STAG.ENTHALPY = 6.606599E+06 REF.LENGTH =   0.00

MAXIMUM NO.OF MESH POINTS IN THE Y DIRECTION IS   50
PRINT DENSITY IS EVERY   1 STEPS
MESH PARAMETERS   ALPHA = 1.300000E+00   DELTA PSI = 5.000000E+00

PROFILES WILL BE PRINTED AT RETHETA =   1.300000E+04 3.000000E+04

INDICATORS

 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36

-0 -0 2 -0 -0 2 -0 -0 1 -0 2 5 -0 -0 -0 1 1 -0 1 -0 1 -0 1 2 1 1 -0 -0 1 -0 -0 -0 -0 -0 -0 -0

37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72

-0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0

```
$INPUT

LXEO      =  0.349309331E+04,

REGLO     =  0.128934700698044E+07,

PEO       =  0.571824E+01,

EMEO      =  0.679099988A9837E+01,

MTOTE     =  0.660659873E+07,

TTE       =  0.1100850234161 5E+04,

PTE       =  0.1070140772A973E+05,

PIO       = -0.75E+00,

PHIBRO    =  0.18AE+02,

ETLOAO    =  0.1E+01,

UEBARO    =  0.1E+01,

TW        =  0.55E+03,

ACONST    =  0.243E+01,

B         =  0.75E+01,

BETA      =  0.91E-01,

ETASTW    =  0.5E+00,

YBPLUS    =  0.10AE+02,

BPSY      =  0.5E+01,

ALPHA     =  0.13E+01,

PHIMAX    =  0.1E+03,

CHIPAX    =  0.1E+09,

DCHIBG    =  0.5E+04,

CHIO      =  0.0,

CHIPAB    =  0.0,

XO        =  0.0,

LREF      =  0.0,

ELEI      =  0.1E-03,  0.1E-03,  0.1E-03,  0.1E-03,  0.1E-01,  0.1E-03,              0.1E-03,

ELE2      =  0.1E-08,  0.1E-08,  0.1E-08,  0.1E-08,  0.1E+03,  0.1E-08,              0.1E-08,

ELT       =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

DCIMAX    =  0.1E+07,

SPEC      =  0.0,

XBWOEL    =  0.13E+05,  0.3E+05,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
             0.0,  0.0,  0.0,  0.0,
```

```
$CHEM

GAMA    =  0.14F+01.

WGT     =  0.29F+02.

PRNLAM  =  0.72F+00.

PRNTUR  =  0.72F+00.

CAYPRM  =  0.1986F+03.

XMOLE   =  0.209727F+00,  0.778987E+00,  0.25E-06,  0.9288E-02,  0.25E-06,      0.1997E-02,  0.25E-06,  0.25E-06,
           0.0,  0.0.

$END
```

```
$TRNSPT
VEX      =  0.1E+01,
VISTR    =  0.387E-06,
TEMPR    =  0.5E+03,
$END
```

```
$TESTER

X      =  0.0,   0.1E+05,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,

PE     =  0.571824E+01,   0.571824E+01,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,

UE     =  0.345309331E+04,   0.345309331E+04,   0.0,   0.0,   0.0,   0.0,   0.0,          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,

DUEDX  =  0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,

RHOF   =  0.31044995262869E-04,   0.31044995262869E-04,   0.0,   0.0,   0.0,             0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,

DROEDX =  0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,

EMUF   =  0.83143843320403E-07,   0.83143843320403E-07,   0.0,   0.0,   0.0,             0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,

DMUEDX =  0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,

HE     =  0.644672026216664E+06,   0.644672026216664E+06,   0.0,   0.0,   0.0,           0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,

CPE    =  0.60013601532567E+04,   0.60013601532567E+04,   0.0,   0.0,   0.0,             0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,

TRMLKE =  0.69302242818289E-03,   0.69302242818289E-03,   0.0,   0.0,   0.0,             0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,

EME    =  0.67999998889836E+01,   0.67999998889836E+01,   0.0,   0.0,   0.0,             0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,

TE     =  0.10742098620207E+03,   0.10742098620207E+03,   0.0,   0.0,   0.0,             0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,        0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
          0.0,   0.0,   0.0,   0.0,   0.0,

RHOKO  =  0.60634254686836E-05,
```

```
EMUW0   =  0.4257E-06.

TMLKW0  =  0.3548304190613E-02.

RHOW    =  0.60634254686836E-05.  0.60634254686836E-05.  0.0.  0.0.  0.0.        0.0.  0.0.  0.0.  0.0.  0.0.  0.0.
           0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.        0.0.  0.0.  0.0.  0.0.  0.0.  0.0.
           0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.        0.0.  0.0.  0.0.  0.0.  0.0.  0.0.
           0.0.  0.0.  0.0.  0.0.  0.0.

EMUW    =  0.4257E-06.  0.4257E-06.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.     0.0.  0.0.  0.0.  0.0.  0.0.  0.0.
           0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.        0.0.  0.0.  0.0.  0.0.  0.0.  0.0.
           0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.        0.0.  0.0.  0.0.  0.0.  0.0.  0.0.
           0.0.

TRMLKW  =  0.3548304190613E-02.  0.3548304190613E-02.  0.0.  0.0.  0.0.  0.0.     0.0.  0.0.  0.0.  0.0.  0.0.  0.0.
           0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.        0.0.  0.0.  0.0.  0.0.  0.0.  0.0.
           0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.        0.0.  0.0.  0.0.  0.0.  0.0.  0.0.
           0.0.  0.0.  0.0.  0.0.

SEND

ERROR  6

CALLED FROM*PERFCT*.T(DEG F)=    275.18   MU(TIMES E10)=      2129   T IS OUTSIDE RANGE OF VALIDITY OF SIMPLE POWER LAW VARIATION

ERROR  6

CALLED FROM*PERFCT*.T(DEG F)=    245.54   MU(TIMES E10)=      1900   T IS OUTSIDE RANGE OF VALIDITY OF SIMPLE POWER LAW VARIATION
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PROPERTIES IN THE TRANSFORMED PLANE

DEPENDENT VARIABLES

CHIBAP	PHIBAP	PI	RBAR	UEBAR	ETATILDA	SGMATLDA	CHI
0.	1.840000E+01	-2.500000E-01	7.854389E+03	1.000000E+00	1.000000E+00	2.225168E-01	0.
5.000000E+03	1.845959E+01	-2.484881E-01	8.056188E+03	1.000000E+00	9.962295E-01	2.216778E-01	1.186122E+05
1.000000E+04	1.851711E+01	-2.471857E-01	8.253331E+03	1.000000E+00	9.925737E-01	2.208643E-01	2.347682E+05
2.000000E+04	1.862654E+01	-2.450888E-01	8.648190E+03	1.000000E+00	9.856671E-01	2.193275E-01	4.632106E+05
4.000000E+04	1.882639E+01	-2.423261E-01	9.437960E+03	1.000000E+00	9.734236E-01	2.166031E-01	9.157548E+05
6.000000E+04	1.900573E+01	-2.407437E-01	1.022520E+04	1.000000E+00	9.629304E-01	2.142682E-01	1.368928E+06
8.000000E+04	1.916869E+01	-2.398395E-01	1.100829E+04	1.000000E+00	9.538115E-01	2.122391E-01	1.824927E+06
1.200000E+05	1.945649E+01	-2.390882E-01	1.255962E+04	1.000000E+00	9.386480E-01	2.088649E-01	2.747608E+06
1.600000E+05	1.970553E+01	-2.389964E-01	1.409056E+04	1.000000E+00	9.264592E-01	2.061528E-01	3.686375E+06
2.000000E+05	1.992534E+01	-2.391734E-01	1.560216E+04	1.000000E+00	9.163688E-01	2.039075E-01	4.640182E+06
2.400000E+05	2.012224E+01	-2.394609E-01	1.709603E+04	1.000000E+00	9.078252E-01	2.020064E-01	5.607543E+06
3.200000E+05	2.046380E+01	-2.401280E-01	2.003681E+04	1.000000E+00	8.940143E-01	1.989332E-01	7.575486E+06
4.000000E+05	2.075355E+01	-2.407826E-01	2.292391E+04	1.000000E+00	8.832257E-01	1.965326E-01	9.583261E+06
4.800000E+05	2.100532E+01	-2.413809E-01	2.576573E+04	1.000000E+00	8.744786E-01	1.945862E-01	1.162412E+07
5.600000E+05	2.122802E+01	-2.419190E-01	2.856872E+04	1.000000E+00	8.671882E-01	1.929639E-01	1.369264E+07
7.200000E+05	2.160878E+01	-2.428393E-01	3.407699E+04	1.000000E+00	8.555990E-01	1.903852E-01	1.789250E+07
8.800000E+05	2.192705E+01	-2.435982E-01	3.947766E+04	1.000000E+00	8.466929E-01	1.884034E-01	2.216585E+07
1.040000E+06	2.220060E+01	-2.442386E-01	4.479013E+04	1.000000E+00	8.395534E-01	1.868147E-01	2.649843E+07
1.360000E+06	2.265432E+01	-2.452726E-01	5.520212E+04	1.000000E+00	8.286480E-01	1.843881E-01	3.528965E+07
1.680000E+06	2.302265E+01	-2.460849E-01	6.538767E+04	1.000000E+00	8.205799E-01	1.825928E-01	4.422568E+07
2.000000E+06	2.333288E+01	-2.467502E-01	7.539305E+04	1.000000E+00	8.142762E-01	1.811901E-01	5.327383E+07
2.640000E+06	2.383704E+01	-2.477956E-01	9.497964E+04	1.000000E+00	8.048837E-01	1.791002E-01	7.159758E+07
3.280000E+06	2.423876E+01	-2.485979E-01	1.141245E+05	1.000000E+00	7.980908E-01	1.775886E-01	9.018797E+07
4.280000E+06	2.473885E+01	-2.495607E-01	1.433710E+05	1.000000E+00	7.903890E-01	1.758748E-01	1.195949E+08

PROPERTIES IN THE TRANSFORMED PLANE

DIMENSIONAL BOUNDARY LAYER PARAMETERS

CHIBAR	CFBAR	HBAR	RDLTBAR	RRRDLSTR	RTHETABR	CFRTHT/2	TAULAW
0.	5.907372E-03	1.297223E+00	7.859389E+03	7.784639E+02	6.001002E+02	1.772508E+00	5.684342E-14
5.000000E+03	5.869295E-03	1.296287E+00	8.056188E+03	7.969842E+02	6.148206E+02	1.804282E+00	4.405365E-13
1.000000E+04	5.832889E-03	1.295360E+00	8.253331E+03	8.153616E+02	6.294480E+02	1.835750E+00	7.123191E-13
2.000000E+04	5.764552E-03	1.293539E+00	8.648190E+03	8.517167E+02	6.584393E+02	1.897804E+00	1.512035E-11
4.000000E+04	5.642815E-03	1.290071E+00	9.437960E+03	9.229957E+02	7.154611E+02	2.018607E+00	4.621157E-10
6.000000E+04	5.536829E-03	1.286862E+00	1.022520E+04	9.926179E+02	7.713479E+02	2.135411E+00	6.588134E-10
8.000000E+04	5.443085E-03	1.283907E+00	1.100829E+04	1.060813E+03	8.262384E+02	2.248643E+00	7.486261E-10
1.200000E+05	5.283246E-03	1.278681E+00	1.255962E+04	1.193582E+03	9.334481E+02	2.465818E+00	2.724450E-09
1.600000E+05	5.150552E-03	1.274211E+00	1.409056E+04	1.322310E+03	1.037748E+03	2.672488E+00	3.309205E-09
2.000000E+05	5.037540E-03	1.270335E+00	1.560216E+04	1.447675E+03	1.139601E+03	2.870392E+00	3.507918E-09
2.400000E+05	4.939436E-03	1.266932E+00	1.709603E+04	1.570170E+03	1.239349E+03	3.060842E+00	3.583819E-09
3.200000E+05	4.775925E-03	1.261194E+00	2.003681E+04	1.807961E+03	1.433531E+03	3.423218E+00	5.927282E-09
4.000000E+05	4.643497E-03	1.256499E+00	2.292391E+04	2.037833E+03	1.621834E+03	3.765491E+00	6.572106E-09
4.800000E+05	4.532849E-03	1.252547E+00	2.576573E+04	2.261222E+03	1.805300E+03	4.091575E+00	6.786330E-09
5.600000E+05	4.438242E-03	1.249147E+00	2.856872E+04	2.479152E+03	1.984675E+03	4.404235E+00	6.868163E-09
7.200000E+05	4.283211E-03	1.243539E+00	3.407699E+04	2.901518E+03	2.333276E+03	4.996956E+00	1.056948E-08
8.800000E+05	4.159774E-03	1.239038E+00	3.947766E+04	3.309254E+03	2.670825E+03	5.555013E+00	1.154780E-08
1.040000E+06	4.057893E-03	1.235300E+00	4.479013E+04	3.705174E+03	2.999411E+03	6.085644E+00	1.186431E-08
1.340000E+06	3.896979E-03	1.229351E+00	5.520212E+04	4.468905E+03	3.635175E+03	7.083099E+00	2.383505E-08
1.680000E+06	3.773281E-03	1.224738E+00	6.538767E+04	5.203184E+03	4.248407E+03	8.015218E+00	2.644255E-08
2.000000E+06	3.673611E-03	1.220993E+00	7.539305E+04	5.914366E+03	4.843897E+03	8.897297E+00	2.718129E-08
2.640000E+06	3.519855E-03	1.215168E+00	9.497964E+04	7.283163E+03	5.993546E+03	1.054821E+01	5.095148E-08
3.250000E+06	3.404154E-03	1.210741E+00	1.141245E+05	8.597001E+03	7.100610E+03	1.208578E+01	5.551565E-08
4.280000E+06	3.267916E-03	1.205479E+00	1.433710E+05	1.056826E+04	8.766860E+03	1.432468E+01	7.689733E-08

PROPERTIES IN THE TRANSFORMED PLANE

DERIVATIVES OF THE DEPENDENT VARIABLES

CHIBAP	PHIBARP	PIP	RBARP	UEBARP	ETATLDAP	SGMATLDP	CHIP
0.	1.213634E-05	3.257590E-07	3.931615E-02	0.	-7.719311E-07	-1.717676E-07	2.336389E+01
5.000000E+03	1.170517E-05	2.802764E-07	3.939869E-02	2.000022E-18	-7.425193E-07	-1.652230E-07	2.348650E+01
1.000000E+04	1.130737E-05	2.417116E-07	3.945471E-02	-1.219568E-18	-7.178661E-07	-1.597373E-07	2.306310E+01
2.000000E+04	1.059687E-05	1.808733E-07	3.950507E-02	4.099511E-19	-6.625376E-07	-1.474257E-07	2.273540E+01
4.000000E+04	9.438397E-06	1.030591E-07	3.944439E-02	2.032633E-18	-5.644928E-07	-1.256091E-07	2.263830E+01
6.000000E+04	8.528881E-06	5.918492E-08	3.926693E-02	3.600022E-18	-4.874791E-07	-1.084723E-07	2.273285E+01
8.000000E+04	7.791684E-06	3.342956E-08	3.903622E-02	3.926969E-19	-4.264981E-07	-9.490299E-08	2.289694E+01
1.200000E+05	6.661374E-06	8.091046E-09	3.852658E-02	1.891796E-18	-3.372514E-07	-7.504410E-08	2.328410E+01
1.600000E+05	5.829083E-06	-2.025283E-09	3.802562E-02	3.654152E-19	-2.756639E-07	-6.133986E-08	2.367173E+01
2.000000E+05	5.187275E-06	-6.216102E-09	3.756142E-02	3.540966E-19	-2.310971E-07	-5.142299E-08	2.402696E+01
2.400000E+05	4.675796E-06	-7.888100E-09	3.713841E-02	1.721023E-18	-1.975930E-07	-4.396776E-08	2.434574E+01
3.200000E+05	3.909723E-06	-8.434999E-09	3.640419E-02	1.640140E-18	-1.511254E-07	-3.362794E-08	2.486973E+01
4.000000E+05	3.362051E-06	-7.859122E-09	3.579057E-02	3.147244E-19	-1.205919E-07	-2.683371E-08	2.532014E+01
4.800000E+05	2.950411E-06	-7.094531E-09	3.526840E-02	3.948728E-18	-9.930090E-08	-2.209612E-08	2.569566E+01
5.600000E+05	2.629458E-06	-6.370563E-09	3.481641E-02	1.472536E-18	-8.374323E-08	-1.863428E-08	2.601233E+01
7.200000E+05	2.160987E-06	-5.194579E-09	3.406640E-02	-8.397862E-19	-6.281117E-08	-1.397654E-08	2.649670E+01
8.800000E+05	1.835244E-06	-4.335955E-09	3.346182E-02	2.413608E-18	-4.945732E-08	-1.100508E-08	2.690602E+01
1.040000E+06	1.595467E-06	-3.699211E-09	3.295815E-02	2.586350E-19	-4.034092E-08	-8.976533E-09	2.723824E+01
1.360000E+06	1.265873E-06	-2.833718E-09	3.215417E-02	1.220925E-18	-2.889828E-08	-6.430354E-09	2.771513E+01
1.680000E+06	1.049822E-06	-2.280413E-09	3.152900E-02	2.329307E-19	-2.207423E-08	-4.911888E-09	2.811002E+01
2.000000E+06	8.971621E-07	-1.899364E-09	3.102060E-02	1.120093E-18	-1.762498E-08	-3.921853E-09	2.842035E+01
2.640000E+06	6.955972E-07	-1.412372E-09	3.022780E-02	-6.324186E-19	-1.227705E-08	-2.731849E-09	2.884960E+01
3.280000E+06	5.683647E-07	-1.116615E-09	2.962406E-02	1.003399E-18	-9.214039E-09	-2.050278E-09	2.921078E+01
4.280000E+06	4.423973E-07	-8.346382E-10	2.890481E-02	9.459992E-19	-6.470263E-09	-1.439742E-09	2.959245E+01

DELTAX	CF	H	RDELTA	RDLTSTR	RTHETA	DLTASTR	THETA
0.	1.314490E-03	1.594414E+01	7.482133E+04	4.299935E+04	2.696876E+03	3.334971E-02	2.091660E-03
9.199400E-02	1.301092E-03	1.593705E+01	7.694784E+04	4.420120E+04	2.773488E+03	3.428185E-02	2.151079E-03
1.820830E-01	1.284277E-03	1.593016E+01	7.907649E+04	4.539984E+04	2.849931E+03	3.521150E-02	2.210368E-03
3.592598E-01	1.264325E-03	1.591695E+01	8.333119E+04	4.778401E+04	3.002083E+03	3.706063E-02	2.328375E-03
7.102470E-01	1.222251E-03	1.589275E+01	9.180667E+04	5.249530E+04	3.303097E+03	4.071464E-02	2.561837E-03
1.061722E+00	1.186366E-03	1.587118E+01	1.002239E+05	5.713495E+04	3.599918E+03	4.431309E-02	2.792047E-03
1.415389E+00	1.155236E-03	1.585188E+01	1.085799E+05	6.171073E+04	3.892961E+03	4.786200E-02	3.019327E-03
2.131008E+00	1.103485E-03	1.581876E+01	1.251144E+05	7.069634E+04	4.469147E+03	5.483112E-02	3.466209E-03
2.859102E+00	1.061800E-03	1.579128E+01	1.414273E+05	7.949140E+04	5.033880E+03	6.165245E-02	3.904209E-03
3.598862E+00	1.027192E-03	1.576800E+01	1.575406E+05	8.812439E+04	5.588814E+03	6.834808E-02	4.334608E-03
4.349134E+00	9.977976E-04	1.574791E+01	1.734748E+05	9.661651E+04	6.135197E+03	7.493445E-02	4.758375E-03
5.875444E+00	9.500901E-04	1.571472E+01	2.048748E+05	1.132417E+05	7.206092E+03	8.782876E-02	5.588947E-03
7.432647E+00	9.125983E-04	1.568812E+01	2.357350E+05	1.294622E+05	8.252243E+03	1.004091E-01	6.400327E-03
9.015508E+00	8.820297E-04	1.566608E+01	2.661365E+05	1.453442E+05	9.277636E+03	1.127270E-01	7.195608E-03
1.061982E+01	8.564208E-04	1.564734E+01	2.961406E+05	1.609362E+05	1.028521E+04	1.248200E-01	7.977071E-03
1.387718E+01	8.154598E-04	1.561683E+01	3.551424E+05	1.913929E+05	1.225555E+04	1.484418E-01	9.505241E-03
1.719153E+01	7.837155E-04	1.559267E+01	4.130165E+05	2.210433E+05	1.417610E+04	1.714381E-01	1.099479E-02
2.055193E+01	7.580741E-04	1.557280E+01	4.699531E+05	2.500296E+05	1.605554E+04	1.939196E-01	1.245246E-02
2.737017E+01	7.185566E-04	1.554147E+01	5.815405E+05	3.063969E+05	1.971480E+04	2.376373E-01	1.529053E-02
3.430084E+01	6.889741E-04	1.551739E+01	6.906551E+05	3.610448E+05	2.326711E+04	2.800214E-01	1.804565E-02
4.131846E+01	6.656222E-04	1.549796E+01	7.977763E+05	4.143190E+05	2.673378E+04	3.213402E-01	2.073435E-02
5.553011E+01	6.304065E-04	1.546791E+01	1.007280E+06	5.176300E+05	3.346477E+04	4.014668E-01	2.595482E-02
6.994856E+01	6.045389E-04	1.544518E+01	1.211776E+06	6.175520E+05	3.998388E+04	4.789649E-01	3.101064E-02
9.275616E+01	5.747442E-04	1.541826E+01	1.523654E+06	7.685562E+05	4.984715E+04	5.960817E-01	3.866077E-02

PROPERTIES IN THE COORESPONDING PHYSICAL PLANES

DELTAX	TTLDAW	GWALL	ROTLDAW	MUTLDAW	QDOTW	ST.NO.	2ST/CF
0.	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	4.156115E-01	9.127022E-04	1.388679E+00
9.199400F-02	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	2.975295E-01	6.533886E-04	1.004369E+00
1.820830F-01	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	2.764604E-01	6.071200E-04	9.425301E-01
3.592598F-01	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	2.578137E-01	5.661710E-04	8.956101E-01
7.102470F-01	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	2.383035E-01	5.233256E-04	8.563307E-01
1.061722F+00	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	2.271160E-01	4.987573E-04	8.408151E-01
1.415389F+00	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	2.191633F-01	4.812929E-04	8.332377E-01
2.131008F+00	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	2.063595E-01	4.531750E-04	8.213525E-01
2.859102F+00	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.988123E-01	4.366011E-04	8.223789E-01
3.598862E+00	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.929006E-01	4.236186E-04	8.248092E-01
4.349134F+00	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.879713E-01	4.127939E-04	8.274100E-01
5.875444F+00	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.781278E-01	3.911769E-04	8.234521E-01
7.432647F+00	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.722329E-01	3.782316E-04	8.289114E-01
9.015508F+00	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.673032E-01	3.674056F-04	8.330913E-01
1.061982F+01	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.630290E-01	3.580193E-04	8.360828E-01
1.387718F+01	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.542475E-01	3.387348E-04	8.307823E-01
1.719153F+01	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.490243E-01	3.272643E-04	8.351610E-01
2.055193F+01	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.446463E-01	3.176501E-04	8.380448E-01
2.737017F+01	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.358919E-01	2.984249E-04	8.306231E-01
3.430084F+01	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.309103E-01	2.874852F-04	8.345312E-01
4.131846F+01	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.268001E-01	2.784589E-04	8.366876E-01
5.553011F+01	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.188169E-01	2.609274F-04	8.278067E-01
6.994856E+01	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.144696E-01	2.513806E-04	8.316440E-01
9.275616F+01	5.120042E+00	4.996138E-01	1.953109E-01	5.120042E+00	1.081886E-01	2.375872E-04	8.267581E-01

PROFILES AT STATION RETHETA = 1.300000E+04

X =   15.161899   RFX2 = 1.954895E+07

DEPENDENT VARIABLES.THEIR DERIVATIVES.PROPERTIES IN THE CORRESPONDING PHYSICAL PLANE.AND BOUNDARY LAYER PROPERTIES

CHIBAR= 7.82020E+05   PHI= 2.17321E+01   PI=-2.43133E-01   RBAR= 3.61704E+04   UEBAR= 1.00000E+00   ETILDA= 8.52147E-01
STILDA= 2.13141E-01   CHI= 1.95489E+07   CFBAR= 4.23536E-03   HBAR= 1.24179E+00   RBRDSR= 3.61704E+04   RBRDSR= 3.05957E+03
RRRTRB= 2.46412E+03   CFTHD2= 5.21327E+00   TAULAW= 1.09487E-08   PHIP= 2.03472E-06   PIP=-4.86176E-09   RBARP= 3.38320E-02
UEBARP= 4.21303E-19   ETLDAP=-5.76349E-08   STLDAP=-1.28247E-08   CHIP= 2.66554E+01   DELTAX= 1.51619E+01   CF= 8.03155E-04
H= 1.56075E+01   RDELTA= 3.77576E+05   RDLTSR= 2.02886E+05   DLTSTR= 1.57356E-01   THETA= 1.00826E-02   TTLDAW= 5.12004E+00
GWALL= 4.99614E-01   RTLDAW= 1.95311E-01   MUTLDW= 5.12004E+00   QDOTW= 1.52223E-01   ST= 3.34289E-04   TWSTCF= 8.32480E-01

EXTERNAL QUANTITIES

UEX= 3.45309E+03   RHOFX= 3.10450E-05   MUEX= 8.31438E-08   PEX= 5.71824E+00   TEX= 1.07421E+02   MEX= 6.80000E+00
CONDUC= 6.93022E-04   UEXP= 0.   ROEXP= 0.   MUEXP= 0.   HTILDX= 1.02480E+01   CPX= 6.00136E+03
                HTLDXP= 0.   RHORHW= 1.95311E-01   RHOMUW= 1.00000E+00

FTABAR	ETA	PSI	G	UTILDA	RTILDA	MUTLDA	TTILDA
0.	0.	0.	4.996138E-01	0.	1.953109E-01	5.120042E+00	5.120042E+00
1.89998IE-03	5.06138DE-03	5.000000E+00	5.48A155E-01	1.455115E-01	1.842147E-01	5.428448E+00	5.428448E+00
2.881463E-03	7.766084E-03	1.150000E+01	5.785965E-01	2.206791E-01	1.825122E-01	5.479086E+00	5.479086E+00
3.79520BE-03	1.029138E-02	1.995000E+01	6.090072E-01	2.906590E-01	1.831566E-01	5.459810E+00	5.459810E+00
4.725951F-03	1.243901E-02	3.093500E+01	6.426692E-01	3.619407E-01	1.860612E-01	5.374576E+00	5.374576E+00
5.713574F-03	1.548029E-02	4.521550E+01	6.813857E-01	4.375785E-01	1.918620E-01	5.212080E+00	5.212080E+00
6.795275F-03	1.823305E-02	6.378015E+01	6.970961E-01	4.962326E-01	2.054844F-01	4.866550E+00	4.866550E+00
8.112791E-03	2.144939E-02	8.791419E+01	7.083339E-01	5.160449E-01	2.084966E-01	4.796242E+00	4.796242E+00
9.759672F-03	2.540769E-02	1.192885E+02	7.202674E-01	5.367056E-01	2.119817E-01	4.717387E+00	4.717387E+00
1.181834F-02	3.026910E-02	1.600750E+02	7.328547E-01	5.580992E-01	2.159932F-01	4.629776E+00	4.629776E+00
1.439249F-02	3.622797F-02	2.130975E+02	7.460564E-01	5.801222E-01	2.205924F-01	4.533248E+00	4.533248E+00
1.761273F-02	4.351794F-02	2.820267E+02	7.598363E-01	6.026830E-01	2.258519E-01	4.427681E+00	4.427681E+00
2.164369F-02	5.241878E-02	3.716348E+02	7.741608E-01	6.257021E-01	2.318583F-01	4.312980E+00	4.312980E+00
2.669311F-02	6.326389E-02	4.881252E+02	7.889984E-01	6.491100E-01	2.387166E-01	4.189068E+00	4.189068E+00
3.30232BF-02	7.644834E-02	6.395627E+02	8.043176E-01	6.728455E-01	2.465555E-01	4.055882E+00	4.055882E+00
4.096572F-02	9.243718E-02	8.364316E+02	8.200847E-01	6.968521E-01	2.555340E-01	3.913373E+00	3.913373E+00
5.093974F-02	1.117734E-01	1.092361E+03	8.362602E-01	7.210750E-01	2.658511F-01	3.761504E+00	3.761504E+00
6.347634F-02	1.350851E-01	1.425069E+03	8.527938E-01	7.454566E-01	2.777573E-01	3.600265F+00	3.600265E+00
7.924860F-02	1.630900E-01	1.857590E+03	8.696173E-01	7.699302E-01	2.915713E-01	3.429692E+00	3.429692E+00
9.911100F-02	1.965973E-01	2.419867E+03	8.866342E-01	7.944118E-01	3.077012F-01	3.249906E+00	3.249906E+00
1.24150?F-01	2.365040F-01	3.150827E+03	9.037059E-01	8.187889E-01	3.266716E-01	3.061178E+00	3.061178E+00
1.557513F-01	2.837779E-01	4.101075E+03	9.206337E-01	8.429052E-01	3.491558E-01	2.864051F+00	2.864051E+00
1.956851F-01	3.394585E-01	5.336398E+03	9.371384E-01	8.665415E-01	3.760070E-01	2.659525E+00	2.659525E+00
2.462244F-01	4.046230F-01	6.942318E+03	9.529449E-01	8.893951E-01	4.082687E-01	2.449367E+00	2.449367E+00
3.103004F-01	4.803841F-01	9.030013E+03	9.672908E-01	9.110669E-01	4.471154E-01	2.236559E+00	2.236559E+00
3.917143F-01	5.679167E-01	1.174402E+04	9.800035E-01	9.310833E-01	4.936236E-01	2.025835E+00	2.025835E+00
4.954191F-01	6.685923E-01	1.527222E+04	9.907153E-01	9.490256E-01	5.483531E-01	1.823642E+00	1.823642E+00
6.278610F-01	7.840113E-01	1.985889E+04	9.995656E-01	9.649421E-01	6.125155E-01	1.632612F+00	1.632612E+00
7.973014F-01	9.128922E-01	2.582155E+04	1.003232E+00	9.804675E-01	7.189778E-01	1.390864E+00	1.390864E+00
1.01282DF+00	1.039537E+00	3.357302E+04	9.982601E-01	1.000000E+00	1.01A154E+00	9.821696E-01	9.821696E-01
1.291415F+00	1.179053F+00	4.364993E+04	1.000007E+00	1.000000E+00	9.999333F-01	1.000067F+00	1.000067E+00
1.653589F+00	1.362064F+00	5.674991E+04	1.000000E+00	1.000000E+00	1.000000F+00	1.000000F+00	1.000000E+00
2.124415F+00	1.599970F+00	7.377988F+04	1.000000E+00	1.000000E+00	1.000000E+00	1.000000F+00	1.000000E+00
2.736499F+00	1.909248E+00	9.591884E+04	1.000000E+00	1.000000E+00	1.000000E+00	1.000000F+00	1.000000E+00
3.532185F+00	2.311310E+00	1.246995E+05	1.000000E+00	1.000000E+00	1.000000F+00	1.000000F+00	1.000000E+00
4.566689F+00	2.833989E+00	1.621143E+05	1.000000E+00	1.000000E+00	1.000000F+00	1.000000F+00	1.000000E+00
5.911316F+00	3.513473F+00	2.107536E+05	1.000000E+00	1.000000E+00	1.000000F+00	1.000000F+00	1.000000F+00
7.659459F+00	4.346802F+00	2.739847E+05	1.000000E+00	1.000000E+00	1.000000F+00	1.000000F+00	1.000000E+00

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ETA	RYBAR	Y	RSUBY	TAUFCT	EDDY1	EDDY2	LMIX
0.		0.	0.	0.	1.000000E+00	0.	0.
5.061380E-03	5.872309E+01	1.481939E-03	1.910733E+03	-3.452124E-04	1.123673E+00	1.796287E-05	1.772271E-03
7.766094E-03	1.042237E+02	2.273858E-03	2.931792E+03	-1.203944E-03	1.122708E+00	1.815673E-05	1.796354E-03
1.029138E-02	1.372743E+02	3.013249E-03	3.885124E+03	-2.750301E-03	1.120970E+00	1.777381E-05	1.785500E-03
1.283901E-02	1.709396E+02	3.759178E-03	4.846884E+03	-5.309082E-03	1.118094E+00	1.681370E-05	1.741614E-03
1.548029E-02	2.066623E+02	4.532526E-03	5.843998E+03	-9.378148E-03	1.113520E+00	1.519994E-05	1.659824E-03
1.823305E-02	2.457879E+02	5.338516E-03	6.883200E+03	-1.320165E-02	5.163310E+00	4.859916E-04	6.957402E-03
2.144939E-02	2.934430E+02	6.280240E-03	8.097409E+03	-1.373937E-02	6.161400E+00	5.852176E-04	8.125246E-03
2.540769E-02	3.530114E+02	7.439204E-03	9.591715E+03	-1.447070E-02	7.407283E+00	7.027886E-04	9.531865E-03
3.026910E-02	4.274742E+02	8.842592E-03	1.142696E+04	-1.546339E-02	8.961854E+00	8.411664E-04	1.121820E-02
3.622797E-02	5.205823E+02	1.060731E-02	1.367650E+04	-1.680833E-02	1.090103E+01	1.002876E-03	1.323013E-02
4.351794E-02	6.370596E+02	1.274177E-02	1.642856E+04	-1.862727E-02	1.331930E+01	1.190383E-03	1.561818E-02
5.241878E-02	7.828613E+02	1.534787E-02	1.978873E+04	-2.108313E-02	1.633401E+01	1.405913E-03	1.843689E-02
6.326389E-02	9.655008E+02	1.852325E-02	2.388290E+04	-2.439348E-02	2.009038E+01	1.651190E-03	2.174344E-02
7.648836E-02	1.194466E+03	2.238357E-02	2.886019E+04	-2.884821E-02	2.476739E+01	1.927081E-03	2.559565E-02
9.243718E-02	1.481747E+03	2.706500E-02	3.489617E+04	-3.483243E-02	3.058455E+01	2.233136E-03	3.004893E-02
1.117734E-01	1.842512E+03	3.272652E-02	4.285553E+04	-4.285553E-02	3.780947E+01	2.567027E-03	3.515245E-02
1.350851E-01	2.295966E+03	3.955202E-02	5.099628E+04	-5.358713E-02	4.676652E+01	2.923915E-03	4.094472E-02
1.630900E-01	2.866455E+03	4.775167E-02	6.156847E+04	-6.789961E-02	5.784670E+01	3.295819E-03	4.744948E-02
1.965973E-01	3.584886E+03	5.756239E-02	7.421790E+04	-8.691408E-02	7.152017E+01	3.671154E-03	5.467393E-02
2.365040E-01	4.490564E+03	6.924680E-02	8.928315E+04	-1.120416E-01	8.835398E+01	4.034667E-03	6.261294E-02
2.837779E-01	5.635589E+03	8.308830E-02	1.071296E+05	-1.450011E-01	1.090410E+02	4.368153E-03	7.126554E-02
3.394585E-01	7.078011E+03	9.939120E-02	1.281498E+05	-1.877776E-01	1.344495E+02	4.652356E-03	8.067321E-02
4.046230E-01	8.906039E+03	1.184710E-01	1.527502E+05	-2.424623E-01	1.656977E+02	4.870160E-03	9.099064E-02
4.803941E-01	1.122370E+04	1.406533E-01	1.813509E+05	-3.109042E-01	2.041875E+02	5.009628E-03	1.025797E-01
5.679167E-01	1.416847E+04	1.662822E-01	2.143955E+05	-3.941907E-01	2.510712E+02	5.058476E-03	1.159676E-01
6.685923E-01	1.791948E+04	1.957594E-01	2.524018E+05	-4.924734E-01	3.031010E+02	4.951985E-03	1.306378E-01
7.840113E-01	2.270999E+04	2.295533E-01	2.959739E+05	-6.076235E-01	3.316011E+02	4.343281E-03	1.376861E-01
9.128922E-01	2.883872E+04	2.672888E-01	3.446280E+05	-7.579415E-01	2.380965E+02	2.260695E-03	9.897400E-02
1.039537E+00	3.663411E+04	3.043694E-01	3.924378E+05	-1.000000E+00	1.000000E+00	0.	0.
1.179053E+00	4.671102E+04	3.452190E-01	4.451071E+05	-1.000000E+00	1.000000E+00	0.	0.
1.362064E+00	5.981100E+04	3.988034E-01	5.141960E+05	-1.000000E+00	1.000000E+00	0.	0.
1.599970E+00	7.684097E+04	4.684607E-01	6.040085E+05	-1.000000E+00	1.000000E+00	0.	0.
1.909246E+00	9.897993E+04	5.590153E-01	7.207647E+05	-1.000000E+00	1.000000E+00	0.	0.
2.311310E+00	1.277606E+05	6.767362E-01	8.725478E+05	-1.000000E+00	1.000000E+00	0.	0.
2.833999E+00	1.651754E+05	8.297734E-01	1.069866E+06	-1.000000E+00	1.000000E+00	0.	0.
3.513473E+00	2.138147E+05	1.028722E+00	1.326379E+06	-1.000000E+00	1.000000E+00	0.	0.
4.396802E+00	2.770458E+05	1.287355E+00	1.659847E+06	-1.000000E+00	1.000000E+00	0.	0.

AXI-SYMMETRIC PROPERTIES IN CORRESPONDING PHYSICAL PLANES

DELTAX	CF	H	RDELTA	RDLTSTR	RTHETA	DLTASTR	THETA
0.	2.255174E-03	3.719857F+00	4.107097F+04	1.221300E+04	3.283191E+03	7.761486E-03	2.086501E-03
1.973599F-03	2.216294E-03	3.832446F+00	4.185274E+04	1.271956E+04	3.318916F+03	8.074971E-03	2.107002E-03
3.924122E-03	2.195091E-03	3.860670F+00	4.236165F+04	1.295102E+04	3.354605E+03	8.213438E-03	2.127465E-03
7.866311F-03	2.154798E-03	3.879435F+00	4.327515E+04	1.329656E+04	3.427449E+03	8.415168F-03	2.169174E-03
1.590357F-02	2.093724E-03	3.888523F+00	4.508007E+04	1.391434E+04	3.578310F+03	8.769924E-03	2.255336E-03
2.375432E-02	2.028370F-03	3.890104E+00	4.695274E+04	1.453110E+04	3.735400E+03	9.121435E-03	2.344779E-03
3.166264F-02	1.963354E-03	3.889194E+00	4.890882F+04	1.516086E+04	3.898202F+03	9.478815F-03	2.437218E-03
3.948358F-02	1.893850E-03	3.887496F+00	5.095391F+04	1.580763E+04	4.066276E+03	9.844758F-03	2.532416E-03
4.718059F-02	1.835137F-03	3.885753E+00	5.309068E+04	1.647264E+04	4.239240F+03	1.022018F-02	2.630167E-03
5.587392E-02	1.769712E-03	3.862072F+00	5.539346F+04	1.722271E+04	4.459448E+03	1.057807E-02	2.738963E-03
6.498965F-02	1.703314F-03	3.826540E+00	5.784384F+04	1.802841E+04	4.711414F+03	1.092935F-02	2.856198E-03
7.391311F-02	1.637030F-03	3.792628E+00	6.040138E+04	1.885121E+04	4.970487E+03	1.129102E-02	2.977098E-03
8.353580F-02	1.574629E-03	3.750970E+00	6.312911E+04	1.975523E+04	5.266700F+03	1.165596F-02	3.107452E-03
9.306122F-02	1.514304F-03	3.708785E+00	6.595951E+04	2.067406E+04	5.574348F+03	1.202534E-02	3.242394E-03
1.025960F-01	1.455484F-03	3.668208F+00	6.892925E+04	2.162128E+04	5.894236F+03	1.241041F-02	3.383234E-03
1.129274F-01	1.393893F-03	3.631384F+00	7.216538F+04	2.265976E+04	6.239981F+03	1.283898F-02	3.535563E-03
1.229123F-01	1.342131F-03	3.596485F+00	7.555306F+04	2.373155E+04	6.598541E+03	1.328682F-02	3.694389E-03
1.337789F-01	1.290740F-03	3.559081F+00	7.919594E+04	2.490379E+04	6.999220F+03	1.375786F-02	3.866651E-03
1.445352F-01	1.235045F-03	3.518454F+00	8.298768E+04	2.610104E+04	7.418328F+03	1.423604F-02	4.046107E-03
1.557086F-01	1.185501F-03	3.482631E+00	8.705124E+04	2.736159E+04	7.856588F+03	1.475525E-02	4.236811E-03
1.674221F-01	1.136399F-03	3.451647F+00	9.146913E+04	2.872531E+04	8.322203F+03	1.533447F-02	4.442653E-03
1.923200F-01	1.036669F-03	3.391988E+00	1.014229E+05	3.180061E+04	9.375211F+03	1.664730F-02	4.907829E-03
2.197743F-01	9.409125F-04	3.332634E+00	1.132743E+05	3.549454E+04	1.065060E+04	1.822028E-02	5.467233E-03
2.514919F-01	8.431904E-04	3.252052F+00	1.274065E+05	4.006636E+04	1.232033F+04	2.003527F-02	6.160808E-03
2.674154F-01	7.934994F-04	3.210559E+00	1.351959E+05	4.267674E+04	1.329262E+04	2.104784F-02	6.555818E-03

AXI-SYMMETRIC PROPERTIES IN CORRESPONDING PHYSICAL PLANES

DELTAY	XAXIS	GWALL	R/LREF	REY NO.	QDOTW	ST.NO.	2ST/CF
0.	4.000000E-01	8.921674E-01	7.264024E-02	3.147078E+06	0.	0.	0.
1.973549E-03	4.019735E-01	9.322574E-01	7.226801E-02	3.165912E+06	0.	0.	0.
3.928122E-03	4.039241E-01	9.431245E-01	7.189938E-02	3.184587E+06	0.	0.	0.
7.866311E-03	4.078663E-01	9.517553E-01	7.115662E-02	3.222289E+06	0.	0.	0.
1.580357E-02	4.158036E-01	9.589137E-01	6.965962E-02	3.298565E+06	0.	0.	0.
2.375432E-02	4.237543E-01	9.631021E-01	6.816008E-02	3.375354E+06	0.	0.	0.
3.156264E-02	4.316626E-01	9.660350E-01	6.666853E-02	3.452108E+06	0.	0.	0.
3.948353E-02	4.394836E-01	9.682905E-01	6.519347E-02	3.528373E+06	0.	0.	0.
4.718059E-02	4.471806E-01	9.701203E-01	6.374179E-02	3.603774E+06	0.	0.	0.
5.573392E-02	4.553739E-01	9.716559E-01	6.212271E-02	3.711160E+06	0.	0.	0.
6.494956E-02	4.649896E-01	9.729797E-01	6.043532E-02	3.835096E+06	0.	0.	0.
7.341311E-02	4.731131E-01	9.741411E-01	5.880199E-02	3.955332E+06	0.	0.	0.
8.353590E-02	4.835354E-01	9.751715E-01	5.711702E-02	4.097631E+06	0.	0.	0.
9.306122E-02	4.930612E-01	9.760850E-01	5.548187E-02	4.238373E+06	0.	0.	0.
1.025960E-01	5.025960E-01	9.769002E-01	5.397796E-02	4.378088E+06	0.	0.	0.
1.129274E-01	5.129274E-01	9.776368E-01	5.223517E-02	4.526376E+06	0.	0.	0.
1.229123E-01	5.229123E-01	9.783161E-01	5.064749E-02	4.669863E+06	0.	0.	0.
1.337749E-01	5.337749E-01	9.789458E-01	4.902289E-02	4.831100E+06	0.	0.	0.
1.445352E-01	5.445352E-01	9.795210E-01	4.743910E-02	4.991886E+06	0.	0.	0.
1.557066E-01	5.557066E-01	9.800458E-01	4.585599E-02	5.152429E+06	0.	0.	0.
1.674221E-01	5.674221E-01	9.805309E-01	4.425870E-02	5.314619E+06	0.	0.	0.
1.923200E-01	5.923200E-01	9.813987E-01	4.103661E-02	5.657415E+06	0.	0.	0.
2.197743E-01	6.197743E-01	9.821858E-01	3.774727E-02	6.036844E+06	0.	0.	0.
2.514919E-01	6.514919E-01	9.828934E-01	3.438271E-02	6.514241E+06	0.	0.	0.
2.674184E-01	6.674184E-01	9.832480E-01	3.280444E-02	6.766309E+06	0.	0.	0.

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VIII. DESCRIPTION OF ROUTINES

Deck Name

AXISYM
This routine uses the Mangler Transformation to convert the axisymmetric inputs to a corresponding two-dimensional set of coordinates. Once the two-dimensional solution has been obtained, this routine is also used to convert back to the physical axisymmetric plane. A flow chart of this routine is included at the end of this section.

BLOCK DATA
All pre-set data and default-option data are stored and initialized in this routine.

BLPROP
This routine calculates all the boundary layer properties in both the transformed and physical planes and sets up the output arrays for x, Re_θ, Re_x and G.

CHSUB
This routine is called by the integration package to perform certain tests. At present it is a dummy.

CLEM7X
This routine is a service routine for the equilibrium-chemistry package and solves a system of simultaneous equations using the method known as pivotal condensation.

COEFFS
This routine calculates the coefficients for the matrix of ordinary differential equations and their solution vector.

CONV
This subroutine converts specific properties from PSI coordinates to ETA coordinates and generates the velocity profile UTILDA.

DEFINT   This routine calculates certain definite integrals,
            their related quantities and certain important
            derivatives for both the Crocco and non-Crocco
            integral portions of the calculation for each of
            the different viscosity-law options and wall
            conditions.

DERSUB   This routine is called by the integration package
            to evaluate the derivatives of the dependent
            variables. It, in turn, contains the logic which
            calls the routines which solve the energy equation;
            determine the proper edge conditions, determine the
            coefficients needed to solve the matrix of ordinary
            differential equations and invert that matrix. A
            flow chart of this routine is presented at the end
            of this section.

ERROR   This routine prints all error messages and sets
            up the standard error termination mode of the
            program. When termination is complete, this
            routine returns to the true main program (sub-
            routine Main) for processing of the next case or
            run termination.

FPRIM   This function sub-program is used by the service
            routine, NERIT, to evaluate the derivative of the
            function required to find the ETA associated
            with a particular PSI.

FUNCT   This function sub-program is used by various
            routines in the program to; (a) evaluate the
            integrand required to find the integral I3ETA
            (from subroutines, PROFIL and THERMO), (b)
            evaluate the function required to find the ETA
            associated with a particular PSI (from subroutines
            INIT3 and CONV), and (c) evaluate the function
            required to determine the reference length and the
            transformed 2-D coordinates for an axisymmetric
            case (from AXISYM).

Deck Name

GENL7X   This routine is the essential part of the
                 equilibrium-chemistry package used in this program.
                 Given the pressure and the temperature, enthalpy or
                 entropy, this routine generates the remaining
                 thermodynamic properties for 8-specie-air
                 using curve-fit data. It should be noted that
                 GENL7X is a general chemistry routine which can
                 be generated for a wide variety of gaseous chemical
                 systems via a chemistry-routine-generator program
                 (Ref. 4) developed at GASL.

GETFS   This subroutine calculates some of the coefficients
                 required in the solution of the energy equation.

GETPHI   This routine calculates quantities required to
                 determine the coefficients of the tri-diagonalized
                 matrix used in solving the energy equation. In
                 addition, it also stores the G profile into the
                 GOLD array after the completion of an integration
                 step.

HSITER   This routine does essentially a Mollier-type
                 calculation (i.e., when presented with the enthalpy
                 and entropy of a mixture of gases, it uses the
                 equilibrium chemistry package to determine the
                 pressure and temperature of the mixture via an
                 iteration. It is used only with the equilibrium-
                 chemistry package and then only when the external
                 velocity as a function of axial distance is input.

INITL1   This subroutine calculates the remaining free stream
                 or reference condition quantities, calculates and
                 tabulates all the external quantities and their
                 derivatives, and generates the initial wall-enthalpy
                 ratio.

INT1A   The integration package which is a closed routine used to solve the set of ordinary differential equations. It is a fifth-order integration routine which uses a classicial fourth-order Runge-Kutta formula in conjunction with Richardson's Extrapolation to the Limit Theory. The routine provides for variable step size with the computing interval varied to meet local relative truncation-error tolerances, independently, on each of the dependent variables. The routine uses the single precision mode exclusively.

INIT2   This subroutine calculates certain constants required by the program. The first group depends on ETASTR while the second group is associated with the mesh parameters and is needed in the solution of the energy equation. The third group contains the members of the two-dimensional array, A, which are needed for both the adiabatic and non-adiabatic wall options. In addition, certain miscellaneous constants depending on the initial conditions and laminar sublayer properties are evaluated depending upon the viscosity option selected. A flow chart of this routine is included at the end of this section.

INIT3   This subroutine initially forms the arrays G, I3ETA, UTILDA, RTILDA, MUTLDA, ETABAR and PSI using a Crocco-integral solution to the energy equation.

INPUT   This routine is responsible for input of all required program data and options. It, in turn, calls the necessary routines to; (a) convert the units of all input quantities to the desired system, (b) to complete the evaluation of freestream or reference conditions, (c) to evaluate external quantities, and (d) to convert axisymmetric input information to transformed two-dimensional coordinates. A flow chart of this routine is included at the end of this section.

Deck Name

LAGDER

This is a service routine which numerically calculates the derivative of a function using the Lagrangian scheme.

LAGR

This is another service routine which when given tables of an independent variable, x, and a function $y = F(x)$ will find, by Lagrangian interpolation, (up to tenth order) the value of y_n associated with a particular x_n.

LGRANG

This service routine interpolates to any desired order from tabulated values of one or more functions of a single independent variable. (It is similar to the above service routine but is more general.)

MAIN

This subroutine is, in reality, the true main program. It sets up all the internal switches, sets up the initial values of the dependent variables for the integration package, sets up and increments all counters and terminates the program in a non-error mode. It is the only program routine which contains all the common blocks.

MATRIX

This subroutine calculates the coefficients of the tri-diagonal matrix which has been generated by writing the energy equation in finite difference form.

NERIT

This service routine when given a function $F(x)$ and its derivative $F'(x)$, finds the zeros of $F(x)$ within some prescribed interval (a,b).

OUTPUT

This routine, once integration has begun, processes all program output. Two separate entry points are included for processing the output of profile information and for processing the output for the special blocks of information printed in the axisymmetric option.

Deck Name

PRFILE   This subroutine sets up the necessary inter-
polations of boundary layer properties required to
obtain profiles at pre-specified points. In
addition, it sets up the interpolation to obtain
the enthalpy profile at a particular profile point.
A flow chart of this routine is included at the
end of this section.

PRINT   This subroutine sets up the output format and prints
all the unit designations, option selections, case
identifying information, free stream or
reference condition information and control card
selections.

PRNDL   This routine extracts the laminar Prandtl number
from tabulated information in Reference 5 as a function
of temperature only. The pressure is included in
the calling sequence for possible future extensions.

PRNDLT   This routine has been included to permit extraction
of the turbulent Prandtl from tabulated or curve fit
data. At present, this routine is a dummy, but the
calling sequence permits specification of this para-
meter as a function of any two variables.

PROFIL   This routine calculates certain profile properties
required in order to solve the energy equation.
A separate entry point, PRFL2, is provided for the
evaluation of EDDY2, LMIX, ETA, YDIS, RYBAR and
RSUBY, which are calculated and printed at a
particular profile point.

SIMQ   This service routine solves the system of linear
ordinary differential equations AY = B by matrix
inversion.

STDM   This service routine is used to obtain a solution
to the energy equation by the inversion of a
tri-diagonalized matrix. The enthalpy profile thus
obtained is valid down to but not including the
wall. The computation for the wall enthalpy is
treated separately.

STICKY

This subroutine calculates all the transport properties for the options which are available in this program. A separate entry point, PERFCT, is provided for the calculation of the viscosity from a $\mu \sim T^n$ law or from Sutherland's Law.

TBLAYR

This is a dummy main program and is simply a device for permitting the true main program, subroutine MAIN, to be referenced by other program subroutines. This provides for ease of handling multiple case input.

THERMO

This subroutine, when presented with boundary layer external conditions and velocity and enthalpy profiles, calculates the remaining thermodynamic and transport properties of the fluid, as a function of y, after which it normalizes these quantities, and then constructs profiles of them. This function is performed with either the perfect gas or equilibrium chemistry options. In addition, the routine calculates the density and density-viscosity ratios at the wall, RHORHW and RHOMUW, respectively, and updates the integral, I3ETA. A flow chart of this routine is presented at the end of this section.

TRAPIN

This is a service routine which performs numerical integration by quadratures using the trapezoidal rule.

XTERNL

This subroutine calculates the requisite external conditions and their derivatives at a prescribed station along the body by Lagrangian interpolation of existing tables of this information constructed by the INITL1 routine. In addition, this routine calculates, (a) certain other quantities which depend only on these external conditions, (b) certain logarithmic derivatives needed elsewhere in the program, and the normalized wall quantities for a non-adiabatic case. A major portion of this routine is bypassed for the flat plate (i.e. dp/dx=0) option.

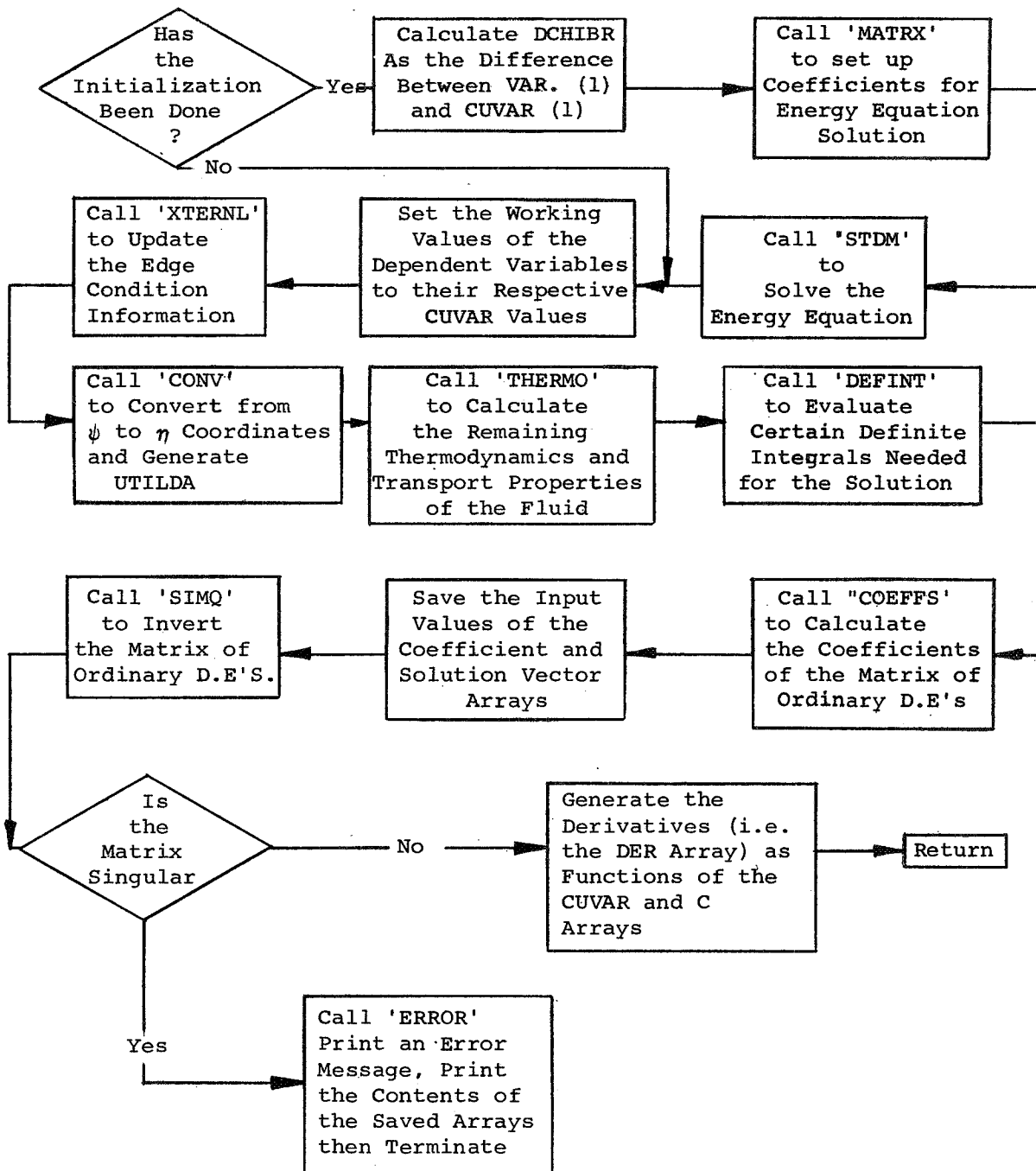## Deck Name

UNITS   This subroutine makes all the necessary unit
         conversions between English system engineering
         units and S.I. (International) units for all
         input and output information. Five separate
         entry points are provided in this routine to
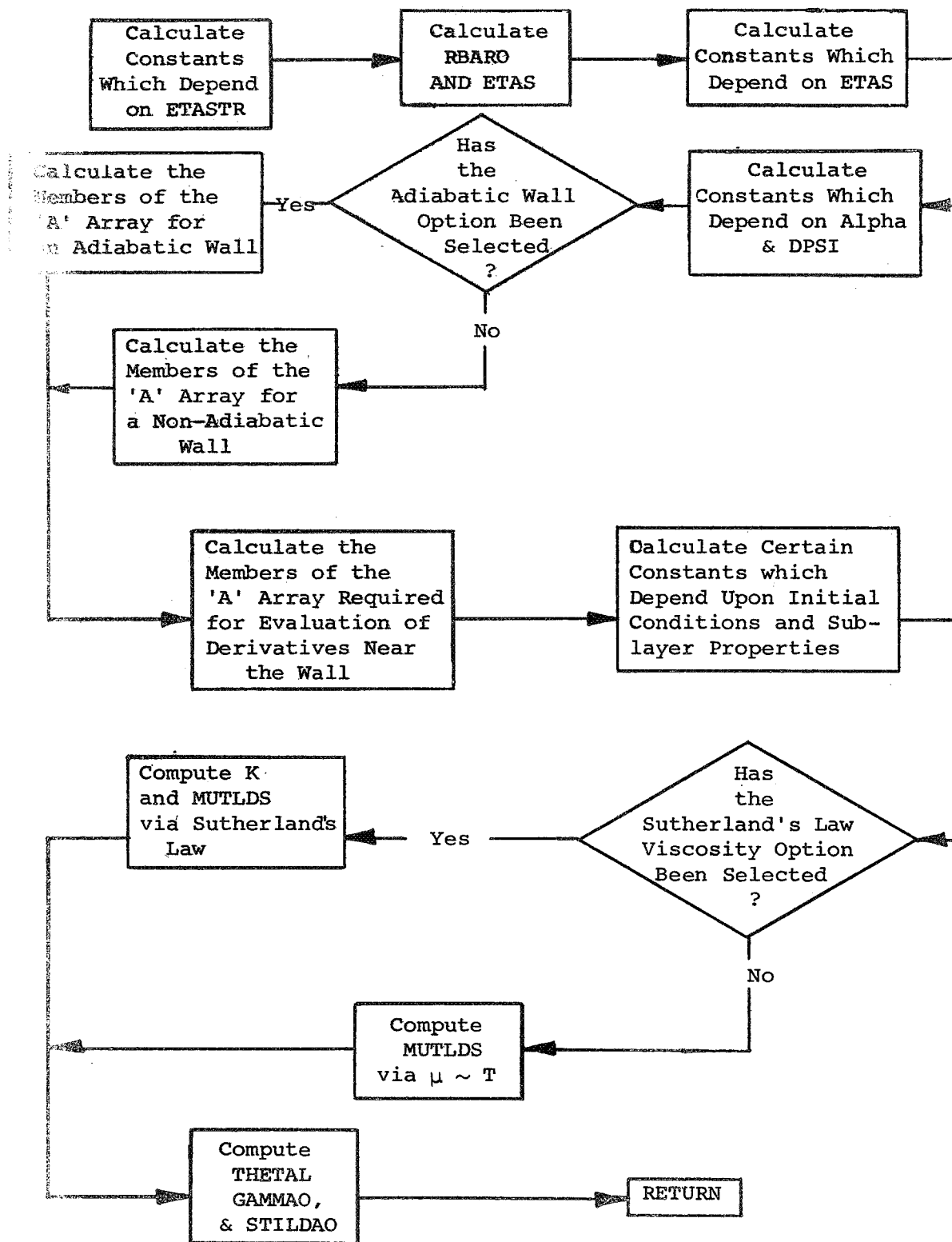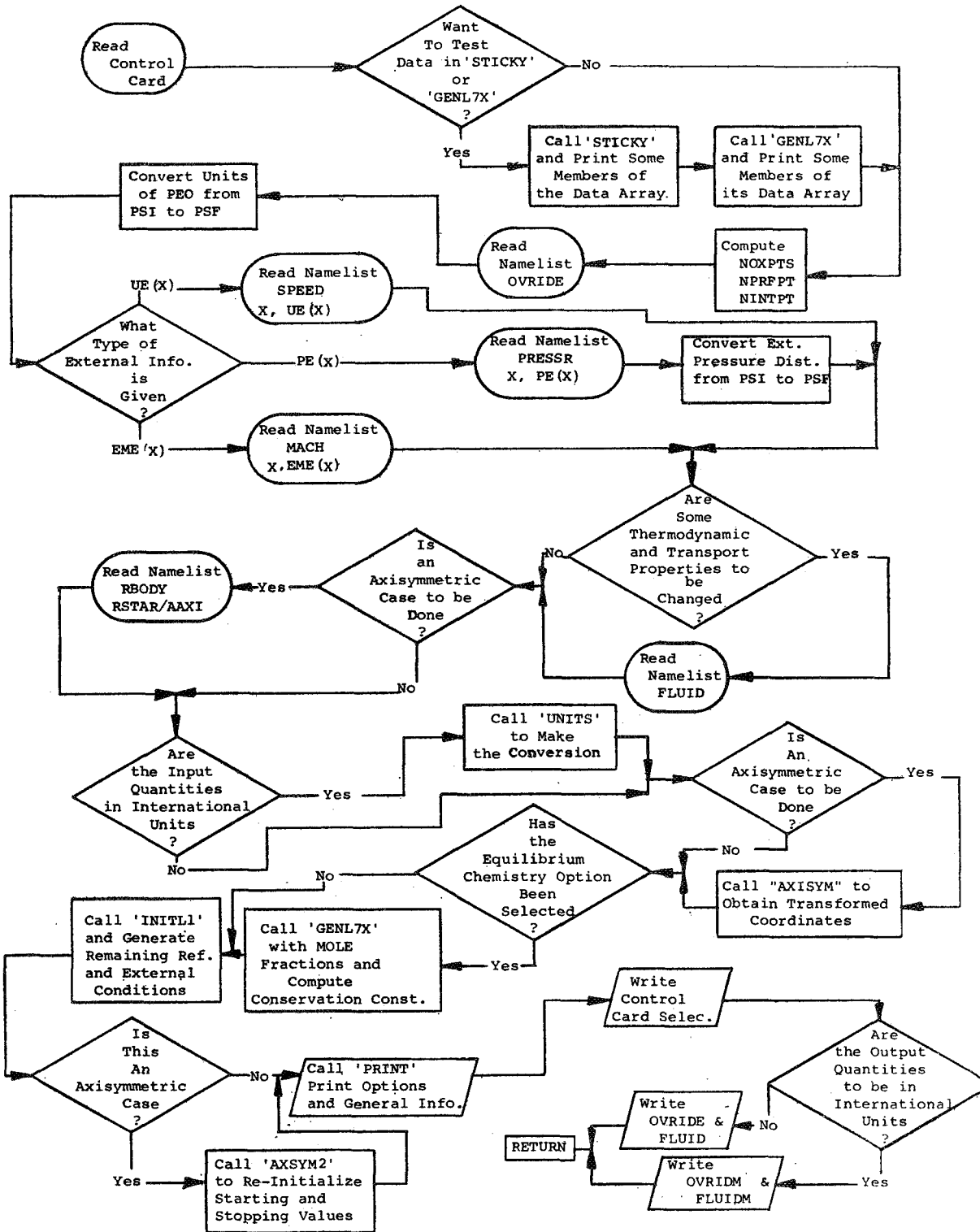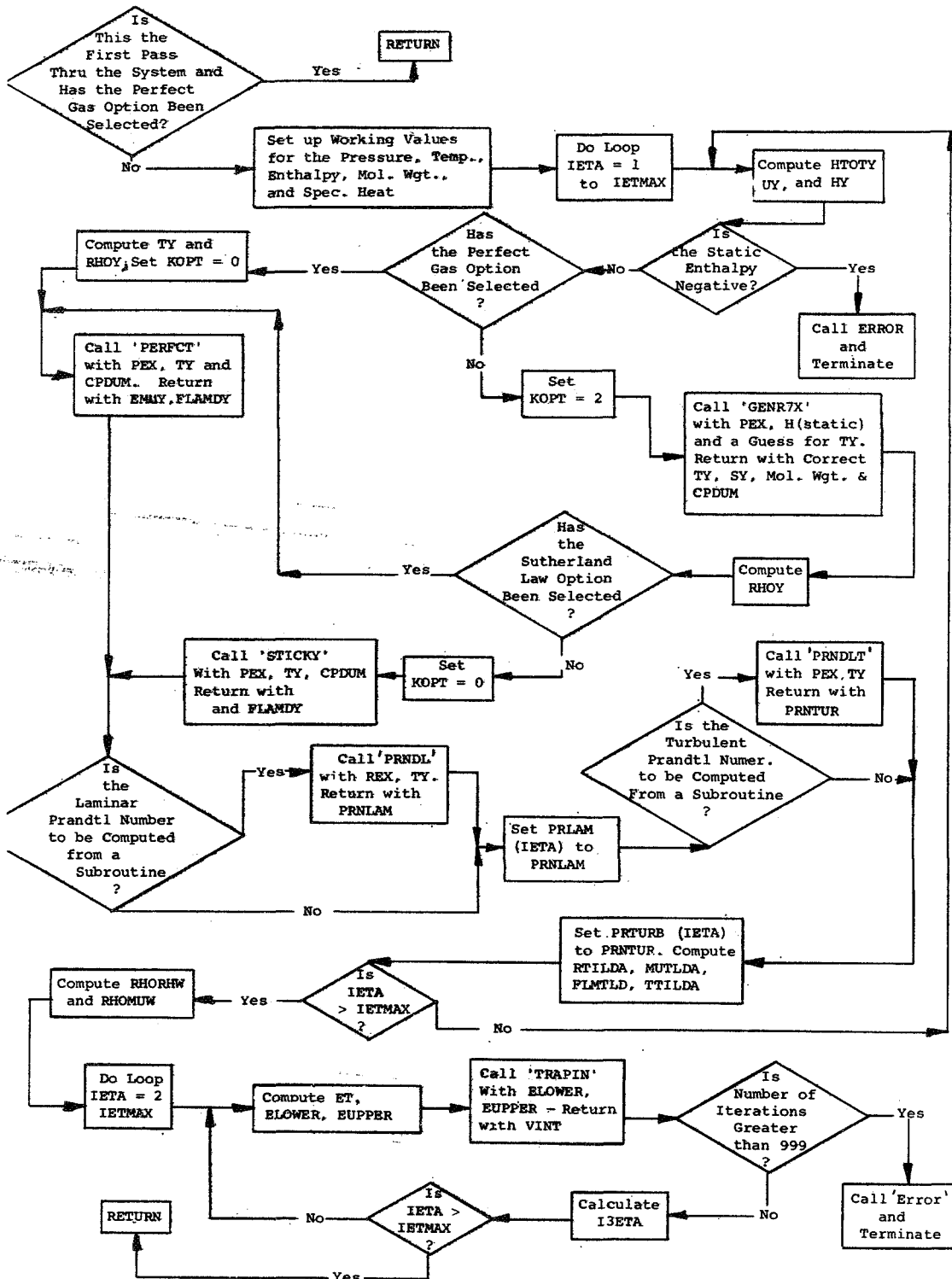   facilitate the conversion.

Set XSTARO to XO, JAXI to NC(15) and IN to 1

Has the Tabular Form of Input for the Geometry Been Selected ? → No → Do Loop JAX = 1 to JAXI → Do Loop IX = IN to NOXPTS

Yes

Is The Current Value of X > the Terminating Value For This Portion of the Fits ? → No

Yes

Evaluate DRSDX(IX) From Polynomial Coefficients ← Evaluate RSTAR(IX) from the Polynomial Coeff.

Is The Loop on IX Complete ? → No → Increment (IX)

Yes → Set IN = IX → Is the Loop on JAX Complete ? → No → Increment (JAX)

Yes

Call 'ERROR' and Terminate Program

Call 'LAGDER' to Calculate DRSDX from Tables of X & RSTAR → Call 'LAGR' to Compute RSTARO from X and RSTAR Given XSTARO → Has Interpolation Been Completed Successfully ? → No → (above) / Yes

Call 'TRAPIN' to Calculate the Transformed 2-D Coordinates (Do Loop)

RETURN ← (Do Loop) Store Values of Stretched 2-D Coordinates in the X Array ← (Do Loop) Set up a New Array (XAXI) to Store Orig. Values of Axi. Coor.

Entry AXSYM2 → Call 'LAGR' To Recompute Starting Value, XO, Given XSTARO → Has Interpolation Been Completed Successfully ? → No → Call 'ERROR' and Terminate PGM / Yes → Calculate XSTMAX

Has Interpolation Been Successfully Completed ? → Yes → Compute CHIMAX → RETURN
No → Call 'ERROR' and Terminate → No

Call 'LAGR' to Recompute Stopping Value, XL Given XSTMAX

Entry AXSYM4 → Do Loop I2D = 1 to XCOUNT → Compute X2DI → Call 'LAGR' to Interpolate for RSAX1, Given X2DI and Tables of X2D and RSTAR → Has Interpolation Been Completed Successfully ?

Has Interpolation Been Completed Successfully ? → Yes → Calculate All the Axisymmetric Forms of the Boundary Layer Properties

Call 'LAGR' to Interpolate for XSAXI Given X2DI and Tables of X2D & YAXI → Yes

No

Store the Axisymmetric Properties in the First Three Columns of the OUTRYY Array → Set up the Output Array AXIPRO for the Axisymmetric Boundary Layer Properties → Is the Loop on I2D Complete ? → Yes → RETURN

No → Increment I2D

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SUBROUTINE DERSUB

```
                  ┌─────────────────┐      ┌───────────────────┐
  ╱ Has ╲         │ Calculate DCHIBR│      │  Call 'MATRX'     │
 ╱  the  ╲  Yes   │ As the Difference│     │  to set up        │
╱Initialization╲─────▶│ Between VAR. (1)│───▶│ Coefficients for │───┐
╲Been Done╱       │  and CUVAR (1)  │      │  Energy Equation  │   │
 ╲   ?  ╱         └─────────────────┘      │     Solution      │   │
  ╲────╱                                   └───────────────────┘   │
    │                                                              │
    No ──────────────────────────────────────────────┐            │
                                                      │            │
┌─────────────┐    ┌─────────────────┐      ┌────────▼────────┐   │
│Call 'XTERNL'│    │ Set the Working │      │   Call 'STDM'   │   │
│ to Update   │    │  Values of the  │      │      to         │◀──┘
│ the Edge    │◀───│Dependent Variables│◀───│  Solve the      │
│ Condition   │    │to their Respective│    │ Energy Equation │
│ Information │    │   CUVAR Values   │      └─────────────────┘
└─────────────┘    └─────────────────┘
    │
┌───▼─────────┐    ┌─────────────────┐      ┌───────────────────┐
│Call 'CONV'  │    │  Call 'THERMO'  │      │  Call 'DEFINT'    │
│to Convert from│  │  to Calculate   │      │  to Evaluate      │
│ψ to η Coordinates│─│ the Remaining  │────▶│ Certain Definite  │──┐
│and Generate │    │Thermodynamics and│     │ Integrals Needed  │  │
│   UTILDA    │    │Transport Properties│   │ for the Solution  │  │
└─────────────┘    │   of the Fluid  │      └───────────────────┘  │
                   └─────────────────┘                             │
┌─────────────┐    ┌─────────────────┐      ┌───────────────────┐  │
│Call 'SIMQ'  │    │ Save the Input  │      │  Call "COEFFS'    │  │
│ to Invert   │    │  Values of the  │      │ to Calculate      │  │
│the Matrix of│◀───│ Coefficient and │◀─────│ the Coefficients  │◀─┘
│Ordinary D.E'S.│  │ Solution Vector │      │ of the Matrix of  │
└─────────────┘    │     Arrays      │      │  Ordinary D.E's   │
    │              └─────────────────┘      └───────────────────┘
    │
  ╱───╲           ┌───────────────────┐
 ╱ Is  ╲          │ Generate the      │
╱  the  ╲   No    │ Derivatives (i.e. │      ┌────────┐
╲ Matrix ╱──────▶ │ the DER Array) as │─────▶│ Return │
 ╲Singular╱       │ Functions of the  │      └────────┘
  ╲────╱          │ CUVAR and C       │
    │             │ Arrays            │
    │             └───────────────────┘
   Yes  ┌───────────────────┐
    │   │ Call 'ERROR'      │
    │   │ Print an Error    │
    └──▶│ Message, Print    │
        │ the Contents of   │
        │ the Saved Arrays  │
        │ then Terminate    │
        └───────────────────┘
```

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SUBROUTINE INIT2

SUBROUTINE INPUT

SUBROUTINE THERMO

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SUBROUTINE PROFILE

IX. PROGRAM USE, OPERATION, AND LIMITATIONS

This program is designed for use on the CDC 6600 series computer. All coding has been done in standard FORTRAN IV language with the idea of making the program as readily convertible to other computer systems as possible. The source program is approximately 5000 cards and has been compiled and executed on both the standard run FORTRAN and Extended FORTRAN CDC systems. No intermediate utility tapes are required.

With little modification, the program may be executed on an IBM System/360 Computer. To accomplish this, the following subroutines would have to be replaced with their System/360 counterparts:

GENL7X

STICKY

forms of the data statements which store curve fit information into multiple subscripted arrays is not compatible between the systems

COEFFS

the members of the AA and C one-dimensional arrays constructed in this routine were formed from a two-dimensional array. The conversion is not the same in both systems.

INT1A

the present form of the integrator package takes advantage of the word size of the CDC 6600 series computer to afford adequate control of round-off error without resort to some double precision computation – a companion integrator package, INT1, which uses a "partial double-precision mode" of operation should be used for program execution on the System/360 computers.

The program may be batch-processed with others and any number of cases may be input at one time. The program logic (including common block) requires approximately 33,000 decimal locations ($\approx 100,000_8$) for execution and an additional $14,000_8$ for loading on the 6600 series computer. Program execution time depends to a large extent on the options selected and the problem attempted. Present experience indicates computation time in the range of from 1/2 to 1-1/2 seconds per integration step.

Most of the present program limitations have been mentioned elsewhere in the text. They are summarized below:

1) A maximum of 50 data points may be specified in the axial direction.

2) The $\bar{\psi}$-mesh is permitted to grow to a maximum of 50 points.

3) The subroutine which generates the laminar Prandtl number has tabulated data which is a function of temperature only.

4) The subroutine for generating the turbulent Prandtl number is at present a dummy routine.

5) Only NINTPT Print Control is available in the present version of the program.

Two sections of the program have, as yet, not been thoroughly tested. These are:

1) the routine which calculates transport properties as functions of pressure and temperature - the user is advised to use the $\mu \sim T^n$ or Sutherland law formulations at present,

2) the equilibrium chemistry package - the user is advised to use the perfect gas option of the program at present.

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5. De Rienzo, P., and Pallone, A., "Convective Stagnation Point Heating for Reentry Speeds up to 70,000 feet/second Including Effects of Large Blowing Rates," AVCO RAD, RAD-TM-65-68, January 1966.

TABLE OF SYMBOLS AND PROGRAM NOTATION

NOTE: When appropriate the correspondence between program
        notation and the notation utilized in Part I of this
        report is given in parentheses.

ALPHA $(\bar{\alpha})$ — a variable grid system parameter

$a_1 \rightarrow a_5$ — polynomial coefficients used for geometry
                          specification in conjunction with the axi-
                          symmetric option.

A   — the 2-D array of constants used to evaluate
               wall quantities for the various wall options.

ACONST(A)   — law of the wall constant

AA   — a 1-D array of coefficients used to solve the
               system of ordinary differential equations.

B(b)   — mixing length constant

BETA (β) — Clauser eddy viscosity parameter

C   — the solution vector for the system of ordinary
               differential equations.

CP   — the constant pressure specific heat capacity
               of the gas — ft^2/sec^2 ${}^\circ R$ or Joules/kg ${}^\circ K$

CPE   — local external value of CP

CHIBAR$(\bar{\chi})$ — streamwise independent variable of the system

CHI (χ) — the physical streamwise Reynolds number,
                   a dependent variable

CHIO(χ_o) — the initial value CHI

CHIP(χ') — the derivative of the dependent variable, CHI

CHIMAX   — the maximum value of CHI — an input used for
               normal case termination.

CAYPRM   — Sutherland Viscosity Law constant — ${}^\circ R$ or ${}^\circ K$.

COLD   — the solution vector, C, before being operated on
               by the matrix inversion routine, SIMQ.

CFBAR$(\bar{c}_f)$ — the skin friction coefficient in the transformed
                      plane.

CF (c_f) – the skin friction coefficient in the physical plane.

CFRTHT/2   –
$(c_f R_\theta /2)$

DPSI $(\Delta \bar{\psi})$ – the minimum increment, PSI

DCHIBR $(\Delta \bar{\chi})$ – the initial increment of CHIBAR

DCIMAX   – the maximum permitted increment of CHIBAR.

DRSDXI   – a derivative needed to transform axisymmetric coordinates to 2-D coordinates.

DPEDX (dp_e/dx) – lbs/ft^2/ft or Newton/m^2/m

DUEDX (dU_e/dx) – ft/sec/ft or meters/sec/meter

DROEDX $(d\rho_e/dx)$ – slugs/ft^3/ft or kg/m^3/m

DMUEDX $(d\mu_e/dx)$ – lbs sec/ft^2/ft or Newton-sec/m^2/m

DEMDEX (dM_e/dx) – ft^{-1} or meters^{-1}

DTEDX (dT_e/dx) – $^\circ$R/ft or $^\circ$K/meter

The derivatives of the external pressure, velocity, density, viscosity, Mach number, and static temperature, respectively.

DELTAX (Δx) – the axial displacement along the body-ft or meters

DLTASTR $(\delta*)$ – the notation used in the output format for the physical displacement thickness – ft or meters

ELE1   – a 1-D array containing the upper bound of the local relative truncation errors

ELE2   – a 1-D array containing the lower bound or relative zero for each dependent variable

EMUW (μ_w) – the viscosity of the fluid at the wall – lbs-sec/ft^2 or Newtons-sec/meter^2

EMUWO (μ_{wo}) – the initial value EMUW

EMUE (μ_e) – the local external value of viscosity – lbs-sec/ft^2 or Newton-sec/m^2

EME (M_e) – local external Mach number

EMEO (M_{eo}) – initial or reference value of EME

ETABAR $(\bar{\eta})$ – transformed normal coordinate normalized w.r.t boundary layer thickness

ETASTR $(\bar{\eta}*)$ – specified (constant) value of ETABAR

ETA (η) – physical normal coordinate normalized w.r.t boundary layer thickness

ETATILDA $(\tilde{\eta})$ – the name used in the output for one of Coles scaling parameters

ETLDA) $(\tilde{\eta}_o)$ — the initial value of ETATILDA

ETATLDAP $(\tilde{\eta}')$ — the output name of the derivative of ETATILDA

EDDY1 $(1+\epsilon/\nu)$ — output names for eddy viscosity functions
EDDY2 $(\epsilon/u_e \; \delta*)$

FLUID — the namelist name used to input changes to thermodynamics and/or transport properties of the fluid.

G(g) — the 1-D array containing the working value of the enthalpy profile

GWALL (g_w) — the wall value of G

GOLD — the 1-D array of the G profile at the end of an integration step

GAMA (γ) — the specific heat ratio of the gas

H (H) — the compressible form factor $\Big\}$ output names
HBAR $(\bar{H})$ — the transformed form factor

HE (h_e) — the static enthalpy of the external fluid — ft^2/sec^2 or Joules/kg

HTOTE (H_e) — the total enthalpy of the free stream — ft^2/sec^2 or Joules/kg

HTILDA $(\tilde{H}_e)$ — the local ratio HTOTE/HE

IETMAX — the maximum number of mesh points in the PSI direction

IERR — an error indicator set by the integration package

IINTRL — running counter which indicates the number of integration steps completed.

ITEXT — a print switch used by the integrator for printing a history of the computing interval and reasons for its change

I3ETA (I_3) — density integral

I3ETAS (I_{3_s}) — I3ETA evaluated at the sublayer edge

I3EDGE (I_{3_e}) — I3ETA evaluated at the edge of the boundary layer

K — dimensionless grouping utilized in the Sutherland viscosity law $K \equiv CAYPRM(CP)/HTOTE$

KE	— an error indicator printed by LAGR(c.f., error message 19, Section VI)
KTEST	— the input integer with which the user selects the number of lines in each output print block.
LORDR1 LORDR2	— input parameters which may be used for changing the order of the interpolation performed by LGRANG in subroutine PRFILE and XTERNL, respectively.
LREF LBODY $\Big\} (L)$	— these two parameters are used in different places to refer to the same quantity (i.e., the body length) in the axisymmetric option — ft or meters
LMIX(ℓ/δ)	— the output notation used to present the dimensionless mixing length.
MORDR1 MORDR2 MORDR3 MORDR4	— the quantities which may be input to change the order of the interpolation performed by the service routine, LAGR in DEFINT, FUNCT(twice) and by AXISYM, respectively.
MACH	— the namelist name used for input of the external Mach number distribution.
MUTLDA($\tilde{\mu}$)	— viscosity normalized with respect to local external value
MUTLDS($\tilde{\mu}_s$)	— MUTLDA evaluated at the sub-layer edge
MUTLDAW($\tilde{\mu}_w$)	— MUTLDA evaluated at the wall
NOXPTS	— the number of axial points along which external information is supplied
NPRFPT	— the number of points at which profiles are desired
NINTPT	— the number of integration steps between adjacent lines of printout in an output block.
NORDR1 NORDR2	— the quantities which may be input in order to change the number of points used in computing the derivative in INITL1 and AXISYM, respectively.
OVRIDE	— the namelist name used for input of all required program input information
P(P)	— the PI correlation parameter — a function of HTILDA and GWALL
PE (p_e)	— the external pressure distribution — input in lbs/in^2 or Newtons/m^2

PEO (p_{e_o}) — the initial or reference value of PE

PRESSR — the namelist name used for input of the external pressure distribution

PTE (p_t) — the total pressure of the free stream lbf/ft^2 or Newtons/meter^2

PI (π) — the working value of the wake parameter, a dependent variable

PIO (π_o) — the initial value of the PI

PIP (π') — the derivative of the dependent variable PI

PHI (φ) — the working value of the incompressible skin friction parameter, a dependent variable

PHIBAR ($\overline{\varphi}$) — the output name used for the dependent variable, PHI

PHIBRO ($\overline{\varphi}_o$) — the initial value of PHI

PHIMAX — the maximum value of PHI parameter, (i.e., if PHI exceeds this value, an error message is printed and the program terminates).

PHIBARP ($\overline{\varphi}'$) — the derivative of the dependent variable PHI

PRNLAM (P_L) — laminar Prandtl number ⎫

PRNTUR (P_T) — turbulent Prandtl number ⎬ may be input with these names

PSI ($\tilde{\psi}$) — the lateral independent variable of the system

QDOTW ($\dot{q}_w$) — the heat transfer rate to the surface –BTU/ft^2/sec or watts/meter^2

RBAR ($\overline{R}$) — the transformed Reynolds number based on boundary layer height and initial unit Reynolds number – a dependent variable

RBARP ($\overline{R}'$) — the derivative of the dependent variable RBAR

RYBAR ($R_{\overline{y}}$) — transformed Reynolds number based on the normal coordinate and the local unit Reynolds number

RDLTBAR ($R_{\overline{\delta}}$) — the output name used for the transformed Reynolds number based on the boundary layer height and the local unit Reynolds number

RBRDLSTR ($\overline{R}_{\delta *}$) — the output name used for the transformed Reynolds number based on the displacement thickness and local unit Reynolds number

RTHETABR ($R_{\overline{\theta}}$) — the output name used for the transformed Reynolds number based on the momentum thickness and local unit Reynolds number

RSUBY (R_y)   – physical Reynolds number based on normal coordinate and local unit Reynolds number

RDELTA (R_δ)   – the output name used for the physical Reynolds number based on the boundary layer height and the local unit Reynolds number

RDLTSTR ($R_{\delta*}$) – the output name used for the physical Reynolds number based on the displacement thickness and the local unit Reynolds number

RTHETA (R_θ)   – the output name used for the physical Reynolds number based on the momentum thickness and the local unit Reynolds number

REX   – local value of the physical unit Reynolds number ft^{-1} or $meters^{-1}$

REQLO   – Initial value of REX

REX2   – physical streamwise Reynolds number based on local unit Reynolds number

RHOE (ρ_e)   – the local external value of density – $slugs/ft^3$ or kg/m^3

RHOW (ρ_w)   – the density of the fluid at the wall – $slugs/ft^3$ or kg/m^3

RHOWO (ρ_{wo})   – the initial value of RHOW

RTILDA ($\tilde{\rho}$)   – the density normalized w.r.t the local external value

RTILDAS ($\tilde{\rho}_s$) – RTILDA evaluated at the sublayer edge

RHORW ($\tilde{\rho}_w$)   – RTILDA evaluated at the wall

ROTLDAW ($\tilde{\rho}_w$) – the name used for the output of RHORW

RHOMUW ($\tilde{\rho}_w \tilde{\mu}_w$) – the normalized wall value of the density viscosity product

RSTAR   – radius of body of revolution normalized w.r.t LBODY

RSTARO   – value of RSTAR corresponding to the starting length x^*_o

RSTARI   – an interpolated value of RSTAR

SPEED   – the namelist name used for input of the external velocity distribution

SGMATILDA $(\tilde{\sigma})$ – the program output name used for one of Coles' scaling parameters

SGMATLDA – the derivative of SGMATLDA

ST (St) – the Stanton number

T – the temperature in the $u \sim T^n$ viscosity law formulation – $^\circ$R or $^\circ$K

TW (T_w) – the wall temperature – $^\circ$R or $^\circ$K

TEMPR – the reference temperature used in the $\mu \sim T^n$ and Sutherland law formulation– $^\circ$R or $^\circ$K

TE (T_e) – the temperature of the external fluid – $^\circ$R or $^\circ$K

TTE (T_{t_e}) – the free stream or reference total temperature $^\circ$R or $^\circ$K

TTILDA $(\tilde{T})$ – the static temperature normalized w.r.t. the local edge value

TTLDAW $(\tilde{T})_w$ – the wall value of TTILDA

TRMLKE – the thermal conductivity distribution of the external fluid

TMLKWO – the initial thermal conductivity of the fluid at the wall

TRMLKW – the working value of the therm. cond. of the fluid at the wall

$\left. \begin{array}{l} \\ \\ \\ \end{array} \right\}$ $\dfrac{\text{lbf}}{\text{sec } ^\circ\text{R}}$, or $\dfrac{\text{Joules}}{\text{msec } ^\circ\text{R}}$

TAUFCT $\left(\dfrac{\tau}{\tau_w} -1 \right)$ – the output name used for the shear stress functions

TAULAW – PHI/ACONST + ALOG(PHI/(RBRDPR*B))-2.*PI

THETA (θ) – physical momentum thickness – ft or meters

UE (U_e) – the local external velocity – ft/sec or meters/sec

UEO (U_{e_o}) – the initial or reference value of UE

UEBAR $(\bar{U}_e)$ – the local external velocity normalized with respect to UEO – a dependent variable

UEBARO $(\overline{U}_{e_o})$ — initial value of the dependent variable UEBAR

UEBARP $(\overline{U}_e')$ — the derivative of the dependent variable UEBAR

UTILDA $(\tilde{u})$ — the velocity normalized with respect to the local external value

VEX (n) — the exponent of the temperature in a $\mu \sim T^n$ formulation

WGT — the molecular weight of the fluid - lb/lb mole or gr/gr mole

X (x) — the running value of the axial coordinate along the body - ft or meters

XO (x_o) — the initial, starting or reference value of X

XPROFL — the 1-D array of user-prescribed values of X, RE_θ or REX at which profiles are to be computed

XMOLE — the mole fractions of the species used in the equilibrium chemistry package

X_o^* — the initial starting or reference value of the axial coordinate normalized w.r.t. LBODY

XL — the maximum body length in transformed 2-D coordinates - ft or meters

XSAXI — the interpolated value of the normalized axisymmetric coordinate used to generate profiles

YBPLUS — a transformed Reynolds number based on sub-layer height and shear velocity- a program constant

Y (y) — the physical normal coordinate - ft or meters

CONTROL CARD TABLE

COLUMN		IDENTIFICATION	
1		No. of 100's	No. of x pts.
2	NOXPTS	No. of 10's	which are to
3		No. of 1's	be input
4		No. of 100's	No. of pts. at
5	NPRFPT	No. of 10's	which profiles
6		No. of 1's	are desired
7		No. of 100's	No. of integration steps
8	NINTPT	No. of 10's	between adjacent lines of
9		No. of 1's	printout
10		No. of 100's	No. of lines
11	KTEST	No. of 10's	of printout in
12		No. of 1's	each print block.
13	0 - English System Units (INPUT)		
	1 - S.I. units		
14	0 - English System Units (OUTPUT)		
	1 - S.I. units		
15	0 - 2-D case		
	1-9 Axisymmetric case		
16	0 - Profiles at specified x		
	1 - " " " Re_θ		
	2 - " " " Re_x		
17	0 - Leave blank		
18	0 - Do nothing		
	1 - If S.I. units are used and K' is to be changed		
19	0 - with dp/dx		
	1 - dp/dx = 0		
20	0 - Pe(x)		
	1 - ue(x) (INPUT)		
	2 - Me(x)		
21	0 - No fluid property changes		
	1 - Changes to either thermo. and/or transp. properties		
22	0 - Perfect gas		
	1 - Equilibrium chemistry		

COLUMN	IDENTIFICATION
23	0 - Do nothing 1 - Stop after printing a short block
24	0 - Sutherland's Law (both chem. option) 1 - μ from fits - only (Viscosity equil. chem.) (Options) 2 - $\mu \sim T^n$ -(only perfect gas)
25	0 - Adiabatic wall 1 - Isothermal wall
26	0 - Use Prandtl No. from subroutine 1 - Uses input or block data value
27	0 - Do nothing 1 - If S.I. units are used and viscosity ref. values are to be changed
28	0 - Do nothing 1 - Dump data array in chem. package
29	0 - Do nothing 1 - Stop after printing edge condition info.
30 -	0 - ITEXT = 0 Do nothing 1 - ITEXT = 1 - Trace reasons for step size changes
31 -	0 - Default 1 - Change order of LGRANG in PRFILE
32 -	0 - Default 1 - Change order of LGRANG in XTERNL
33	0 - Default 1 - Change order of LAGR in DEFINT
34	0 - Default 1 - Change order of LAGR in FUNCT for evaluating the integral I3ETA
35	0 - Default 1 - Change order of LAGR in FUNCT for evaluating r* and dr*/dx
36	0 - Default 1 - Change order of LAGR in AXISYM
37	0 - Default 1 - Change order of LAGR in AXISYM

COLUMN	IDENTIFICATION
38	0 - Default 1 - Change order of LAGDER in AXISYM
39	Dump switch for HSITER
40	Dump switch for THERMO
41	Dump switch for AXISYM
42	Dump switch for PRFILE
43	Dump switch for STDM
44	Dump switch for DERSUB
45	Dump switch for MAIN
46	Dump switch for BI.PROP
47	Dump switch for XTERNL
48	Dump switch for CONV
49	Dump switch for PROFIL
50	Dump switch for FUNCT
51	Dump switch for COEFF
52	Dump switch for FPRIM
53	Dump switch for GETFS
54	Dump switch for MATRX
55	Dump switch for GETPHI
56	Dump switch for INIT2
57	Dump switch for DEFINT
58	Dump switch for INIT3
59	Dump switch for NERIT
60	0 - Do not use PI correlation 1 - Use PI correlation
61	No. of 1000's } First integration
62	No. of 100's } step at which trace
63	No. of 10's } sequence is to change
64	No. of 1's
65	No. of 1000's } Second integration
66	No. of 100's } step at which trace
67	No. of 10's } sequence is to change
68	No. of 1's
69	No. of 1000's } Third integration
70	No. of 100's } step at which trace
71	No. of 10's } sequence is to change
72	No. of 1's

SUMMARY OF PRE-SET DATA

ACONST = 2.43
B = 7.5
BETA = 0.016
ETASTR = 0.5
YBPLUS = 10.6

VEX = 0.76
PRNLAM = 0.72
PRNTUR = 0.72
CAYPRM = 198.6°R
GAMA = 1.40
TEMPR = 500°R
VISTR = $3.5847 \times 10^{-7} \frac{lbf\text{-}sec}{ft^2}$

XMOLE
(O_2) = .209727
(N_2) = .778987
(e^-) = $.25 \times 10^{-6}$
(AR) = .009288
(N) = $.25 \times 10^{-6}$
(NO) = .00197
(NO^+) = $.25 \times 10^{-6}$
(O) = $.25 \times 10^{-6}$

DPSI = 5.0
ALPHA = 1.3

LORDR1,LORDR2 = 2
MORDR1,MORDR2,
MORDR3,MORDR4 = 1

NORDR1,NORDR2 = 1
ETLDAO,UEBARO = 1
CHIO,CHIBAR
XO,LREF = 0

PHIMAX = 100.
CHIMAX = 0.1×10^9
DCHIBR = 5000.
DCIMAX = 1.0×10^6

ELE1	DEP. VAR.	ELE2
.0001	PHI	1.0×10^{-9}
.0001	RBAR	1.0×10^{-9}
.0001	PI	1.0×10^{-9}
.0001	UEBAR	1.0×10^{-9}
.01	CHI	1.0×10^{2}
.0001	ETILDA	1.0×10^{-9}
.0001	STILDA	1.0×10^{-9}

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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