Chapter 5 ORGANISATION OF THE COMPUTER PROGRAM

5.1 Variable names

(a) Introduction

In the present chapter, the GENMIX computer program will be examined rather more systematically, but still with recognition of two facts: that it is never possible or even desirable to describe a program so completely that nothing is left to the exploratory capabilities of the user; and that the structure and interconnectedness of the program are best perceived by looking at the program from several different points of view, rather as one visualizes a three-dimensional object by examining sections of different location and angle.

First some of the more important variable names will be determined (all names can be found in the program glossary in Appendix B). Then the program will be scanned from the point of view of the velocity array, to see how it is filled and what is done with its contents. The third section of the chapter examines the differences between plane and axi-symmetrical flows, and how they affect the manner of computation; and the final section looks at the program from the point of view of the execution of one forward step of the marching integration.

(b) Variables stored in arrays

If the DIMENSION and COMMON statements are inspected, all the array names will be found. Of those encountered already, there is no need for further discussion; they are A, B, C, D, F, OM, U, SI, SIP.

Certain other arrays have names of which the significances are immediately perceived. They are:-

R , for radius, r;

RHO , for density, ρ;

Y , for normal distance, y.

Somewhat less transparent, but still with mnemonic qualities, are the following names:

EMU , for effective viscosity, μ_{eff};

PRL , the Prandtl/Schmidt number appropriate to the property in

question, σ_ϕ. (This is the
laminar value, and is treated
as a constant);

PRT   , the <u>effective</u> Prandtl/Schmidt
number, $\sigma_{\phi,\text{eff}}$. (This is also
treated as a constant. Other
assumptions can be easily
incorporated.)

RECRU , the reciprocal* of the product of RHO and U.

(c)   <u>Some important unsubscripted variables</u>

Not all the variable names with which one must make
early acquaintance relate to arrays. Inspection of
COMMON block COMA reveals the following important
unsubscripted variables, the names of which are easily
interpreted:-

CSALFA, for $\cos \alpha$;

PEI   , for $(\psi_E - \psi_I)$;

RME   , for flow rate out of the
boundary layer through
the E boundary, $r_E \, \dot{m}''_E$;

RMI   , for flow rate into the
boundary layer through the
I boundary, $r_I \, \dot{m}''_I$;

TAUE   , for shear stress on a wall
at the E boundary, τ_E;

TAUI   , for shear stress on a wall
at the I boundary, τ_I;

XD   , for downstream x, x_D;

XU   , for upstream x, x_U.

Other physically-significant unsubscripted variables
have their first mention in the body of sub-routine
MAIN. Consider, for example, Chapter 4 of MAIN. There
can be seen:-

GASCON   , the universal gas constant (note
that Systeme Internationale units
are employed throughout the program);

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*Footnote: REC in a variable name usually means that the
reciprocal of a quantity is being stored in order that
divisions can be replaced by multiplications wherever possible.

CFU,COX,)   , the specific heats of respectively
CPR,CMIX)   , fuel, oxidant, product and mixture;

WFU,WOX,)   , the molecular weights of those same
WPR,WMIX)   substances;

VISFU   , the viscosity constant of fuel, etc.;

GAMMA   , specific-heat ratio.

(d)   Some important counting indices

A counting index which has already been met is I, the
index of the place of the grid point in question,
numbered from the I boundary. Related indices are:-

        N   , the total number of grid points,

        NM1   , ($\equiv$ N-1) the total number of cells,

        NM2   , ($\equiv$ N-2),denoting the last-but-two
                  points of the grid.

It has been seen already that NF is the index which counts
the number of dependent variables other than velocity, to each of
which is allocated a value of J lying in the inclusive
range 1 to NF. To avoid the user's having to remember
that J = 1 stands for stagnation enthalpy, J = 2 for
$(m_{ox} - m_{fu}$, s) etc., the symbols JH (=1), JP (=2),
JF(=3), etc., are introduced and defined in Chapter 3
of MAIN.

Other important "counting" indices include:-

ISTEP   , the index of the x-location of the
           grid; it has the value 0 at the start
           of the marching integration;

LASTEP   , the largest permitted value of ISTEP;

NSTAT   , the number of marching-integration
           steps between print-outs of "station
           variables", minus 1;

NPROF   , the number of marching-integration
           steps between print-outs of "profile
           variables", minus 1;

NPLOT   , the number of marching-integration
           steps between plots of variables by
           way of the line printer.

(e)   Some important "switching" indices

The index ILPLOT determines whether longitudinal line-
printer plots will be printed at the end of the
integration: ILPLOT = 2 means yes, and ILPLOT = 1 means no.
The value is normally set at the beginning of OUTPUT.

The reader will already have noticed, during his
examination of the program listing, the indices KIN
and KEX. These indices, relating to the I and E (i.e.
internal and external) boundaries respectively, indicate
what kind of boundary is present at the edge of the
integration domain. The code is:-

1   denotes a "wall", i.e. a phase interface;

2   denotes a "free" boundary, i.e. an
         imaginary surface so located that the
         variations in fluid properties are
         negligibly small outside it (Note:
         what is to be regarded as small is
         arbitrary);

3   denotes a symmetry plane or axis.

Of course, KIN and KEX may change their values as the
integration proceeds; for the same type of boundary
may not be present at all values of x.

Another important index is KRAD. This takes the
value 1 for a plane flow and 2 for an axi-symmetrical
one. Its profound effect on the calculation will be
displayed later in this chapter.

The indices IBIN(J) and IBEX(J) relate to boundary
conditions (hence the B) at the internal and external
grid edges, when walls are present (KIN = 1, and/or
KEX = 1). If IBIN(J) equals 1, the implication is
that the value of F(1,J) (i.e. ϕ_I) is fixed; when

IBIN(J) equals 2, it is the flux of the relevant
variable that is specified, probably by way of the
radius times the total flux RJTOTI(J). Similar
remarks can be made about the E boundary, and IBEX(J),
F(N,J) and RJTOTE(J). "Fixed" and "specified" here
mean "given for the x value in question"; different
values may be given for each value of x; and indeed
the value of the indices can also be different for
different locations on the surface.

There are several statements, distributed through the
program, referring to the index ITEST. Ordinarily,
this is given the value 1. When ITEST is given the
value of 2, a large amount of additional printout

is elicited, from the scrutiny of which program
malfunctions can be interpreted.

Lastly, three indices may be mentioned which affect
the physical model on which the program will base
its calculations. These are:-

MODEL   , which activates laminar-flow assumptions
                 when it equals unity and turbulent-flow
                 assumptions (mixing-length) when it
                 equals 2;

INERT   , which suppresses chemical reaction when
                 set equal to unity;

NOVEL   , which suppresses the velocity
                 calculation, and indeed puts u = 1,
                 when set equal to unity.

The last of these is useful when the program is to
calculate unsteady one-dimensional transfer processes.
For then, with u = 1 m/s,x in metres can be
interpreted directly as time in seconds.

5.2   The treatment of the velocity in the various sub-routines

The reader is now invited to scan the listing in
Appendix A to take note of the various points at
which the U(I) array is mentioned, and to interpret
the relevant statements and operations with the aid
of the following commentary.

(a)   Subroutine MAIN (and BLOCK DATA)

In the following discussion, MAIN and BLOCK DATA are
treated as a single subroutine. The chapter headings
of both sub-routines correspond precisely.

Chapter 1. U(I) appears in COMMON, dimensioned to 20.
UEX(X) appears in an arithmetic statement function,
defining the external (D boundary) velocity.

Chapter 2. There is no mention of U in this chapter.

Chapter 3. The first comment card simply states what
U(I) stands for, as part of a general ascription of
variable names to physical properties.

NOVEL = 2; so the velocity equation is to be solved.

Chapter 4. This chapter contains no mention of U,
except for UFAC = .01. This sets a minimum turbulence

level for use in subroutine PHYS.

Chapter 5. Here the "initial" values of U(I) are specified, i.e. those which represent the velocity distribution at the upstream edge of the boundary layer. The values are set in the DO 501 loop to be UB and UC, which are set in BLOCK DATA. The B and C in these names refer to the streams illustrated in Fig. 2.3-1. UB and UC also appear, squared, in expressions for the stagnation enthalpies, ENTHA and ENTHB.

Chapter 6. Here U(I) appears in sequences which calculate RMI and RME, and so exerts some influence on the rate of spread of the grid into undisturbed fluid. They are of course activated only for KIN or KEX values of 2.

Chapter 7. Boundary values of velocity are set in this chapter. The reader will find it illuminating to note how the statements U(1) = 0. (for a wall at I), U(1) = UA (for a free boundary at I), U(N) = 0. (for a wall at E), and U(N) = UD (for a free boundary at E) are actually reached. Evidently the comparisons of ISTEP with JUSTIN and JUSTEX, and the inspection of KIN and KEX, play important parts.

How is U(1) to be calculated when the I boundary coincides with a symmetry axis? The answer can be found in subroutine COMP.

Chapter 8. Here the mass-average velocity UBAR is calculated; this is used in the following sequence, which is concerned with calculating the pressure gradient when the flow is confined in a duct.

Chapter 9. U(I) appears in the DO 907 loop, in which the enthalpy ENTH is calculated from the stagnation enthalpy F(I,JH) by subtraction of the kinetic energy and of the heat of reaction of the fuel. U(1) appears in the expression where the radius at the I boundary is calculated, for KIN = 2, from PSII.

Chapter 10. For confined flow, KEX = 1, U appears in the DO 1025 loop, in which the variation of area with pressure is calculated. Later, in the DO 1027 loop, velocities (and densities) are adjusted to make the flow fit the duct better.

(b)   Subroutine OUTPUT

Under "Headings", Reynolds and Mach numbers are computed

from UBAR. They are printed, along with UA, UB,
etc., by way of WRITE instructions.

Under "compute output required at each step", UBAR is
calculated again (because the relevant sequence
in Chapter 8 is not always traversed), and used
for calculation of the momentum flow rate, UFLUX.
Under the guise of URUREF also appears in dimension-
less shear-stress expressions TAUID and TAUED.

Under "cross-stream profiles and plots", a sequence
arranges for the printing out of the U(I) array.

(c)   Subroutine PHYS

There is considerable use of the U(I) array in
this sub-routine, especially when the flow is
turbulent. The reader's understanding of this
use may be enhanced by perusal of the following
notes; but a complete understanding will
probably have to await the discussion of the
turbulence model which is employed in GENMIX;
this can be found in Section 8.2 below.

When MODEL = 1. If the flow is laminar, MODEL is
put equal to unity; then this causes control
to go immediately to the second part of PHYSU, so
missing many uses of U(I). Indeed, control is
then almost immediately transferred back to MAIN;
so no use of U(I) actually occurs in the PHYSU
Chapter.

The velocity does however appear again in Chapter
B in the DO 322 loop, where kinetic-heating
sources are computed.

No other uses of U(I) appear in the sub-routine
for MODEL = 1.

When MODEL = 2. If the flow is turbulent, the
effective viscosity is influenced by the velocity
gradient. Indeed, if the mixing-length hypothesis
is to be believed, it is proportional to the
modulus of the velocity gradient. It is not
surprising therefore to find the velocity gradients
calculated in DO 104, and put into a special
storage location.

The velocity gradients are used for two purposes:
for the computation of effective viscosity in the
DO 201 loop, and for determining the width of the

relevant shear layer, and so the magnitude of the
mixing length, in a rather complicated sequence which
begins in the DO 104 loop and continues in DO 130.
Detailed examination of this operation is best deferred
until Section 8.2

(d)   Subroutine COMP

Chapter C. Below ENTRY DISTAN, the velocities are used
in the calculation of the ρu reciprocals, to be stored
in RECRU(I) and used in the calculation of distances
(y's and r's). The relevant loop is DO 221.

Chapter D. Soon after ENTRY SOLVE, comment cards
indicate that the A, B, C and D coefficients for u are
under construction. The variable name U(I) appears
explicitly only in the statement for C(I), expressing
the influence of the convection of momentum from up-
stream. The same statements, it may be noted, contain
the SI terms, expressing the influences of pressure
gradient in changing the velocity.

U(1) and U(N) appear, in statements deducing them from
the pressure gradients if free boundaries are present,
i.e. when KIN = 2 and KEX = 2. These statements have
to be executed before solution of the finite-difference
equations, because the latter need, as input, the
downstream values of the boundary velocities.

The sequences for calculating all the downstream
velocities by way of the TDMA then follows. Before
leaving subroutine COMP, the reader should note the
statements with numbers 446 and 448. These set the
edge values equal to the nearby values when there is a
symmetry axis. This practice is consistent with the
idea contained in the wall-boundary practice: that the
ϕ-flux to the I boundary is proportional to the difference
between the ϕ-value there and ϕ_2; for certainly the
flux to a symmetry axis is zero. It should be mentioned
that the calculation of symmetry axis values is purely
"decorative", and does not influence the further
calculation. If alternative practices are desired by
the user, to make the printed profiles "look better",
the corresponding statements can early be inserted by
him; this should preferably be done in Chapter 9 of
MAIN, to give them prominence.

(e)   Subroutine WALL

As will be explained later (Chapter 6), shear stresses
and other fluxes at walls are calculated by way of
wall-functions of Reynolds number, and of other
dimensionless variables; and the velocity appears in
several of these. Subroutine WALL therefore calculates
the "reference velocity" which must enter the Reynolds

number, etc., namely UREF. This is taken as U(2) if
the I boundary is in question, and U(NM1) if it is
the E boundary.

UREF then features in many statements, of which some
of the more important compute:

-      the Reynolds number, RE;

-      the pressure-gradient parameter, EF;

-      the kinetic-heating term (H-1.)*.5*UREF**2.

5.3   Differences between plane and axi-symmetric flow

(a)   Subroutine MAIN

KRAD is set in Chapter 2 of BLOCK DATA; and it is used
in Chapter 2 of MAIN to set the value of an index KIND,
which describes the type of geometry (see Section 9.1
below). KRAD = 1 stands for plane flow, and KRAD = 3
for axi-symmetrical flow.

KRAD is employed in Chapters 5, 7 (twice), 8, 9 and
10 (three times). In each case, its use determines
how geometrical quantities are to be calculated.

For example, areas have to be computed in Chapters 5
and 7, so that the flow rates in the B, C and A streams
can be determined from the quantities HIN, HEX and HDIV
shown in Fig. 2.3-1. Obviously, the formulae must
differ according to whether that diagram represents a
plane or an axi-symmetrical geometry; and also
according to whether the angle α of Fig. 2.1-1 is zero
(as it is for Fig. 2.3-1) or some other value.

KRAD determines which formula is used. It is there-
fore a very important index; and its presence greatly
increases the flexibility of the program.

(b)   Subroutine PHYS and COMP

PHYS

These subroutines must not be problem-dependent. It
must therefore be expected that all switches between
plane and axi-symmetric flow are controlled by KRAD
alone; this is truly the case. There are however no
appearances of KRAD in PHYS. All the statements hold
for both plane and axi-symmetrical flow.

COMP - Chapter A

KRAD appears in Chapter A, to set NOVEL = 1 for
KRAD = 3. Moreover, unless KRAD equals 2, the

specification R(I) = 1.at DO 13 in INIT will never be countermanded.

COMP - Chapter C

KRAD acts as a controlling index in several places in Chapter C, which starts with ENTRY DISTAN. The sequences entered when KRAD equals 1 (plane flow) are the simplest. Those for axial and point symmetry (KRAD = 2 and 3 respectively) involve additional operations.

COMP - Chapter D

There is a further use of KRAD below ENTRY SOLVE: when KRAD equals 2 or 3, radii are introduced into the expression for DIFU(I). This ensures that the viscous transport processes take proper account of radius; and, because other transport properties are calculated from DIFU(I), namely in PHYS (ENTRY PHYSF), the radii are also introduced into DIF(I).

This is a computer-time-saving device. Since all radii are unity for KRAD = 1, the other forms could be employed regardless of the value of KRAD. However, it is undesirable to do more arithmetic than necessary; so the switch promotes economy.

(d)   Subroutine WALL

Radius is explicitly mentioned in this subroutine, and is used whether KRAD equals 1 or 2; since R(I) equals unity for all plane flows, no error results.

However, it should be observed that the wall-function expressions are strictly accurate only for plane flow, or for axi-symmetrical flows in which the radius is much larger than the thickness of the near-wall laminar flows, for which indeed the more correct wall-function formulae are easiest to derive. However, this task remains to be performed.

5.4   The execution of a forward step

(a)   The operation to be considered

In this final section of the chapter, the computer program GENMIX will be looked at in yet another way. The various moves that must be made in the advancement of the marching integration from one x-location to the next will be listed; then the corresponding computer-program sequences will be sought and commented upon.

The discussion begins from the supposition that a step has just been completed or that the computation stands at the very start: the arrays containing the

dependent variables are all filled by appropriate values,
and the secondary variables also; a forward step to the
next x-station is about to be made.

Inevitably, the discussion takes the form of a commentary
on Chapters 6 to 12 of MAIN; this extends that of
Section 2.2(b) above.

(a)   The forward step

The decision as the value of x to which the marching
integration should be advanced, should take note of the
fact that, at least when the geometry is of the kind
illustrated in Fig. 2.3-1, there are certain values of
x at which it is very desirable that grid lines should
be placed; these are the ones at which there are dis-
continuities in the boundary conditions, namely x_{end},
x_{ax}, x_{out} and x_{last}. Of the first and the last two of
these, the values are known before the integration
begins; but the second is specified indirectly.

Inspection of the comment cards of Chapter 6 of MAIN,
and then the sequences which they describe, show that
these tests are made in the last quarter of the chapter,
below the statement:

DX = AMIN1(DXY, DXRE, DXINC, DXPSI) and the following
"special DX limit".

The quantities DXY, DXRE and DXINC are set in the first
few statements of the chapter. Their purpose is to
provide possible values of DX: the first is proportional
to the boundary-layer width; the second multiplies this
by the Reynolds number, and so has an effect (in view
of the AMIN1 operation) at very low Re; and the third
prevents the DX from exceeding its previous value by
more than a certain factor.

Next follows a sequence in which the type of boundary
is determined. This is performed by way of indices
IEND, IOUT, IAX, ISTEP; and the result is an appropriate
setting of the boundary-type indices KIN and KEX.

When KIN is equal to 2, the entrainment rate at the I
boundary, RMI, must then be computed; and when KEX
equals 2, a similar computation must be made for the
E-boundary entrainment rate, RME. Once these
quantities are known, the quantity DXPSI is computed;
this sets a limit to DX, with the aid of the factor
PEILIM, which ensures that the amount of fluid
entrainment in the forward step does not exceed a
fixed fraction of that which is already flowing, PEI.

Then follows the sequence mentioned at the start of
this sub-section, in which DX is adjusted so as not
to "step over" one of the crucial x values: XEND, XOUT,
XAX (but this variable does not explicitly appear), and

XULAST. Whenever "stepping over" is imminent, DX is
diminished so that the step terminates precisely at the
crucial value; and the appropriate index (IEND, IOUT,
etc.) is set so that a change of boundary type is
effected on the _next_ entry to Chapter 6.

(b)   Fixing the downstream width of the grid

Where the integration domain is bounded by an impermeable
wall, or by a symmetry axis, the stream function at that
boundary is invariant with x. Where the boundary adjoins
undisturbed fluid, however, it is possible and likely
that the stream function values will change, i.e. that
$\dot{m}''_I$ and $\dot{m}''_E$ will be non-zero. In any case, values must
be ascribed to these quantities.

Inspection of Chapter 6 has just revealed that the mass-
transfer rates, or rather their products with the
relevant radii, RMI and RME, are set there when the
boundaries are free ones (KIN = 2, KEX = 2).

If walls are present (KIN = 1, KEX = 1), the values of
RMI and RME ($r_I\dot{m}_I$ and $-r_E\dot{m}''_E$ respectively) are set as
part of the boundary condition information. The same
is true for symmetry axes (KIN = 3, KEX = 3). The free
boundary formulae will be discussed later in this book,
under the heading of "entrainment" (Section 7.2).

The actual values of the downstream ψ_E and ψ_I are
deduced from RME and RMI at the very end of subroutine
COMP.

(c)   Calculation of source terms

Before the execution of the forward step can proceed
further, it is necessary to compute the finite-
difference coefficients; and for these the source
terms are needed. An especially important source is
that of momentum, i.e. the pressure gradient. This is
sometimes specified in advance; in the case of a
confined flow however, it has to be calculated.

DP is calculated in Chapter 8. If the flow is un-
confined, the pressure increment is set equal to that
which will produce the specified external velocity,
UEX. The card is the one below 800; for UD has been
set to UEX(XD - XUEX0) at 746; and U(N) is equal to the
UD of the earlier station.

When the flow is confined, the pressure gradient is
calculated by the much-more-complex sequence which
occupies the next sequence in Chapter 8. This will
be described in more detail later (Section 7.3).

The momentum sources themselves are computed in PHYS,
which is next called from COMP (CALL PHYSU). DP is

added to the gravitational term in the DO 210 loop, at
the end of Chapter A. The latter term contains the
gravitational acceleration, and the difference in
density between RHO(I) and a reference density, here
taken as that appropriate to the E boundary of the
flow. MOMSOU = 0 signifies zero momentum sources.

The source terms for the other variables (F's) are
computed in Chapter B of subroutine PHYS, below ENTRY
PHYSU. There are three sections, starting at addresses
314 (for J = JH), 3000 (for J = JF) and 4000 (for J =
JP). The CALL to PHYSU is from COMP (Chapter D); and
it is within a loop in which J varies from 1 to NF.

The J = JP section is the easiest to understand; for
it simply puts index KSOURC equal to 3. This is done
because the variable in question is (m_{ox} - m_{fu}s),
which is a zero-source variable.

For J = JH, the variable is stagnation enthalpy. If
the variable NOVEL equals unity, KSOURC is again put
equal to 3, because there is no such thing as kinetic
heating in the one-dimensional transient process.
However, for the actual situation represented by the
basic version of GENMIX, NOVEL equals 2; and SI is
calculated by the loop DO 322. Here it should be noted
that the SIP array is not needed; to signify this,
KSOURC is set equal to 2. If radiation were present,
the SI array would require to be augmented; and
perhaps SIP would be needed (KSOURC = 1).

For J = JF, the variable is m_{fu}, the mass fraction of
fuel. There are two alternative sequences for
computing SI and SIP: the first is entered when MODEL
equals unity (laminar flow); the second when it equals
2 (turbulent, mixing length model).

Because both arrays are used, KSOURC equals 1. These
sequences will be discussed at greater length in
Chapter 8 below.

(d)   Calculation of transport terms

The transport properties necessary for making a forward
step are also computed in PHYS. The effective viscosity
is produced by PHYSU, in the DO 110 loop for laminar
flow and in the DO 201 loop for turbulent flow.
Although the laminar viscosity is computed at grid
points, it is needed for cell boundaries; therefore
an arithmetic-averaging process is carried out at DO
203. The turbulent contribution to EMU(I) is most
easily computed at cell boundaries in any case; no
corresponding arithmetic-averaging is therefore needed
when MODEL = 2.

The transport properties for the F's are easily handled
in GENMIX; for the effective Prandtl/Schmidt numbers are

taken as constant. They are used, just after the ENTRY
PHYSF to subroutine PHYS, to create the values of DIF(I)
from those of DIFU(I). The latter has already been
computed in COMP from the values of EMU(I) (DO 413 and
DO 416),below ENTRY SOLVE.

(e)   Boundary conditions and related quantities

The special attention which must be devoted to the
boundaries of the grid, in preparation for a forward
step, is reflected in Chapter 7. This allocates values
to the dependent variables, or to the fluxes of the
corresponding physical entities, according to the nature
of the boundary and the boundary conditions.

Which section of Chapter 7 is appropriate depends on the
values of the indices KIN and KEX; and these are set by
reference to the value of XU in Chapter 6 as discussed
above. Corresponding GO TO statements result in the
insertion of the appropriate boundary-condition
information. The coding is sufficiently transparent
to be understood directly by the reader.

(f)   The calculation of the finite-difference
         coefficients and the solution of the equations

The next step in the making of a forward step is to
combine the information which has been assembled about
the step size, the sources, the transport terms and the
boundary conditions; from their combination, the finite-
difference equations can be solved.

A preliminary examination of the corresponding Fortran
sequences in COMP, Chapter D, was made in Section 4.4
above. Here a few additional points will be presented,
namely:-

●   Only one-dimensional arrays are
         needed for the coefficients, because
         the equations are solved successively.

●   One implication of this is that, since
         U(I) is computed for the downstream
         station before F(I,JH) is attended to,
         the kinetic-heating sources are based
         on downstream velocities.

●   Similarly, since the fuel concentration
         F(I,JF) is computed after the quantity
         F(I,JP) ($\equiv m_{ox} - m_{fu}s$), the most up-to-
         date value of the latter is employed
         when the sources of the former are
         computed. This is advantageous, and it
         is the reason why JP is given the value
         2 and JF the value 3, rather than vice
         versa.

- The equation-solving sequences follow hard upon those which form the co-efficients; and they are in turn succeeded by sequences which make tidying-up moves, especially in relation to boundary fluxes.

- Thus the wall shear stresses, TAUI and TAUE are computed at statement numbers 444 and 447.

- Similarly total fluxes, and wall values of F's if the fluxes are prescribed, are computed in the sequence below address 466.

- If the variable ITEST is put equal to 2, WRITE sequences print out the coefficients and other interesting material. This is often useful when new versions of the program are under development, and errors have to be detected or diagnosed.

(g)   Completion of the step

When the main dependent variables have been computed in this way, the next step is to compute the secondary ones, namely density ρ (RHO(I)), temperature T(F(I,JTE)), oxygen concentration m_{ox} (F(I,JOX) and combustion product m_{pr}(F(I,JPR)).

The place for this is the "complete" section of MAIN, namely Chapter 9. When these variables have been computed, it is also possible to compute the distance variables, r and y; therefore DISTAN is called at the end of this chapter.

What if the computed width of the flow Y(N), does not fit the available width of the duct? Then an adjustment must be made. This is performed in Chapter 10 of MAIN according to principles which will be described in Section 7.3.

(h)   Print out

Once the step has been completed, it is necessary to consider whether to print any information about it; for the variables are in one-dimensional storage, and will be over-written when the next forward step is performed.

The arrangement of MAIN corresponds to this natural order: Chapter 11 is concerned with calling the sub-routine OUTPUT, where, as described in Section 2.2(b) above, the appropriate decisions and actions are taken.

(i)   Preparations for the next step

When all this has been done, it is time to consider a
further step. Chapter 12 of MAIN therefore returns
control to address 600, at the beginning of Chapter 6;
unless, that is to say, termination is called for by
the XU's having reached XULAST or ISTEP's having
reached LASTEP. In the latter case, IFIN is put equal
to 2, and the computation stops.