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USER'S MANUAL FOR A TEACH COMPUTER PROGRAM FOR THE ANALYSIS OF TURBULENT, SWIRLING REACTING FLOW IN A RESEARCH COMBUSTOR

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Abstract

Described herein is a computer program for the analysis of the subsonic, swirling, reacting turbulent flow in an axisymmetric, bluff-body research combustor. The program features an improved finite-difference procedure designed to reduce the effects of numerical diffusion and a new algorithm for predicting the pressure distribution within the combustor.

A research version of the computer program described in the report was supplied to United Technologies Research Center by Professor A. D. Gosman and his students, R. Benodeker and R. I. Issa, of Imperial College, London. The Imperial College staff also supplied much of the program documentation contained in this report.

This report presents a description of the mathematical model for flow within an axisymmetric bluff-body combustor, the development of the finite-difference procedure used to represent the system of equations, an outline of the algorithm for determining the static pressure distribution within the combustor, a description of the computer program including its input format, and the results for representative test cases.

This report constitutes the final report for Task VII of NASA Lewis Research Center Contract NAS3-22771.

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1.0 SUMMARY

Described herein is a computer program for the analysis of the subsonic, swirling, reacting turbulent flow in an axisymmetric, bluff-body research combustor. The program features an improved finite-difference procedure designed to reduce the effects of numerical diffusion and a new algorithm for predicting the pressure distribution within the combustor.

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The NASA project monitor is Dr. C. J. Marek.

2.0 INTRODUCTION

This report presents a description of the mathematical basis for and operation of a new version of the TEACH computer program developed originally by workers at Imperial College, London. The program is intended for use in the analysis of the subsonic, swirling, reacting, turbulent flow in a cylindrical bluff-body research combustor (Fig. 1). This combustor has been developed by W. M. Rocquemore and colleagues of AFAPL as a research tool for gas turbine combustor modelling and for diagnostic instrumentation development (Ref. 1). The flowfield of interest is that which is developed in the open-ended, cylindrical chamber downstream of the base of the bluff-body which houses the fuel injector (Fig. 1). Such flows can be described by the fully-elliptic, steady-state equations of motion. The present version of TEACH solves these equations using an improved finite-difference procedure--the Bounded Skew-Upwind Differencing (BSUD) method. The axisymmetric pressure distribution is estimated by means of a new algorithm--The Pressure-Implicit Split Operation (PISO) predictor-corrector technique.

Sections of the computer program have been reorganized by UTRC in an attempt to minimize the changes necessary to install the program on different computer systems. The input format has been extensively revised to permit more flexibility in setting up and running cases. In the program that was supplied to UTRC, Imperial College included a number of additional options. These include switches that permit (1) the analysis of two-dimensional (planar) flows and (2) the selection of the more conventional hybrid differencing scheme. Verification of the operational status of these optional features was beyond the scope of the present contract and would have required additional documentation from Imperial College. These options have been retained in the present version of TEACH for the convenience of the user.

In Section 3, the system of equations describing the flow within the research combustor is presented. In Section 4, the finite-difference forms of these equations, the special numerical treatment for certain source terms, and the PISO algorithm are described. In Section 5, the input format, source language listings, and other documentation for the computer program are presented. In Section 6, three representative sample cases are used to illustrate the results obtained with the computer program.

References are listed in Section 7 and the nomenclature is presented in Section 8.

3.0 MATHEMATICAL MODEL

In this section, the governing equations describing the subsonic, swirling, reacting turbulent flow in an axisymmetric research combustor are presented. The two-equation turbulence model is then described. Finally, a combustion model for the turbulent reaction of propane with air is outlined.

3.1 Governing Equations

The governing conservation equations for the mean motion of a two-dimensional (axisymmetric), steady-state turbulent flow are presented below using cylindrical coordinates. Closure of this set of equations is provided by using the turbulent kinetic energy k and energy dissipation rate ε which are derived from additional transport equations (see Sect. 3.2 and Launder and Spalding (Ref. 2)) to obtain an effective eddy viscosity such that the unknown turbulence diffusional fluxes can be expressed as the product of the eddy viscosity and the gradient of the appropriate dependent variable; i.e., from the "gradient transport hypothesis" (Hinze, Ref. 3).

The governing equations are:

Continuity

$$\frac{\partial}{\partial x}(r\rho u) + \frac{\partial}{\partial r}(r\rho v) = 0 \tag{3.1.1}$$

Axial Momentum

$$\frac{1}{r}\left[\frac{\partial}{\partial x}(r\rho uu) + \frac{\partial}{\partial r}(r\rho vu)\right] = -\frac{\partial p}{\partial x} + \frac{1}{r}\left[\frac{\partial}{\partial x}\left(r\mu_{eff}\frac{\partial u}{\partial x}\right) + \frac{\partial}{\partial r}\left(r\mu_{eff}\frac{\partial u}{\partial r}\right)\right] + S_u \tag{3.1.2}$$

Radial Momentum

$$\frac{1}{r}\left[\frac{\partial}{\partial x}(r\rho uv) + \frac{\partial}{\partial r}(r\rho vv)\right] = -\frac{\partial p}{\partial y} + \frac{1}{r}\left[\frac{\partial}{\partial x}\left(r\mu_{eff}\frac{\partial v}{\partial x}\right) + \frac{\partial}{\partial r}\left(r\mu_{eff}\frac{\partial v}{\partial r}\right)\right] - \mu_{eff}\frac{v}{r^2} + S_v \tag{3.1.3}$$

Tangential Momentum

$$\frac{1}{r}\left\{\frac{\partial}{\partial x}(r\rho urw) + \frac{\partial}{\partial r}(r\rho vrw)\right\} = \frac{1}{r}\left\{\frac{\partial}{\partial x}\left(r\mu_{eff}\frac{\partial rw}{\partial x}\right) + \frac{\partial}{\partial r}\left(r\mu_{eff}\frac{\partial rw}{\partial r}\right)\right\} + S_w \tag{3.1.4}$$

Scalar Transport

$$\frac{1}{r}\left[\frac{\partial}{\partial x}(r\rho u\phi) + \frac{\partial}{\partial r}(r\rho v\phi)\right] = \frac{1}{r}\left[\frac{\partial}{\partial x}\left(r\Gamma_{eff}\frac{\partial \phi}{\partial x}\right) + \frac{\partial}{\partial r}\left(r\Gamma_{eff}\frac{\partial \phi}{\partial r}\right)\right] + S_\phi \tag{3.1.5}$$

where ϕ represents such scalars as temperature, mass fraction, turbulent kinetic energy, etc. The quantities μ_{eff} and Γ_{eff} are the effective exchange coefficients and are the sum of both the laminar and turbulent transport coefficients.

$$\mu_{eff} = \mu_l + \mu_t ; \ \Gamma_{eff} = \frac{\mu_l}{\sigma_{\phi_\ell}} + \frac{\mu_t}{\sigma_{\phi t}} \qquad (3.1.6)$$

The sources S_u, S_v and S_w in the momentum equations represent additional terms associated with non-uniform viscosity. Their influence is generally small except where changes in fluid properties have considerable effects. These terms are given by:

$$S_u = \frac{\partial}{\partial x}\left(\mu_{eff}\frac{\partial u}{\partial x}\right) + \frac{1}{r}\frac{\partial}{\partial r}\left(r\mu_{eff}\frac{\partial v}{\partial x}\right) \qquad (3.1.7)$$

$$S_v = \frac{\partial}{\partial x}\left(\mu_{eff}\frac{\partial u}{\partial x}\right) + \frac{1}{r}\frac{\partial}{\partial r}\left(r\mu_{eff}\frac{\partial v}{\partial r}\right)$$

$$- 2\mu_{eff}\frac{v}{r^2} - \frac{\partial}{\partial r}\left[\frac{2}{3}\rho k + \frac{2}{3}\mu_{eff}\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial r}\right)\right] + \frac{\rho w^2}{r} \qquad (3.1.8)$$

$$S_w = -\frac{2}{r}\frac{\partial}{\partial r}\left(rw\mu_{eff}\right) \qquad (3.1.9)$$

The governing equations (3.1.1) to (3.1.5) can be represented by the following general equation:

$$\frac{1}{r}\left[\frac{\partial}{\partial x}(\rho r u\phi) + \frac{\partial}{\partial r}(\rho r v\phi) - \frac{\partial}{\partial x}\left(r\,\Gamma_\phi\frac{\partial\phi}{\partial x}\right) - \frac{\partial}{\partial r}\left(r\,\Gamma_\phi\frac{\partial\phi}{\partial r}\right)\right] - S_\phi = 0 \qquad (3.1.10)$$

where it is now assumed that the axial and radial pressure gradients have been incorporated into S_u and S_v, respectively.

3.2 Turbulence Model

The two equation (k-ε) turbulence model, developed by Launder and Spalding (Ref. 2), is used in the computer program. In the model, the turbulent viscosity is determined from the time-mean values of the kinetic energy of turbulence (k) and the volumetric turbulent kinetic energy dissipation rate (ε) by the relationship:

$$\mu_t = C_\mu \rho \frac{k^2}{\varepsilon} \qquad (3.2.1)$$

where C_μ is a constant. The quantities k and ε are determined from transport-equations of the same form as Eq. (3.1.10) where for the k equation:

$$\phi = k, \quad S_\phi = \mu_t G - C_\mu \rho^2 k^2/\mu_t \qquad (3.2.2)$$

and for the ε equation

$$\phi = \varepsilon, \quad S_\phi = C_1 \; G \; C_\mu \rho k - C_2 \rho \varepsilon^2/k \qquad (3.2.3)$$

where

$$G = 2\left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial r}\right)^2 + \left(\frac{v}{r}\right)^2\right] + \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial r}\right)^2 \qquad (3.2.4)$$

The quantity G represents the production of turbulent kinetic energy by the mean motion. Turbulent kinetic energy is dissipated at a rate proportional to ε which, in turn, is also generated and dissipated at rates that depend on k and ε as can be seen from Eq. (3.2.3). Thus, the equations for k and ε are strongly coupled. In the vicinity of the walls, the determination of both k and ε requires special consideration as noted in Section 4.3. The constants appearing in the turbulence model are listed in Table 1.

3.3 Combustion Model

The model proposed by Magnussen and Hjertager (Ref. 4) is used in the computer program. This model relates the rate of combustion of the fuel (restricted to propane in the present analysis) to the rate of dissipation of turbulent eddies and expresses the rate of reaction in terms of the mean concentration of the reacting species, the turbulent kinetic energy, and the rate of dissipation of turbulent kinetic energy.

For propane, the stoichiometric relationship is:

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O + 5.008\times10^7 \text{ J/kg} \qquad (3.3.1)$$

In the combustion model, the species concentrations are determined from the governing partial differential equations for the fuel mass fraction and the mixture fraction defined below. The enthalpy is defined as:

$$h = m_f \, H_R + C_{p,m}T \qquad (3.3.2)$$

The mean specific heat is obtained from

$$C_{p,m} = \sum_i m_i \, C_{pi} \qquad (3.3.3)$$

with the summation over all species. The specific heats of individual species are obtained using polynomials of the form:

$$C_{p,i} = \frac{R}{M_i}\left(C_{1i} + C_{2i}T + C_{3i}T^2 + C_{4i}T^3 + C_{5i}T^4\right) \qquad (3.3.4)$$

where R is the universal gas constant, 8314.3 J/kg-molK).

The constants of the polynomials are obtained from standard thermochemical tables and are listed in Table 2.

The mixture fraction (f), enthalpy (h) and fuel mass fraction (m_f) are governed by equations identical in form to Eq. (3.1.10). For both the mixture fraction and enthalpy, the source term is zero. For the fuel mass fraction, the source term is calculated in accordance with the Magnussen-Hjertager model:

$$Sm_f = - c \frac{\varepsilon}{k} \min \left[Am_f,\ A \frac{m_{o2}}{i},\ AB \frac{m_{pr}}{i+1} \right] \tag{3.3.5}$$

for which the constants are A = 4, B = 0.5; for propane, the stoichiometric oxygen to fuel mass ratio is 3.635. The rate of combustion is then,

$$R_f = -Sm_f \tag{3.3.6}$$

The fuel mass fraction is defined by the sum of the unburned and burned fuel:

$$f = m_f + \frac{1}{3} m_{CO2} \tag{3.3.7}$$

where, from (Eq. 3.3.1) and the fact that propane and carbon dioxide have nearly identical molecular weights, the mass fraction of burned fuel equals one-third of the mass fraction of CO_2. Since both the mixture fraction and fuel mass fraction are determined by the solution of the respective transport equation, Eq. (3.3.7) can be used to determine the mass fraction for CO_2.

$$m_{CO_2} = 3\ (f-m_f) \tag{3.3.8}$$

Similarly, for the remaining species:

$$\begin{aligned} m_{H_2O} &= 0.545\ m_{CO_2} \\ &= 1.635\ (f-m_f) \end{aligned} \tag{3.3.9}$$

$$m_{pr} = m_{CO_2} + m_{H_2O} = 4.635\ (f-m_f) = (i+1)(f-m_f) \tag{3.3.10}$$

$$m_{N_2} = 0.767\ (1-f) \tag{3.3.11}$$

$$\begin{aligned} m_{O_2} &= 1 - (m_{N_2} + m_f + m_{CO_2} + m_{H2O}) \\ &= 0.233 - 3.868f + 3.635\ m_f \\ &= 0.233 - (i+0.233)f + im_f \end{aligned} \tag{3.3.12}$$

The average density is given by

$$\rho = \frac{P}{RT \sum\limits_i \frac{m_i}{M_i}} \tag{3.3.13}$$

and the temperature is calculated from Eq. (3.3.2).

4.0 FINITE-DIFFERENCE APPROXIMATIONS

In this section, the finite-difference approximations used in the computer program are discussed. In Section 4.1, the Bounded Skew-Upwind Differencing (BSUD) scheme is presented. In Section 4.2, the special treatment given to certain source terms in the equations of motion are discussed briefly. In Section 4.3, the boundary condition formulations are outlined. Finally, in Section 4.4, the predictor-corrector algorithm for determining the static pressure distribution is presented.

4.1 The Bounded Skew-Upwind Differencing Scheme

In this section, the Bounded Skew-Upwind Differencing (BSUD) scheme is described. First, a brief review of the flux form of the equations of motion is presented. Second, a detailed description of the finite-difference form of the flux contribution to a representative face of a typical control volume is given; the derivation of the flux contributions to the other faces is then outlined. Third, the resulting coefficients for the finite-difference equations representing the total flux (and sources) are presented. Finally, the bounding scheme for the coefficients is detailed.

4.1.1 Flux Form of the Equations of Motion

Further generalization of Eq. (3.1.10) leads to the conclusion that the equations of motion for both laminar flow and (time-averaged) turbulent flow can be written in similar fashion for all of the dependent variables:

$$\frac{\partial}{\partial x}(\rho u\phi) + \frac{1}{r^{\xi}}\frac{\partial}{\partial r}(r^{\xi}\rho v\phi) = \frac{\partial}{\partial x}\left(\Gamma_{\phi}\ \frac{\partial\phi}{\partial x}\right) + \frac{1}{r^{\xi}}\frac{\partial}{\partial r}\left(\Gamma_{\phi}\ \frac{\partial\phi}{\partial r}\right) + S_{\phi} \qquad (4.1.1.1)$$

where $\xi = 0$ for two-dimensional (planar) flow and $\xi = 1$ for axisymmetric flow. The variable ϕ represents any of the dependent variables (e.g., the velocity components u, v, w, mixture fraction, turbulent kinetic energy and turbulent energy dissipation rate, etc.). The exchange coefficient, Γ_{ϕ}, represents the sum of both laminar and turbulent contributions and is interpreted as the effective viscosity for ϕ = u, v, w, the effective diffusivity for ϕ = mixture fraction, etc. S_{ϕ} is a generalized source term.

Eq. (4.1.1.1) is integrated over a control volume appropriate for each dependent variable ϕ and, after some manipulation, the finite-difference equivalent form of Eq. (4.1.1.1) is obtained. The control volumes are defined using an orthogonal grid formed by the intersection of co-ordinate lines in the axial and radial co-ordinate directions. The intersection of the grid lines, Fig. 2, form the grid nodes at which all flow properties except the axial (u) and radial (v) velocities are calculated; i.e., all scalars and the tangential velocity component (w) for swirling flows. The axial velocity is calculated using a second grid with grid lines such that the grid nodes of the scalars in the axial direction are midway between the axial velocity grid nodes, Fig. 3. The axial velocity and scalar grid nodes are co-incident in radial position. The radial velocity is calculated using a third grid such that the grid nodes of the scalars in the radial direction are midway between the radial velocity grid nodes, Fig. 3. The radial velocity and scalar grid nodes are co-incident in axial position. Directions in the grids are identified as north, south, east and west. It should be noted that it is the axial grid line locations for the axial velocity and the radial grid line locations for the radial velocity which are input to the present version of the computer program.

Control volumes for each scalar and the tangential velocity are defined such that (1) the east and west faces of the control volume are co-incident with the axial velocity axial grid line locations and (2) the north and south faces are co-incident with the radial velocity radial grid line locations as shown in Fig. 4. The control volumes for the u velocity are shifted relative to the scalar control volumes such that the east and west faces are co-incident with the scalar grid node axial locations; similarly, the v velocity control volumes are shifted such that the north and south faces are co-incident with the scalar grid node radial positions.

The finite-difference form of Eq. (4.1.1.1) is derived by integrating this equation over the appropriate control volume. In performing the integration over the control volume for each term in Eq. (4.1.1.1), the mean-value theorem is employed and the source term is linearized in the vicinity of the center of the control volume (point P). After some manipulation, the finite-difference form of Eq. (4.1.1.1) is obtained

$$C_E\phi_e - C_W\phi_w + C_N\phi_n - C_S\phi_s = D_E\,(\phi_E - \phi_P) - D_W\,(\phi_P - \phi_W)$$
$$+ D_N\,(\phi_N - \phi_P) - D_S\,(\phi_P - \phi_S) + (S_u + S_P\phi_P) \qquad (4.1.1.2)$$

where C_E, C_W, etc. are "convective coefficients" as defined below

$$C_E = (\rho u)_e\, a_e$$
$$C_N = (\rho v)_n\, a_n$$
$$C_W = (\rho u)_w\, a_w \qquad (4.1.1.3)$$
$$C_S = (\rho v)_s\, a_s$$

and $a_n = a_s$, $a_e = a_w$ are the areas of the faces of the control volume. The "diffusion" coefficients are given by

$$D_E = \left(\frac{\Gamma\phi}{\Delta x}\right)_e a_e$$
$$D_N = \left(\frac{\Gamma\phi}{\Delta y}\right)_n a_n$$
$$D_W = \left(\frac{\Gamma\phi}{\Delta x}\right)_w a_w \qquad (4.1.1.4)$$
$$D_S = \left(\frac{\Gamma\phi}{\Delta y}\right)_s a_s$$

and $(\Delta x)_e$ is the distance between points P and E, etc. (e.g., see Fig. 4).

It is important to note that Eq. (4.1.1.2) applies to all of the dependent variables although the appropriate grid must be used in each case to define the geometric parameters used in the calculation. Also, Eq. (4.1.1.2) applies to both the hybrid and bounded skew-upwind differencing procedures used in the computer program since each scheme is simply an alternative method for defining (interpolating for) the fluxes at the faces of the control volume (e.g., ϕ_e, ϕ_w, ϕ_n, ϕ_s). However, the diffusion terms are always represented by central differences.

It is convenient to define a total flux for each face of the control volume as the sum of a convective flux and a diffusive flux such that

$$F_e - F_w + F_n - F_s = S_u + S_P \phi_P \tag{4.1.1.5}$$

where

$$\begin{aligned} F_e &= C_E \phi_e - D_E (\phi_E - \phi_P) \\ F_w &= C_W \phi_w - D_W (\phi_P - \phi_W) \\ F_n &= C_N \phi_n - D_N (\phi_N - \phi_P) \\ F_s &= C_S \phi_s - D_S (\phi_P - \phi_S) \end{aligned} \tag{4.1.1.6}$$

In the following section, the skew upwind differencing procedure will be used to calculate the values of the dependent variables at the faces of the control volume. As a result, Eq. (4.1.1.5) will include not only the values of ϕ at the "normal", or main, grid node locations (E, W, N, S and P) but also at the corner locations (NE, SE, NW, and SW). The finite-difference form for Eq. (4.1.1.5) will be shown to be

$$\begin{aligned} A_P \phi_P = {} & A_E \phi_E + A_W \phi_W + A_N \phi_N + A_S \phi_S + A_{NE} \phi_{NE} + A_{SE} \phi_{SE} \\ & + A_{NW} \phi_{NW} + A_{SW} \phi_{SW} + S_U + S_P \phi_P \end{aligned} \tag{4.1.1.7}$$

4.1.2 - Calculation of the Fluxes

Recall that the equation of motion, Eq. (4.1.1.1), can be written in terms of fluxes to each face of the control volume, Eq. (4.1.1.5). In this section, a procedure will be described to calculate fluxes, F_e, F_w, F_n, and F_s. The derivation of F_w, the flux to the west face, of a typical scalar control volume is given in detail. The derivation of the fluxes for the other faces or the fluxes for the u and v velocity components are outlined.

Consider the control volume shown in Fig. 5. For this case, it has been assumed that the velocity vector is oriented as shown; i.e., the u and v components are non-negative. The flux to the west face is given by:

$$F_w = C_W \phi_w - D_W (\phi_P - \phi_W) \tag{4.1.2.1}$$

For central-differencing (CD), the value of the dependent variable at the west face, ϕ_w, is given by linear interpolation between ϕ at the W and P grid nodes:

$$\phi_w = (1 - \alpha_w)\,\phi_W + \alpha_w \phi_P \tag{4.1.2.2}$$

where the interpolating factor is

$$\alpha_w = \frac{X_w - X_W}{X_P - X_W} \tag{4.1.2.3}$$

The central difference form of the flux at the west face is then:

$$\frac{F_{w_{CD}}}{D_w} = \left[P_{e_w}\,(1 - \alpha_w) + 1 \right] \phi_W + \left(\alpha_w P_{e_w} - 1 \right) \phi_P \tag{4.1.2.4}$$

where the Peclet number at this face is given by:

$$P_{e_w} = C_W / D_W \tag{4.1.2.5}$$

The upwind difference (UD) form for the flux at the west face is obtained by setting α_w to zero and neglecting the diffusion term:

$$\frac{F_{w_{UD}}}{D_W} = P_{e_w}\,\phi_W \tag{4.1.2.6}$$

Equation (4.1.2.1) is also the starting point for the skew upwind differencing (SUD) scheme. The value of ϕ at the west face of the control volume, ϕ_w, is determined by extrapolating the velocity vector upstream to the point w' which lies along the grid line connecting the west and southwest nodes (see Fig. 5) to give:

$$\phi_{w'} = (1 - k_w)\,\phi_W + k_w\,\phi_{SW} \tag{4.1.2.7}$$

where the skew interpolation factor is the ratio of the vertical distance between w' and SW to the vertical distance between W and SW:

$$k_w = \frac{1}{2}\,\frac{V_w}{U_w}\,\frac{\Delta x}{\Delta y} \tag{4.1.2.8}$$

For very large flow angles (skewing) relative to the co-ordinate directions, k_w will exceed unity and $\phi w'$ will be defined in terms of ϕ at the SW and S nodes; however, it is known that this approach can yield negative coefficients at the corner nodes (NW, SW, NE, SE) which can in turn produce oscillations in the solution. To assure that the coefficients for the corner nodes are non-negative, then:

$$k_w = \min\left(1.0,\ \frac{1}{2}\left|\frac{V_w}{U_w}\right|\frac{\Delta x}{\Delta y}\right) \qquad (4.1.2.9)$$

The use of absolute value in Eq. (4.1.2.9) permits this equation to be used to define k for all velocity components at the west face.

In his original development of the skew upwind differencing approximation, Raithby (Ref. 5) assumed that $\phi_w = \phi_{w'}$. Thus,

$$\frac{F_{w_{SUD}}}{D_w} = P_{e_w}\phi_{w'} - (\phi_P - \phi_W) \qquad (4.1.2.10)$$

It is desirable to use the central-difference procedure for small values of the grid Peclet number and the skew upwind differencing method for large values of the grid Peclet number. It is also desirable that these two formulations produce a continuous transition at the transition Peclet number which in the present case is:

$$P_{e_w}^{*} = \frac{1}{\alpha_w} \qquad (4.1.2.11)$$

At the transition Peclet number, the central difference result (Eq. 4.1.2.4) is:

$$\frac{F_{w_{CD}}}{D_w} = \frac{\phi_w}{\alpha_w} \qquad (4.1.2.12)$$

while the skew upwind differencing method (Eq. 4.1.2.10) yields:

$$\frac{F_{w_{SUD}}}{D_w} = \frac{\phi_{w'}}{\alpha_w} - (\phi_P - \phi_W) \qquad (4.1.2.13)$$

Noting the definition given by Eq. (4.1.2.7), it is clear that these two results are not equal.

The fluxes at the transition Peclet number can be made equal by noting (contrary to the assumption made by Raithby) that ϕ_w and $\phi_{w'}$ are related by:

$$\phi_{w'} = \phi_w - \left(\frac{\partial\phi}{\partial s}\right)_w \Delta s + \ldots \qquad (4.1.2.14)$$

so that Eq. (4.1.2.10) becomes

$$\frac{F_{w_{SUD}}}{D_w} = P_{e_w}\phi_w - P_{e_w}\left(\frac{\partial\phi}{\partial s}\right)_w \Delta s - (\phi_P - \phi_W) \qquad (4.1.2.15)$$

Writing the central difference result in terms of the flux definition, Eq. (4.1.2.1) then:

$$\frac{F_{w_{CD}}}{D_W} = P_{e_w}\phi_w - (\phi_P - \phi_W) \qquad (4.1.2.16)$$

Clearly,. these two fluxes will be equal at the transition Peclet number if a correction $Pe^*(\partial\phi/\partial S)_w \Delta s$ is added to the skew upwind differencing flux, Eq. 4.1.2.10, to obtain:

$$\frac{F_{w_{SUD}}}{D_W} = P_{e_w}\phi_{w'} + P_{e_w}^*\left(\frac{\partial\phi}{\partial s}\right)_w \Delta s - (\phi_P - \phi_W) \qquad (4.1.2.17)$$

The derivative $(\partial\phi/\partial s)w$ can be computed by

$$\frac{\partial\phi}{\partial s} = \frac{\phi_w - \phi_{w'}}{\Delta s} \qquad (4.1.2.18)$$

Then, using Eq. (4.1.2.2), (4.1.2.7) and (4.1.2.11), Eq. (4.1.2.17) becomes

$$\frac{F_{w_{SUD}}}{D_W} = P_{e_w}\phi_W - (P_{e_w} - P_{e_w}^*)\, k_w\, (\phi_W - \phi_{SW}) \qquad (4.1.2.19)$$

At the transition Peclet number, the fluxes calculated by central differencing (Eq. 4.1.2.12) and skew upwind differencing (Eq. 4.1.2.19) are equal.

It will be recalled that the above result for the skew upwind differencing flux at the west face of the control volume was derived for non-negative values of the axial and radial velocities. Similar results can be derived for other combinations of u and v by consistent application of the process leading to Eq. (4.1.2.19). The result is a general expression for the flux as calculated using skew upwind differencing:

$$\begin{aligned}\frac{F_{w_{SUD}}}{D_W} &= P_{e_w}\,[\sigma_w^u\,\phi_W + (1 - \sigma_w^u)\,\phi_P] \\ &- (P_{e_w} - P_{e_w}^*)\,k_w\left[\sigma_w^u\left\{\phi_W - \sigma_w^v\,\phi_{SW} - (1 - \sigma_w^v)\,\phi_{NW}\right\}\right. \\ &\left. + (1 - \sigma_w^u)\left\{\phi_P - \sigma_w^v\,\phi_S - (1 - \sigma_w^v)\,\phi_N\right\}\right]\end{aligned} \qquad (4.1.2.20)$$

The parameters, σ_w^u and σ_w^v, are switches that indicate the direction of the components of the local flow velocities

$$\sigma_w^u = \frac{1}{2}\left(1 + \frac{U_w}{|U_w|}\right) \qquad (4.1.2.21)$$

$$\sigma_w^v = \frac{1}{2}\left(1 + \frac{V_w}{|V_w|}\right) \qquad (4.1.2.22)$$

Each of these parameters has a value of unity if the velocity component is positive (or, by convention, non-negative) and zero if it is negative. The transition Peclet number is now given by the general result.

$$P_{e_w}^{*} = \frac{1}{\sigma_w^u - (1 - \alpha_w)} \qquad (4.1.2.23)$$

In the hybrid differencing procedure, the more accurate central differencing formulation (Eq. 4.1.2.4) is used when the Peclet number is less than the transition value while the less accurate, but stable, upwind differencing result (the generalization of Eq. (4.1.2.6))

$$\frac{F_{w_{UD}}}{D_W} = P_{e_w}\,[\sigma_w^u\,\phi_W + (1 - \sigma_w^u)\,\phi_P] \qquad (4.1.2.24)$$

is used when the Peclet number is greater than the transition value. Originally it was believed that a similar hybrid procedure could be developed for skew upwind differencing with Eq. (4.1.2.4) used for Pe < Pe* and Eq. (4.1.2.20) used for Pe > Pe* . However, this approach proved to be unworkable since some of the coefficients derived from this hybrid formulation for use in Eq. (4.1.2.7) can be negative. As an alternative, a flux blending scheme is used in which a weighted average of the upwind differencing and the skew upwind differencing fluxes is used. The weighting (blending) factor, γ, is chosen in such a way as to assure boundedness (i.e., all co-efficients of Eq. (4.1.1.7) are non-negative). The bounded skew-upwind differencing (BSUD) flux is defined by

$$F_{w_{BSHD}} = \gamma_w F_{w_{SUD}} + (1 - \gamma_w)\,F_{w_{UD}} \qquad (4.1.2.25)$$

with the weighting factor restricted to the range, $0 \leq \gamma_W \leq 1$. As a consequence of this definition:

$$\frac{F_{w_{BSUD}}}{D_W} = P_{e_w}\,[\sigma_w^u\,\phi_W + (1 - \sigma_w^u)\,\phi_P] - (P_{e_w} - P_{e_w}^{*})\,\gamma_w k_w \left[\sigma_w^u\left\{\phi_W - \sigma_w^v\,\phi_{SW} - (1 - \sigma_w^v)\,\phi_{NW}\right\} + (1 - \sigma_w^u)\left\{\phi_P - \sigma_w^v\,\phi_S - (1 - \sigma_w^v)\,\phi_N\right\}\right] \qquad (4.1.2.26)$$

Finally, a bounded skew hybrid differencing (BSHD) formulation can be defined as:

$$F_{w_{BSUD}} = \lambda_w F_{w_{CD}} + (1 - \lambda_w)\,F_{w_{BSUD}} \qquad (4.1.2.27)$$

where γ is permitted to assume only two values: $\gamma = 1$ for central differencing ($Pe < Pe^*$) and $\lambda = 0$ for bounded skew-upwind differencing ($Pe > Pe^*$). Eqs. (4.1.2.26) and (4.1.2.27) are the basic working relationships to determine the flux at the west face of the control volume. The contributions of the flux to each of the co-efficients in Eq. (4.1.1.7) can be immediately identified by using Eqs. (4.1.2.26) and (4.1.2.27) in Eq. (4.1.1.5).

Equations analogous to Eq. (4.1.2.26) can be derived for the other three faces of the control volume in exactly the same manner as employed above. However, the results can be obtained by inspection as follows:

<u>East</u>

The east face flux is obtained by translating the nodal subscripts eastward such that:

West Subscript		East Subscript
W	becomes	P
P	becomes	E
SW	becomes	S
NW	becomes	N
S	becomes	SE
N	becomes	NE

Of course, the lower case subscript "w" becomes "e".

<u>South</u>

The south face flux is obtained from the west flux Eq. 4.1.2.26 by rotating the nodal subscripts through 90 degrees in the counterclockwise

West Subscript		East Subscript
W	becomes	S
SW	becomes	SE
NW	becomes	SW
S	becomes	E
N	becomes	W
σ^u	becomes	σ^v

$1 - \sigma^u$	becomes	$1 - \sigma^v$
σ^v	becomes	$1 - \sigma^u$
$1 - \sigma^v$	becomes	σ^u

North

The north face flux is derived by translating the south flux result northward:

South Subscript		North Subscript
S	becomes	P
P	becomes	N
SE	becomes	E
SW	becomes	W
E	becomes	NE
W	becomes	NW

The results of the manipulations are summarized in Tables 3 through 5.

4.1.3 - Calculation of the Coefficients for the Finite-Difference Form of the Equations of Motion

The finite-difference form of the equations of motion, (e.g., Eq. (4.1.1.7)) can be derived directly from the flux information presented in Tables 3 through 5 and the sign conventions determined from Eq. (4.1.1.5). The resulting expressions will contain the unknown blending factor, γ. The blending strategy requires that the terms in the equations for the coefficients most responsible for producing negative co-efficients be isolated so that appropriate values for γ can be determined. Furthermore, the coefficients for the control volumes adjacent to the physical boundaries of the flow may require modification to incorporate the effect of the boundary conditions. Thus, to simplify manipulation and modification, some additional notation will be defined.

Let the center of the control volume (point P) be located at the Ith axial position and Jth radial position. The flux contributions (the components of the total flux) to the east face are denoted as E1(I,J), E2(I,J), E3(I,J) and the flux contributions to the north face are denoted as N1(I,J), N2(I,J), N3(I,J). These flux contributions are defined as follows:

$1 - \sigma^u$	becomes	$1 - \sigma^v$
σ^v	becomes	$1 - \sigma^u$
$1 - \sigma^v$	becomes	σ^u

North

The north face flux is derived by translating the south flux result northward:

South Subscript		North Subscript
S	becomes	P
P	becomes	N
SE	becomes	E
SW	becomes	W
E	becomes	NE
W	becomes	NW

The results of the manipulations are summarized in Tables 3 through 5.

4.1.3 - Calculation of the Coefficients for the Finite-Difference Form of the Equations of Motion

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Let the center of the control volume (point P) be located at the Ith axial position and Jth radial position. The flux contributions (the components of the total flux) to the east face are denoted as E1(I,J), E2(I,J), E3(I,J) and the flux contributions to the north face are denoted as N1(I,J) N2(I,J), N3(I,J). These flux contributions are defined as follows:

Central Differencing:

$$E1(I,J) = D_E - \alpha_e C_E$$
$$E2(I,J) = E1(I,J) + C_E \qquad (4.1.3.1)$$
$$E3(I,J) = 0$$

$$N1(I,J) = D_N - \alpha_n C_N$$
$$N2(I,J) = N1(I,J) + C_N \qquad (4.1.3.2)$$
$$N3(I,J) = 0$$

Bounded Skew-Upwind Differencing

$$E1(I,J) = (c_e^u - 1)\ C_E$$
$$E2(I,J) = E1(I,J) + C_E \qquad (4.1.3.3)$$
$$E3(I,J) = k_e(C_E - P_{e_e}^{*} D_E)$$

$$N1(I,J) = (c_n^v - 1)\ C_N$$
$$N2(I,J) = N1(I,J) + C_N \qquad (4.1.3.4)$$
$$N3(I,J) = k_n(C_N - P_{e_n}^{*} D_N)$$

The use of central vs. bounded skew-upwind differencing is determined by the value of the Peclet number at each face. The parameters C_E, D_E, α_e, k_e, . . . are local values; the subscripts (I,J) have been omitted in the interest of readability. The corresponding flux contributions at the west face are given immediately by E1(I-1,J), E2(I-1,J), E3(I-1,J) and the flux contributions at the south face are N1(I,J-1), N2(I,J-1), N3(I,J-1).

The coefficients of the finite-difference form of the equations of motion may then be defined in terms of these flux contributions. The results are presented in Table 6. The coefficient Ap can be shown to be equal to the sum of the other eight coefficients when use is made of the mass continuity restriction:

$$C_E - C_W + C_N - C_S = 0 \qquad (4.1.3.5)$$

The boundary conditions (Section 4.3) and the bounding scheme (Section 4.1.4)) can be applied directly to the flux contributions so that the results shown in Table 6 are general.

4.1.4 - The Bounding Scheme

The calculation of the bounded skew-upwind differencing fluxes and, therefore, the determination of the coefficients to the finite-difference form of the equations of motion requires that the blending factor, γ, be determined. The blending factor specifies the relative proportions of the flux computed using skew and upwind differencing. For example, at the west face of the typical control volume, Eq. (4.1.2.25) states:

$$\frac{F_{w_{BSUD}}}{D_W} = \gamma_w F_{w_{SUD}} + (1 - \gamma_w) F_{w_{UD}} \qquad (4.1.4.1)$$

The co-efficients including the local blending factor are listed in Table 6.

It is possible to show that the corner co-efficients (A_{SW}, A_{SE}, A_{NW}, A_{NE}) are unconditionally non-negative. For example, consider the coëfficient A_{SW}:

$$A_{SW}\ (I,J) = \gamma_w\ [\sigma^u_e c^u_e E3]_{I-1,J} + \gamma_s\ [c^u_n c^u_n N3]_{I,J-1} \qquad (4.1.4.2)$$

Both γ_w and γ_s are restricted to the range $0 \leq \gamma \leq 1$. If both the axial and radial velocities at the west face of the control volume are positive, then both σ^u_e and c^v_e at this location are unity; in any other case, either (or both) are zero. For positive u and v velocities, the flux contribution E3(I-1,J) at the west face is positive. Therefore, the west face flux contribution to A_{SW} is always nonnegative. The same reasoning when applied to the south face leads to a similar conclusion. Therefore, A_{SW} is unconditionally non-negative. The other corner coefficients are treated in the same manner.

Now, consider the four main co-efficients (A_W, A_E, A_S, A_N). From Table 6:

$$\begin{aligned} A_W(I,J) = {} & E2(I-1,J) - \gamma_w\ [c^u_e E3]_{I-1,J} \\ & + \gamma_s\ [(1-c^v_n)\ c^u_n N3]_{I,J-1} \\ & - \gamma_n\ [c^v_n c^u_n N3]_{I,J} \end{aligned} \qquad (4.1.4.3)$$

From the definitions of the flux contributions, Eqs. (4.1.3.1) through (4.1.3.4), it is evident that:

(1) E2(I-1,J) is positive if the axial velocity is positive and it is zero otherwise;

(2) σ^u_e and E3 at the west face (I-1,J) are positive if the axial velo-

city is positive but σ_e^u is zero if u is negative;

(3) from the definitions of E2 and E3 and the fact that $\gamma_w \leq 1$, it is therefore concluded that the first two terms in Eq. (4.1.4.3) must yield a non-negative result;

(4) the third term is zero unless u is positive and v is negative at the south face, in which case, it is negative;

(5) the fourth term is non-positive because the term within the brackets is always non-negative.

Therefore, it is possible that the co-efficient A_W is negative.

It is desirable that all of the co-efficients of the finite-difference form of the equations of motion (Eq. (4.1.1.7)) be non-negative for in this case the value of the dependent variable ϕ at the node P is simply a weighted average of the values of ϕ at the surrounding nodes exclusive of the (somewhat complicating) effects of local sources. A bounding scheme is a procedure to limit the values of the co-efficients of the finite-difference equations in such a manner as to produce this physically realistic result. Its principal computational advantage is to exclude under- and overshoots of the solution during the iterative procedure; these oscillations can produce severe numerical instability.

The bounding procedure used herein is based upon the following sequence:

(1) For convenience, the following quantities are defined:

$$\tilde{a} = E2(I-1,J) - \gamma_w [\sigma_e^u E3]_{I,J-1} \quad (4.1.4.4)$$

$$\tilde{a}_s = -[(1-\sigma_n^v) \sigma_n^u N3]_{I,J-1} \quad (4.1.4.5)$$

$$\tilde{a}_n = [\sigma_n^v \sigma_n^u N3]_{I,J} \quad (4.1.4.6)$$

so that

$$A_w = \tilde{a} - \gamma_s \tilde{a}_s - \gamma_n \tilde{a}_n \quad (4.1.4.7)$$

From the previous discussion, $\tilde{a} \geq 0$, $\tilde{a}_s \geq 0$ and $\tilde{a}_n \geq 0$.

(2) It is desired that $A_W > 0$. Therefore, the blending factors, γ_s and γ_n, are the solution to the linear programming problem

$$\tilde{a}_s \gamma_s + \tilde{a}_n \gamma_n \leq \tilde{a} \quad (4.1.4.8)$$

subject to the constraints

$$0 \leq \gamma_s \leq \tilde{\gamma}_s \qquad (4.1.4.9)$$

$$0 \leq \gamma_n \leq \tilde{\gamma}_n \qquad (4.1.4.10)$$

(3) The solution to this problem is given by:

If $\tilde{a}_s \geq \tilde{a}_n$

$$\gamma_s = \min [\ \tilde{\gamma}_s,\ \tilde{a}/\tilde{a}_s] \qquad (4.1.4.11)$$

$$\gamma_n = \max [\ 0,\ (\tilde{a} - \tilde{a}_s\gamma_s)/\tilde{a}_n\ ] \qquad (4.1.4.12)$$

If $\tilde{a}_n \geq \tilde{a}_s$

$$\gamma_n = \min [\ \tilde{\gamma}_n,\ \tilde{a}/\tilde{a}_n] \qquad (4.1.4.13)$$

$$\gamma_s = \max [\ 0,\ (\tilde{a}-\tilde{a}_n\gamma_n)/\tilde{a}_s] \qquad (4.1.4.14)$$

The upper limits, $\tilde{\gamma}_s$ and $\tilde{\gamma}_n$, are normally equal to unity or are the values determined for the faces of adjacent control volumes; e.g., the west face of the control volume at (I, J) is the east face of the control volume at (I-1, J).

The resulting set of blending factors are then used to compute all of the coefficients in Table 6.

4.2 Source Terms

In this section, the finite-difference approximation to representative source terms of the governing equations are described briefly. From Eqs. (4.1.1.2) and (4.1.1.7) it can be seen that the source term is linearized into a term independent (in an explicit sense) of the dependent variable at the grid node P and a term explicitly dependent on ϕ_P:

$$S_\phi = S_u + S_p\phi_P \qquad (4.2.1)$$

Then, using Eq. (4.1.1.7), one "solves" for ϕ_P:

$$\phi_P = \frac{\sum_i A_i\phi_i + S_u}{A_P - S_P} \qquad (4.2.2)$$

The determination of S_u and S_p for each dependent variable may be illustrated by considering the source term for the rate of reaction of fuel, Eq. (3.3.5):

$$S_{m_f} = -\rho \frac{\varepsilon}{k} \min \left[Am_f, \frac{Am_{O_2}}{i}, \frac{ABm_{pr}}{i+1} \right] \tag{4.2.3}$$

If either the fuel or oxidizer are the minimum of the three rates contained in the brackets, then:

$$S_{m_f} = -\rho \frac{\varepsilon}{k} Am_f \tag{4.2.4}$$

or

$$S_{m_f} = 0 + \left(-\frac{\rho \varepsilon A}{k} \right) m_f \tag{4.2.5}$$

Hence,

$$S_u = 0 \tag{4.2.6}$$

$$S_p = -\frac{\rho \varepsilon A}{k} \tag{4.2.7}$$

But if the third term (the product term) is the minimum, then

$$\begin{aligned} S_{m_f} &= -\frac{\rho \varepsilon}{k} \frac{ABm_{pr}}{i+1} \\ &= -\frac{\rho \varepsilon}{k} AB\ (f-m_f) \\ &= -\frac{\rho \varepsilon}{k} AB\ (f-2m_f) - \frac{\rho \varepsilon}{k} ABm_f \end{aligned} \tag{4.2.8}$$

Then,

$$S_u = -\frac{\rho \varepsilon}{k} AB\ (f-2m_f) \tag{4.2.9}$$

$$S_p = -\frac{\rho \varepsilon}{k} AB \tag{4.2.10}$$

It is seen that Eq. (4.2.9) depends explicitly on the fuel mass fraction; necessarily, S_u is evaluated using the results from the previous iteration.

Numerical stability in the determintion of ϕ_p is enhanced if the coefficient S_p is non-positive. If S_p is positive, then it can be seen that the denominator in Eq. (4.2.2) may become negative (or zero) causing oscillations in the solution for ϕ_p. The linearization of the source term for the fuel mass fraction guarantees that S_p is non-positive.

Other source terms in the governing equations require similar treatment. For example, the source term (per unit volume) in the tangential (swirl velocity) momentum equation is:

$$\frac{S_w}{\delta V} = -\frac{2}{r}\frac{\partial}{\partial r}(rw\mu_{eff}) \qquad (4.2.11)$$

which is written in finite-differences as:

$$\frac{S_w}{\delta V} = -\frac{2}{r_p \Delta r}\left[r_n w_n \mu_{eff_n} - r_s w_s \mu_{eff_s} \right] \qquad (4.2.12)$$

It is maintained that the form of Eq. (4.2.12) is essential to preserving the equivalency between the partial differential equation for swirl velocity and the finite-difference approximation. Other forms such as:

$$\frac{S_w}{\delta V} = -\frac{2}{r_p \Delta r}\left[(rw)_n \mu_{eff_n} - (rw)_s \mu_{eff_s} \right] \qquad (4.2.13)$$

or

$$\frac{S_w}{\delta V} = -\frac{2}{r_p \Delta r}\left[(rw\mu_{eff})_n - (rw\mu_{eff})_s \right] \qquad (4.2.14)$$

do not preserve the desired equivalency because the quantities w_s, w_n, μ_{eff_s} and μ_{eff_n} must be interpolated at the desired locations (i.e., at r_s and r_n). The source term, when multiplied by the cell volume ($r_p \Delta r \Delta x$) becomes

$$S_w = -2\Delta x r_n w_n \mu_{eff_n} + 2\Delta x r_s w_s \mu_{eff_s} \qquad (4.2.15)$$

or

$$S_w = 2\Delta x r_s w_s \mu_{eff_s} + \left(-\frac{2\Delta x r_n w_n \mu_{eff_n}}{w_p} \right) w_p \qquad (4.2.16)$$

so that

$$S_u = 2\Delta x r_s w_s \mu_{eff_s} \qquad (4.2.17)$$

and

$$S_p = -\frac{2\Delta x r_n w_n \mu_{eff_n}}{w_p} \qquad (4.2.18)$$

It must be noted that both w_s and w_n may depend on w_p and that the values of w_n, w_s and w_p in Eqs. (4.2.17) and (4.2.18) are obtained from values at the previous iteration.

4.3 Boundary Conditions

The boundary conditions are applied to the flux contributions as defined by Eqs. (4.1.3.1) through (4.1.3.4) so that the set of coefficients (e.g., Table 6) for each dependent variable is the same throughout the computational domain. This consistency simplifies the application of both (1) the algorithm for solving the set of simultaneous equations for each variable and (2) the bounding procedure.

The boundary conditions are applied to the control volumes in the vicinity of the physical boundaries for the flow field (see Fig. 1). Thus, the left-most control volumes include either the main flow or secondary flow inlets or the bluff body. The right-most control volumes include the combustor outlet. The top-most control volumes include a solid wall while the bottom-most control volumes include the axis of symmetry.

Inlets

The flows in either the main or secondary inlet are known and specified. It is assumed that constant values of axial velocity, swirl velocity, turbulence intensity, fuel concentration, and temperature are known for each inlet. The radial velocity is assumed to be zero and the static pressure is assumed to be the same for both inlets.

Axis of Symmetry

At the axis of symmetry, the normal gradient for each dependent variable, except for the radial velocity, is assumed to vanish; the radial velocity is assumed to be zero. By setting the co-efficients A_N and A_S to zero for the radial gridline adjacent to the axis of symmetry, then the finite difference form of the normal gradient becomes:

$$\left(\frac{\Delta \phi}{\Delta r}\right)_{\text{Axis of symmetry}} = 0 \qquad (4.3.1)$$

For all variables, except the radial velocity, the axis of symmetry is located midway between the J=1 and J=2 radial gridlines. For the converged solution, the boundary condition (Eq. (4.3.1)) produces the result:

$$\phi_{I,1} = \phi_{I,2} \quad (\phi \neq v) \qquad (4.3.2)$$

where I is the axial gridline index. For the radial velocity, the axis of symmetry and the radial gridline for radial velocity are coincident and the boundary condition becomes:

$$v_{I,1} = 0 \qquad (4.3.3)$$

Outlet

At the outlet of the combustor, the axial gradient in all variables except axial velocity is assumed to vanish. By setting the co-efficients A_E and A_W at the outlet to zero, the finite-difference approximation to the gradient becomes

$$\left(\frac{\Delta\phi}{\Delta x}\right)_{outlet} = 0 \qquad (4.3.4)$$

so that

$$\phi_{NI,J} = \phi_{NI-1,J} \qquad (4.3.5)$$

where NI is the number of axial grid lines. For the axial velocity, a velocity correction U_{INC} is applied uniformly so that

$$U_{NIU,J} = U_{NIU-1,J} + U_{INC} \qquad (4.3.6)$$

where NIU = NI-1. The correction U_{INC} is the velocity increment necessary to conserve mass flow at the outlet.

Solid Wall

If the resolution of the grid system could be made arbitrarily fine in the vicinity of a wall, then application of the appropriate boundary conditions at the wall would be straightforward. For example, the velocity components u, v, w vanish at a wall. However, for a realistic grid system, setting the velocity to zero for components of the velocity vector parallel to the wall (by adjusting the co-efficients of the finite-difference equations) is improper because the co-efficients do not properly account for the effects of the wall; i.e., the shear is computed incorrectly. Instead, wall functions are used to compute contributions to the source terms in the governing equations. For a velocity component normal to the wall, the co-efficients may be adjusted so that this velocity component vanishes. (See the discussion for the axis of symmetry boundary condition.)

Consider the case for which the axial velocity is parallel to a wall. The flow in the region near the wall is assumed to behave as one-dimensional Couette flow. For turbulent flow, the shear stress is assumed to be constant in the Couette flow region except in the laminar sublayer immediately adjacent to the wall. Following Launder and Spalding (Ref. 2), the laminar sublayer extends from the wall to y+ = 11.63 where

$$y^+ = \left(\frac{\rho \, C_\mu^{1/4} \sqrt{k} \, y}{\mu_\ell}\right)_P \qquad (4.3.7a)$$

with the density, molecular viscosity, turbulent kinetic energy and grid distance from the wall evaluated at node P. If y+ is less than 11.63, then the shear stress is given by:

$$\tau_w = \left(\mu_\ell \frac{u}{y} \right)_P \qquad (4.3.7b)$$

Otherwise the point P is within the turbulent flow region and the shear stress is calculated using the logarithmic law of the wall so that

$$\tau_w = \left[\rho \, C_\mu^{\frac{1}{4}} \, K \sqrt{k} \;\; u/\ell n \, (Ey^+) \right]_P \qquad (4.3.8)$$

Here K and E are constants given in Table 1. The shear stress contribution to the source term for the axial velocity momentum equation is

$$S_P U_P = \left(- \frac{\tau_w}{U_P} A_\tau \right) U_P + \ . \ . \ . \qquad (4.3.9)$$

where A_τ is the area of the face of the control volume adjacent to the wall.

The influence of the walls on the v and w velocity components is treated similarly. Of course, the normal distance y in Eq. (4.3.7) must be interpreted appropriately. For swirling flows, the shear stress on the top wall must be resolved into axial and azimuthal components.

For the turbulent kinetic energy equation, the coefficient corresponding to the wall node is set to zero and the source term (see Eq. 3.2.2) is given by:

$$S_k = \mu_t G - \left[C_\mu^{3/4} \, \rho \, k^{3/2} \;\; y^+/y \right]_P \quad , \; y^+ < 11.63 \qquad (4.3.10)$$

$$S_k = \mu_t G - \left[C_\mu^{3/4} \, \rho \, k^{3/2} \; \ell n \, (Ey^+)/(Ky) \right]_P \quad , \; y^+ \geq 11.63 \qquad (4.3.11)$$

The shear stress evaluated above is used in the generation term G to compute $(\mu \partial u/\partial y)$.

The turbulent dissipation rate, ε, is computed in the vicinity of a wall by assuming that the rates of turbulent kinetic energy generation and dissipation are equal so that the value of ε at the edge of the Couette flow region is given by:

$$\varepsilon_P = \left[\frac{C_\mu^{3/4} \, k^{3/2}}{Ky} \right]_P \qquad (4.3.12)$$

By defining the source for ε as

$$S_\varepsilon = 10^{30} + 10^{30}\,\varepsilon_p \tag{4.3.13}$$

then by Eq. (4.1.1.7), $\phi_p = \varepsilon_p$.

For both the mixture fraction, f, and the fuel mass fraction, m_f, it is assumed that the flux normal to the wall vanishes. Thus, for both f and m_f, this boundary condition is mathematically identical to the axis of symmetry boundary condition.

The enthalpy at the wall is determined using Eq. (3.3.2) with the wall temperature specified and the fuel mass fraction calculated as above.

$$h_{wall} = m_{f_{wall}} H_R + C_{p,m} T_{wall} \tag{4.3.14}$$

4.4 Pressure Implicit Split Operator

The finite-difference approximations to the governing equations are solved using the Pressure Implicit Split Opertor (PISO) developed at Imperial College by Issa (Ref. 6). The finite-difference equations are solved iteratively. The velocities are first calculated from the momentum equations using a guessed pressure distribution; then the pressure distribution is adjusted so that the velocities satisfy the mass continuity equation and the cycle is repeated.

The PISO algorithm involves splitting operations that couple the velocity and pressure variables.

Let the superscripts *, ** and *** denote intermediate field values obtained during the operation of the algorithm which consists of a predictor step and two corrector steps.

<u>Predictor Step</u> - The pressure distribution prevailing at the nth iteration is used in the solution of the axial and radial velocity momentum equations which can be written in the general form:

$$A_p^{u_i} u_i^* = \sum_m A_m^{u_i} u_{im}^* + D_p^{u_i} \Delta_i p^n + S_p^{u_i} \tag{4.4.1}$$

where U_i represents either of the velocity components, u or v, and the operator Δ_i is a difference operator given by

$$\begin{aligned} \Delta_{ip} &= p_w - p_e \quad \text{for} \quad u_i = u \\ &= p_s - p_n \quad \text{for} \quad u_i = v \end{aligned} \tag{4.4.2}$$

The subscript m denotes the nodes, E, W, NE, . . .

First Corrector Stage - A new velocity field u_i^{**} together with a corresponding new pressure field p^* are calculated such that the zero divergence (incompressible continuity) condition

$$\Delta u_i^{**} = 0 \tag{4.4.3}$$

is satisfied. The momentum equation is now written as:

$$A_p^{u_i} u_i^{**} = \sum_m A_m^{u_i} u_{i_m}^{*} - D_p^{u_i} \Delta_i p^* + S_p^{u_i} \tag{4.4.4}$$

By subtracting Eq. (4.4.1) from Eq. (4.4.4), a velocity-increment equation is obtained:

$$A_p^{u_i} (u_i^{**} - u_i^*) = D_p^{u_i} \Delta_i (p^* - p^n) \tag{4.4.5}$$

Combining the divergence of this equation with Eq. (4.4.3) the pressure-correction equation is obtained:

$$\Delta_i \left[A_p^{u_i -1} D_p^{u_i} \Delta_i \right] p' = \Delta_i u_i^* \tag{4.4.6}$$

where

$$p' = p^* - p^n \tag{4.4.7}$$

Eq. (4.4.6) is solved for the p' field so that the revised pressure distribution p^* is determined and a new velocity field u_i^{**} is calculated.

Second Corrector Step - A new velocity field u_i^{***} together with a corresponding pressure distribution p^{**} are calculated such that

$$\Delta_i u_i^{***} = 0 \tag{4.4.8}$$

The momentum equation is now written as:

$$A_p^{u_i} u_i^{***} = \sum_m A_m^{u_i} u_{i_m}^{**} - D_p^{u_i} \Delta_i p^{**} + S_p^{u_i} \tag{4.4.9}$$

Subtracting Eq. (4.4.5) from Eq. (4.4.9) yields:

$$A_p^{u_i} (u_i^{***} - u_i^{**}) = \sum_m A_m^{u_i} (u_i^{**} - u_i^*)_m - D_p^{u_i} \Delta_i (p^{**} - p^*) \tag{4.4.10}$$

This equation combined with the continuity relations (4.4.3) and (4.4.8) yields the second pressure-correction equation:

$$\Delta_i \left[A_p^{u_i -1} D_p^{u_i} \Delta_i \right] p'' = \Delta_i \left[A_p^{u_i -1} \sum_m A_m^{u-1} (u_i^{**} - u_i^*)_m \right] \tag{4.4.11}$$

where

$$p'' = p^{**} - p^{*} \quad (4.4.12)$$

Eq. (4.4.11) is solved for the p" field so that the revised pressure distribution p^{**} is computed and a new velocity field u_i^{***} is determined. The pressure and velocity distributions for the (n+1)th iteration are taken as p^{**} and u_i^{***}, respectively.

A similar procedure is used for the turbulent kinetic energy and turbulent energy dissipation equations because these equations are strongly coupled by means of their source terms. The equations for k and ε are first solved for the source term components based on the previous iteration values. A corrector step is then applied to account for the changes in the source terms.

5.0 DESCRIPTION OF COMPUTER PROGRAM

The computer program based on the mathematical model described in Section 3.0 is described in this section. Information is presented to assist the user in the installation of the program on modern large-scale computers. Additionally, an input format is provided.

5.1 General Remarks

The computer program is intended for use in the batch-operating mode on modern large-scale computers. Specifically, programming constructions have been avoided that refer to the characteristics of specific computer operating systems. In addition, all logical units referred to by the program are defined using integer constants initialized in the BLOCK DATA routine BLOCKD. In the present version of the program, these logical units have been assigned as follows:

Name	Value	Purpose
LU4	4	Restart file
LU5	5	Card reader
LU6	6	Line printer
LU8	8	Scratch unit
LU9	9	Scratch unit

The program may be stopped periodically and the results stored in the restart file, LU4. The calculation may subsequently be continued from the latest iteration by using the restart file in conjunction with the options described on Card No. 2 of the Input Format, Section 5.7.

The present program was derived from the development version provided by Imperial College to UTRC. The Imperial College computer is taken to be a CDC 6600 computer with a FORTRAN IV compiler. Except for eliminating two minor incompatible constructions and the CDC PROGRAM card, the development program was completely compatible with the FORTRAN V compiler used on the UNIVAC 1100/81A computer at UTRC. For the convenience of users of CDC computers, the PROGRAM card has been retained but rendered inoperable in the present version (see routine AMAIN, lines 1-2). It is believed that the present version is also compatible with the IBM FORTRAN IV compiler.

No attempt was made to compile the present version of the program using the UNIVAC 1977 ASCII FORTRAN compiler since it would have been necessary to eliminate any incompatibilities between the constructions used in the development version and the 1977 ASCII standard; in addition, it is known that some 1977 ASCII standard compilers are not compatible with each other.

The workers at Imperial College have indicated throughout the program those sections of the code that are restricted to flow within a research combustor of the type shown in Fig. 1. They have labeled these sections of the code as "Problem Dependent". No attempt has been made to determine if other sections of the code should be designated in a similar manner.

The computer program can be allocated in approximately 50000 decimal words, or 200000 bytes.

5.2 Program Flow Chart

A general flow chart of the computer program is shown in Fig. 6. The input to the program is read in subroutine MODINP; additional constants are initialized in the BLOCK DATA routine. Initial guesses are assigned for the distributions of each of the field variables. The program then proceeds as follows:

1. A pressure distribution is guessed. For the first iteration, the estimated pressure distribution is provided by subroutine MODINP. On subsequent iterations, it is assumed to be the distribution determined at the end of the previous iteration.

2. The axial and radial momentum equations are solved for the axial and radial velocity distributions using subroutines COEFU and COEFV.

3. The pressure-correction equations (i.e., the PISO algorithm) are solved using subroutine CALUVP to obtain the corrected pressure, axial velcoity and radial velocity distributions.

4. The swirl velocity (actually, the product of radius and swirl velocity) distribution is solved for using subroutine CALCFI.

5. The turbulent kinetic energy and energy dissipation rate are determined using subroutine CALCFI.

6. The turbulent kinetic energy and energy dissipation rate are adjusted using the predictor-corrector technique noted in Section 4.4.

7. The distributions of the remaining dependent variables (e.g., enthalpy, mixture fraction, fuel concentration) are calculated using subroutine CALCFI.

8. The absolute values of the normalized residuals for each variable are examined at all points in the flow field. If the residuals are all less than a specified maximum value, the solution is considered to be converged; otherwise, the iteration is repeated from Step 1.

The distributions for each variable are solved using a line-by-line iterative procedure which utilizes a tridiagonal matrix algorithm (subroutine LISOLV) to solve simultaneously for the variables along each grid line. An alternating direction scanning procedure is employed to sweep the whole field. The number of sweeps is usually different for each variable. Generally, two sweeps are used for the axial and radial velocities and one sweep is used for all other variables except for the primary pressure correction equation. Since this equation is strongly elliptic and has Neumann boundary conditions specified at all boundaries, at least three sweeps are generally made.

5.3 Description of Routines

A brief description of each of the routines used in the computer program is presented in this section. The principal FORTRAN variables are listed in Section 5.4, the entry point and external reference table is presented in Section 5.5, the source language listings are displayed in Section 5.6, and the input format is presented in Section 5.7.

AMAIN

AMAIN is the main program whose principal operation is to control the progress of the iterative solution described in the previous section. Additionally, AMAIN controls the rate of intermediate printout (e.g., the printing of the maximum residuals and values of the dependent variables at the monitoring grid node) and it determines which of the distributions for the dependent variables will be displayed by subroutine PRINT. For reacting flows, this routine initiates the combustion reaction by introducing at the iteration ITREAX an artifical difference in the mixture fraction and fuel concentration (e.g., by setting $m_f = 0.9f$) at the monitoring grid node (IMON, JMON). Finally, AMAIN retrieves dependent variable distributions from the file on logical unit LU4 to restart a calculation; and it stores these distributions in the same file at the end of the current execution so that the case may be started subsequently from the latest iteration.

BLOCKD

The BLOCK DATA routine initializes certain print heading arrays, assigns values to the constants used for logical units and for the turbulence model, and sets some miscellaneous controls.

BOUNDS

This subroutine determines the values of the flux blending factor used to adjust the flux contributions to the coefficients of the finite-difference equations such that the coefficients are non-negative. The bounding procedure is described in Section 4.1.4. It should be noted that γ does not appear explicitly in this subroutine; instead, the values of the flux contributions are reduced in accordance with the bounding procedure.

CALCFI

Subroutine CALCFI is a general subroutine for calculating the distributions of all scalar variables and the product of swirl velocity with radial position. The coefficients of the finite-difference equations are calculated for each variable (i.e., for each call to CALCFI). In some cases, it is known that the co-efficients for one scalar are simply related to those for another. A provision is made to determine one set of co-efficients from the other without the need to recompute all of the flux contributions. Often, two sets have identical values or differ only by the ratio of the Prandtl numbers for each variable. The source term contributions to the finite-difference equations are then calculated by calling subroutine SORCFI. The modifications to the co-efficients due to the boundary conditions are determined by calling subroutine MODFI. The co-efficients are then bounded using subroutine BOUNDS. The underrelaxation factors are then applied. The system of simultaneous equations is then solved using subroutine LISOLV.

CALUVP

Subroutine CALUVP uses the coefficients assembled in subroutines COEFU and COEFV for the axial and radial momentum equations to solve for the initial estimates of the axial and radial velocity distributions, respectively, for the current iteration. The co-efficients for the finite-difference form of the primary and secondary pressure-correction (predictor-corrector) equations are then calculated and the final velocity fields are determined. (See the discussion of the PISO algorithm, Section 4.4.)

COEFU

Subroutine COEFU is used to calculate the co-efficients of the finite-difference form of the axial momentum equation. First, the convection and diffusion contributions to the coefficients are calculated. Next, the components of the source term are determined. The flux contributions to the finite-difference coefficients are then calculated. The effects of the boundary conditions are incorporated by calling the entry point MODU of subroutine MODUVP. The bounding strategy is then applied by using subroutine BOUNDS. Finally, the coefficients are stored for use by subroutine CALUVP.

COEFV

Subroutine COEFV is used for calculating the coefficients for the finite-difference form of the radial momentum equation. Its operation is similar to that of subroutine COEFU. The boundary conditions are applied by calling the entry point MODV of subroutine MODUVP.

CORECT

This subroutine determines the values of the flux blending factor used by subroutine BOUNDS to limit the co-efficients of the finite-difference equations to non-negative values.

CORTED

The turbulent kinetic energy and energy dissipation rate equations are strongly coupled to each other by their source terms. Subroutine CORTED performs a predictor-corrector operation for the two equations to provide more accurate estimates of these variables and thereby improve the rate of convergence of the entire system of equations.

INIT

Subroutine INIT defines the grids used in the calculation, determines cell dimensions for the control volumes, and calculates the factors used for interpolating variables at each face of the control volumes. The subroutine also initializes all arrays to appropriate values.

LISOLV

This subroutine solves the system of simultaneous finite-difference equations for each variable using an alternating direction method with a tridiagonal matrix solution algorithm. The first sweep of the system of equations is from west to east, the second form south to north, etc. The total number of sweeps is specified for each variable in the input.

MODFI

Subroutine MODFI is used to modify the coefficients of the finite-difference equations for each scalar variable due to the influence of the boundary conditions appropriate for that variable. The scalars are: turbulent kinetic energy, turbulent energy dissipation rate, enthalpy, fuel mass fraction, mixture fraction, and swirl velocity (actually, the product of swirl velocity with radial position). The boundary conditions are described in Section 4.3.

MODINP

This subroutine reads the input cards, writes the input on the line printer, sets all logical variables, calculates the reference values for the residuals, and initializes the dependent variables.

MODUVP

Subroutine MODUVP modifies the coefficients for the axial and radial momentum equations and for the pressure-correction coefficients in accordance with the boundary conditions (Section 4.3). The entry point MODPRO was provided by the authors of the program at Imperial College to deal with the effects of transport properties on the coefficients that are not incorporated elsewhere in the program; presently, this entry point contains no executable code.

OUTPUT

Subroutine OUTPUT prints the values of selected integrated quantities (main flow rate, secondary flow rate, etc.) and other parameters that characterize the flow field. For reacting flows, the distributions of oxygen, nitrogen, water vapor, and carbon dioxide are also printed.

PRINT

This subroutine generates a printout of the tabulated values of the field variables.

PROPS

Subroutine PROPS is used to determine the fluid properties at each point in the flow field. It is assumed that the main flow contains air with an oxygen mass fraction of 0.233 and a nitrogen mass fraction of 0.767. The average heat capacity, molecular weight, and density can then be determined. The viscosity at each point in the flow field is the sum of the laminar viscosity and turbulent viscosity. The effective diffusivity for the turbulent kinetic energy equation is also calculated. The diffusivities for other scalars are determined in subroutine CALCFI by multiplying the diffusivity for the turbulent kinetic energy equation by the ratio of the turbulent Prandtl number for another scalar to that for the turbulent kinetic energy.

SORCFI

This subroutine calculates the linearized source term components for each scalar in accordance with Section 4.2.

5.4 Principal FORTRAN Variables

The principal FORTRAN variables are listed in this section. The variables are arranged in logically occurring groups rather than in strict alphabetical order. Variables written as var(I,J) denote two-dimensional arrays defined for each axial gridline location I and each radial gridline location J.

AE(I,J) AW(I,J) AN(I,J) AS(I,J) ANE(I,J) ANW(I,J) ASE(I,J) ASW(I,J) AP(I,J)	Coefficients for the finite-difference equation for the control volume at point (I,J). E = east, W = west, etc., P = point (I,J)
CAPPA,ELOG	Constants in the velocity law of the wall
CCEN,CIN	Input mass fraction of second species (fuel) in secondary and main stream, respectively.
CMU,CD,C1,C2	Constants in the two-equation turbulence model
CPM(I,J)	Specific heat of mixture
CPO2 CPN2 CPCO2 CPH2O CPF	Specific heats of oxygen, nitrogen, carbon dioxide, water vapor and fuel, respectively
DELCEN,DELTA	Input value of boundary layer thicknesses for secondary and main stream, respectively

DEN(I,J)	Density
DENSIT	Input value for density for incompressible flow case
ED(I,J)	Turbulent kinetic energy dissipation rate
EN(I,J)	Enthalpy
E1(I,J) E2(I,J) E3(I,J)	Flux contributions, east face of control volume
F(I,J)	Mixture fraction
FM(I,J)	Fuel mass fraction
FN1(I,J) FN2(I,J) FN3(I,J)	Flux contributions, north face of control volume
FO2 FN2 FCO2 FH2O FPR	Mass fraction of oxygen, nitrogen, carbon dioxide, water vapor, and products of reaction, respectively
GAMH(I,J)	Diffusivity for turbulent kinetic energy
HR	Heat of reaction
IED IEN IF IFM IP IPP ISWR ITE IU IV	Parameters used to set the logical array INCAL for turbulent energy dissipation rate, enthalpy, mixture fraction, fuel mass fraction, primary and secondary pressure corrections, swirl velocity, turbulent kinetic energy, axial velocity, and radial velocity, respectively
IMON,JMON	Location for grid node used to monitor the calculation
INCAL	Linear array for the logical variable that determines if the differential equation for the Kth dependent variable is to be solved (INCAL(K)=.TRUE.) or not solved (INCAL(K)=.FALSE.)
INCOMP	Logical variable indicating whether flow is compressible (.FALSE.) or incompressible (.TRUE.)
INDCOS	Parameter to indicate whether flow is two-dimensional (1) or axisymmetric (2)

INDPRI	The number of iterations between the output of the tabulated field variables
INPRO	Logical variable indicating whether flow properties are constant (.FALSE.) or variable (.TRUE.)
IPREF,JPREF	Location of reference pressure node
ISCEME	Parameter indicating whether hybrid differencing (1) or skew-upwind differencing (2) is to be used
IT,JT	Maximum dimensions of the arrays var (I,J)
ITREAX	Iteration at which chemical reaction starts
ITSTEP	Number of iterations to be performed for current execution
IVISCO	Logical variable indicating whether viscosity is constant (.TRUE.) or variable (.FALSE.)
JEXIT	Radial grid line number for location of maximum radius at exit
JINS	Radial grid line number for location of maximum radius for secondary inlet
MAXIT	The maximum number of iterations to be executed
MAXSWP	The maximum number of sweeps to be executed by LISOLV for solving the pressure-correction equation
MODOP	Parameter indicating whether a new case is being started (1) or a previous case is being run using the Restart file (2)
NI,NJ	Number of input axial gridline and radial grid line locations, respectively
NSWP	A linear array denoting the number of sweeps to be used when solving for each of the dependent variables
NUMPRI	The number of iterations between output of the maximum residuals and monitoring node information
P(I,J)	Pressure
PERR	Maximum allowable residual in pressure correction equation
PIN	Input value of pressure
PRANDL	Laminar Prandtl number

PRANDT	A linear array of turbulent Prandtl numbers for each dependent variable
PREF	Reference pressure at node (IPREF,JPREF)
PP(I,J)	Pressure correction
SORMAX	Maximum allowable residual for any dependent variable
SNORM	A linear array of the maximum residuals for the dependent variables
SP(I,J) SU(I,J)	Coefficients in linearized source term that are dependent on and independent of the dependent variable at (I,J), respectively
STOIC	Stoichiometric oxygen to fuel mass ratio
T(I,J)	Temperature
TE(I,J)	Turbulent kinetic energy
TCEN,TIN	Input values of temperature for secondary and mainstream, respectively
TURBCN,TURBIN	Input values of constant of proportionality for turbulent kinetic energy for secondary and main stream, respectively
U(I,J)	Axial velocity
UCEN,UIN	Input values of axial velocity for secondary and main stream, respectively
UGC	Universal gas constant
URF	Linear array for underrelaxation factors for dependent variables except for density and viscosity
URFDEN	Underrelaxation factor for density
URFVIS	Underrelaxation factor for viscosity
V(I,J)	Radial velocity
VIS(I,J)	Total (laminar plus turbulent) viscosity
VISCOS	Input value of laminar viscosity
W(I,J)	Swirl velocity
WCEN,WIN	Input values of swirl to axial velocity ratio for secondary and main stream, respectively

XU — Input linear array of axial locations of axial velocity grid lines

YV — Input linear array of radial locations of radial velocity grid lines

5.5 Entry Points and External References

The entry points for each routine and the external references by each routine are listed in this section. An asterisk is used to denote external references to FORTRAN library routines.

Routine	Entry Points	External References
AMAIN	AMAIN	AMAX1*
		CALCFI
		CALUVP
		COEFU
		CALFV
		CORTED
		GAM
		INITOP
		INTOP
		PARAM
		PRINT
		PROPS
		STARTV
BOUNDS	BOUNDS	CORECT
CALCFI	CALCFI	AMIN1*
		BOUNDS
		LISOLV
		MODFI
		SIGN*
		SORCFI
CALUVP	CALUVP	LISOLV
		MODP
		MODU1
COEFU	COEFU	AMAX1*
		AMIN1*
		BOUNDS
		MODU
		SIGN*
COEFV	COEFV	AMAX1*
		AMIN1*
		BOUNDS
		MODV
		SIGN*
CORECT	CORECT	AMAX1*
		AMIN1*

CORTED	CORTED	MODFI SORCFI VISC
INIT	GRID INIT SET	
LISOLV	LISOLV	
MODFI	MODFI	AMAX1*
MODINP	MODINP PARAM STARTV	GRID PROPS SET
MODUVP	MODP MODPRO MODU MODUVP MODU1 MODV	
OUTPUT	FINOP INITOP INTOP OUTPUT	PRINT
PRINT	PRINT	MINO*
PROPS	DENS GAM PROPS VISC	AMAX1*
SORCFI	SORCFI	AMAX1* AMIN1*

5.6 Source Listings of Routines

The listing of the FORTRAN source language for each routine is presented in this section.

```
TEACH*TEACH(2).AMAIN(U)
      CLC    PROGRAM AMAIN( INPUT,OUTPUT,RESULT,TAPE5=INPUT,TAPE6=OUTPUT
      CLC  1                ,TAPE4=RESULT,TAPE6,TAPE9)
      C*****************************************************************
      C
      C                              TEACH
      C
      C           A COMPUTER PROGRAM FOR THE SIMULATION OF TURBULENT FLOW
      C           WITH COMBUSTION IN A BLUFF BODY COMBUSTOR
      C           COMBUSTION MODEL OF MAGNUSSEN & HJERTAGER (1976)
      C
      C*****************************************************************
      C
      C
      C           DEVELOPMENT VERSION
      C
      C
      C           JUNE      1983
      C*****************************************************************
      C
      C
      C-----------------------PROGRAM-CONTROL ROUTINE--------------------
      C
      CHAPTER  0  0  0  0  0  0  0  0  PRELIMINARIES  0  0  0  0  0  0  0  0
      C
            COMMON
           1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
           2      ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
           3      ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
           4      ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
           5      ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
           6      ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
           7      ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
           8      ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
           9      ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
           1      ,DYNPV(30),DYPSV(30),DT
           2      ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
           3      ,TAUNS(30),TAUSS(30),TAUWS(30)
           4      ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
            COMMON
           1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PPANDL(10),URF(10)
           2      ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
           3      ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
           4      ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
           5      ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
           6      ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
           7      ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
           8      ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
           9      ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
           1      ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
           2      ,GREAT,SMALL,PI,UGC,SWNO
           3      ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
           4      ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
           5      ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
           6      ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
           7      ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
            COMMON /COM3/LU4,LU5,LU6,LU8,LU9
            COMMON /COM4/ CPFTRM(5), ITREAX
            COMMON /COM5/WCEN,TURBCN,DELCEN
            LOGICAL INCAL,INCOMP,INPRO,IREAD,IVISCO,IWRITE,LAMINR
```

```
      1          ,NFREE,SSYM
C
CHAPTER 1 1 1 1 1 1 INPUT DATA 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
C
C
CHAPTER 2 2 2 2 2 2 INITIAL OPERATIONS 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
C
      CALL PARAM
C     CALL PRELIM
      IF(.NOT.IREAD) GO TO 30
      READ(LU4) NITER,U,V,P,TE,ED,EN,FM,F,VIS,DEN,W
      REWIND LU4
      CALL STARTV
   30 CONTINUE
      CALL INITOP
C
CHAPTER  3  3  3  3  3  3  3  ITERATION LOOP  3  3  3  3  3  3  3  3  3
C
      WRITE(LU6,310) IMON,JMON
      NITERS=NITER+1
      NITERE=NITER+ITSTEP
      DO 300 NITER=NITERS,NITERE
      DO 333 I=1,NI
      DO 333 J=1,NJ
      DU(I,J)=0.0
  333 DV(I,J)=0.0
C
C     START CHEMICAL REACTION?
C
      IF(NITER.EQ.ITREAX) FM(IMON,JMON)=0.9*F(IMON,JMON)
C-----UPDATE FLUID PROPERTIES
      CALL PROPS
C-----UPDATE MAIN DEPENDENT VARIABLES
      IF(INCAL(1)) CALL COEFU
      IF(INCAL(2)) CALL COEFV
      IF(INCAL(3)) CALL CALUVP
      IF(.NOT.INCAL(9)) GO TO 113
      DO 111 I=2,NI
      JSTR=JS(I)
      JEND=JN(I)
      DO 111 J=JSTR,JEND
  111 GAMH(I,J)=VIS(I,J)
      DO 200 I=1,NI
      W(I,1)=W(I,1)*R(2)
      DO 200 J=2,NJ
  200 W(I,J)=W(I,J)*R(J)
      CALL CALCFI(W,ISWR,1)
      DO 210 I=1,NI
      W(I,1)=W(I,1)/R(2)
      DO 210 J=2,NJ
  210 W(I,J)=W(I,J)/R(J)
  113 CALL GAM
      IF(INCAL(4)) CALL CALCFI(TE,ITE,1)
      IF(INCAL(5)) CALL CALCFI(ED,IED,2)
      IF (INCAL(4)) CALL CORTED
      IF(INCAL(6)) CALL CALCFI(EN,IEN,2)
      IF(INCAL(7)) CALL CALCFI(FM,IFM,0)
      IF(INCAL(8)) CALL CALCFI(F,IF,0)
C-----UPDATE BOUNDARY CONDITIONS
      IF(IU.EQ.1)RLSOR(IU)=RESOR(IU)/SNORM(IU)
```

```
      IF(IV.EQ.2)RESOR(IV)=RESOR(IV)/SNORM(IV)
      IF(IP.EQ.3)RESOR(IP)=RESOR(IP)/SNORM(IP)
      IF(IPP.EQ.10)RESOR(IPP)=RESOR(IPP)/SNORM(IPP)
      IF(ITE.EQ.4)RESOR(ITE)=RESOR(ITE)/SNORM(ITE)
      IF(IED.EQ.5)RESOR(IED)=RESOR(IED)/SNORM(IED)
      IF(IFM.EQ.7)RESOR(IFM)=RESOR(IFM)/SNORM(IFM)
      IF(IF.EQ.8)RESOR(IF)=RESOR(IF)/SNORM(IF)
      IF(IEN.EQ.6)RESOR(IEN)=RESOR(IEN)/SNORM(IEN)
      IF(IPP.EQ.10)RESOR(IPP)=RESOR(IP)+RESOR(IPP)
      IF(ISWR.EQ.9)RESOR(ISWR)=RESOR(ISWR)/SNORM(ISWR)
C-----OUTPUT OF RESIDUALS AND MONITORING INFORMATION-------------------
      IF(MOD(NITER,NUMPRI).NE.0) GO TO 303
      WRITE(LU6,311) NITER,RESOR(1),RESOR(2),RESOR(9),RESOR(3),
     1 RESOR(6),RESOR(4),RESOR(5),U(IMON,JMON),V(IMON,JMON),
     2 W(IMON,JMON),P(IMON,JMON),TE(IMON,JMON),ED(IMON,JMON),
     3 RESOR(7),RESOR(8),EN(IMON,JMON),T(IMON,JMON),FM(IMON,JMON),
     4 F(IMON,JMON)
  303 CONTINUE
C-----CONDITIONAL OUTPUT OF FIELDS-------------------------------------
      IF(MOD(NITER,INDPRI).NE.0) GO TO 301
      IF(INCAL(1)) CALL PRINT(1,1,NIU,NJ,IT,JT,XU,Y,U,HEDU)
      IF(INCAL(2)) CALL PRINT(1,1,NI,NJV,IT,JT,X,YV,V,HEDV)
      IF(INCAL(9)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,W,HEDSWR)
      IF(INCAL(3)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,P,HEDP)
      IF(INCAL(6)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,EN,HEDEN)
      IF(INCAL(4)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,TE,HEDK)
      IF(INCAL(5)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,ED,HEDD)
      IF(INCAL(7)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,FM,HEDCON)
      IF(INCAL(8)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,F,HEDF)
C-----ADDITIONAL USER-SPECIFIED OUTPUT---------------------------------
      CALL INTOP
      WRITE(LU6,310) IMON,JMON
  301 CONTINUE
C-----TERMINATION TESTS
      SOURCE=AMAX1(RESOR(1),RESOR(2),RESOR(3),RESOR(6),RESOR(7)
     1          ,RESOR(8),RESOR(9))
      IF(NITER.GE.MAXIT) GO TO 302
      IF((NITER-NITERS).LT.5) GO TO 300
      IF(SOURCE.LT.SORMAX) GO TO 401
  300 CONTINUE
  302 WRITE (6,320)
C
CHAPTER  4  4  4  4  4  4  FINAL OPERATIONS AND OUTPUT  4  4  4  4  4  4
C
  401 CONTINUE
C-----FINAL OUTPUT OF FIELDS-------------------------------------------
      IF(INCAL(1)) CALL PRINT(1,1,NIU,NJ,IT,JT,XU,Y,U,HEDU)
      IF(INCAL(2)) CALL PRINT(1,1,NI,NJV,IT,JT,X,YV,V,HEDV)
      IF(INCAL(9)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,W,HEDSWR)
      IF(INCAL(3)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,P,HEDP)
      IF(INCAL(4)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,TE,HEDK)
      IF(INCAL(5)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,ED,HEDD)
      IF(INCAL(7)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,FM,HEDCON)
      IF(INCAL(8)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,F,HEDF)
      IF(INCAL(6)) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,EN,HEDEN)
      IF(INPRO) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,VIS,HEDM)
      IF(INPRO) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,DEN,HEDDEN)
      IF(INPRO) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,T,HEDT)
      IF(INPRO) CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,CPM,HEDCP)
      CALL INTOP
```

```
C-----CONDITIONAL STORAGE OF RESULTS-----------------------------------
      IF(.NOT.IWRITE) STOP
      WRITE(LU4) NITER,U,V,P,TE,ED,EN,FM,F,VIS,DLN,W
      REWIND LU4
      STOP
C-----FORMAT STATEMENTS
  310 FORMAT(1H0,7HITER    , 107HI---------------ABSOLUTE RESIDUAL SOURCE
     1 SUMS---------------I    I-------FIELD VALUES AT MONITORING LOCATIO
     2N,1H(,I2,1H,,I2,1H),9H--------I / 2X,3HNO.,5X,4HUMOM,5X,4HVMOM,
     35X,4HWMOM,5X,4HMASS,5X,4HENTH,5X,4HT EN,5X,4HDISS,11X,1HU,8X,
     41HV,8X,1HW,8X,1HP,8X,2HTE,8X,1HD/9X,6HF.CONC,3X,6HM.FRAC,
     554X,2HEN,8X,1HT,7X,2HFM,8X,1HF/)
  311 FORMAT(1H ,I4,2X,1P7E9.2,5X,1P6E9.2/7X,1P2E9.2,50X,1P4E9.2/)
  320 FORMAT (//69H  ***  PROGRAM TERMINATED BEFORE CONVERGENCE CRITERIO
     1N SATISFIED  ***)
      END
```

@PRT,S TEACH*TEACH.BLOCKD

```
TEACH*TEACH(2).BLOCKD(1)
      BLOCK DATA
      COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANL(10),URF(10)
     2      ,URFVIS,URFDEN,RESOR(10),NSWP(10),TPOLE,UPREF,PREF,PELS
     3      ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TAULN,DELTA
     4      ,UIN,UCEN,TEIN,TURBIN,FLIN,TIN,FLOWIN,DENSIT,VISCOS,FNIN,CINT
     5      ,CPF,CPO2,CPN2,CPH2O,CPCO2,HF,STOIC,FLOWA,FLOWF
     6      ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TFLUF,CPIN,WIN
     7      ,AL1,AL2,ALAMDA,RLARGL,ESMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8      ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PEPR,MAXSWP
     9      ,ISCEME,MODOP,IREAD,IWRITE,WCOFNP,INCAL(10),INPRO
     1      ,IU,IV,IP,ITE,IED,ILN,IFM,IF,IFF,ISWP
     2      ,GREAT,SMALL,PI,UGC,SWNO
     3      ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4      ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5      ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6      ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7      ,HEDCF(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH20(9),HEDSWR(9)
      COMMON /COM3/LU4,LU5,LU6,LU8,LU9
      LOGICAL INCAL,INCOMP,INPRO,IREAD,IVISCO,IWRITE,LAMINR
     1       ,NFREE,SSYM
      DATA  HEDU  /
     X 4H      , 4H  U ,4HVELO, 4HCITY,4H (M/, 4HSEC),
     X 4H      , 4H     ,4H     /
      DATA  HEDV  /
     X 4H      , 4H  V ,4HVELO, 4HCITY,4H (M/, 4HSEC),
     X 4H      , 4H     ,4H     /
      DATA  HEDP  /
     X 4H      , 4H  PR,4HESSU, 4HRE  ,4H(PAS, 4HCAL),
     X 4H      , 4H     ,4H     /
      DATA  HEDT  /
     X 4H      , 4H  TE,4HMPER, 4HATUR,4HE (K, 4H)    ,
     X 4H      , 4H     ,4H     /
      DATA  HEDEN /
     X 4H      , 4H  EN,4HTHAL, 4HPY (,4HM*2/, 4HSEC*, 4H2)   ,
     X 4H      , 4H     /
      DATA  HEDA  /
     X 4H      , 4H NON,4H-DIM, 4H TUR,4HB.EN, 4HERGY,
     X 4H      , 4H     ,4H     /
      DATA  HEDB  /
     X 4H      , 4H NON,4H-DIM, 4H LEN,4HGTH , 4HSCAL, 4HE    ,
     X 4H      , 4H     /
      DATA  HEDD  /
     X 4H      , 4HDISS,4HIPAT, 4HION ,4H(M*2, 4H/SEC, 4H*3) ,
     X 4H      , 4H     /
      DATA  HEDM  /
     X 4H      , 4HVISC,4HOSIT, 4HY  (,4HN-SE, 4HC/M*, 4H2)   ,
     X 4H      , 4H     /
      DATA  HEDK  /
     X 4H      , 4HKIN.,4HLVER, 4HGY (,4HM*2/, 4HSEC*, 4H2)   ,
     X 4H      , 4H     /
      DATA  HEDC  /
     X 4H      , 4HSTRE,4HAM F, 4HUNCT,4HION , 4H    ,
     X 4H      , 4H     ,4H     /
      DATA  HEDCON/
     X 4H      , 4HFUEL,4H CON, 4HCENT,4HRATI, 4HON  ,
     X 4H      , 4H     ,4H     /
      DATA  HEDF  /
     X 4H      , 4H  MI,4HXTUR, 4HE FR,4HACTI, 4HON  ,
```

```
X 4H     , 4H     ,4H     /
 DATA  HEDDEN/
X 4H     , 4HDENS,4HITY , 4H(KG/,4HM**3), 4H     ,
X 4H     , 4H     ,4H     /
 DATA  HEDCP /
X 4H     , 4HMEAN,4H SP., 4H HT.,4H(J/K, 4HG-K),
X 4H     , 4H     ,4H     /
 DATA  HEDO2 /
X 4H     , 4HO2  ,4HMASS, 4H FRA,4HCTIC, 4HN    ,
X 4H     , 4H     ,4H     /
 DATA  HEDN2 /
X 4H     , 4HN2  ,4HMASS, 4H FRA,4HCTIC, 4HN    ,
X 4H     , 4H     ,4H     /
 DATA  HEDCO2/
X 4H     , 4HCO2 ,4HMASS, 4H FRA,4HCTIC, 4HN    ,
X 4H     , 4H     ,4H     /
 DATA  HEDH20/
X 4H     , 4HH20 ,4HMASS, 4H FRA,4HCTIC, 4HN    ,
X 4H     , 4H     ,4H     /
 DATA  HEDSWR/
X 4H     , 4H  W ,4HVELO, 4HCITY,4H (M/, 4HSEC),
X 4H     , 4H     ,4H     /
C
 DATA IT,JT/30,30/
C
 DATA CMU,CD,C1,C2,CAPPA,ELOG/0.09,1.00,1.44,1.92,0.4187
1     ,9.0/
C
 DATA LU4,LU5,LU6,LU8,LU9/4,5,6,8,9/
C
 END
```

@RESUML,P PR4

TEACH*TEACH(2).BOUNDS(0)

```
      SUBROUTINE BOUNDS (IENDIN,JENDIN)
C
C-----SUBROUTINE TO CALCULATE COEFFICIENTS FOR HBSD SCHEME
C
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2      ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3      ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4      ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
     5      ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6      ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7      ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8      ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9      ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1      ,DYNPV(30),DYPSV(30),DT
     2      ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3      ,TAUNS(30),TAUSS(30),TAUWS(30)
     4      ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
      COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2      ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3      ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4      ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5      ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6      ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7      ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8      ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
     9      ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1      ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2      ,GREAT,SMALL,PI,UGC,SWNO
     3      ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4      ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5      ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6      ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7      ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
      DIMENSION E1(30,30),E2(30,30),E3(30,30),FN1(30,30),FN2(30,30)
     1         ,FN3(30,30),SUE(30,30),SVE(30,30),SUN(30,30),SVN(30,30)
     2         ,FE(30,30),FN(30,30)
      EQUIVALENCE (E1(1,1),DU(1,1)),(E2(1,1),DV(1,1)),(E3(1,1),AP(1,1))
     1 ,(FN1(1,1),GAMH(1,1)),(FN2(1,1),VIS(1,1)),(FN3(1,1),SP(1,1))
     2 ,(SUE(1,1),PP(1,1)),(SVE(1,1),SPARE(1,1)),(SUN(1,1),DEN(1,1))
     3 ,(SVN(1,1),GEN(1,1)),(FN(1,1),ASE(1,1)),(FE(1,1),ASW(1,1))
C
CHAPTER 1  1  1  POSITIVITY CHECK ON THE COEFFICIENTS  1  1  1  1  1
C
C-----1.1  INITIALISATION OF THE CONTROL WEIGHTING FACTORS TO UNITY
      IEND=NIM1+IENDIN
      JEND=NJM1+JENDIN
      IF(ISCEME.EQ.1) GO TO 231
      DO 200 J=2,JEND
      LIW=IW(J)
      LIE=IE(J)+IENDIN
      DO 201 I=LIW,LIE
      FN(I,J-1)=1.0
      FE(I-1,J)=1.0
  201 CONTINUE
      FE(LIE,J)=1.0
  200 CONTINUE
      DO 202 I=2,IEND
```

```
      J=JN(I)+JENDIN
  202 FN(I,J)=1.0
C-----1.2  MAIN LOOP
      DO 210 J=2,JEND
      LIW=IW(J)
      LIE=IE(J)+IENDIN
      DO 220 I=LIW,LIE
C-----1.CHECK FOR THE NEGATIVE COEFFICIENTS
C-----2.ADJUST THE WEIGHTING FACTORS IF REQUIRED
C-----SOUTH SIDE
      FB=FN2(I,J-1)-SVN(I,J-1)*FN3(I,J-1)
      FL=-(1.0-SUE(I-1,J))*SVE(I-1,J)*E3(I-1,J)
      FR=SUE(I,J)*SVE(I,J)*E3(I,J)
      IF((FB-FL-FR).LT.0.0)
     1  CALL CORECT(FB,FL,FR,FE(I-1,J),FE(I,J))
C-----NORTH SIDE
      FB=FN1(I,J)+(1.0-SVN(I,J))*FN3(I,J)
      FL=-(1.0-SUE(I-1,J))*(1.0-SVE(I-1,J))*E3(I-1,J)
      FR=SUE(I,J)*(1.0-SVE(I,J))*E3(I,J)
      IF((FB-FL-FR).LT.0.0)
     1  CALL CORECT(FB,FL,FR,FE(I-1,J),FE(I,J))
C-----WEST SIDE
      FB=E2(I-1,J)-SUE(I-1,J)*E3(I-1,J)
      FL=-(1.0-SVN(I,J-1))*SUN(I,J-1)*FN3(I,J-1)
      FR=SVN(I,J)*SUN(I,J)*FN3(I,J)
      IF((FB-FL-FR).LT.0.0)
     1  CALL CORECT(FB,FL,FR,FN(I,J-1),FN(I,J))
C-----EAST SIDE
      FB=E1(I,J)+(1.0-SUE(I,J))*E3(I,J)
      FL=-(1.0-SVN(I,J-1))*(1.0-SUN(I,J-1))*FN3(I,J-1)
      FR=SVN(I,J)*(1.0-SUN(I,J))*FN3(I,J)
      IF((FB-FL-FR).LT.0.0)
     1  CALL CORECT(FB,FL,FR,FN(I,J-1),FN(I,J))
C-----CALCULATE THE EFFECTIVE FLUXES
      E3(I-1,J)=FE(I-1,J)*E3(I-1,J)
      FN3(I,J-1)=FN(I,J-1)*FN3(I,J-1)
  220 CONTINUE
      E3(LIE,J)=FE(LIE,J)*E3(LIE,J)
  210 CONTINUE
      DO 230 I=2,IEND
      J=JN(I)+JENDIN
      FN3(I,J)=FN(I,J)*FN3(I,J)
  230 CONTINUE
  231 CONTINUE
C
CHAPTER  2  2  2  FINAL OPERATIONS  2  2  2  2  2  2  2  2  2  2
C
C-----2.1  ASSEMBLE THE COEFFICIENTS
      DO 300 J=2,JEND
      LIW=IW(J)
      LIE=IE(J)+IENDIN
      DO 300 I=LIW,LIE
C-----CORNER NODAL POINTS
      ASW(I,J)=SUE(I-1,J)*SVE(I-1,J)*E3(I-1,J)
     1         +SVN(I,J-1)*SUN(I,J-1)*FN3(I,J-1)
      ASE(I,J)=SVN(I,J-1)*(1.0-SUN(I,J-1))*FN3(I,J-1)
     1         -(1.0-SUE(I,J))*SVE(I,J)*E3(I,J)
      ANW(I,J)=SUE(I-1,J)*(1.0-SVE(I-1,J))*E3(I-1,J)
     1         -(1.0-SVN(I,J))*SUN(I,J)*FN3(I,J)
      ANE(I,J)=-(1.0-SUE(I,J))*(1.0-SVE(I,J))*E3(I,J)
```

```
     1              -(1.0-SVN(I,J))*(1.0-SUN(I,J))*FN3(I,J)
C-----STANDARD NODAL POINTS
      AW(I,J)=E2(I-1,J)-SUE(I-1,J)*E3(I-1,J)
     1        +(1.0-SVN(I,J-1))*SUN(I,J-1)*FN3(I,J-1)
     2        -SVN(I,J)*SUN(I,J)*FN3(I,J)
      AE(I,J)=E1(I,J)+(1.0-SUE(I,J))*E3(I,J)
     1        +(1.0-SVN(I,J-1))*(1.0-SUN(I,J-1))*FN3(I,J-1)
     2        -SVN(I,J)*(1.0-SUN(I,J))*FN3(I,J)
      AS(I,J)=FN2(I,J-1)-SVN(I,J-1)*FN3(I,J-1)
     1        +(1.0-SUE(I-1,J))*SVE(I-1,J)*E3(I-1,J)
     2        -SUE(I,J)*SVE(I,J)*E3(I,J)
      AN(I,J)=FN1(I,J)+(1.0-SVN(I,J))*FN3(I,J)
     1        +(1.0-SUE(I-1,J))*(1.0-SVE(I-1,J))*E3(I-1,J)
     2        -SUE(I,J)*(1.0-SVE(I,J))*E3(I,J)
  300 CONTINUE
      RETURN
      END
```

@PRT,S TEACH*TEACH.CALCFI

ORIGINAL PAGE IS
OF POOR QUALITY

TEACH*TEACH(2).CALCFI(L)

```
      SUBROUTINE CALCFI(PHI,IVAR,ICOEF)

CHAPTER  0  0  0  0  0  0  0  PRELIMINARIES  0  0  0  0  0  0  0
C
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2      ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3      ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4      ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
     5      ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6      ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7      ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8      ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9      ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1      ,DYNPV(30),DYPSV(30),DT
     2      ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3      ,TAUNS(30),TAUSS(30),TAUWS(30)
     4      ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
      COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2     ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3     ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4     ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5     ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6     ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7     ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8     ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
     9     ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1     ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2     ,GREAT,SMALL,PI,UGC,SWNO
     3     ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4     ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5     ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6     ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7     ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
      COMMON /COM3/LU4,LU5,LU6,LU8,LU9
      DIMENSION E1(30,30),E2(30,30),E3(30,30),FN1(30,30),FN2(30,30)
     1          ,FN3(30,30),SUE(30,30),SVE(30,30),SUN(30,30),SVN(30,30)
     2          ,CE(30,30),CN(30,30),DE(30,30),DN(30,30),PHI(30,30)
      EQUIVALENCE (E1(1,1),DU(1,1)),(E2(1,1),DV(1,1))
     1           ,(E3(1,1),AP(1,1)),(FN1(1,1),GAMH(1,1))
     2           ,(FN2(1,1),VIS(1,1)),(FN3(1,1),SP(1,1))
     3           ,(SUE(1,1),PP(1,1)),(SVE(1,1),SPARE(1,1))
     4           ,(SUN(1,1),DEN(1,1)),(SVN(1,1),GEN(1,1))
     5           ,(CE(1,1),DU(1,1)),(CN(1,1),DV(1,1))
     6           ,(DE(1,1),PP(1,1)),(DN(1,1),SPARE(1,1))
C
C------ICOEF=0    COEFFICIENTS UNALTERED
C------ICOEF=1    COEFFICIENTS FULLY CALCULATED
C------ICOEF=2    SIMPLE PRANDTL NO CHANGE
C
C
C
C
CHAPTER  1  1  1  1  1  1  ASSEMBLY OF COEFFICIENTS  1  1  1  1  1  1
C
      FACTOR=1.0
C-----DECIDE ON CONSTRUCTION OF MAIN COEFFICIENTS
      IF (ICOEF.EQ.0) GO TO 110
```

```
      IF(ICOEF.EQ.1) IVARO=IVAR
      IF(ICOEF.NE.1) FACTOR=PRANDT(IVARO)/PRANDT(IVAR)
      IF(ICOEF.NE.1.AND.FACTOR.EQ.1.0) GO TO 110
C-----WEST BOUNDARY
      DO 10 J=2,NJM1
      I=IW(J)-1
      IF (ICOEF.EQ.2) GO TO 11
      AREAEW=R(J)*SNS(J)
      CE(I,J)=DEN(I,J)*U(I,J)*AREAEW
      DE(I,J)=GAMH(I,J)*AREAEW/(0.5*SEW(I+1))
      GO TO 9
   11 DE(I,J)=DE(I,J)*FACTOR
    9 AE(I,J)=CE(I,J)
      AW(I,J)=DE(I,J)
   10 CONTINUE
C-----ALL OTHER LOCATIONS
      DO 100 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
C-----SOUTH BOUNDARY
      LJSM1=LJS-1
      ALPHA=AU(I)
      ALPHA1=1.0-ALPHA
      IF (ICOEF.EQ.2) GO TO 102
      AREAS=RV(LJSM1)*SEW(I)
      CN(I,LJSM1)=DEN(I,LJSM1)*V(I,LJSM1)*AREAS
      DN(I,LJSM1)=GAMH(I,LJSM1)*AREAS/(0.5*SNS(LJS))
      GO TO 105
  102 DN(I,LJSM1)=DN(I,LJSM1)*FACTOR
  105 AN(I,LJSM1)=CN(I,LJSM1)
      AS(I,LJSM1)=DN(I,LJSM1)
C-----FLOW POINTS
      DO 101 J=LJS,LJN
C-----COMPUTE AREAS, VOLUME AND INTERPOLATION FACTORS
      BETA=AV(J)
      BETA1=1.0-BETA
      IF (ICOEF.EQ.2) GO TO 120
      AREAN=RV(J)*SEW(I)
      AREAEW=R(J)*SNS(J)
      VOL=R(J)*SNS(J)*SEW(I)
C-----CALCULATE CONVECTION COEFFICIENTS
      GN=(DEN(I,J)*BETA1+DEN(I,J+1)*BETA)*V(I,J)
      GE=(DEN(I,J)*ALPHA1+DEN(I+1,J)*ALPHA)*U(I,J)
      CN(I,J)=GN*AREAN
      CE(I,J)=GE*AREAEW
C-----CALCULATE DIFFUSION COEFFICIENTS
      GAMN=GAMH(I,J)*BETA1+GAMH(I,J+1)*BETA
      GAME=GAMH(I,J)*ALPHA1+GAMH(I+1,J)*ALPHA
      DN(I,J)=GAMN*AREAN/DYNP(J)
      IF(J.EQ.LJN) DN(I,J)=GAMN*AREAN/(0.5*SNS(J))
      DE(I,J)=GAME*AREAEW/DXEP(I)
      GO TO 150
  120 DN(I,J)=DN(I,J)*FACTOR
      DE(I,J)=DE(I,J)*FACTOR
C-----STORE CONVEC. & DIFF. PARTS IN MAIN COEFF. ARRAYS
  150 AN(I,J)=CN(I,J)
      AE(I,J)=CE(I,J)
      AS(I,J)=DN(I,J)
      AW(I,J)=DE(I,J)
  101 CONTINUE
```

```
  100 CONTINUE
C
C-----CALCULATE SOURCE TERMS
  110 CALL SORCFI(IVAR)
C
CHAPTER  2  2  2  2  2  PROBLEM MODIFICATIONS  2  2  2  2  2  2  2  2
C
      CALL MODFI(IVAR)
      IF(ICOEF.EQ.0) GO TO 130
      IF(ICOEF.NE.1.AND.FACTOR.EQ.1.0) GO TO 130
C
CHAPTER  3  3  3  3  3  CALCULATE BSHD COEFFICIENTS  3  3  3  3  3  3
C
C-----DUMP INFORMATION ON TAPE------------------------------------------
      WRITE (LU9) DU,DV,GAMH,VIS,SP,PP,SPARE,DEN,GEN
      REWIND LU9
C-----CALCULATE COEFFICIENT COMPONENTS
C-----NORTH SIDE
      DO 600 I=2,NIM1
      LJS=JS(I)-1
      LJN=JN(I)
      DO 600 J=LJS,LJN
      BETA=AV(J)
      BETA1=1.0-BETA
      UN=0.5*(BETA1*(U(I-1,J)+U(I,J))+BETA*(U(I-1,J+1)+U(I,J+1)))
      VN=V(I,J)
      CNP=AN(I,J)
      DNP=AS(I,J)
      SIU=0.5+SIGN(0.5,UN)
      SIV=0.5+SIGN(0.5,CNP)
      SUN(I,J)=SIU
      SVN(I,J)=SIV
      PECRIT=1.0/(SIV-BETA1+SMALL)
      CNCRIT=PECRIT*DNP+SMALL
      IF(CNP/CNCRIT.GT.1.0) GO TO 601
C-----CENTRAL DIFFERENCING
      FN1(I,J)=DNP-BETA*CNP
      FN3(I,J)=0.0
      GO TO 602
C-----SKEW DIFFERENCING
  601 IX=I-INT(SIU)
      DX=DXEP(IX)
      JY=J+INT(1.0-SIV)
      DY=0.5*SNS(JY)
      IF((IX-IW(JY)+1)*(IX-NIM1)) 609,608,609
  608 DX=0.5*SEW(I)
  609 TANBN=UN/(VN+SMALL)
      AK=AMIN1(1.0,ABS(DY/DX*TANBN))
      FN1(I,J)=(SIV-1.)*CNP
      FN3(I,J)=WCORNR*AK*(CNP-CNCRIT)
  602 FN2(I,J)=FN1(I,J)+CNP
  600 CONTINUE
C-----EAST SIDE
      DO 603 J=2,NJM1
      LIW=IW(J)-1
      LIE=IE(J)
      DO 603 I=LIW,LIE
      ALPHA=AU(I)
      ALPHA1=1.0-ALPHA
      UE=U(I,J)
```

```
      VE=0.5*(ALPHA1*(V(I,J-1)+V(I,J))+ALPHA*(V(I+1,J-1)+V(I+1,J)))
      CEP=AE(I,J)
      DEP=AW(I,J)
      SIU=0.5+SIGN(0.5,CEP)
      SIV=0.5+SIGN(0.5,VE)
      SUE(I,J)=SIU
      SVE(I,J)=SIV
      PECRIT=1.0/(SIU-ALPHA1+SMALL)
      CECRIT=PECRIT*DEP+SMALL
      IF(CEP/CECRIT.GT.1.0) GO TO 604
C-----CENTRAL DIFFERENCING
      E1(I,J)=DEP-ALPHA*CEP
      E3(I,J)=0.0
      GO TO 605
C-----SKEW DIFFERENCING
  604 IX=I+INT(1.0-SIU)
      DX=0.5*SEW(IX)
      JY=J-INT(SIV)
      DY=DYNP(JY)
      IF((JY-JS(IX)+1)*(JY-JN(IX))) 607,606,607
  606 DY=0.5*SNS(J)
  607 TANTE=VE/(UE+SMALL)
      AK=AMIN1(1.0,ABS(DX/DY*TANTE))
      E1(I,J)=(SIU-1.)*CEP
      E3(I,J)=WCORNR*AK*(CEP-CECRIT)
  605 E2(I,J)=E1(I,J)+CEP
  603 CONTINUE
C-----CALCULATE BOUNDED COEFFICIENTS
      CALL BOUNDS(0,0)
C-----RESTORE INFORMATION FROM TAPE---------------------------------
      READ (LU9) DU,DV,GAMH,VIS,SP,PP,SPARE,DEN,GEN
      REWIND LU9
  130 CONTINUE
C
CHAPTER 4 FINAL COEFFICIENT ASSEMBLY AND RESIDUAL SOURCE CALCULATION 4
C
      RESOR(IVAR)=0.0
      DO 300 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
      DO 301 J=LJS,LJN
      AP(I,J)=AN(I,J)+AS(I,J)+AE(I,J)+AW(I,J)-SP(I,J)
     1          +ASW(I,J)+ASE(I,J)+ANW(I,J)+ANE(I,J)
      RESOR1=AN(I,J)*PHI(I,J+1)+AS(I,J)*PHI(I,J-1)+AE(I,J)*PHI(I+1,J)
     1        +AW(I,J)*PHI(I-1,J)-AP(I,J)*PHI(I,J)+SU(I,J)
     2        +ASW(I,J)*PHI(I-1,J-1)+ASE(I,J)*PHI(I+1,J-1)
     3        +ANW(I,J)*PHI(I-1,J+1)+ANE(I,J)*PHI(I+1,J+1)
      VOL=R(J)*SEW(I)*SNS(J)
      SORVOL=GREAT*VOL
      IF(-SP(I,J).GT.0.5*SORVOL) RESOR1=RESOR1/SORVOL
      RESOR(IVAR)=RESOR(IVAR)+ABS(RESOR1)
C-----UNDER-RELAXATION
      AP(I,J)=AP(I,J)/URF(IVAR)
      SU(I,J)=SU(I,J)+(1.-URF(IVAR))*AP(I,J)*PHI(I,J)
  301 CONTINUE
  300 CONTINUE
      IF(IVAR.EQ.4.OR.IVAR.EQ.5) WRITE(LU4) AP,SP,SU,PHI
C
CHAPTER  5  5  5  5  5  SOLUTION OF DIFFERENCE EQUATIONS  5  5  5  5  5
C
```

```
      CALL LISOLV(0,0,PHI,IVAR,2,2)
      IVARO=IVAR
      RETURN
      END
@PRT,S TEACH*TEACH.CALUVP
```

TEACH*TEACH(2).CALUVP(0)

```
      SUBROUTINE CALUVP
CLC   SUBROUTINE CALCUVP
C
CHAPTER  0  0  0  0  0  0  0  0  PRELIMINARIES  0  0  0  0  0  0  0  0
C
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2      ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3      ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4      ,AE(30,30),AW(30,30), AN(30,30),AS(30,30),AP(30,30)
     5      ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6      ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7      ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8      ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9      ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1      ,DYNPV(30),DYPSV(30),DT
     2      ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3      ,TAUNS(30),TAUSS(30),TAUWS(30)
     4      ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
      COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2    ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3    ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4    ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5    ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6    ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7    ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8    ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
     9    ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1    ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2    ,GREAT,SMALL,PI,UGC,SWNO
     3    ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4    ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5    ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6    ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7    ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
      COMMON /COM3/LU4,LU5,LU6,LU8,LU9
        DIMENSION CWT(30)
C
CHAPTER 1  1  1  SOLVE FOR U* AND V*  1  1  1  1  1  1  1  1  1  1  1
C
      READ(LU4) AE,AW,AN,AS,AP,ASW,ASE,ANW,ANE,SU
      CALL LISOLV(-1,0,U,IU,2,2)
      CALL MODU1
      READ(LU4) AE,AW,AN,AS,AP,ASW,ASE,ANW,ANE,SU
      CALL LISOLV(0,-1,V,IV,2,2)
C
CHAPTER 2  2  2  PISO ALGORITHM FIRST CORRECTOR STAGE  2  2  2  2  2  2
C
C-2.1------ASSEMBLY OF PRESSURE EQUATION
C
      RESOR(IP)=0.0
C-----WEST BOUNDARY
      DO 10 J=2,NJM1
      I=IW(J)-1
      AREAEW=R(J)*SNS(J)
      CWT(J)=DEN(I,J)*U(I,J)*AREAEW
   10 AE(I,J)=0.0
C-----ALL OTHER LOCATIONS
```

```
      DO 100 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
C-----SOUTH BOUNDARY
      LJSM1=LJS-1
      AREAS=RV(LJSM1)*SEW(I)
      CN=DEN(I,LJSM1)*V(I,LJSM1)*AREAS
      AN(I,LJSM1)=0.0
      ALPHA=AU(I)
      ALPHA1=1.0-ALPHA
C-----FLOW POINTS
      DO 101 J=LJS,LJN
C-----COMPUTE AREAS AND INTERPOLATION FACTORS
      AREAN=RV(J)*SEW(I)
      BETA=AV(J)
      BETA1=1.0-BETA
      AREAEW=R(J)*SNS(J)
C-----CALCULATE COEFFICIENTS
      DENN=DEN(I,J)*BETA1+DEN(I,J+1)*BETA
      DENE=DEN(I,J)*ALPHA1+DEN(I+1,J)*ALPHA
      AS(I,J)=AN(I,J-1)
      AN(I,J)=DENN*AREAN*DV(I,J)
      AW(I,J)=AE(I-1,J)
      AE(I,J)=DENE*AREAEW*DU(I,J)
C-----CALCULATE SOURCE TERMS
      CS=CN
      CW=CWT(J)
      CN=DENN*V(I,J)*AREAN
      CE=DENE*U(I,J)*AREAEW
      CWT(J)=CE
      SMP=CN-CS+CE-CW
      SP(I,J)=0.0
      SU(I,J)=-SMP
C-----COMPUTE SUM OF ABSOLUTE MASS SOURCES
      RESOR(IP)=RESOR(IP)+ABS(SMP)
  101 CONTINUE
  100 CONTINUE
C
C-2.2------PROBLEM MODIFICATIONS
C
      CALL MODP
C
C-2.3-------FINAL COEFFICIENT ASSEMBLY
C
      DO 300 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
      DO 301 J=LJS,LJN
      PP(I,J)=0.0
  301 AP(I,J)=AN(I,J)+AS(I,J)+AE(I,J)+AW(I,J)-SP(I,J)
  300 CONTINUE
      WRITE(LU4) DU,DV,AE,AW,AN,AS,AP
      REWIND LU4
C
C-2.4------SOLUTION OF DIFFERENCE EQUATIONS
C
      PRES=RESOR(IP)
      CALL LISOLV(0,0,PP,IP,2,2)
C
C-2.5------CORRECT VELOCITIES AND PRESSURE
```

```
C
      PPREF=PP(IPREF,JPREF)
      DO 500 I=2,NIU
      LJS=JS(I)
      LJN=JN(I)
      DO 500 J=LJS,LJN
      IF (I.EQ.IE(J)) GO TO 501
      DU(I,J)=DU(I,J)*(PP(I,J)-PP(I+1,J))
      U(I,J)=U(I,J)+DU(I,J)
  501 IF(J.EQ.LJN) GO TO 500
      DV(I,J)=DV(I,J)*(PP(I,J)-PP(I,J+1))
      V(I,J)=V(I,J)+DV(I,J)
  500 P(I,J)=P(I,J)+PP(I,J)-PPREF
C
CHAPTER  3  3  PISO ALGORITHM SECOND CORRECTOR  STAGE
C
      READ(LU4) AE,AW,AN,AS,AP,ASW,ASE,ANW,ANE,SU
C
C-3.1------EVALUATION OF U*=SUM.(AI.UI') AND CORRECT U VELOCITIES
C-----U* VALUES TEMPORARILY STORED IN PP(I,J) ARRAY
      DO 520 I=2,NIUM1
      LJS=JS(I)
      LJN=JN(I)
      DO 520 J=LJS,LJN
      PPP=AW(I,J)*DU(I-1,J)+AE(I,J)*DU(I+1,J)+AS(I,J)*DU(I,J-1)
     1   +AN(I,J)*DU(I,J+1)
     2   +ASW(I,J)*DU(I-1,J-1)+ASE(I,J)*DU(I+1,J-1)
     3   +ANW(I,J)*DU(I-1,J+1)+ANE(I,J)*DU(I+1,J+1)
      PPP=PPP/AP(I,J)
      U(I,J)=U(I,J)+PPP
  520 PP(I,J)=PPP
      DO 521 I=2,NIUM1
      LJS=JS(I)
      LJN=JN(I)
      DO 521 J=LJS,LJN
  521 DU(I,J)=PP(I,J)
      READ(LU4) AE,AW,AN,AS,AP,ASW,ASE,ANW,ANE,SU
C
C-3.2------EVALUATION OF V*=SUM.(AI.VI') AND CORRECT V VELOCITIES
C
C-----V* VALUES TEMPORARILY STORED IN PP(I,J) ARRAY
      DO 530 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)-1
      DO 530 J=LJS,LJN
      PPP=AW(I,J)*DV(I-1,J)+AE(I,J)*DV(I+1,J)+AS(I,J)*DV(I,J-1)
     1   +AN(I,J)*DV(I,J+1)
     2   +ASW(I,J)*DV(I-1,J-1)+ASE(I,J)*DV(I+1,J-1)
     3   +ANW(I,J)*DV(I-1,J+1)+ANE(I,J)*DV(I+1,J+1)
      PPP=PPP/AP(I,J)
      V(I,J)=V(I,J)+PPP
  530 PP(I,J)=PPP
      DO 531 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)-1
      DO 531 J=LJS,LJN
  531 DV(I,J)=PP(I,J)
C
C-3.3------ASSEMBLY OF SECONDARY PRESSURE EQUATION COEFFICIENTS
C
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```
      RESOR(IPP)=0.0
      DO 540 J=2,NJM1
  540 CWT(J)=0.0
      DO 545 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
      CN=0.0
      ALPHA=AU(I)
      ALPHA1=1.0-ALPHA
      DO 545 J=LJS,LJN
      AREAN=RV(J)*SEW(I)
      BETA=AV(J)
      BETA1=1.0-BETA
      AREAEW=R(J)*SNS(J)
      DENN=DEN(I,J)*BETA1+DEN(I,J+1)*BETA
      DENE=DEN(I,J)*ALPHA1+DEN(I+1,J)*ALPHA
      CS=CN
      CW=CWT(J)
      CN=DENN*DV(I,J)*AREAN
      CE=DENE*DU(I,J)*AREAEW
      CWT(J)=CE
      SU(I,J)=-(CE-CW+CN-CS)
      PP(I,J)=0.0
  545 RESOR(IPP)=RESOR(IPP)+ABS(SU(I,J))
      READ(LU4) DU,DV,AE,AW,AN,AS,AP
      REWIND LU4
C
C-3.4------SOLUTION OF DIFFERENCE EQUATION
C
      PRES=RESOR(IPP)
      CALL LISOLV(0,0,PP,IP,2,2)
      PPREF=PP(IPREF,JPREF)
C
C-3.5------CORRECT VELOCITIES AND PRESSURE
C
      DO 580 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
      DO 580 J=LJS,LJN
      IF (I.NE.IE(J))
     1   U(I,J)=U(I,J)+DU(I,J)*(PP(I,J)-PP(I+1,J))
      IF(J.NE.LJN)
     1   V(I,J)=V(I,J)+DV(I,J)*(PP(I,J)-PP(I,J+1))
      P(I,J)=P(I,J)+PP(I,J)-PPREF
      PP(I,J)=0.
  580 CONTINUE
      CALL MODU1
      RETURN
      END

@PRT,S TEACH*TEACH.COEFU
```

TEACH*TEACH(2).COEFU(0)

```
      SUBROUTINE COEFU
C
CHAPTER  0  0  0  0  0  0  0  0  PRELIMINARIES  0  0  0  0  0  0  0  0
C
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2       ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3       ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4       ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
     5       ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6       ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7       ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8       ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9       ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1       ,DYNPV(30),DYPSV(30),DT
     2       ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3       ,TAUNS(30),TAUSS(30),TAUWS(30)
     4       ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
      COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2     ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3     ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4     ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5     ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6     ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7     ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8     ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
     9     ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1     ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2     ,GREAT,SMALL,PI,UGC,SWNO
     3     ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4     ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5     ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6     ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7     ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
      COMMON /COM3/LU4,LU5,LU6,LU8,LU9
      LOGICAL INCAL,INCOMP,INPRO,IREAD,IVISCO,IWRITE,LAMINR
     1       ,NFREE,SSYM
      DIMENSION E1(30,30),E2(30,30),E3(30,30),FN1(30,30),FN2(30,30)
     1          ,FN3(30,30),SUE(30,30),SVE(30,30),SUN(30,30),SVN(30,30)
     2          ,SWT(30)
      EQUIVALENCE (E1(1,1),DU(1,1)),(E2(1,1),DV(1,1))
     1            ,(E3(1,1),AP(1,1)),(FN1(1,1),GAMH(1,1))
     2            ,(FN2(1,1),VIS(1,1)),(FN3(1,1),SP(1,1))
     3            ,(SUE(1,1),PP(1,1)),(SVE(1,1),SPARE(1,1))
     4            ,(SUN(1,1),DEN(1,1)),(SVN(1,1),GEN(1,1))
C
CHAPTER  1  1  1  1  1  1  ASSEMBLY OF COEFFICIENTS  1  1  1  1  1  1  1
C
C-----WEST BOUNDARY
      DO 10 J=2,NJM1
      I=IW(J)-1
      AREAEW=R(J)*SNS(J)
      UP=U(I,J)
      UE=U(I+1,J)
      CE=0.5*(UE+UP)*DEN(I+1,J)*AREAEW
      DE=VIS(I+1,J)*AREAEW/DXEPU(I)
      AE(I,J)=CE
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```
      AW(I,J)=DE
      DUDXE=(U(I+1,J)-U(I,J))/SEW(I+1)
      SWT(J)=VIS(I+1,J)*DUDXE
   10 CONTINUE
C-----ALL OTHER LOCATIONS
      DO 100 I=2,NIUM1
      LJS=JS(I)
      LJN=JN(I)
C-----SOUTH BOUNDARY
      LJSM1=LJS-1
      AREAS=RV(LJSM1)*SEWU(I)
      CN=0.5*(DEN(I,LJSM1)*V(I,LJSM1)+DEN(I+1,LJSM1)*V(I+1,LJSM1))
     1      *AREAS
      VISN=0.5*(VIS(I,LJSM1)+VIS(I+1,LJSM1))
      DN=VISN*AREAS/(0.5*SNS(LJS))
      DVDXN=RV(LJSM1)*(V(I+1,LJSM1)-V(I,LJSM1))/DXEP(I)
      AN(I,LJSM1)=CN
      AS(I,LJSM1)=DN
      TSUN=VISN*DVDXN
C-----FLOW POINTS
      DO 101 J=LJS,LJN
C-----COMPUTE AREAS, VOLUME AND INTERPOLATION FACTORS
      AREAN=RV(J)*SEWU(I)
      AREAEW=R(J)*SNS(J)
      VOL=AREAEW*SEWU(I)
      ALPHA=AV(J)
      ALPHA1=1.-ALPHA
C-----CONVECTION COEFFICIENTS
      GNW=(ALPHA1*DEN(I,J)+ALPHA*DEN(I,J+1))*V(I,J)
      GNE=(ALPHA1*DEN(I+1,J)+ALPHA*DEN(I+1,J+1))*V(I+1,J)
      CN=0.5*(GNW+GNE)*AREAN
      UE=U(I+1,J)
      UP=U(I,J)
      CE=0.5*(UE+UP)*DEN(I+1,J)*AREAEW
C-----DIFFUSION COEFFICIENTS
      VISN=0.5*((VIS(I,J)+VIS(I+1,J))*ALPHA1
     1         +(VIS(I,J+1)+VIS(I+1,J+1))*ALPHA)
      DN=VISN*AREAN/DYNP(J)
      IF(J.EQ.LJN) DN=VISN*AREAN/(0.5*SNS(J))
      DE=VIS(I+1,J)*AREAEW/DXEPU(I)
C-----CALCULATE COEFFICIENTS OF SOURCE TERMS
      SMP=CN-AN(I,J-1)+CE-AE(I-1,J)
      CP=AMAX1(0.0,SMP)
      DU(I,J)=VOL/DXEP(I)
C-----STORE CONVEC. & DIFF. PARTS IN MAIN COEFF. ARRAYS
      AN(I,J)=CN
      AE(I,J)=CE
      AS(I,J)=DN
      AW(I,J)=DE
C-----CALCULATE SOURCE TERMS
      SU(I,J)=CP*U(I,J)-DU(I,J)*(P(I+1,J)-P(I,J))
      SP(I,J)=-CP
      IF(IVISCO) GO TO 102
      SUS=TSUN
      SUW=SWT(J)
      DUDXE=(U(I+1,J)-U(I,J))/SEW(I+1)
      TSUE=VIS(I+1,J)*DUDXE
      DVDXN=RV(J)*(V(I+1,J)-V(I,J))/DXEP(I)
      TSUN=VISN*DVDXN
      SU(I,J)=SU(I,J)+(TSUE-SUW)*VOL/SEWU(I)+(TSUN-SUS)*VOL/
```

```
     1 (SNS(J)*R(J))
      SWT(J)=TSUE
      IF(LAMINR) GO TO 102
      SU(I,J)=SU(I,J)-0.66667*(DEN(I+1,J)*TE(I+1,J)-DEN(I,J)*TE(I,J))
     1                              *VOL/SEWU(I)
  102 IF(INCOMP) GO TO 101
      DUDXE=(U(I+1,J)-U(I,J))/SEW(I+1)
      DUDXW=(U(I,J)-U(I-1,J))/SEW(I)
      SU1=(VIS(I+1,J)*DUDXE-VIS(I,J)*DUDXW)*VOL/SEWU(I)
      DRVDYE=(RV(J)*V(I+1,J)-RV(J-1)*V(I+1,J-1))/SNS(J)
      DRVDYP=(RV(J)*V(I,J)-RV(J-1)*V(I,J-1))/SNS(J)
      SU2=(VIS(I+1,J)*DRVDYE-VIS(I,J)*DRVDYP)*VOL/(SEWU(I)*R(J))
      SU(I,J)=SU(I,J)-0.66666*(SU1+SU2)
      IF(.NOT.IVISCO) GO TO 101
      SU(I,J)=SU(I,J)+SU1+SU2
  101 CONTINUE
  100 CONTINUE
C
CHAPTER  2  2  2  2  2  PROBLEM MODIFICATIONS  2  2  2  2  2  2  2
C
      CALL MODU
C
CHAPTER  3  3  3  3  3  CALCULATE BSHD COEFFICIENTS  3  3  3  3  3  3
C
C-----DUMP INFORMATION TO TAPE------------------------------------------
      WRITE(LU9) DU,DV,GAMH,VIS,SP,PP,SPARE,DEN,GEN
      REWIND LU9
C-----CALCULATE COEFFICIENT COMPONENTS
C-----NORTH SIDE
      DO 600 I=2,NIUM1
      LJS=JS(I)-1
      LJN=JN(I)
      DO 600 J=LJS,LJN
      BETA=AV(J)
      BETA1=1.0-BETA
      UN=BETA1*U(I,J)+BETA*U(I,J+1)
      VN=0.5*(V(I,J)+V(I+1,J))
      CNP=AN(I,J)
      DNP=AS(I,J)
      SIU=0.5+SIGN(0.5,UN)
      SIV=0.5+SIGN(0.5,CNP)
      SUN(I,J)=SIU
      SVN(I,J)=SIV
      PECRIT=1.0/(SIV-BETA1+SMALL)
      CNCRIT=PECRIT*DNP+SMALL
      IF(CNP/CNCRIT.GT.1.0) GO TO 601
C-----CENTRAL DIFFERENCING
      FN1(I,J)=DNP-BETA*CNP
      FN3(I,J)=0.0
      GO TO 602
C-----SKEW DIFFERENCING
C 601 DX=SEW(I+INT(1.0-SIU))
C     DY=0.5*SNS(J+INT(1.0-SIV))
  601 CONTINUE
      INTX=INT(1.0-SIU)
      DX  =SEW(I+INTX)
      INTY=INT(1.0-SIV)
      DY  =0.5*SNS(J+INTY)
      TANBN=UN/(VN+SMALL)
      AK=AMIN1(1.0,ABS(DY/DX*TANBN))
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      FN1(I,J)=(SIV-1.)*CNP
      FN3(I,J)=WCORNR*AK*(CNP-CNCRIT)
  602 FN2(I,J)=FN1(I,J)+CNP
  600 CONTINUE
C-----EAST SIDE
      DO 603 J=2,NJM1
      LIW=IW(J)-1
      LIE=IE(J)-1
      DO 603 I=LIW,LIE
      UE=0.5*(U(I,J)+U(I+1,J))
      VE=0.5*(V(I+1,J)+V(I+1,J-1))
      CEP=AE(I,J)
      DEP=AW(I,J)
      SIU=0.5+SIGN(0.5,CEP)
      SIV=0.5+SIGN(0.5,VE)
      SUE(I,J)=SIU
      SVE(I,J)=SIV
      PECRIT=1.0/(SIU-0.5)
      CECRIT=PECRIT*DEP+SMALL
      IF(CEP/CECRIT.GT.1.0) GO TO 604
C-----CENTRAL DIFFERENCING
      E1(I,J)=DEP-0.5*CEP
      E3(I,J)=0.0
      GO TO 605
C-----SKEW DIFFERENCING
  604 JY=J-INT(SIV)
      DY=DYNP(JY)
      IX=I+INT(1.0-SIU)
      IF((JY-JS(IX)+1)*(JY-JN(IX))) 607,606,607
  606 DY=0.5*SNS(J)
  607 DX=0.5*SEW(I+1)
      TANTE=VE/(UE+SMALL)
      AK=AMIN1(1.0,ABS(DX/DY*TANTE))
      E1(I,J)=(SIU-1.)*CEP
      E3(I,J)=WCORNR*AK*(CEP-CECRIT)
  605 E2(I,J)=E1(I,J)+CEP
  603 CONTINUE
C-----CALCULATE BOUNDED COEFFICIENTS
      CALL BOUNDS (-1,0)
C-----RESTORE INFORMATION FROM TAPE-----------------------------------
      READ(LU9) DU,DV,GAMH,VIS,SP,PP,SPARE,DEN,GEN
      REWIND LU9
C
CHAPTER  4  FINAL COEFF. ASSEMBLY AND RESIDUAL SOURCE CALCULATION  4
C
      RESOR(IU)=0.0
      DO 300 I=2,NIUM1
      LJS=JS(I)
      LJN=JN(I)
      DO 301 J=LJS,LJN
      AP(I,J)=AN(I,J)+AS(I,J)+AE(I,J)+AW(I,J)-SP(I,J)
     1        +ASW(I,J)+ASE(I,J)+ANW(I,J)+ANE(I,J)
      RESOR1=AN(I,J)*U(I,J+1)+AS(I,J)*U(I,J-1)+AE(I,J)*U(I+1,J)
     1        +AW(I,J)*U(I-1,J)-AP(I,J)*U(I,J)+SU(I,J)
     2        +ASW(I,J)*U(I-1,J-1)+ASE(I,J)*U(I+1,J-1)
     3        +ANW(I,J)*U(I-1,J+1)+ANE(I,J)*U(I+1,J+1)
      VOL=R(J)*SEW(I)*SNS(J)
      SORVOL=GREAT*VOL
      IF(-SP(I,J).GT.0.5*SORVOL) RESOR1=RESOR1/SORVOL
      RESOR(IU)=RESOR(IU)+ABS(RESOR1)
```

```
C-----UNDER-RELAXATION
      AP(I,J)=AP(I,J)/URF(IU)
      SU(I,J)=SU(I,J)+(1.-URF(IU))*AP(I,J)*U(I,J)
      DU(I,J)=DU(I,J)/AP(I,J)
  301 CONTINUE
  300 CONTINUE
C
CHAPTER  5  5  5  SOLUTION OF DIFFERENCE EQUATION  5  5  5  5  5  5  5
C
      WRITE(LU4) AE,AW,AN,AS,AP,ASW,ASE,ANW,ANE,SU
      RETURN
      END
```

@PRT,S TEACH*TEACH.COEFV

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TEACH*TEACH(2).COEFV(0)
      SUBROUTINE COEFV
C
CHAPTER  0  0  0  0  0  0  0  0  PRELIMINARIES  0  0  0  0  0  0  0  0
C
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2      ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3      ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4      ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
     5      ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6      ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7      ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8      ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9      ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1      ,DYNPV(30),DYPSV(30),DT
     2      ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3      ,TAUNS(30),TAUSS(30),TAUWS(30)
     4      ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
      COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2      ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3      ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4      ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5      ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6      ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7      ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8      ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
     9      ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1      ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2      ,GREAT,SMALL,PI,UGC,SWNO
     3      ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4      ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5      ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6      ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7      ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
      COMMON /COM3/LU4,LU5,LU6,LU8,LU9
      LOGICAL INCAL,INCOMP,INPRO,IREAD,IVISCO,IWRITE,LAMINR
     1        ,NFREE,SSYM
      DIMENSION E1(30,30),E2(30,30),E3(30,30),FN1(30,30),FN2(30,30)
     1          ,FN3(30,30),SUE(30,30),SUN(30,30),SVN(30,30),SVE(30,30)
     2          ,SST(30)
      EQUIVALENCE (E1(1,1),DU(1,1)),(E2(1,1),DV(1,1))
     1            ,(E3(1,1),AP(1,1)),(FN1(1,1),GAMH(1,1))
     2            ,(FN2(1,1),VIS(1,1)),(FN3(1,1),SP(1,1))
     3            ,(SUE(1,1),PP(1,1)),(SVE(1,1),SPARE(1,1))
     4            ,(SUN(1,1),DEN(1,1)),(SVN(1,1),GEN(1,1))
C
CHAPTER  1  1  1  1  1  1  ASSEMBLY OF COEFFICIENTS  1  1  1  1  1  1  1
C
C-----SOUTH BOUNDARY
      DO 10 I=2,NIM1
      J=JS(I)-1
      AREAS=R(J+1)*SEW(I)
      VP=V(I,J)
      VN=V(I,J+1)
      CN=0.5*(VN+VP)*DEN(I,J+1)*AREAS
      DN=VIS(I,J+1)*AREAS/DYNPV(J)
      AN(I,J)=CN
      AS(I,J)=DN
```

```
      DVDYN=R(J+1)*(V(I,J+1)-V(I,J))/SNS(J+1)
      SST(I)=VIS(I,J+1)*DVDYN
   10 CONTINUE
C-----ALL OTHER LOCATIONS
      DO 100 J=2,NJVM1
      LIW=IW(J)
      LIE=IE(J)
C-----WEST BOUNDARY
      LIWM1=LIW-1
      AREAEW=RV(J)*SNSV(J)
      CE=0.5*(DEN(LIWM1,J)*U(LIWM1,J)+DEN(LIWM1,J+1)*U(LIWM1,J+1))
     1      *AREAEW
      VISE=0.5*(VIS(LIWM1,J)+VIS(LIWM1,J+1))
      DE=VISE*AREAEW/(0.5*SEW(LIW))
      DUDYE=(U(LIWM1,J+1)-U(LIWM1,J))/SNSV(J)
      AE(LIWM1,J)=CE
      AW(LIWM1,J)=DE
      TSUE=VISE*DUDYE
C-----FLOW POINTS
      DO 101 I=LIW,LIE
C-----COMPUTE AREAS, VOLUME AND INTERPOLATION FACTORS
      AREAN=R(J+1)*SEW(I)
      AREAEW=RV(J)*SNSV(J)
      VOL=AREAEW*SEW(I)
      ALPHA=AU(I)
      ALPHA1=1.-ALPHA
C-----CALCULATE CONVECTION COEFFICIENTS
      GSE=(DEN(I,J)*ALPHA1+DEN(I+1,J)*ALPHA)*U(I,J)
      GNE=(DEN(I,J+1)*ALPHA1+DEN(I+1,J+1)*ALPHA)*U(I,J+1)
      CE=0.5*(GSE+GNE)*AREAEW
      VN=V(I,J+1)
      VP=V(I,J)
      CN=0.5*(VN+VP)*DEN(I,J+1)*AREAN
C-----CALCULATE DIFFUSION COEFFICIENTS
      VISE=0.5*((VIS(I,J)+VIS(I,J+1))*ALPHA1
     1          +(VIS(I+1,J)+VIS(I+1,J+1))*ALPHA)
      DN=VIS(I,J+1)*AREAN/DYNPV(J)
      DE=VISE*AREAEW/DXEP(I)
C-----CALCULATE COEFFICIENTS OF SOURCE TERMS
      SMP=CN-AN(I,J-1)+CE-AE(I-1,J)
      CP=AMAX1(0.0,SMP)
      DV(I,J)=VOL/DYNP(J)
C-----STORE CONVEC. & DIFF. PARTS IN MAIN COEFF. ARRAYS
      AE(I,J)=CE
      AN(I,J)=CN
      AW(I,J)=DE
      AS(I,J)=DN
C-----CALCULATE SOURCE TERMS
      SU(I,J)=CP*V(I,J)-DV(I,J)*(P(I,J+1)-P(I,J))
      SP(I,J)=-CP
      IF(INDCOS.EQ.2) SP(I,J)=SP(I,J)-0.5*(VIS(I,J)+VIS(I,J+1))*
     1     VOL/RV(J)**2
      IF(IVISCO) GO TO 102
      SUW=TSUE
      SUS=SST(I)
      DUDYE=(U(I,J+1)-U(I,J))/SNSV(J)
      TSUE=VISE*DUDYE
      DVDYN=R(J+1)*(V(I,J+1)-V(I,J))/SNS(J+1)
      TSUN=VIS(I,J+1)*DVDYN
      SU(I,J)=SU(I,J)+(TSUE-SUW)*VOL/SEW(I)+(TSUN-SUS)*VOL/
```

```
     1 (RV(J)*SNSV(J))
      SST(I)=TSUN
      IF(INDCOS.EQ.2) SP(I,J)=SP(I,J)-0.5*(VIS(I,J)+VIS(I,J+1))*
     1     VOL/RV(J)**2
      IF(LAMINR) GO TO 102
      SU(I,J)=SU(I,J)-0.66667*(DEN(I,J+1)*TE(I,J+1)-DEN(I,J)*TE(I,J))
     1                            *VOL/SNSV(J)
C-----ADDITIONAL SOURCE DUE TO SWIRL
  102 IF(INDCOS.EQ.1) GO TO 103
      SWS=DEN(I,J)*W(I,J)**2/R(J)
      SWN=DEN(I,J+1)*W(I,J+1)**2/R(J+1)
      SU(I,J)=SU(I,J)+(SWN+SWS)*0.5*VOL
  103 IF(INCOMP) GO TO 101
      DUDXN=(U(I,J+1)-U(I-1,J+1))/SEW(I)
      DUDXS=(U(I,J)-U(I-1,J))/SEW(I)
      SU1=(VIS(I,J+1)*DUDXN-VIS(I,J)*DUDXS)*VOL/SNSV(J)
      DRVDYN=(RV(J+1)*V(I,J+1)-RV(J)*V(I,J))/SNS(J+1)
      DRVDYS=(RV(J)*V(I,J)-RV(J-1)*V(I,J-1))/SNS(J)
      SU2=(VIS(I,J+1)/R(J+1)*DRVDYN-VIS(I,J)/R(J)*DRVDYS)*VOL/SNSV(J)
      SU(I,J)=SU(I,J)-0.66666*(SU1+SU2)
      IF(.NOT.IVISCO) GO TO 101
      SU(I,J)=SU(I,J)+SU1+SU2
      IF(INDCOS.EQ.2) SP(I,J)=SP(I,J)-VIS(I,J)*VOL/RV(J)**2
  101 CONTINUE
  100 CONTINUE
C
CHAPTER  2  2  2  2  2  2  PROBLEM MODIFICATIONS  2  2  2  2  2  2  2
C
      CALL MODV
C
CHAPTER  3  3  3  3  3  3  CALCULATE BSHD COEFFICIENTS  3  3  3  3  3
C
C-----DUMP INFORMATION ON TAPE-------------------------------------------
      WRITE(LU9) DU,DV,GAMH,VIS,SP,PP,SPARE,DEN,GEN
      REWIND LU9
C-----CALCULATE COEFFICIENT COMPONENTS
C-----NORTH SIDE
      DO 600 I=2,NIM1
      LJS=JS(I)-1
      LJN=JN(I)-1
      DO 600 J=LJS,LJN
      UN=0.5*(U(I,J+1)+U(I-1,J+1))
      VN=0.5*(V(I,J)+V(I,J+1))
      CNP=AN(I,J)
      DNP=AS(I,J)
      SIU=0.5+SIGN(0.5,UN)
      SIV=0.5+SIGN(0.5,CNP)
      SUN(I,J)=SIU
      SVN(I,J)=SIV
      PECRIT=1.0/(SIV-0.5)
      CNCRIT=PECRIT*DNP
      IF(CNP/CNCRIT.GT.1.0) GO TO 601
C-----CENTRAL DIFFERENCING
      FN1(I,J)=DNP-0.5*CNP
      FN3(I,J)=0.0
      GO TO 602
C-----SKEW DIFFERENCING
  601 IX=I-INT(SIU)
      DX=DXEP(IX)
      JY=J+INT(1.0-SIV)
```

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```
      IF((IX-IW(JY)+1)*(IX-NIM1)) 609,608,609
  608 DX=0.5*SEW(I)
  609 DY=0.5*SNS(J+1)
      TANBN=UN/(VN+SMALL)
      AK=AMIN1(1.0,ABS(DY/DX*TANBN))
      FN1(I,J)=(SIV-1.)*CNP
      FN3(I,J)=WCORNR*AK*(CNP-CNCRIT)
  602 FN2(I,J)=FN1(I,J)+CNP
  600 CONTINUE
C-----EAST SIDE
      DO 603 J=2,NJVM1
      LIW=IW(J)-1
      LIE=IE(J)
      DO 603 I=LIW,LIE
      ALPHA=AU(I)
      ALPHA1=1.0-ALPHA
      UE=0.5*(U(I,J)+U(I,J+1))
      VE=ALPHA1*V(I,J)+ALPHA*V(I+1,J)
      CEP=AE(I,J)
      DEP=AW(I,J)
      SIU=0.5+SIGN(0.5,CEP)
      SIV=0.5+SIGN(0.5,VE)
      SUE(I,J)=SIU
      SVE(I,J)=SIV
      PECRIT=1.0/(SIU-ALPHA1+SMALL)
      CECRIT=PECRIT*DEP+SMALL
      IF(CEP/CECRIT.GT.1.0) GO TO 604
C-----CENTRAL DIFFERENCING
      E1(I,J)=DEP-ALPHA*CEP
      E3(I,J)=0.0
      GO TO 605
C-----SKEW DIFFERENCING
C 604 DX=0.5*SEW(I+INT(1.0-SIU))
C     DY=SNS(J+INT(1.0-SIV))
  604 CONTINUE
      INTX=INT(1.0-SIU)
      DX  =0.5*SEW(I+INTX)
      INTY=INT(1.0-SIV)
      DY  =SNS(J+INTY)
      TANTE=VE/(UE+SMALL)
      AK=AMIN1(1.0,ABS(DX/DY*TANTE))
      E1(I,J)=(SIU-1.)*CEP
      E3(I,J)=WCORNR*AK*(CEP-CECRIT)
  605 E2(I,J)=E1(I,J)+CEP
  603 CONTINUE
C-----CALCULATE BOUNDED COEFFICIENTS
      CALL BOUNDS (0,-1)
C-----RESTORE INFORMATION FROM TAPE----------------------------------
      READ(LU9) DU,DV,GAMH,VIS,SP,PP,SPARE,DEN,GEN
      REWIND LU9
C
CHAPTER  4  FINAL COEFF. ASSEMBLY AND RESIDUAL SOURCE CALCULATION  4  4
C
      RESOR(IV)=0.0
      DO 300 J=2,NJVM1
      LIW=IW(J)
      LIE=IE(J)
      DO 301 I=LIW,LIE
      AP(I,J)=AN(I,J)+AS(I,J)+AE(I,J)+AW(I,J)-SP(I,J)
     1        +ASW(I,J)+ASE(I,J)+ANW(I,J)+ANE(I,J)
```

```
      RESOR1=AN(I,J)*V(I,J+1)+AS(I,J)*V(I,J-1)+AE(I,J)*V(I+1,J)
     1      +AW(I,J)*V(I-1,J)-AP(I,J)*V(I,J)+SU(I,J)
     2      +ASW(I,J)*V(I-1,J-1)+ASE(I,J)*V(I+1,J-1)
     3      +ANW(I,J)*V(I-1,J+1)+ANE(I,J)*V(I+1,J+1)
      VOL=R(J)*SEW(I)*SNS(J)
      SORVOL=GREAT*VOL
      IF(-SP(I,J).GT.0.5*SORVOL) RESOR1=RESOR1/SORVOL
      RESOR(IV)=RESOR(IV)+ABS(RESOR1)
C-----UNDER-RELAXATION
      AP(I,J)=AP(I,J)/URF(IV)
      SU(I,J)=SU(I,J)+(1.-URF(IV))*AP(I,J)*V(I,J)
      DV(I,J)=DV(I,J)/AP(I,J)
  301 CONTINUE
  300 CONTINUE
C
CHAPTER  5  5  5  SOLUTION OF DIFFERENCE EQUATION  5  5  5  5  5  5  5
C
      WRITE(LU4) AE,AW,AN,AS,AP,ASW,ASE,ANW,ANE,SU
      REWIND LU4
      RETURN
      END
@PRT,S TEACH*TEACH.CORECT
```

```
TEACH*TEACH(2).CORECT(0)
            SUBROUTINE CORECT(FB,FL,FR,WL,WR)
      C
      C-----ROUTINE FOR OPTIMISING WEIGHTING FACTORS
      C
            IF(FL.GT.FR) GO TO 1
            WL=AMIN1(WL,FB/(FL+1.0E-30))
            WR=AMAX1(0.0,(FB-WL*FL)/FR)
            RETURN
          1 CONTINUE
            WR=AMIN1(WR,FB/(FR+1.0E-30))
            WL=AMAX1(0.0,(FB-WR*FR)/FL)
            RETURN
            END

@PRT,S TEACH*TEACH.CORTED
```

TEACH*TEACH(2).CORTED(U)

```
      SUBROUTINE CORTED
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2       ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3       ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4       ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
     5       ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6       ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7       ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8       ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9       ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1       ,DYNPV(30),DYPSV(30),DT
     2       ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3       ,TAUNS(30),TAUSS(30),TAUWS(30)
     4       ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
       COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2      ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3      ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4      ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5      ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6      ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7      ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8      ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
     9      ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1      ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2      ,GREAT,SMALL,PI,UGC,SWNO
     3      ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4      ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5      ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6      ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7      ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
       COMMON /COM3/LU4,LU5,LU6,LU8,LU9
       DIMENSION SUO(30,30),SPO(30,30),PHIO(30,30)
       EQUIVALENCE (SUO(1,1),ASW(1,1)),(SPO(1,1),ASE(1,1))
     1            ,(PHIO(1,1),ANW(1,1))
       REWIND LU4
C-----CORRECT TURBULENCE ENERGY FIELD
      CALL VISC
      CALL SORCFI(ITE)
      CALL MODFI(ITE)
      READ(LU4) AP,SPO,SUO,PHIO
      DO 150 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
      DO 150 J=LJS,LJN
      APSTAR=AP(I,J)-(SP(I,J)-SPO(I,J))/URF(ITE)
      SUSTAR=SU(I,J)+(1.0-URF(ITE))*APSTAR*PHIO(I,J)
      TE(I,J)=(AP(I,J)*TE(I,J)+SUSTAR-SUO(I,J))/APSTAR
  150 CONTINUE
C-----CORRECT ENERGY DISSIPATION FIELD
      CALL SORCFI(IED)
      CALL MODFI(IED)
      READ(LU4) AP,SPO,SUO,PHIO
      DO 250 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
      DO 250 J=LJS,LJN
      APSTAR=AP(I,J)-(SP(I,J)-SPO(I,J))/URF(IED)
```

```
      SUSTAR=SU(I,J)+(1.0-URF(IED))*APSTAR*PHIO(I,J)
      ED(I,J)=(AP(I,J)*ED(I,J)+SUSTAR-SUO(I,J))/APSTAR
  250 CONTINUE
      REWIND LU4
      RETURN
      END
```

@PRT,S TEACH*TEACH.INIT

TEACH*TEACH(2).INIT(U)

```
      SUBROUTINE INIT
C
CHAPTER  0  0  0  0  0  0  0  0  PRELIMINARIES  0  0  0  0  0  0  0  0
C
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2       ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3       ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4       ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
     5       ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6       ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7       ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8       ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9       ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1       ,DYNPV(30),DYPSV(30),DT
     2       ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3       ,TAUNS(30),TAUSS(30),TAUWS(30)
     4       ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
      COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2       ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3       ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4       ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5       ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6       ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7       ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8       ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
     9       ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1       ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2       ,GREAT,SMALL,PI,UGC,SWNO
     3       ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4       ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5       ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6       ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7       ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
      COMMON /COM3/LU4,LU5,LU6,LU8,LU9
C
CHAPTER  1  1  1  1  1  CALCULATE GRID QUANTITIES  1  1  1  1  1
C
      ENTRY GRID
      NIM1=NI-1
      NJM1=NJ-1
      ISTP1=ISTEP+1
      ISTM1=ISTEP-1
      JSTP1=JSTEP+1
      JSTM1=JSTEP-1
      JINS1=JINS+1
      NIU=NIM1
      NJV=NJM1
      NIUM1=NIU-1
      NJVM1=NJV-1
      DO 100 J=1,NJM1
      RV(J)=YV(J)
  100 IF(INDCOS.EQ.1)RV(J)=1.0
      DO 105 I=2,NIU
  105 X(I)=0.5*(XU(I)+XU(I-1))
      X(1)=2.*XU(1)-X(2)
      X(NI)=2.*XU(NIU)-X(NIM1)
      DO 108 J=2,NJV
```

```
      R(J)=0.5*(RV(J)+RV(J-1))
  108 Y(J)=0.5*(YV(J)+YV(J-1))
      R(1)=-R(2)
      Y(1)=-Y(2)
      Y(NJ)=2.*YV(NJV)-Y(NJM1)
      R(NJ)=1.0
      IF (INDCOS.EQ.2) R(NJ)=Y(NJ)
      DXPW(1)=0.0
      DXEP(NI)=0.0
      DO 101 I=1,NIM1
      DXEP(I)=X(I+1)-X(I)
  101 DXPW(I+1)=DXEP(I)
      DYPS(1)=0.0
      DYNP(NJ)=0.0
      DO 102 J=1,NJM1
      DYNP(J)=Y(J+1)-Y(J)
  102 DYPS(J+1)=DYNP(J)
      SEW(1)=0.0
      SEW(NI)=0.0
      DO 103 I=2,NIM1
  103 SEW(I)=XU(I)-XU(I-1)
      SNS(1)=0.0
      SNS(NJ)=0.0
      DO 104 J=2,NJM1
  104 SNS(J)=YV(J)-YV(J-1)
      DXPWU(1)=0.0
      DXEPU(NIU)=0.0
      DO 106 I=1,NIUM1
      DXEPU(I)=XU(I+1)-XU(I)
  106 DXPWU(I+1)=DXEPU(I)
      SEWU(1)=0.0
      SEWU(NIU)=0.0
      DO 107 I=2,NIUM1
  107 SEWU(I)=0.5*(DXEPU(I)+DXPWU(I))
      DYPSV(1)=0.0
      DYNPV(NJV)=0.0
      DO 109 J=1,NJVM1
      DYNPV(J)=YV(J+1)-YV(J)
  109 DYPSV(J+1)=DYNPV(J)
      SNSV(1)=0.0
      SNSV(NJV)=0.0
      DO 110 J=2,NJVM1
  110 SNSV(J)=0.5*(DYNPV(J)+DYPSV(J))
      DO 121 I=2,NIUM1
  121 AU(I)=(XU(I)-X(I))/DXEP(I)
      AU(NIU)=1.0
      AU(1)=0.0
      DO 122 J=2,NJVM1
  122 AV(J)=(YV(J)-Y(J))/DYNP(J)
      AV(NJV)=1.
      AV(1)=0.0
      RETURN
C
CHAPTER  2  2  2  2  2  2  SET VARIABLES TO ZERO  2  2  2  2  2  2
C
      ENTRY SET
      DO 200 I=1,NI
      TAUN(I)=0.0
      TAUS(I)=0.0
      TAUNS(I)=0.0
```

```
      TAUSS(I)=0.0
      DO 200 J=1,NJ
      AE(I,J)=0.0
      AN(I,J)=0.0
      AP(I,J)=0.0
      AS(I,J)=0.0
      AW(I,J)=0.0
      ASW(I,J)=0.0
      ASE(I,J)=0.0
      ANW(I,J)=0.0
      ANE(I,J)=0.0
      U(I,J)=0.0
      V(I,J)=0.0
      W(I,J)=0.0
      P(I,J)=0.0
      PP(I,J)=0.0
      DEN(I,J)=DENSIT
      VIS(I,J)=VISCOS
      GAMH(I,J)=VISCOS/PRANDT(ITE)
      TE(I,J)=0.0
      ED(I,J)=0.0
      DU(I,J)=0.0
      DV(I,J)=0.0
      SU(I,J)=0.0
      SP(I,J)=0.0
      GEN(I,J)=0.0
      SPARE(I,J)=0.0
      EN(I,J)=0.0
      FM(I,J)=0.0
      F(I,J)=0.0
      CPM(I,J)=CPIN
  200 T(I,J)=TIN
      DO 210 J=1,NJ
      TAUWS(J)=0.0
      TAUE(J)=0.0
  210 TAUW(J)=0.0
      RESOR(1)=0.0
      RESOR(2)=0.0
      RESOR(3)=0.0
      RESOR(4)=0.0
      RESOR(5)=0.0
      RESOR(6)=0.0
      RESOR(7)=0.0
      RESOR(8)=0.0
      RESOR(9)=0.0
      RESOR(10)=0.0
      RETURN
      END
@PRT,S TEACH*TEACH.LISOLV
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ILACH*IEACH(2).LISOLV(0)
      SUBROUTINE LISOLV(IENDIN,JENDIN,PHI,IVAR,IXSW,JYSW)
C
CHAPTER  0  0  0  0  0  0  0  0  PRELIMINARIES  0  0  0  0  0  0  0  0
C
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2      ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3      ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4      ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
     5      ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6      ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7      ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8      ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9      ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1      ,DYNPV(30),DYPSV(30),DT
     2      ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3      ,TAUNS(30),TAUSS(30),TAUWS(30)
     4      ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
      COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2     ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3     ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4     ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5     ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6     ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7     ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8     ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
     9     ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1     ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2     ,GREAT,SMALL,PI,UGC,SWNO
     3     ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4     ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5     ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6     ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7     ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
      DIMENSION A(30),C(30),PHI(30,30)
C
CHAPTER  1  1  1  1  1  1  1  W-E SWEEP  1  1  1  1  1  1  1  1  1
C
      NCOUNT=0
      NSWEEP=NSWP(IVAR)
  111 DO 400 N=1,NSWEEP
      IEND=NI-1+IENDIN
C-----COMMENCE W-E SWEEP
      ISUM=2+IEND
      IXSL=IXSW
  120 DO 100 II=2,IEND
      IF (IXSL.EQ.1) GO TO 12
      I=II
      GO TO 10
   12 I=ISUM-II
   10 CONTINUE
      JSTART=JS(I)
      JEND=JN(I)+JENDIN
      JSM1=JSTART-1
      A(JSM1)=0.0
      C(JSM1)=PHI(I,JSM1)
C-----COMMENCE S-N TRAVERSE
      DO 101 J=JSTART,JEND
```

```
C-----ASSEMBLE TDMA COEFFICIENTS
      A(J)=AN(I,J)
      C(J)=AE(I,J)*PHI(I+1,J)+AW(I,J)*PHI(I-1,J)+SU(I,J)
      IF(IVAR.NE.3) C(J)=C(J)
     1    +ANE(I,J)*PHI(I+1,J+1)+ANW(I,J)*PHI(I-1,J+1)
     2    +ASE(I,J)*PHI(I+1,J-1)+ASW(I,J)*PHI(I-1,J-1)
C-----CALCULATE COEFFICIENTS OF RECURRENCE FORMULA
      TERM=1./(AP(I,J)-AS(I,J)*A(J-1)+SMALL)
      A(J)=A(J)*TERM
  101 C(J)=(C(J)+AS(I,J)*C(J-1))*TERM
C-----OBTAIN NEW PHI*S
      DO 102 JJ=JSTART,JEND
      J=JSTART+JEND-JJ
  102 PHI(I,J)=A(J)*PHI(I,J+1)+C(J)
  100 CONTINUE
      IXSL1=IXSL
      IXSL=0
      IF (IXSL1.EQ.2) IXSL=1
      IF (IXSL.EQ.1) GO TO 120
C
CHAPTER  2  2  2  2  2  2  2  S-N SWEEP  2  2  2  2  2  2  2  2  2
C
      JSTART=2
      JEND=NJ-1+JENDIN
      JSUM=JSTART+JEND
C-----COMMENCE S-N SWEEP
      JYSL=JYSW
  220 DO 200 JJ=JSTART,JEND
      IF (JYSL.EQ.1) GO TO 22
      J=JJ
      GO TO 20
   22 J=JSUM-JJ
   20 CONTINUE
      ISTART=IW(J)
      IEND=IE(J)+IENDIN
      ISM1=ISTART-1
      A(ISM1)=0.0
      C(ISM1)=PHI(ISM1,J)
C-----COMMENCE W-E TRAVERSE
      DO 201 I=ISTART,IEND
C-----ASSEMBLE TDMA COEFFICIENTS
      A(I)=AE(I,J)
      C(I)=AN(I,J)*PHI(I,J+1)+AS(I,J)*PHI(I,J-1)+SU(I,J)
      IF(IVAR.NE.3) C(I)=C(I)
     1    +ANE(I,J)*PHI(I+1,J+1)+ANW(I,J)*PHI(I-1,J+1)
     2    +ASE(I,J)*PHI(I+1,J-1)+ASW(I,J)*PHI(I-1,J-1)
      TERM=1./(AP(I,J)-AW(I,J)*A(I-1)+SMALL)
      A(I)=A(I)*TERM
  201 C(I)=(C(I)+AW(I,J)*C(I-1))*TERM
C-----OBTAIN NEW PHI*S
      DO 202 II=ISTART,IEND
      I=ISTART+IEND-II
  202 PHI(I,J)=A(I)*PHI(I+1,J)+C(I)
  200 CONTINUE
      JYSL1=JYSL
      JYSL=0
      IF (JYSL1.EQ.2) JYSL=1
      IF (JYSL.EQ.1) GO TO 220
      NCOUNT=NCOUNT+1
  400 CONTINUE
```

```
      IF(IVAR.NE.3) RETURN
      RESORP=0.
      DO 500 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
      DO 500 J=LJS,LJN
      SRESOR=AW(I,J)*PHI(I-1,J)+AE(I,J)*PHI(I+1,J)+AS(I,J)*PHI(I,J-1)
     1 +AN(I,J)*PHI(I,J+1)-AP(I,J)*PHI(I,J)+SU(I,J)
  500 RESORP=RESORP+ABS(SRESOP)
      RESORP=RESORP/PRES
      IF(INCOUNT.GE.MAXSWP) GO TO 502
      IF(RESORP.GT.PERR) GO TO 111
  502 CONTINUE


      RETURN
      END

@PRT,S TEACH*TEACH.MODFI
```

```
TEACH*TEACH(2).MODFI(0)
      SUBROUTINE MODFI(IVAR)
C
CHAPTER  0  0  0  0  0  0  0  0  PRELIMINARIES  0  0  0  0  0  0  0  0
C
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2      ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3      ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4      ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
     5      ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6      ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7      ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8      ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9      ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1      ,DYNPV(30),DYPSV(30),DT
     2      ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3      ,TAUNS(30),TAUSS(30),TAUWS(30)
     4      ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
      COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2      ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3      ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4      ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5      ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6      ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7      ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8      ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
     9      ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1      ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2      ,GREAT,SMALL,PI,UGC,SWNO
     3      ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4      ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5      ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6      ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7      ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
      LOGICAL INCAL,INCOMP,INPRO,IREAD,IVISCO,IWRITE,LAMINR
     1        ,NFREE,SSYM
      DIMENSION CE(30,30),CN(30,30),DE(30,30),DN(30,30)
      EQUIVALENCE (CE(1,1),DU(1,1)),(CN(1,1),DV(1,1))
     1           ,(DE(1,1),PP(1,1)),(DN(1,1),SPARE(1,1))
      ILVAR=IVAR-3
      GO TO (100,200,300,400,500,600),ILVAR
C
CHAPTER  1  1  1  1  1  1  TURBULENT KINETIC ENERGY  1  1  1  1  1  1
C
  100 CONTINUE
      CDTERM=CMU75/CAPPA
C
C-1.1-TOP WALL (NORTH BOUNDARY)
      DO 340 I=2,NIM1
      J=JN(I)
      YP=YV(J)-Y(J)
      DENU=DEN(I,J)
      SQRTK=SQRT(TE(I,J))
      VOL=R(J)*SNS(J)*SEW(I)
      GENCOU=0.5*(ABS(TAUN(I-1)*U(I-1,J))+ABS(TAUN(I)*U(I,J)))/YP
      GENCOU=GENCOU+ABS(TAUNS(I)*W(I,J))/YP+VIS(I,J)*(W(I,J)/R(J))**2
     1        -2.0*ABS(TAUNS(I)*W(I,J)/R(J))
      GEN(I,J)=GEN(I,J)*(VIS(I,J)-VISCOS)+GENCOU
```

```
      IF (YPLUSN(I).LE.11.63) GO TO 341
      DITERM=DENU*CDTERM*SQRTK*ALOG(ELOG*YPLUSN(I))/YP
      GO TO 342
  341 DITERM=DENU*CMU75*SQRTK*YPLUSN(I)/YP
  342 CONTINUE
      SMP=CN(I,J)-CN(I,J-1)+CE(I,J)-CE(I-1,J)
      CP=AMAX1(0.0,SMP)
      SU(I,J)=CP*TE(I,J)+GEN(I,J)*VOL
      SP(I,J)=-CP-DITERM*VOL
      AN(I,J)=0.0
      AS(I,J)=0.0
  340 CONTINUE
C
C-1.2-SIDE WALL OF BLUFF BODY (WEST BOUNDARY)
      JSTR=JINS+1
      DO 260 J=JSTR,JSTEP
      I=IW(J)
      XP=XU(I)-X(I)
      DENV=DEN(I,J)
      SQRTK=SQRT(TE(I,J))
      VOL=R(J)*SNS(J)*SEW(I)
      GENCOU=0.5*(ABS(TAUW(J-1)*V(I,J-1))+ABS(TAUW(J)*V(I,J)))/XP
      GENCOU=GENCOU+ABS(TAUWS(J)*W(I,J))/XP+VIS(I,J)*(W(I,J)/R(J))**2
      GEN(I,J)=GEN(I,J)*(VIS(I,J)-VISCOS)+GENCOU
      IF(XPLUSW(J).LE.11.63) GO TO 263
      DITERM=DENV*CDTERM*SQRTK*ALOG(ELOG*XPLUSW(J))/XP
      GO TO 264
  263 DITERM=DENV*CMU75*SQRTK*XPLUSW(J)/XP
  264 CONTINUE
      SMP=CN(I,J)-CN(I,J-1)+CE(I,J)+CE(I-1,J)
      CP=AMAX1(0.0,SMP)
      SU(I,J)=CP*TE(I,J)+GEN(I,J)*VOL
      SP(I,J)=-CP-DITERM*VOL
      AE(I-1,J)=0.0
      AW(I-1,J)=0.0
  260 CONTINUE
C
C-1.3-TOP WALL OF BLUFF BODY (SOUTH BOUNDARY)
      DO 140 I=2,ISTEP
      J=JS(I)
      YP=YV(J)-Y(J)
      DENU=DEN(I,J)
      SQRTK=SQRT(TE(I,J))
      VOL=R(J)*SNS(J)*SEW(I)
      GENCOU=0.5*(ABS(TAUS(I-1)*U(I-1,J))+ABS(TAUS(I)*U(I,J)))/YP
      GENCOU=GENCOU+ABS(TAUSS(I)*W(I,J))/YP+VIS(I,J)*(W(I,J)/R(J))**2
     1      -2.0*ABS(TAUSS(I)*W(I,J)/R(J))
      GEN(I,J)=GEN(I,J)*(VIS(I,J)-VISCOS)+GENCOU
      IF(YPLUSS(I).LE.11.63) GO TO 141
      DITERM=DENU*CDTERM*SQRTK*ALOG(ELOG*YPLUSS(I))/YP
      GO TO 142
  141 DITERM=DENU*CMU75*SQRTK*YPLUSS(I)/YP
  142 CONTINUE
      SMP=CN(I,J)-CN(I,J-1)+CE(I,J)-CE(I-1,J)
      CP=AMAX1(0.0,SMP)
      SU(I,J)=CP*TE(I,J)+GEN(I,J)*VOL
      SP(I,J)=-CP-DITERM*VOL
      AN(I,J-1)=0.0
      AS(I,J-1)=0.0
  140 CONTINUE
```

```
C
C-1.4-SYMMETRY AXIS AT THE BOTTOM (SOUTH BOUNDARY)
      DO 160 I=ISTP1,NI
      AN(I,1)=0.0
      AS(I,1)=0.0
  160 TE(I,1)=TE(I,2)
C
C-1.5-OUTLET  (EAST BOUNDARY)
      DO 130 J=2,JEXIT
      AE(NIM1,J)=0.0
      AW(NIM1,J)=0.0
  130 TE(NI,J)=TE(NIM1,J)
      RETURN
C
CHAPTER  2  2  2  2  2  2  2  2  2  DISSIPATION  2  2  2  2  2  2  2
C
  200 CONTINUE
      TERM=GREAT*CMU75/CAPPA
C-2.1-TOP WALL (NORTH BOUNDARY)
C
      DO 440 I=2,NIM1
      J=JN(I)
      YP=YV(J)-Y(J)
      AN(I,J)=0.0
      AS(I,J)=0.0
      SU(I,J)=TERM*TE(I,J)**1.5/YP
  440 SP(I,J)=-GREAT
C
C-2.2-SIDE WALL OF BLUFF BODY (WEST BOUNDARY)
      JSTR=JINS+1
      DO 222 J=JSTR,JSTEP
      I=IW(J)
      XP=XU(I)-X(I)
      AE(I-1,J)=0.0
      AW(I-1,J)=0.0
      SU(I,J)=TERM*TE(I,J)**1.5/XP
      SP(I,J)=-GREAT
  222 CONTINUE
C
C-2.3-TOP WALL OF BLUFF BODY (SOUTH BOUNDARY)
      DO 240 I=2,ISTEP
      J=JS(I)
      YP=YV(J)-Y(J)
      AN(I,J-1)=0.0
      AS(I,J-1)=0.0
      SU(I,J)=TERM*TE(I,J)**1.5/YP
  240 SP(I,J)=-GREAT
C
C-2.4-SYMMETRY AXIS AT THE BOTTOM (SOUTH BOUNDARY)
      DO 280 I=ISTP1,NI
      AN(I,1)=0.0
      AS(I,1)=0.0
  280 ED(I,1)=ED(I,2)
C
C-2.5-OUTLET (EAST BOUNDARY)
      DO 230 J=2,JEXIT
      AE(NIM1,J)=0.0
      AW(NIM1,J)=0.0
  230 ED(NI,J)=ED(NIM1,J)
      RETURN
```

```
C
CHAPTER  3  3  3  3  3  3  3  3  ENTHALPY  3  3  3  3  3  3  3  3  3  3
C
  300 CONTINUE
C
C-3.1-TOP WALL (NORTH BOUNDARY)
      DO 505 I=2,NIM1
      J=JN(I)
      AN(I,J)=0.0
      AS(I,J)=0.0
      SU(I,J)=SU(I,J)+DN(I,J)*(CPM(I,J)*TWALL+FM(I,J)*HP)
  505 SP(I,J)=SP(I,J)-DN(I,J)
C
C-3.2-SIDE WALL OF BLUFF BODY (WEST BOUNDARY)
      JSTR=JINS+1
      DO 510 J=JSTR,JSTEP
      I=IW(J)
      AE(I-1,J)=0.0
      AW(I-1,J)=0.0
      SU(I,J)=SU(I,J)+DE(I-1,J)*(CPM(I,J)*TBLUF+FM(I,J)*HR)
  510 SP(I,J)=SP(I,J)-DE(I-1,J)
C
C-3.3-TOP WALL OF BLUFF BODY (SOUTH BOUNDARY)
      DO 515 I=2,ISTEP
      J=JS(I)
      AN(I,J-1)=0.0
      AS(I,J-1)=0.0
      SU(I,J)=SU(I,J)+DN(I,J-1)*(CPM(I,J)*TBLUF+FM(I,J)*HR)
  515 SP(I,J)=SP(I,J)-DN(I,J-1)
C
C-3.4-SYMMETRY AXIS AT THE BOTTOM (SOUTH BOUNDARY)
      DO 520 I=ISTP1,NI
      AN(I,1)=0.0
      AS(I,1)=0.0
      T(I,1)=T(I,2)
  520 EN(I,1)=EN(I,2)
C
C-3.5-OUTLET (EAST BOUNDARY)
      DO 525 J=2,JEXIT
      AE(NIM1,J)=0.0
      AW(NIM1,J)=0.0
      T(NI,J)=T(NIM1,J)
  525 EN(NI,J)=EN(NIM1,J)
      RETURN
C
CHAPTER  4  4  4  4  4  4  SPECIES CONCENTRATION  4  4  4  4  4  4  4
C
  400 CONTINUE
C
C-4.1-SYMMETRY AXIS AT THE BOTTOM (SOUTH BOUNDARY)
      DO 410 I=ISTP1,NI
  410 FM(I,1)=FM(I,2)
C
C-4.2-OUTLET (EAST BOUNDARY)
      DO 420 J=1,NJ
  420 FM(NI,J)=FM(NIM1,J)
      RETURN
C
CHAPTER  5  5  5  5  MIXTURE FRACTION  5  5  5  5  5  5  5  5  5
C
```

```
  500 CONTINUE
C
C-5.1-SYMMETRY AXIS AT THE BOTTOM (SOUTH BOUNDARY)
      DO 550 I=ISTP1,NI
  550 F(I,1)=F(I,2)
C
C-5.2-OUTLET (EAST BOUNDARY)
      DO 560 J=1,NJ
  560 F(NI,J)=F(NIM1,J)
      RETURN
C
CHAPTER 6  6  6  6 SWIRL 6  6  6  6  6
C
  600 CONTINUE
C
C-6.1-TOP WALL (NORTH BOUNDARY)
      DO 601 I=2,NIM1
      J=JN(I)
      YP=YV(J)-Y(J)
      YPLUSN(I)=DEN(I,J)*CMU25*SQRT(TE(I,J))*YP/VISCOS
      VPLUS=ALOG(ELOG*YPLUSN(I))/CAPPA
      IF(YPLUSN(I).LE.11.63) GO TO 602
      TMULT=DEN(I,J)*CMU25*SQRT(TE(I,J))
      TMULT=TMULT/VPLUS
      GO TO 603
  602 TMULT=VISCOS/YP
  603 TAUNS(I)=-TMULT*W(I,J)/R(J)
      T1=SEW(I)*(RV(J)**2)*TMULT*W(I,J)/R(J)
      SP(I,J)=SP(I,J)-T1/W(I,J)
      WS=(AV(J-1)*W(I,J)/R(J)+(1.-AV(J-1))*W(I,J-1)/R(J-1))*RV(J-1)
      VISS=AV(J-1)*VIS(I,J)+(1.0-AV(J-1))*VIS(I,J-1)
      T2=2.0*SEW(I)*WS*VISS
      SU(I,J)=SU(I,J)+T2
      AN(I,J)=0.0
      AS(I,J)=0.0
  601 CONTINUE
      TAUNS(1)=TAUNS(2)
      TAUNS(NI)=TAUNS(NIM1)
C
C-6.2-TOP WALL OF BLUFF BODY (SOUTH BOUNDARY)
      DO 604 I=2,ISTEP
      J=JS(I)
      YP=YV(J)-Y(J)
      YPLUSS(I)=DEN(I,J)*CMU25*SQRT(TE(I,J))*YP/VISCOS
      VPLUS=ALOG(ELOG*YPLUSS(I))/CAPPA
      IF(YPLUSS(I).LE.11.63) GO TO 605
      TMULT=DEN(I,J)*CMU25*SQRT(TE(I,J))
      TMULT=TMULT/VPLUS
      GO TO 606
  605 TMULT=VISCOS/YP
  606 TAUSS(I)=-TMULT*W(I,J)/R(J)
      T3=SEW(I)*(RV(J-1)**2)*TMULT*W(I,J)/R(J)
      WN=(AV(J)*W(I,J+1)/R(J+1)+(1.-AV(J))*W(I,J)/R(J))*RV(J)
      VISN=AV(J)*VIS(I,J+1)+(1.0-AV(J))*VIS(I,J)
      T4=SEW(I)*2.0*WN*VISN
      SP(I,J)=SP(I,J)-(T3+T4)/W(I,J)
      AN(I,J-1)=0.0
      AS(I,J-1)=0.0
  604 CONTINUE
      TAUSS(1)=TAUSS(2)
```

```
      TAUSS(NI)=TAUSS(NIM1)
C
C-6.3-SIDE WALL OF BLUFF BODY (WEST BOUNDARY)
      JSTR=JINS+1
      DO 607 J=JSTR,JSTEP
      I=IW(J)
      XP=XU(I)-X(I)
      XPLUSW(J)=DEN(I,J)*SQRT(TE(I,J))*CMU25*XP/VISCOS
      VPLUS=ALOG(ELOG*XPLUSW(J))/CAPPA
      IF (XPLUSW(J).LE.11.63) GO TO 608
      TMULT=DEN(I,J)*CMU25*SQRT(TE(I,J))
      TMULT=TMULT/VPLUS
      GO TO 609
  608 TMULT=VISCOS/XP
  609 TAUWS(J)=-TMULT*W(I,J)
      SP(I,J)=SP(I,J)-TMULT*SNS(J)*R(J)
      AE(I-1,J)=0.0
      AW(I-1,J)=0.0
  607 CONTINUE
C
C-6.4-SYMMETRY AXIS AT THE BOTTOM (SOUTH BOUNDARY)
      DO 610 I=2,NI
      AN(I,1)=0.0
      AS(I,1)=0.0
  610 W(I,1)=W(I,2)
C
C-6.5-OUTLET (EAST BOUNDARY)
      DO 611 J=2,JEXIT
      AE(NIM1,J)=0.0
      AW(NIM1,J)=0.0
  611 W(NI,J)=W(NIM1,J)
      RETURN
      END
```

@PRT,S TEACH*TEACH.MODINP

TEACH*TEACH(2).MODINP(U)

```
      SUBROUTINE MODINP
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2       ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3       ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4       ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
     5       ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6       ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7       ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8       ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9       ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1       ,DYNPV(30),DYPSV(30),DT
     2       ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3       ,TAUNS(30),TAUSS(30),TAUWS(30)
     4       ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
       COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2       ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3       ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4       ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5       ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6       ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7       ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8       ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INOPRI,NUMPRI,PERR,MAXSWP
     9       ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1       ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2       ,GREAT,SMALL,PI,UGC,SWNO
     3       ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4       ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5       ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6       ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7       ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
       COMMON /COM3/LU4,LU5,LU6,LU8,LU9
       COMMON /COM4/ CPFTRM(5), ITREAX
       COMMON /COM5/WCEN,TURBCN,DELCEN
       LOGICAL INCAL,INCOMP,INPRO,IREAD,IVISCO,IWRITE,LAMINR
     1       ,NFREE,SSYM
       DIMENSION TITLE(20), ISWDUM(10)
C
C      ////////////////////////////////////////////////////////////// RLARGE,
C      -------------------------------------------------------------- REXIT
C      .                                                            .
C      .                                                            .
C      .                                                            .
C      ##############RSMALL,JSTEP                                   .
C      //////////////:                                              .
C                   /:                                              .
C                   /:                                              .
C      //////////////:                                              .
C      --------------RINS,JINS                                      .
C                    .                                              .
C     # . # . # . # : # . # . # . # . # . # . # . # . # . # . # . #
C                    :
C                  ISTEP
C
       ENTRY PARAM
C
C      READ CARD IMAGE INPUT
```

```
C
      READ(LU5,1005) (TITLE(I),I=1,20)
 1005 FORMAT(20A4)
C
      READ(LU5,1010) ITSTEP,MODOP
 1010 FORMAT(8I10)
C
      READ(LU5,1010) ISCEME,INDCOS,KNPRO,KNCOMP,KVISCO,KLAMNR
C
      READ(LU5,1010) NI,NJ,ISTEP,JSTEP,JEXIT,JINS,IMON,JMON
C
      READ(LU5,1010) IU,IV,IP,ITE,IED,IEN,IFM,IF
      READ(LU5,1010) ISWR,IPP
C
      ISWDUM( 1) = IU
      ISWDUM( 2) = IV
      ISWDUM( 3) = IP
      ISWDUM( 4) = ITE
      ISWDUM( 5) = IED
      ISWDUM( 6) = IEN
      ISWDUM( 7) = IFM
      ISWDUM( 8) = IF
      ISWDUM( 9) = ISWR
      ISWDUM(10) = IPP
C
      READ(LU5,1010) (NSWP(I),I=1,10)
C
      READ(LU5,1015) (URF(I), I=1,10),URFVIS,URFDEN
 1015 FORMAT(8E10.5)
C
      READ(LU5,1015) VISCOS,DENSIT,TWALL,TBLUF
C
      READ(LU5,1015) UIN,WIN,TIN,CIN,TURBIN,DELTA,PIN
C
      READ(LU5,1015) UCEN,WCEN,TCEN,CCEN,TURBCN,DELCEN
C
      READ(LU5,1015) STOIC,HR,WMF
C
      READ(LU5,1015) CPO2, CPN2, CPCO2, CPH2O
C
      READ(LU5,1015) (CPFTRM(I),I=1,5)
C
      DO 1020 I=1,NI
      READ(LU5,1015) XU(I)
 1020 CONTINUE
C
      DO 1025 J=1,NJ
      READ(LU5,1015) YV(J)
 1025 CONTINUE
C
      READ(LU5,1030) PREF,IPREF,JPREF,PERR,MAXSWP
 1030 FORMAT(E10.5,2I10,E10.5,I10)
C
      READ(LU5,1035) SORMAX,MAXIT,INDPRI,NUMPRI,ITREAX
 1035 FORMAT(E10.5,4I10)
C
C     WRITE CARD IMAGE INPUTS
C
      WRITE(LU6,2005) (TITLE(I),I=1,20)
 2005 FORMAT(1H1/10X,'TURBULENT FLOW IN A BLUFF-BODY COMBUSTOR',
```

```
     X          //10X,'FOR ',20A4/)
C
      WRITE(LU6,2010) ITSTEP
 2010 FORMAT(/10X,'NUMBER OF ITERATIONS TO EXECUTE',1X,I10)
C
      IF(MODOP.NE.2) WRITE(LU6,2015)
      IF(MODOP.EQ.2) WRITE(LU6,2020)
 2015 FORMAT(/10X,'MODOP  = 1, THIS IS A NEW CASE')
 2020 FORMAT(/10X,'MODOP  = 2, START FROM RESTART FILE')
C
      IF(ISCEME.EQ.1) WRITE(LU6,2025)
      IF(ISCEME.EQ.2) WRITE(LU6,2030)
 2025 FORMAT(/10X,'ISCEME = 1, USE HYBRID DIFFERENCING' )
 2030 FORMAT(/10X,'ISCEME = 2, USE SKEW DIFFERENCING')
C
      IF(INDCOS.EQ.1) WRITE(LU6,2032)
      IF(INDCOS.EQ.2) WRITE(LU6,2035)
 2032 FORMAT(/10X,'INDCOS = 1, CARTESIAW CO-ORDINATES')
 2035 FORMAT(/10X,'INDCOS = 2, CYLINDRICAL CO-ORDINATES')
C
      IF(KNPRO.LE.0) WRITE(LU6,2040)
      IF(KNPRO.GE.1) WRITE(LU6,2045)
 2040 FORMAT(/10X,'KNPRO  = 0, FLUID PROPERTIES ARE CONSTANT')
 2045 FORMAT(/10X,'KNPRO  = 1, FLUID PROPERTIES ARE VARIABLE')
C
      IF(KNCOMP.LE.0) WRITE(LU6,2050)
      IF(KNCOMP.GE.1) WRITE(LU6,2055)
 2050 FORMAT(/10X,'KNCOMP = 0, FLOW IS COMPRESSIBLE')
 2055 FORMAT(/10X,'KNCOMP = 1, FLOW IS INCOMPRESSIBLE')
C
      IF(KVISCO.LE.0) WRITE(LU6,2060)
      IF(KVISCO.GE.1) WRITE(LU6,2065)
 2060 FORMAT(/10X,'KVISCO = 0, VISCOSITY IS VARIABLE')
 2065 FORMAT(/10X,'KVISCO = 1, VISCOSITY IS CONSTANT')
C
      IF(KLAMNR.LE.0) WRITE(LU6,2070)
      IF(KLAMNR.GE.1) WRITE(LU6,2075)
 2070 FORMAT(/10X,'KLAMNR = 0, FLOW IS TURBULENT')
 2075 FORMAT(/10X,'KLAMNR = 1, FLOW IS LAMINAR')
C
      WRITE(LU6,2080) NI,NJ,ISTEP,JSTEP,JEXIT,JINS,IMON,JMON
 2080 FORMAT(/10X,'GRID CONTROLS'/
     X/10X,'NI       = ', I5,
     X/10X,'NJ       = ', I5,
     X/10X,'ISTEP    = ', I5,
     X/10X,'JSTEP    = ', I5,
     X/10X,'JEXIT    = ', I5,
     X/10X,'JINS     = ', I5,
     X/10X,'IMON     = ', I5,
     X/10X,'JMON     = ', I5,
     X/)
C
      WRITE(LU6,2100)
 2100 FORMAT(/10X,'DEPENDENT VARIABLE EQUATION CONTROLS'/
     X/10X,'VARIABLE',22X,   'SWITCH  NO. SWEEPS UNDER RELAX'
     X/10X, 30X,          '                         FACTOR')
      WRITE(LU6,2105)  (ISWDUM(I),NSWP(I),URF(I),I=1,10),URFVIS,URFDEN
 2105 FORMAT(
     X/10X,'U VELOCITY                    ', 2I12, E12.5,
     X/10X,'V VELOCITY                    ', 2I12, E12.5,
```

```
     X/10X,'PRIMARY PRESSURE CORRECT', 2112, E12.5,
     X/10X,'TURBULENCE ENERGY        ', 2112, E12.5,
     X/10X,'ENERGY DISSIPATION       ', 2112, E12.5,
     X/10X,'ENTHALPY                 ', 2112, E12.5,
     X/10X,'FUEL CONCENTRATION       ', 2112, E12.5,
     X/10X,'MIXTURE FRACTION         ', 2112, E12.5,
     X/10X,'SWIRL VELOCITY           ', 2112, E12.5,
     X/10X,'SEC. PRESSURE CORRECT.   ', 2112, E12.5,
     X/10X,'VISCOSITY                ', 24X,  E12.5,
     X/10X,'DENSITY                  ', 24X,  E12.5,
     X/)
C
      WRITE(LU6,2120) VISCOS,DENSIT, TWALL, TBLUF
 2120 FORMAT(
     X/10X,'VISCOSITY      N-SEC/M**2', E12.5,
     X/10X,'DENSITY           KG/M**3', E12.5,
     X/10X,'WALL TEMPERATURE        K', E12.5,
     X/10X,'BLUFF BODY TEMPERATURE K', E12.5,
     X/)
C
      WRITE(LU6,2150)
 2150 FORMAT(/10X,'FLOW CONDITIONS...',
     X/10X,'VARIABLE                    OUTER FLOW  INNER FLOW'/)
      WRITE(LU6,2155)   UIN, UCEN,  WIN, WCEN, TIN, TCEN, CIN, CCEN,
     X                  TURBIN, TURBCN, DELTA, DELCEN, PIN
 2155 FORMAT(
     X/10X,'AXIAL VELOCITY        M/SEC', 2E12.5,
     X/10X,'SWIRL/AXIAL VEL. RATIO     ', 2E12.5,
     X/10X,'TEMPERATURE               K', 2E12.5,
     X/10X,'CONC.-SECOND COMPONENT     ', 2E12.5,
     X/10X,'TURB. INTENSITY FACTOR     ', 2E12.5,
     X/10X,'BNDY. LAYER THICKNESS     M', 2E12.5,
     X/10X,'PRESSURE            N/M**2',  E12.5,
     X/)
C
      WRITE(LU6,2160) STOIC,HR,WMF
 2160 FORMAT(
     X/10X,'STOIC. O2/FUEL MASS RAT.', E12.5,
     X/10X,'HEAT OF COMBUSTION  J/KG', E12.5,
     X/10X,'FUEL MOLECULAR WEIGHT   ', E12.5,
     X/)
C
      WRITE(LU6,2165) CPO2,CPN2,CPCO2,CPH2O
 2165 FORMAT(
     X/10X,'CP-O2                 J/KG-K', E12.5,
     X/10X,'CP-N2                 J/KG-K', E12.5,
     X/10X,'CP-CO2                J/KG-K', E12.5,
     X/10X,'CP-H2O                J/KG-K', E12.5,
     X/)
C
      WRITE(LU6,2170) (CPFTRM(I),I=1,5)
 2170 FORMAT(/10X,'CO-EFFICIENTS OF THE POLYNOMIAL FOR THE HEAT ',
     X            'CAPACITY FOR THE SECOND COMPONENT (E.G.,FUEL) ',/
     X/10X,'CP = (C1 + C2*T + C3*T**2 + C4*T**3 + C5*T**4)*UGC /WMF ',
     X/10X,'       WITH T IN DEG K AND CP IN J/KG-K'/
     X/10X,'C1      = ', E12.5,
     X/10X,'C2      = ', E12.5,
     X/10X,'C3      = ', E12.5,
     X/10X,'C4      = ', E12.5,
     X/10X,'C5      = ', E12.5,)
```

```
C
      WRITE(LU6,2180)
 2180 FORMAT(/10X,'AXIAL STORAGE LOCATIONS FOR AXIAL VELOCITY',
     X       //10X,'     I        X-METER'/)
      DO 2181 I=1,NI
      WRITE(LU6,2182)I,XU(I)
 2182 FORMAT(10X,I5,E12.5)
 2181 CONTINUE
C
      WRITE(LU6,2190)
 2190 FORMAT(/10X,'RADIAL STORAGE LOCATIONS FOR RADIAL VELOCITY',
     X       //10X,'     J        Y-METER'/)
      DO 2191 J=1,NJ
      WRITE(LU6,2182)J,YV(J)
 2191 CONTINUE
C
      WRITE(LU6,2200) PREF,IPREF,JPREF,PERR,MAXSWP
 2200 FORMAT(
     X/10X,'REFERENCE PRESSURE PASCL', E12.5,
     X/10X,'IPREF                   ', I12,
     X/10X,'JPREF                   ', I12,
     X/10X,'TOL.FOR RESIDUAL FOR    ',
     X/10X,'PRESSURE CORRECT. EQN.  ', E12.5,
     X/10X,'MAX. NO. OF SWEEPS FOR  ',
     X/10X,'PRESS. CORRECT. EQN.    ', I12,
     X/)
C
      WRITE(LU6,2210) SORMAX, MAXIT, INDPRI, NUMPRI, ITREAX
 2210 FORMAT(
     X/10X,'MAX. RESIDUAL FOR FIELD VARIABLE     ', E12.5,
     X/10X,'MAX. NO. OF ITERATIONS TO BE RUN     ', I12,
     X/10X,'NO. OF ITERATIONS BETWEEN TABULATION', I12,
     X/10X,'    OF FIELD VARIABLES               ',
     X/10X,'NO. OF ITERATIONS BETWEEN OUTPUT OF  ', I12,
     X/10X,'      MONITORING INFORMATION         ',
     X/10X,'ITERATION TO START CHEMICAL REACTION', I12,
     X/)
C
      WRITE(LU6,2999)
 2999 FORMAT(1H1)
C
C
CHAPTER  1  1  1  1  1  PARAMETERS AND CONTROL INDICES  1  1  1  1  1  1
C
C-1.0--------- CONSTANTS ---------------------------------------------
      NITER=0
      GREAT=1.0E30
      SMALL=1.0E-30
      PI=4.*ATAN(1.)
      UGC=8.3149E3
      IF(MODOP.EQ.1) IREAD=.FALSE.
      IF(MODOP.EQ.2) IREAD=.TRUE.
      IF(ISCEME.EQ.1) WCORNR=0.0
      IF(ISCEME.EQ.2) WCORNR=1.0
      IWRITE=.TRUE.
C
C-1.1---------GRID SPECIFICATION--------------------------------------
C-----GRID PARAMETERS
      RLARGE = YV(NJ)
      REXIT  = YV(NJ)
```

```
C-----SET VERTICAL TRAVERSE LIMITS
      DO 110 I=1,NI
      JS(I)=2
      JN(I)=NJ-1
      IF(I.LE.ISTEP) JS(I)=JSTEP+1
  110 CONTINUE
C-----SET HORIZONTAL TRAVERSE LIMITS
      DO 120 J=1,NJ
      IW(J)=2
      IF(J.LE.JSTEP) IW(J)=ISTEP+1
      IE(J)=NI-1
  120 CONTINUE
      CALL GRID
      RSMALL=YV(JSTEP)
C
C-1.2---------CONTROL PARAMETERS-----------------------------------------
C-----DEPENDENT VARIABLE SELECTION
      DO 130 I=1,10
      INCAL(I) = .FALSE.
  130 CONTINUE
C
      IF(IU    .EQ.  1) INCAL(IU  ) = .TRUE.
      IF(IV    .EQ.  2) INCAL(IV  ) = .TRUE.
      IF(IP    .EQ.  3) INCAL(IP  ) = .TRUE.
      IF(ITE   .EQ.  4) INCAL(ITE ) = .TRUE.
      IF(IED   .EQ.  5) INCAL(IED ) = .TRUE.
      IF(IEN   .EQ.  6) INCAL(IEN ) = .TRUE.
      IF(IFM   .EQ.  7) INCAL(IFM ) = .TRUE.
      IF(IF    .EQ.  8) INCAL(IF  ) = .TRUE.
      IF(ISWR  .EQ.  9) INCAL(ISWR) = .TRUE.
C
      INPRO = .FALSE.
      INCOMP= .FALSE.
      IVISCO= .FALSE.
      LAMINR= .FALSE.
      IF(KNPRO   .GT.0)  INPRO   = .TRUE.
      IF(KNCOMP  .GT.0)  INCOMP  = .TRUE.
      IF(KVISCO  .GT.0)  IVISCO  = .TRUE.
      IF(KLAMNR  .GT.0)  LAMINR  = .TRUE.
C-----BOUNDARY CONDITIONS---------
      NFREE=.FALSE.
      SSYM=.TRUE.
C-----PRESSURE CALCULATION
CLC   RETURN
CLC   ENTRY PRELIM
C
CHAPTER  2  2  2  2  2  PRELIMINARY OPERATIONS  2  2  2  2  2  2  2  2
C
C-2.1------FLUID AND  FLOW PROPERTIES
      DO 20 IVAR=1,9
      PRANDL(IVAR)=0.7
   20 PRANDT(IVAR)=0.9
      PRANDL(ISWR)=1.0
C
C-2.2------TURBULENCE CONSTANTS
      CMU25=SQRT(SQRT(CMU))
      CMU75=CMU25**3
      PRANDT(ITE)=1.0
      PRANDT(IED)=CAPPA*CAPPA/(C2-C1)/(CMU**0.5)
      PRANDT(IFM)=0.5
```

```
      PRANDT(IF)=0.5
      PRANDT(IEN)=0.5
      PRANDT(ISWR)=1.0
      PFUN=PRANDL(IEN)/PRANDT(IEN)
      CPIN=0.767*CPN2+0.233*CPO2
      PFUN=9.24*(PFUN**0.75-1.0)*(1.0+0.28/EXP(0.007*PFUN))
C
C-2.3------SET VARIABLES TO ZERO
      CALL SET
C
C-2.4------BOUNDARY VALUES
      TEIN=TURBIN*UIN**2
      TWALLN=0.0
      ALAMDA=0.005
      EDIN=TEIN**1.5/(0.09*DELTA)*CMU75
      TECEN=TURBCN*UCEN**2
      EDCEN=TECEN**1.5/(0.09*DELCEN)*CMU75
      ENTRY STARTV
C
CHAPTER  3  3  SET VARIABLES TO STARTING VALUES 3 3 3 3 3 3 3
C
C-3.1------INITIALISE VARIABLE FIELDS
      JSTR=JS(1)
      JEND=NJM1
      DO 21 J=JSTR,JEND
      U(1,J)=UIN
      FM(1,J)=CIN
      EN(1,J)=CPIN*TIN
      F(1,J)=CIN
      V(1,J) = 0.0
      W(1,J) = WIN*UIN
   21 CONTINUE
      TP=TCEN
      TP2=TP*TP
      TP3=TP2*TP
      TP4=TP3*TP
      CPF   = (CPFTRM(1) + CPFTRM(2)*TP + CPFTRM(3)*TP2
     X        + CPFTRM(4)*TP3 + CPFTRM(5)*TP4) * UGC/WMF
C
C
      DO 28 I=1,ISTEP
      DO 28 J=1,JINS
      FM(I,J)=CCEN
      EN(I,J)=HR+CPF*TCEN
      CPM(I,J)=CPF
      T(I,J)=TCEN
      F(I,J)=CCEN
      U(I,J)=UCEN
      V(I,J) = 0.0
      W(I,J) = WCEN*UCEN
      TE(I,J)=TECEN
      ED(I,J)=EDCEN
      DEN(I,J)=PIN*WMF/(UGC*TCEN)
   28 VIS(I,J)=DEN(I,J)*TE(I,J)**2*CMU/ED(I,J)+VISCOS
C
C-3.2-CALCULATE MASS,MOMENTUM & TOTAL KINETIC ENERGY FLOW AT THE INLET
      ENIN=0.0
      CINT=0.0
      XKININ=0.0
      XMONIN=0.0
```

```
      FLOWIN=0.0
      AMONIN=0.0
      DO 25 J=JSTR,JEND
      ARDEN=DEN(1,J)*R(J)*SNS(J)
      ENIN=ENIN+ARDEN*U(1,J)*EN(1,J)
      CINT=CINT+ARDEN*U(1,J)*F(1,J)
      XKININ=XKININ+ARDEN*U(1,J)**3
      XMONIN=XMONIN+ARDEN*U(1,J)**2
      AMONIN=AMONIN+ARDEN*W(1,J)*R(J)*U(1,J)
   25 FLOWIN=FLOWIN+ARDEN*U(1,J)
      FLOWA=2.0*PI*FLOWIN
      DO 35 J=2,JINS
      ARDEN=DEN(ISTEP,J)*R(J)*SNS(J)
      ENIN=ENIN+ARDEN*U(ISTEP,J)*EN(ISTEP,J)
      CINT=CINT+ARDEN*U(ISTEP,J)*F(ISTEP,J)
      XKININ=XKININ+ARDEN*U(ISTEP,J)**3
      XMONIN=XMONIN+ARDEN*U(ISTEP,J)**2
      AMONIN=AMONIN+ARDEN*W(ISTEP,J)*U(ISTEP,J)*R(J)
   35 FLOWIN=FLOWIN+ARDEN*U(ISTEP,J)
      SWNO=2.0*AMONIN/(XMONIN*RLARGE)
      FLOWF=2.0*PI*FLOWIN-FLOWA
      UFIELD=2.0*FLOWIN/(DENSIT*RLARGE**2)
      IF(INDCOS.EQ.1) UFIELD=FLOWIN/(DENSIT*RLARGE)
      ULARGE=UFIELD
      UEXIT=2.0*FLOWIN/(DENSIT*REXIT**2)
      IF(INDCOS.EQ.1) UEXIT=FLOWIN/(DENSIT*REXIT)
      IF(IREAD) GO TO 202
      DO 26 I=2,NIM1
      JSTAR=JS(I)
      JLAST=JN(I)
      DO 26 J=JSTAR,JLAST
      U(I,J)=UFIELD
      IF (I.LE.ISTEP) U(I,J)=UIN
   26 CONTINUE
      DO 27 J=2,JEXIT
   27 U(NIU,J)=UEXIT
      DO 29 I=2,NIM1
      JSTR=JS(I)
      JEND=JN(I)
      DO 29 J=JSTR,JEND
   29 W(I,J)=WIN*0.5*(U(I,J)+U(I-1,J))
      DO 200 I=2,NIU
      JSTAR=JS(I)
      JLAST=JN(I)
      DO 200 J=JSTAR,JLAST
      TE(I,J)=TEIN
      ED(I,J)=EDIN
  200 CONTINUE
      DO 230 J=2,JEXIT
      W(NI,J)=WIN*0.5*UEXIT
      TE(NI,J)=TEIN
  230 ED(NI,J)=EDIN
      DO 213 J=2,JEXIT
      FM(NI,J)=CIN
      F(NI,J)=CIN
  213 EN(NI,J)=CPIN*TIN
      DO 212 I=1,NI
      JSTAR=JS(I)
      JLAST=JN(I)
      DO 212 J=JSTAR,JLAST
```

```
      FM(I,J)=CIN
      F(I,J)=CIN
  212 EN(I,J)=CPIN*TIN
  202 CONTINUE
      JSTR=JS(1)
      JEND=JN(1)
      DO 201 J=JSTR,JEND
      TE(1,J)=TEIN
      ED(1,J)=EDIN
  201 VIS(1,J)=DEN(1,J)*TE(1,J)**2*CMU/ED(1,J)+VISCOS
      DO 203  I=2,NIM1
      YPLUSN(I)=0.0
      IF(.NOT.NFREE) YPLUSN(I)=11.0
      YPLUSS(I)=0.0
      IF(.NOT.SSYM) YPLUSS(I)=11.0
      IF(I.LE.ISTEP) YPLUSS(I)=11.0
  203 CONTINUE
      DO 220 J=1,NJ
      XPLUSW(J)=0.0
      XPLUSE(J)=0.0
  220 CONTINUE
      DO 204 J=JINS1,JSTEP
  204 XPLUSW(J)=11.0
      IF(.NOT.NFREE) GO TO 245
      DO 240 I=1,NIM1
      U(I,NJ)=UIN
      V(I,NJV)=0.0
      W(I,NJ)=WIN*UIN
      TE(I,NJ)=TEIN
      ED(I,NJ)=EDIN
      VIS(I,NJ)=DEN(I,NJ)*TE(I,NJ)**2*CMU/ED(I,NJ)+VISCOS
      FM(I,NJ)=CIN
      F(I,NJ)=CIN
  240 EN(I,NJ)=CPIN*TIN
      W(NI,NJ)=WIN*UIN
      TE(NI,NJ)=TEIN
      ED(NI,NJ)=EDIN
      EN(NI,NJ)=CPIN*TIN
      FM(NI,NJ)=CIN
      F(NI,NJ)=CIN
      VIS(NI,NJ)=DEN(NI,NJ)*TE(NI,NJ)**2*CMU/ED(NI,NJ)+VISCOS
      GO TO 250
  245 DO 246 I=1,NI
      U(I,NJ)=0.0
      V(I,NJV)=0.0
      W(I,NJ)=0.0
      TE(I,NJ)=0.0
      ED(I,NJ)=0.0
      EN(I,NJ)=0.0
      FM(I,NJ)=0.0
      F(I,NJ)=0.0
  246 VIS(I,NJ)=VISCOS
  250 CONTINUE
      P(IPREF,JPREF)=PREF
      CALL PROPS
C
C-3.3------CALCULATE SOURCE NORMALISATION FACTORS
      SNORM(IU)=XMONIN
      SNORM(IV)=XMONIN
      SNORM(IP)=FLOWIN
```

```
      SNORM(ITL)=XKININ
      SNORM(IED)=XKININ/(RLARGE/UIN)
      SNORM(IEN)=ENIN
      SNORM(IFM)=CINT
      SNORM(IF)=CINT
      SNORM(IPP)=FLOWIN
      SNORM(ISWR)=AMONIN
      RETURN
      END
@PRT,S TEACH*TEACH.MODUVP
```

```
      SUBROUTINE MODUVP
C
CHAPTER  0  0  0  0  0  0  0  PRELIMINARIES  0  0  0  0  0  0  0  0  0
C
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2      ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3      ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4      ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
     5      ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6      ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7      ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8      ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9      ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1      ,DYNPV(30),DYPSV(30),DT
     2      ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3      ,TAUNS(30),TAUSS(30),TAUWS(30)
     4      ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
      COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2     ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3     ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4     ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5     ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6     ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7     ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8     ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
     9     ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1     ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2     ,GREAT,SMALL,PI,UGC,SWNO
     3     ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4     ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5     ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6     ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7     ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
      LOGICAL INCAL,INCOMP,INPRO,IREAD,IVISCO,IWRITE,LAMINR
     1       ,NFREE,SSYM
C
CHAPTER  1  1  1  1  1  1  1  1  PROPERTIES  1  1  1  1  1  1  1  1  1
C
      ENTRY MODPRO
C-----NO MODIFICATIONS FOR THIS PROBLEM
      RETURN
C
CHAPTER  2  2  2  2  2  2  2  2  U MOMENTUM  2  2  2  2  2  2  2  2  2
C
      ENTRY MODU
      CDTERM=CMU25*CAPPA
      TERM1=CMU25/VISCOS
C
C-2.1-CALCULATION OF XPLUS AND YPLUS FOR WALL NEAREST SCALAR NODES
      DO 10 J=JINS1,JSTEP
      I=IW(J)
      XP=XU(I)-X(I)
      XPLUSW(J)=DEN(I,J)*SQRT(TE(I,J))*XP*TERM1
   10 CONTINUE
      DO 20 I=1,NI
      J=JS(I)
      YP=YV(J)-Y(J)
```

C-2

```
      IF(I.LE.ISTEP) YPLUSS(I)=DEN(I,J)*SQRT(TE(I,J))*YP*TERM1
      J=JN(I)
      YP=YV(J)-Y(J)
      YPLUSN(I)=DEN(I,J)*SQRT(TE(I,J))*YP*TERM1
   20 CONTINUE
C
C-2.2-TOP WALL (NORTH BOUNDARY)
      DO 210 I=2,NIUM1
      J=JN(I)
      YP=YV(J)-Y(J)
      SQRTK=SQRT(0.5*(TE(I,J)+TE(I+1,J)))
      DENU=0.5*(DEN(I,J)+DEN(I+1,J))
      YPLUSA=0.5*(YPLUSN(I)+YPLUSN(I+1))
      IF (YPLUSA.LE.11.63) GO TO 211
      TMULT=DENU*CDTERM*SQRTK/ALOG(ELOG*YPLUSA)
      GO TO 212
  211 TMULT=VISCOS/YP
  212 TAUN(I)=-TMULT*U(I,J)
      AN(I,J)=0.0
      AS(I,J)=0.0
      SP(I,J)=SP(I,J)-TMULT*SEWU(I)*RV(J)
  210 CONTINUE
C
C-2.3-TOP WALL OF BLUFF BODY (SOUTH BOUNDARY)
      DO 410 I=2,ISTEP
      J=JS(I)
      YP=YV(J)-Y(J)
      SQRTK=SQRT(0.5*(TE(I,J)+TE(I+1,J)))
      DENU=0.5*(DEN(I,J)+DEN(I+1,J))
      YPLUSA=0.5*(YPLUSS(I)+YPLUSS(I+1))
      IF(YPLUSA.LE.11.63) GO TO 411
      TMULT=DENU*CDTERM*SQRTK/ALOG(ELOG*YPLUSA)
      GO TO 412
  411 TMULT=VISCOS/YP
  412 TAUS(I)=-TMULT*U(I,J)
      IF (I.NE.ISTEP) GO TO 414
C-----CORNER CELLS
      ALPHA=AU(I)
      ALPHA1=1.0-ALPHA
      YPLUSA=DENU*SQRTK*CMU25*YP/VISCOS
      IF(YPLUSA.LE.11.63) GO TO 416
      TMULT=DENU*CDTERM*SQRTK/ALOG(ELOG*YPLUSA)
      GO TO 417
  416 TMULT=VISCOS/YP
  417 TAUS(I)=-TMULT*U(I,J)
      TMULT=TMULT*ALPHA
      AN(I,J-1)=2.0*ALPHA1*AN(I,J-1)
      AS(I,J-1)=ALPHA1*AS(I,J-1)
      GO TO 419
  414 AN(I,J-1)=0.0
      AS(I,J-1)=0.0
  419 SP(I,J)=SP(I,J)-TMULT*SEWU(I)*RV(J-1)
  410 CONTINUE
      TAUS(1)=TAUS(2)
      TAUN(1)=TAUN(2)
      TAUN(NIU)=TAUN(NIUM1)
C
C-2.4-SYMMETRY AXIS AT THE BOTTOM (SOUTH BOUNDARY)
      DO 430 I=ISTP1,NIU
      AN(I,1)=0.0
```

```
      AS(I,1)=0.0
  430 U(I,1)=U(I,2)
C
CHAPTER  3  3  3  3  INTEGRAL CONTINUITY EQUATION AT OUTLET  3  3  3  3
C
      ENTRY MODU1
      ARDENT=0.0
      FLOW=0.0
      I=NIM1
      ALPHA=AU(I)
      ALPHA1=1.0-ALPHA
      DO  204  J=2,JEXIT
      ARDEN=(ALPHA*DEN(I,J)+ALPHA1*DEN(I-1,J))*R(J)*SNS(J)
      ARDENT=ARDENT+ARDEN
  204 FLOW=FLOW+ARDEN*U(NIUM1,J)
      UINC=(FLOWIN-FLOW)/ARDENT
      DO  205  J=2,JEXIT
      AE(NIUM1,J)=0.0
      AW(NIUM1,J)=0.0
  205 U(NIU,J)=U(NIUM1,J)+UINC
      RETURN
C
CHAPTER  4  4  4  4  4  4  4  4  V MOMENTUM  4  4  4  4  4  4  4  4  4
C
      ENTRY MODV
C
C-4.1-SIDE WALL OF BLUFF BODY (WEST BOUNDARY)
      DO 360 J=JINS,JSTEP
      I=IW(J)
      XP=XU(I)-X(I)
      SQRTK=SQRT(0.5*(TE(I,J)+TE(I,J+1)))
      DENV=0.5*(DEN(I,J)+DEN(I,J+1))
      XPLUSA=0.5*(XPLUSW(J)+XPLUSW(J+1))
      IF(XPLUSA.LE.11.63) GO TO 371
      TMULT=DENV*CDTERM*SQRTK/ALOG(ELOG*XPLUSA)
      GO TO 372
  371 TMULT=VISCOS/XP
  372 TAUW(J)=-TMULT*V(I,J)
      IF (J.EQ.JINS) GO TO 375
      IF (J.EQ.JSTEP) GO TO 373
      GO TO 374
C-----CORNER CELLS
  373 BETA=AV(J)
      GO TO 378
  375 BETA=1.0-AV(J)
  378 XPLUSA=DENV*SQRTK*CMU25*XP/VISCOS
      IF(XPLUSA.LE.11.63) GO TO 376
      TMULT=DENV*CDTERM*SQRTK/ALOG(ELOG*XPLUSA)
      GO TO 377
  376 TMULT=VISCOS/XP
  377 TAUW(J)=-TMULT*V(I,J)
      TMULT=TMULT*BETA
      AE(I-1,J)=2.0*(1.0-BETA)*AE(I-1,J)
      AW(I-1,J)=(1.0-BETA)*AW(I-1,J)
      GO TO 379
  374 AE(I-1,J)=0.0
      AW(I-1,J)=0.0
  379 SP(I,J)=SP(I,J)-TMULT*SNSV(J)*RV(J)
  360 CONTINUE
C
```

```
C-4.2-OUTLET (EAST BOUNDARY)
      DO 320 J=2,JEXIT
      AE(NIM1,J)=0.0
      AW(NIM1,J)=0.0
  320 V(NI,J)=V(NIM1,J)
      RETURN
C
CHAPTER  5  5  5  5  5  5  PRESSURE CORRECTION  5  5  5  5  5  5  5  5
C
      ENTRY MODP
C
C-5.1-SYMMETRY AXIS AT THE BOTTOM (SOUTH BOUNDARY)
      DO 480 I=ISTP1,NI
      AS(I,2)=0.0
  480 P(I,1)=P(I,2)
      RETURN
      END
```

@PRT,S TEACH*TEACH.OUTPUT

TEACH*TEACH(2).OUTPUT(U)

```
      SUBROUTINE OUTPUT
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2      ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3      ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4      ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
     5      ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6      ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7      ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8      ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9      ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1      ,DYNPV(30),DYPSV(30),DT
     2      ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3      ,TAUNS(30),TAUSS(30),TAUWS(30)
     4      ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
      COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2      ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3      ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4      ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5      ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6      ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7      ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8      ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
     9      ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1      ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2      ,GREAT,SMALL,PI,UGC,SWNO
     3      ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4      ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5      ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6      ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7      ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
      COMMON /COM3/LU4,LU5,LU6,LU8,LU9
      LOGICAL INCAL,INCOMP,INPRO,IREAD,IVISCO,IWRITE,LAMINR
     1      ,NFREE,SSYM
C
CHAPTER  1  1  1  1  1  1  1  INITIAL OUTPUT  1  1  1  1  1  1  1
C
      ENTRY INITOP
      WRITE(LU6,210) FLOWA,FLOWF,TIN,TCEN,PIN,CIN,CCEN,SWNO
  210 FORMAT(1H0,54X,9H         //29X,56HTURBULENT FLOW WITH COMBUSTION
     1IN A BLUFF-BODY COMBUSTOR//
     2/26X,50H FLOW RATE OF MAIN STREAM (AIR), KG/S------------=,1PE12.3
     3/26X,50H FLOW RATE OF SECONDARY STREAM (FUEL), KG/S-------=,1PE12.3
     4/26X,50H TEMPERATURE OF MAIN STREAM, K--------------------=,1PE12.3
     5/26X,50H TEMPERATURE OF SECONDARY STREAM, K---------------=,1PE12.3
     6/26X,50H PRESSURE AT INLET, N/M**2------------------------=,1PE12.3
     7/26X,50H CONCENTRATION OF FUEL IN MAIN STREAM-------------=,1PE12.3
     8/26X,50H CONCENTRATION OF FUEL IN SECONDARY STREAM--------=,1PE12.3
     9/26X,50H SWIRL NUMBER-------------------------------------=,1PE12.3
     1/)
      RETURN
C
CHAPTER  2  2  2  2  2  2  INTERMEDIATE OUTPUT  2  2  2  2  2  2  2
C
      ENTRY INTOP
      DO 310 I=1,NI
      DO 310 J=1,NJ
  310 SPARE(I,J)=0.233-(STOIC+0.233)*F(I,J)+STOIC*FM(I,J)
```

```
      CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,SPARE,HEDO2)
      DO 320 I=1,NI
      DO 320 J=1,NJ
  320 SPARE(I,J)=0.767*(1.0-F(I,J))
      CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,SPARE,HEDN2)
      DO 330 I=1,NI
      DO 330 J=1,NJ
  330 SPARE(I,J)=3.0*(F(I,J)-FM(I,J))
      CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,SPARE,HEDCO2)
      DO 340 I=1,NI
      DO 340 J=1,NJ
  340 SPARE(I,J)=0.545*SPARE(I,J)
      CALL PRINT(1,1,NI,NJ,IT,JT,X,Y,SPARE,HEDH2O)
      UARDT=0.0
      FUADT=0.0
      ENUADT=0.0
      TUADT=0.0
      DO 341 J=1,NJ
      UARDEN=U(NIM1,J)*R(J)*SNS(J)*DEN(NI,J)
      UARDT=UARDT+UARDEN
      FUARD=F(NI,J)*UARDEN
      ENUARD=EN(NI,J)*UARDEN
      TUARD=T(NI,J)*UARDEN
      FUADT=FUADT+FUARD
      ENUADT=ENUADT+ENUARD
      TUADT=TUADT+TUARD
  341 CONTINUE
      FOUT=FUADT/UARDT
      ENOUT=ENUADT/UARDT
      TOUT=TUADT/UARDT
      FIN=CINT/FLOWIN
      ENIN=ENIN/FLOWIN
      FLOWT=2.0*PI*FLOWIN
      WRITE(LU6,101) FLOWT,FIN,FOUT,ENIN,ENOUT,TIN,TOUT
  101 FORMAT(//8X,7HFLOWIN=,1PE11.3,//
     1       ,10X,5H FIN=,1PE11.3,10X,5HFOUT=,1PE11.3//
     2       ,10X,5HENIN=,1PE11.3,9X,6HENOUT=,1PE11.3//
     3       ,10X,5H TIN=,1PE11.3,10X,5HTOUT=,1PE11.3/)
      RETURN
C
CHAPTER  3  3  3  3  3  3  3  FINAL OUTPUT  3  3  3  3  3  3  3  3
C
      ENTRY FINOP
C-----CALCULATION OF NON-DIMENSIONAL TURBULENCE ENERGY AND LENGTH SCALE
      DO 400 I=2,NIM1
      JSTR=JS(I)
      JEND=NJ
      DO 400 J=JSTR,JEND
      SU(I,J)=TE(I,J)*DEN(I,J)/(0.5*(ABS(TAUS(I))+ABS(TAUS(I-1))))
  400 SP(I,J)=TE(I,J)**1.5/ED(I,J)/RSMALL*CMU75
      CALL PRINT(1,1,NIU,NJ,IT,JT,X,Y,SU,HEDA)
      CALL PRINT(1,1,NIU,NJ,IT,JT,X,Y,SP,HEDB)
C-----CALCULATION OF SHEAR-STRESS COEFFICIENT ALONG LARGE DUCT WALL
      WRITE(LU6,402)
      DO 410 I=1,NIM1
      SSCS=0.0
      RESTAN=SQRT(TAUN(I)**2+TAUNS(I)**2)
      SSCN=RESTAN/(DENSIT*ULARGE*ULARGE)
      RESTAS=SQRT(TAUS(I)**2+TAUSS(I)**2)
      IF (I.LE.ISTEP) SSCS=RESTAS/(DENSIT*ULARGE*ULARGE)
```

```
      XUD=XU(I)/RSMALL
      WRITE(LU6,403) I,XUD,SSCN,SSCS
  410 CONTINUE
  402 FORMAT(///9X,1HI,3X,5HXU(I),5X,10HS.S.COEFF.)
  403 FORMAT(5X,I5,3(1PE11.3))
      WRITE(LU6,404)
      DO 420 J=JINS,JSTEP
      RESTAW=SQRT(TAUW(J)**2+TAUWS(J)**2)
      SSCW=RESTAW/(DENSIT*ULARGE*ULARGE)
      YVD=YV(J)/RSMALL
      WRITE(LU6,405) J,YVD,SSCW
  420 CONTINUE
  404 FORMAT(///9X,1HJ,3X,5HYV(J),5X,10HS.S.COEFE.,1X,10HS.S.COEFW.)
  405 FORMAT(5X,I5,2(1PE11.3))
C-----CALCULATION OF STREAM FUNCTION
      DO 500 I=1,NI
      DO 500 J=1,NJ
  500 SPARE(I,J)=0.0
      DO 600 I=1,NIU
      LJS=JS(I)
      LJN=JN(I)
      LJSM1=LJS-1
      AREAEW=0.25*(R(LJS)+RV(LJSM1))*DYNP(LJSM1)
      SPARE(I,LJS)=SPARE(I,LJSM1)+0.5*(U(I,LJSM1)+U(I,LJS))*AREAEW
      DO 600 J=LJS,LJN
      AREAEW=RV(J)*DYNP(J)
      SPARE(I,J+1)=SPARE(I,J)+0.5*(U(I,J)+U(I,J+1))*AREAEW
  600 CONTINUE
      TERM=DENSIT*UIN*RSMALL
      DO 601 I=1,NIU
      LJS=JS(I)
      LJN=NJ
      DO 601 J=LJS,LJN
      SPARE(I,J)=SPARE(I,J)/TERM
  601 CONTINUE
      CALL PRINT(1,1,NIU,NJ,IT,JT,XU,Y,SPARE,HEDC)
      RETURN
      END

@PRT,S TEACH*TEACH.PRINT
```

```
TEACH*TEACH(2).PRINT(0)
      SUBROUTINE PRINT(ISTART,JSTART,IEND,JEND,IT,JT,X,Y,PHI,HEAD)
C
C------------------- OUTPUT OF DEPENDENT-VARIABLE FIELDS ----------------
C
      COMMON /COM3/LU4,LU5,LU6,LU8,LU9
C
CHAPTER  0  0  0  0  0  0  0  0  PRELIMINARIES  0  0  0  0  0  0  0  0
C
      DIMENSION PHI(IT,JT),X(IT),Y(JT),HEAD(9),STORE(12)
      DIMENSION F(8),F4(13),FD(8)
      DATA F(1),F(2),F(3),F(4),F(5),F(6),F(7),F(8)
     1     /4H(/1H,4H ,A4,4H,I3,,4H7X,  4H  1,4H(I3,,4H7X),,4HA4) /
      DATA FD(1),FD(2),FD(3),FD(4),FD(5),FD(6),FD(7),FD(8)
     1     /4H(1H ,4H,I3,,4H  12,4H(1PE,4H10.2,4H),0P,4HF7.4,4H)   /
      DATA F4(1),F4(2),F4(3),F4(4),F4(5),F4(6),F4(7)
     1     ,F4(8),F4(9),F4(10),F4(11),F4(12),F4(13)
     1     /4HA6, ,4H   1,4H   2,4H   3,4H   4,4H   5,
     1      4H   6,4H   7,4H   8,4H   9,4H  10,4H  11,4H  12/
      DATA HI,HY/4H I =,4H Y =/
C
CHAPTER  1  1  1  1  1  1  INITIALIZATION AND HEADINGS  1  1  1  1  1
C
      ISKIP=1
      JSKIP=1
      LINLIM=12
      LINSTA=ISTART
C-----PRINT ARRAY HEADING
      WRITE(LU6,1800)HEAD
 1100 CONTINUE
      LINEND=LINSTA+(LINLIM-1)*ISKIP
      LINEND=MIN0(IEND,LINEND)
      IF4=(LINEND-LINSTA)/ISKIP+1
      F(5)=F4(IF4)
      FD(3)=F4(IF4+1)
C-----PRINT LINE HEADINGS
      WRITE(LU6,F) HI, (I,I=LINSTA,LINEND,ISKIP), HY
      WRITE(LU6,1900)
C
CHAPTER  2  2  2  2  2  2  OUTPUT OF PHI ARRAY  2  2  2  2  2  2  2  2
C
      DO 2200 JJ=JSTART,JEND,JSKIP
      J=JSTART+JEND-JJ
      IS=0
      DO 2100 I=LINSTA,LINEND,ISKIP
      A=PHI(I,J)
      IF(ABS(A).LT.1.E-20) A=0.0
      IS=IS+1
 2100 STORE(IS)=A
 2200 WRITE(LU6,FD)  J,(STORE(I),I=1,IS),Y(J)
      WRITE(LU6,2900) (X(I),I=LINSTA,LINEND,ISKIP)
      LINSTA=LINEND+ISKIP
      IF(LINEND.LT.IEND)GO TO 1100
      RETURN
 1800 FORMAT(//1X,20(2H*-),7X,9A4,7X,20(2H-*))
 1900 FORMAT(3H  J)
 2900 FORMAT(/4H X =,12E10.3)
      END
@PRT,S TEACH*TEACH.PROPS
```

```
      SUBROUTINE PROPS
C
CHAPTER  0  0  0  0  0  0  0  0  PRELIMINARIES  0  0  0  0  0  0  0  0
C
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2      ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3      ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4      ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
     5      ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6      ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7      ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8      ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9      ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1      ,DYNPV(30),DYPSV(30),DT
     2      ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3      ,TAUNS(30),TAUSS(30),TAUWS(30)
     4      ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
      COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2     ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3     ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4     ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5     ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6     ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7     ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8     ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
     9     ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1     ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2     ,GREAT,SMALL,PI,UGC,SWNO
     3     ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4     ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5     ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6     ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7     ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
      COMMON /COM4/ CPFTRM(5), ITREAX
      LOGICAL INCAL,INCOMP,INPRO,IREAD,IVISCO,IWRITE,LAMINR
     1         ,NFREE,SSYM
C
CHAPTER  1  1  1  1  1  1  1  DENSITY  1  1  1  1  1  1  1
C
      ENTRY DENS
      DO 100 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
      DO 100 J=LJS,LJN
C-----MASS FRACTION OF SPECIES
      FCO2=AMAX1(0.0,3.0*(F(I,J)-FM(I,J)))
      FH2O=0.545*FCO2
      FN2=(1.0-F(I,J))*0.767
      FO2=AMAX1(0.0,0.233-(STOIC+0.233)*F(I,J)+STOIC*FM(I,J))
C-----MEAN SPECIFIC HEAT
      DO 1115 N=1,10
      TP=T(I,J)
      TP2=TP*TP
      TP3=TP2*TP
      TP4=TP3*TP
      IF(TP.GT.1000.0) GO TO 1111
      CPCO2=(2.4008+8.7351E-3*TP-6.6071E-6*TP2+2.0022E-9*TP3+6.3274E-16
```

```
     1        *TP4)*UGC/44.0
      CPH2O=(4.0701-1.1084E-3*TP+4.1521E-6*TP2-2.9637E-9*TP3+8.0702E-13
     1        *TP4)*UGC/18.0
      CPN2 =(3.6748-1.2081E-3*TP+2.324E-6*TP2-6.3218E-10*TP3-2.2577E-13
     1        *TP4)*UGC/28.0
      CPO2 =(3.6256-1.8782E-3*TP+7.0555E-6*TP2-6.7635E-9*TP3+2.1556E-12
     1        *TP4)*UGC/32.0
      GO TO 1112
 1111 CPCO2=(4.4608+3.0982E-3*TP-1.2392E-6*TP2+2.2741E-10*TP3-1.5526E-14
     1        *TP4)*UGC/44.0
      CPH2O=(2.7168+2.9454E-3*TP-8.0224E-7*TP2+1.0227E-10*TP3-4.8472E-15
     1        *TP4)*UGC/18.0
      CPN2 =(2.8963+1.5155E-3*TP-5.7235E-7*TP2+9.9807E-11*TP3-6.5224E-16
     1        *TP4)*UGC/28.0
      CPO2 =(3.6200+7.3612E-4*TP-1.9652E-7*TP2+3.6202E-11*TP3-2.8946E-15
     1        *TP4)*UGC/32.0
      CPF   = (CPFTRM(1) + CPFTRM(2)*TP + CPFTRM(3)*TP2
     X         + CPFTRM(4)*TP3 + CPFTRM(5)*TP4)* UGC/WMF
 1112 CONTINUE
      CPM(I,J)=CPCO2*FCO2+CPH2O*FH2O+CPN2*FN2+CPO2*FO2+CPF*FM(I,J)
C-----TEMPERATURE
      TOLD=T(I,J)
      T(I,J)=(EN(I,J)-FM(I,J)*HR)/CPM(I,J)
      IF(T(I,J).LE.TIN) T(I,J)=TIN
      IF(ABS((TOLD-T(I,J))/T(I,J)).LE.0.01) GO TO 1120
 1115 CONTINUE
 1120 CONTINUE
C-----MEAN MOLECULAR WEIGHT INVERSE
      AVMINV=FM(I,J)/WMF+FCO2/44.0+FH2O/18.0+FN2/28.0+FO2/32.0
C-----NEW DENSITY
      DENOLD=DEN(I,J)
      DENP=PIN/(UGC*T(I,J)*AVMINV)
      DEN(I,J)=URFDEN*DENP+(1.0-URFDEN)*DENOLD
  100 CONTINUE
      DO 105 J=2,JEXIT
      CPM(NI,J)=CPM(NIM1,J)
  105 DEN(NI,J)=DEN(NIM1,J)
      IF (.NOT.SSYM) GO TO 150
      DO 110 I=2,NIM1
      CPM(I,1)=CPM(I,2)
  110 DEN(I,1)=DEN(I,2)
  150 CONTINUE

C
CHAPTER  2  2  2  2  2  2  2  EDDY VISCOSITY  2  2  2  2  2  2  2
C
      ENTRY VISC
      DO 200 I=2,NIM1
      JSTR=JS(I)
      JEND=JN(I)
      DO 210 J=JSTR,JEND
      VISOLD=VIS(I,J)
      IF(ED(I,J).LT.SMALL) GO TO 220
      VIS(I,J)=DEN(I,J)*TE(I,J)**2*CMU/ED(I,J)+VISCOS
      GO TO 230
  220 VIS(I,J)=VISCOS
  230 VIS(I,J)=URFVIS*VIS(I,J)+(1.0-URFVIS)*VISOLD
  210 CONTINUE
      DO 240 J=2,JEXIT
  240 VIS(NI,J)=VIS(NIM1,J)
```

```
  200 CONTINUE
      IF(.NOT.SSYM) GO TO 500
      DO 400 I=2,NIM1
  400 VIS(I,1)=VIS(I,2)
  500 CONTINUE

C
CHAPTER  3  3  3  3  3  3  3  OTHER DIFFUSION COEFF  3  3  3  3  3  3  3
C
      ENTRY GAM
      IPHI=ITE
      DO 300 I=2,NI
      JSTR=JS(I)
      JEND=JN(I)
      DO 300 J=JSTR,JEND
  300 GAMH(I,J)=VISCOS/PRANDL(IPHI)+(VIS(I,J)-VISCOS)/PRANDT(IPHI)
      RETURN
      END

@PRT,S TEACH*TEACH.SORCFI
```

TEACH*TEACH(2).SORCFI(0)

```
      SUBROUTINE SORCFI(IVAR)
      COMMON
     1/COM1/ U(30,30),V(30,30),P(30,30),TE(30,30),ED(30,30),EN(30,30)
     2      ,FM(30,30),F(30,30),VIS(30,30),PP(30,30),T(30,30),W(30,30)
     3      ,DEN(30,30),GAMH(30,30),GEN(30,30),DU(30,30),DV(30,30)
     4      ,AE(30,30),AW(30,30),AN(30,30),AS(30,30),AP(30,30)
     5      ,ASW(30,30),ASE(30,30),ANW(30,30),ANE(30,30)
     6      ,SU(30,30),SP(30,30),SPARE(30,30),CPM(30,30)
     7      ,X(30),Y(30),IE(30),IW(30),JN(30),JS(30),R(30),RV(30)
     8      ,SEW(30),SNS(30),SEWU(30),SNSV(30),RCV(30),AU(30),AV(30)
     9      ,DXEP(30),DXPW(30),DYNP(30),DYPS(30),DXEPU(30),DXPWU(30)
     1      ,DYNPV(30),DYPSV(30),DT
     2      ,SNORM(30),TAUE(30),TAUW(30),TAUN(30),TAUS(30)
     3      ,TAUNS(30),TAUSS(30),TAUWS(30)
     4      ,XPLUSE(30),XPLUSW(30),YPLUSN(30),YPLUSS(30)
      COMMON
     1/COM2/XU(30),YV(30),INDCOS,INCOMP,LAMINR,IVISCO,PRANDL(10),URF(10)
     2      ,URFVIS,URFDEN,RESOR(10),NSWP(10),IPREF,JPREF,PREF,PRES
     3      ,C1,C2,CMU,CMU25,CMU75,CAPPA,CD,ELOG,PFUN,TWALLN,DELTA
     4      ,UIN,UCEN,TEIN,TURBIN,EDIN,TIN,FLOWIN,DENSIT,VISCOS,ENIN,CINT
     5      ,CPF,CPO2,CPN2,CPH2O,CPCO2,HR,STOIC,FLOWA,FLOWF
     6      ,PIN,CIN,CCEN,WMF,TCEN,TWALL,TBLUF,CPIN,WIN
     7      ,AL1,AL2,ALAMDA,RLARGE,RSMALL,ULARGE,NFREE,SSYM,PRANDT(10)
     8      ,SORMAX,MAXIT,ITSTEP,NITER,NITERS,INDPRI,NUMPRI,PERR,MAXSWP
     9      ,ISCEME,MODOP,IREAD,IWRITE,WCORNR,INCAL(10),INPRO
     1      ,IU,IV,IP,ITE,IED,IEN,IFM,IF,IPP,ISWR
     2      ,GREAT,SMALL,PI,UGC,SWNO
     3      ,NI,NJ,NIU,NJV,NIM1,NJM1,NIUM1,NJVM1,IMON,JMON
     4      ,IT,JT,ISTEP,ISTM1,ISTP1,JSTEP,JINS,JINS1,JSTM1,JSTP1,JEXIT
     5      ,HEDA(9),HEDB(9),HEDC(9),HEDU(9),HEDV(9),HEDP(9),HEDK(9)
     6      ,HEDD(9),HEDEN(9),HEDM(9),HEDCON(9),HEDDEN(9),HEDF(9),HEDT(9)
     7      ,HEDCP(9),HEDO2(9),HEDN2(9),HEDCO2(9),HEDH2O(9),HEDSWR(9)
      LOGICAL INCAL,INCOMP,INPRO,IREAD,IVISCO,IWRITE,LAMINR
     1      ,NFREE,SSYM
      DIMENSION CE(30,30),CN(30,30)
      EQUIVALENCE (CE(1,1),DU(1,1)),(CN(1,1),DV(1,1))
C
C
      IVARM3=IVAR-3
      GO TO(100,200,300,400,500,600),IVARM3
C
CHAPTER 1  1  1  1  TURBULENT KINETIC ENERGY  1  1  1  1
C
  100 DO 110 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
      DO 120 J=LJS,LJN
      VOL=R(J)*SNS(J)*SEW(I)
      SMP=CN(I,J)-CN(I,J-1)+CE(I,J)-CE(I-1,J)
      CP=AMAX1(0.0,SMP)
      DUDX=(U(I,J)-U(I-1,J))/SEW(I)
      DVDY=(V(I,J)-V(I,J-1))/SNS(J)
      GENIJ=2.0*(DUDX**2+DVDY**2)
C*********************************************************************
C*******  PROBLEM DEPENDENT STATEMENTS  *******************************
      IF(I.EQ.IW(J).AND.(J.GT.JINS.AND.J.LE.JSTEP)) GO TO 108
      IF(J.EQ.LJS.OR.J.EQ.LJN) GO TO 108
C*********************************************************************
      FX=AU(I)
```

```
      FXM1=AU(I-1)
      FY=AV(J)
      FYM1=AV(J-1)
      UP=0.5*(U(I-1,J)+U(I,J))
      UN=0.5*(U(I-1,J+1)+U(I,J+1))*FY+UP*(1.0-FY)
      US=0.5*(U(I-1,J-1)+U(I,J-1))*(1.0-FYM1)+UP*FYM1
      DUDY=(UN-US)/SNS(J)
      VP=0.5*(V(I,J-1)+V(I,J))
      VE=0.5*(V(I+1,J-1)+V(I+1,J))*FX+VP*(1.0-FX)
      VW=0.5*(V(I-1,J-1)+V(I-1,J))*(1.0-FXM1)+VP*FXM1
      DVDX=(VE-VW)/SEW(I)
      GENIJ=GENIJ+(DUDY+DVDX)**2
      IF (INDCOS.EQ.1) GO TO 108
      WW=W(I,J)*FXM1+(1.0-FXM1)*W(I-1,J)
      WE=W(I,J)*(1.0-FX)+W(I+1,J)*FX
      DWDX=(WE-WW)/SEW(I)
      WN=(W(I,J+1)/R(J+1))*FY+(W(I,J)/R(J))*(1.0-FY)
      WS=(W(I,J)/R(J))*FYM1+(W(I,J-1)/R(J-1))*(1.0-FYM1)
      DWRDY=(WN-WS)*R(J)/SNS(J)
      GENIJ=GENIJ+DWDX**2+DWRDY**2
  108 GEN(I,J)=GENIJ
      IF(INDCOS.EQ.1) GO TO 114
      VDR=V(I,J-1)/(RV(J-1)+SMALL)
      GEN(I,J)=GEN(I,J)+0.5*(VDR+V(I,J)/RV(J))**2
  114 IF(INCOMP) GO TO 115
      DRVDY=(RV(J)*V(I,J)-RV(J-1)*V(I,J-1))/(R(J)*SNS(J))
      GEN(I,J)=GEN(I,J)-0.66667*(DUDX+DRVDY)
     1        *((DUDX+DRVDY)+DEN(I,J)*TE(I,J))
  115 SU(I,J)=CP*TE(I,J)+GEN(I,J)*(VIS(I,J)-VISCOS)*VOL
      SP(I,J)=-CP-CMU*DEN(I,J)**2*TE(I,J)*VOL/(VIS(I,J)-VISCOS)
  120 CONTINUE
  110 CONTINUE
      RETURN
C
CHAPTER  2  2  2  2 ENERGY DISSIPATION   2  2  2  2
C
  200 CONTINUE
      DO 210 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
      DO 220 J=LJS,LJN
      VOL=R(J)*SNS(J)*SEW(I)
      SMP=CN(I,J)-CN(I,J-1)+CE(I,J)-CE(I-1,J)
      CP=AMAX1(0.0,SMP)
      SU(I,J)=CP*ED(I,J)+C1*GEN(I,J)*CMU*DEN(I,J)*TE(I,J)*VOL
      SP(I,J)=-CP-C2*DEN(I,J)*ED(I,J)*VOL/TE(I,J)
      IF(INCOMP) GO TO 220
      DUDX=(U(I,J)-U(I-1,J))/SEW(I)
      DRVDY=(RV(J)*V(I,J)-RV(J-1)*V(I,J-1))/(R(J)*SNS(J))
      SU(I,J)=SU(I,J)+DEN(I,J)*ED(I,J)*(DUDX+DRVDY)*VOL
  220 CONTINUE
  210 CONTINUE
      RETURN
C
CHAPTER  3  3  3  3  3  ENTHALPY  3  3  3  3  3  3  3  3  3  3  3  3
C
  300 CONTINUE
      DO 301 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
```

```
      DO 301 J=LJS,LJN
      SMP=CN(I,J)-CN(I,J-1)+CE(I,J)-CE(I-1,J)
      CP=AMAX1(0.0,SMP)
      SU(I,J)=CP*EN(I,J)
  301 SP(I,J)=-CP
      RETURN
C
CHAPTER  4  4  4  4  4  FULL CONCENTRATION  4  4  4  4  4  4  4  4  4
C
  400 CONTINUE
      DO 401 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
      DO 401 J=LJS,LJN
      VOL=R(J)*SNS(J)*SEW(I)
      SMP=CN(I,J)-CN(I,J-1)+CE(I,J)-CE(I-1,J)
      CP=AMAX1(0.0,SMP)
      FO2=AMAX1(0.0,0.233-(STOIC+0.233)*F(I,J)+STOIC*FM(I,J))
      FPR=AMAX1(0.0,(STOIC+1.)*(F(I,J)-FM(I,J)))
      R1=FM(I,J)
      R2=FO2/STOIC
      R3=0.5*FPR/(STOIC+1.)
      TMULT=4.0*DEN(I,J)*ED(I,J)/TE(I,J)
      RMIN=AMIN1(R1,R2,R3)
      IF(RMIN.NE.0.0.AND.RMIN.EQ.R3) GO TO 410
      SU(I,J)=CP*FM(I,J)
      SP(I,J)=-CP-TMULT*RMIN/(FM(I,J)+SMALL)*VOL
      GO TO 401
  410 SU(I,J)=CP*FM(I,J)-TMULT*0.5*(F(I,J)-2.0*FM(I,J))*VOL
      SP(I,J)=-CP-TMULT*0.5*VOL
  401 CONTINUE
      RETURN
C
CHAPTER  5  5  5  5  MIXTURE FRACTION  5  5  5  5  5  5  5  5
C
  500 CONTINUE
      DO 501 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
      DO 501 J=LJS,LJN
      SMP=CN(I,J)-CN(I,J-1)+CE(I,J)-CE(I-1,J)
      CP=AMAX1(0.0,SMP)
      SU(I,J)=CP*F(I,J)
  501 SP(I,J)=-CP
      RETURN
C
CHAPTER  6  6  6  6  6  6  SWIRL VELOCITY  6  6  6  6  6  6  6  6  6
C
  600 CONTINUE
      DO 610 I=2,NIM1
      LJS=JS(I)
      LJN=JN(I)
      DO 610 J=LJS,LJN
      VOL=R(J)*SNS(J)*SEW(I)
      SMP=CN(I,J)-CN(I,J-1)+CE(I,J)-CE(I-1,J)
      CP=AMAX1(0.0,SMP)
      SU(I,J)=CP*W(I,J)
      SP(I,J)=-CP
      IF (J.NE.LJN.AND.(J.NE.LJS.OR.I.GT.ISTEP)) GO TO 601
      GO TO 610
```

```
  601 WN=(AV(J)*W(I,J+1)/R(J+1)+(1.-AV(J))*W(I,J)/R(J))*RV(J)
      WS=(AV(J-1)*W(I,J)/R(J)+(1.-AV(J-1))*W(I,J-1)/R(J-1))*RV(J-1)
      VISN=AV(J)*VIS(I,J+1)+(1.0-AV(J))*VIS(I,J)
      VISS=AV(J-1)*VIS(I,J)+(1.0-AV(J-1))*VIS(I,J-1)
      SORN=2.0*WN*VISN
      SORS=2.0*WS*VISS
      SP(I,J)=SP(I,J)-SORN*SEW(I)/W(I,J)
      SU(I,J)=SU(I,J)+SORS*SEW(I)
  610 CONTINUE
      END
@PRT,S TEACH*TEACH.WPAFB1
```

5.7 Input Format

CARD NO. 1 FORMAT (20A4)

1	2	3	4	5	6	7–80
T	I	T	L	E		

TITLE	Alphanumeric data for title of case

ORIGINAL PAGE IS OF POOR QUALITY

CARD NO. 2 FORMAT (8I10)

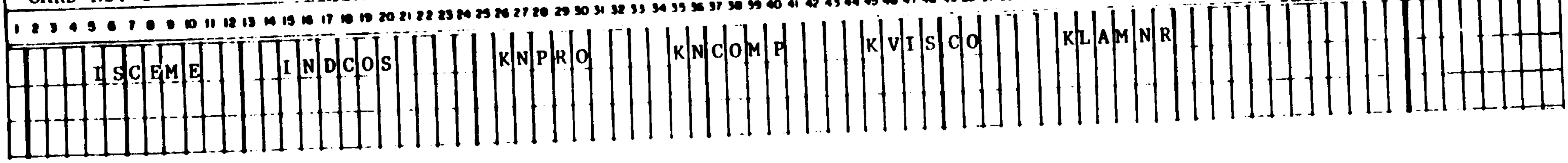
ITSTEP	MODOP

ITSTEP Number of iterations to be run during present execution

MODOP = 1 New case - start with first iteration

= 2 Start case using distributions of dependent variables stored in Restart file on logical unit LU4

CARD NO. 3 FORMAT (8I10)



ISCEME	= 1	Use hybrid differencing
	= 2	Use bounded skew-upwind differencing
INDCOS	= 1	Cartesian co-ordinates
	= 2	Cylindrical co-ordinates
KNPRO	= 0	Fluid properties are constant
	= 1	Fluid properties are variable
KNCOMP	= 0	Flow is compressible
	= 1	Flow is incompressible
KVISCO	= 0	Viscosity is variable
	= 1	Viscosity is constant
KLAMNR	= 0	Flow is turbulent
	= 1	Flow is laminar

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CARD NO. 4 FORMAT (8I10)

1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80
NI	NJ	ISTEP	JSTEP	JEXIT	JINS	IMON	JMON

NI	Number of axial gridline locations (NI $\leq$ 30)
NJ	Number of radial gridline locations (NJ $\leq$ 30)
ISTEP	Axial gridline number of downstream end of centerbody
JSTEP	Radial gridline number of outside radius of centerbody
JEXIT	Radial gridline number of maximum radius at exit (use JEXIT = NJ-1)
JINS	Radial gridline number of inside radius of centerbody
IMON	Axial gridline number of node used for monitoring output
JMON	Radial gridline number of node used for monitoring output

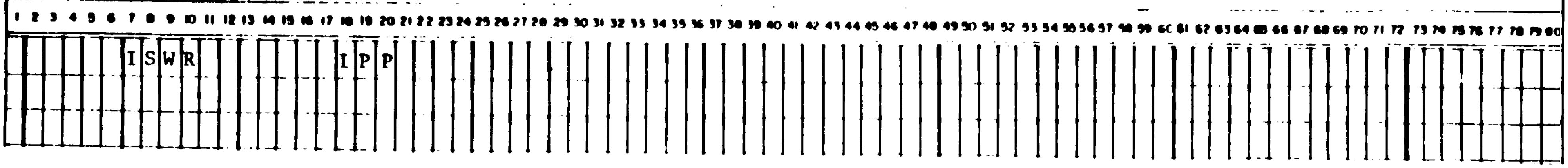
CARD NO. 5 FORMAT (8I10)

IU	IV	IP	ITE	IED	IEN	IFM	IF

These variables are used to determine which dependent variables are to be calculated; that is, which partial differential equations will be solved. If a switch is input with a value other than indicated below, the corresponding variable is <u>NOT</u> calculated.

IU	= 1	Axial velocity
IV	= 2	Radial velocity
IP	= 3	Primary pressure correction
ITE	= 4	Turbulent kinetic energy
IED	= 5	Turbulent energy dissipation rate
IEN	= 6	Enthalpy
IFM	= 7	Fuel concentration
IF	= 8	Mixture fraction

CARD NO. 5A FORMAT (8I10)



ISWR = 9 Swirl velocity

IPP = 10 Secondary pressure correction

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CARD NO. 6 FORMAT (8I10)

1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80
NSWP(1)	NSWP(2)	NSWP(3)	NSWP(4)	NSWP(5)	NSWP(6)	NSWP(7)	NSWP(8)

NSWP(K) Number of sweeps through difference equations per iteration for the Kth dependent variable where K = 1 through 8 corresponds to the variables calculated as specified on Card No. 5

K	Variable	Recommended Value
1	Axial velocity	2
2	Radial velocity	2
3	Primary pressure correction	3
4	Turbulent kinetic energy	1
5	Turbulent energy dissipation rate	1
6	Enthalpy	1
7	Fuel concentration	1
8	Mixture fraction	1

CARD NO. 6A　　　FORMAT (8I10)

1–10	11–20
NSWP(9)	NSWP(10)

NSWP(K)　　Number of sweeps through the difference equation per iteration for variables calculated as specified on Card 5A.

K	Variable	Recommended Value
9	Swirl velocity	1
10	Secondary pressure correction	1

CARD NO. 7 FORMAT (8E10.5)

1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80
URF(1)	URF(2)	URF(3)	URF(4)	URF(5)	URF(6)	URF(7)	URF(8)

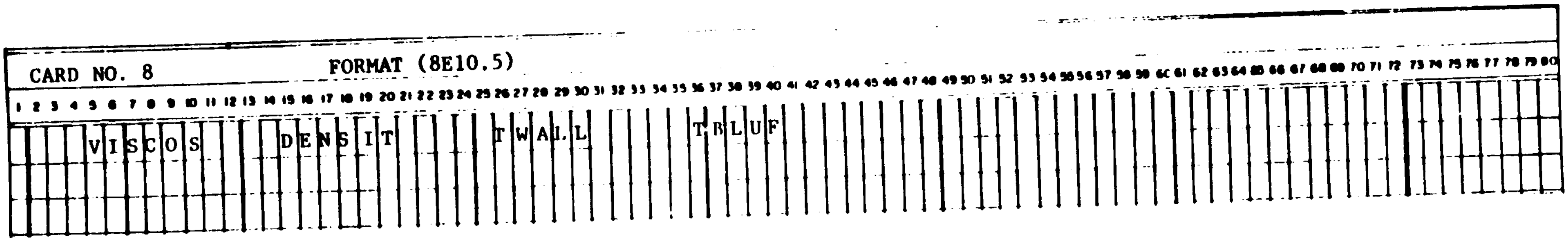
URF(K) Underrelaxation factor of the Kth dependent variable calculated as specified on Card No. 5

K	Variable	Recommended Value
1	Axial velocity	0.7
2	Radial velocity	0.7
3	Primary pressure correction	1.0
4	Turbulent kinetic energy	0.7
5	Turbulent energy dissipation rate	0.7
6	Enthalpy	0.6
7	Fuel concentration	0.6
8	Mixture fraction	0.6

CARD NO. 7A FORMAT (8E10.5)

1–10	11–20	21–30	31–40	41–80
URF(9)	URF(10)	URFVIS	URFDEN	

	Underrelaxation Factor For	Recommended Value
URF(9)	Swirl velocity	0.7
URF(10)	Secondary pressure correction	0.7
URFVIS	Viscosity	1.0
URFDEN	Density	0.4



VISCOS	Laminar viscosity, N-sec/M^2
DENSIT	Density, KG/M^3
TWALL	Temperature of combustor outer wall, K
TBLUF	Bluff body surface temperature, K

CARD NO. 9 FORMAT (8E10.5)

1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80
UIN	WIN	TIN	CIN	TURBIN	DELTA	PIN	

UIN	Axial velocity of main (outer) flow, M/sec
WIN	Ratio of swirl to axial velocity of main flow
TIN	Temperature of main flow, K
CIN	Concentration (mass fraction) of secondary component (e.g., fuel) in main flow
TURBIN	Turbulence constant for main flow. Turbulent kinetic energy = TURBIN*UIN**2
DELTA	Boundary layer thickness for each surface (bluff body and wall) of main flow, M
PIN	Pressure at inlet for both main and secondary flow, Pascal

CARD NO. 10 FORMAT (8E10.5)

1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80
UCEN	WCEN	TCEN	CCEN	TURBCN	DELCEN		

UCEN Axial velocity of secondary (inner) flow, m/sec

WCEN Ratio of swirl to axial velocity of secondary flow

TCEN Temperature of secondary flow, K

CCEN Concentration (mass fraction) of secondary component in secondary flow

TURBCN Turbulence constant for secondary flow
Turbulent kinetic energy = TURBCN*UCEN**2

DELCEN Boundary layer thickness for secondary flow, M

CARD NO. 11 FORMAT (8E10.5)

Columns 1–10	Columns 11–20	Columns 21–30
STOIC	HR	WMF

STOIC	Stoichiometric oxygen to fuel mass ratio
HR	Heat of combustion, J/Kg
WMF	Fuel (secondary component) molecular weight

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CARD NO. 12 FORMAT (8E10.5)

1–10	11–20	21–30	31–40
CPO2	CPN2	CPCO2	CPH2O

Heat capacities used during program initialization and for cases in which flow properties are constant. Therefore, these heat capacities must be input.

CPO2	Heat capacity for oxygen, J/kg-K
CPN2	Heat capacity for nitrogen, J/kg-K
CPCO2	Heat capacity for carbon dioxide, J/kg-K
CPH2)	Heat capacity for water, J/kg-K

CARD NO. 13 FORMAT (8E10.5)

1–10	11–20	21–30	31–40	41–50
CPFTRM(1)	CPFTRM(2)	CPFTRM(3)	CPFTRM(4)	CPFTRM(5)

Heat capacity variation with temperature for secondary (e.g., fuel) component

```
CPF = [CPFTRM(1) + CPFTRM(2)*T + CPFTRM(3)*T**2
       +CPFTRM(4)*T**3 + CPFTRM(5)*T**4]*UGC/WMF
```

where CPF = Secondary component heat capacity, J/kg-K

T = Temperature, K

UGC = Universal gas constant = 8314.9 J/kg-mol-K

WMF = Secondary component molecular weight

CARD NO. 14 FORMAT (E10.5)

1-10
XU(I)

There are NI of these cards, each containing one value of XU(I) where XU(I) is the axial location (in meters) of the Ith axial gridline for the axial velocity.

The axial storage locations for all other dependent variables are defined by X(I) = 0.5*(XU(I) + XU(I-1)), $2 \leq I \leq NI - 1$

Rule 1: For the upstream physical boundary located at an axial distance XB (typically, XB = 0), input XU(2) = XB and XU(1) = -XB

Rule 2: For the downstream physical boundary located at an axial distance XB, input XU(NI-1) = XB = XU(NI)

CARD NO.15 FORMAT (E10.5)

Columns 1–10
YV(J)

There are NJ of these cards, each containing one value of YV(J) where YV(J) is the radial location (in meters) of the Jth radial gridline for the radial velocity.

The radial storage locations for all other dependent variables are defined by

$$Y(J) = 0.5*(YV(J) + YV(J-1)),\ 2 \leq J \leq NJ - 1$$

Rule 1: For the centerline in axisymmetric flow input YV(1) = 0

Rule 2 For the upper physical boundary located at a radial distance RB input YV(NJ-1) = RB = YV(NJ)

CARD NO. 16 FORMAT (E10.5,2I10,E10.5,I10)

1–10	11–20	21–30	31–40	41–50
PREF	IPREF	JPREF	PERR	MAXSWP

PREF	Reference pressure, Pascal (NOTE: For incompressible flow, it is sufficient to use PREF = 0.0 and this value is recommended by the authors of the development version of the program.)
IPREF	Axial gridline number for PREF
JPREF	Radial gridline number for PREF
PERR	Tolerance for residual in the primary pressure-correction equation. Recommended value = 0.05
MAXSWP	Maximum number of sweeps through the primary pressure-correction equation.

CARD NO. 17 FORMAT (E10.5,4I10)

Columns 1–10	11–20	21–30	31–40	41–50
SORMAX	MAXIT	INDPRI	NUMPRI	ITREAX

SORMAX	Maximum residual for field variables (recommended range .001 to .005). As a practical matter, there is no suitable means of normalizing the residual for turbulent energy dissipation rate. As a result, the maximum residual for this variable tends to be large compared to residuals for all other variables. Therefore, the program continues to execute iterations until the criterion specified by ITSTEP (Card No. 2) or MAXIT (this card) is satisfied. The user decides whether the case must be continued by examining the change in the maximum residual for turbulent energy dissipation rate between the first and last iteration.
MAXIT	The maximum total number of iterations that can be run irrespective of the additional iterations requested by ITSTEP (see Card No. 2)
INDPRI	Number of iterations between outputs of the distributions for the dependent variables.
NUMPRI	Number of iterations between outputs of the monitoring node information.
ITREAX	Start chemical reaction on iteration ITREAX; this variable is used to permit flow calculation to stabilize prior to start of combustion. Typically, ITREAX = 30.

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6.0 TEST CASES

Three test cases are described in this section. The first two cases are based upon flow conditions and data supplied to UTRC by W. M. Roquemore of Wright-Patterson Air Force Base in consultation with the NASA Project Monitor. These data were obtained for nonswirling flows in a research combustor of the type shown in Fig. 1. Both a cold flow run and a hot flow run are simulated. The cold flow and hot flow nonswirling test cases are designated cases WPAFB1 and WPAFB2, respectively. The third case (WPAFB3) is derived from the hot flow test case without swirl by including swirl in the main (outer) stream and neglecting chemical reaction. It is included only to provide confirmation that the swirl option is operational.

For all the cases, the main flow consisted of air with a flow rate of 2 kg/sec. For the cold flow test cases, the secondary flow consisted of carbon dioxide having a flowrate of 6 kg/hr; for the hot flow test case, the same flow rate was used but the carbon dioxide was replaced with propane. The secondary inlet temperature and flow velocity also differed between the hot and cold flow cases. It was assumed that the turbulence was isotropic. From the test data provided to UTRC, it was estimated that the ratio of turbulent kinetic energy to the square of the flow velocity in each stream was 0.005. The inlet flow conditions are summarized in Table 7.

The primary purpose of the test cases was to demonstrate that the computer program is capable of producing a physically realistic result with a minimum of user intervention. Achieving an accurate comparison between calculated and measured results was considered to be of secondary importance. Therefore, a relatively coarse grid system, consisting of twelve axial and ten radial grid lines, was used for all calculations. The grid system is shown schematically in Fig. 7. The numbering of the grid lines is consistent with that defined in Sections 5.4 and 5.7.

6.1 Cold Flow Test Case Without Swirl

The cold flow test case without swirl (case WPAFB1) was run for a total of 100 iterations. A listing of the input cards and a copy of the printout corresponding to iterations 1 through 5 are included in Appendix 1. A copy of the printout for iterations 31 through 100 is also included in Appendix 1. All input values for underrelaxation factors, number of sweeps per iteration, etc. were the same for all of the runs.

At the end of 100 iterations, the calculation had not converged since some of the residuals exceeded the input maximum, SORMAX = 0.001. Generally, SORMAX is assigned a value between 0.001 and 0.005. The residuals for fuel concentration (F.CONC.) and mixture fraction (M.FRAC.) are about 0.01. However, for purposes of illustrating the operation of the program, these residuals may be considered to be small enough. No suitable length scale has been defined in the program for normalizing the turbulent energy dissipation rate. It is seen that the final value of the residual (DISS) for this variable is 1.78; however, since the value of DISS on the first iteration was 96200, the iteration for turbulent energy dissipation has probably converged. Therefore, the case has essentially converged as of the 100th iteration. Approximately 1670 seconds of UNIVAC 1100/81A machine time were used for this calculation.

The computed variation of centerline velocity with axial distance is shown by the solid line in Fig. 8. The measured data correspond to carbon dioxide flow rates of 4 and 8 kg/hr; data are not available for the carbon dioxide flow rate of 6 kg/hr used in the calculation. It can be seen that the calculated results show a more rapid initial deceleration of centerline velocity than that shown by the data. This could be the result of a greater rate of mixing of the two streams with the rapid mixing the result of severe numerical diffusion due to the very coarse grid used for the calculation. Similar behavior is exhibited by the calculated results for axial variation of centerline carbon dioxide concentration shown in Fig. 9 which are compared to measured data at the simulated flow rate.

6.2 Hot Flow Test Case Without Swirl

The hot flow test case without swirl (case WPAFB2) was run for 125 iterations; a listing of the input cards and a copy of the results for iterations 1 through 125 are shown in Appendix 2. The final residual for the fuel concentration and the mixture fraction is slightly greater than the specified maximum (SORMAX = 0.001). The residual for the turbulent dissipation rate decreased from a value of 135000 on the first iteration to a value of 463 on the last iteration. Therefore, this case has converged. Use of the combustion model was initiated on the 30th iteration. All underrelaxation factors, number of sweeps per iteration, etc. remained fixed throughout the entire calculation which used approximately 2080 seconds of UNIVAC 1100/81A machine time.

The calculated and measured variations of axial velocity are shown in Fig. 10 and of temperature in Fig. 11. A comparison of calculated and measured temperature profiles is shown in Fig. 12 for a downstream location. In all cases the predicted results exhibit greater mixing between the main and secondary streams than that shown by the data; again the greater mixing could be due to numerical diffusion caused by the use of a very coarse grid.

6.3 Cold Flow Test Case With Swirl

A cold flow test case (case WPAFB3) was run to demonstrate that the computer program was operating properly. The case was terminated after twenty iterations. A listing of the input cards and a copy of the results are included in Appendix 3. The calculation has obviously not converged but appears to be stable. This test case is provided only for documentation purposes and to aid the user in installing the computer program on another computer system.

7.0 REFERENCES

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4. Magnussen, B. F. and B. H. Hjertager: On Mathematical Modeling of Turbulent Combustion with Special Emphasis on Soot Formation and Combustion, Sixteenth Symposium (International) on Combustion, The Combustion Institute, 1978, pp. 719-729.

5. Raithby, G. D.: Skew Upwind Differencing for Problems Involving Fluid Flow, Computational Methods in Applied Mechanics and Engineering, Vol. 9, 1976, pp. 153-164.

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8.0 LIST OF SYMBOLS

A	Co-efficient in finite-difference equations
a	Flow area
$\tilde{a}$	Flux contribution
C	Convective flux
C_p	Heat capacity
C_μ, C_1, C_2	Constants in turbulence model
D	Diffusive flux
E	Constant in law of the wall
E1,E2,E3	Flux contributions, east face of control volume
F	Flux
f	Mixture fraction
G	Turbulence generation term
h	Enthalpy
H_R	Heat of reaction
I	Index for nodes - axial direction
i	Stoichiometric oxygen to fuel mass ratio
J	Index for nodes - radial direction
K	Constant in law of the wall
k	Skewing interpolation factor or turbulent kinetic energy
M	Molecular weight
m	Mass fraction
N1,N2,N3	Flux contributions, north face of control volume
Pe	Peclet number
R	Universal gas constant
R_f	Reaction rate
S	Source

s	Distance along streamline
u	Axial velocity
v	Radial velocity
x	Axial co-ordinate
y	Distance from wall
α	Interpolation factor
Γ	Exchange co-efficient
γ	Blending factor
δ	Coordinate indicator (0 for planar, 1 for axisymmetric)
δv	Differential volume
$\delta x, \delta y$	Control volume dimensions
$\Delta x, \Delta y$	Internodal distances
ε	Turbulent energy dissipation rate
λ	Hybrid differencing switch (1 for central differencing, 0 for bounded skew-upwind differencing)
ϕ	Dependent variable
ρ	Density
σ^u, σ^v	Flow velocity direction switches
σ_ϕ	Turbulent Prandtl number for ϕ
τ	Shear stress

<u>Subscripts</u>

BSHD	Bounded skew hybrid differencing
BSUD	Bounded skew-upwind differencing
CD	Central differencing
CO_2	Carbon dioxide
E	East node
e	East face
eff	Effective value

f	Fuel
H_2O	Water vapor
ℓ	Laminar
m	Mean value
max	Maximum value
min	Minimum value
N	North node
N_2	Nitrogen
n	North face
NE	Northeast node
NW	Northwest node
O_2	Oxygen
P	Node at center of control volume
pr	Product
S	South node
s	South face
SE	Southeast node
SW	Southwest node
SUD	Skew upwind differencing
t	Turbulent
u	Value not dependent on
UD	Upwind differencing
W	West node
w	West face or swirl velocity
ϕ	Dependent variable

Superscripts

$( )^u$	Axial velocity

$(\ )^{v}$	Radial velocity
$(\ )^{*}$	Transition
$(\ )'$	For co-efficients, value not associated with
$(\ )''$	For co-efficients, value associated with

9.0 TABLES

TABLE 1

Turbulence Model Constants

Constant	Value
C_1	1.44
C_2	1.92
C_μ	0.09
σ_k	1.0
σ_ε	$K^2/\{(C_2 - C_1)\, C_\mu^{1/2}\}$
E	9.0
K	0.4187

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TABLE 2

Constants in the Polynomials for Heat Capacity for Various Species

		H_2O	C_3H_8	O_2	N_2	CO_2
T > 1000K	C_1	2.7168	-0.24515	3.620	3.8963	4.4608
	C_2	2.9454×10^{-3}	0.36714×10^{-1}	7.3612×10^{-4}	1.5155×10^{-3}	3.0982×10^{-3}
	C_3	-8.0224×10^{-7}	-0.19576×10^{-4}	-1.9652×10^{-7}	-5.7235×10^{-7}	-1.2392×10^{-6}
	C_4	1.0227×10^{-10}	0.46527×10^{-8}	3.6202×10^{-11}	9.9807×10^{-11}	2.[illegible]
	C_5	-4.8472×10^{-15}	-0.29008×10^{-12}	-2.8946×10^{-15}	-6.5224×10^{-16}	-[illegible].5526[illegible]
T < 1000K	C_1	4.0701	-0.24515	3.6256	3.6748	2.4008
	C_2	-1.1084×10^{-3}	0.36714×10^{-1}	-1.8782×10^{-3}	-1.2081×10^{-3}	8.7351×10^{-3}
	C_3	4.1521×10^{-6}	-0.19576×10^{-4}	7.0555×10^{-6}	2.324×10^{-6}	-6.6[illegible]
	C_4	-2.9637×10^{-9}	0.46527×10^{-8}	-6.7635×10^{-9}	-6.3218×10^{-10}	2.0022[illegible]
	C_5	8.0702×10^{-13}	-0.29008×10^{-12}	2.1556×10^{-12}	-2.2577×10^{-13}	6.327[illegible]

TABLE 3

Definition of Bounded Skew Hybrid Differencing Fluxes

West

$$\frac{F_{w_{BSHD}}}{D_W} = \lambda_w F_{w_{CD}} + (1 - \lambda_w)\, F_{w_{BSUD}}$$

East

$$\frac{F_{e_{BSHD}}}{D_E} = \lambda_e F_{e_{CD}} + (1 - \lambda_e)\, F_{e_{BSUD}}$$

South

$$\frac{F_{s_{BSHD}}}{D_S} = \lambda_s F_{s_{CD}} + (1 - \lambda_s)\, F_{s_{BSUD}}$$

North

$$\frac{F_{n_{BSHD}}}{D_N} = \lambda_n F_{n_{CD}} + (1 - \lambda_n)\, F_{n_{BSUD}}$$

TABLE 4

Central Differencing Fluxes

West

$$\frac{F_{w_{CD}}}{D_W} = \left[Pe_w \; (1 - \alpha_w) + 1 \right] \phi_W + \left(\alpha_w Pe_w - 1 \right) \phi_P$$

East

$$\frac{F_{e_{CD}}}{D_E} = \left[Pe_e \; (1 - \alpha_e) + 1 \right] \phi_P + \left(\alpha_e Pe_e - 1 \right) \phi_E$$

South

$$\frac{F_{s_{CD}}}{D_S} = \left[Pe_s \; (1 - \alpha_s) + 1 \right] \phi_S + \left(\alpha_s Pe_s - 1 \right) \phi_P$$

North

$$\frac{F_{n_{CD}}}{D_N} = \left[Pe_n \; (1 - \alpha_n) + 1 \right] \phi_P + \left(\alpha_n Pe_n - 1 \right) \phi_N$$

TABLE 5

Bounded Skew-Upwind Differencing Fluxes

West

$$\frac{F_{w_{BSUD}}}{D_W} = Pe_w \left[\sigma_w^u \phi_W + (1 - \sigma_w^u) \phi_P\right] - (Pe_w - Pe_w^*) \gamma_w k_w$$

$$\left[\sigma_w^u \left| \phi_W - \sigma_w^v \phi_{SW} - (1 - \sigma_w^v) \phi_{NW} \right| \right.$$

$$\left. + (1 - \sigma_w^u) \left| \phi_P - \sigma_w^v \phi_S - (1 - \sigma_w^v) \phi_N \right| \right]$$

East

$$\frac{F_{e_{BSUD}}}{D_E} = Pe_e \left[\sigma_e^u \phi_P + (1 - \sigma_e^u) \phi_E\right] - (Pe_e - Pe_e^*) \gamma_e k_e$$

$$\left[\sigma_e^u \left| \phi_P - \sigma_e^v \phi_S - (1 - \sigma_e^v) \phi_N \right| \right.$$

$$\left. + (1 - \sigma_e^u) \left| \phi_E - \sigma_e^v \phi_{SE} - (1 - \sigma_e^v) \phi_{NE} \right| \right]$$

South

$$\frac{F_{s_{BSUD}}}{D_S} = Pe_s \left[\sigma_s^v \phi_S + (1 - \sigma_s^v) \phi_P\right] - (Pe_s - Pe_s^*) \gamma_s k_s$$

$$\left[\sigma_s^v \left| \phi_S - (1 - \sigma_s^u) \phi_{SE} - \sigma_s^u \phi_{SW} \right| \right.$$

$$\left. + (1 - \sigma_s^v) \left| \phi_P - (1 - \sigma_s^u) \phi_E - \sigma_s^u \phi_W \right| \right]$$

North

$$\frac{F_{n_{BSUD}}}{D_N} = Pe_n \left[\sigma_n^v \phi_P + (1 - \sigma_n^v) \phi_N\right] - (Pe_n - Pe_n^*) \gamma_n k_n$$

$$\left[\sigma_n^v \left| \phi_P - (1 - \sigma_n^u) \phi_E - \sigma_n^u \phi_W \right| \right.$$

$$\left. + (1 - \sigma_n^v) \left| \phi_N - (1 - \sigma_n^u) \phi_{NE} - \sigma_n^u \phi_{NW} \right| \right]$$

TABLE 6

Co-efficients of the Finite-Difference Equations

$$A_W(I,J) = E2(I-1,J) - \gamma_w\,[c_e^u\ E3]_{I-1,J} + \gamma_s\,[(1 - c_n^v)\ c_n^u\ N3]_{I,J-1} - \gamma_n\,[c_n^v\ c_n^u\ N3]_{I,J}$$

$$A_E(I,J) = E1(I,J) + \gamma_e\,[(1 - c_e^u)\ E3]_{I,J} + \gamma_s\,[(1 - c_n^v)(1 - c_n^u)\ N3]_{I,J-1} - \gamma_n\,[c_n^v\ (1 - c_n^u)\ N3]_{I,J}$$

$$A_S(I,J) = N2(I,J-1) - \gamma_s\,[c_n^v\ N3]_{I,J-1} + \gamma_w\,[(1 - c_e^u)\ c_e^v\ E3]_{I-1,J} - \gamma_e\,[c_e^u\ c_e^v\ E3]_{I,J}$$

$$A_N(I,J) = N1(I,J) + \gamma_n\,[(1 - c_n^v)\ N3]_{I,J} + \gamma_w\,[(1 - c_e^u)(1 - c_e^v)\ E3]_{I-1,J} - \gamma_e\,[c_e^u\ (1 - c_e^v)\ E3]_{I,J}$$

$$A_{SW}(I,J) = \gamma_w\,[c_e^u\ c_e^v\ E3]_{I-1,J} + \gamma_s\,[c_n^u\ c_n^v\ N3]_{I,J-1}$$

$$A_{SE}(I,J) = \gamma_s\,[c_n^v\ (1 - c_n^u)\ N3]_{I,J-1} - \gamma_e\,[(1 - c_e^u)\ c_e^v\ E3]_{I,J}$$

$$A_{NW}(I,J) = \gamma_w\,[c_e^u\ (1 - c_e^v)\ E3]_{I-1,J} - \gamma_n\,[(1 - c_n^v)\ c_n^u\ N3]_{I,J}$$

$$A_{NE}(I,J) = -\gamma_e\,[(1 - c_e^u)(1 - c_e^v)\ E3]_{I,J} - \gamma_n\,[(1 - c_n^v)(1 - c_n^u)]N3_{I,J}$$

NOTE: The blending factors γ_w, γ_e, γ_s and γ_n are the factors appropriate for the (I,J) node as determined by the procedure discussed in Section 4.1.4.

TABLE 7

Inlet Flow Conditions for Test Cases

Case	WPAFB1	WPAFB2	WPAFB3
Main Flow			
Axial Velocity, m/sec	49.3	49.3	49.3
Swirl/Axial Velocity	0.0	0.0	0.101
Temperature, K	293	293	293
Turbulent Kinetic Energy/ (Main Velocity)^2	0.005	0.005	0.005
Secondary Flow			
Axial Velocity, m/sec	52.5	69.6	69.6
Swirl/Axial Velocity	0.0	0.0	0.0
Temperature, K	293	400	400
Turbulent Kinetic Energy/ (Sec. Velocity)^2	0.005	0.005	0.005
Pressure, Pa	98000	98000	98000

10.0 FIGURES

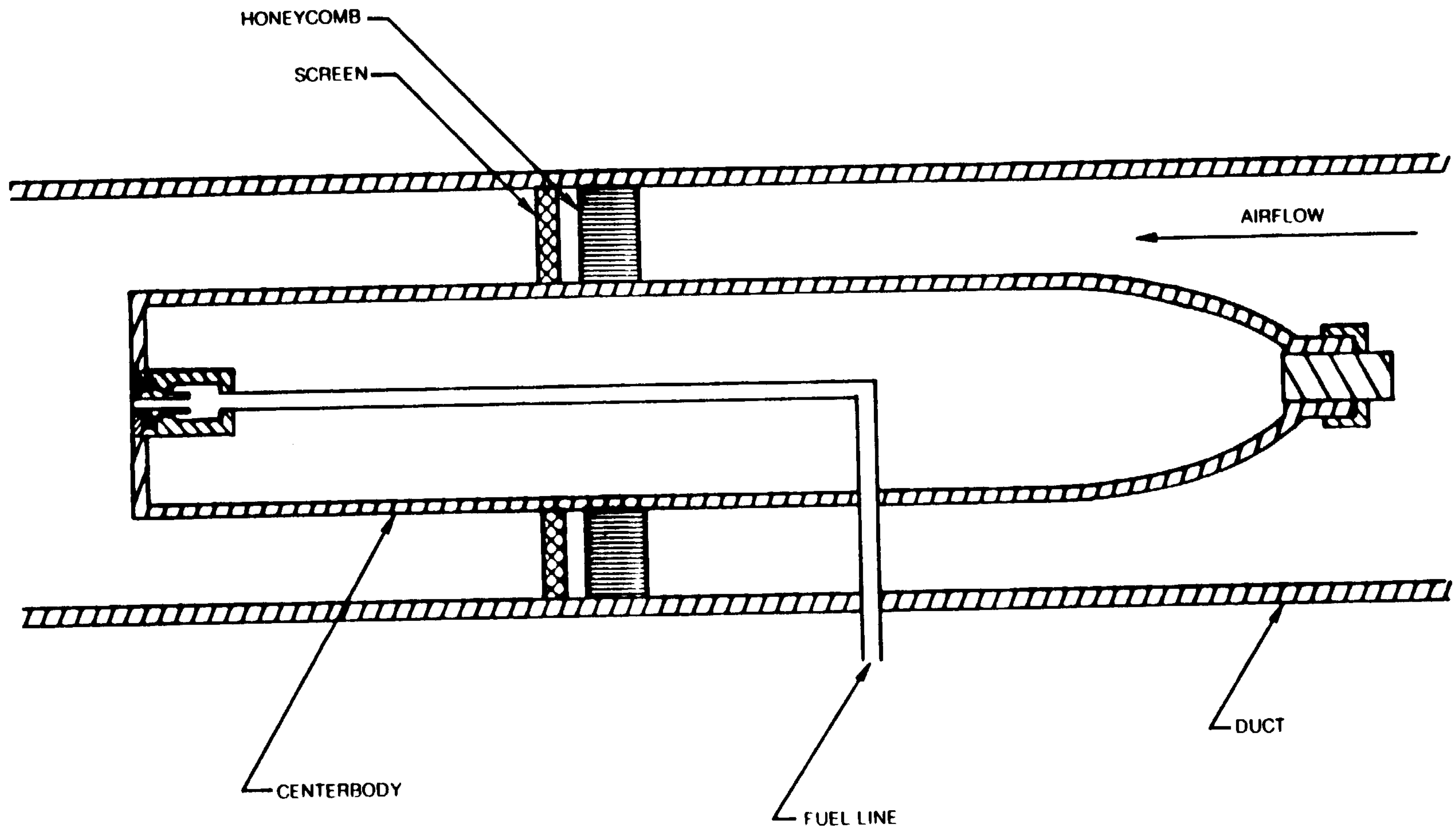


Fig. 1 Geometry of Bluff-Body Research Combustor

83-8-30-7

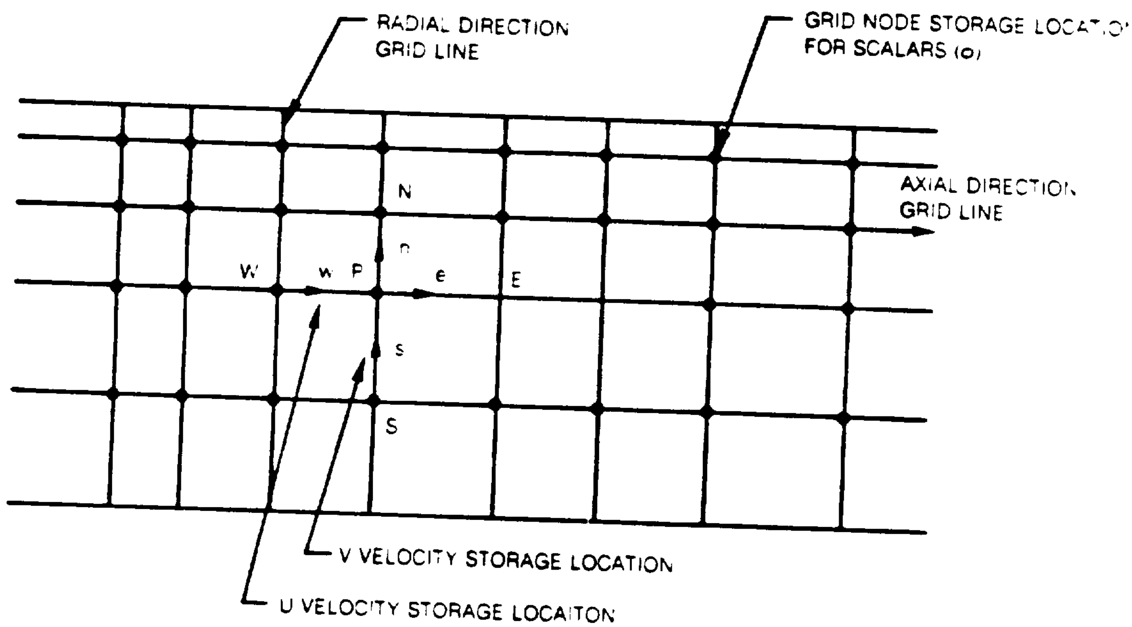


Fig. 2 Grid System for Scalars and Tangential Velocity

83–8–30–6

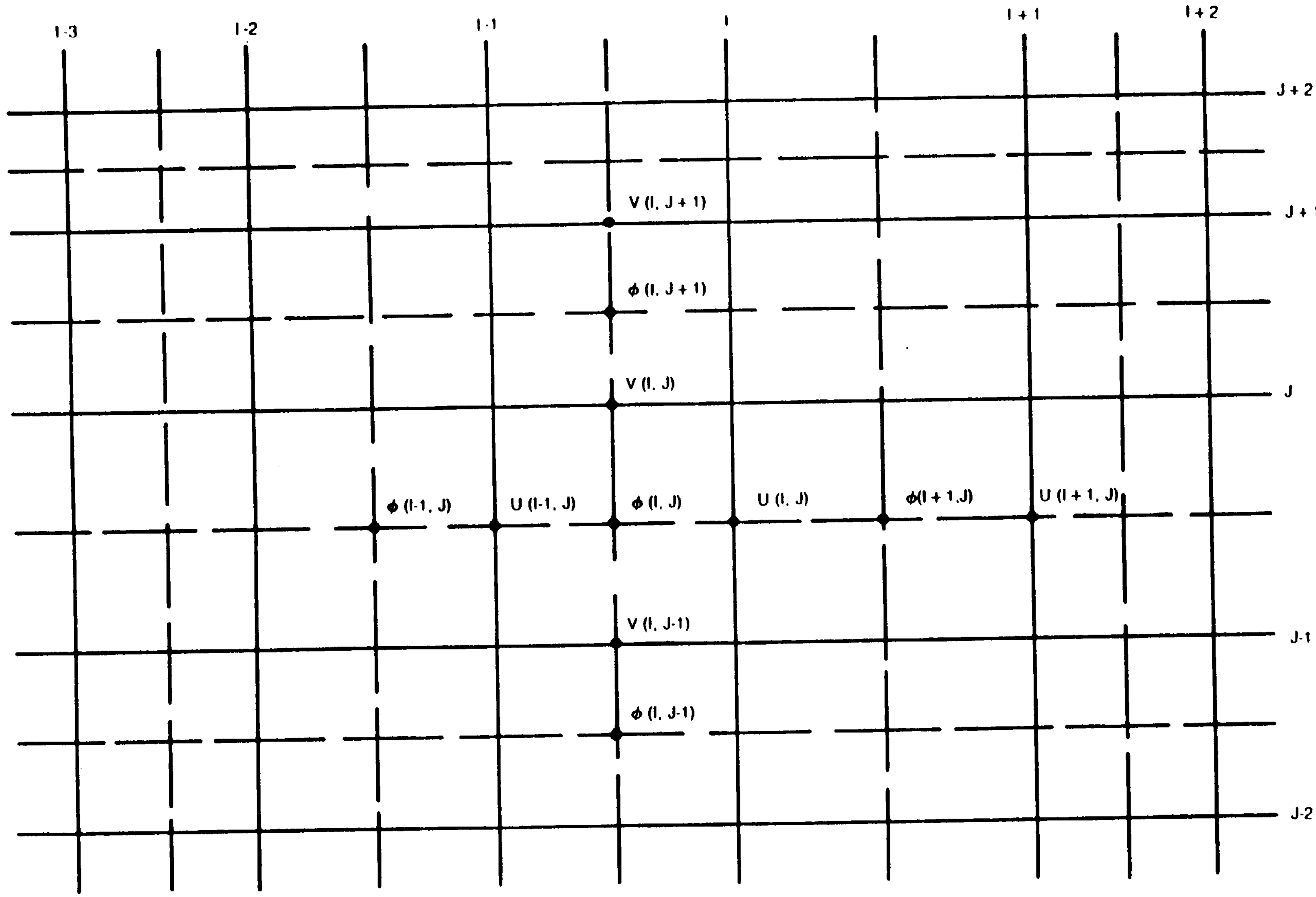


Fig. 3 Relative Positions of Axial Velocity, Radial Velocity, and Scalar Grid Systems

83-8-30-8

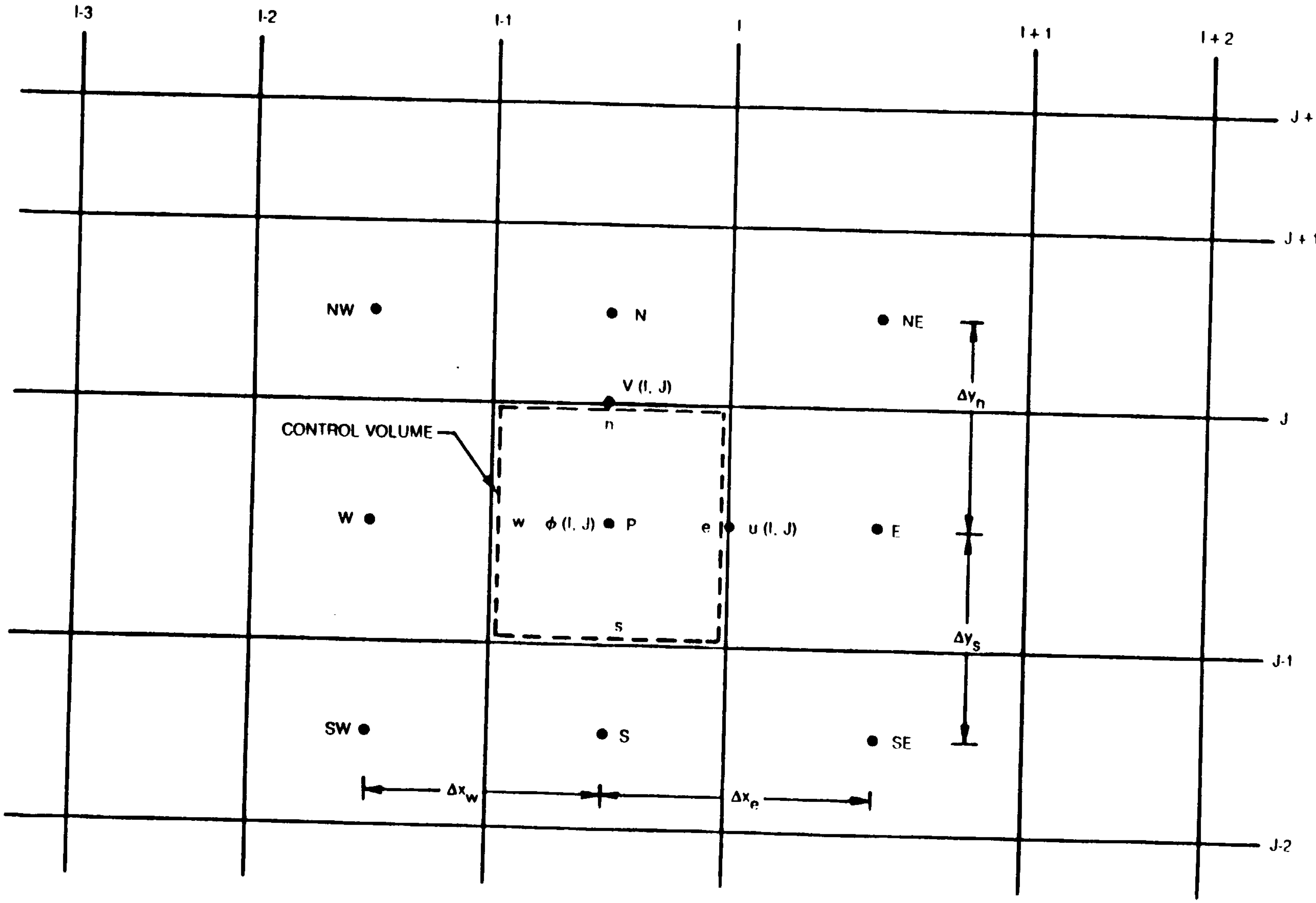
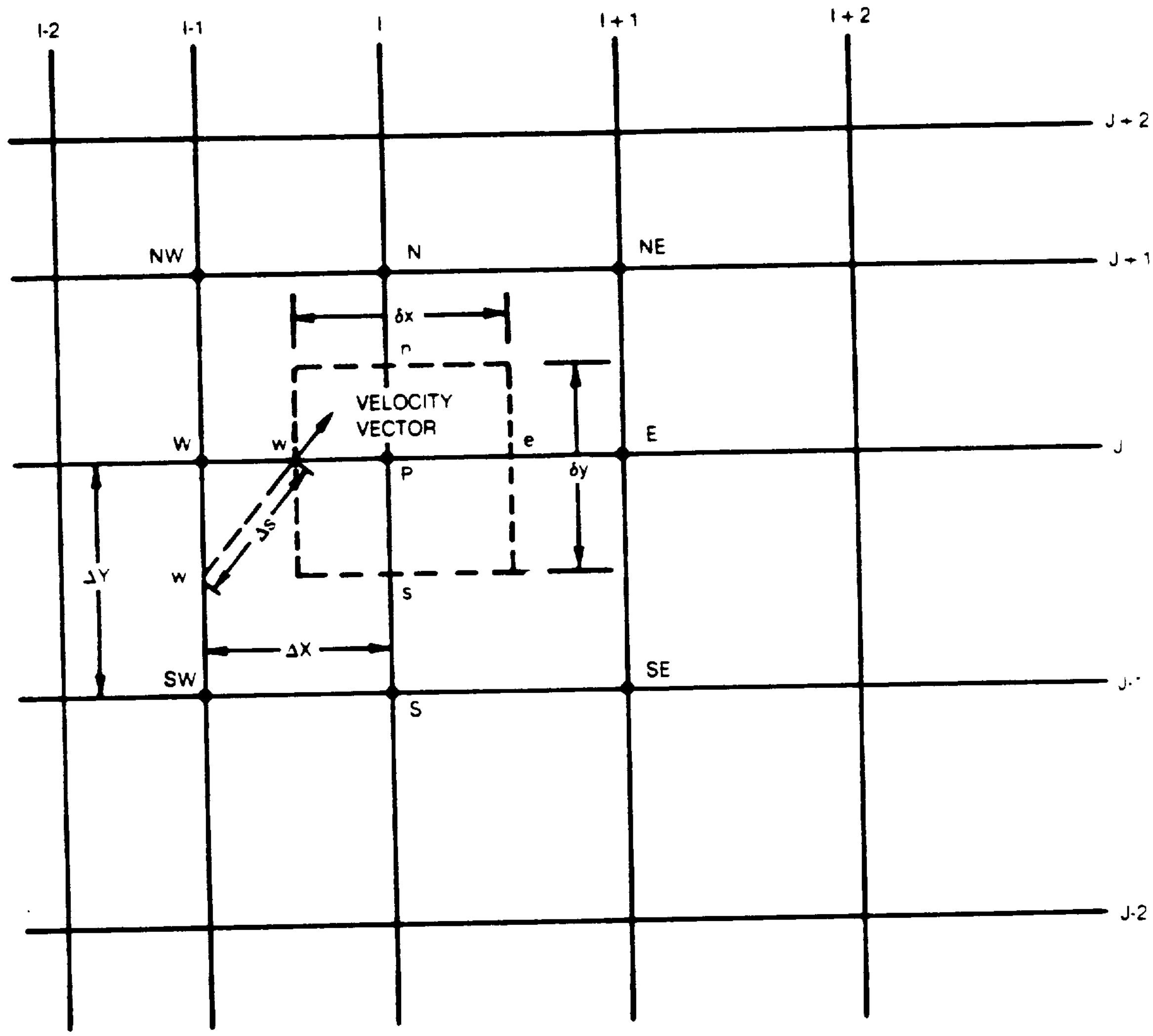


Fig. 4 Control Volume for Scalar ϕ (I, J)

83-8-30-5



NOTE: INDICES I, J REFER TO LOCATION OF SCALAR

Fig. 5 Control Volume for Skew Upwind Differencing for West Face of Control Volume and Positive Velocity Components

83–8–30–10

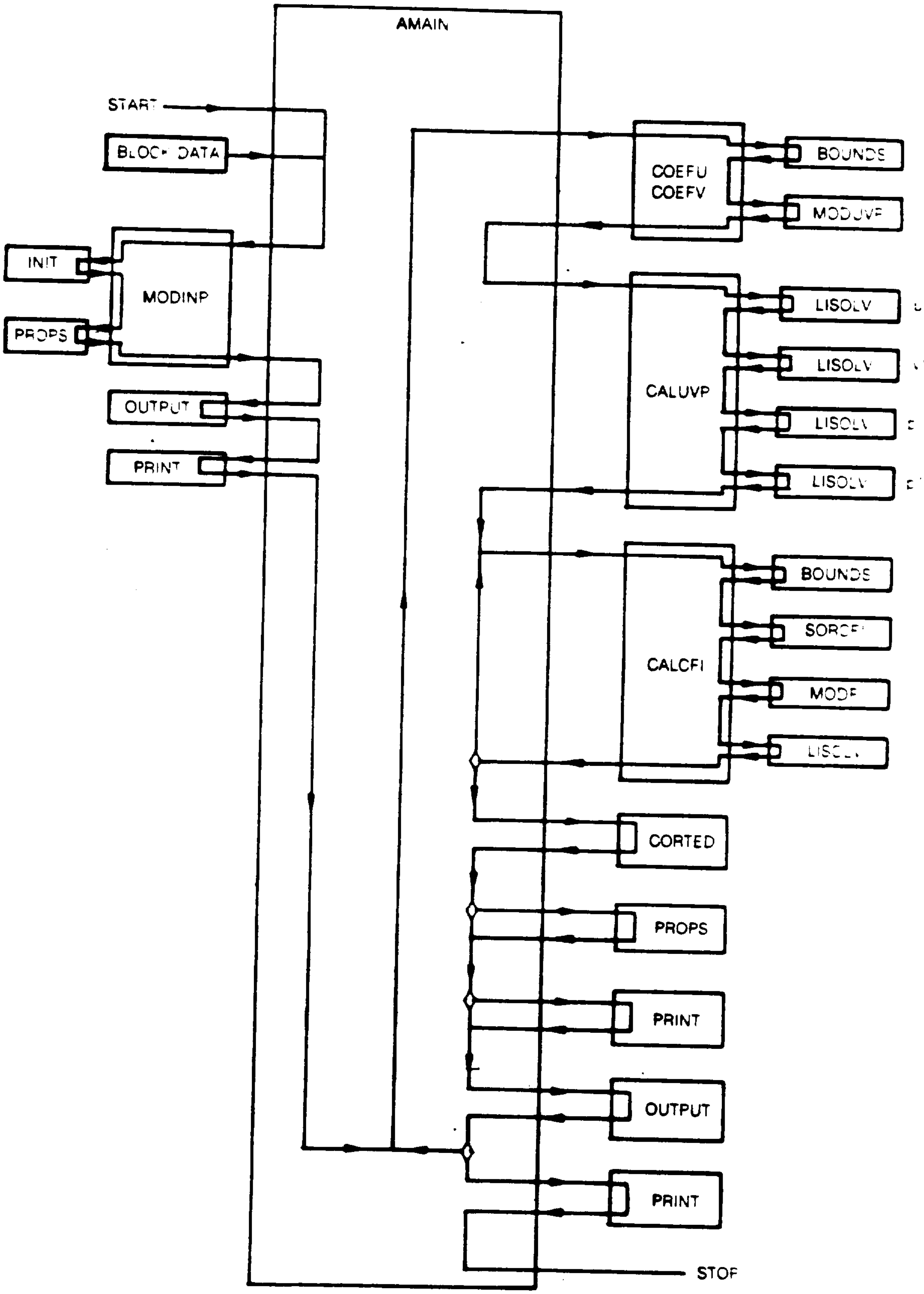


Fig. 6 Program Flow Chart

83-6-30-11

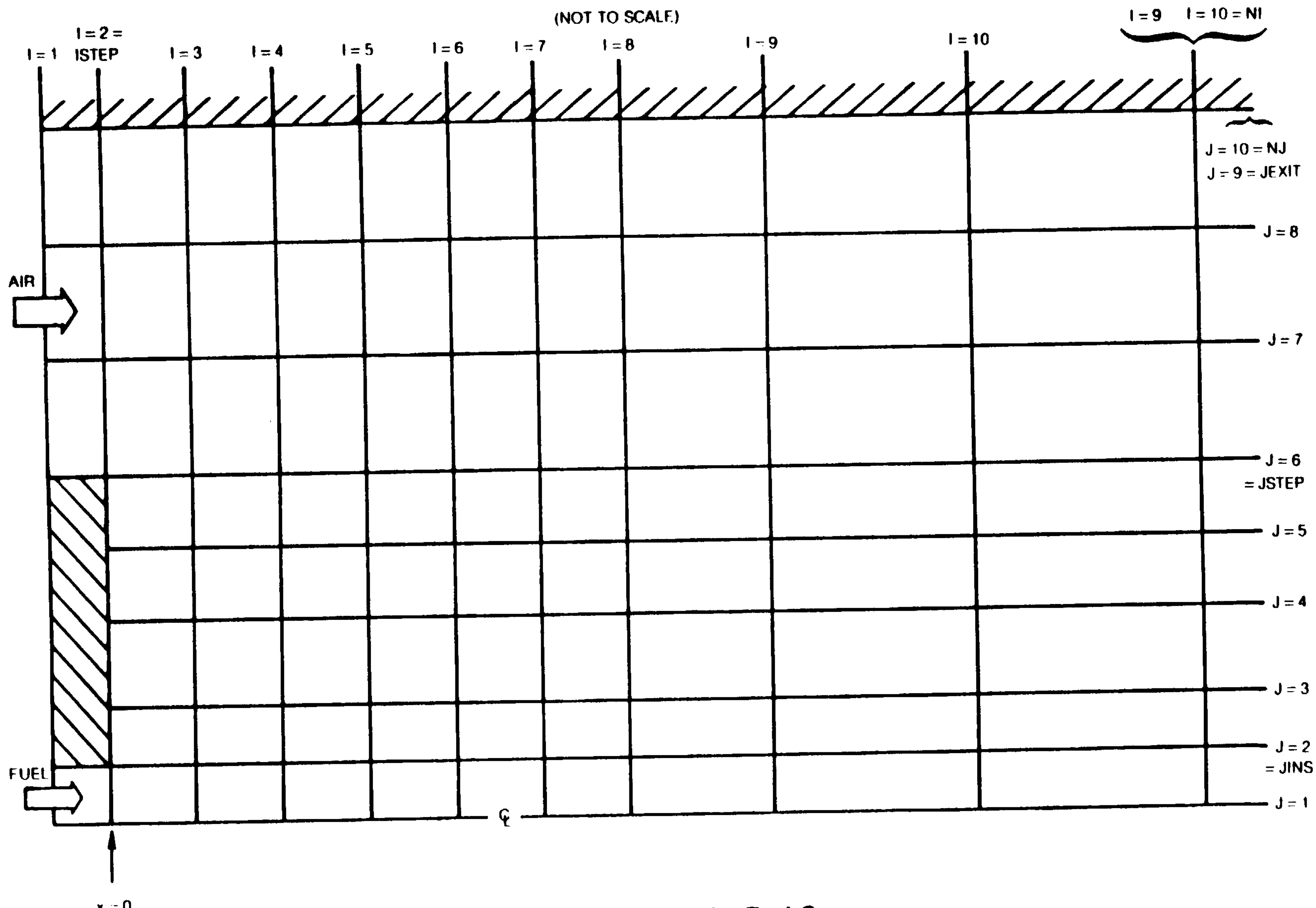


Fig. 7 Grid System Used for Test Cases

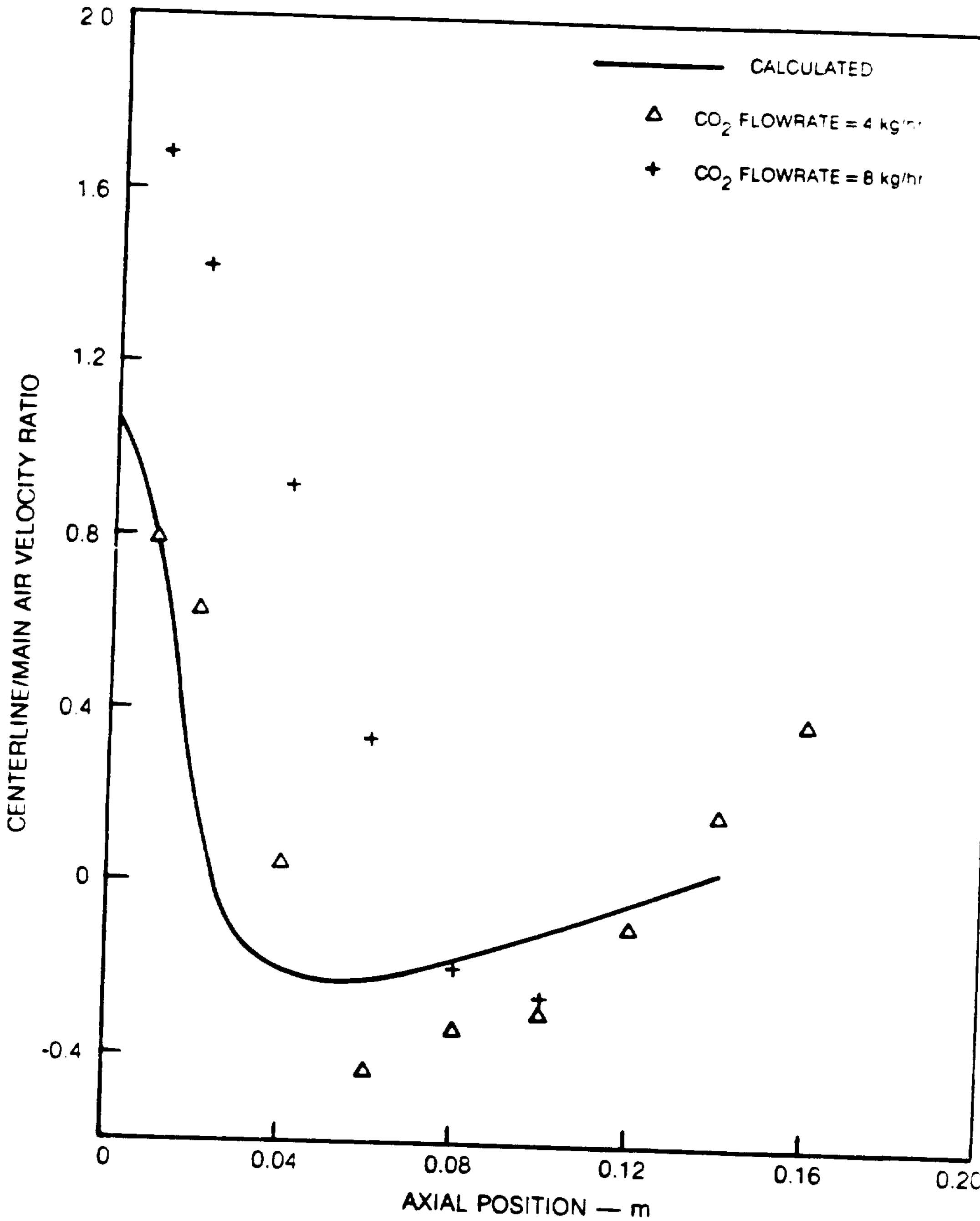


Fig. 8 Centerline Axial Velocity Distribution for Cold Flow Test Case Without Swirl

83-6-30-5

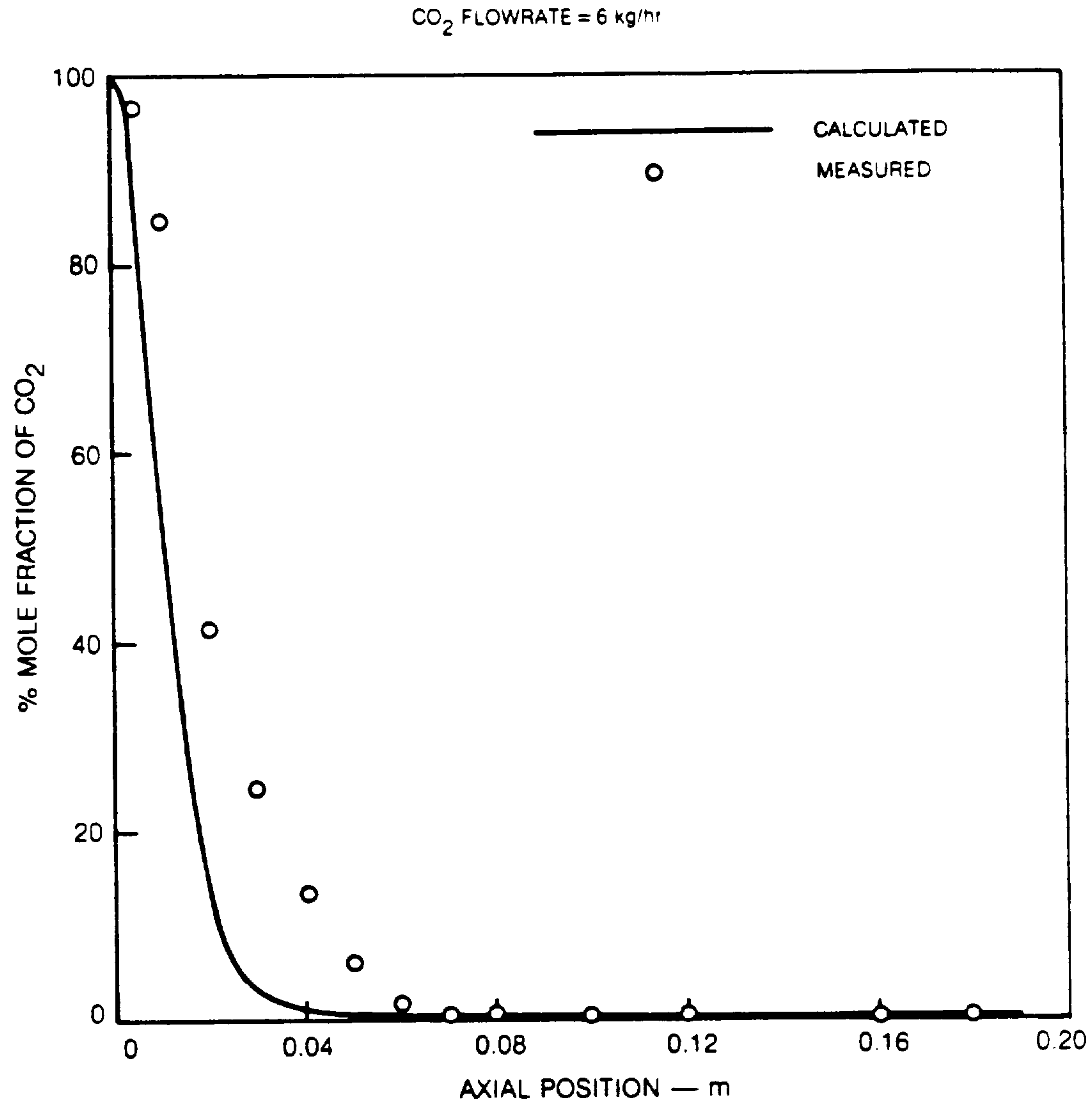


Fig. 9 Centerline CO_2 Concentration Distribution for Cold Flow Test Case Without Swirl

83-8-30-4

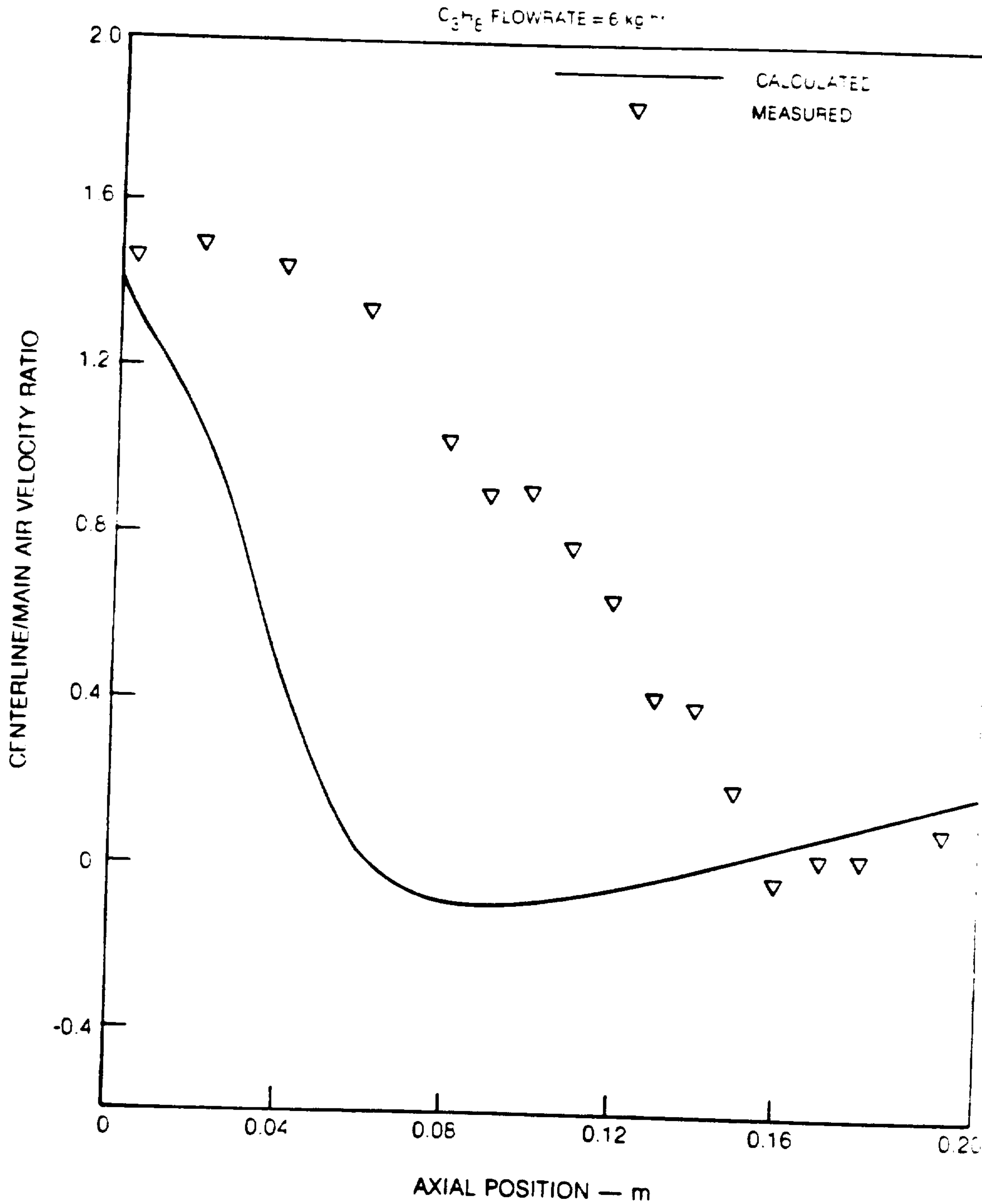


Fig. 10 Centerline Axial Velocity Distribution for Hot Flow Test Case Without Swirl

83-6-30-3

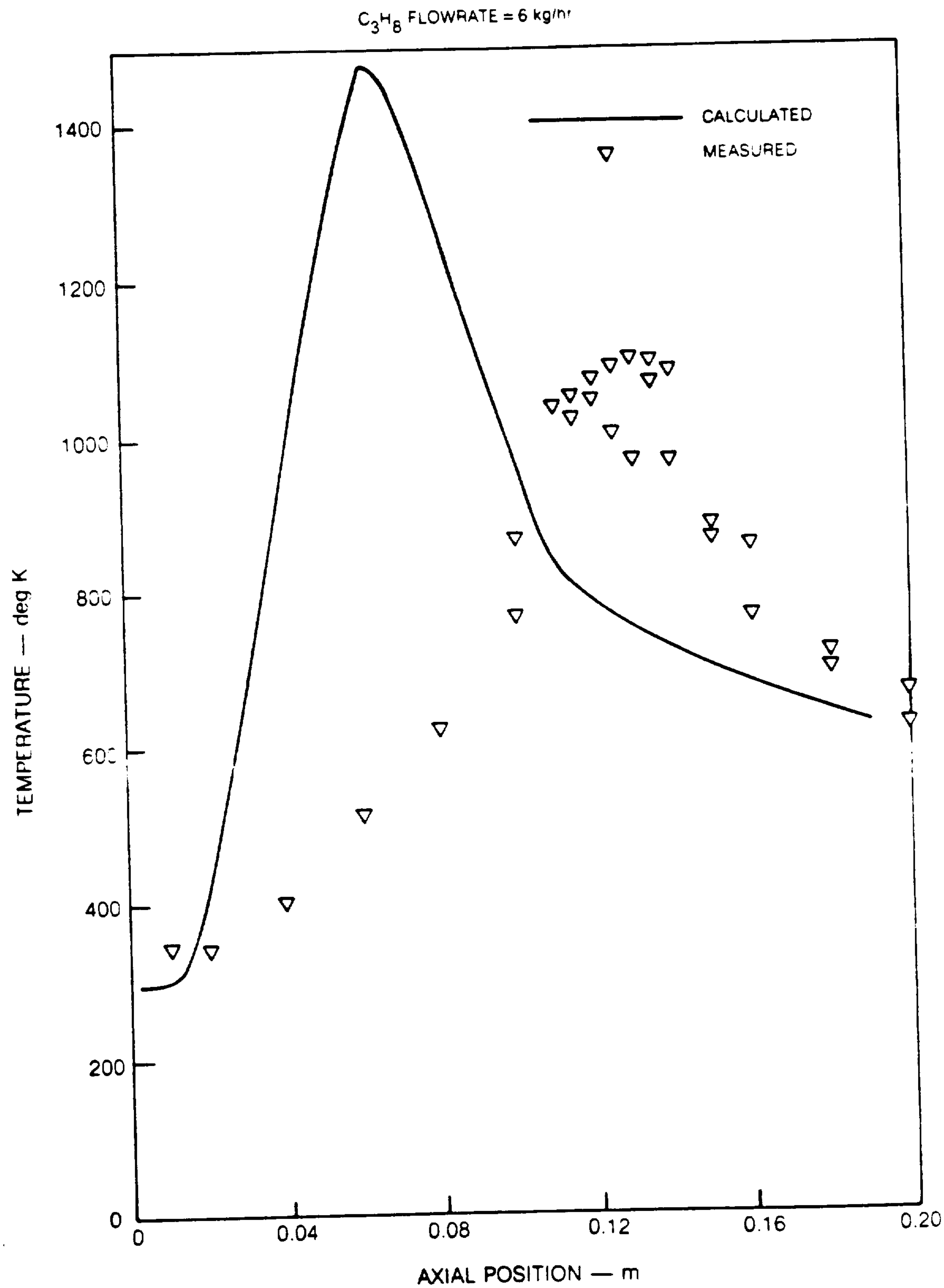


Fig. 11 Centerline Temperature Distribution for Hot Flow Test Case Without Swirl

83-8-30-2

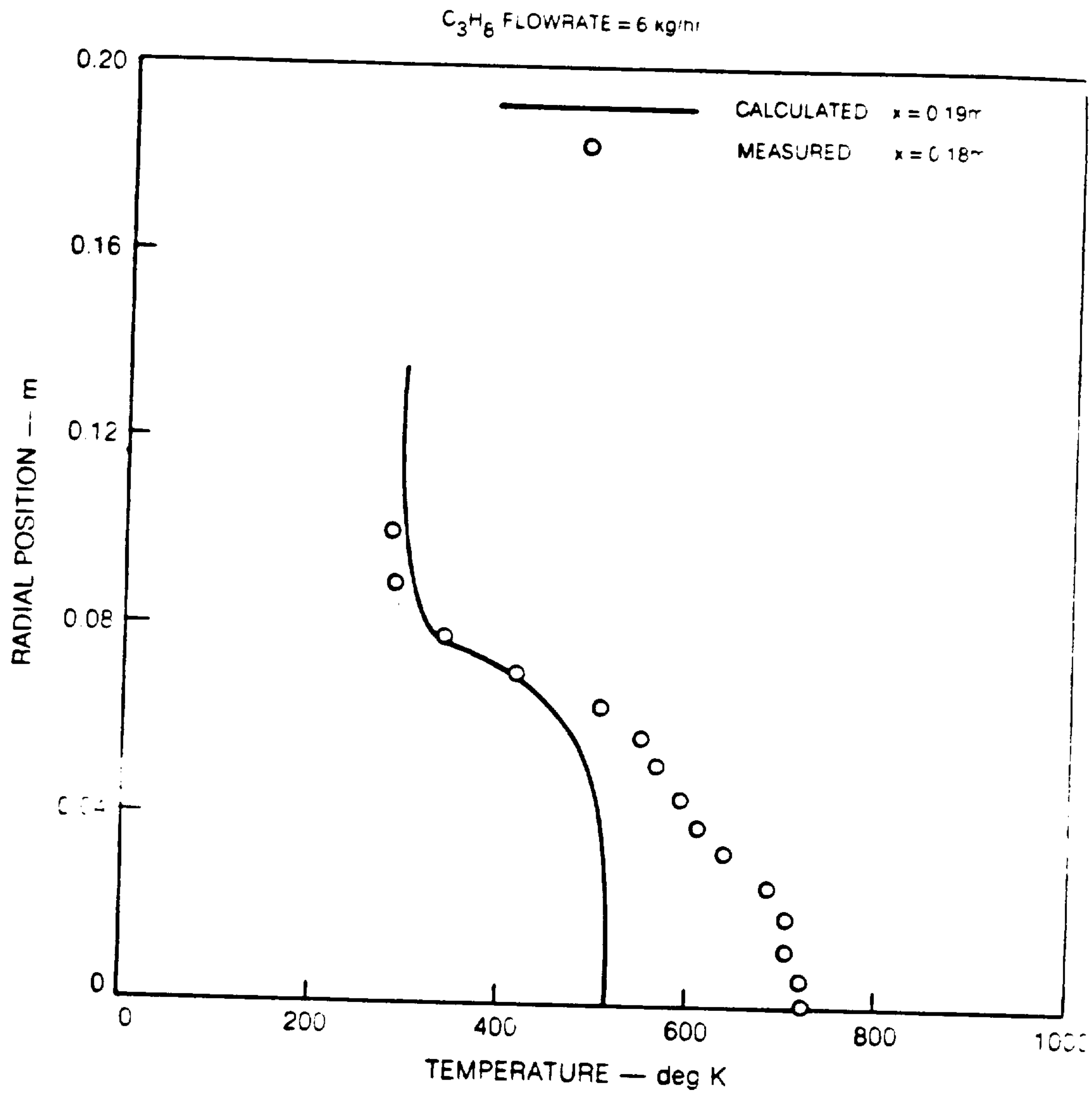


Fig. 12 Temperature Profile for Hot Flow Test Case Without Swirl

83-8-30-1

APPENDIX 1

TEACH*TEACH(2).WPAFB1(3)

```
          WPAFB1 - COLD FLOW TEST CASE
                  5         1
                  2         2         1         1         0         0
                 12        10         2         6         9         2         5         4
                  1         2         3         4         5         6         7         8
                  0        10
                  2         2         3         1         1         1         1         1
                  0         1
          0.7      0.7       1.0       0.7       0.7       0.6       0.6       0.6
          0.0      0.7       1.0       0.4
            1.88E-051.1609   293.0     293.0
          49.3     0.0       293.0     0.0       0.005     0.01      98000.0
          52.5     0.0       293.0     1.0       0.005     0.01
          3.635    5.0080E+0744.0
          913.0    1040.0    834.0     2020.0
          2.4008   8.7351E-03-6.6071E-6 2.0022E-96.3274E-16
          -0.001
           0.000
           0.003
           0.008
           0.016
           0.028
           0.045
           0.080
           0.140
           0.240
           0.390
           0.390
           0.000
           0.0024
           0.010
           0.030
           0.055
           0.070
           0.085
           0.112
           0.127
           0.127
          0.0                 2     70.02               50
          0.001             300     500        1        500
```

@PRT,S TEACH*TEACH.WPAFB2

```
TURBULENT FLOW IN A BLUFF-BODY COMBUSTOR
FOR *PAFB1 - COLD FLOW TEST CASE

NUMBER OF ITERATIONS TO EXECUTE          5
MODOP  = 1, THIS IS A NEW CASE
ISCEME = 2, USE SKEW DIFFERENCING
INDCOS = 2, CYLINDRICAL CO-ORDINATES
KNPRO  = 1, FLUID PROPERTIES ARE VARIABLE
KNCOMP = 1, FLOW IS INCOMPRESSIBLE
KVISCO = 0, VISCOSITY IS VARIABLE
KLAMNR = 0, FLOW IS TURBULENT
GRID CONTROLS

NI     =    12
NJ     =    10
ISTEP  =     2
JSTEP  =     6
JEXIT  =     9
JINS   =     2
IMON   =     5
JMON   =     4

DEPENDENT VARIABLE EQUATION CONTROLS
VARIABLE                         SWITCH  NO. SWEEPS  UNDER RELAX
                                                          FACTOR
U VELOCITY                          1          2     .70000+00
V VELOCITY                          2          2     .70000+00
PRIMARY PRESSURE CORRECT            3          3     .10000+01
TURBULENCE ENERGY                   4          1     .70000+00
ENERGY DISSIPATION                  5          1     .70000+00
ENTHALPY                            6          1     .60000+00
FUEL CONCENTRATION                  7          1     .60000+00
MIXTURE FRACTION                    8          1     .60000+00
SWIRL VELOCITY                      0          0     .00000
SEC. PRESSURE CORRECT.             10          1     .70000+00
VISCOSITY                                            .10000+01
DENSITY                                              .40000+00

VISCOSITY         N-SEC/M**2    .18800-04
DENSITY              KG/M**3    .11609+01
WALL TEMPERATURE           K    .29300+03
BLUFF BODY TEMPERATURE     K    .29300+03

FLOW CONDITIONS...
```

```
VARIABLE                          OUTER FLOW   INNER FLOW

AXIAL VELOCITY           M/SEC    .49300+02    .52500+02
SWIRL/AXIAL VEL. RATIO            .00000       .00000
TEMPERATURE                  K    .29300+03    .29300+03
CONC.-SECOND COMPONENT            .00000       .10000+01
TURB. INTENSITY FACTOR            .50000-02    .50000-02
BNDY. LAYER THICKNESS   M         .10000-01    .10000-01
PRESSURE                N/M**2    .98000+05

STOIC. O2/FUEL MASS RAT.          .36350+01
HEAT OF COMBUSTION   J/KG         .50080+08
FUEL MOLECULAR WEIGHT             .44000+02

CP-O2               J/KG-K        .91300+03
CP-N2               J/KG-K        .10400+04
CP-CO2              J/KG-K        .83400+03
CP-H2O              J/KG-K        .20200+04

CO-EFFICIENTS OF THE POLYNOMIAL FOR THE HEAT CAPACITY FOR THE SECOND COMPONENT (E.G.,FUEL)

CP = (C1 + C2*T + C3*T**2 + C4*T**3 + C5*T**4)*UGC /WMF
     WITH T IN DEG K AND CP IN J/KG-K

C1     =      .24008+01
C2     =      .87351-02
C3     =     -.66071-05
C4     =      .20022-08
C5     =      .63274-15

AXIAL STORAGE LOCATIONS FOR AXIAL VELOCITY

   I      X-METER

   1    -.10000-02
   2     .00000
   3     .30000-02
   4     .80000-02
   5     .16000-01
   6     .28000-01
   7     .45000-01
   8     .80000-01
   9     .14000+00
  10     .24000+00
  11     .39000+00
  12     .39000+00

RADIAL STORAGE LOCATIONS FOR RADIAL VELOCITY

   J      Y-METER

   1     .00000
   2     .24000-02
   3     .10000-01
   4     .30000-01
   5     .55000-01
```

```
     6    .70000-01
     7    .65000-01
     8    .11200+00
     9    .12700+00
    10    .12700+00

REFERENCE PRESSURE PASCL    .00000
IPREF                                2
JPREF                                7
TOL.FOR RESIDUAL FOR
PRESSURE CORRECT. EQN.      .20000-01
MAX. NO. OF SWEEPS FOR
PRESS. CORRECT. EQN.                50

MAX. RESIDUAL FOR FIELD VARIABLE               .10000-02
MAX. NO. OF ITERATIONS TO BE RUN                     300
NO. OF ITERATIONS BETWEEN TABULATION                 500
   OF FIELD VARIABLES
NO. OF ITERATIONS BETWEEN OUTPUT OF
     MONITORING INFORMATION                            1
ITERATION TO START CHEMICAL REACTION                 500
```

TURBULENT FLOW WITH COMBUSTION IN A BLUFF-BODY COMBUSTOR

```
FLOW RATE OF MAIN STREAM (AIR), KG/S-------------:      2.019+00
FLOW RATE OF SECONDARY STREAM (FUEL), KG/S-------:      1.681-03
TEMPERATURE OF MAIN STREAM, K---------------------:     2.930+02
TEMPERATURE OF SECONDARY STREAM, K----------------:     2.930+02
PRESSURE AT INLET, N/M**2-------------------------:     9.800+04
CONCENTRATION OF FUEL IN MAIN STREAM--------------:     0.000
CONCENTRATION OF FUEL IN SECONDARY STREAM---------:     1.000+00
SWIRL NUMBER--------------------------------------:     0.000
```

ITER NO.	UMOM / F.CONC	VMOM / M.FRAC	WMOM	MASS	ENTH	T EN	DISS	U / EN	V / T	W / FM	P / F	TE	D
	I---------------ABSOLUTE	RESIDUAL SOURCE SUMS					---I	I-------FIELD VALUES AT MONITORING LOCATION(5, 4)					--------I
1	3.82-01 / 1.00+00	2.34-04 / 1.00+00	0.00	5.88-01	1.23-01	3.30-02	9.62+04	2.84+00 / 4.03+05	-3.25+00 / 2.93+02	0.00 / 2.18-03	-1.37+03 / 2.18-03	5.25+00	2.89+03
2	9.51-01 / 7.99+00	1.82-01 / 7.99+00	0.00	1.43+01	9.78-01	1.16-02	3.15+05	-6.78+01 / 4.01+05	4.33+01 / 2.93+02	0.00 / 2.11-03	-1.97+02 / 2.11-03	1.03+01	9.43+03
3	5.86-01 / 4.03+00	4.33-01 / 4.03+00	0.00	1.19+00	4.94-01	7.09-03	2.38+05	-3.74+01 / 4.66+05	2.10+01 / 2.93+02	0.00 / 3.41-03	5.19+02 / 3.41-03	1.05+01	1.25+04
4	2.22-01 / 2.13+00	1.45-01 / 2.13+00	0.00	7.70-01	2.60-01	3.48-03	1.52+05	-2.31+01 / 4.77+05	1.08+01 / 2.93+02	0.00 / 3.62-03	-1.60+02 / 3.62-03	8.71+00	8.93+03
5	1.16-01 / 1.49+00	5.36-02 / 1.49+00	0.00	4.19-01	1.83-01	2.79-03	2.14+05	-1.85+01 / 5.48+05	1.01+01 / 2.93+02	0.00 / 5.04-03	-2.07+02 / 5.04-03	7.38+00	6.72+03

*** PROGRAM TERMINATED BEFORE CONVERGENCE CRITERION SATISFIED ***

- U VELOCITY (M/SEC) -

I = / J	1	2	3	4	5	6	7	8	9	10	11	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	4.93+01	4.93+01	4.93+01	4.93+01	4.91+01	4.86+01	4.74+01	4.42+01	4.04+01	3.85+01	3.85+01	.1195
8	4.93+01	4.93+01	4.94+01	4.94+01	4.94+01	4.88+01	4.73+01	4.38+01	4.01+01	3.89+01	3.89+01	.0985
7	4.93+01	4.93+01	4.99+01	5.11+01	5.17+01	4.99+01	4.59+01	4.12+01	3.80+01	3.74+01	3.74+01	.0775
6	0.00	0.00	5.04+00	9.35+00	1.47+01	2.32+01	2.79+01	3.16+01	3.19+01	3.28+01	3.28+01	.0625
5	0.00	0.00	-2.64+00	-4.94+00	-7.69+00	-1.00+01	-5.03+00	8.49+00	2.13+01	2.39+01	2.39+01	.0425
4	0.00	0.00	-7.89+00	-1.42+01	-1.85+01	-2.00+01	-1.74+01	-1.10+01	3.66+00	1.22+01	1.22+01	.0200
3	0.00	0.00	1.03+01	-2.18+00	-1.66+01	-2.46+01	-2.26+01	-1.71+01	-4.21+00	6.51+00	6.52+00	.0062
2	5.25+01	5.25+01	5.86+01	6.07+01	6.32+01	6.18+01	-6.52+00	-1.95+01	-1.12+01	6.55+00	6.56+00	.0012
1	5.25+01	5.25+01	6.12+01	6.41+01	7.00+01	6.08+01	-2.66+01	-1.56+01	-4.86+00	1.07+01	1.07+01	-.0012
X =	-.100-02	.000	.300-02	.800-02	.160-01	.280-01	.450-01	.800-01	.140+00	.240+00	.390+00	

- V VELOCITY (M/SEC) -

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1270
8	0.00	-1.61-02	-7.20-02	-1.65-01	-3.51-01	-6.93-01	-1.13+00	-1.46+00	-1.01+00	-3.13-01	-8.57-03	-3.32-02	.1120
7	0.00	5.56-02	2.08-01	1.59-01	-6.35-01	-2.36+00	-4.22+00	-5.10+00	-3.28+00	-7.89-01	-2.13-02	-9.00-02	.0850
6	0.00	0.00	3.50+00	4.23+00	4.36-01	-5.40+00	-8.97+00	-8.45+00	-4.86+00	-1.06+00	-2.89-02	-1.17-01	.0700
5	0.00	0.00	3.31+01	2.01+01	1.21+01	5.24+00	-6.67+00	-8.94+00	-6.10+00	-1.20+00	-3.30-02	-1.32-01	.0550
4	0.00	0.00	2.94+01	2.07+01	1.01+01	2.69+00	-1.74+00	-2.69+00	-3.60+00	-1.32+00	-2.66-02	-9.46-02	.0300
3	0.00	0.00	-1.63+01	1.20+01	8.51+00	3.23+00	6.84-01	-6.47-01	-1.05+00	-5.54-01	-2.16-03	2.34-02	.0100
2	0.00	0.00	1.14-01	3.68-01	1.85-01	5.78-01	5.14+00	4.35-01	-1.65-01	-2.13-01	2.22-03	2.60-03	.0024
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0000
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

PRESSURE (PASCAL)

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	-6.57+01	-6.89+01	-7.01+01	-7.02+01	-6.47+01	-4.20+01	1.22+01	1.59+02	3.21+02	3.74+02	0.00	.1195
8	0.00	-8.79+01	-8.97+01	-9.11+01	-9.44+01	-9.31+01	-6.53+01	7.47+00	1.71+02	3.33+02	3.83+02	0.00	.0985
7	0.00	0.00	-2.25+01	-1.03+02	-2.03+02	-2.59+02	-1.90+02	-3.10+01	1.91+02	3.55+02	3.88+02	0.00	.0775
6	0.00	0.00	-3.19+02	-3.85+02	-5.30+02	-5.57+02	-3.75+02	-6.08+01	2.09+02	3.75+02	3.92+02	0.00	.0625
5	0.00	0.00	-4.05+02	-4.46+02	-5.23+02	-5.77+02	-4.29+02	-6.14+01	2.35+02	4.04+02	3.98+02	0.00	.0425
4	0.00	0.00	1.05+02	-9.69+00	-2.07+02	-3.58+02	-2.79+02	-4.86+00	2.72+02	4.21+02	4.02+02	0.00	.0200
3	0.00	0.00	1.99+02	9.65+01	-1.07+02	-2.93+02	-2.02+02	2.53+01	2.85+02	4.27+02	4.04+02	0.00	.0062
2	0.00	0.00	6.58+02	1.48+02	-7.17+01	-2.75+02	-1.28+02	3.73+01	2.89+02	4.29+02	4.04+02	0.00	.0012
1	0.00	0.00	1.34+03	6.31+02	1.24+02	-2.62+02	-1.68+02	7.06+01	3.04+02	4.18+02	4.05+02	0.00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

KIN.EVERGY (M*2/SEC*2)

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	1.22+01	1.23+01	1.28+01	1.35+01	1.42+01	1.49+01	1.53+01	1.48+01	1.33+01	1.17+01	1.09+01	1.10+01	.1195
8	1.22+01	1.20+01	1.16+01	1.09+01	1.01+01	9.05+00	7.96+00	6.54+00	5.00+00	3.57+00	2.36+00	2.24+00	.0985
7	1.22+01	1.23+01	1.36+01	1.40+01	1.36+01	1.28+01	1.16+01	8.71+00	5.74+00	3.59+00	2.03+00	1.90+00	.0775
6	0.00	0.00	1.29+01	1.08+01	9.57+00	1.09+01	1.17+01	1.11+01	7.76+00	4.54+00	2.46+00	2.28+00	.0625
5	0.00	0.00	1.60+01	7.25+00	5.72+00	6.57+00	9.10+00	1.16+01	8.35+00	4.61+00	2.21+00	2.07+00	.0425
4	0.00	0.00	1.57+01	1.03+01	7.38+00	5.84+00	5.96+00	6.27+00	5.87+00	3.54+00	1.29+00	9.95-01	.0200
3	0.00	0.00	1.13+01	4.23+01	8.03+01	5.35+01	2.00+01	3.64+00	4.01+00	2.63+00	6.27-01	5.09-01	.0062
2	1.38+01	1.38+01	1.44+01	1.48+01	1.62+01	1.62+01	2.79+01	1.82+00	1.55+00	1.19+00	2.83-01	2.25-01	.0012
1	1.38+01	1.38+01	1.44+01	1.48+01	1.60+01	1.60+01	2.72+01	1.71+00	1.41+00	9.95-01	2.25-01	3.64-01	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

DISSIPATION (M*2/SEC*3)

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	7.73+03	2.28+03	2.41+03	2.59+03	2.80+03	3.00+03	3.09+03	2.94+03	2.51+03	2.08+03	1.88+03	1.90+03	.1195
8	7.73+03	7.55+03	7.05+03	6.34+03	5.44+03	4.43+03	3.43+03	2.28+03	1.34+03	7.13+02	3.73+02	3.48+02	.0985
7	7.73+03	2.28+03	2.83+03	3.27+03	3.29+03	3.29+03	3.21+03	2.50+03	1.47+03	7.46+02	3.49+02	3.26+02	.0775

J													
6	0.00	0.00	1.31+04	8.12+03	5.52+03	4.83+03	4.16+03	3.53+03	2.08+03	9.93+02	4.57+02	4.38+02	.0625
5	0.00	0.00	1.77+04	4.88+03	2.39+03	1.96+03	3.07+03	3.70+03	2.30+03	1.03+03	4.24+02	4.39+02	.0425
4	0.00	0.00	1.96+04	1.32+04	6.72+03	2.26+03	1.75+03	1.80+03	1.57+03	8.60+02	2.87+02	1.86+02	.0200
3	0.00	0.00	1.21+04	7.53+04	1.44+05	8.07+04	1.92+04	1.00+03	1.00+03	5.88+02	1.17+02	8.22+01	.0062
2	9.34+03	9.34+03	9.94+03	1.06+04	1.47+04	1.48+04	3.42+04	3.94+02	2.95+02	1.99+02	5.35+01	4.04+01	.0012
1	9.34+03	9.34+03	9.90+03	1.04+04	1.41+04	1.41+04	3.39+04	3.33+02	2.42+02	1.55+02	4.04+01	1.12+02	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

FUEL CONCENTRATION

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J													
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	1.69-10	1.39-09	2.16-09	2.28-09	1.77-09	1.17-09	1.21-09	2.47-09	8.54-09	6.46-10	.1195
8	0.00	0.00	1.46-07	7.38-07	5.23-07	3.62-07	2.45-07	1.61-07	1.01-07	6.06-08	1.38-07	8.26-09	.0985
7	0.00	0.00	1.85-04	5.75-04	5.02-04	3.57-04	2.28-04	1.12-04	5.00-05	2.94-05	2.09-05	5.75-06	.0775
6	0.00	0.00	2.14-02	1.13-02	6.94-03	4.36-03	2.35-03	1.16-03	4.64-04	2.79-04	1.91-04	9.57-05	.0625
5	0.00	0.00	2.16-02	4.39-03	2.60-03	2.20-03	2.44-03	9.40-04	8.55-04	5.32-04	3.79-04	1.96-04	.0425
4	0.00	0.00	3.42-02	1.05-02	5.04-03	1.20-03	6.78-04	6.46-04	6.65-04	6.40-04	4.62-04	2.33-04	.0200
3	0.00	0.00	6.40-02	1.19-01	1.08-01	8.58-02	1.72-02	7.11-04	5.86-04	5.37-04	4.56-04	3.48-04	.0062
2	1.00+00	1.00+00	9.67-01	9.04-01	8.03-01	6.89-01	5.02-01	1.17-03	6.57-04	5.05-04	4.50-04	4.10-04	.0012
1	1.00+00	1.00+00	9.56-01	8.67-01	7.31-01	6.06-01	3.24-01	1.91-03	8.11-04	4.57-04	4.10-04	4.10-04	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

MIXTURE FRACTION

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J													
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	1.69-10	1.39-09	2.16-09	2.28-09	1.77-09	1.17-09	1.21-09	2.47-09	8.54-09	6.46-10	.1195
8	0.00	0.00	1.46-07	7.38-07	5.23-07	3.62-07	2.45-07	1.61-07	1.01-07	6.06-08	1.38-07	8.26-09	.0985
7	0.00	0.00	1.85-04	5.75-04	5.02-04	3.57-04	2.28-04	1.12-04	5.00-05	2.94-05	2.09-05	5.75-06	.0775
6	0.00	0.00	2.14-02	1.13-02	6.94-03	4.36-03	2.35-03	1.16-03	4.64-04	2.79-04	1.91-04	9.57-05	.0625
5	0.00	0.00	2.16-02	4.39-03	2.60-03	2.20-03	2.44-03	9.40-04	8.55-04	5.32-04	3.79-04	1.96-04	.0425
4	0.00	0.00	3.42-02	1.05-02	5.04-03	1.20-03	6.78-04	6.46-04	6.65-04	6.40-04	4.62-04	2.33-04	.0200
3	0.00	0.00	6.40-02	1.19-01	1.08-01	8.58-02	1.72-02	7.11-04	5.86-04	5.37-04	4.56-04	3.48-04	.0062
2	1.00+00	1.00+00	9.67-01	9.04-01	8.03-01	6.89-01	5.02-01	1.17-03	6.57-04	5.05-04	4.50-04	4.10-04	.0012
1	1.00+00	1.00+00	9.56-01	8.67-01	7.31-01	6.06-01	3.24-01	1.91-03	8.11-04	4.57-04	4.10-04	4.10-04	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

ENTHALPY (M*2/SEC*2)

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J													
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	.1195
8	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	.0985
7	2.96+05	2.96+05	3.05+05	3.25+05	3.21+05	3.14+05	3.07+05	3.02+05	2.99+05	2.98+05	2.97+05	2.96+05	.0775
6	0.00	0.00	1.36+06	8.55+05	6.40+05	5.12+05	4.12+05	3.54+05	3.19+05	3.10+05	3.05+05	3.01+05	.0625
5	0.00	0.00	1.37+06	5.14+05	4.25+05	4.05+05	4.17+05	3.43+05	3.38+05	3.22+05	3.15+05	3.06+05	.0425
4	0.00	0.00	2.00+06	8.20+05	5.48+05	3.56+05	3.30+05	3.28+05	3.29+05	3.28+05	3.19+05	3.08+05	.0200
3	0.00	0.00	3.49+06	6.22+06	5.71+06	4.59+06	1.16+06	3.31+05	3.25+05	3.23+05	3.19+05	3.13+05	.0062
2	5.03+07	5.03+07	4.87+07	4.55+07	4.05+07	3.48+07	2.54+07	3.54+05	3.29+05	3.21+05	3.18+05	3.16+05	.0012
1	5.03+07	5.03+07	4.81+07	4.37+07	3.68+07	3.06+07	1.65+07	3.91+05	3.36+05	3.19+05	3.16+05	3.17+05	-.0012

X = -.150-02 -.500-03 .150-02 .550-02 .120-01 .220-01 .365-01 .625-01 .110+00 .190+00 .315+00 .465+00

VISCOSITY (N-SEC/M**2)

J \ I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	.1345
9	2.01-03	6.99-03	7.13-03	7.34-03	7.58-03	7.81-03	7.95-03	7.86-03	7.43-03	6.91-03	6.66-03	6.66-03	.1195
8	2.01-03	2.01-03	2.00-03	1.99-03	1.97-03	1.95-03	1.95-03	1.99-03	1.98-03	1.86-03	1.52-03	1.52-03	.0985
7	2.01-03	6.99-03	6.83-03	6.18-03	5.80-03	5.15-03	4.25-03	3.09-03	2.30-03	1.76-03	1.18-03	1.18-03	.0775
6	1.88-05	1.88-05	1.30-03	1.68-03	1.85-03	2.55-03	3.30-03	3.46-03	2.84-03	2.02-03	1.25-03	1.25-03	.0625
5	1.88-05	1.88-05	1.44-03	1.22-03	1.48-03	2.26-03	2.81-03	3.42-03	2.82-03	1.91-03	1.03-03	1.03-03	.0425
4	1.88-05	1.88-05	1.29-03	8.86-04	9.03-04	1.64-03	2.19-03	2.32-03	2.17-03	1.36-03	5.75-04	5.75-04	.0200
3	1.88-05	1.88-05	1.17-03	2.94-03	3.99-03	2.95-03	1.97-03	1.41-03	1.59-03	1.27-03	3.48-04	3.48-04	.0062
2	3.26-03	3.26-03	3.08-03	2.89-03	2.34-03	2.23-03	2.45-03	9.32-04	8.74-04	6.86-04	1.50-04	1.50-04	.0012
1	3.26-03	3.26-03	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

DENSITY (KG/M*3)

J \ I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.1345
9	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.1195
8	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0985
7	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0775
6	1.16+00	1.16+00	1.17+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0625
5	1.16+00	1.16+00	1.17+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0425
4	1.16+00	1.16+00	1.17+00	1.16+00	1.16 00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0200
3	1.16+00	1.16+00	1.23+00	1.22+00	1.19+00	1.17+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0062
2	1.77+00	1.77+00	1.61+00	1.52+00	1.43+00	1.36+00	1.24+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0012
1	1.77+00	1.77+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

TEMPERATURE (K)

J \ I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.1345
9	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.1195
8	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0985
7	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0775
6	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0625
5	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0425
4	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0200
3	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0062
2	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0012
1	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

MEAN SP. HT. (J/KG-K)

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J 10	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.1345
9	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.1195
8	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0985
7	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0775
6	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0625
5	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0425
4	1.01+03	1.01+03	1.00+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0200
3	1.01+03	1.01+03	9.96+02	9.90+02	9.99+02	1.00+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0062
2	8.40+02	8.40+02	8.47+02	8.62+02	8.86+02	9.07+02	9.56+02	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0012
1	8.40+02	8.40+02	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

- O2 MASS FRACTION -

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J 10	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.1345
9	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.1195
8	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.0985
7	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.0775
6	2.33-01	2.33-01	2.28-01	2.30-01	2.31-01	2.32-01	2.32-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.0625
5	2.33-01	2.33-01	2.28-01	2.32-01	2.32-01	2.32-01	2.32-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.0425
4	2.33-01	2.33-01	2.25-01	2.31-01	2.32-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.0200
3	2.33-01	2.33-01	2.18-01	2.05-01	2.08 01	2.13-01	2.29-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.0062
2	0.00	0.00	7.76-03	2.24-02	4.59-02	7.25-02	1.16-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.0012
1	0.00	0.00	1.03-02	3.09-02	6.28-02	9.18-02	1.58-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

- N2 MASS FRACTION -

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J 10	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	.1345
9	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	.1195
8	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	.0985
7	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	.0775
6	7.67-01	7.67-01	7.51-01	7.58-01	7.62-01	7.64-01	7.65-01	7.66-01	7.67-01	7.67-01	7.67-01	7.67-01	.0625
5	7.67-01	7.67-01	7.50-01	7.64-01	7.65-01	7.65-01	7.65-01	7.66-01	7.66-01	7.67-01	7.67-01	7.67-01	.0425
4	7.67-01	7.67-01	7.41-01	7.59-01	7.63-01	7.66-01	7.66-01	7.67-01	7.66-01	7.67-01	7.67-01	7.67-01	.0200
3	7.67-01	7.67-01	7.18-01	6.76-01	6.84-01	7.01-01	7.54-01	7.66-01	7.67-01	7.67-01	7.67-01	7.67-01	.0062
2	0.00	0.00	2.56-02	7.36-02	1.51-01	2.19-01	3.82-01	7.66-01	7.66-01	7.67-01	7.67-01	7.67-01	.0012
1	0.00	0.00	3.39-02	1.02-01	2.07-01	3.02-01	5.19-01	7.66-01	7.66-01	7.67-01	7.67-01	7.67-01	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

- CO2 MASS FRACTION -

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J 10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1195
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0985
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0775

J	1	2	3	4	5	6	7	8	9	10	11	12	Y
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0625
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0425
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0200
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0062
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0012
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

- H2O MASS FRACTION -*

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1195
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0985
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0775
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0625
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0425
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0200
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0062
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0012
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

FLOWIN=	2.021+00		
FIN=	8.321-04	FOUT=	3.398-05
ENIN=	3.377+05	ENOUT=	2.977+05
TIN=	2.930+02	TOUT=	2.930+02

@BRKPT PRINTS

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TURBULENT FLOW IN A BLUFF-BODY COMBUSTOR

FOR WPAFB1 - COLD FLOW TEST CASE

NUMBER OF ITERATIONS TO EXECUTE          70

MODOP  = 2, START FROM RESTART FILE

ISCEME = 2, USE SKEW DIFFERENCING

INDCOS = 2, CYLINDRICAL CO-ORDINATES

KNPRO  = 1, FLUID PROPERTIES ARE VARIABLE

KNCOMP = 1, FLOW IS INCOMPRESSIBLE

KVISCO = 0, VISCOSITY IS VARIABLE

KLAMNR = 0, FLOW IS TURBULENT

GRID CONTROLS

NI     =     12
NJ     =     10
ISTEP  =      2
JSTEP  =      6
JEXIT  =      9
JINS   =      2
IMON   =      5
JMON   =      4


DEPENDENT VARIABLE EQUATION CONTROLS

VARIABLE                          SWITCH  NO. SWEEPS UNDER RELAX
                                                       FACTOR

U VELOCITY                           1          2    .70000+00
V VELOCITY                           2          2    .70000+00
PRIMARY PRESSURE CORRECT             3          3    .10000+01
TURBULENCE ENERGY                    4          1    .70000+00
ENERGY DISSIPATION                   5          1    .70000+00
ENTHALPY                             6          1    .60000+00
FULL CONCENTRATION                   7          1    .60000+00
MIXTURE FRACTION                     8          1    .60000+00
SWIRL VELOCITY                       0          0    .00000
SEC. PRESSURE CORRECT.              10          1    .70000+00
VISCOSITY                                            .10000+01
DENSITY                                              .40000+00

VISCOSITY      N-SEC/M**2   .18800-04
DENSITY          KG/M**3    .11609+01
WALL TEMPERATURE        K   .29300+03
BLUFF BODY TEMPERATURE  K   .29300+03

FLOW CONDITIONS...
```

VARIABLE		OUTER FLOW	INNER FLOW
AXIAL VELOCITY	M/SEC	.49300+02	.52500+02
SWIRL/AXIAL VEL. RATIO		.00000	.00000
TEMPERATURE	K	.29300+03	.29300+03
CONC.-SECOND COMPONENT		.00000	.10000+01
TURB. INTENSITY FACTOR		.50000-02	.50000-02
BNDY. LAYER THICKNESS	M	.10000-01	.10000-01
PRESSURE	N/M**2	.98000+05	

STOIC. O2/FUEL MASS RAT.		.36350+01
HEAT OF COMBUSTION	J/KG	.50080+08
FUEL MOLECULAR WEIGHT		.44000+02

CP-O2	J/KG-K	.91300+03
CP-N2	J/KG-K	.10400+04
CP-CO2	J/KG-K	.83400+03
CP-H2O	J/KG-K	.20200+04

CO-EFFICIENTS OF THE POLYNOMIAL FOR THE HEAT CAPACITY FOR THE SECOND COMPONENT (E.G.,FUEL)

```
CP = (C1 + C2*T + C3*T**2 + C4*T**3 + C5*T**4)*UGC /WMF
     WITH T IN DEG K AND CP IN J/KG-K
```

C1	=	.24008+01
C2	=	.87351-02
C3	=	-.66071-05
C4	=	.20022-08
C5	=	.63274-15

AXIAL STORAGE LOCATIONS FOR AXIAL VELOCITY

I	X-METER
1	-.10000-02
2	.00000
3	.30000-02
4	.80000-02
5	.16000-01
6	.28000-01
7	.45000-01
8	.80000-01
9	.14000+00
10	.24000+00
11	.39000+00
12	.39000+00

RADIAL STORAGE LOCATIONS FOR RADIAL VELOCITY

J	Y-METER
1	.00000
2	.24000-02
3	.10000-01
4	.30000-01
5	.55000-01

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   6     .70000-01
   7     .85000-01
   8     .11200+00
   9     .12700+00
  10     .12700+00

REFERENCE PRESSURE PASCL      .00000
IPREF                              2
JPREF                              7
TOL.FOR RESIDUAL FOR
PRESSURE CORRECT. EQN.        .20000-01
MAX. NO. OF SWEEPS FOR
PRESS. CORRECT. EQN.              50

MAX. RESIDUAL FOR FIELD VARIABLE           .10000-02
MAX. NO. OF ITERATIONS TO BE RUN                 300
NO. OF ITERATIONS BETWEEN TABULATION             500
   OF FIELD VARIABLES
NO. OF ITERATIONS BETWEEN OUTPUT OF                1
   MONITORING INFORMATION
ITERATION TO START CHEMICAL REACTION             500
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TURBULENT FLOW WITH COMBUSTION IN A BLUFF-BODY COMBUSTOR

FLOW RATE OF MAIN STREAM (AIR), KG/S-------------:	2.019+00
FLOW RATE OF SECONDARY STREAM (FUEL), KG/S-------:	1.681-03
TEMPERATURE OF MAIN STREAM, K--------------------:	2.930+02
TEMPERATURE OF SECONDARY STREAM, K---------------:	2.930+02
PRESSURE AT INLET, N/M**2------------------------:	9.800+04
CONCENTRATION OF FUEL IN MAIN STREAM-------------:	0.000
CONCENTRATION OF FUEL IN SECONDARY STREAM--------:	1.000+00
SWIRL NUMBER-------------------------------------:	0.000

ITER NO.	UMOM F.CONC	VMOM M.FRAC	WMOM	MASS	ENTH	T EN	DISS	U EN	V T	W FM	P F	TE	D
	I---------------ABSOLUTE RESIDUAL SOURCE SUMS						---I	I-------FIELD VALUES AT MONITORING LOCATION(5, 4)					---I
31	6.57-03 5.82-01	1.06-02 5.82-01	0.00	7.03-02	7.18-02	2.36-03	4.34+03	-7.29+00 3.43+06	5.08+00 2.93+02	0.00 6.26-02	-1.56+02 6.26-02	9.87+01	2.87+04
32	5.89-03 4.95-01	7.92-03 4.95-01	0.00	5.44-02	6.10-02	1.78-03	4.17+03	-7.33+00 3.44+06	5.17+00 2.93+02	0.00 6.28-02	-1.58+02 6.28-02	9.98+01	2.91+04
33	5.51-03 4.20-01	6.26-03 4.20-01	0.00	4.08-02	5.18-02	1.34-03	4.23+03	-7.39+00 3.44+06	5.26+00 2.93+02	0.00 6.29-02	-1.60+02 6.29-02	1.01+02	2.96+04
34	4.84-03 3.61-01	4.83-03 3.61-01	0.00	3.08-02	4.45-02	1.10-03	3.87+03	-7.46+00 3.44+06	5.34+00 2.93+02	0.00 6.28-02	-1.62+02 6.28-02	1.03+02	3.02+04
35	4.21-03 3.14-01	3.80-03 3.14-01	0.00	2.38-02	3.86-02	9.30-04	3.66+03	-7.53+00 3.43+06	5.41+00 2.93+02	0.00 6.26-02	-1.64+02 6.26-02	1.04+02	3.08+04
36	3.83-03 2.79-01	3.04-03 2.79-01	0.00	1.81-02	3.45-02	8.10-04	3.73+03	-7.58+00 3.42+06	5.48+00 2.93+02	0.00 6.24-02	-1.66+02 6.24-02	1.06+02	3.13+04
37	3.23-03 2.49-01	2.38-03 2.49-01	0.00	1.38-02	3.07-02	7.01-04	3.80+03	-7.63+00 3.40+06	5.54+00 2.93+02	0.00 6.21-02	-1.68+02 6.21-02	1.07+02	3.17+04
38	2.77-03 2.27-01	1.91-03 2.27-01	0.00	1.11-02	2.80-02	6.09-04	3.52+03	-7.66+00 3.39+06	5.58+00 2.93+02	0.00 6.18-02	-1.70+02 6.18-02	1.08+02	3.21+04
39	2.40-03 2.12-01	1.59-03 2.12-01	0.00	9.28-03	2.62-02	5.31-04	1.14+04	-7.69+00 3.37+06	5.62+00 2.93+02	0.00 6.15-02	-1.71+02 6.15-02	1.10+02	3.24+04
40	2.10-03 1.99-01	1.35-03 1.99-01	0.00	7.96-03	2.45-02	4.69-04	1.63+04	-7.71+00 3.36+06	5.65+00 2.93+02	0.00 6.12-02	-1.73+02 6.12-02	1.11+02	3.27+04
41	1.88-03 1.87-01	1.16-03 1.87-01	0.00	6.88-03	2.30-02	4.16-04	1.65+04	-7.72+00 3.34+06	5.67+00 2.93+02	0.00 6.09-02	-1.74+02 6.09-02	1.12+02	3.29+04
42	1.70-03 1.76-01	1.02-03 1.76-01	0.00	6.00-03	2.17-02	3.68-04	1.43+04	-7.73+00 3.33+06	5.68+00 2.93+02	0.00 6.05-02	-1.75+02 6.05-02	1.13+02	3.31+04
43	1.54-03 1.65-01	8.99-04 1.65-01	0.00	5.28-03	2.03-02	3.26-04	1.18+04	-7.73+00 3.31+06	5.69+00 2.93+02	0.00 6.02-02	-1.76+02 6.02-02	1.14+02	3.32+04

44	1.41-03 1.55-01	7.99-04 1.55-01	0.00	4.63-03	1.91-02	2.68-04	9.69+03	-7.72+00 3.30+06	5.70+00 2.93+02	0.00 5.99-02	-1.77+02 5.99-02	1.15+02	3.33+04
45	1.29-03 1.47-01	7.15-04 1.47-01	0.00	4.05-03	1.82-02	2.53-04	8.38+03	-7.72+00 3.28+06	5.71+00 2.93+02	0.00 5.97-02	-1.78+02 5.97-02	1.15+02	3.33+04
46	1.17-03 1.41-01	6.42-04 1.41-01	0.00	3.51-03	1.74-02	2.22-04	6.87+03	-7.71+00 3.27+06	5.71+00 2.93+02	0.00 5.94-02	-1.79+02 5.94-02	1.16+02	3.34+04
47	1.07-03 1.35-01	5.73-04 1.35-01	0.00	3.04-03	1.66-02	1.93-04	5.96+03	-7.71+00 3.25+06	5.72+00 2.93+02	0.00 5.91-02	-1.79+02 5.91-02	1.16+02	3.34+04
48	9.65-04 1.30-01	5.09-04 1.30-01	0.00	2.62-03	1.60-02	1.67-04	5.25+03	-7.70+00 3.24+06	5.72+00 2.93+02	0.00 5.89-02	-1.80+02 5.89-02	1.17+02	3.34+04
49	8.67-04 1.26-01	4.49-04 1.26-01	0.00	2.33-03	1.55-02	1.45-04	4.79+03	-7.70+00 3.23+06	5.72+00 2.93+02	0.00 5.86-02	-1.80+02 5.86-02	1.17+02	3.34+04
50	7.73-04 1.23-01	3.94-04 1.23-01	0.00	2.07-03	1.52-02	1.27-04	4.57+03	-7.69+00 3.22+06	5.73+00 2.93+02	0.00 5.84-02	-1.80+02 5.84-02	1.17+02	3.35+04
51	6.84-04 1.21-01	3.43-04 1.21-01	0.00	1.82-03	1.49-02	1.14-04	4.46+03	-7.69+00 3.21+06	5.73+00 2.93+02	0.00 5.82-02	-1.81+02 5.82-02	1.18+02	3.35+04
52	6.04-04 1.19-01	2.97-04 1.19-01	0.00	1.60-03	1.46-02	1.02-04	4.36+03	-7.69+00 3.20+06	5.73+00 2.93+02	0.00 5.80-02	-1.81+02 5.80-02	1.18+02	3.35+04
53	5.26-04 1.16-01	2.55-04 1.16-01	0.00	1.41-03	1.43-02	9.02-05	4.22+03	-7.68+00 3.19+06	5.74+00 2.93+02	0.00 5.78-02	-1.81+02 5.78-02	1.18+02	3.35+04
54	4.54-04 1.14-01	2.17-04 1.14-01	0.00	1.23-03	1.40-02	7.89-05	4.01+03	-7.68+00 3.18+06	5.74+00 2.93+02	0.00 5.77-02	-1.82+02 5.77-02	1.19+02	3.35+04
55	3.89-04 1.11-01	1.83-04 1.11-01	0.00	1.05-03	1.36-02	6.85-05	3.75+03	-7.68+00 3.17+06	5.74+00 2.93+02	0.00 5.75-02	-1.82+02 5.75-02	1.19+02	3.36+04
56	3.32-04 1.07-01	1.54-04 1.07-01	0.00	9.05-04	1.32-02	5.90-05	3.47+03	-7.68+00 3.17+06	5.75+00 2.93+02	0.00 5.74-02	-1.82+02 5.74-02	1.19+02	3.36+04
57	2.81-04 1.04-01	1.32-04 1.04-01	0.00	7.83-04	1.28-02	5.05-05	3.18+03	-7.68+00 3.16+06	5.75+00 2.93+02	0.00 5.72-02	-1.82+02 5.72-02	1.19+02	3.36+04
58	2.37-04 1.01-01	1.13-04 1.01-01	0.00	6.75-04	1.24-02	4.31-05	2.90+03	-7.68+00 3.15+06	5.75+00 2.93+02	0.00 5.71-02	-1.82+02 5.71-02	1.19+02	3.36+04
59	1.99-04 9.75-02	9.55-05 9.75-02	0.00	5.78-04	1.20-02	3.67-05	2.62+03	-7.68+00 3.15+06	5.75+00 2.93+02	0.00 5.70-02	-1.82+02 5.70-02	1.20+02	3.36+04
60	1.66-04 9.40-02	8.04-05 9.40-02	0.00	4.92-04	1.16-02	3.13-05	2.37+03	-7.68+00 3.14+06	5.76+00 2.93+02	0.00 5.69-02	-1.83+02 5.69-02	1.20+02	3.36+04
61	1.39-04 9.04-02	6.72-05 9.04-02	0.00	4.16-04	1.11-02	2.67-05	2.12+03	-7.68+00 3.14+06	5.76+00 2.93+02	0.00 5.68-02	-1.83+02 5.68-02	1.20+02	3.36+04
62	1.16-04 8.68-02	5.59-05 8.68-02	0.00	3.49-04	1.07-02	2.26-05	1.90+03	-7.68+00 3.13+06	5.76+00 2.93+02	0.00 5.67-02	-1.83+02 5.67-02	1.20+02	3.36+04
63	9.66-05 8.32-02	4.73-05 8.32-02	0.00	2.92-04	1.03-02	1.93-05	1.70+03	-7.68+00 3.13+06	5.76+00 2.93+02	0.00 5.66-02	-1.83+02 5.66-02	1.20+02	3.36+04

64	9.11-05 7.96-02	4.31-05 7.96-02	0.00	2.44-04	9.81-03	1.64-05	1.51+03	-7.68+00 3.12+06	5.76+00 2.93+02	0.00 5.65-02	-1.83+02 5.65-02	1.20+02	3.37+04
65	6.85-05 7.61-02	3.44-05 7.61-02	0.00	2.03-04	9.36-03	1.41-05	1.35+03	-7.68+00 3.12+06	5.76+00 2.93+02	0.00 5.64-02	-1.83+02 5.64-02	1.20+02	3.37+04
66	5.83-05 7.27-02	3.03-05 7.27-02	0.00	1.71-04	8.96-03	1.21-05	1.19+03	-7.68+00 3.12+06	5.76+00 2.93+02	0.00 5.64-02	-1.83+02 5.64-02	1.20+02	3.37+04
67	5.01-05 6.93-02	2.73-05 6.93-02	0.00	1.48-04	8.54-03	1.09-05	1.06+03	-7.67+00 3.11+06	5.76+00 2.93+02	0.00 5.63-02	-1.83+02 5.63-02	1.20+02	3.37+04
68	4.34-05 6.60-02	2.49-05 6.60-02	0.00	1.35-04	8.14-03	9.81-06	9.37+02	-7.67+00 3.11+06	5.76+00 2.93+02	0.00 5.62-02	-1.83+02 5.62-02	1.20+02	3.37+04
69	3.78-05 6.28-02	2.29-05 6.28-02	0.00	1.25-04	7.74-03	8.89-06	8.28+02	-7.67+00 3.11+06	5.76+00 2.93+02	0.00 5.62-02	-1.83+02 5.62-02	1.20+02	3.37+04
70	3.33-05 5.97-02	2.12-05 5.97-02	0.00	1.17-04	7.36-03	8.13-06	7.32+02	-7.67+00 3.10+06	5.77+00 2.93+02	0.00 5.61-02	-1.83+02 5.61-02	1.20+02	3.37+04
71	2.96-05 5.67-02	1.95-05 5.67-02	0.00	1.09-04	6.99-03	7.42-06	6.47+02	-7.67+00 3.10+06	5.77+00 2.93+02	0.00 5.61-02	-1.83+02 5.61-02	1.20+02	3.37+04
72	2.65-05 5.38-02	1.79-05 5.38-02	0.00	1.01-04	6.64-03	6.75-06	5.72+02	-7.67+00 3.10+06	5.77+00 2.93+02	0.00 5.60-02	-1.83+02 5.60-02	1.20+02	3.37+04
73	2.39-05 5.11-02	1.63-05 5.11-02	0.00	9.33-05	6.29-03	6.13-06	5.06+02	-7.67+00 3.10+06	5.77+00 2.93+02	0.00 5.60-02	-1.83+02 5.60-02	1.20+02	3.37+04
74	2.17-05 4.84-02	1.49-05 4.84-02	0.00	8.53-05	5.96-03	5.54-06	4.47+02	-7.67+00 3.09+06	5.77+00 2.93+02	0.00 5.59-02	-1.83+02 5.59-02	1.20+02	3.37+04
75	1.97-05 4.56-02	1.35-05 4.58-02	0.00	7.72-05	5.65-03	5.00-06	3.95+02	-7.67+00 3.09+06	5.77+00 2.93+02	0.00 5.59-02	-1.83+02 5.59-02	1.20+02	3.37+04
76	1.79-05 4.34-02	1.22-05 4.34-02	0.00	6.95-05	5.35-03	4.49-06	3.49+02	-7.67+00 3.09+06	5.77+00 2.93+02	0.00 5.59-02	-1.83+02 5.59-02	1.20+02	3.37+04
77	1.63-05 4.10-02	1.09-05 4.10-02	0.00	6.23-05	5.06-03	4.02-06	3.09+02	-7.67+00 3.09+06	5.77+00 2.93+02	0.00 5.58-02	-1.83+02 5.58-02	1.20+02	3.37+04
78	1.48-05 3.88-02	9.76-06 3.88-02	0.00	5.53-05	4.78-03	3.57-06	2.73+02	-7.67+00 3.09+06	5.77+00 2.93+02	0.00 5.58-02	-1.83+02 5.58-02	1.20+02	3.37+04
79	1.35-05 3.66-02	8.67-06 3.66-02	0.00	4.87-05	4.52-03	3.17-06	2.41+02	-7.67+00 3.09+06	5.77+00 2.93+02	0.00 5.58-02	-1.83+02 5.58-02	1.20+02	3.37+04
80	1.23-05 3.46-02	7.66-06 3.46-02	0.00	4.29-05	4.26-03	2.81-06	2.13+02	-7.67+00 3.08+06	5.77+00 2.93+02	0.00 5.57-02	-1.83+02 5.57-02	1.20+02	3.37+04
81	1.11-05 3.26-02	6.83-06 3.26-02	0.00	3.76-05	4.02-03	2.48-06	1.88+02	-7.67+00 3.08+06	5.77+00 2.93+02	0.00 5.57-02	-1.83+02 5.57-02	1.20+02	3.37+04
82	1.01-05 3.06-02	6.06-06 3.08-02	0.00	3.28-05	3.80-03	2.19-06	1.67+02	-7.67+00 3.08+06	5.77+00 2.93+02	0.00 5.57-02	-1.83+02 5.57-02	1.20+02	3.37+04
83	9.03-06 2.90-02	5.35-06 2.90-02	0.00	2.84-05	3.58-03	1.93-06	1.47+02	-7.67+00 3.08+06	5.77+00 2.93+02	0.00 5.57-02	-1.83+02 5.57-02	1.20+02	3.37+04

84	9.12-06 2.74-02	4.70-06 2.74-02	0.00	2.46-05	3.37-03	1.70-06	1.30+02	-7.67+00 3.08+06	5.77+00 2.93+02	0.00 5.56-02	-1.83+02 5.56-02	1.20+02	3.37+04
85	7.26-06 2.58-02	4.12-06 2.58-02	0.00	2.14-05	3.18-03	1.49-06	1.15+02	-7.67+00 3.08+06	5.77+00 2.93+02	0.00 5.56-02	-1.83+02 5.56-02	1.20+02	3.37+04
86	6.46-06 2.43-02	3.60-06 2.43-02	0.00	1.86-05	2.99-03	1.31-06	1.02+02	-7.67+00 3.08+06	5.77+00 2.93+02	0.00 5.56-02	-1.83+02 5.56-02	1.20+02	3.37+04
87	5.70-06 2.28-02	3.16-06 2.28-02	0.00	1.64-05	2.82-03	1.15-06	8.98+01	-7.67+00 3.08+06	5.77+00 2.93+02	0.00 5.56-02	-1.83+02 5.56-02	1.20+02	3.37+04
88	5.05-06 2.15-02	2.74-06 2.15-02	0.00	1.43-05	2.65-03	1.01-06	7.94+01	-7.67+00 3.08+06	5.77+00 2.93+02	0.00 5.56-02	-1.83+02 5.56-02	1.20+02	3.37+04
89	4.41-06 2.02-02	2.37-06 2.02-02	0.00	1.25-05	2.49-03	8.82-07	7.02+01	-7.67+00 3.08+06	5.77+00 2.93+02	0.00 5.56-02	-1.83+02 5.56-02	1.20+02	3.37+04
90	3.64-06 1.90-02	2.05-06 1.90-02	0.00	1.08-05	2.34-03	7.73-07	6.21+01	-7.67+00 3.08+06	5.77+00 2.93+02	0.00 5.55-02	-1.83+02 5.55-02	1.20+02	3.37+04
91	3.34-06 1.79-02	1.75-06 1.79-02	0.00	9.34-06	2.20-03	6.80-07	5.49+01	-7.67+00 3.07+06	5.77+00 2.93+02	0.00 5.55-02	-1.83+02 5.55-02	1.20+02	3.37+04
92	2.86-06 1.68-02	1.49-06 1.68-02	0.00	8.07-06	2.07-03	5.96-07	4.85+01	-7.67+00 3.07+06	5.77+00 2.93+02	0.00 5.55-02	-1.83+02 5.55-02	1.20+02	3.37+04
93	2.54-06 1.58-02	1.28-06 1.58-02	0.00	7.01-06	1.95-03	5.24-07	4.29+01	-7.67+00 3.07+06	5.77+00 2.93+02	0.00 5.55-02	-1.83+02 5.55-02	1.20+02	3.37+04
94	2.18-06 1.48-02	1.09-06 1.48-02	0.00	5.99-06	1.83-03	4.57-07	3.79+01	-7.67+00 3.07+06	5.77+00 2.93+02	0.00 5.55-02	-1.83+02 5.55-02	1.20+02	3.37+04
95	1.87-06 1.39-02	9.14-07 1.39-02	0.00	5.06-06	1.72-03	4.00-07	3.34+01	-7.67+00 3.07+06	5.77+00 2.93+02	0.00 5.55-02	-1.83+02 5.55-02	1.20+02	3.37+04
96	1.63-06 1.31-02	7.76-07 1.31-02	0.00	4.30-06	1.61-03	3.50-07	2.95+01	-7.67+00 3.07+06	5.77+00 2.93+02	0.00 5.55-02	-1.83+02 5.55-02	1.20+02	3.37+04
97	1.39-06 1.23-02	6.74-07 1.23-02	0.00	3.89-06	1.51-03	3.06-07	2.60+01	-7.67+00 3.07+06	5.77+00 2.93+02	0.00 5.55-02	-1.83+02 5.55-02	1.20+02	3.37+04
98	1.24-06 1.15-02	5.65-07 1.15-02	0.00	3.27-06	1.42-03	2.69-07	2.29+01	-7.67+00 3.07+06	5.77+00 2.93+02	0.00 5.55-02	-1.83+02 5.55-02	1.20+02	3.37+04
99	1.01-06 1.08-02	4.94-07 1.08-02	0.00	2.94-06	1.33-03	2.34-07	2.02+01	-7.67+00 3.07+06	5.77+00 2.93+02	0.00 5.55-02	-1.83+02 5.55-02	1.20+02	3.37+04
100	9.49-07 1.01-02	4.13-07 1.01-02	0.00	2.40-06	1.25-03	2.04-07	1.78+01	-7.67+00 3.07+06	5.77+00 2.93+02	0.00 5.55-02	-1.83+02 5.55-02	1.20+02	3.37+04

*** PROGRAM TERMINATED BEFORE CONVERGENCE CRITERION SATISFIED ***

-*- U VELOCITY (M/SEC) -*-

I = 1 2 3 4 5 6 7 8 9 10 11 Y =
J

J												Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	4.93+01	4.93+01	4.93+01	4.93+01	4.91+01	4.88+01	4.80+01	4.58+01	4.22+01	3.91+01	3.91+01	.1195
8	4.93+01	4.93+01	4.93+01	4.93+01	4.92+01	4.90+01	4.83+01	4.61+01	4.26+01	4.01+01	4.01+01	.0985
7	4.93+01	4.93+01	4.93+01	4.93+01	4.92+01	4.87+01	4.77+01	4.55+01	4.23+01	3.82+01	3.82+01	.0775
6	0.00	0.00	1.94+00	4.62+00	8.27+00	1.20+01	1.51+01	2.09+01	2.67+01	2.99+01	2.99+01	.0625
5	0.00	0.00	-9.56-01	-2.22+00	-3.54+00	-3.84+00	-2.26+00	2.71+00	1.20+01	2.03+01	2.03+01	.0425
4	0.00	0.00	-2.34+00	-4.96+00	-7.67+00	-9.67+00	-1.00+01	-6.33+00	3.46+00	1.43+01	1.43+01	.0200
3	0.00	0.00	4.19+00	5.41+00	1.31+00	-7.45+00	-1.08+01	-8.18+00	1.70+00	1.30+01	1.30+01	.0062
2	5.25+01	5.25+01	5.03+01	4.20+01	1.89+01	-5.70+00	-1.09+01	-8.35+00	1.54+00	1.29+01	1.29+01	.0012
1	5.25+01	5.25+01	5.03+01	4.20+01	1.89+01	-5.70+00	-1.09+01	-8.35+00	1.54+00	1.29+01	1.29+01	-.0012
X =	-.100-02	.000	.300-02	.800-02	.160-01	.280-01	.450-01	.800-01	.140+00	.240+00	.390+00	

V VELOCITY (M/SEC)

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1270
8	0.00	-1.68-02	-6.84-02	-1.50-01	-2.76-01	-4.61-01	-7.04-01	-1.01+00	-9.80-01	-4.96-01	5.01-05	5.00-05	.1120
7	0.00	-2.84-02	-1.21-01	-2.92-01	-6.56-01	-1.31+00	-2.22+00	-3.28+00	-3.13+00	-1.41+00	5.19-04	5.19-04	.0850
6	0.00	0.00	-2.43-01	-3.35-01	-1.11+00	-2.21+00	-3.66+00	-5.00+00	-4.69+00	-2.40+00	6.00-04	6.00-04	.0700
5	0.00	0.00	1.07+01	8.66+00	6.35+00	2.42+00	-1.50+00	-3.58+00	-4.32+00	-2.51+00	4.11-04	4.11-04	.0550
4	0.00	0.00	8.32+00	6.91+00	5.77+00	3.54+00	5.68-01	-1.54+00	-2.45+00	-1.64+00	1.56-04	1.57-04	.0300
3	0.00	0.00	-6.22+00	-2.61-01	3.68+00	4.09+00	9.93-01	-3.84-01	-8.24-01	-5.68-01	4.63-05	4.63-05	.0100
2	0.00	0.00	1.49+00	3.10+00	4.44+00	2.66+00	3.53-01	-8.74-02	-1.98-01	-1.37-01	1.10-05	1.10-05	.0024
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0000
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

PRESSURE (PASCAL)

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	5.61+01	5.49+01	5.36+01	5.31+01	5.64+01	6.99+01	1.01+02	2.03+02	3.63+02	4.76+02	0.00	.1195
8	0.00	3.68+01	3.51+01	3.58+01	3.74+01	4.25+01	5.87+01	9.82+01	2.09+02	3.74+02	4.85+02	0.00	.0985
7	0.00	0.00	-3.13+00	-7.99+00	-2.25+01	-3.16+01	-1.63+01	4.81+01	1.96+02	3.78+02	4.74+02	0.00	.0775
6	0.00	0.00	-1.59+02	-1.86+02	-2.09+02	-2.11+02	-1.97+02	-1.22+02	8.54+01	3.32+02	4.51+02	0.00	.0625
5	0.00	0.00	-1.07+02	-1.77+02	-2.01+02	-2.12+02	-1.98+02	-1.13+02	6.87+01	3.24+02	4.51+02	0.00	.0425
4	0.00	0.00	-4.75+01	-1.60+02	-1.83+02	-1.92+02	-1.65+02	-8.20+01	8.71+01	3.38+02	4.65+02	0.00	.0200
3	0.00	0.00	-9.79+01	-2.06+02	-2.33+02	-1.66+02	-1.27+02	-6.92+01	9.44+01	3.43+02	4.69+02	0.00	.0062
2	0.00	0.00	1.01+02	2.29+02	1.99+02	2.40+01	-1.01+02	-6.76+01	9.53+01	3.43+02	4.69+02	0.00	.0012
1	0.00	0.00	1.01+02	2.29+02	1.99+02	2.41+01	-1.01+02	-6.76+01	9.53+01	3.43+02	4.69+02	0.00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

KIN.EVERGY (M*2/SEC*2)

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	1.22+01	1.23+01	1.28+01	1.35+01	1.43+01	1.51+01	1.57+01	1.56+01	1.43+01	1.25+01	1.15+01	1.15+01	.1195
8	1.22+01	1.20+01	1.16+01	1.09+01	1.01+01	8.99+00	7.83+00	6.32+00	4.87+00	3.67+00	4.43+00	4.43+00	.0985
7	1.22+01	1.23+01	1.31+01	1.45+01	1.66+01	1.94+01	2.14+01	2.16+01	1.84+01	2.06+01	3.01+01	3.01+01	.0775
6	0.00	0.00	6.29+00	6.49+01	1.06+02	1.39+02	1.67+02	1.92+02	1.60+02	9.65+01	7.03+01	7.03+01	.0625
5	0.00	0.00	1.22+01	7.26+01	8.82+01	1.01+02	1.26+02	1.65+02	1.74+02	1.18+02	8.39+01	8.39+01	.0425
4	0.00	0.00	1.53+01	9.88+01	1.20+02	1.23+02	1.13+02	1.31+02	1.51+02	1.01+02	7.26+01	7.26+01	.0200

J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
3	0.00	0.00	8.53+00	1.75+02	2.64+02	[illegible]	1.17+02	[illegible]	1.44+02	9.61+01	6.89+01	6.89+01	.0062
2	1.38+01	1.38+01	1.35+01	2.20+01	1.36+02	2.38+02	1.16+02	1.23+02	1.44+02	9.56+01	6.85+01	6.85+01	.0012
1	1.38+01	1.38+01	1.35+01	2.20+01	1.36+02	2.38+02	1.18+02	1.23+02	1.44+02	9.56+01	6.85+01	6.85+01	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

*- DISSIPATION (M**2/SEC**3) -*

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	7.73+03	2.27+03	2.40+03	2.60+03	2.84+03	3.08+03	3.24+03	3.21+03	2.84+03	2.31+03	2.03+03	2.03+03	.1195
8	7.73+03	7.55+03	7.05+03	6.33+03	5.42+03	4.40+03	3.39+03	2.24+03	1.32+03	7.20+02	5.52+02	5.52+02	.0985
7	7.73+03	[illegible]	2.47+03	2.83+03	3.40+03	4.07+03	4.61+03	4.81+03	3.84+03	3.21+03	3.65+03	3.65+03	.0775
6	0.00	0.00	4.13+03	2.21+04	3.39+04	4.33+04	5.09+04	5.54+04	3.93+04	1.89+04	1.02+04	1.02+04	.0625
5	0.00	0.00	1.11+04	1.41+04	1.45+04	1.59+04	2.33+04	3.35+04	3.17+04	1.83+04	1.03+04	1.03+04	.0425
4	0.00	0.00	1.56+04	2.89+04	3.37+04	2.20+04	1.51+04	1.91+04	2.13+04	1.22+04	7.12+03	7.12+03	.0200
3	0.00	0.00	6.52+03	1.33+05	1.85+05	9.48+04	1.49+04	1.61+04	1.87+04	1.06+04	6.27+03	6.27+03	.0062
2	9.34+03	9.34+03	8.90+03	1.32+04	9.67+04	1.21+05	1.49+04	1.59+04	1.85+04	1.04+04	6.19+03	6.19+03	.0012
1	9.34+03	9.34+03	8.90+03	1.32+04	9.67+04	1.21+05	1.49+04	1.59+04	1.85+04	1.04+04	6.19+03	6.19+03	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

- FUEL CONCENTRATION -

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	4.10-11	6.78-10	2.65-09	5.14-09	7.72-09	1.04-08	1.46-08	3.08-08	2.30-05	2.30-05	.1195
8	0.00	0.00	2.61-08	2.56-07	5.44-07	5.42-07	5.38-07	5.31-07	5.06-07	4.60-07	2.28-04	2.28-04	.0985
7	0.00	0.00	3.68-05	2.55-04	6.51-04	1.15-03	1.56-03	1.80-03	1.73-03	1.67-03	1.60-03	1.60-03	.0775
6	0.00	0.00	2.83-02	2.53-02	2.19-02	1.75-02	1.25-02	7.25-03	4.13-03	2.75-03	2.20-03	2.20-03	.0625
5	0.00	0.00	3.46-02	3.20-02	2.86 02	2.20-02	1.44-02	7.91-03	4.70-03	3.28-03	2.61-03	2.62-03	.0425
4	0.00	0.00	6.12-02	6.12-02	5.55-02	3.35-02	1.53-02	7.05-03	4.67-03	3.40-03	2.77-03	2.77-03	.0200
3	0.00	0.00	1.75-01	2.29-01	2.13-01	8.82-02	1.94-02	6.85-03	4.66-03	3.42-03	2.80-03	2.81-03	.0062
2	1.00+00	1.00+00	9.88-01	8.92-01	5.50-01	1.34-01	2.03-02	6.83-03	4.67-03	3.43-03	2.81-03	2.81-03	.0012
1	1.00+00	1.00+00	9.88-01	8.93-01	5.50-01	1.34-01	2.03-02	6.84-03	4.67-03	3.43-03	2.81-03	2.81-03	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

- MIXTURE FRACTION -

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	4.10-11	6.78-10	2.65-09	5.14-09	7.72-09	1.04-08	1.46-08	3.08-08	2.30-05	2.30-05	.1195
8	0.00	0.00	2.61-08	2.56-07	5.44-07	5.42-07	5.38-07	5.31-07	5.06-07	4.60-07	2.28-04	2.28-04	.0985
7	0.00	0.00	3.68-05	2.55-04	6.51-04	1.15-03	1.56-03	1.80-03	1.73-03	1.67-03	1.60-03	1.60-03	.0775
6	0.00	0.00	2.83-02	2.53-02	2.19-02	1.75-02	1.25-02	7.25-03	4.13-03	2.75-03	2.20-03	2.20-03	.0625
5	0.00	0.00	3.46-02	3.20-02	2.86-02	2.20-02	1.44-02	7.91-03	4.70-03	3.28-03	2.61-03	2.62-03	.0425
4	0.00	0.00	6.12-02	6.12-02	5.55-02	3.35-02	1.53-02	7.05-03	4.67-03	3.40-03	2.77-03	2.77-03	.0200
3	0.00	0.00	1.75-01	2.29-01	2.13-01	8.82-02	1.94-02	6.85-03	4.66-03	3.42-03	2.80-03	2.81-03	.0062
2	1.00+00	1.00+00	9.88-01	8.92-01	5.50-01	1.34-01	2.03-02	6.83-03	4.67-03	3.43-03	2.81-03	2.81-03	.0012
1	1.00+00	1.00+00	9.88-01	8.93-01	5.50-01	1.34-01	2.03-02	6.84-03	4.67-03	3.43-03	2.81-03	2.81-03	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

ENTHALPY (M**2/SEC**2)

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J 10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.97+05	2.97+05	.1195
8	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	3.07+05	3.07+05	.0985
7	2.96+05	2.96+05	2.98+05	3.09+05	3.29+05	3.54+05	3.74+05	3.66+05	3.82+05	3.80+05	3.76+05	3.76+05	.0775
6	0.00	0.00	1.71+06	1.56+06	1.39+06	1.17+06	9.19+05	6.59+05	5.02+05	4.34+05	4.06+05	4.06+05	.0625
5	0.00	0.00	2.03+06	1.89+06	1.73+06	1.40+06	1.02+06	6.92+05	5.31+05	4.60+05	4.27+05	4.27+05	.0425
4	0.00	0.00	3.36+06	3.36+06	3.07+06	1.97+06	1.06+06	6.49+05	5.30+05	4.66+05	4.35+05	4.35+05	.0200
3	0.00	0.00	9.03+06	1.17+07	1.10+07	4.71+06	1.27+06	6.39+05	5.29+05	4.67+05	4.36+05	4.36+05	.0062
2	5.03+07	5.03+07	4.97+07	4.49+07	2.78+07	6.99+06	1.31+06	6.38+05	5.29+05	4.67+05	4.37+05	4.37+05	.0012
1	5.03+07	5.03+07	4.97+07	4.49+07	2.78+07	6.99+06	1.31+06	6.38+05	5.30+05	4.68+05	4.37+05	4.37+05	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

VISCOSITY (N-SEC/M**2)

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J 10	1.86-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	.1345
9	2.01-03	7.03-03	7.16-03	7.35-03	7.57-03	7.78-03	7.92-03	7.89-03	7.57-03	7.07-03	6.77-03	6.77-03	.1195
8	2.01-03	2.01-03	2.00-03	1.99-03	1.97-03	1.94-03	1.91-03	1.88-03	1.90-03	1.97-03	3.74-03	3.74-03	.0985
7	2.01-03	7.03-03	7.29-03	7.73-03	8.51-03	9.66-03	1.04-02	1.02-02	9.20-03	1.38-02	2.59-02	2.59-02	.0775
6	1.88-05	1.88-05	1.03-03	2.01-02	3.47-02	4.72-02	5.76-02	6.99-02	6.80-02	5.16-02	5.04-02	5.04-02	.0625
5	1.88-05	1.88-05	1.43-03	3.94-02	5.65-02	6.78-02	7.15-02	8.48-02	9.97-02	7.87-02	7.12-02	7.12-02	.0425
4	1.88-05	1.88-05	1.61-03	3.61-02	4.59-02	7.27-02	8.85-02	9.46-02	1.13-01	8.83-02	7.74-02	7.74-02	.0200
3	1.88-05	1.88-05	1.26-03	2.60-02	4.25-02	5.50-02	9.63-02	9.94-02	1.16-01	9.14-02	7.91-02	7.91-02	.0062
2	3.26-03	3.26-03	3.26-03	5.55-03	2.48-02	5.12-02	9.76-02	9.99-02	1.17-01	9.17-02	7.93-02	7.93-02	.0012
1	3.26-03	3.26-03	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

DENSITY (KG/M**3)

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J 10	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.1345
9	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.1195
8	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0985
7	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0775
6	1.16+00	1.16+00	1.17+00	1.17+00	1.17+00	1.17+00	1.17+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0625
5	1.16+00	1.16+00	1.17+00	1.17+00	1.17+00	1.17+00	1.17+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0425
4	1.16+00	1.16+00	1.19+00	1.19+00	1.18+00	1.17+00	1.17+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0200
3	1.16+00	1.16+00	1.23+00	1.26+00	1.25+00	1.20+00	1.17+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0062
2	1.77+00	1.77+00	1.76+00	1.68+00	1.43+00	1.22+00	1.17+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0012
1	1.77+00	1.77+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

TEMPERATURE (K)

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J 10	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.1345

J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
9	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.1195
8	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0985
7	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0775
6	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0625
5	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0425
4	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0200
3	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0062
2	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0012
1	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

MEAN SP. HT.(J/KG-K)

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.1345
9	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.1195
8	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0985
7	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0775
6	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0625
5	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0425
4	1.01+03	1.01+03	1.00+03	1.00+03	1.00+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0200
3	1.01+03	1.01+03	9.81+02	9.72+02	9.75+02	9.96+02	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0062
2	8.40+02	8.40+02	8.42+02	8.58+02	9.17+02	9.88+02	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0012
1	8.40+02	8.40+02	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

O2 MASS FRACTION

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.1345
9	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.1195
8	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.0985
7	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.0775
6	2.33-01	2.33-01	2.26-01	2.27-01	2.28-01	2.29-01	2.30-01	2.31-01	2.32-01	2.32-01	2.32-01	2.32-01	.0625
5	2.33-01	2.33-01	2.25-01	2.26-01	2.26-01	2.28-01	2.30-01	2.31-01	2.32-01	2.32-01	2.32-01	2.32-01	.0425
4	2.33-01	2.33-01	2.19-01	2.19-01	2.20-01	2.25-01	2.29-01	2.31-01	2.32-01	2.32-01	2.32-01	2.32-01	.0200
3	2.33-01	2.33-01	1.92-01	1.80-01	1.83-01	2.12-01	2.28-01	2.31-01	2.32-01	2.32-01	2.32-01	2.32-01	.0062
2	0.00	0.00	2.70-03	2.50-02	1.05-01	2.02-01	2.28-01	2.31-01	2.32-01	2.32-01	2.32-01	2.32-01	.0012
1	0.00	0.00	2.70-03	2.50-02	1.05-01	2.02-01	2.28-01	2.31-01	2.32-01	2.32-01	2.32-01	2.32-01	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

N2 MASS FRACTION

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	.1345
9	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	.1195
8	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	.0985
7	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.66-01	7.66-01	7.66-01	7.66-01	7.66-01	7.66-01	7.66-01	.0775
6	7.67-01	7.67-01	7.45-01	7.48-01	7.50-01	7.54-01	7.57-01	7.61-01	7.64-01	7.65-01	7.65-01	7.65-01	.0625
5	7.67-01	7.67-01	7.40-01	7.42-01	7.45-01	7.50-01	7.56-01	7.61-01	7.63-01	7.64-01	7.65-01	7.65-01	.0425
4	7.67-01	7.67-01	7.20-01	7.20-01	7.24-01	7.41-01	7.55-01	7.62-01	7.63-01	7.64-01	7.65-01	7.65-01	.0200

J													
3	7.67-01	7.67-01	6.33-01	5.91-01	6.04-01	6.99-01	7.52-01	7.62-01	7.63-01	7.64-01	7.65-01	7.65-01	.0062
2	0.00	0.00	8.89-03	8.25-02	3.45-01	6.64-01	7.51-01	7.62-01	7.63-01	7.64-01	7.65-01	7.65-01	.0012
1	0.00	0.00	8.89-03	8.25-02	3.45-01	6.64-01	7.51-01	7.62-01	7.63-01	7.64-01	7.65-01	7.65-01	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

CO2 MASS FRACTION

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1195
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0985
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0775
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0625
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0425
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0200
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0062
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0012
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

H2O MASS FRACTION

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1195
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0985
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0775
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0625
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0425
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0200
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0062
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0012
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

FLOWIN= 2.021+00

FIN= 8.321-04 FOUT= 8.406-04

ENIN= 3.377+05 ENOUT= 3.381+05

TIN= 2.930+02 TOUT= 2.930+02

[illegible]

APPENDIX 2

```
TEACH*TEACH(2).WPAFB2(2)
          WPAFB2 - HOT FLOW TEST CASE
               50       1
               2        2        1        1        0        0
               12       10       2        6        9        2        5        4
               1        2        3        4        5        6        7        8
               0        10
               2        2        3        1        1        1        1        1
               0        1
          0.7      0.7      1.0      0.7      0.7      0.6      0.6      0.6
          0.0      0.7      1.0      0.4
            1.88E-051.1609  293.0    293.0
          49.3     0.0      293.0    0.0      0.005    0.01     98000.0
          69.6     0.0      400.0    1.0      0.005    0.01
          3.635    5.0080E+0744.0
          913.0    1040.0   834.0    2020.0
          -0.24515 0.36714E-1-.19576E-4 .46527E-8-.2901E-12
          -0.001
           0.000
           0.003
           0.008
           0.016
           0.028
           0.045
           0.080
           0.140
           0.240
           0.390
           0.390
           0.000
           0.0024
           0.010
           0.030
           0.055
           0.070
           0.085
           0.112
           0.127
           0.127
          0.0               2        70.02             50
          0.001             300      500      1        30

@PRT,S TEACH*TEACH.WPAFB3
```

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TURBULENT FLOW IN A BLUFF-BODY COMBUSTOR
FOR WPAFB2 - HOT FLOW TEST CASE

NUMBER OF ITERATIONS TO EXECUTE        12[illegible]
NCDOP   = 1, THIS IS A NEW CASE
ISCEME  = 2, USE SKEW DIFFERENCING
INDCOS  = 2, CYLINDRICAL CO-ORDINATES
KNPPO   = 1, FLUID PROPERTIES ARE VARIABLE
KNCOMP  = 1, FLOW IS INCOMPRESSIBLE
KVISCO  = 0, VISCOSITY IS VARIABLE
KLAMNR  = 0, FLOW IS TURBULENT
GRID CONTROLS

NI      =    12
NJ      =    10
ISTEP   =     2
JSTEP   =     6
JEXIT   =     9
JINS    =     2
IMON    =     5
JMON    =     4

DEPENDENT VARIABLE EQUATION CONTROLS

VARIABLE                     SWITCH  NO. SWEEPS UNDER RELAX
                                                    FACTOR
U VELOCITY                      1         2     .70000+00
V VELOCITY                      2         2     .70000+00
PRIMARY PRESSURE CORRECT        3         3     .10000+01
TURBULENCE ENERGY               4         1     .70000+00
ENERGY DISSIPATION              5         1     .70000+00
ENTHALPY                        6         1     .60000+00
FUEL CONCENTRATION              7         1     .60000+00
MIXTURE FRACTION                8         1     .60000+00
SWIRL VELOCITY                  9         1     .50000
SEC. PRESSURE CORRECT.         10         1     .70000+00
VISCOSITY                                       .10000+01
DENSITY                                         .40000+00

VISCOSITY          N-SEC/M**2    .19800-04
DENSITY              KG/M**3     .1160[illegible]+01
WALL TEMPERATURE           K     .2930[illegible]+03
BLUFF BODY TEMPERATURE     K     .2930[illegible]+03

[illegible]...
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VARIABLE                      OUTER FLOW   INNER FLOW

AXIAL VELOCITY       M/SEC     .49300+02    .69600+02
SWIRL/AXIAL VEL. RATIO         .00000       .00000
TEMPERATURE              K     .29300+03    .40000+03
CONC.-SECOND COMPONENT         .00000       .10000+01
TURB. INTENSITY FACTOR         .50000-02    .50000-02
BNDY. LAYER THICKNESS    M     .10000-01    .10000-01
PRESSURE            N/M**2     .98000+05

STOIC. O2/FUEL MASS RAT.       .36350+01
HEAT OF COMBUSITON  J/KG       .50000+08
FUEL MOLECULAR WEIGHT          .44000+02

CP-O2              J/KG-K      .91300+03
CP-N2              J/KG-K      .10400+04
CP-CO2             J/KG-K      .83400+03
CP-H2O             J/KG-K      .20200+04

CO-EFFICIENTS OF THE POLYNOMIAL FOR THE HEAT CAPACITY FOR THE SECOND COMPONENT (E.G.,FUEL)

CP = (C1 + C2*T + C3*T**2 + C4*T**3 + C5*T**4)*UGC /WMF
     WITH T IN DEG K AND CP IN J/KG-K

C1      =   -.24515+00
C2      =    .36714-01
C3      =   -.19576-04
C4      =    .46527-08
C5      =   -.29010-12

AXIAL STORAGE LOCATIONS FOR AXIAL VELOCITY

    I      X-METER

    1   -.10000-02
    2    .00000
    3    .30000-02
    4    .80000-02
    5    .16000-01
    6    .28000-01
    7    .45000-01
    8    .80000-01
    9    .14000+00
   10    .24000+00
   11    .39000+00
   12    .39000+00

RADIAL STORAGE LOCATIONS FOR RADIAL VELOCITY

    J      Y-METER

    1    .00000
    2    .24000-02
    3    .10000-01
    4    [illegible]
         [illegible]
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   6    .70000-01
   7    .85000-01
   8    .11200+00
   9    .12700+00
  10    .12700+00

REFERENCE PRESSURE PASCL      .00000
IPREF                                 2
JPREF                                 7
TOL.FOR RESIDUAL FOR
PRESSURE CORRECT. EQN.        .20000-01
MAX. NO. OF SWEEPS FOR
PRESS. CORRECT. EQN.                 50

MAX. RESIDUAL FOR FIELD VARIABLE          .10000-02
MAX. NO. OF ITERATIONS TO BE RUN                300
NO. OF ITERATIONS BETWEEN TABULATION            500
   OF FIELD VARIABLES
NO. OF ITERATIONS BETWEEN OUTPUT OF               1
    MONITORING INFORMATION
ITERATION TO START CHEMICAL REACTION             30
```

ORIGINAL PAGE IS
OF POOR QUALITY

TURBULENT FLOW WITH COMBUSTION IN A BLUFF-BODY COMBUSTOR

FLOW RATE OF MAIN STREAM (AIR), KG/S	2.019+00
FLOW RATE OF SECONDARY STREAM (FUEL), KG/S	1.633-03
TEMPERATURE OF MAIN STREAM, K	2.930+02
TEMPERATURE OF SECONDARY STREAM, K	4.000+02
PRESSURE AT INLET, N/M**2	9.800+04
CONCENTRATION OF FUEL IN MAIN STREAM	0.000
CONCENTRATION OF FUEL IN SECONDARY STREAM	1.000+00
SWIRL NUMBER	0.000

ITER NO.	UMOM F.CONC	VMOM M.FRAC	WMOM	MASS	ENTH	T EN	DISS	U EN	V T	W FM	P F	TE	D
	ABSOLUTE RESIDUAL SOURCE SUMS							FIELD VALUES AT MONITORING LOCATION (5, 4)					
1	3.6[illegible]-01 1.00+00	2.38-04 1.00+00	0.00	5.88-01	1.21-01	3.3[illegible]-02	1.35+05	2.81+00 3.70+05	-3.26+00 2.93+02	0.00 1.50-03	-1.37+03 1.50-03	5.24+00	2.89+03
2	9.51-01 3.41+00	1.81-01 8.41+00	0.00	1.44+01	1.01+00	1.20-02	4.63+05	-6.73+01 3.85+05	4.31+01 2.93+02	0.00 1.78-03	-1.97+02 1.78-03	1.05+01	1.11+04
3	5.42-01 4.15+00	4.33-01 4.15+00	0.00	1.19+00	5.01-01	7.39-03	1.79+05	-3.71+01 4.56+05	2.11+01 2.93+02	0.00 3.21-03	5.34+02 3.21-03	1.10+01	1.62+04
4	2.25-01 2.15+00	1.46-01 2.15+00	0.00	7.67-01	2.60-01	5.72-03	3.36+05	-2.28+01 4.90+05	1.06+01 2.93+02	0.00 3.65-03	-1.58+02 3.65-03	8.73+00	1.39+04
5	1.21-01 1.47+00	5.44-02 1.47+00	0.00	4.39-01	1.78-01	2.99-03	3.04+05	-1.83+01 2.37+05	9.97+00 2.93+02	0.00 4.76-03	-2.14+02 4.76-03	7.49+00	1.02+04
6	7.41-02 1.32+00	3.74-02 1.32+00	0.00	3.13-01	1.60-01	2.53-03	1.89+05	-1.64+01 6.33+05	1.01+01 2.93+02	0.00 6.65-03	-1.77+02 6.65-03	6.87+00	9.48+03
7	4.51-02 1.50+00	2.46-02 1.50+00	0.00	1.64-01	1.82-01	2.37-03	9.81+04	-1.61+01 9.18+05	1.04+01 2.94+02	0.00 1.23-02	-1.24+02 1.23-02	7.32+00	1.30+04
8	4.20-02 1.77+00	1.79-02 1.77+00	0.00	1.61-01	2.16-01	3.20-03	5.66+04	-1.56+01 1.48+06	9.64+00 2.95+02	0.00 2.34-02	-7.68+01 2.34-02	9.44+00	1.87+04
9	4.[illegible]6-02 2.49+00	1.99-02 2.49+00	0.00	1.74-01	3.03-01	4.51-03	4.70+04	-1.44+01 1.90+06	8.27+00 2.97+02	0.00 3.16-02	-6.35+01 3.16-02	1.30+01	2.57+04
10	3.3[illegible]-02 4.40+00	2.[illegible]2-02 4.4[illegible]+00	0.00	1.15-01	5.42-01	[illegible].19-03	3.75+04	-1.32+01 2.11+06	7.77+00 2.99+02	0.00 3.57-02	-6.36+01 3.57-02	2.55+01	3.71+04
11	2.15-02 3.[illegible]+00	1.[illegible]2-02 3.[illegible]+00	0.00	1.02-01	4.45-01	4.06-03	1.79+04	-1.[illegible]+01 2.41+06	7.6[illegible]+00 3.[illegible]+02	0.00 4.17-02	-5.53+01 4.17-02	4.38+01	4.59+04
12	[illegible]-02 [illegible]+00	1.[illegible]-02 2.7[illegible]+00	0.00	7.92-02	3.[illegible]-01	2.[illegible]-03	6.97+[illegible]	-1.74+01 [illegible]+06	7.71+00 3.01+02	0.00 4.72-02	-6.18+01 4.72-02	6.15+01	5.34+04
13	1.[illegible]-02 [illegible]+00	9.[illegible]-03 2.[illegible]+00	0.00	[illegible]	[illegible]	[illegible]	1.[illegible]	-1.[illegible]+01 [illegible]+06	7.[illegible]+00 [illegible]+02	[illegible] 4.[illegible]-02	-6.82+01 4.[illegible]-02	7.43+01	5.59+04

14	2.19-02 1.80+00	1.01-02 1.80+00	0.00	8.99-02	2.19-01	4.03-03	1.08+04	-1.25+01 2.96+06	7.99+00 3.03+02	0.00 5.78-02	-7.67+01 5.26-02	6.06+01	4.94+04
15	1.62-02 1.45+00	9.74-03 1.45+00	0.00	8.57-02	1.76-01	3.49-03	6.32+03	-1.26+01 2.95+06	8.01+00 3.04+02	0.00 5.23-02	-8.57+01 5.23-02	6.62+01	3.60+04
16	1.28-02 1.44+00	8.65-03 1.44+00	0.00	9.25-02	1.75-01	3.56-03	1.14+04	-1.24+01 2.98+06	7.89+00 3.03+02	0.00 5.31-02	-7.50+01 5.31-02	6.03+01	3.75+04
17	1.56-02 1.03+00	9.01-03 1.03+00	0.00	9.30-02	1.25-01	3.74-03	7.87+03	-1.17+01 2.96+06	7.45+00 3.04+02	0.00 5.27-02	-8.04+01 5.27-02	6.50+01	2.97+04
18	2.30-02 9.38-01	9.82-03 9.38-01	0.00	1.57-01	1.14-01	5.17-03	7.85+03	-1.11+01 3.02+06	7.17+00 3.04+02	0.00 5.38-02	-8.82+01 5.38-02	7.58+01	3.41+04
19	2.54-02 7.99-01	1.26-02 7.99-01	0.00	1.12-01	9.70-02	5.49-03	1.09+03	-9.94+00 3.10+06	6.69+00 3.04+02	0.00 5.53-02	-1.02+02 5.53-02	7.47+01	3.49+04
20	1.14-02 7.29-01	1.25-02 7.29-01	0.00	9.85-02	8.86-02	6.31-03	6.72+03	-9.17+00 3.16+06	6.21+00 3.04+02	0.00 5.66-02	-1.03+02 5.66-02	7.23+01	3.37+04
21	1.76-02 7.13-01	1.21-02 7.13-01	0.00	8.80-02	8.66-02	7.21-03	6.06+03	-8.70+00 3.23+06	5.85+00 3.04+02	0.00 5.79-02	-1.04+02 5.79-02	7.09+01	3.25+04
22	1.69-02 6.74-01	1.17-02 6.74-01	0.00	8.49-02	8.19-02	8.75-03	3.24+03	-8.46+00 3.29+06	5.65+00 3.05+02	0.00 5.92-02	-1.05+02 5.92-02	7.16+01	3.22+04
23	2.17-02 6.93-01	1.35-02 6.93-01	0.00	1.01-01	8.42-02	1.03-02	9.57+02	-8.26+00 3.34+06	5.46+00 3.05+02	0.00 6.01-02	-1.09+02 6.01-02	7.45+01	3.27+04
24	2.24-02 7.30-01	1.74-02 7.30-01	0.00	1.31-01	8.88-02	1.03-02	1.82+03	-8.00+00 3.36+06	5.19+00 3.05+02	0.00 6.04-02	-1.16+02 6.04-02	7.85+01	3.37+04
25	2.39-02 8.55-01	1.99-02 8.55-01	0.00	1.67-01	1.04-01	9.10-03	2.44+03	-7.85+00 3.33+06	5.04+00 3.05+02	0.00 6.00-02	-1.21+02 6.00-02	8.21+01	3.61+04
26	2.17-02 9.86-01	1.73-02 9.86-01	0.00	1.69-01	1.20-01	7.54-03	9.11+03	-7.66+00 3.32+06	4.95+00 3.05+02	0.00 5.97-02	-1.27+02 5.97-02	8.99+01	3.62+04
27	1.79-02 9.75-01	1.76-02 9.75-01	0.00	1.63-01	1.18-01	6.05-03	5.90+03	-7.50+00 3.33+06	4.80+00 3.05+02	0.00 5.98-02	-1.38+02 5.98-02	9.55+01	3.66+04
28	1.42-02 8.92-01	1.85-02 8.92-01	0.00	1.61-01	1.08-01	4.87-03	7.72+03	-7.37+00 3.35+06	4.69+00 3.05+02	0.00 6.03-02	-1.46+02 6.03-02	9.89+01	3.72+04
29	1.14-02 7.80-01	1.79-02 7.80-01	0.00	1.41-01	9.48-02	4.19-03	9.22+03	-7.27+00 3.37+06	4.62+00 3.05+02	0.00 6.07-02	-1.52+02 6.07-02	1.00+02	3.77+04
30	1.12-02 [illegible]8-01	1.58-02 6.75-01	0.00	1.18-01	8.19-02	3.4[illegible]-03	8.[illegible]1+03	-7.72+00 [illegible].40+06	4.79+00 5.65+02	0.00 5.62-02	-1.42+02 6.13-02	1.03+02	3.95+04
31	7.78-03 [illegible]4-01	1.22-02 [illegible].56-01	0.00	8.24-02	6.75-02	2.72-03	7.[illegible]3+03	-7.99+00 [illegible].43+06	5.02+00 5.26+02	0.00 5.74-02	-1.38+02 6.19-02	1.06+02	4.10+04
32	6.[illegible]3-03 5.[illegible]3-01	9.68-03 4.61-01	0.00	6.56-02	[illegible].84-02	[illegible].1[illegible]-03	1.[illegible]+04	-[illegible].70+00 [illegible].43+06	[illegible].30+00 [illegible]	0.00 [illegible].78-02	-1.37+02 6.[illegible]9-02	1.[illegible]8+02	4.13+04
33	6.[illegible]-03 [illegible]-01	7.[illegible]-03 4.[illegible]-01	0.00	4.91-02	[illegible]	1.[illegible]	1.71+04	-[illegible]+00 [illegible]+06	[illegible].57+00 [illegible]	0.00 [illegible]-02	-1.[illegible]+02 6.1[illegible]-02	1.10+02	4.10+04

34	6.[illegible]5-03 7.[illegible]0-01	5.98-03 5.02-01	0.00	3.68-02	6.09-02	1.25-03	2.66+04	-8.92+00 3.35+06	5.87+00 4.73+02	0.00 5.65-02	-1.37+02 6.03-02	1.11+02	4.07+04
35	5.70-03 7.12-01	4.93-03 4.46-01	0.00	3.16-02	5.42-02	1.09-03	4.50+04	-8.42+00 3.27+06	5.99+00 4.30+02	0.00 5.50-02	-1.40+02 5.88-02	1.12+02	4.03+04
36	5.06-03 9.84-01	4.15-03 6.41-01	0.00	2.37-02	7.79-02	9.89-04	3.11+04	-8.47+00 3.23+06	6.06+00 4.32+02	0.00 5.35-02	-1.44+02 5.79-02	1.13+02	4.13+04
37	4.31-03 1.06+00	3.33-03 6.41-01	0.00	1.70-02	7.79-02	8.96-04	3.20+04	-8.67+00 3.21+06	6.16+00 4.53+02	0.00 5.23-02	-1.47+02 5.75-02	1.16+02	4.36+04
38	3.70-03 1.12+00	2.46-03 5.89-01	0.00	1.37-02	7.17-02	6.16-04	2.34+04	-8.95+00 3.21+06	6.26+00 4.91+02	0.00 5.09-02	-1.50+02 5.75-02	1.18+02	4.66+04
39	3.15-03 1.15+00	2.13-03 4.91-01	0.00	1.20-02	5.97-02	7.40-04	1.38+04	-9.30+00 3.22+06	6.42+00 5.43+02	0.00 4.96-02	-1.51+02 5.77-02	1.22+02	4.99+04
40	2.65-03 1.17+00	2.11-03 4.63-01	0.00	1.12-02	5.64-02	7.08-04	9.16+03	-9.68+00 3.24+06	6.57+00 5.97+02	0.00 4.84-02	-1.52+02 5.81-02	1.26+02	5.22+04
41	2.94-03 1.23+00	2.26-03 4.22-01	0.00	1.18-02	5.13-02	6.97-04	2.32+04	-1.00+01 3.27+06	6.72+00 6.61+02	0.00 4.73-02	-1.52+02 5.87-02	1.29+02	5.36+04
42	3.20-03 1.33+00	2.67-03 4.03-01	0.00	1.27-02	4.90-02	7.05-04	4.12+04	-1.03+01 3.32+06	6.87+00 7.16+02	0.00 4.64-02	-1.51+02 5.97-02	1.32+02	5.49+04
43	3.73-03 1.49+00	3.16-03 4.00-01	0.00	1.47-02	4.87-02	7.26-04	5.81+04	-1.04+01 3.38+06	7.00+00 7.83+02	0.00 4.54-02	-1.50+02 6.08-02	1.35+02	5.57+04
44	4.52-03 1.63+00	3.62-03 4.05-01	0.00	1.69-02	4.94-02	7.76-04	6.29+04	-1.05+01 3.44+06	7.13+00 8.58+02	0.00 4.41-02	-1.48+02 6.20-02	1.37+02	5.65+04
45	5.59-03 1.66+00	4.38-03 4.23-01	0.00	1.98-02	5.16-02	6.28-04	6.10+04	-1.05+01 3.50+06	7.25+00 9.29+02	0.00 4.30-02	-1.46+02 6.33-02	1.39+02	5.72+04
46	6.71-03 [illegible]	5.19-03 4.71-01	0.00	2.22-02	5.74-02	9.17-04	6.76+04	-1.05+01 3.60+06	7.36+00 1.02+03	0.00 4.22-02	-1.45+02 6.52-02	1.40+02	5.84+04
47	[illegible] 2.29+00	6.04-03 5.25-01	0.00	2.62-02	6.37-02	1.12-03	3.65+04	-1.04+01 3.71+06	7.41+00 1.10+03	0.00 4.14-02	-1.45+02 6.75-02	1.42+02	5.99+04
48	9.29-03 2.47+00	7.25-03 5.61-01	0.00	3.09-02	7.06-02	1.40-03	4.72+04	-1.04+01 3.86+06	7.41+00 1.19+03	0.00 4.07-02	-1.45+02 7.04-02	1.44+02	6.21+04
49	1.03-02 2.68+00	8.71-03 6.26-01	0.00	3.74-02	7.61-02	1.72-03	4.18+04	-1.04+01 4.04+06	7.37+00 1.29+03	0.00 3.99-02	-1.46+02 7.39-02	1.47+02	6.42+04
50	1.11-02 2.[illegible]4+00	1.02-02 6.79-01	0.00	4.65-02	8.23-02	2.13-03	2.55+04	-1.04+01 4.24+06	7.32+00 1.41+03	0.00 3.91-02	-1.45+02 7.80-02	1.49+02	6.62+04
51	1.21-02 [illegible]	1.14-02 7.20-01	0.00	5.57-02	8.71-02	2.55-03	[illegible]	-1.05+01 4.51+06	7.33+00 1.54+03	0.00 3.86-02	-1.41+02 8.33-02	1.52+02	6.93+04
52	[illegible]	[illegible] 7.34-01	0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 4.91+06	7.39+00 1.69+03	0.00 4.12-02	-1.34+02 8.93-02	1.57+02	7.30+04
53	[illegible]	[illegible] 7.31-01	0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 1.77+03	0.00 [illegible]	-1.27+02 9.58-02	1.62+02	7.70+04

54	1.09-02 1.97+00	1.07-02 7.09-01	0.00	6.79-02	9.55-02	2.84-03	9.89+03	-1.15+01 5.49+06	7.49+00 1.80+03	0.00 5.06-02	-1.21+02 1.03-01	1.68+02	8.10+04
55	1.11-02 1.35+00	9.51-03 6.84-01	0.00	6.30-02	8.25-02	2.71-03	1.89+04	-1.18+01 5.83+06	7.53+00 1.83+03	0.00 5.73-02	-1.18+02 1.09-01	1.73+02	8.48+04
56	9.81-03 3.61-01	8.50-03 6.30-01	0.00	5.72-02	7.66-02	2.39-03	1.33+04	-1.18+01 6.15+06	7.52+00 1.81+03	0.00 6.38-02	-1.17+02 1.16-01	1.78+02	8.77+04
57	8.02-03 6.56-01	7.43-03 6.16-01	0.00	5.11-02	7.43-02	2.01-03	2.08+04	-1.17+01 6.43+06	7.46+00 1.78+03	0.00 6.96-02	-1.18+02 1.21-01	1.80+02	8.92+04
58	6.74-03 4.76-01	6.53-03 5.84-01	0.00	4.44-02	7.03-02	1.69-03	2.01+04	-1.14+01 6.69+06	7.37+00 1.76+03	0.00 7.48-02	-1.20+02 1.26-01	1.81+02	8.94+04
59	6.6[illegible]-03 3.16-01	5.91-03 5.72-01	0.00	3.79-02	6.89-02	1.41-03	1.74+04	-1.10+01 6.93+06	7.17+00 1.74+03	0.00 7.96-02	-1.23+02 1.31-01	1.80+02	8.85+04
60	6.78-03 3.60-01	5.25-03 5.48-01	0.00	3.34-02	6.59-02	1.24-03	1.79+04	-1.07+01 7.15+06	6.97+00 1.73+03	0.00 8.41-02	-1.25+02 1.36-01	1.78+02	8.68+04
61	6.65-03 2.72-01	4.59-03 5.09-01	0.00	2.92-02	6.12-02	1.12-03	1.99+04	-1.03+01 7.36+06	6.79+00 1.71+03	0.00 8.82-02	-1.26+02 1.40-01	1.76+02	8.48+04
62	6.66-03 2.37-01	4.19-03 4.97-01	0.00	2.55-02	5.95-02	9.66-04	2.22+04	-9.92+00 7.54+06	6.64+00 1.70+03	0.00 9.19-02	-1.27+02 1.43-01	1.73+02	8.26+04
63	6.58-03 2.35-01	3.62-03 4.83-01	0.00	2.08-02	5.78-02	8.16-04	2.24+04	-9.60+00 7.72+06	6.46+00 1.69+03	0.00 9.53-02	-1.28+02 1.47-01	1.70+02	8.03+04
64	6.45-03 2.41-01	3.01-03 4.78-01	0.00	1.72-02	5.72-02	7.67-04	2.08+04	-9.33+00 7.87+06	6.30+00 1.68+03	0.00 9.84-02	-1.27+02 1.50-01	1.68+02	7.81+04
65	5.91-03 2.26-01	2.52-03 4.58-01	0.00	1.41-02	5.48-02	7.27-04	2.41+04	-9.12+00 8.01+06	6.16+00 1.67+03	0.00 1.01-01	-1.26+02 1.53-01	1.65+02	7.61+04
66	5.53-03 2.23-01	2.22-03 4.43-01	0.00	1.12-02	5.33-02	7.37-04	1.63+04	-8.97+00 8.15+06	6.05+00 1.66+03	0.00 1.04-01	-1.25+02 1.55-01	1.63+02	7.45+04
67	4.93-03 2.22-01	1.93-03 4.33-01	0.00	1.06-02	5.18-02	7.22-04	1.03+04	-8.85+00 8.28+06	5.95+00 1.66+03	0.00 1.07-01	-1.24+02 1.58-01	1.62+02	7.32+04
68	4.28-03 2.12-01	1.74-03 4.23-01	0.00	1.02-02	5.07-02	6.74-04	7.26+03	-8.76+00 8.40+06	5.87+00 1.65+03	0.00 1.09-01	-1.22+02 1.61-01	1.60+02	7.21+04
69	3.55-03 2.11-01	1.72-03 4.10-01	0.00	9.88-03	4.91-02	6.47-04	6.40+03	-8.69+00 8.52+06	5.82+00 1.64+03	0.00 1.11-01	-1.21+02 1.63-01	1.59+02	7.12+04
70	2.97-03 [illegible]	1.71-03 3.96-01	0.00	9.30-03	4.75-02	[illegible]	6.39+03	-8.61+00 8.63+06	5.73+00 1.64+03	0.00 1.14-01	-1.20+02 1.65-01	1.58+02	7.04+04
71	[illegible]	1.68-03 [illegible]	0.00	8.84-03	4.55-02	[illegible]	[illegible]	-8.54+00 [illegible]	5.66+00 1.67+03	0.00 1.16-01	-1.19+02 1.67-01	1.58+02	6.95+04
72	[illegible]	[illegible]	0.00	6.38-03	[illegible]	[illegible]	[illegible]	[illegible]	5.59+00 [illegible]	0.00 1.18-01	-1.19+02 1.69-01	1.57+02	6.87+04
73	[illegible]	[illegible]	[illegible]	7.74-03	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00 [illegible]	-1.19+02 1.70-01	1.56+02	6.78+04

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74	1.57-03 1.76-01	1.25-03 3.32-01	0.00	7.60-03	3.98-02	3.77-04	6.31+07	-8.77+00 9.98+06	5.47+00 1.61+03	0.00 1.21-01	-1.19+02 1.72-01	1.55+02	6.69+04
75	1.55-03 1.70-01	1.27-03 3.37-01	0.00	8.47-03	4.04-02	3.76-04	6.46+07	-9.18+00 9.04+06	5.33+00 1.60+03	0.00 1.22-01	-1.19+02 1.73-01	1.54+02	6.60+04
76	1.61-03 1.76-01	1.18-03 3.27-01	0.00	9.12-03	3.92-02	3.82-04	5.76+03	-9.10+00 9.11+06	5.25+00 1.60+03	0.00 1.24-01	-1.18+02 1.75-01	1.53+02	6.52+04
77	1.67-03 1.56-01	1.23-03 3.15-01	0.00	9.83-03	3.78-02	3.67-04	5.06+07	-8.02+00 9.18+06	5.18+00 1.60+03	0.00 1.25-01	-1.18+02 1.76-01	1.53+02	6.44+04
78	1.69-03 1.69-01	1.30-03 2.96-01	0.00	1.02-02	3.58-02	3.76-04	4.97+07	-7.94+00 9.24+06	5.10+00 1.59+03	0.00 1.26-01	-1.18+02 1.77-01	1.52+02	6.37+04
79	1.67-03 1.56-01	1.32-03 2.60-01	0.00	1.00-02	3.37-02	3.60-04	4.71+07	-7.86+00 9.29+06	5.08+00 1.59+03	0.00 1.27-01	-1.17+02 1.78-01	1.51+02	6.31+04
80	1.63-03 1.43-01	1.31-03 2.66-01	0.00	9.68-03	3.20-02	3.36-04	4.86+07	-7.79+00 9.34+06	4.97+00 1.58+03	0.00 1.28-01	-1.17+02 1.79-01	1.51+02	6.25+04
81	1.60-03 1.44-01	1.26-03 2.65-01	0.00	9.05-03	3.19-02	3.17-04	1.06+04	-7.71+00 9.39+06	4.91+00 1.58+03	0.00 1.29-01	-1.17+02 1.80-01	1.50+02	6.18+04
82	1.53-03 1.28-01	1.15-03 2.50-01	0.00	8.30-03	3.01-02	2.82-04	8.9[illegible]	-7.63+00 9.43+06	4.85+00 1.58+03	0.00 1.30-01	-1.17+02 1.81-01	1.49+02	6.12+04
83	1.46-03 1.20-01	1.09-03 2.37-01	0.00	7.44-03	2.86-02	2.54-04	5.26+03	-7.57+00 9.46+06	4.79+00 1.58+03	0.00 1.31-01	-1.16+02 1.82-01	1.48+02	6.05+04
84	1.42-03 1.10-01	9.92-04 2.30-01	0.00	6.59-03	2.77-02	2.28-04	2.75+07	-7.51+00 9.50+06	4.74+00 1.57+03	0.00 1.32-01	-1.16+02 1.82-01	1.48+02	5.99+04
85	1.35-03 1.17-01	9.06-04 2.21-01	0.00	5.84-03	2.67-02	2.04-04	1.58+07	-7.45+00 9.53+06	4.68+00 1.57+03	0.00 1.32-01	-1.15+02 1.83-01	1.47+02	5.93+04
86	1.30-03 1.11-01	8.55-04 2.13-01	0.00	5.20-03	2.57-02	1.84-04	1.59+07	-7.40+00 9.57+06	4.63+00 1.57+03	0.00 1.33-01	-1.15+02 1.84-01	1.46+02	5.87+04
87	1.24-03 1.06-01	7.89-04 2.04-01	0.00	4.67-03	2.46-02	1.69-04	1.41+13	-7.35+00 9.60+06	4.59+00 1.57+03	0.00 1.34-01	-1.15+02 1.84-01	1.46+02	5.81+04
88	1.16-03 1.01-01	7.44-04 1.94-01	0.00	4.25-03	2.34-02	1.61-04	1.81+07	-7.31+00 9.63+06	4.54+00 1.56+03	0.00 1.34-01	-1.14+02 1.85-01	1.45+02	5.76+04
89	1.[illegible]7-03 9.58-02	7.09-04 1.85-01	0.00	3.92-03	2.23-02	1.57-04	1.63+07	-7.27+00 9.66+06	4.51+00 1.56+03	0.00 1.35-01	-1.14+02 1.85-01	1.44+02	5.71+04
90	9.84-04 8.93-02	6.80-04 1.76-01	0.00	3.67-03	2.13-02	1.46-04	1.09+07	-7.24+00 9.68+06	4.47+00 1.56+03	0.00 1.35-01	-1.14+02 1.86-01	1.44+02	5.66+04
91	9.[illegible]-04 [illegible]	6.54-04 1.69-01	0.00	3.48-03	2.04-02	1.30-04	1.75+07	-7.21+00 9.71+06	4.44+00 1.56+03	0.00 1.36-01	-1.13+02 1.86-01	1.44+02	5.62+04
92	[illegible] 7.[illegible]-02	6.3[illegible]-04 1.61-01	0.00	3.34-03	1.9[illegible]	1.2[illegible]-04	1.64+07	-7.15+00 9.73+06	4.41+00 1.56+03	0.00 1.36-01	-1.13+02 1.87-01	1.43+02	5.59+04
93	7.[illegible]-04 7.[illegible]-02	6.0[illegible]-04 1.54-01	0.00	3.24-03	[illegible]	1.2[illegible]-04	1.74+07	-7.16+00 9.7[illegible]+06	4.38+00 1.56+03	0.00 1.37-01	-1.13+02 1.87-01	1.43+02	5.56+04

94	7.11-04 7.19-02	5.79-04 1.47-01	0.00	3.18-03	1.78-02	1.19-04	1.16+02	-7.15+00 9.77+06	4.35+00 1.56+03	0.00 1.37-01	-1.13+02 1.88-01	1.43+02	5.53+04
95	6.69-04 6.90-02	5.54-04 1.41-01	0.00	3.13-03	1.70-02	1.16-04	8.51+02	-7.13+00 9.79+06	4.33+00 1.56+03	0.00 1.37-01	-1.13+02 1.88-01	1.43+02	5.51+04
96	6.45-04 6.63-02	5.31-04 1.35-01	0.00	3.08-03	1.63-02	1.13-04	6.82+02	-7.11+00 9.80+06	4.30+00 1.55+03	0.00 1.38-01	-1.13+02 1.88-01	1.43+02	5.49+04
97	6.24-04 6.25-02	5.09-04 1.29-01	0.00	3.02-03	1.55-02	1.09-04	4.32+02	-7.10+00 9.82+06	4.28+00 1.55+03	0.00 1.38-01	-1.13+02 1.89-01	1.43+02	5.48+04
98	6.15-04 5.93-02	4.86-04 1.23-01	0.00	2.96-03	1.49-02	1.05-04	3.51+02	-7.08+00 9.83+06	4.26+00 1.55+03	0.00 1.38-01	-1.12+02 1.89-01	1.43+02	5.47+04
99	5.86-04 5.69-02	4.65-04 1.16-01	0.00	2.88-03	1.43-02	1.01-04	2.58+02	-7.07+00 9.85+06	4.24+00 1.55+03	0.00 1.39-01	-1.12+02 1.89-01	1.43+02	5.45+04
100	5.66-04 5.39-02	4.45-04 1.13-01	0.00	2.79-03	1.37-02	9.67-05	1.97+02	-7.06+00 9.87+06	4.23+00 1.55+03	0.00 1.39-01	-1.12+02 1.90-01	1.43+02	5.45+04
101	5.48-04 6.12-02	4.26-04 1.16-01	0.00	2.70-03	1.41-02	9.26-05	5.56+03	-7.04+00 9.96+06	4.21+00 1.55+03	0.00 1.39-01	-1.12+02 1.90-01	1.43+02	5.43+04
102	5.35-04 5.70-02	4.11-04 1.07-01	0.00	2.58-03	1.30-02	8.76-05	4.56+03	-7.03+00 9.90+06	4.20+00 1.55+03	0.00 1.40-01	-1.12+02 1.90-01	1.43+02	5.43+04
103	5.14-04 4.93-02	3.87-04 1.00-01	0.00	2.45-03	1.21-02	8.27-05	2.05+03	-7.02+00 9.91+06	4.19+00 1.55+03	0.00 1.40-01	-1.12+02 1.90-01	1.43+02	5.42+04
104	4.93-04 4.53-02	3.66-04 9.51-02	0.00	2.32-03	1.15-02	7.77-05	1.77+02	-7.01+00 9.92+06	4.18+00 1.55+03	0.00 1.40-01	-1.12+02 1.91-01	1.43+02	5.41+04
105	4.74-04 4.44-02	3.48-04 9.16-02	0.00	2.20-03	1.11-02	7.31-05	7.55+02	-7.00+00 9.94+06	4.16+00 1.55+03	0.00 1.40-01	-1.12+02 1.91-01	1.43+02	5.41+04
106	4.55-04 4.31-02	3.32-04 8.82-02	0.00	2.07-03	1.07-02	6.87-05	9.36+02	-6.99+00 9.95+06	4.15+00 1.55+03	0.00 1.41-01	-1.12+02 1.91-01	1.43+02	5.40+04
107	4.34-04 4.22-02	3.16-04 8.48-02	0.00	1.95-03	1.03-02	6.44-05	7.16+02	-6.98+00 9.97+06	4.14+00 1.55+03	0.00 1.41-01	-1.12+02 1.92-01	1.43+02	5.39+04
108	4.13-04 4.16-02	3.01-04 8.12-02	0.00	1.83-03	9.83-03	6.09-05	5.78+02	-6.97+00 9.99+06	4.13+00 1.55+03	0.00 1.41-01	-1.12+02 1.92-01	1.43+02	5.39+04
109	3.91-04 4.07-02	2.87-04 7.77-02	0.00	1.73-03	9.39-03	5.66-05	5.03+02	-6.95+00 1.00+07	4.12+00 1.54+03	0.00 1.42-01	-1.12+02 1.92-01	1.43+02	5.38+04
110	3.71-04 3.92-02	2.73-04 7.41-02	0.00	1.64-03	8.96-03	5.31-05	4.77+02	-6.94+00 1.00+07	4.10+00 1.54+03	0.00 1.42-01	-1.12+02 1.93-01	1.43+02	5.37+04
111	3.52-04 3.75-02	2.61-04 7.06-02	0.00	1.55-03	8.53-03	5.00-05	4.48+02	-6.93+00 1.00+07	4.09+00 1.54+03	0.00 1.42-01	-1.12+02 1.93-01	1.43+02	5.36+04
112	[illegible]	2.49-04 6.71-02	0.00	1.48-03	[illegible]	[illegible]	[illegible]	-6.92+00 1.00+07	4.08+00 1.54+03	0.00 1.43-01	-1.12+02 1.93-01	1.43+02	5.35+04
113	[illegible]	2.37-04 [illegible]	0.00	1.42-03	[illegible]	[illegible]	[illegible]	-6.91+00 1.01+07	[illegible]	0.00 1.43-01	-1.12+02 1.93-01	1.43+02	5.35+04

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OF POOR QUALITY

114	3.13-04 3.60-02	2.26-04 6.08-02	0.00	1.36-03	7.35-03	4.36-05	3.71+02	-6.90+00 1.01+07	4.07+00 1.54+03	0.00 1.43-01	-1.12+02 1.94-01	1.43+02	5.34+04
115	2.89-04 3.47-02	2.15-04 5.79-02	0.00	1.32-03	7.01-03	4.21-05	3.39+02	-6.89+00 1.01+07	4.06+00 1.54+03	0.00 1.43-01	-1.12+02 1.94-01	1.42+02	5.33+04
116	2.76-04 3.31-02	2.06-04 5.53-02	0.00	1.27-03	6.69-03	4.08-05	3.13+02	-6.88+00 1.01+07	4.05+00 1.54+03	0.00 1.44-01	-1.12+02 1.94-01	1.42+02	5.32+04
117	2.65-04 3.16-02	1.97-04 5.27-02	0.00	1.24-03	6.38-03	3.97-05	3.26+02	-6.87+00 1.01+07	4.04+00 1.54+03	0.00 1.44-01	-1.12+02 1.94-01	1.42+02	5.31+04
118	2.54-04 3.00-02	1.89-04 5.03-02	0.00	1.20-03	6.09-03	3.86-05	3.79+02	-6.86+00 1.01+07	4.03+00 1.54+03	0.00 1.44-01	-1.12+02 1.94-01	1.42+02	5.31+04
119	2.44-04 2.86-02	1.82-04 4.80-02	0.00	1.16-03	5.81-03	3.75-05	4.13+02	-6.85+00 1.01+07	4.02+00 1.54+03	0.00 1.44-01	-1.12+02 1.95-01	1.42+02	5.30+04
120	2.34-04 2.71-02	1.74-04 4.58-02	0.00	1.13-03	5.54-03	3.63-05	4.41+02	-6.85+00 1.01+07	4.02+00 1.54+03	0.00 1.44-01	-1.12+02 1.95-01	1.42+02	5.29+04
121	2.24-04 2.59-02	1.66-04 4.37-02	0.00	1.09-03	5.29-03	3.51-05	4.55+02	-6.84+00 1.01+07	4.01+00 1.54+03	0.00 1.45-01	-1.12+02 1.95-01	1.42+02	5.28+04
122	2.15-04 2.46-02	1.59-04 4.17-02	0.00	1.05-03	5.05-03	3.38-05	4.67+02	-6.83+00 1.01+07	4.00+00 1.54+03	0.00 1.45-01	-1.12+02 1.95-01	1.41+02	5.28+04
123	2.05-04 2.35-02	1.52-04 3.99-02	0.00	1.01-03	4.83-03	3.25-05	4.68+02	-6.82+00 1.02+07	4.00+00 1.54+03	0.00 1.45-01	-1.12+02 1.95-01	1.41+02	5.27+04
124	1.96-04 2.23-02	1.45-04 3.81-02	0.00	9.64-04	4.61-03	3.11-05	4.69+02	-6.82+00 1.02+07	3.99+00 1.53+03	0.00 1.45-01	-1.12+02 1.96-01	1.41+02	5.26+04
125	1.87-04 2.13-02	1.38-04 3.64-02	0.00	9.21-04	4.40-03	2.96-05	4.63+02	-6.81+00 1.02+07	3.98+00 1.53+03	0.00 1.45-01	-1.12+02 1.96-01	1.41+02	5.26+04

*** PROGRAM TERMINATED BEFORE CONVERGENCE CRITERION SATISFIED ***

--*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*- U VELOCITY (M/SEC) -*

I = J	1	2	3	4	5	6	7	8	9	10	11	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	4.93+01	4.93+01	4.93+01	4.93+01	4.92+01	4.91+01	4.87+01	4.76+01	4.54+01	4.29+01	4.29+01	.1195
8	4.93+01	4.93+01	4.93+01	4.94+01	4.94+01	4.93+01	4.90+01	4.81+01	4.64+01	4.45+01	4.45+01	.0985
7	4.93+01	4.94+01	4.98+01	5.01+01	5.03+01	5.01+01	4.96+01	4.84+01	4.66+01	4.42+01	4.42+01	.0775
6	0.00	0.00	3.06+00	8.10+00	1.51+01	2.16+01	2.68+01	3.18+01	3.46+01	3.58+01	3.58+01	.0625
5	0.00	0.00	-1.86+00	-4.26+00	-6.72+00	-7.16+00	[illegible]	4.11+00	1.34+01	2.33+01	2.33+01	.0425
4	0.00	0.00	-1.57+00	-4.03+00	-6.81+00	-9.47+00	-1.10+01	-7.45+00	2.43+00	1.49+01	1.49+01	.0200
3	0.00	.00	2.51+00	8.97+00	1.45+01	[illegible]	[illegible]	-9.28+00	1.49-01	1.31+01	1.30+01	.0062
2	[illegible]	6.96+01	6.21+01	6.18+01	5.66+01	[illegible]	1.70+01	-9.34+00	[illegible]	1.29+01	1.29+01	.0012
1	[illegible]	6.96+01	6.21+01	6.18+01	[illegible]	[illegible]	1.70+01	-9.34+00	-4.81-02	1.29+01	1.29+01	-.0012
X =	-.100-02	.000	.300-02	.800-02	.160-01	.280-01	.450-01	.690-01	.140+00	.240+00	.390+00	

--*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*- V VELOCITY (M/SEC) -*

J \ I	1	2	3	4	5	6	7	8	9	10	11	12	Y =
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1270
8	0.00	-8.65-03	-3.43-02	-7.44-02	-1.37-01	-2.33-01	-3.61-01	-5.10-01	-5.72-01	-4.06-01	-3.82-03	-3.94-03	.1120
7	0.00	1.50-02	4.91-02	1.52-02	-1.61-01	-5.38-01	-1.00+00	-1.50+00	-1.71+00	-1.24+00	-8.51-02	-8.55-02	.0850
6	0.00	0.00	-5.81-01	-1.23+00	-1.86+00	-2.41+00	-3.03+00	[illegible]	-3.45+00	-2.97+00	-5.06-01	-5.06-01	.0700
5	0.00	.00	1.46+01	1.18+01	8.32+00	[illegible]	-5.42-01	[illegible]	-4.61+00	-3.51+00	-3.60-01	-3.59-01	.0550
4	0.00	0.00	3.94+00	4.01+00	3.98+00	4.02+00	[illegible]	7.16-01	-2.04+00	-2.78+00	-1.38-01	-1.37-01	.0300
3	0.00	0.00	-9.53+00	-6.95+00	-2.31+00	1.71+00	6.21+00	3.53+00	-5.58-01	-6.96-01	-4.06-02	-4.05-02	.0100
2	0.00	0.00	-3.86+00	7.24-01	3.08+00	5.21+00	4.07+00	1.43+00	-1.31-01	-1.67-01	-9.62-03	-9.61-03	.0024
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0000
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

PRESSURE (PASCAL)

J \ I	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	-8.67+00	-1.19+01	-1.36+01	-1.54+01	-1.61+01	-1.24+01	-1.72+00	4.30+01	1.31+02	2.22+02	0.00	.1195
8	0.00	-1.85+01	-2.13+01	-2.13+01	-2.16+01	-2.11+01	-1.54+01	9.95-01	4.96+01	1.40+02	2.33+02	0.00	.0985
7	0.00	0.00	-7.63+00	-3.05+01	-5.07+01	-6.27+01	-5.33+01	-2.25+01	3.82+01	1.40+02	2.32+02	0.00	.0775
6	0.00	0.00	-1.05+02	-1.04+02	-9.75+01	-8.61+01	-7.81+01	-4.60+01	1.45+01	1.22+02	2.17+02	0.00	.0625
5	0.00	0.00	-8.45+01	-1.05+02	-1.09+02	-1.10+02	-1.02+02	-7.44+01	-2.48+01	9.88+01	2.12+02	0.00	.0425
4	0.00	.00	-8.35+01	-1.06+02	-1.12+02	-1.17+02	-9.86+01	-6.39+01	-1.40+01	1.04+02	2.22+02	0.00	.0200
3	0.00	0.00	-1.05+02	-1.30+02	-1.58+02	-1.98+02	-1.26+02	-4.34+01	-8.39+00	1.07+02	2.26+02	0.00	.0062
2	0.00	0.00	-2.52+02	1.65+02	6.28+01	7.40+01	-2.16+01	-2.92+01	-7.94+00	1.08+02	2.26+02	0.00	.0012
1	0.00	.00	-2.52+02	1.65+02	6.29+01	7.41+01	-2.15+01	-2.92+01	-7.90+00	1.08+02	2.26+02	0.00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

KIN.ENERGY (M**2/SEC**2)

J \ I	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	1.22+01	1.23+01	1.28+01	1.35+01	1.43+01	1.52+01	1.58+01	1.60+01	1.54+01	1.42+01	1.34+01	1.34+01	.1195
8	1.22+01	1.20+01	1.16+01	1.09+01	1.01+01	9.01+00	7.85+00	6.25+00	4.70+00	3.57+00	3.12+00	3.12+00	.0985
7	1.22+01	1.23+01	1.30+01	1.41+01	1.52+01	1.62+01	1.67+01	1.62+01	1.40+01	1.08+01	1.68+01	1.68+01	.0775
6	0.00	0.00	7.84+00	5.18+01	9.39+01	1.01+02	5.87+01	9.16+01	8.11+01	6.10+01	6.23+01	6.23+01	.0625
5	0.00	0.00	2.38+01	1.20+02	1.36+02	1.52+02	1.80+02	1.93+02	2.00+02	1.28+02	9.87+01	9.87+01	.0425
4	0.00	0.00	1.91+01	1.16+02	1.41+02	1.83+02	1.90+02	1.63+02	1.68+02	1.16+02	8.82+01	8.82+01	.0200
3	0.00	0.00	9.27+00	1.16+02	2.91+02	4.08+02	[illegible]	2.09+02	1.57+02	1.10+02	8.31+01	8.31+01	.0062
2	2.42+01	2.42+01	2.35+01	2.40+01	3.14+01	[illegible]	[illegible]	2.14+02	1.56+02	1.10+02	8.26+01	8.26+01	.0012
1	2.42+01	2.42+01	2.35+01	2.40+01	3.14+01	1.72+02	[illegible]	2.14+02	1.56+02	1.10+02	8.26+01	8.26+01	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

DISSIPATION (M**2/SEC**3)

J \ I	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	[illegible]	0.00	0.00	0.00	[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.57+03	2.57+03	.1195
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.61+02	.0985
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0775

ORIGINAL PAGE IS OF POOR QUALITY

J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
6	0.00	0.00	5.75+03	2.41+04	3.51+04	7.45+04	7.15+04	2.62+04	1.94+04	1.16+04	9.09+03	9.09+03	.0625
5	0.00	0.00	3.04+04	2.95+04	2.99+04	3.40+04	4.08+04	4.18+04	4.01+04	2.15+04	1.33+04	1.33+04	.0425
4	0.00	0.00	2.19+04	4.16+04	5.26+04	7.87+04	6.21+04	2.74+04	2.57+04	1.51+04	9.49+03	9.49+03	.0200
3	0.00	0.00	7.38+03	1.28+05	3.04+05	7.91+05	2.83+05	8.11+04	2.19+04	1.31+04	8.25+03	8.25+03	.0062
2	2.16+04	2.18+04	2.10+04	2.02+04	2.27+04	9.16+04	2.03+05	8.99+04	2.16+04	1.29+04	8.14+03	8.14+03	.0012
1	2.18+04	2.18+04	2.10+04	2.02+04	2.26+04	9.18+04	2.03+05	9.00+04	2.16+04	1.29+04	8.14+03	8.13+03	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

FUEL CONCENTRATION

I =	1		3	4	5	6	7	8	9	10	11	12	Y =
J													
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	2.94-11	1.97-10	6.55-10	1.19-09	1.39-09	1.16-09	7.29-10	3.40-10	1.77-09	1.76-09	.1195
8	0.00	0.00	1.91-08	6.90-08	1.32-07	1.34-07	8.30-08	3.99-08	1.57-08	5.21-09	6.45-08	6.42-08	.0985
7	0.00	0.00	2.41-05	4.42-05	5.74-05	5.75-05	4.44-05	2.73-05	1.30-05	5.57-06	2.70-06	2.68-06	.0775
6	0.00	0.00	2.65-02	2.07-02	1.30-02	7.53-03	3.72-03	1.07-03	2.29-04	3.93-05	6.97-06	6.93-06	.0625
5	0.00	0.00	5.52-02	5.33-02	4.86-02	3.67-02	1.58-02	1.87-03	1.74-04	2.83-05	6.08-06	6.05-06	.0425
4	0.00	0.00	1.40-01	1.41-01	1.45-01	1.45-01	8.69-02	6.46-03	8.64-05	1.61-05	4.35-06	4.32-06	.0200
3	0.00	0.00	1.68-01	2.76-01	3.82-01	3.89-01	3.07-01	4.60-02	7.13-05	1.38-05	3.94-06	3.92-06	.0062
2	1.00+00	1.00+00	8.96-01	8.64-01	8.11-01	6.46-01	4.01-01	6.13-02	6.98-05	1.35-05	3.89-06	3.87-06	.0012
1	1.00+00	1.00+00	8.96-01	8.64-01	8.11-01	6.46-01	4.01-01	6.10-02	6.94-05	1.34-05	3.87-06	3.87-06	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

MIXTURE FRACTION

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J													
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	1.13-10	9.25-10	4.17-09	1.09-08	1.93-08	3.38-08	5.51-08	9.40-08	6.96-06	6.96-06	.1195
8	0.00	0.00	7.00-08	3.06-07	7.88-07	1.16-06	1.15-06	1.13-06	1.09-06	1.02-06	7.67-05	7.67-05	.0985
7	0.00	0.00	7.65-05	1.58-04	2.53-04	3.23-04	3.17-04	3.00-04	2.63-04	4.22-04	1.18-03	1.18-03	.0775
6	0.00	0.00	8.05-02	7.14-02	6.02-02	4.67-02	2.46-02	2.05-02	1.07-02	5.14-03	3.19-03	3.18-03	.0625
5	0.00	0.00	1.11-01	1.08-01	1.03-01	8.85-02	6.24-02	2.87-02	1.35-02	7.22-03	4.58-03	4.57-03	.0425
4	0.00	0.00	1.92-01	1.92-01	1.96-01	1.94-01	1.73-01	3.70-02	1.32-02	7.53-03	5.05-03	5.04-03	.0200
3	0.00	0.00	2.18-01	3.19-01	4.19-01	4.26-01	3.47-01	8.70-02	1.31-02	7.54-03	5.12-03	5.10-03	.0062
2	1.00+00	1.00+00	9.02-01	8.73-01	8.23-01	6.67-01	4.36-01	1.03-01	1.31-02	7.53-03	5.11-03	5.10-03	.0012
1	1.00+00	1.00+00	9.03-01	8.73-01	8.23-01	6.67-01	4.36-01	1.03-01	1.30-02	7.51-03	5.10-03	5.10-03	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

ENTHALPY (M*2/SEC*2)

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J													
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	2.76+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	.1195
8	2.76+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	3.00+05	3.00+05	.0985
7	2.76+05	2.96+05	3.00+05	3.04+05	3.05+05	[illegible]	3.12+05	3.11+05	3.79+05	3.17+05	3.55+05	3.55+05	.0775
6	0.00	0.00	4.23+06	3.83+06	3.25+06	[illegible]	2.03+06	1.32+06	8.31+05	5.53+05	4.56+05	4.55+05	.0625
5	0.00	0.00	5.15+06	5.73+06	5.40+06	4.70+06	3.44+06	1.74+06	9.75+05	6.56+05	5.25+05	5.25+05	.0425
4	0.00	0.00	9.93+06	9.97+06	1.02+07	1.01+07	7.04+06	[illegible]	9.60+05	6.73+05	5.49+05	5.48+05	.0200
3	0.00	0.00	1.12+07	1.64+07	[illegible]	[illegible]	[illegible]	[illegible]	9.53+05	6.74+05	5.54+05	5.51+05	.0062
2	[illegible]	[illegible]	[illegible]	4.45+07	[illegible]	[illegible]	[illegible]	[illegible]	9.51+05	6.77+05	5.52+05	5.51+05	.0012
1	[illegible]	[illegible]	[illegible]	4.45+07	[illegible]	[illegible]	[illegible]	[illegible]	9.50+05	6.72+05	5.51+05	5.50+05	-.0012

VISCOSITY (N-SEC/M**2)

J \ I	1	2	3	4	5	6	7	8	9	10	11	12	Y =
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	
10	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	.1345
9	2.01-03	7.03-03	7.16-03	7.35-03	7.58-03	7.79-03	7.95-03	8.01-03	7.86-03	7.55-03	7.32-03	7.32-03	.1195
8	2.01-03	2.01-03	2.00-03	1.99-03	1.97-03	1.94-03	1.90-03	1.92-03	1.75-03	1.81-03	2.20-03	2.20-03	.0985
7	2.01-03	7.03-03	7.22-03	7.51-03	7.85-03	8.16-03	8.38-03	8.33-03	7.72-03	6.77-03	1.24-02	1.24-02	.0775
6	1.88-05	1.88-05	1.91-04	1.84-03	4.22-03	5.55-03	6.71-03	9.33-03	1.41-02	1.88-02	2.97-02	2.97-02	.0625
5	1.88-05	1.88-05	3.24-04	8.02-03	1.02-02	1.11-02	1.33-02	2.11-02	3.62-02	3.83-02	4.46-02	4.48-02	.0425
4	1.98-05	1.88-05	3.60-04	6.89-03	7.83-03	8.97-03	1.13-02	2.13-02	4.00-02	4.41-02	4.80-02	4.80-02	.0200
3	1.88-05	1.88-05	2.75-04	2.93-03	9.63-03	1.73-02	1.42-02	1.06-02	4.12-02	4.56-02	4.88-02	4.88-02	.0062
2	3.16-03	3.16-03	3.96-03	4.23-03	6.02-03	1.33-02	1.57-02	1.02-02	4.14-02	4.58-02	4.89-02	4.89-02	.0012
1	3.16-03	3.16-03	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

DENSITY (KG/M**3)

J \ I	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.1345
9	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.1195
8	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.15+00	1.15+00	.0985
7	1.16+00	1.16+00	1.15+00	1.14+00	1.13+00	1.11+00	1.11+00	1.11+00	1.12+00	1.09+00	9.74-01	9.74-01	.0775
6	1.16+00	1.16+00	1.79-01	1.81-01	1.86-01	2.38-01	2.41-01	3.23-01	4.61-01	6.48-01	7.71-01	7.71-01	.0625
5	1.16+00	1.16+00	1.82-01	1.83-01	1.82-01	1.82-01	1.86-01	2.62-01	4.03-01	5.57-01	6.77-01	6.77-01	.0425
4	1.16+00	1.16+00	2.27-01	2.26-01	2.29-01	2.33-01	2.17-01	2.44-01	4.07-01	5.45-01	6.51-01	6.51-01	.0200
3	1.16+00	1.16+00	2.45-01	3.10-01	3.84-01	4.51-01	2.34-01	2.17-01	4.09-01	5.45-01	6.48-01	6.48-01	.0062
2	1.30+00	1.30+00	1.66+00	1.65+00	1.53+00	9.19-01	4.58-01	2.21-01	4.09-01	5.45-01	6.48-01	6.48-01	.0012
1	1.30+00	1.30+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

TEMPERATURE (K)

J \ I	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.1345
9	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.1195
8	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.96+02	2.96+02	.0985
7	2.93+02	2.93+02	2.95+02	2.98+02	3.02+02	3.05+02	3.06+02	3.06+02	3.05+02	3.13+02	3.49+02	3.49+02	.0775
6	2.93+02	2.93+02	1.68+03	1.86+03	1.81+03	1.62+03	1.40+03	1.75+03	7.76+02	5.24+02	4.41+02	4.41+02	.0625
5	2.93+02	2.93+02	1.87+03	1.86+03	1.86+03	1.86+03	1.81+03	1.29+03	8.43+02	6.11+02	5.02+02	5.02+02	.0425
4	2.93+02	2.93+02	1.55+03	1.55+03	1.53+03	1.51+03	1.59+03	1.39+03	8.35+02	6.23+02	5.22+02	5.22+02	.0200
3	2.93+02	2.93+02	1.45+03	1.19+03	1.01+03	9.59+02	1.12+03	1.57+03	8.30+02	6.24+02	5.25+02	5.25+02	.0062
2	4.30+02	4.30+02	2.95+02	2.93+02	[illegible]	[illegible]	4.49+02	1.55+03	8.29+02	6.23+02	5.25+02	5.25+02	.0012
1	4.30+02	4.30+02	2.95+02	2.93+02	3.06+02	4.72+02	4.49+02	1.55+03	8.29+02	6.23+02	5.25+02	5.24+02	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

ORIGINAL PAGE IS
OF POOR QUALITY

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J													
10	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.1345
9	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.1195
8	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0985
7	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.02+03	1.02+03	.0775
6	1.01+03	1.01+03	1.54+03	1.50+03	1.46+03	1.38+03	1.71+03	1.21+03	1.11+03	1.05+03	1.03+03	1.03+03	.0625
5	1.01+03	1.01+03	1.65+03	1.64+03	1.62+03	1.57+03	1.46+03	1.27+03	1.15+03	1.07+03	1.04+03	1.04+03	.0425
4	1.01+03	1.01+03	1.88+03	1.88+03	1.89+03	1.88+03	1.68+03	1.32+03	1.14+03	1.08+03	1.05+03	1.05+03	.0200
3	1.01+03	1.01+03	1.94+03	2.17+03	2.34+03	2.72+03	2.21+03	1.52+03	1.14+03	1.08+03	1.05+03	1.05+03	.0062
2	2.19+03	2.19+03	3.79+03	4.54+03	4.31+03	3.64+03	2.69+03	1.57+03	1.14+03	1.08+03	1.05+03	1.05+03	.0012
1	2.19+03	2.19+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

O2 MASS FRACTION

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J													
10	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.1345
9	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.1195
8	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.0985
7	2.33-01	2.33-01	2.33-01	2.33-01	2.32-01	2.32-01	2.32-01	2.32-01	2.32-01	2.31-01	2.28-01	2.28-01	.0775
6	2.33-01	2.33-01	1.82-02	3.21-02	4.74-02	7.99-02	1.13-01	1.58-01	1.93-01	2.13-01	2.21-01	2.21-01	.0625
5	2.33-01	2.33-01	3.10-03	8.20-03	1.29-02	2.39-02	4.89-02	1.29-01	1.91-01	2.05-01	2.15-01	2.15-01	.0425
4	2.33-01	2.33-01	7.87-04	2.37-03	4.21-03	9.89-03	7.29-02	1.14-01	1.92-01	2.04-01	2.13-01	2.14-01	.0200
3	2.33-01	2.33-01	3.08-04	3.38-04	5.96-04	1.53-03	6.11-03	6.37-02	1.83-01	2.04-01	2.13-01	2.13-01	.0062
2	0.00	0.00	1.53-04	1.29-04	1.37-04	5.33-04	7.80-03	5.74-02	1.83-01	2.04-01	2.13-01	2.13-01	.0012
1	0.00	0.00	1.52-04	1.29-04	1.36-04	5.34-04	7.82-03	5.76-02	1.83-01	2.04-01	2.13-01	2.13-01	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

N2 MASS FRACTION

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J													
10	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	.1345
9	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	.1195
8	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	.0985
7	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.66-01	7.66-01	.0775
6	7.67-01	7.67-01	7.05-01	7.12-01	7.21-01	7.31-01	7.40-01	7.51-01	7.59-01	7.63-01	7.65-01	7.65-01	.0625
5	7.67-01	7.67-01	6.82-01	6.84-01	6.88-01	6.99-01	7.19-01	7.45-01	7.57-01	7.61-01	7.63-01	7.63-01	.0425
4	7.67-01	7.67-01	6.20-01	6.20-01	6.17-01	6.18-01	6.65-01	7.39-01	7.57-01	7.61-01	7.63-01	7.63-01	.0200
3	7.67-01	7.67-01	5.99-01	5.22-01	4.46-01	4.41-01	5.01-01	7.00-01	7.57-01	7.61-01	7.63-01	7.63-01	.0062
2	0.00	0.00	7.48-02	9.78-02	1.36-01	2.55-01	4.33-01	6.88-01	7.57-01	7.61-01	7.63-01	7.63-01	.0012
1	0.00	0.00	7.48-02	9.78-02	1.36-01	2.55-01	4.33-01	6.88-01	7.57-01	7.61-01	7.63-01	7.63-01	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

CO2 MASS FRACTION

I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
J													
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.53-07	2.81-07	2.09-05	2.09-05	.1195
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.30-04	2.30-04	.0985
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.53-03	[illegible]	.0775

J	1	2	3	4	5	6	7	8	9	10	11	12	Y
6	0.00	0.00	1.62-01	1.52-01	1.82-01	1.17-01	9.26-02	5.82-02	3.13-02	1.53-02	9.54-03	9.52-03	.0625
5	0.00	0.00	1.68-01	1.65-01	1.62-01	1.56-01	1.40-01	8.05-02	4.01-02	2.16-02	1.37-02	1.37-02	.0425
4	0.00	0.00	1.55-01	1.53-01	1.51-01	1.47-01	1.39-01	9.14-02	3.95-02	2.25-02	1.51-02	1.51-02	.0200
3	0.00	0.00	1.50-01	1.31-01	1.11-01	1.09-01	1.20-01	1.23-01	3.91-02	2.26-02	1.53-02	1.53-02	.0062
2	0.00	0.00	1.86-02	2.44-02	3.40-02	6.35-02	1.05-01	1.25-01	3.90-02	2.26-02	1.53-02	1.53-02	.0012
1	0.00	0.00	1.86-02	2.44-02	3.41-02	6.36-02	1.05-01	1.25-01	3.89-02	2.25-02	1.53-02	1.53-02	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

H2O MASS FRACTION

I = J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	1.36-10	1.19-09	5.75-09	1.59-08	2.93-08	5.33-08	8.99-08	1.53-07	1.14-05	1.14-05	.1195
8	0.00	0.00	4.31-08	3.88-07	1.07-06	1.68-06	1.74-06	1.79-06	1.76-06	1.66-06	1.25-04	1.25-04	.0985
7	0.00	0.00	8.57-05	1.86-04	3.20-04	4.33-04	4.45-04	4.46-04	4.09-04	6.80-04	1.92-03	1.92-03	.0775
6	0.00	0.00	8.82-02	8.29-02	7.72-02	6.40-02	5.05-02	3.17-02	1.71-02	8.34-03	5.20-03	5.19-03	.0625
5	0.00	0.00	9.17-02	8.98-02	8.82-02	8.48-02	7.63-02	4.19-02	2.19-02	1.18-02	7.48-03	7.46-03	.0425
4	0.00	0.00	8.43-02	8.36-02	8.24-02	9.00-02	7.60-02	4.98-02	2.15-02	1.23-02	8.26-03	8.23-03	.0200
3	0.00	0.00	8.18-02	7.12-02	6.06-02	5.95-02	6.56-02	6.70-02	2.13-02	1.23-02	8.36-03	8.33-03	.0062
2	0.00	0.00	1.02-02	1.33-02	1.85-02	3.46-02	5.74-02	6.82-02	2.13-02	1.23-02	8.35-03	8.33-03	.0012
1	0.00	0.00	1.01-02	1.33-02	1.85-02	3.46-02	5.74-02	6.81-02	2.12-02	1.23-02	8.33-03	8.33-03	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

FLOWIN= 2.021+0-

FIN= 8.081-04 FOUT= 7.786-04

ENIN= 3.370+05 ENOUT= 3.350+05

TIN= 2.930+02 TOUT= 3.291+02

6BRKPT POINTS

APPENDIX 3

```
TEACH*TEACH(2).WPAFB3(2)
        WPAFB3 - COLD FLOW TEST CASE WITH SWIRL
                     20         1
                      2         2         1         1         0         0
                     12        10         2         6         9         2         5         4
                      1         2         3         4         5         6         7         8
                      9        10
                      2         2         3         1         1         1         1         1
                      1         1
        0.7          0.7       1.0       0.7       0.7       0.6       0.6       0.6
        0.7          0.7       1.0       0.4
          1.88E-051.1609       293.0     293.0
        49.3         0.1014199 293.0     0.0       0.005     0.01      98000.0
        69.6         0.0       400.0     1.0       0.005     0.01
        3.635        5.0080E+0744.0
        913.0        1040.0    834.0     2020.0
        -0.24515     0.36714E-1-.19576E-4 .46527E-8-.2901E-12
        -0.001
         0.000
         0.003
         0.008
         0.016
         0.028
         0.045
         0.080
         0.140
         0.240
         0.390
         0.390
         0.000
         0.0024
         0.010
         0.030
         0.055
         0.070
         0.085
         0.112
         0.127
         0.127
        0.0                      2          70.02                50
        0.001                  300       500            1       500

@BRKPT PRINTS
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```
TURBULENT FLOW IN A BLUFF-BODY COMBUSTOR
FOR WPAFB3 - COLD FLOW TEST CASE WITH SWIRL

NUMBER OF ITERATIONS TO EXECUTE         20
MODOP  = 1, THIS IS A NEW CASE
ISCEME = 2, USE SKEW DIFFERENCING
INDCOS = 2, CYLINDRICAL CO-ORDINATES
KNPRO  = 1, FLUID PROPERTIES ARE VARIABLE
KNCOMP = 1, FLOW IS INCOMPRESSIBLE
KVISCO = 0, VISCOSITY IS VARIABLE
KLAMNR = 0, FLOW IS TURBULENT
GRID CONTROLS

NI     =    12
NJ     =    10
ISTEP  =     2
JSTEP  =     6
JEXIT  =     9
JINS   =     2
IMON   =     5
JMON   =     4

DEPENDENT VARIABLE EQUATION CONTROLS
VARIABLE                      SWITCH  NO. SWEEPS UNDER RELAX
                                                     FACTOR

U VELOCITY                       1          2    .70000+00
V VELOCITY                       2          2    .70000+00
PRIMARY PRESSURE CORRECT         3          3    .10000+01
TURBULENCE ENERGY                4          1    .70000+00
ENERGY DISSIPATION               5          1    .70000+00
ENTHALPY                         6          1    .60000+00
FUEL CONCENTRATION               7          1    .60000+00
MIXTURE FRACTION                 8          1    .60000+00
SWIRL VELOCITY                   9          1    .70000+00
SEC. PRESSURE CORRECT.          10          1    .70000+00
VISCOSITY                                        .10000+01
DENSITY                                          .40000+00

VISCOSITY        N-SEC/M**2   .18800-04
DENSITY            KG/M**3    .11609+01
WALL TEMPERATURE         K    .29300+03
BLUFF BODY TEMPERATURE   K    .29300+03

FLOW CONDITIONS...
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VARIABLE		OUTER FLOW	INNER FLOW
AXIAL VELOCITY	M/SEC	.49300+02	.69600+02
SWIRL/AXIAL VEL. RATIO		.10142+00	.00000
TEMPERATURE	K	.29300+03	.40000+03
CONC.-SECOND COMPONENT		.00000	.10000+01
TURB. INTENSITY FACTOR		.50000-02	.50000-02
BNDY. LAYER THICKNESS	M	.10000-01	.10000-01
PRESSURE	N/M**2	.98000+05	
STOIC. O2/FUEL MASS RAT.		.36350+01	
HEAT OF COMBUSTION	J/KG	.50080+08	
FUEL MOLECULAR WEIGHT		.44000+02	
CP-O2	J/KG-K	.91300+03	
CP-N2	J/KG-K	.10400+04	
CP-CO2	J/KG-K	.83400+03	
CP-H2O	J/KG-K	.20200+04	

CO-EFFICIENTS OF THE POLYNOMIAL FOR THE HEAT CAPACITY FOR THE SECOND COMPONENT (E.G.,FUEL)

CP = (C1 + C2*T + C3*T**2 + C4*T**3 + C5*T**4)*UGC /WMF
WITH T IN DEG K AND CP IN J/KG-K

C1	=	-.24515+00
C2	=	.36714-01
C3	=	-.19576-04
C4	=	.46527-08
C5	=	-.29010-12

AXIAL STORAGE LOCATIONS FOR AXIAL VELOCITY

I	X-METER
1	-.10000-02
2	.00000
3	.30000-02
4	.80000-02
5	.16000-01
6	.28000-01
7	.45000-01
8	.80000-01
9	.14000+00
10	.24000+00
11	.39000+00
12	.39000+00

RADIAL STORAGE LOCATIONS FOR RADIAL VELOCITY

J	Y-METER
1	.00000
2	.24000-02
3	.10000-01
4	.30000-01
5	.55000-01

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     6   .70000-01
     7   .85000-01
     8   .11200+00
     9   .12700+00
    10   .12700+00

REFERENCE PRESSURE PASCL      .00000
IPREF                              2
JPREF                              7
TOL.FOR RESIDUAL FOR
PRESSURE CORRECT. EQN.       .20000-01
MAX. NO. OF SWEEPS FOR
PRESS. CORRECT. EQN.              50

MAX. RESIDUAL FOR FIELD VARIABLE           .10000-02
MAX. NO. OF ITERATIONS TO BE RUN                 300
NO. OF ITERATIONS BETWEEN TABULATION             500
   OF FIELD VARIABLES
NO. OF ITERATIONS BETWEEN OUTPUT OF                1
    MONITORING INFORMATION
ITERATION TO START CHEMICAL REACTION             500
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ORIGINAL PAGE IS
OF POOR QUALITY

TURBULENT FLOW WITH COMBUSTION IN A BLUFF-BODY COMBUSTOR

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FLOW RATE OF MAIN STREAM (AIR), KG/S-------------=   2.019+00
FLOW RATE OF SECONDARY STREAM (FUEL), KG/S-------=   1.633-03
TEMPERATURE OF MAIN STREAM, K--------------------=   2.930+02
TEMPERATURE OF SECONDARY STREAM, K---------------=   4.000+02
PRESSURE AT INLET, N/M**2------------------------=   9.800+04
CONCENTRATION OF FUEL IN MAIN STREAM-------------=   0.000
CONCENTRATION OF FUEL IN SECONDARY STREAM--------=   1.000+00
SWIRL NUMBER-------------------------------------=   1.609-01
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ITER NO.	UMOM F.CONC	VMOM M.FRAC	WMOM	MASS	ENTH	T EN	DISS	U EN	V T	W FM	P F	TE	D
	I---------------ABSOLUTE RESIDUAL SOURCE SUMS						---------------I	I-------FIELD VALUES AT MONITORING LOCATION(5, 4)					--------I
1	3.82-01 1.00+00	4.34-02 1.00+00	4.24-01	7.12-01	1.21-01	3.24-02	1.34+05	2.82+00 3.65+05	-3.27+00 2.93+02	7.38+00 1.38-03	-1.39+03 1.38-03	5.43+00	2.96+03
2	9.51-01 8.25+00	1.90-01 8.25+00	4.17-01	1.45+01	9.95-01	1.26-02	4.61+05	-6.65+01 3.82+05	4.35+01 2.93+02	8.81+00 1.71-03	-2.51+02 1.71-03	1.26+01	1.50+04
3	5.79-01 3.87+00	4.96-01 3.87+00	3.21-01	1.87+00	4.68-01	8.09-03	3.06+05	-3.73+01 4.47+05	2.15+01 2.93+02	1.07+01 3.00-03	4.22+02 3.00-03	1.46+01	2.28+04
4	2.17-01 2.17+00	2.50-01 2.17+00	2.28-01	2.03+00	2.62-01	5.68-03	2.14+05	-2.36+01 4.90+05	1.10+01 2.93+02	1.24+01 3.85-03	-3.01+02 3.85-03	1.52+01	2.24+04
5	1.09-01 1.62+00	1.22-01 1.62+00	1.55-01	1.65+00	1.95-01	8.46-03	3.22+05	-1.95+01 5.77+05	1.04+01 2.93+02	1.36+01 5.56-03	-3.73+02 5.56-03	1.37+01	2.39+04
6	8.37-02 1.48+00	2.68-01 1.48+00	1.21-01	7.41+00	1.79-01	3.71-02	3.36+05	-1.62+01 6.92+05	9.09+00 2.94+02	1.41+01 7.83-03	-3.47+02 7.83-03	4.72+00	1.96+04
7	9.52-02 2.81+00	8.73-01 2.81+00	1.46-01	6.28+00	3.40-01	9.73-02	1.41+05	-1.46+01 5.81+05	9.97+00 2.94+02	1.49+01 5.63-03	-2.67+02 5.63-03	1.67+00	1.63+04
8	1.23-01 4.74+00	9.89-01 4.74+00	1.67-01	4.51+00	5.75-01	2.79-01	6.20+04	-1.58+01 6.76+05	9.98+00 2.94+02	1.48+01 7.50-03	-2.95+02 7.50-03	5.63-01	1.07+04
9	1.35-01 1.27+01	7.74-01 1.27+01	2.14-01	4.06+00	1.55+00	3.10-01	2.11+04	-1.96+01 6.66+05	1.03+01 2.94+02	1.62+01 7.31-03	-2.19+02 7.31-03	2.55-01	5.52+03
10	8.24-02 1.45+01	3.88-01 1.45+01	2.53-01	1.92+00	1.76+00	2.18-01	1.42+05	-1.18+01 8.77+05	8.47+00 2.94+02	1.83+01 1.15-02	-2.58+02 1.15-02	4.71-01	3.33+03
11	4.97-02 1.12+01	2.80-01 1.12+01	3.25-01	1.08+00	1.36+00	1.41-01	4.64+04	-8.68+00 1.46+06	7.24+00 2.95+02	1.99+01 2.30-02	-3.23+02 2.30-02	3.81+00	4.36+03
12	5.83-02 8.20+00	3.02-01 8.20+00	2.05-01	1.43+00	9.96-01	8.44-02	1.04+05	-6.85+00 2.28+06	7.38+00 2.97+02	1.93+01 3.93-02	-3.58+02 3.93-02	2.70+01	1.43+04
13	4.30-02 8.52+00	2.46-01 8.52+00	2.09-01	1.09+00	1.03+00	5.42-02	5.79+04	-4.82+00 3.40+06	9.68+00 3.01+02	1.47+01 6.14-02	-2.97+02 6.14-02	6.45+01	3.16+04

14	3.42-02 6.35+00	1.99-01 6.35+00	1.56-01	1.04+00	7.72-01	3.54-02	1.80+06	-4.59+00 3.73+06	6.12+00 3.01+02	1.27+01 6.78-02	-2.67+02 6.78-02	1.08+02	4.62+04
15	2.86-02 5.42+00	1.51-01 5.42+00	1.10-01	8.16-01	6.57-01	2.27-02	1.41+06	-5.90+00 4.08+06	5.62+00 3.00+02	1.01+01 7.48-02	-2.69+02 7.48-02	1.56+02	5.80+04
16	2.85-02 4.97+00	1.09-01 4.97+00	8.20-02	6.42-01	6.00-01	1.57-02	1.01+06	-6.17+00 4.36+06	5.18+00 3.03+02	7.45+00 8.04-02	-2.78+02 8.04-02	1.59+02	6.55+04
17	2.50-02 4.20+00	7.26-02 4.20+00	5.93-02	4.68-01	5.09-01	1.03-02	1.95+05	-6.30+00 4.53+06	5.11+00 3.05+02	5.49+00 8.37-02	-2.53+02 8.37-02	1.45+02	5.92+04
18	2.51-02 3.17+00	5.14-02 3.17+00	4.44-02	3.30-01	3.84-01	7.49-03	4.89+05	-6.37+00 4.61+06	5.05+00 3.06+02	4.14+00 8.51-02	-2.27+02 8.51-02	1.31+02	5.27+04
19	2.33-02 2.23+00	3.80-02 2.23+00	3.47-02	2.31-01	2.71-01	6.22-03	5.73+05	-6.30+00 4.59+06	4.96+00 3.07+02	3.23+00 8.49-02	-2.08+02 8.49-02	1.20+02	4.74+04
20	2.10-02 1.67+00	3.02-02 1.67+00	2.82-02	1.94-01	2.02-01	5.52-03	4.90+05	-6.12+00 4.53+06	4.79+00 3.08+02	2.59+00 8.37-02	-1.98+02 8.37-02	1.10+02	4.31+04

*** PROGRAM TERMINATED BEFORE CONVERGENCE CRITERION SATISFIED ***

U VELOCITY (M/SEC)

I = / J	1	2	3	4	5	6	7	8	9	10	11	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	4.93+01	4.93+01	4.93+01	4.93+01	4.91+01	4.88+01	4.80+01	4.57+01	4.14+01	3.80+01	3.80+01	.1195
8	4.93+01	4.93+01	4.93+01	4.93+01	4.92+01	4.90+01	4.83+01	4.59+01	4.15+01	3.87+01	3.87+01	.0985
7	4.93+01	4.93+01	4.93+01	4.94+01	4.94+01	4.93+01	4.81+01	4.53+01	4.09+01	3.87+01	3.87+01	.0775
6	0.00	0.00	1.58+00	3.96+00	7.55+00	1.26+01	1.93+01	3.06+01	3.33+01	3.27+01	3.27+01	.0625
5	0.00	0.00	-9.44-01	-2.33+00	-4.11+00	-5.77+00	-6.01+00	-3.10+00	1.51+01	2.26+01	2.26+01	.0425
4	0.00	0.00	-1.61+00	-3.62+00	-6.12+00	-8.73+00	-1.11+01	-1.07+01	-4.89+00	1.47+01	1.47+01	.0200
3	0.00	0.00	4.29+00	6.79+00	5.04+00	-3.22+00	-1.02+01	-1.24+01	-7.45+00	1.26+01	1.26+01	.0062
2	6.96+01	6.96+01	6.41+01	5.06+01	2.50+01	3.52-01	-1.01+01	-1.26+01	-7.16+00	1.27+01	1.27+01	.0012
1	6.96+01	6.96+01	6.38+01	5.06+01	2.50+01	3.18-01	-1.02+01	-1.27+01	-5.55+00	1.31+01	1.31+01	-.0012
X =	-.100-02	.000	.300-02	.800-02	.160-01	.280-01	.450-01	.800-01	.140+00	.240+00	.390+00	

V VELOCITY (M/SEC)

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1270
8	0.00	-1.63-02	-6.62-02	-1.47-01	-2.73-01	-4.62-01	-7.22-01	-1.07+00	-1.14+00	-5.46-01	-9.11-03	-1.01-02	.1120
7	0.00	-2.82-02	-1.20-01	-2.93-01	-6.50-01	-1.30+00	-2.29+00	-3.51+00	-3.78+00	-1.61+00	-2.63-02	-2.90-02	.0850
6	0.00	0.00	-1.41-01	-2.06-01	-6.55-01	-1.78+00	-3.92+00	-5.58+00	-5.81+00	-2.32+00	-3.76-02	-4.16-02	.0700
5	0.00	0.00	8.84+00	7.91+00	6.82+00	4.91+00	1.71+00	-1.61+00	-6.63+00	-3.05+00	-4.28-02	-4.89-02	.0550
4	0.00	0.00	5.19+00	4.90+00	4.79+00	4.16+00	2.63+00	-2.24-02	-1.43+00	-2.94+00	-2.38-02	-2.89-02	.0300
3	0.00	0.00	-5.92+00	-1.27+00	2.06+00	3.82+00	2.11+00	3.33-01	-4.09-01	-1.00+00	-1.03-03	-2.51-03	.0100
2	0.00	0.00	2.85+00	4.10+00	4.27+00	2.51+00	7.39-01	9.06-02	-1.08-01	-2.38-01	1.04-03	8.55-04	.0024
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0000
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

W VELOCITY (M/SEC)

J \ I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	5.00+00	5.00+00	5.00+00	5.00+00	4.99+00	4.99+00	4.99+00	4.98+00	4.96+00	4.94+00	4.87+00	4.87+00	.1195
8	5.00+00	5.00+00	5.00+00	5.00+00	5.00+00	5.00+00	5.01+00	5.03+00	5.07+00	5.11+00	5.16+00	5.16+00	.0985
7	5.00+00	5.00+00	5.00+00	5.00+00	5.01+00	5.05+00	5.15+00	5.41+00	5.83+00	6.06+00	6.39+00	6.43+00	.0775
6	0.00	0.00	3.62+00	4.00+00	4.39+00	4.91+00	5.53+00	6.09+00	6.71+00	7.35+00	7.92+00	8.05+00	.0625
5	0.00	0.00	5.09+00	5.59+00	5.95+00	6.73+00	8.11+00	9.43+00	9.69+00	1.08+01	9.53+00	9.76+00	.0425
4	0.00	0.00	3.01+00	2.73+00	2.59+00	3.41+00	5.68+00	8.44+00	9.28+00	9.04+00	6.92+00	7.22+00	.0200
3	0.00	0.00	6.85+00	3.16+00	1.76+00	1.48+00	2.61+00	4.45+00	5.11+00	4.89+00	3.70+00	3.96+00	.0062
2	0.00	0.00	1.79-04	1.80-01	5.28-01	6.74-01	1.23+00	2.07+00	2.34+00	2.25+00	1.72+00	1.88+00	.0012
1	0.00	0.00	5.96-04	1.64-01	5.90-01	8.30-01	1.40+00	2.29+00	2.52+00	2.40+00	1.88+00	2.10+00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

PRESSURE (PASCAL)

J \ I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	6.52+01	6.20+01	6.06+01	5.99+01	6.27+01	7.52+01	1.06+02	2.09+02	3.91+02	5.14+02	0.00	.1195
8	0.00	3.96+01	3.79+01	3.86+01	4.00+01	4.44+01	5.86+01	9.59+01	2.08+02	3.96+02	5.18+02	0.00	.0985
7	0.00	0.00	-3.07+00	-7.38+00	-1.90+01	-2.84+01	-2.10+01	3.94+01	1.84+02	4.02+02	5.14+02	0.00	.0775
6	0.00	0.00	-9.74+01	-1.16+02	-1.37+02	-1.52+02	-1.49+02	-3.87+01	1.44+02	3.99+02	4.95+02	0.00	.0625
5	0.00	0.00	-7.82+01	-1.36+02	-1.55+02	-1.69+02	-1.75+02	-9.17+01	3.36+01	3.42+02	4.46+02	0.00	.0425
4	0.00	0.00	-8.77+01	-1.73+02	-1.98+02	-2.00+02	-1.97+02	-1.69+02	-4.16+01	2.30+02	3.84+02	0.00	.0200
3	0.00	0.00	-2.32+02	-4.21+02	-4.07+02	-2.74+02	-2.18+02	-2.53+02	-1.38+02	1.46+02	3.27+02	0.00	.0062
2	0.00	0.00	6.77+01	3.05+02	8.28+01	-1.32+02	-2.07+02	-2.81+02	-1.70+02	1.20+02	3.07+02	0.00	.0012
1	0.00	0.00	6.83+01	3.10+02	8.63+01	-1.42+02	-2.39+02	-3.14+02	-1.97+02	1.04+02	2.75+02	0.00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

KIN.EVERGY (M*2/SEC*2)

J \ I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	1.22+01	1.23+01	1.28+01	1.35+01	1.44+01	1.52+01	1.58+01	1.56+01	1.42+01	1.22+01	1.11+01	1.11+01	.1195
8	1.22+01	1.20+01	1.16+01	1.09+01	1.01+01	8.99+00	7.84+00	6.35+00	4.98+00	3.71+00	2.91+00	2.92+00	.0985
7	1.22+01	1.23+01	1.31+01	1.44+01	1.62+01	1.77+01	1.83+01	1.61+01	1.05+01	6.85+00	7.37+00	7.41+00	.0775
6	0.00	0.00	3.12+00	4.18+01	7.47+01	9.37+01	9.15+01	6.90+01	3.65+01	2.17+01	2.56+01	2.60+01	.0625
5	0.00	0.00	8.69+00	5.74+01	6.76+01	7.01+01	7.13+01	7.69+01	1.03+02	6.92+01	5.45+01	5.49+01	.0425
4	0.00	0.00	1.14+01	8.52+01	1.10+02	1.06+02	8.14+01	7.69+01	9.52+01	8.64+01	6.28+01	6.16+01	.0200
3	0.00	0.00	2.38+01	3.50+02	4.03+02	2.78+02	1.31+02	1.07+02	1.17+02	1.04+02	7.95+01	7.81+01	.0062
2	2.42+01	2.42+01	2.44+01	6.62+01	2.54+02	3.03+02	1.43+02	1.12+02	1.20+02	1.01+02	8.24+01	8.22+01	.0012
1	2.42+01	2.42+01	2.44+01	6.66+01	2.55+02	3.04+02	1.43+02	1.12+02	1.20+02	1.01+02	8.22+01	9.56+01	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

DISSIPATION (M*2/SEC*3)

J \ I =	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345

J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
9	7.73+03	2.27+03	2.41+03	2.61+03	2.86+03	3.11+03	3.27+03	3.21+03	2.79+03	2.21+03	1.92+03	1.92+03	.1195
8	7.73+03	7.55+03	7.05+03	6.33+03	5.42+03	4.40+03	3.39+03	2.24+03	1.33+03	7.14+02	4.10+02	4.12+02	.0985
7	7.73+03	2.27+03	2.47+03	2.81+03	3.31+03	3.75+03	4.02+03	3.58+03	2.21+03	1.19+03	9.38+02	9.42+02	.0775
6	0.00	0.00	1.31+03	1.47+04	2.61+04	3.20+04	3.21+04	2.31+04	1.04+04	4.79+03	3.88+03	3.98+03	.0625
5	0.00	0.00	6.49+03	1.22+04	1.25+04	1.15+04	1.28+04	1.75+04	2.39+04	1.41+04	8.12+03	8.12+03	.0425
4	0.00	0.00	1.01+04	3.11+04	4.31+04	2.58+04	1.26+04	1.25+04	1.82+04	1.51+04	8.40+03	7.90+03	.0200
3	0.00	0.00	3.58+04	3.62+05	3.53+05	1.68+05	3.07+04	2.05+04	2.39+04	2.01+04	1.27+04	1.21+04	.0062
2	2.18+04	2.18+04	2.16+04	5.50+04	2.15+05	2.03+05	3.68+04	2.20+04	2.48+04	1.98+04	1.36+04	1.35+04	.0012
1	2.18+04	2.18+04	2.16+04	5.47+04	2.15+05	2.02+05	3.64+04	2.18+04	2.45+04	1.97+04	1.35+04	1.83+04	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

FUEL CONCENTRATION

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	6.95-11	6.19-10	1.53-09	2.12-09	2.37-09	2.38-09	2.40-09	5.07-09	2.39-06	2.12-06	.1195
8	0.00	0.00	4.78-08	2.70-07	3.83-07	2.79-07	2.07-07	1.57-07	1.20-07	9.24-08	2.78-05	2.52-05	.0985
7	0.00	0.00	7.13-05	3.08-04	7.03-04	9.51-04	7.23-04	4.73-04	2.37-04	1.39-04	7.00-04	6.39-04	.0775
6	0.00	0.00	5.03-02	4.65-02	4.12-02	3.25-02	2.38-02	1.50-02	7.39-03	4.04-03	2.86-03	2.65-03	.0625
5	0.00	0.00	5.36-02	4.83-02	4.20-02	3.13-02	1.90-02	1.24-02	8.35-03	5.84-03	4.21-03	3.95-03	.0425
4	0.00	0.00	9.81-02	9.56-02	8.37-02	5.32-02	2.28-02	1.15-02	8.16-03	5.63-03	4.49-03	4.34-03	.0200
3	0.00	0.00	2.46-01	2.65-01	2.35-01	1.34-01	4.19-02	1.41-02	8.75-03	5.61-03	4.56-03	4.54-03	.0062
2	1.00+00	1.00+00	9.93-01	8.34-01	4.86-01	1.82-01	4.88-02	1.58-02	9.16-03	5.65-03	4.59-03	4.63-03	.0012
1	1.00+00	1.00+00	9.92-01	8.29-01	4.95-01	1.90-01	5.60-02	1.85-02	9.82-03	5.71-03	4.63-03	4.63-03	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

MIXTURE FRACTION

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	6.95-11	6.19-10	1.53-09	2.12-09	2.37-09	2.38-09	2.40-09	5.07-09	2.39-06	2.12-06	.1195
8	0.00	0.00	4.78-08	2.70-07	3.83-07	2.79-07	2.07-07	1.57-07	1.20-07	9.24-08	2.78-05	2.52-05	.0985
7	0.00	0.00	7.13-05	3.08-04	7.03-04	9.51-04	7.23-04	4.73-04	2.37-04	1.39-04	7.00-04	6.39-04	.0775
6	0.00	0.00	5.03-02	4.65-02	4.12-02	3.25-02	2.38-02	1.50-02	7.39-03	4.04-03	2.86-03	2.65-03	.0625
5	0.00	0.00	5.36-02	4.83-02	4.20-02	3.13-02	1.90-02	1.24-02	8.35-03	5.84-03	4.21-03	3.95-03	.0425
4	0.00	0.00	9.81-02	9.56-02	8.37-02	5.32-02	2.28-02	1.15-02	8.16-03	5.63-03	4.49-03	4.34-03	.0200
3	0.00	0.00	2.46-01	2.65-01	2.35-01	1.34-01	4.19-02	1.41-02	8.75-03	5.61-03	4.56-03	4.54-03	.0062
2	1.00+00	1.00+00	9.93-01	8.34-01	4.86-01	1.82-01	4.88-02	1.58-02	9.16-03	5.65-03	4.59-03	4.63-03	.0012
1	1.00+00	1.00+00	9.92-01	8.29-01	4.95-01	1.90-01	5.60-02	1.85-02	9.82-03	5.71-03	4.63-03	4.63-03	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

ENTHALPY (M*2/SEC*2)

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	.1195
8	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.96+05	2.97+05	2.97+05	.0985
7	2.96+05	2.96+05	3.00+05	3.12+05	3.32+05	3.44+05	3.33+05	3.20+05	3.08+05	3.03+05	3.31+05	3.28+05	.0775
6	0.00	0.00	2.84+06	2.64+06	2.38+06	1.94+06	1.50+06	1.05+06	6.69+05	5.00+05	4.41+05	4.30+05	.0625
5	0.00	0.00	3.01+06	2.74+06	2.42+06	1.88+06	1.26+06	9.22+05	7.17+05	5.91+05	5.08+05	4.96+05	.0425
4	0.00	0.00	5.26+06	5.13+06	4.53+06	2.29+06	1.45+06	8.78+05	7.08+05	5.80+05	5.23+05	5.15+05	.0200

ORIGINAL PAGE IS OF POOR QUALITY

J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
3	0.00	0.00	1.28+07	1.37+07	1.22+07	7.07+06	2.42+06	1.01+06	7.38+05	5.80+05	5.27+05	5.26+05	.0062
2	5.10+07	5.10+07	5.06+07	4.25+07	2.49+07	9.51+06	2.77+06	1.10+06	7.59+05	5.82+05	5.28+05	5.30+05	.0012
1	5.10+07	5.10+07	5.06+07	4.23+07	2.54+07	9.90+06	3.13+06	1.23+06	7.92+05	5.85+05	5.30+05	5.37+05	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

*- VISCOSITY (N-SEC/M*2) -*

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	1.88-05	.1345
9	2.01-03	7.03-03	7.17-03	7.36-03	7.59-03	7.81-03	7.95-03	7.92-03	7.58-03	7.02-03	6.67-03	6.67-03	.1195
8	2.01-03	2.01-03	2.00-03	1.99-03	1.97-03	1.94-03	1.91-03	1.90-03	1.97-03	2.03-03	2.18-03	2.18-03	.0985
7	2.01-03	7.03-03	7.29-03	7.70-03	8.26-03	8.66-03	8.64-03	7.50-03	5.19-03	4.09-03	6.10-03	6.10-03	.0775
6	1.88-05	1.88-05	8.46-04	1.16-02	2.12-02	2.70-02	2.53-02	1.94-02	1.24-02	9.68-03	1.78-02	1.78-02	.0625
5	1.88-05	1.88-05	1.24-03	2.85-02	3.84-02	4.46-02	4.09-02	3.34-02	4.05-02	3.43-02	3.89-02	3.89-02	.0425
4	1.88-05	1.88-05	1.35-03	2.50-02	3.00-02	4.57-02	5.54-02	5.00-02	5.27-02	5.13-02	5.02-02	5.02-02	.0200
3	1.88-05	1.88-05	1.50-03	3.60-02	4.79-02	4.75-02	5.88-02	5.91-02	6.12-02	5.57-02	5.29-02	5.29-02	.0062
2	3.16-03	3.16-03	3.23-03	9.01-03	3.12-02	4.60-02	5.74-02	5.97-02	6.12-02	5.45-02	5.24-02	5.24-02	.0012
1	3.16-03	3.16-03	3.23-03	9.01-03	3.12-02	4.60-02	5.74-02	5.97-02	6.12-02	5.45-02	5.24-02	1.88-05	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

*- DENSITY (KG/M*3) -*

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.1345
9	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.1195
8	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0985
7	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0775
6	1.16+00	1.16+00	1.17+00	1.18+00	1.17+00	1.17+00	1.17+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0625
5	1.16+00	1.16+00	1.16+00	1.16+00	1.15+00	1.15+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0425
4	1.16+00	1.16+00	1.15+00	1.15+00	1.14+00	1.14+00	1.15+00	1.16+00	1.16+00	1.16+00	1.16+00	1.16+00	.0200
3	1.16+00	1.16+00	1.12+00	1.12+00	1.11+00	1.12+00	1.14+00	1.15+00	1.16+00	1.16+00	1.16+00	1.16+00	.0062
2	1.30+00	1.30+00	1.29+00	1.23+00	1.15+00	1.12+00	1.14+00	1.15+00	1.16+00	1.16+00	1.16+00	1.16+00	.0012
1	1.30+00	1.30+00	1.29+00	1.23+00	1.15+00	1.12+00	1.14+00	1.15+00	1.16+00	1.16+00	1.16+00	1.16+00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

- TEMPERATURE (K) -

I = / J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.1345
9	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.1195
8	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0985
7	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	2.93+02	.0775
6	2.93+02	2.93+02	2.98+02	2.96+02	2.96+02	2.95+02	2.94+02	2.94+02	2.93+02	2.93+02	2.93+02	2.93+02	.0625
5	2.93+02	2.93+02	3.01+02	3.00+02	2.99+02	2.98+02	2.95+02	2.94+02	2.93+02	2.93+02	2.93+02	2.93+02	.0425
4	2.93+02	2.93+02	3.11+02	3.09+02	3.08+02	3.03+02	2.97+02	2.94+02	2.94+02	2.93+02	2.93+02	2.93+02	.0200
3	2.93+02	2.93+02	3.37+02	3.37+02	3.32+02	3.18+02	3.02+02	2.95+02	2.94+02	2.93+02	2.93+02	2.93+02	.0062
2	4.00+02	4.00+02	4.00+02	3.90+02	3.64+02	3.27+02	3.04+02	2.96+02	2.94+02	2.93+02	2.93+02	2.93+02	.0012
1	4.00+02	4.00+02	4.00+02	3.90+02	3.64+02	3.27+02	3.04+02	2.96+02	2.94+02	2.93+02	2.93+02	2.93+02	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.675-01	.110+00	.190+00	.315+00	.465+00	

MEAN SP. HT.(J/KG-K)

J \ I	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.1345
9	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.1195
8	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0985
7	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	.0775
6	1.01+03	1.01+03	1.07+03	1.07+03	1.06+03	1.05+03	1.04+03	1.03+03	1.02+03	1.02+03	1.01+03	1.01+03	.0625
5	1.01+03	1.01+03	1.08+03	1.07+03	1.06+03	1.05+03	1.03+03	1.03+03	1.02+03	1.02+03	1.02+03	1.02+03	.0425
4	1.01+03	1.01+03	1.13+03	1.13+03	1.11+03	1.08+03	1.04+03	1.03+03	1.02+03	1.02+03	1.02+03	1.02+03	.0200
3	1.01+03	1.01+03	1.32+03	1.33+03	1.29+03	1.17+03	1.07+03	1.03+03	1.02+03	1.02+03	1.02+03	1.02+03	.0062
2	2.19+03	2.19+03	2.18+03	1.99+03	1.60+03	1.24+03	1.08+03	1.03+03	1.02+03	1.02+03	1.02+03	1.02+03	.0012
1	2.19+03	2.19+03	2.18+03	1.99+03	1.60+03	1.24+03	1.08+03	1.03+03	1.02+03	1.02+03	1.02+03	1.01+03	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

O2 MASS FRACTION

J \ I	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.1345
9	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.1195
8	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.0985
7	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	2.33-01	.0775
6	2.33-01	2.33-01	2.21-01	2.22-01	2.23-01	2.25-01	2.27-01	2.30-01	2.31-01	2.32-01	2.32-01	2.32-01	.0625
5	2.33-01	2.33-01	2.21-01	2.22-01	2.23-01	2.26-01	2.29-01	2.30-01	2.31-01	2.32-01	2.32-01	2.32-01	.0425
4	2.33-01	2.33-01	2.10-01	2.11-01	2.13-01	2.21-01	2.28-01	2.30-01	2.31-01	2.32-01	2.32-01	2.32-01	.0200
3	2.33-01	2.33-01	1.76-01	1.71-01	1.78-01	2.02-01	2.23-01	2.30-01	2.31-01	2.32-01	2.32-01	2.32-01	.0062
2	0.00	0.00	1.62-03	3.88-02	1.20-01	1.91-01	2.22-01	2.29-01	2.31-01	2.32-01	2.32-01	2.32-01	.0012
1	0.00	0.00	1.83-03	3.98-02	1.18-01	1.89-01	2.20-01	2.29-01	2.31-01	2.32-01	2.32-01	2.32-01	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

N2 MASS FRACTION

J \ I	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	.1345
9	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	.1195
8	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	7.67-01	.0985
7	7.67-01	7.67-01	7.67-01	7.67-01	7.66-01	7.66-01	7.66-01	7.67-01	7.67-01	7.67-01	7.66-01	7.67-01	.0775
6	7.67-01	7.67-01	7.28-01	7.31-01	7.35-01	7.42-01	7.49-01	7.55-01	7.61-01	7.64-01	7.65-01	7.65-01	.0625
5	7.67-01	7.67-01	7.26-01	7.30-01	7.35-01	7.43-01	7.52-01	7.57-01	7.61-01	7.63-01	7.64-01	7.64-01	.0425
4	7.67-01	7.67-01	6.92-01	6.94-01	7.03-01	7.26-01	7.50-01	7.58-01	7.61-01	7.63-01	7.64-01	7.64-01	.0200
3	7.67-01	7.67-01	5.78-01	5.64-01	5.87-01	6.64-01	7.35-01	7.56-01	7.60-01	7.63-01	7.64-01	7.64-01	.0062
2	0.00	0.00	5.35-03	1.28-01	3.94-01	6.28-01	7.30-01	7.55-01	7.60-01	7.63-01	7.63-01	7.63-01	.0012
1	0.00	0.00	6.03-03	1.31-01	3.87-01	6.22-01	7.24-01	7.53-01	7.59-01	7.63-01	7.63-01	7.63-01	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.675-01	.110+00	.190+00	.315+00	.465+00	

CO2 MASS FRACTION

J \ I	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345

ORIGINAL PAGE IS
OF POOR QUALITY

9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1195
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0985
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0775
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0625
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0425
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0200
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0062
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0012
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

- H2O MASS FRACTION --

I = J	1	2	3	4	5	6	7	8	9	10	11	12	Y =
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1345
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.1195
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0985
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0775
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0625
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0425
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0200
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0062
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.0012
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-.0012
X =	-.150-02	-.500-03	.150-02	.550-02	.120-01	.220-01	.365-01	.625-01	.110+00	.190+00	.315+00	.465+00	

FLOWIN=	2.021+00		
FIN=	8.081-04	FOUT=	8.508-04
ENIN=	3.370+05	ENOUT=	3.390+05
TIN=	2.930+02	TOUT=	2.930+02

@BRKPT PRINTS