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Abstract		
This report describes a comp	uter program for solution of the	boundary layer equations. The
program is an outgrowth of the	e original procedure developed b	oy Patankar and Spalding at
Imperial College, London, In	cluded in the report is a listing	of the program and sample data
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NOMENCLATURE

constant in program correlation for A^+ or B^+ , or constant а in constant eddy diffusivity model, or coefficient in transformed equation (4.7). production constant, turbulent kinetic energy equation. A A⁺ damping constant, van Driest damping function (see equation 2.24 for correlation). constant in program correlation for A^+ or B^+ , or constant Ъ in constant eddy diffusivity model, or coefficient in transformed equation (4.7). generalized x-direction body force, momentum equation. Ъf dissipation constant, turbulent kinetic energy equation. Bq в⁺ damping constant, Evans damping function (see equation 2.24 for program correlation). constant in program correlation for A^+ or B^+ , or constant С in variable turbulent Prandtl number model, or specific heat of fluid, or coefficient in transformed equation (4.7). constant in differential lag equation to compute effective С P^+ or V_+^+ . friction coefficient, $g_c \tau_o / (\rho U^2)$, or $g_c \tau_o / \overline{\rho U^2}$) for pipe $C_f/2$ and channel flows. coefficient in transformed equation (4.7). đ damping function to suppress mixing length in the region D immediately adjacent to a wall, equation (2.22) and (2.23). ${\mathcal D}$ dissipation term, turbulent kinetic energy equation. E-surface see Figure 4.1. total energy flux boundary condition at a wall, $\hat{m}_{0}^{"} I_{0}^{*} + \dot{q}_{0}^{"}$. Étotal (see Figure 2.2). local gravitational constant to determine free-convection g body force. proportionality constant, Newton's Second Law. 8_c fluctuation in static enthalpy. 11

*' i	fluctuation in stagnation enthalpy.
I	static enthalpy of fluid.
I-surface	see Figure 4.1.
ı*	stagnation enthalpy of fluid, $I + U^2/(2g_cJ)$.
1 ^{*+}	non-dimensional stagnation enthalpy, $(I_0^*-I^*) U_{\tau}/(\dot{q}_0'/\rho_0)$.
J	conversion constant, mechanical to thermal energy.
Jq	diffusion term, turbulent kinetic energy equation.
k	thermal conductivity of fluid.
٤	mixing-length (see section 2.3.1)
m ^e ii	mass flux at I or E surface (see Figures 2.2 and 4.1).
Nu	Nusselt number, pipe and channel flow, St \cdot \overline{Pr} \cdot Re.
P	thermodynamic pressure.
P+	non-dimensional pressure, $g_{c}v_{o}(dP/dx)/(\rho_{o}U_{\tau}^{3})$
Pet	turbulent Peclet number, program correlation for \Pr_t .
Pr	Prandtl number, µc/k .
Pr _{eff}	combined laminar and turbulent Prandtl number, equation (2.14).
Prt	turbulent Prandtl number, $\epsilon_M^{\prime} \epsilon_H^{\prime}$ (see equation 2.37 for program correlation).
å''	combined laminar and turbulent heat flux, Figure 2.2 and equation (3.2).
q ⁺	non-dimensional heat flux, \dot{q}''/\dot{q}''_0 .
q ² /2	turbulent kinetic energy
r	radius
Re	pipe or channel flow Reynolds number, equation (3.29).
Re _H	enthalpy thickness Reynolds number, $\Delta_2 U_{\infty}^{\nu}/V_{\infty}$
Re _M	momentum thickness Reynolds number, $\Delta_2 U_{\infty} / v_{\infty}$
Re tran	Reynolds number (Re or Re _M) for transition from laminar to turbulent flow.
9	generalized energy source, stagnation enthalpy equation.

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s ⁺	non-dimensional generalized energy source, $v_0 s/(\dot{q}_0''U_1)$.
S	energy source term, stagnation enthalpy equation, $UX/J + s$.
Scq	turbulent Schmidt number, $\varepsilon_M^{/\varepsilon}q$.
St	Stanton number, $\dot{q}_{o}^{\prime\prime}/\{\rho_{\omega}U_{\omega}(I_{o}^{*}-I_{\omega}^{*})\}$, or $\dot{q}_{o}^{\prime\prime}/\{\overline{\rho}\overline{U}(I_{o}^{*}-\overline{I}^{*})\}$.
Tu	longitudinal free-stream turbulence intensity, $\sqrt{u^2}/U_{\infty}$.
u'	fluctuation in U component of velocity .
U	velocity component in x-direction.
υ _τ	shear velocity $\sqrt{g_c \tau_o}/\rho_o$.
υ ⁺	non-dimensional U velocity component U/U_{τ} .
v'	fluctuation in V component of velocity .
v	velocity component in y-direction.
v _o +	non-dimensional V velocity component at wall, v_o/u_{τ} or $(m_o'/\rho_o)/u_{\tau}$.
W	$\rho_0 U_{\tau}^3 / (g_c J q_0'')$
x	distance along surface (see Figures 2.1 and 4.1).
* x	non-dimensional x distance, xU_{τ}/v_{o} .
X	body force term, momentum equation, $\frac{\rho g}{g_c}$ + bf .
.x ⁺	non-dimensional body force term, $g_{c} v_{o} X / (\rho_{o} U_{\tau}^{3})$.
у	distance normal to surface (see Figures 2.1a and 4.1).
y ⁺	non-dimensional y distance, $y U_{\tau} / v_{o}$.
α	angle between surface tangent and axis-of-symmetry line (see Figures 2.1a and 4.1), or constant in internal cor- relation for Pr _t .
β	power-law coefficient velocity equation slip scheme.
Y	power-law coefficient, diffusion equation slip scheme.
δ ₁	displacement thickness, equation (3.22a).
δ ₂	momentum thickness, equation (3.22b).
^δ .99	boundary layer thickness where $U/U_{\infty} = 0.99$.

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۵ ₂	enthalpy thickness, equation (3.22c).
с _н	eddy diffusivity for heat.
ε M	eddy diffusivity for momentum.
e q	eddy diffusivity for turbulent kinetic energy.
ĸ	Karman constant, mixing-length model.
λ	outer length scale constant mixing-length model.
λ _o	program input value of λ .
μ	dynamic viscosity of fluid.
$^{\mu}$ eff	combined laminar and turbulent viscosity, equation (2.6).
μ+	non-dimensional viscosity, $\mu_{eff}^{/\mu}$.
ν	kinematic viscosity of fluid.
ρ	density of fluid.
τ _	combined laminar and turbulent shear stress, equation (3.1).
τ +	non-dimensional shear stress, τ/τ_o .
φ	generalized dependent variable in transformed equation (4.7).
ψ	stream function coordinate.
ω	non-dimensional stream function coordinate.
Subscripts	
axi	axisymmetric (see section 3.6).
đ	downstream edge of finite-difference control volume.
e	edge of shear layer, equation (2.18).
eff	effective value.
fp	"flat plate" value, without transpiration or pressure gradient.
eq	equilibrium value, equation (2.25).
N	number of stream tubes.
° v	wall value.
t	turbulent value.

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- u upstream edge of finite-difference control volume.
- ∞ free-stream value.
- 2.5 join-point value.

Superscript

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overbar time averaged quantity, or bulk mean value (Section 3.7).

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Chapter 1

INTRODUCTION

In recent years it has become practicable and popular to compute turbulent boundary layers using finite-difference techniques and the digital computer. These techniques have now been developed to the point where one can readily develop one's own program for particular applications, and numerous workers have described their programs in the literature and have made listings or card decks available to others. There is no question that the development of one's own program is a tedious process and the programs become sufficiently complex that a great deal of development effort is usually required. For the user who doesn't expect to devote a great amount of time (and money) on a program it is often more practicable to make use of someone else's program, provided that the program is sufficiently well documented that it can be used intelligently.

It is the objective of this report to describe one such program which has gone through a considerable period of development, and which has been found useful in connection with an experimental turbulent boundary layer research program at Stanford University. Enough people have asked for copies of this program that it seems worthwhile to provide in a more formal way the documentation that is really necessary if the program is to be used properly.

No claim of superiority is made; in fact, there is no question that there are other programs developed for particular applications that are faster and are in some cases even more precise. However, this program is believed to be unique in its degree of generality, in the large variety of different kinds of problems that can be handled, and, in particular, in an input-output scheme that makes it possible to handle a great variety of problems without touching the deck. Very minor modifications in the deck open up a whole realm of additional possibilities.

The original basic program from which this one was developed was the Patankar/Spalding program described in their 1967 book [1]. Much of that program will be recognized in this present version, and a complete understanding of all the details of the present program may require reference to that publication. However, it is hoped that this description will be sufficiently complete to make further study unnecessary in most cases. A later revision of

the Spalding program was published in 1970 [2] in which a number of important improvements were made. Some of these improvements have been incorporated in the present version, and it is our belief that the present version suffers in comparison only with respect to size and speed, and perhaps in accuracy for some unusual types of problems. The largest source of inaccuracy and uncertainty in turbulent boundary layer finite-difference procedures lies in the methods used to model the turbulence, and this has nothing to do with the computational procedure.

The basic features of the program will now be described, and then elaborated upon in the chapters that follow.

The program is designed to solve two-dimensional parabolic differential equations only, i.e., the boundary layer equations incorporating the usual boundary layer approximations. The eddy diffusivity concept must be used in modeling the turbulent stresses, although beyond that point there is great flexibility. The program does not handle re-circulating flows.

The program solves the momentum equation of the boundary layer, as a minimum, plus any number of diffusion equations, all simultaneously. The listing presented in the Appendix is dimensioned to a maximum of five diffusion equations, and the output routine handles only five, but it is a simple matter to increase this number if desired.

A coordinate system for axi-symmetric flows is used so that a large variety of flow types can be accommodated by simple manipulation of variables in the input routine. These include the boundary layer on a flat plate, flow inside nozzles and diffusers (for a prescribed potential flow distribution), flow over axi-symmetric bodies, both developing and fully developed flow inside circular pipes and flat ducts, circular and flat jets and free-shear flows. As presently set up, the program provides for one wall surface, and thus the duct-flow problems are limited to simple pipes and flat ducts with symmetrical boundary conditions. In principle there is no reason why two walls, such as are encountered in circular tube annuli, cannot be handled, but this does require some additional program modification.

The program solves laminar boundary layers as well as turbulent boundary layers, and provision is made for a transition from a laminar to a turbulent boundary layer based on a momentum thickness Reynolds number criterion. Solution of laminar boundary layers is of necessity slower than is possible with

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programs developed for laminar boundary layers alone, because the program was developed for the more complex turbulent problems.

Fluid properties are treated as variable with the properties of any particular fluid supplied through a separate subroutine. In the present program listing the only fluid properties provided are those of air (essentially the Keenan and Kaye Gas Tables). Properties of other fluids may be introduced by attaching additional property subroutines. Fluid properties may also be treated as constant, in which case the properties are introduced directly into the input routine. The types of problems that can be handled with the present listing are obviously limited by inclusion of only the properties of air. For example, the program could readily solve a binary diffusion problem, together with heat transfer, but it would be necessary to append an additional properties subroutine unless the constant properties mode is deemed adequate.

Viscous dissipation in the energy equation is included as an option controllable through the input routine, so high velocity flows can be readily solved. Provision is also made for introducing axial body forces and internal heat generation. A particular provision is made to introduce an axial gravity force, and this together with the variable property option allows solution of both laminar and turbulent free-convection problems.

In principle the chemically reacting boundary layer may be solved to various degrees of approximation, but this does require the addition of source terms which are not included in the present listing.

Any kind of initial conditions can be accommodated, and the boundary condition possibilities using the input routine, while not infinite, are nevertheless large. Free-stream velocity, rather than pressure, is treated as a variable boundary condition, and heat and mass flux along a wall may assume any values. Alternatively, wall enthalpy (or concentration in the case of mass diffusion) and mass flux may be treated as independent. In the case of duct flows there is no free-stream and pressure is computed as a dependent variable.

Several possibilities for turbulence modeling are included and can be activated in a simple manner in the input routine. The Prandtl mixing-length scheme may be used throughout, or, alternatively, a one-differential-equation turbulent kinetic energy scheme may be used for the flow outside the sublayer region. This alternative involves solution of the turbulent kinetic energy differential equation of the boundary layer, which is simply another diffusion equation. As another possibility, eddy diffusivity in the outer part of the boundary layer may be evaluated as an empirical function of Reynolds number. In all cases a mixing-length scheme is used to calculate the sublayer near the wall, and two possibilities are programmed. In one the Van Driest exponential damping function is used, while in the other the Evans linear damping function is used. Internal empirical correlations for the damping constants to account for effects of pressure gradient and transpiration are contained in the program, or, alternatively, the user can supply his own constants. Other variations in the turbulence physics can be quite easily made, but this does require some re-programming.

The energy equation, and any other type of diffusion equations, is solved through the concept of turbulent Prandtl number (or turbulent Schmidt number). The program contains an internal calculation for turbulent Prandtl number as a function of turbulent Peclet number, which gives reasonably good results over the entire spectrum of Prandtl number, including the liquid metal region. Alternatively, the user may specify his own turbulent Prandtl number.

The concepts of "slip" values at the wall and a "Wall Function" are employed, allowing the use of a relatively coarse grid in the direction normal to a wall surface. The region adjacent to the wall is computed by numerically integrating the Couette flow forms of the boundary layer equations, but with physics input identical to that used outside the wall region. This option can, however, be bypassed, but at the cost of a greatly increased number of grid points near the wall. The Wall Function is especially useful in high Reynolds number applications where the number of cross-stream grid points can otherwise become excessive.

The program is "almost" independent of any particular dimensioning system. It would be completely independent were it not for the fact that the property subroutine for air which is packaged with the program is based on Btu, ft, lb_m units. The dimensioning system to be used is designated in the input routine by two constants.

Finally, a word about the differencing scheme employed is in order, because in this respect it differs from many other programs. A fully implicit scheme is employed for the main dependent variables (velocity, enthalpy, mass concentration, etc.), and this, together with the fact that the conservation equations are always satisfied, in principle allows large forward steps to be

taken without stability problems. However, fluid properties and turbulence properties are handled explicitly, and if these are changing markedly in the flow direction it is not possible to take large forward steps without stability and accuracy problems. The advantage is that nowhere is iteration required. This restriction to relatively small forward steps (typically about one or two boundary layer thicknesses) is not necessarily disadvantageous, because one of the reasons for making finite-difference calculations is that variable boundary conditions can be easily handled, and there is often a need for output data, such as heat flux, at frequent intervals along a surface. Both of these requirements dictate a small forward step size anyway.

The remaining chapters of this report will now expand upon this brief description, culminating in detailed instructions about how to set up a problem and use the input routine. It might well be noted here, however, that the input subroutine (which is actually packaged at the end of the program) contains very extensive descriptive comments, suggestions, and instructions, and is thus a convenient summary of much of this report.

Chapter 2

DIFFERENTIAL EQUATIONS AND TURBULENCE MODELS

2.1 <u>Convective Transport Equations</u>

The types of flows modeled by STAN5 are those described by the parabolic boundary layer equations, which include the continuity, momentum, and stagnation enthalpy equations. They are written to describe flow of a turbulent, compressible fluid over an axi-symmetric body. All equations have been timeaveraged, and in the equations all dependent variables and properties are either mean quantities or fluctuating quantities (as denoted by primes). They are also applicable to laminar flows, in which case the turbulent stress and heat flux are ignored. Figure 2.1 describes the coordinate system and typical velocity and stagnation enthalpy profiles. Note the coordinate system is written in terms of the independent variables, x and y. The radius, r, is a transverse radius of curvature and is related to y as shown in Figure 2.1(a), and the longitudinal radius of curvature is neglected (i.e., $\alpha(x)$ in Figure 2.1(a) varies slowly with x).

2.1.1 The Continuity Equation

The time-averaged continuity equation for this coordinate system is given by

$$\frac{\partial}{\partial \mathbf{x}} (\mathbf{r} \rho \mathbf{U}) + \frac{\partial}{\partial \mathbf{y}} (\mathbf{r} \rho \mathbf{V}) = 0 . \qquad (2.1)$$

In the above equation and the momentum and energy equations which follow, thermodynamic quantity-velocity fluctuation correlations are neglected.

2.1.2 The Momentum Equation

The time-averaged momentum equation in the x-direction is given by

$$\rho U \frac{\partial U}{\partial x} + \rho V \frac{\partial U}{\partial y} = -g_c \frac{dP}{dx} + \frac{1}{r} \frac{\partial}{\partial y} \left[r \left(\mu \frac{\partial U}{\partial y} - \rho \overline{u'v'} \right) \right] + g_c X \quad (2.2)$$

In the program, the body-force term in equation (2.2) is decomposed into

$$X = \frac{\rho g}{g_c} + bf , \qquad (2.3)$$







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(b) Velocity and stagnation enthalpy profiles



where the first term is a free convection body force in the positive x direction and bf is a generalized, x-direction body force with units of (force/unit volume). The bf term might be used to model magnetohydrodynamic body forces.

Pressure gradient is computed for pipe/channel flows as described in [1,2]. For flows over a surface dP/dx is computed in terms of the free-stream velocity and body force,

$$-g_{c}\left(\frac{dP}{dx}\right) = \rho_{\infty}U_{\infty}\frac{dU_{\infty}}{dx} - g_{c}X_{\infty} \quad .$$
 (2.4)

In the momentum equation, the turbulent shear stress, -u'v', is modeled using the eddy diffusivity for momentum, ε_{M} , as defined by

$$-\overline{u'v'} = \varepsilon_{M} \frac{\partial U}{\partial y} = \frac{\mu_{t}}{\rho} \frac{\partial U}{\partial y} , \qquad (2.5)$$

where μ_t is the turbulent viscosity. The laminar viscosity combines with the turbulent viscosity to obtain an effective viscosity

$$\mu_{\text{eff}} = (\mu + \mu_{t}) = \rho(\nu + \varepsilon_{M}) . \qquad (2.6)$$

Combining equations (2.2), (2.5), and (2.6) yields the final form for the momentum equation that is programmed.

$$\rho U \frac{\partial U}{\partial x} + \rho V \frac{\partial U}{\partial y} = -g_c \frac{dP}{dx} + \frac{1}{r} \frac{\partial}{\partial y} \left[r \mu_{eff} \frac{\partial U}{\partial y} \right] + g_c X \quad (2.7)$$

2.1.3. The Stagnation Enthalpy Equation

The time-averaged stagnation enthalpy equation is given by

$$\rho U \frac{\partial I^{\star}}{\partial x} + \rho V \frac{\partial I^{\star}}{\partial y} = \frac{1}{r} \frac{\partial}{\partial y} \left\{ r \left[\frac{k}{c} \frac{\partial I}{\partial y} - \rho \overline{I^{\star \prime} v^{\prime}} + \frac{\mu}{g_{c} J} \frac{\partial}{\partial y} \left(\frac{U^{2}}{2} \right) \right] \right\} + S \quad (2.8)$$

where I^* is the stagnation enthalpy of the fluid, defined as $I^* = I + U^2/2g_J$, and I is the static enthalpy.

In the program, the energy source term in equation (2.8) is decomposed into

$$S = \frac{UX}{J} + s$$
 (2.9)

where the first term is work done against x-direction body forces and s is a generalized source (energy rate/unit volume). The s term might be used to model Joulean heating for an electrically conducting fluid or nuclear heating.

In equation (2.8), a model for $-i^{*}v'$ is required. The term is a correlation involving fluctuations in stagnation enthalpy and cross-stream velocity, and is approximated as

$$-i''v' \simeq -i'v' + U(-u'v')$$
, (2.10)

where i' is fluctuation in static enthalpy. The turbulent heat flux, -i'v', is modeled using the concept of eddy diffusivity for heat, $\epsilon_{\rm H}$, as defined by

$$-\overline{\mathbf{i}'\mathbf{v}'} = \varepsilon_{\mathrm{H}} \frac{\partial \mathbf{I}}{\partial \mathbf{y}} = \left(\frac{\mathbf{k}_{\mathrm{t}}/\mathbf{c}}{\rho}\right) \frac{\partial \mathbf{I}}{\partial \mathbf{y}} , \qquad (2.11)$$

where k_t is the turbulent conductivity. The eddy diffusivities for heat and momentum are related through the turbulent Prandtl number,

$$\Pr_{t} = \frac{\varepsilon_{M}}{\varepsilon_{H}} . \qquad (2.12)$$

The laminar conductivity combines with the turbulent conductivity to form an effective conductivity (divided by specific heat, c),

$$\left(\frac{k}{c}\right)_{eff} = \frac{k}{c} + \left(\frac{k}{c}\right)_{t}$$
 (2.13)

Equations (2.6), (2.12), and (2.13) are combined to form an effective Prandtl number,

$$Pr_{eff} = \frac{\mu_{eff}}{(k/c)_{eff}} = \frac{1 + \frac{c_M}{v}}{\frac{1}{Pr} + \frac{c_M}{v} \frac{1}{Pr_{+}}}$$
(2.14)

Equations (2.5), (2.10), (2.11), and the definitions for μ_{eff} and \Pr_{eff} are combined with equation (2.8) to give the final form of the stagnation enthalpy equation that is programmed.

$$\rho U \frac{\partial I^{\star}}{\partial x} + \rho V \frac{\partial I^{\star}}{\partial y} = \frac{1}{r} \frac{\partial}{\partial y} \left\{ r \left[\frac{\mu_{eff}}{Pr_{eff}} \frac{\partial I^{\star}}{\partial y} + \frac{\mu_{eff}}{g_c^J} \left(1 - \frac{1}{Pr_{eff}} \right) \frac{\partial}{\partial y} \left(\frac{U^2}{2} \right) \right] \right\} + S \quad .$$

$$(2.15)$$

2.2 Boundary Conditions

For boundary layer flows in which there are a wall and a free stream, e.g., flow over a flat surface or a body of revolution, the boundary conditions for the momentum equation are given by

$$U(x,0) = 0$$
, (2.16a)

$$V(x,0) = m''_{0}(x)/\rho$$
, (2.16b)

$$\lim_{y \to \infty} U(x,y) = U_{\infty}(x) , \qquad (2.16c)$$

where $\mathbf{m}''_{O}(\mathbf{x})$ is wall mass transfer per unit area due to fluid injection or suction.

Boundary conditions for the stagnation enthalpy equation are given by

$$I^{*}(x,0) = I^{*}_{o}(x) , \text{ or}$$

$$\dot{q}^{"}(x,0) = -\frac{k}{c} \frac{\partial I^{*}(x,0)}{\partial y} = \dot{q}^{"}_{o}(x) ,$$

$$\lim_{y \to \infty} I^{*}(x,y) = I^{*}_{\infty} (\text{constant}) .$$
(2.16e)
(2.16e)

The wall boundary condition (2.16d) is either a level or a flux. For both cases, if there is transpiration at the surface, the transpired fluid is assumed to leave the surface in thermal equilibrium with it. If a flux boundary condition is specified, then the program requires specification of the <u>total</u> energy flux from the surface. This is related to the surface heat flux, $q_0''(x)$ as shown in Figure 2.2 for a differential element of surface area.



Figure 2.2. Wall flux boundary condition.

Boundary layer-type flows with a wall and a line of symmetry, e.g., flow in a circular pipe or a flat duct, have the following boundary conditions at the centerline, y = 0, and wall, $y = r_y$.

$$U(x,r_{y}) = 0$$
, (2.17a)

$$V(x, r_{u}) = 0$$
, (2.17b)

$$\frac{\partial U(\mathbf{x},0)}{\partial \mathbf{y}} = 0 , \qquad (2.17c)$$

$$I^{*}(x,r_{W}) = I^{*}_{0}(x)$$
, or
 $\dot{q}''(x,r_{W}) = \dot{q}_{0}''(x)$, (2.17d)

$$\frac{\partial I^{*}(x,0)}{\partial y} = 0 . \qquad (2.17e)$$

Because such flows are confined flows, the pressure gradient must be determined. This is accomplished indirectly in the program by linking it to conservation of mass: a pressure gradient is computed to conserve the mass flow rate as the momentum equation is integrated in the x-direction.

Boundary layer flows with a free surface and a line of symmetry, e.g., jets and free shear flows, have the following boundary conditions at the centerline, y = 0, and the edge of the shear layer, r_p .

$$\frac{\partial U(x,0)}{\partial y} = 0 , \qquad (2.18a)$$

V(x,0) = 0, (2.18b)

$$\lim_{r \to r} U(x,r) = U_{\infty}(x) , \qquad (2.18c)$$

$$\frac{\partial I'(x,0)}{\partial y} = 0 , \qquad (2.18d)$$

$$\lim_{r \to r_e} I^*(x,r) = I^*_{\infty} (constant) . \qquad (2.18e)$$

2.3 <u>Turbulent Shear Stress</u>

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Turbulent shear stress is modeled using the eddy diffusivity for momentum. The program incorporates three options for modeling $\varepsilon_{\rm M}$, as follows.

2.3.1 Prandtl Mixing-Length Model for EM

The Prandtl mixing-length model relates eddy diffusivity for momentum to the mean velocity gradient by defining a mixing-length, ℓ , such that

$$\varepsilon_{\rm M} = \ell^2 \left| \frac{\partial U}{\partial y} \right| \,. \tag{2.19}$$

The mixing-length for the region near the wall but outside the viscous region immediately adjacent to the wall is given by

A suggested value for κ is 0.41.

Immediately adjacent to the wall, the viscous sublayer is modeled by introducing a damping function, D, that effectively suppresses the linear dependence of equation (2.20). With the damping function, the mixing-length for the viscous region becomes

Two damping function options are available in the program. The first type is the Van Driest damping function,

$$D = 1.0 - \exp[-y^{+}(v_{0}/v)/A^{+}] , \qquad (2.22)$$

where $y^+(v_0^{\prime}/v)$ is the non-dimensional distance from the wall, expressed in "wall coordinates", defined in Section 3.2, and A' is an effective sublayer thickness defined in an analogous manner. The second type of damping function in the program is the Evans damping function,

$$D = \begin{cases} y^{+}(v_{o}/v)/B^{+}, y^{+}(v_{o}/v) \leq B^{+} \\ 1.0, y^{+}(v_{o}/v) > B^{+} \end{cases}$$
(2.23)

where B^{\dagger} is an effective sublayer thickness.

The effective thickness of the viscous sublayer is probably the single most important parameter in computation of turbulent boundary layers. The sublayer, though comprising a very small fraction of the total boundary layer thickness, is the region where the major change in velocity takes place and, except for very low Prandtl number fluids, is the region wherein most of the resistance to heat transfer resides. If this region is modeled accurately, only a very approximate scheme is needed throughout the rest of the boundary layer.

Thickness of the sublayer is evidently determined by viscous stability considerations. The experimental evidence is that a favorable pressure gradient (dP/dx negative) results in increased thickness, while an adverse pressure gradient has the opposite effect. Transpiration into the boundary layer (blowing) decreases the thickness, if it is expressed in non-dimensional wall coordinates, while suction has the opposite effect. Surface roughness, while not a subject of this paper, causes a thinning of the sublayer.

The effects of pressure gradient and transpiration on A^+ or B^+ are conveniently expressed in terms of a non-dimensional pressure gradient parameter, P^+ , and a non-dimensional blowing parameter, V_0^+ , both of which can be either positive or negative. In both of these parameters the main argument is normalized with respect to the same wall coordinate parameters as is the effective sublayer thickness A^+ or B^+ . The functional dependence of A^+ upon P^+ and V_0^+ has been deduced experimentally by examination of a very large number of velocity profiles obtained at Stanford [3]. This functional dependence can be directly related to B^+ , and both can be expressed algebraically as

where

a = 7.1 if $V_0^+ \ge 0.0$, otherwise a = 9.0; b = 4.25 if $P^+ \le 0.0$, otherwise b = 2.9; c = 10.0 if $P^+ \le 0.0$, otherwise c = 0.0.

A recommended value for A_{fp}^{\dagger} and B_{fp}^{\dagger} are 25 and 35, respectively.

Equation (2.24) is plotted on Figure 2.3 for A^+ , and in the graph the effects of pressure gradient and transpiration can be clearly seen. Note that a strong favorable pressure gradient forces A^+ to very high values, and that blowing lessens this effect, while suction increases it. If A^+ becomes very large, the viscous sublayer simply overwhelms the entire boundary layer, resulting in re-laminarization. The thickening of the sublayer caused by a favorable pressure gradient (accelerating flows) results in a decreased Stanton number simply because the major resistance to heat transfer is in the viscous sublayer.

 A^+ , as represented by equation (2.24) and Figure 2.3, has been evaluated under essentially equilibrium conditions, i.e., conditions under which V_0^+ and/or P^+ are invariant or, at worst, are varying only slowly along the surface. This is the case of inner region equilibrium. It is probable that when a sudden change of external conditions is imposed, the inner region comes to equilibrium more rapidly than the outer region, although this has not been proved. In any case, under non-equilibrium conditions where V_0^+ or P^+ are changing rapidly, it has been observed that the sublayer does not change instantaneously to its new equilibrium thickness, i.e., A^+ does not immediately



assume its new equilibrium value. Since $A^+ = A^+(V_0^+, P^+)$, lag equations of the form (suggested by Launder and Jones [4])

$$\frac{dv_{o,eff}^{+}}{dx_{c}^{+}} = -\frac{(v_{o,eff}^{+} - v_{o,eq}^{+})}{C}$$
(2.25)

are solved to simulate the effect. The term $v_{o,eq}^+$ is the local blowing parameter, and $v_{o,eff}^+$ is its effective value, used to compute the damping constant. A similar equation is solved for P^+ . The recommended value for C is 4000.

In the boundary layer momentum equation (2.7), the body force term, X, must exert some influence upon the viscous sublayer thickness. In the program it is assumed that the influence of X upon the damping coefficient is similar to the pressure gradient. Thus a non-dimensional body force, X^+ , is computed, and the algebraic sum $(P^+ - X^+)$ is used in place of P^+ to evaluate an equation of the form of equation (2.25) for P^+_{eff} .

The outer region of the flow, referred to as the wake region, is modeled using a mixing-length directly proportional to the boundary layer thickness. The program input variable FR determines the thickness as $\delta_{(1.00-FR)}$, with a recommended value of 0.01 for FR.

$$\ell = \lambda \delta_{.99} \quad (2.26)$$

A recommended value of λ is 0.085. The outer region is defined as $y > \frac{\lambda \delta}{.99} / \kappa$.

There is some evidence that the effective value of λ is larger than 0.085 for boundary layers in which the momentum thickness Reynolds number is less than 5500. This may be a result of the fact that at low Reynolds numbers the sublayer is a larger fraction of the boundary layer and the approximation of a constant mixing-length over the remainder of the boundary layer is less valid. For strong blowing, even at low Reynolds numbers, λ again appears to be close to 0.085, and this is consistent with the above explanation because the sublayer is then thinner. The following equation has been found to describe the observed low Reynolds behavior of λ quite well.

$$\lambda = 2.942 \lambda_0 \operatorname{Re}_{M}^{-1/8} (1.0 - 67.5 \mathrm{F}) , \qquad (2.27)$$

where $\mathbf{F} = \rho_0 V_0 / \rho_\infty U_\infty$ and λ_0 is the program input value. If λ becomes less than λ_0 , it is set equal to λ_0 .

2.3.2 <u>Turbulent Kinetic Energy Model for</u> E_M

The Prandtl mixing-length is essentially an equilibrium model that can handle turbulent flows with slowly changing boundary conditions. For strongly non-equilibrium boundary layers (especially under adverse pressure gradient conditions or when there is an appreciable amount of free-stream turbulence), a higher level of closure model for the turbulent shear stress is desirable. The turbulent kinetic energy model (TKE model) relates a velocity scale-length scale product to the eddy diffusivity for momentum,

$$\varepsilon_{\rm M} = \frac{\mu_{\rm t}}{\rho} = \left(\frac{A_{\rm q}}{\kappa}\right) \ell \sqrt{\frac{q^2}{2}},$$
 (2.28)

where $q^2/2$ is the turbulent kinetic energy of the flow and l is the mixinglength, as defined by equations (2.21) or (2.26).

Actually, the TKE model incorporated into the program is a hybrid model; the Prandtl mixing-length model for ε_{M} is used in the near-wall viscous region and the TKE model for $y^{+} > 2A^{+}$ or $y^{+} > B^{+}$. In principle, the TKE model may be applied in the viscous region, but this requires modification to the length scales for production and dissipation. At present there are no provisions in the program for computing TKE in the viscous sublayer region.

Turbulent kinetic energy of a flow is computed in the program by solving a differential equation of the form

$$\rho U \frac{\partial (q^2/2)}{\partial x} + \rho V \frac{\partial (q^2/2)}{\partial y} = -\rho \overline{u'v'} \frac{\partial U}{\partial y} - \mathcal{O} + \frac{1}{r} \frac{\partial}{\partial y} (rJ_q) \quad . \quad (2.29)$$

In the TKE equation, the production term (the first term to the right of the equal sign) is modeled from equations (2.5) and (2.28), and given by

$$-\rho \overline{u'v'} \frac{\partial U}{\partial y} = \rho \left(\frac{A_q}{\kappa}\right) \ell \sqrt{\frac{q^2}{2}} \left(\frac{\partial U}{\partial y}\right)^2 . \qquad (2.30)$$

The dissipation term, \mathcal{A} , is modeled as

$$\mathcal{S} = \rho(B_q \kappa) \frac{(\sqrt{q^2/2})^3}{\ell}$$
, (2.31)

where κ is the von Karman constant.

 B_q is the dissipation constant, and it is related to A_q by requiring production to equal dissipation in the logarithmic region near the wall.

$$B_{q} = \frac{A^{3}}{\kappa^{4}} \qquad (2.32)$$

For $\kappa = 0.41$, suggested values for A and B are 0.22 and 0.38, respectively.

The diffusion term, J_{a} , is modeled as

$$J_{q} = \rho \left(v + \varepsilon_{q} \right) \frac{\partial (q^{2}/2)}{\partial y} , \qquad (2.33)$$

where ν is the laminar kinematic viscosity, and ϵ_q is related to ϵ_M by a turbulent Schmidt number,

$$Sc_q = \frac{\varepsilon_M}{\varepsilon_q}$$
 (2.34)

A suggested value for Sc_q is 1.7.

Boundary conditions for equation (2.29), with a wall and a free stream, are

$$\frac{q^2}{2} = \left(\frac{\kappa}{A_q} \, \ell \, \frac{\partial U}{\partial y}\right)^2 \quad \text{at} \quad y^+ = \begin{cases} 2A^+ \\ B^+ \end{cases}$$
(2.35a)

and

$$\lim_{y \to \infty} \frac{q^2}{2} = \left(\begin{array}{c} \text{free stream} \\ \text{turbulence level} \end{array} \right) = \frac{3}{2} T_u^2 U_\infty^2 \quad (2.35b)$$

Equation (2.35b) assumes isotropic free-stream turbulence and $T_u = \sqrt{\frac{1}{u'^2}} U_{\infty}$.

2.3.3 Constant Eddy Diffusivity Model

An alternative to the assumption that mixing-length in the outer region is constant is the assumption that eddy diffusivity for momentum is constant. Eddy diffusivity in this region can be correlated to either displacement thickness or momentum thickness Reynolds number or diameter Reynolds numeber in the case of pipe-flow. In the program, this option is given by

$$\frac{\varepsilon_{\rm M}}{\upsilon} = a {\rm Re}_{\rm M}^{\rm b} . \qquad (2.36)$$

In the above expression, suggested values of a and b for pipe-flow are 0.005 and 0.9, respectively. For pipe-flow this option is to be preferred to the constant mixing-length option.

2.4 <u>Turbulent Heat Flux</u>

Turbulent heat flux is modeled using the eddy diffusivity for heat. The program incorporates two options for modeling $\varepsilon_{\rm H}$, a constant turbulent Prandtl and a variable turbulent Prandtl number.

2.4.1 Constant Turbulent Prandtl Number

The eddy diffusivity for heat is modeled by relating it to the eddy diffusivity for momentum,

$$Pr_{t} = \frac{\varepsilon_{M}}{\varepsilon_{H}} , \qquad (2.12)$$

where Pr, is the turbulent Prandtl number.

A very simple physical model of the turbulent momentum and energy transfer processes leads to the conclusion that $\varepsilon_{\rm H} = \varepsilon_{\rm M}$, i.e., $\Pr_{\rm t} = 1.00$ (the "Reynolds Analogy"). Slightly more sophisticated models suggest that $\Pr_{\rm t} >$ 1.00 when the molecular Prandtl number is very much less than unity. A suggested value for gases is 0.90.

2.4.2 Variable Turbulent Prandtl Number

An improved model for Pr_t is to allow it to vary with distance from the wall, as suggested from experimental data from Stanford [3]. Several conclusions can be drawn from the Stanford data. First, the turbulent Prandtl number, at least for air, apparently has an order of magnitude of unity. Thus the Reynolds Analogy ($Pr_t = 1.00$) is not a bad approximation.

The second conclusion is that Pr_t seems to go to a value higher than unity very near the wall, but is evidently less than unity in the wake or outer region. The situation very close to the wall is especially vexing because it is extremely difficult to make accurate measurements in this region, and yet it seems evident that something interesting and important is happening in the range of y^+ from 10.0 to 15.0. The behavior of Pr_t at values of y^+ less than about 10.0 is highly uncertain but fortunately not very important, because molecular conduction is the predominant transfer mechanism in this region. At the other extreme, in the wake region Pr_t does not need to be known precisely, because the heat flux tends to be small there.

Another conclusion, for which the evidence is not yet very strong, is that there is some small effect of pressure gradient on Pr_t . Data suggest that an adverse pressure gradient tends to decrease Pr_t , and there seems a tendency for Pr_t to be increased by a favorable pressure gradient (an accelerating flow). Transpiration, apparently, does not influence Pr_t unless there is an effect very close to the wall that is hidden in the experimental uncertainty in this region.

Incorporated into the program to predict the general behavior of turbulent Prandtl number for gases, as well as low and high laminar Prandtl number fluids, is a conduction model for Pr_t. The model simulates the idea that an "eddy" exchanges energy both in transit in the vertical direction and while equilibrating with the surrounding fluid at the end of its travel. From analytical considerations, the model is expressed by

$$Pr_{t} = \left[\frac{\alpha^{2}}{2} + \alpha cPe_{t} - (cPe_{t})^{2} (1.0 - exp[-\alpha/cPe_{t}])\right]^{-1}.$$
 (2.37)

In the above equation, Pe_t is the turbulent Peclet number, $(\epsilon_M/\nu)Pr$, and $\alpha = \sqrt{1/PRT}$, where PRT is the asymptotic value of Pr_t for large y^+ , in the wake region. The programmed value for c is 0.2, and the suggested value for PRT is 0.86. Equation (2.37) is plotted in Figure 2.4 for three values of Pr using these constants.



2.5 Laminar-Turbulent Transition

In laminar boundary layers, disturbances to the flow will either die out or grow; if the disturbances continue to grow, there will be a region downstream where transition occurs, beyond which fully turbulent flow will eventually be established. The onset of transition depends to a large extent upon whether the prevailing boundary conditions have a stabilizing or a destabilizing effect on the flow. Smooth surfaces and favorable pressure gradients (acceleration) can cause the former, and rough surfaces, adverse pressure gradients, and free-stream turbulence can cause the latter effect.

For two-dimensional boundary layer flows over a smooth surface, with a constant free stream velocity, and with moderate free-stream turbulence, the onset of transition is usually considered to be related to a critical momentum thickness Reynolds number, Re_{tran} . This is analogous to flow in a pipe where $\text{Re}_{\text{tran}} \simeq 2300$. Once transition commences, it will continue until the flow becomes completely turbulent.

Transition is modeled in the program by flagging the program to commence computation of turbulent shear stress and heat flux when the flow momentum thickness Reynolds number, Re_{M} , exceeds $\operatorname{Re}_{\operatorname{tran}}$. To effect a gradual transition, the local value of A^+ is modified according to the empirical equation

$$A^{+} = A^{+} + (300.0 - A^{+}) \times \left\{ 1.0 - \sin \left(\frac{1.57}{\text{Re}_{\text{tran}}} \left[\text{Re}_{\text{M}} - \text{Re}_{\text{tran}} \right] \right) \right\}^{2}, (2.38)$$

for the region in the downstream flow direction where $\text{Re}_{M} \leq 2\text{Re}_{\text{tran}}$. This equation has the effect of smoothly increasing the turbulent viscosity in the near-wall region. A suggested value for Re_{tran} is 200. Transition with B⁺ is handled in a similar manner.

Chapter 3

FLOW NEAR A WALL

3.1 Computation in the Near-Wall Region

Computation of a flow field involves solving the finite-difference equations at discrete nodes in the cross-stream direction. The nodal spacing, or grid, can be coarse if velocity and enthalpy profiles are slowly changing between nodes. For a turbulent flow, large gradients in velocity exist with the near-wall region requiring a fine nodal spacing. It is customary in most finite-difference turbulent calculations to have at least as many nodal points in the near-wall region (say the inner 20 per cent of the boundary layer) as are used in the remaining coarse part of the grid.

In computing near-wall flows in this program, the Couette flow form of the boundary layer equations are solved between the wall and a point near the wall, the join point. At the join point the Couette flow solutions are matched to the finite-difference solutions, in terms of velocity and shear stress, and enthalpy and heat flux, and the resulting unknowns, wall shear stress and wall heat flux, are thus determined.

In dealing with flow in the near-wall region, the program has two options. The first option is to "<u>use the Wall Function</u>." Here the Couette flow equations are numerically integrated over the region of high velocity gradient. A major advantage of this option is that it greatly reduces the required number of finite-difference nodes. Using the Wall Function is especially advantageous when computing high Reynolds number flows.

The second option in computing flow near a wall is to "<u>bypass the Wall</u> <u>Function</u>." Here the finite-difference mesh is carried down to the wall with a progressively finer spacing. Bypassing the Wall Function is recommended for large pressure gradients when the Couette flow approximation begins to lose its validity.

3.2 The Couette Flow Equations

In the near-wall region both velocity and stagnation enthalpy profiles can have large gradients in the cross-stream direction, but their streamwise gradients are usually small. By neglecting these streamwise gradients, the convective

transport equations are simplified to ordinary differential equations, and the integrated form of these equations is the Couette flow equations.

To develop the Couette flow equations, the boundary layer equations will be recast in terms of shear stress and heat flux using

$$\tau = (\mu + \mu_t) \frac{\partial U}{\partial y} = \mu_{eff} \frac{\partial U}{\partial y} , \qquad (3.1)$$

and

$$\dot{\mathbf{q}}'' = -\left[\frac{\mathbf{k}}{\mathbf{c}} + \left(\frac{\mathbf{k}}{\mathbf{c}}\right)_{\mathbf{t}}\right]\frac{\partial \mathbf{I}}{\partial \mathbf{y}} = -\frac{\mu_{\text{eff}}}{\Pr_{\text{eff}}}\frac{\partial}{\partial \mathbf{y}}\left[\mathbf{I}^{\star} - \frac{\mathbf{U}^2}{2g_{\mathbf{c}}\mathbf{J}}\right] . \quad (3.2)$$

These definitions are substituted into the momentum equation (2.7) and stagnation enthalpy equation (2.15), and they are re-written, along with the continuity equation (2.1), for plane flow (no-radius effect included).

$$\frac{\partial(\rho U)}{\partial x} + \frac{\partial(\rho V)}{\partial y} = 0 , \qquad (3.3a)$$

$$\rho U \frac{\partial U}{\partial x} + \rho V \frac{\partial U}{\partial y} = g_{c} \left(-\frac{dP}{dx} + \frac{\partial \tau}{\partial y} + X \right) , \qquad (3.3b)$$

$$\rho U \frac{\partial I^{\star}}{\partial x} + \rho V \frac{\partial I^{\star}}{\partial y} = -\frac{\partial}{\partial y} \left[\dot{q}^{"} - U \tau \right] + \frac{UX}{J} + s \quad (3.3c)$$

These equations are non-dimensionalized using "wall coordinates". In the definitions which follow, the small zero subscript denotes a wall value.

$$U_{\tau} = \sqrt{g_{c} \tau_{o} / \rho_{o}}$$
, (3.4a)

$$v^+ = v/v_{\tau}$$
, (3.4b)

$$v_{o}^{+} = v_{o}^{\prime} u_{\tau}^{\prime}$$
, (3.4c)

$$x^{+} = x U_{\tau} / v_{o}$$
, (3.4d)

$$y^{+} = y U_{\tau} / v_{o} , \qquad (3.4e)$$

$$\tau^{+} = \tau/\tau_{0}, \qquad (3.4f)$$

$$P^{+} = \frac{g_{c} v_{o}}{\rho_{o} v_{\tau}^{3}} \frac{dP}{dx} , \qquad (3.4g)$$

$$x^{+} = \frac{g_{c}v_{o}}{\rho_{o}u_{T}^{3}}x$$
, (3.4h)

for the momentum equation, and, in addition,

$$I^{*+} = \frac{(I_{o}^{*} - I^{*})U_{\tau}}{q_{o}^{*}/\rho_{o}}, \qquad (3.41)$$

$$q^+ = \frac{q^{''}}{q_0^{''}},$$
 (3.4j)

$$s^{\dagger} = \frac{v_o}{q_o^{\dagger} v_{\tau}} s , \qquad (3.4k)$$

$$W = \frac{\rho_0 U_{\tau}^3}{g_c J q_0^{''}}, \qquad (3.4l)$$

for the stagnation enthalpy equation.

Integration of equations (3.3a) and (3.3b) with respect to y, combining, and transforming to "wall coordinates" yields

$$t^{+} = 1 + V_{o}^{+}U^{+} + (P^{+}-X^{+}) y^{+} \left[1 - \frac{1}{y} \int_{0}^{y} \left(\frac{\rho}{\rho_{\infty}}\right) \left(\frac{U}{U_{\infty}}\right)^{2} dy\right]$$

$$+ f$$
(3.5)

where

$$f_{\mathbf{x}} = \frac{\rho_{\infty} U_{\infty}}{\tau_{o}} \frac{dU_{\infty}}{d\mathbf{x}} \left[\frac{\rho U}{\rho_{\infty} U_{\infty}} \int_{o}^{y} \left(\frac{\rho U}{\rho_{\infty} U_{\infty}} \right) d\mathbf{y} - \int_{o}^{y} \left(\frac{\rho}{\rho_{\infty}} \right) \left(\frac{U}{U_{\infty}} \right)^{2} d\mathbf{y} \right] \\ + \frac{\rho_{\infty} U_{\infty}^{2}}{\tau_{o}} \left[\frac{d}{d\mathbf{x}} \int_{o}^{y} \left(\frac{\rho}{\rho_{\infty}} \right) \left(\frac{U}{U_{\infty}} \right)^{2} d\mathbf{y} - \frac{\rho U}{\rho_{\infty} U_{\infty}} \int_{o}^{y} \left(\frac{\rho U}{\rho_{\infty} U_{\infty}} \right) d\mathbf{y} \right]$$

The Couette flow form of the momentum equation used in the program is equation (3.5) with f_x neglected. This form was developed by Julien et al. [5] ar retains an integral term to better approximate a departure from Couette flow when P^+ is large. The additional term is exact for asymptotic accelerating flows.

Integration of equations (3.3a) and (3.3c) with respect to y, combining, and transforming to "wall coordinates", yields

$$q^{+} = 1 + v_{o}^{+}I^{*+} + u^{+}\tau^{+}W + u^{+}y^{+}X^{+}W + s^{+}y^{+} + g_{X}$$
, (3.6)

where

$$g_{x} = \frac{(I^{*}-I_{\infty}^{*})}{\dot{q}_{0}^{"}} \left[\frac{d}{dx} (\rho_{\infty}U_{\infty}) \cdot \int_{0}^{y} \left(\frac{\rho U}{\rho_{\infty}U_{\infty}} \right) dy \right] \\ + \rho_{\infty}U_{\infty} \frac{d}{dx} \int_{0}^{y} \left(\frac{\rho U}{\rho_{\infty}U_{\infty}} \right) dy \right] \\ - \frac{1}{\dot{q}_{0}^{"}} \frac{d}{dx} \left[\rho_{\infty}U_{\infty} (I_{0}^{*}-I_{\infty}^{*}) \right] \int_{0}^{y} \frac{\rho U}{\rho_{\infty}U_{\infty}} \left(\frac{I^{*}-I_{\infty}^{*}}{I_{0}^{*}-I_{\infty}^{*}} \right) dy \\ - \frac{\rho_{\infty}U_{\infty} (I_{0}^{*}-I_{\infty}^{*})}{\dot{q}_{0}^{"}} \frac{d}{dx} \int_{0}^{y} \frac{\rho U}{\rho_{\infty}U_{\infty}} \left(\frac{I^{*}-I_{\infty}^{*}}{I_{0}^{*}-I_{\infty}^{*}} \right) dy$$

The Couette flow form of the stagnation enthalpy equation used in the program is equation (3.6) with g_{y} neglected.

3.3 Using the Wall Function

In the previous section it was seen that the Couette flow equations are merely first integrals of the Couette flow form of the boundary layer equations, and they relate wall shear stress and wall heat flux to shear stress and heat flux at some point away from the wall. By replacing the shear stress and heat flux with their constitutive equations, the Couette flow equations become first-order ordinary differential equations describing the variation in velocity and stagnation enthalpy across the Couette layer adjacent to the wall. These equations are then numerically integrated across the layer and matched to the finitedifference solutions for velocity and stagnation enthalpy, resulting in explicit expressions for the wall shear stress and heat flux. The match-up point is located midway between the second and third finite-difference nodes from the wall and is referred to as the join point, or 2.5 point.

3.3.1 Momentum Equation

The constitutive equation (3.1) for snear stress is rewritten in terms of "wall coordinates" as

$$\tau^{+} = \mu^{+} \frac{\partial U^{+}}{\partial y^{+}},$$
 (3.7)

where $\mu^{+} = (\mu + \mu_{t})/\mu_{0}$.

From Section 3.2, the Couette flow equation for momentum is

$$\tau^{+} = 1 + V_{o}^{+}U^{+} + (P^{+}-X^{+}) y^{+} \left[1 - y \int_{o}^{y} \left(\frac{\rho}{\rho_{\infty}}\right) \left(\frac{U}{U_{\infty}}\right)^{2} dy\right].$$
(3.8)

An ordinary differential equation describing momentum transport across the Couette layer is obtained by equating (3.7) and (3.8), along with using the mixing-length hypothesis to model μ^+ .

$$\frac{dU^{\dagger}}{dy^{\dagger}} = \frac{2\tau^{\dagger} \left(\frac{\mu_{o}}{\mu}\right)}{1 + \left[1 + 4\kappa^{2}y^{+2}D^{2}\tau^{\dagger}\left(\frac{\rho}{\rho_{o}}\right)\left(\frac{\mu_{o}}{\mu}\right)^{2}\right]^{1/2}} . \quad (3.9)$$

In the program the above equation is numerically integrated, using equation (3.8) for τ^+ , and equation (2.22 or 2.23) for D, from the wall outward to the join point.

The join point, or match-up point, is located at $y_{2.5}$, which is the arithmetic average of y_2 and y_3 , locating nodal points 2 and 3. The required value of U at the join point is $U_{2.5}$, the arithmetic average of U_2 and U_3 , as computed from the finite-difference solution.

Since the integration of equation (3.9) is in "wall coordinates", the upper limit to the integral needs to be in "wall coordinates". It is not yet possible to convert $U_{2.5}$ and $y_{2.5}$ to $U_{2.5}^{+}$ and $y_{2.5}^{+}$ because τ_{0} is still an unknown. However, a join-point Reynolds number can be formed which relates the "physical coordinates" to the "wall coordinates",
$$Re_{2.5} = \frac{U_{2.5} Y_{2.5}}{v_0} = (U^+ y^+)_{2.5}$$
(3.10)

As $U^{+} = U^{+}(y^{+})$ is evaluated from integration of equation (3.9), the $U^{+}y^{+}$ product is computed and compared to $\operatorname{Re}_{2.5}$. Integration is terminated when the $U^{+}y^{+}$ product equals $\operatorname{Re}_{2.5}$. With the join-point values of U^{+} and y^{+} now known, the wall shear stress and friction factor are computed from $U_{2.5}$ and the definition of U^{+} ,

$$\tau_{o} = \frac{\rho_{o} U_{2.5}^{2}}{g_{c} (U_{2.5}^{+})^{2}}$$
(3.11a)

and

$$C_{f}/2 = \frac{g_{c}^{\tau} \sigma_{o}}{\rho_{\omega} U_{\omega}^{2}}$$
(3.11b)

3.3.2 Stagnation Enthalpy Equation

The constitutive equation (3.2) for heat flux is rewritten in terms of wall coordinates as

$$q^{+} = \frac{\mu^{+}}{\Pr_{eff}} \frac{\partial I^{*+}}{\partial y^{+}} + W \frac{\mu^{+}}{\Pr_{eff}} \frac{\partial}{\partial y} \left(\frac{U^{+2}}{2}\right)$$
(3.12)

From Section 3.2, the Couette flow equation for stagnation enthalpy is

$$q^{+} = 1 + v_{o}^{+} I^{*+} + U^{+} \tau^{+} W$$

$$+ U^{+} y^{+} x^{+} W + S^{+} y^{+}$$
(3.13)

An ordinary differential equation describing enthalpy transport across the Couette layer is obtained by equating (3.12) with (3.13),

$$\frac{dI^{\star +}}{dy^{+}} = \frac{\Pr_{eff}}{\mu^{+}} (1 + v_{o}^{+} I^{\star +}) + (\Pr_{eff}^{-1}) \frac{u}{dy^{+}} \left(\frac{U^{+2}}{2}\right) + \frac{\Pr_{eff}^{-1}}{\mu^{+}} (U^{+}y^{+}x^{+}W + S^{+}y^{+})$$
(3.14)

In the program equation 3.14 is numerically integrated in the same loop as equation (3.9) for U^+ .

If the stagnation enthalpy boundary condition is a level type, i.e., $I^*(x,0) = I_0^*(x)$, then wall heat flux and Stanton number are computed from $I_{2.5}^*$, the arithmetic average of I_2^* and I_3^* , and the definition of I^{*+} ,

$$\dot{q}_{o}^{"} = \frac{\rho_{o}^{~} U_{2.5}}{U_{2.5}^{+} I_{2.5}^{*+}} (I_{o}^{*} - I_{2.5}^{*})$$
 (3.15a)

and

St =
$$\frac{\dot{q}_{o}''}{\rho_{\omega} U_{\omega} (I_{o}^{*} - I_{\omega}^{*})}$$
 (3.15b)

If the stagnation enthalpy boundary condition is a flux type, then the wall enthalpy and heat flux are linked through the total energy flux boundary condition (see Figure 2.2).

$$\dot{E}_{total}(x) = \dot{m}_{o}'' I_{o}^{*} + \dot{q}_{o}''$$
 (3.16)

For flux-type boundary conditions, equations (3.15a) and (3.16) are solved algebraically for I_o^* and $\dot{q}_o^{"}$. The Stanton number is then formulated from equation (3.15b). Note that the Stanton number evaluated in the program, equation (3.15b), is based on <u>stagnation</u> enthalpy difference, and <u>not</u> recovery enthalpy difference. The latter would require knowledge of a "recover factor" which has no real significance or usefulness in the general problem, i.e., for other than constant free-stream velocity flows.

3.4 Bypassing the Wall Function

The second user option is to "bypass the Wall Function", implying the join point is in close proximity to the wall where laminar-like flow exists. For turbulent flows, this implies a join-point value y^+ of less than, say, 2.0. In this region the viscosity ratio $(\mu + \mu_{\tau})/\mu_{o}$ is unity, and the Couette flow equations can be integrated in closed form. Match-up with the finitedifference solutions for velocity and stagnation enthalpy is similar to the procedure involved in "using the Wall Function".

3.4.1 Momentum Equation

To obtain an expression for U^+ at the edge of the Couette layer, the constitutive equation (3.7) for the shear stress is equated to the Couette flow equation for momentum (3.8) and integrated (with $\mu^+ = 1$).

$$\mathbf{u}^{+} = \mathbf{y}^{+} + (\mathbf{v}_{o}^{+} + \mathbf{p}^{+} - \mathbf{x}^{+}) \left[\frac{\exp(\mathbf{v}_{o}^{+}\mathbf{y}^{+}) - 1 \cdot - \mathbf{v}_{o}^{+}\mathbf{y}^{+}}{(\mathbf{v}_{o}^{+})^{2}} \right]$$
(3.17)

Recall that while U^+ and y^+ are unknown, their product is the joinpoint Reynolds number (see Section 3.3.1).

$$Re_{2.5} = \frac{U_{2.5} y_{2.5}}{v_0} = (U^+ y^+)_{2.5}$$
(3.10)

In the program, the solution to equation (3.17) is obtained by linearizing and solving in three successive steps:

$$y_{2.5}^{+} = (Re_{2.5})^{1/2}$$
(3.18a)

$$y_{2.5}^{+} = \begin{bmatrix} \frac{Re_{2.5}}{1 + \frac{(P^{+} - x^{+})y_{2.5}^{+}}{2} + \frac{v_{0}^{+}y_{2.5}^{+}}{2} \end{bmatrix}^{1/2}$$
(3.18b)

$$y_{2.5}^{+} = \begin{bmatrix} \frac{Re_{2.5}}{1 + \frac{(P^{+} - x^{+})y_{2.5}^{+}}{2} + \frac{v_{0}^{+}y_{2.5}^{+}}{2} \end{bmatrix}^{1/2}$$
(3.18c)

After solving for $y_{2.5}^+$, the value of $U_{2.5}^+$ is obtained from equation (3.10). The shear stress and friction factor are obtained from equations (3.11a-b).

3.4.2 Stagnation Enthalpy Equation

An expression for I^{*+} at the edge of the Couette layer is obtained by integrating equation (3.14), which relates the constitutive equation for heat flux to the Couette flow equation for stagnation enthalpy. In the integration, the viscous dissipation, work against body forces, and energy source terms are neglected. The resulting expression for I^{*+} , with μ^{++} equal to unity and \Pr_{off} equal to \Pr , is

$$I^{*+} = \frac{\exp[\Pr V_{o}^{+} y^{+}] - 1}{V_{o}^{+}}$$
(3.19)

In the program, equation (3.19) is approximated by

$$I_{2.5}^{*+} = \Pr\left(\frac{v_0^+ y_{2.5}^+}{2} + y_{2.5}^+\right)$$
 (3.20)

After solving for $I_{2.5}^{\star}$, the wall heat flux and Stanton number are obtained as described at the end of Section 3.3.2.

3.5 Routine LAMSUB

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As indicated in the previous sections, the Couette flow equations are solved from the wall out to the join point where $y^+ = y^+_{2.5}$. The main function of the LAMSUB routine is to assure the condition

$$\text{YPMIN} \leq y_{2.5}^{+} \leq \text{YPMAX} \qquad (3.21)$$

where YPMIN and YPMAX are program input variables.

When "bypassing the Wall Function", YPMIN must be zero, and YPMAX should be less than two (unity is recommended). This will give a join-point Reynolds number of less than four, thus assuring the assumption that turbulent viscosity can be neglected in the Couette flow equations.

When "using the Wall Function" typical values for YPMIN and YPMAX are 20 and 40, respectively. These values bracket the upper limits of the integrals, and assure that the Couette flow equations are not applied outside their region of applicability. For a flat plate boundary layer, the upper limit might be 50 to 100, and for high Reynolds number flows, the upper limit might extend out to between 100 and 200. For boundary layer flows with strong pressure gradient, the limit of applicability can drop to near 15 -- thus the reason for the Wall Function bypass option.

Routine LAMSUB controls the join point value as follows: if $y_{2.5}^+$ drops below YPMIN, the routine removes the stream tube located at y_3 , and if $y_{2.5}^+$ becomes larger than YPMAX, the routine inserts a new stream tube midway between $y_{2.5}$ and y_3 . In both cases, after the grid has been readjusted, the wall function is again solved and the new $y_{2.5}^+$ is compared using equation (3.21).

3.6 Integral Parameters

At each integration step, when one surface is a wall, the velocity profile displacement and momentum thicknesses, δ_1 and δ_2 , are calculated along with the enthalpy thickness, Δ_2 , for the stagnation enthalpy profile. These thicknesses are defined as follows:

$$\delta_{1} = \int_{0}^{\delta} \left(1 - \frac{\rho U}{\rho_{\infty} U_{\infty}}\right) \frac{r}{r_{0}} dy , \qquad (3.22a)$$

$$\delta_2 = \int_0^{\delta} \frac{\rho U}{\rho_{\infty} U_{\infty}} \left(1 - \frac{U}{U_{\infty}}\right) \frac{r}{r_0} dy , \qquad (3.22b)$$

$$\Delta_2 = \int_0^{\delta} \frac{\rho U}{\rho_{\infty} U} \left(\frac{\mathbf{I}^* - \mathbf{I}_{\infty}^*}{\mathbf{I}_0^* - \mathbf{I}_{\infty}^*} \right) \frac{\mathbf{r}}{\mathbf{r}_0} \, d\mathbf{y} \quad , \qquad (3.22c)$$

where r is the wall radius. Integration is carried out in the program using a trapezoidal rule.

In the program the boundary layer equations can be solved with or without consideration of transverse radius of curvature. Generally, transverse curvature effects are important for thick axisymmetric boundary layers. If these curvature effects are considered, then δ_1 and δ_2 are modified by solving the equations

$$\delta_{1,axi}\left(1\pm\frac{\delta_{1,axi}\cos\alpha}{2r_o}\right) = \delta_1, \qquad (3.23a)$$

$$\delta_{2,axi}\left(1\pm\frac{\delta_{2,axi}\cos\alpha}{2r_{o}}\right) = \delta_{2} \qquad (3.23b)$$

for $\delta_{1,axi}$ and $\delta_{2,axi}$ after calculating δ_1 and δ_2 using equation (3.22). Figure 2.1 shows α and its relation to the wall radius. The proper sign choice is (+) for external flow over a body of revolution and (-) for flow inside a body of revolution (due to the coordinate system used in the program).

3.7 Pipe and Channel Flows

If the flow is a confined flow, a friction factor, Stanton number, and Nusselt number are computed using the following definitions.

$$\frac{C_{f}}{2} = \frac{g_{c} \tau_{o}}{\overline{\rho} \ \overline{u}^{2}} , \qquad (3.24)$$

St =
$$\frac{q_o''}{\overline{\rho} \ \overline{U}(I_o^* - \overline{I}^*)}$$
, (3.25)

$$Nu = St \cdot \overline{Pr} \cdot Re , \qquad (3.26)$$

where the bar quantities are mean quantities.

The mean stagnation enthalpy is defined by

$$\overline{I}^{*} = \frac{\int_{0}^{r_{w}} \rho U I^{*} r dy}{\int_{0}^{r_{w}} \rho U r dy} \qquad (3.27)$$

The mean velocity is defined by

$$\overline{U} = \frac{2\pi \int_{o}^{r_{w}} \rho Ur dy}{\overline{\rho} \pi r_{w}^{2}} = \frac{2 \left(\frac{\text{mass flow}}{\text{rate/radian}}\right)}{\overline{\rho} r_{w}^{2}} , \qquad (3.28)$$

and the Reynolds number is defined as

$$Re = \frac{\overline{\rho UD}}{\overline{\mu}} = \frac{4 \left(\frac{\text{mass flow}}{\text{rate/radian}}\right)}{\overline{\mu}r_{w}} . \qquad (3.29)$$

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Ξ

The mean values for density, viscosity and Prandtl number are those values at the y location where $I^* = \overline{I}^*$.

Chapter 4

METHOD OF SOLUTION

4.1 Transformation of the Equations

• # 1. P *

The continuity, momentum, and stagnation enthalpy equations were developed in Chapter 2. The first step in transformation is to recast the convective transport equations into stream function coordinates using the von Mises transformation. In essence, the y-coordinate is replaced by a coordinate that is constant along streamlines, namely, the stream function ψ . The new independent variables become x and ψ , and the U velocity component is defined by

$$U = \frac{1}{r\rho} \frac{\partial \psi}{\partial y} . \qquad (4.1)$$

In stream function coordinates the momentum equation (2.7) and the stagnation enthalpy equation (2.15) become

$$\rho U \frac{\partial U}{\partial \mathbf{x}} + \rho U \frac{\partial}{\partial \psi} \left[r^2 \rho U \mu_{eff} \frac{\partial U}{\partial \psi} \right] = -g_c \frac{dP}{d\mathbf{x}} + g_c X , \qquad (4.2)$$

$$\rho U \frac{\partial I^{*}}{\partial x} + \rho U \frac{\partial}{\partial \psi} \left[r^{2} \rho U \frac{\mu_{eff}}{Pr_{eff}} \frac{\partial I^{*}}{\partial \psi} \right] =$$

$$\frac{\partial}{\partial \psi} \left[\frac{\mu_{eff}}{g_{c}^{J}} \left(1 - \frac{1}{Pr_{eff}} \right) r^{2} \rho U \frac{\partial}{\partial \psi} \left(\frac{U^{2}}{2} \right) \right] + S \quad .$$

$$(4.3)$$

Note that in the transformation the V component of velocity disappears and the continuity equation is no longer used explicitly, due to the definition of the stream function.

In the stream function coordinate system, the boundary layer fluid flows between two surfaces, I and E. The I-surface originates at y = 0, and the Esurface forms the second bounding surface. Sign convention for a positive y displacement is <u>always</u> from the I to E surface. Fluid crossing the I surface is $m_{I}^{"}$; this flow might be due to wall transpiration. Fluid crossing the E surface is $m_{E}^{"}$; this flow might be due to entrainment. The bounding solid surface is described by α , related to the rate of change of surface curvature in the x-direction, and r_{T} , which describes the transverse curvature of the I-surface. Location of the E-surface, r_E , is related to r_T and α . Figure 4.1 shows the coordinate system.



Figure 4.1. The stream-function coordinate system.

The sketch in Figure 4.1 depicts an external boundary layer over either a flat or conical surface, with I being a wall and E being a free stream. In the program, there is a limited freedom in defining these bounding surfaces. This will be discussed more thoroughly in Chapter 5.

The second and final step in the transformation is to recast equations (4.2) and (4.3) into the Patankar-Spalding coordinate system using the transformation

$$\omega = \frac{\psi - \psi_{I}}{\psi_{E} - \psi_{I}} , \qquad (4.4)$$

where ψ_E and ψ_I are the stream function values on the bounding surfaces.

In this non-dimensional stream function coordinate system, the momentum and stagnation enthalpy equations become

$$\frac{\partial U}{\partial x} + \left[\frac{\mathbf{r}_{\mathbf{I}}\mathbf{m}_{\mathbf{I}}^{"} + \omega(\mathbf{r}_{\mathbf{E}}\mathbf{m}_{\mathbf{E}}^{"} - \mathbf{r}_{\mathbf{I}}\mathbf{m}_{\mathbf{I}}^{"})}{(\psi_{\mathbf{E}} - \psi_{\mathbf{I}})} \right] \frac{\partial U}{\partial \omega} - \frac{\partial}{\partial \omega} \left[\frac{\mathbf{r}^{2}\rho U\mu_{eff}}{(\psi_{\mathbf{E}} - \psi_{\mathbf{I}})^{2}} \frac{\partial U}{\partial \omega} \right] = \frac{g_{c}}{\rho U} \left[-\frac{dP}{dx} + X \right] . \quad (4.5)$$

$$\frac{\partial \mathbf{I}^{\star}}{\partial \mathbf{x}} + \left[\frac{\mathbf{r}_{\mathbf{I}} \mathbf{m}_{\mathbf{I}}^{\mathsf{m}} + \omega(\mathbf{r}_{\mathbf{E}} \mathbf{m}_{\mathbf{E}}^{\mathsf{m}} - \mathbf{r}_{\mathbf{I}} \mathbf{m}_{\mathbf{I}}^{\mathsf{m}})}{(\psi_{\mathbf{E}} - \psi_{\mathbf{I}})^{2}} \frac{\partial \mathbf{I}^{\star}}{\partial \omega} \right] - \frac{\partial}{\partial \omega} \left[\frac{\mathbf{r}^{2} \rho U_{\mu}_{eff}}{(\psi_{\mathbf{E}} - \psi_{\mathbf{I}})^{2}} \frac{\partial \mathbf{I}^{\star}}{P \mathbf{r}_{eff}} \right]$$

$$= \frac{\partial}{\partial \omega} \left[\frac{\mathbf{r}^{2} \rho U}{(\psi_{\mathbf{E}} - \psi_{\mathbf{I}})^{2}} \mu_{eff} \left(1 - \frac{1}{P \mathbf{r}_{eff}} \right) \frac{\partial}{\partial \omega} \left(\frac{U^{2}}{2} \right) \right] + \frac{S}{\rho U}$$

$$(4.6)$$

The transformed equations have the general form of a diffusion equation:

$$\frac{\partial \phi}{\partial \mathbf{x}} + (\mathbf{a} + \mathbf{b}\omega) \frac{\partial \phi}{\partial \omega} - \frac{\partial}{\partial \omega} \left(c \frac{\mu_{eff}}{Pr_{eff}} \frac{\partial \phi}{\partial \omega} \right) = d , \qquad (4.7)$$

where a, b, c, d are constants.

In the program, equation (4.7) becomes the velocity equation when \Pr_{eff} is set equal to unity.

4.2 Finite-Difference Equations

As indicated in Chapter 1, the original basic program from which STAN5 has evolved is the Patankar/Spalding program, described in their 1967 book [1]. Only the numerics of the finite-difference equations and the concept of a wall function have been carried over into STAN5. It is our intent in this section to point out several facts regarding the finite-differencing scheme. These equations are well documented in Patankar and Spalding [1,2], and, for a revised version of the program, by Spalding [6].

The central theme in obtaining the finite-difference equations, hereafter referred to as FDE's, is twofold: (1) to form a miniature integral equation over a finite-control volume; and (2) to presume a linear variation of the dependent variable over the control volume to effect the integration. Figure 4.2 shows node locations and a control volume for three adjacent nodes at an upstream and a downstream station.

The first term in equation (4.7) is transformed into an FDE term, as follows:

$$\frac{\partial \phi}{\partial \mathbf{x}} \simeq \frac{1}{\delta \mathbf{x} \delta \omega} \int_{\mathbf{i} - \mathbf{i}_{2}}^{\mathbf{i} + \mathbf{i}_{2}} \int_{\mathbf{x}_{u}}^{\mathbf{x}_{d}} \left(\frac{\partial \phi}{\partial \mathbf{x}} \right) d\mathbf{x} d\omega \simeq \frac{1}{\delta \mathbf{x} \delta \omega} \left[\int_{\mathbf{i} - \mathbf{i}_{2}}^{\mathbf{i}} \left(\phi_{\mathbf{x}_{d}} - \phi_{\mathbf{x}_{u}} \right) d\omega + \int_{\mathbf{i}}^{\mathbf{i} + \mathbf{i}_{2}} \left(\phi_{\mathbf{x}_{d}} - \phi_{\mathbf{x}_{u}} \right) d\omega \right]$$
$$\simeq \frac{1}{\delta \mathbf{x} \delta \omega} \left[\left(\frac{1}{4} \phi_{\mathbf{i} - \mathbf{1}} + \frac{3}{4} \phi_{\mathbf{i}} \right) \frac{1}{2} (\omega_{\mathbf{i}} - \omega_{\mathbf{i} - \mathbf{1}}) + \left(\frac{3}{4} \phi_{\mathbf{i}} + \frac{1}{4} \phi_{\mathbf{i} + \mathbf{1}} \right) \frac{1}{2} (\omega_{\mathbf{i} + \mathbf{1}} - \omega_{\mathbf{i}}) \right] \frac{\mathbf{x}_{d}}{\mathbf{x}_{u}}.$$

$$(4.8)$$



Figure 4.2. Typical nodal locations and control volume for finitedifference equations.

The second term in equation (4.7) is transformed into an FDE term using integration by parts:

$$(a+b\omega) \frac{\partial \phi}{\partial \omega} \simeq \frac{1}{\delta x \delta \omega} \int_{x_{u}}^{x_{d}} \int_{1-\frac{1}{2}}^{1+\frac{1}{2}} (a+b\omega) \frac{\partial \phi}{\partial \omega} d\omega dx$$

$$\simeq \frac{1}{\delta \omega} \left[(a+b\omega)_{x_{u},1+\frac{1}{2}} \cdot \phi_{x_{d},1+\frac{1}{2}} - (a+b\omega)_{x_{u},1-\frac{1}{2}} \cdot \phi_{x_{d},1-\frac{1}{2}} \right] \cdot (47.9)$$

$$= b \int_{1-\frac{1}{2}}^{1+\frac{1}{2}} \phi_{x_{d}} d\omega dx$$

In the above equation, the integral is evaluated in a like manner to equation (4.8). Several assumptions are built into equation (4.9): (1) the integrand of the integral is evaluated only at x_d ; (2) the equation is "linearized" in that $(a+b\omega)$ is evaluated at x_u ; and (3) the integrand is presumed to vary linearly with ω over the control volume. Assumption (3) implies small cross-stream convection; this was later changed by Patankar and Spalding [2] using a "high lateral flux modification", or "upwind-differencing" to more properly account for high lateral convection. The modification is not used in STAN5. The third term in equation (4.7) is transformed into an FDE as follows:

$$\frac{\partial}{\partial \omega} \left(c \frac{\partial \phi}{\partial \omega} \right) \simeq \frac{1}{\delta x \delta \omega} \int_{x_{u}}^{x_{d}} \int_{1 - \frac{1}{2}}^{1 + \frac{1}{2}} \frac{\partial}{\partial \omega} \left(c \frac{\partial \phi}{\partial \omega} \right) d\omega dx$$
$$\simeq \frac{1}{\delta \omega} \left[(c)_{x_{u, 1} + \frac{1}{2}} \frac{(\phi_{i+1}^{-\phi_{i}})_{x_{d}}}{(\omega_{i+1}^{-\omega_{i}})} - (c)_{x_{u, 1} - \frac{1}{2}} \frac{(\phi_{i}^{-\phi_{i-1}})_{x_{d}}}{(\omega_{i}^{-\omega_{i-1}})} \right].$$

The above equation is "linearized" in that c is evaluated at x_{i} .

The fourth and final term in equation (4.7) is the source term. It is transformed into an FDE term as follows:

$$d \simeq \frac{1}{\delta x \delta \omega} \int_{x_{u}}^{x_{d}} \int_{1 - \frac{1}{2}}^{1 + \frac{1}{2}} (d) d\omega dx$$
$$\simeq \frac{1}{\delta x \delta \omega} \int_{x_{u}}^{x_{d}} \int_{1 - \frac{1}{2}}^{1 + \frac{1}{2}} \left[(d)_{x_{u}} + \left(\frac{\partial d}{\partial \phi} \right)_{x_{u}} (\phi_{d} - \phi_{u}) \right] d\omega dx \quad .$$
(4.11)

In STAN5, the velocity source term is handled precisely as described by Patankar and Spalding [1]. Sources for stagnation enthalpy and turbulent kinetic energy are evaluated at x_n ; the downstream contribution is neglected.

The FDE terms described by equations (4.8) to (4.11) are assembled into a form

$$\phi_{x_{d,i}}^{\phi} = A\phi_{x_{d,i+1}}^{\phi} + B\phi_{x_{d,i-1}}^{\phi} + C , \qquad (4.12)$$

where A, B, and C are coefficients evaluated at the upstream station, x_u . A set of ϕ equations is written for each dependent variable. In the text which follows, the velocity dependent variable is designated as U, and all other dependent variables are designated as ϕ -equation variables.

4.3 Grid and Slip Scheme

A sketch of the finite-difference grid and nodal locations was previously given in Figure 4.2. Cross-stream grid lines in that sketch divide the region between the I-surface and the E-surface into non-dimensional stream tubes, or flow tubes (from consideration of the definition of ω). The number of flow tubes that comprise the cross-stream grid is denoted by N. Two additional stream tubes (to define slip points) are inserted by the program near the I and E surfaces, making a total of N + 2 tubes, and thus N + 3 nodal points. A cross-stream grid is shown in Figure 4.3.



Figure 4.3. Cross-stream grid between the I and E surfaces.

In the above sketch, the 2.5 point on the grid is the join point, discussed in Section 3.3.1; the (2) point and the (N + 2) point are the slip points. Finite-difference equations of the form of equation (4.12) are solved for all nodes (2) through (N + 2). Boundary conditions for these equations are obtained through wall-function calculations, described in Chapter 3, if one surface is a wall.

The grid is established from the initial velocity profile, U = U(y). The profile is integrated using equation (4.1) to obtain $U = U(\psi)$, where flow between consecutive y locations is $\Delta \psi$, or non-dimensionally $\Delta \omega$. The $\Delta \omega$ values, which represent the fractional amount of the initial flow, remain <u>con-</u><u>stant</u> throughout the calculations, unless altered by routine LAMSUB, discussed in Section 3.5. The amount of boundary layer fluid can change, but the fractional percentages in each stream tube are fixed.

The slip points, along with "using the Wall Function", were developed by Patankar and Spalding [1] to allow use of a linear profile assumption (Section 4.1) in the near-wall region, thus eliminating the need to compute across a region of high velocity gradient. The scheme is an excellent "engineering tool" in terms of computational speed while preserving accuracy.

The idea behind the slip scheme is to presume power-law profiles for velocity and other ϕ -equations in the near-wall region.

$$v = c_1 y^{\beta}$$
, (4.13a)

$$(\phi - \phi_1) = C_2 y^{\gamma}$$
 (4.13b)

Each of the above equations contains two unknowns, which are obtained by matching the function and its first derivative (e.g., shear stress or heat flux) at the join point. From these two criteria come defining FDE's for the slip points.

$$U_{2} = U_{2}(U_{3},\beta)$$
, (4.14a)

$$\phi_2 = \phi_2(\phi_1, \phi_3, \gamma) . \qquad (4.14b)$$

The above equations are linearized in that the upstream values of β and γ are used. Similar types of equations can be developed for slip values near a free stream and near a symmetry line (see Patankar and Spalding [1 or 2] for a complete description).

The procedure described above to obtain slip values near a wall was later changed by Patankar and Spalding [2] to more accurately account for convection between the wall and the join point. In STAN5, this correction was accomplished by a modification to the join-point velocity and essentially accomplishes the same goal. The correction is needed for low values of β ; for $\beta > 0.9$, i.e., a linear profile in the near-wall region due to laminar flow or "bypassing the Wall Function", the power-law slip scheme is adequate.

4.4 Entrainment and Grid Control

Entrainment is applicable to flows in which there are free surfaces. For example, the free surface for a wall boundary layer is the location where U approaches U_{∞} , i.e., its cross-stream gradient approaches zero. The function of entrainment is to introduce new fluid into the region between the I and E surfaces, thus expanding the grid outward into "fresh" fluid and thus preserving the near zero gradient at the outer edge of the computation region. The expansion can be easily seen by recalling that to increment $(\psi_{\rm E} - \psi_{\rm I})$ with a constant $\Delta \omega$ spacing causes $\Delta \psi$ to increase and thus Δy . The entrained fluid is distributed to all flow tubes.

To determine if fluid should be entrained, the dependent variable difference near the free surface is compared with its free-stream value, e.g., $(U_{N+3}-U_{N+1})/U_{N+3}$ is computed and compared to ENFRA, a program input variable. This idea is depicted in Figure 4.4. The entrainment calculation for velocity in STAN5 is

$$\mathbf{m}_{E}^{"} = \mathbf{m}_{E}^{"} + \begin{bmatrix} \mathbf{b} \cdot \mathbf{l} \cdot \\ \mathbf{mass} \\ \mathbf{flux} \end{bmatrix} \begin{bmatrix} \mathrm{ENFRA} - \frac{\mathbf{U}_{N+3} - \mathbf{U}_{N+1}}{\mathbf{U}_{N+3}} \end{bmatrix} . \quad (4.15)$$



Figure 4.4. Entrainment at the free stream.

When there are ϕ -equations being solved in addition to the momentum equation, each of these gradients near the free stream is checked to assure no defects in profiles develop. This is especially important in accelerating flows or low Prandtl number flows, where the thermal boundary layer grows outside of the momentum boundary layer. There is a flag in STAN5 that can be set to base entrainment on either the momentum equation or on the behavior of all equations. Note that in STAN5, fluid is never allowed to be detrained, due to stability considerations. Integration stepsize, Δx , is partly determined by entrainment. The control is via an input variable FRA, say 5%, which requires that the mass flow rate into the boundary layer through the I and E surfaces be no more than FRA $\cdot (\psi_E^- \psi_I)$ over the distance Δx . This control, in effect, cuts back the stepsize if the boundary layer entrainment is large.

4.5 The Calculating Procedure

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Equation (4.12) in Section 4.2 is the general form for the finite-difference equations. The equations couple all grid points in the cross-stream direction, and they are solved by a tri-diagonal matrix algorithm for i = 2to N + 2. They have been linearized in the sense that the coefficients are calculated at the upstream stations. Thus, the program is "one step behind" in fluid properties, eddy viscosity, etc.

Because of linearization, the equations are only partially implicit, and this requires the use of a smaller Δx stepsize than could be used by a fully implicit scheme. For heat transfer calculations this does not present much of a problem, though, because the stepsize must be small enough to follow variable boundary conditions.

Chapter 5

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5.1 Introduction

To facilitate use of the program, a rather flexible input format has been developed which makes it possible to compile and link edit, and still accommodate a large number of input options merely by reading in numerical DATA. Other changes can be readily made in the core of the program, but the objective of this chapter will be to describe in detail how to access the program through DATA that are read directly by the computer.

All of the data input to the program are concentrated in the final subroutine which is labeled SUBROUTINE INPUT (KERROR). This subroutine contains a very large number of comments which in themselves constitute a set of instructions for its use. In reading this chapter it will be useful to refer to the input subroutine, and the present discussion will be based on the assumption that the reader has the input subroutine before him (her).

First it should be noted that each "read" statement is preceded by the symbols ****** extending across the page. Preceding these symbols the in-

All of the "read" statements (except the title) are in the form of either a series of integer numbers or a series of decimal numbers. All of the integer numbers are in fields of five spaces. It is important to note that integers must be justified to the right side of these fields.

All decimal numbers are arranged in fields of 10 digits, and of course may be placed anywhere within that field.

5.2 Flow Descriptors and Controls

On the card following a title, eight integers are read, all of which convey rather fundamental information about the type of problem to be solved. Some of the program nomenclature will be introduced as these, and other variables and constants appearing below, are discussed.

GEOM is an integer, from 1 to 9, which signals in a general way the type of system geometry to be solved. GEOM = 1 is the simple boundary layer on a flat plate, but this case also applies for an axi-symmetric body so long as the boundary layer thickness is small relative to the body radius. Thus it can be used for flow in a nozzle (subsonic or supersonic), or for flow over an axi-symmetric body such as a missile, even including a stagnation region.

GEOM = 2 & 3 differ from 1 only in that radius is included in the boundary layer equations so that boundary layer thickness need not be small relative to body radius.

GEOM = 4 & 5 refer to flow in circular and flat ducts, respectively. Strictly speaking, the "boundary layer" is treated as if it filled the entire duct; however, a judicious choice of grid spacing makes it possible to handle entry-length problems with accuracy. It is also possible to solve pipes or ducts which have slightly convergent or slightly divergent walls.

GEOM = 6, 7, 8, 9 cover the cases of circular and flat jets, and free shear flows.

MODE refers to whether the flow is to be laminar or tubulent. MODE = 1 is a laminar flow, while MODE = 2 is turbulent. As will be seen below, it is possible to start with MODE = 1 and then shift to a turbulent flow on the basis of an input transition criterion.

FLUID refers to the type of fluid. FLUID = 1 is any constant-property fluid, such properties to be supplied in a later read statement. FLUID = 2 refers to air, the properties of which (based on the Keenan and Kaye Gas Tables) are provided as a separate subroutine in the program. The air properties cover temperatures from 180° R to 4620° R, but do not take into consideration dissociation at high temperatures. The program is not provided with the properties of any variable-property fluids other than air, but it is only necessary to designate some other fluid with a number (3 or higher) and then construct a subroutine similar to SUBROUTINE PROP2. The appropriate call for any other property subroutine must be inserted as indicated in the MAIN program.

NEQ refers to the total number of boundary layer equations to be solved. Thus, if the momentum equation alone is to be solved, NEQ = 1, but if momentum and energy are to be solved, NEQ = 2. Actually, the program dimensioning allows NEQ to be as high as 6, if, for example, a number of mass diffusion equations must be solved. Another related variable, NPH, will be found through out the program. NPH = NEQ - 1, and is the number of diffusion equations (energy, mass, etc.) that must be solved. It is assumed that the momentum equation is <u>always</u> solved.

N defines the grid structure in the y-direction; it is the number of flow tubes. Thus the number of grid points in the y-direction is N + 1. Because of the "slip" scheme described earlier, the program inserts two more grid points, one near the I surface, and one near the E surface. Thus the total number of grid points with which the program works is N + 3. Within the program the grid points are numbered starting with 1 at the I (for internal) surface and extending to N + 3 at the E (for external) surface. The character I is used to index the grid points, and I then varies from 1 to N + 3. For convenience, the last three points are designated NP1 = N + 1, NP2 = N + 2, NP3 = N + 3. The two "slip" points, which have no real physical significance, are I = 2 and I = NP2.

The choice of N determines how fine or how coarse a grid structure is to be used, and only experience can tell what is necessary to achieve desired precision for a particular problem. For a turbulent boundary layer when "using the wall function" (this will be discussed further below), N in the range 15-20 is generally satisfactory. If "bypassing the wall function" is used, or if the flow is laminar, N should generally be greater than 30. If N is less than 12 the program will not operate, and N is limited to 50 by the dimensioning of the program. However, this limitation can be readily changed, if desired. Finally, it should be noted that the program will change N internally under special circumstances to be discussed later in connection with the input values of YPMIN and YPMAX.

KIN and KEX are indicators which determine the character of the I and E boundaries, respectively. If either is set equal to 1, that boundary is a wall; if set equal to 2, the boundary is a free stream; 3 indicates a line of symmetry, such as the centerline of a pipe or a free jet. As presently assembled, the program will handle only one wall surface, so, for example, it is not possible for both KIN and KEX to be equal to 1. Note that the I and E boundaries are literally "inner" and "outer" with respect to the axi-symmetric coordinate system, so, for example, for flow in a pipe the I boundary must be the centerline of the pipe and the E boundary must be the pipe wall; they are not interchangeable. On the other hand, for GEOM = 1 the I and E boundaries are interchangeable and either could be the wall.

KENT is an indicator for the entrainment calculation at a free boundary. If there is no free boundary, KENT can be left blank. If KENT = 0 entrainment is calculated based on the behavior of the momentum equation alone; if KENT = 1 all diffusion equations are tested. Since it is quite possible for the thermal boundary layer, for example, to extend outside the momentum boundary layer, and one generally wants to adjust entrainment so that the region of interest (the region enclosed by the I and E boundaries) encloses the thickest boundary layer, it is generally wise to set KENT = 1. On occasion this can lead to some instability, and this is the reason why the option to set KENT = 0 is provided.

The next card to be read contains more general information, all in the form of decimal numbers. XU is the present location of the calculations in the xdirection, and is one of the primary independent variables. Here XU is initialized, so this is where calculations start. Most often XU is 0.0, but it can be any positive number where it is desired to commence calculations. (Actually XU refers to the "upstream" side of the finite-difference step in the x-direction, as opposed to XD on the "downstream" side. The difference between XU and XD is DX, the step length.) XL is the x-distance where it is desired to stop calculations. Thus XU and XL, as read here, define the distance over which calculations are to take place. These are dimensional quantities and may be in feet, inches, meters, or whatever is desired. The actual dimensioning system to be used is designated later. Recall, as shown in Figure 4.1, that x is intrinsic, measured along the I-surface, and is <u>not</u> the projection onto the axis of symmetry.

DELTAX is a number (non-dimensional) from which DX, the step-length, is derived. It is the ratio of DX to boundary layer thickness, so DX grows as the boundary layer thickens. For a pipe-flow it is the ratio of DX to pipe radius. Actually, DELTAX determines a maximum value of DX and can be overridden by another number, FRA, which will be discussed shortly. DELTAX = 1.0 is a reasonable value when dealing with a gas for which properties are varying rapidly. If properties are nearly constant considerably larger values may be used and this is particularly true for laminar flows. For fully developed flow in a pipe DELTAX can sometimes be made equal to 10 or greater. If DELTAX is too large, a slight instability will be noted, with oscillation of the output data. It is often advantageous to use large values of DELTAX to reduce computation time. A further option is available using the constant K1 and the auxiliary

boundary condition, AUX1(M) (see below), whereby DELTAX can be changed arbitrarily in the course of a calculation.

RETRAN provides a way to effect internally a transition from a laminar to a turbulent boundary layer. For a simple boundary layer, the momentum thickness Reynolds number is employed as a transition criterion, and RETRAN is the Reynolds number at which MODE will automatically shift from 1 to 2. Actually, the transition is made smoothly, rather than abruptly, over a range of momentum thickness Reynolds number from RETRAN to twice RETRAN by smoothly bringing the sublayer damping constant down from a large number to its equilibrium value (see SUBROUTINE WALL). Typically, a transition Reynolds number of 200-300 provides realistic results. If it is desired to make laminar boundary layer calculations only, care must be taken to make sure RETRAN is a number larger than any momentum thickness Reynolds numbers anticipated. For flow in a pipe or duct, RETRAN is interpreted as a diameter Reynolds number, but of course diameter Reynolds number does not vary in the x-direction in this case. For totally turbulent boundary layers and flows, RETRAN can be 0.0, or left blank, if desired. For free-convection boundary layers, or for flows for which there is no wall surface, Reynolds number has no useful significance, so RETRAN must be set to unity.

FRA, when multiplied times the total amount of flow between the I and $^{\circ}$ E boundaries, specifies the maximum amount of new fluid that will be permitted to enter the region of interest between XU and XD either by entrainment or by mass transfer through a porous wall. If this amount is exceeded by the specified value of DELTAX, then DX is appropriately reduced in value. FRA = 0.05 is a reasonable value for most applications.

ENFRA is the entrainment fraction. It has significance only when there is a free-stream boundary, in which case it is the desired difference (expressed as a fraction of the total difference through the boundary layer) between the free-stream velocity, or the corresponding dependent variable in a diffusion equation, and the next closest grid point (excluding the slip point). This difference is maintained by automatically adjusting the rate of entrainment of freestream fluid. The appropriate value of ENFRA differs somewhat for different kinds of problems, and is also related to the chosen grid spacing near the outer edge of the boundary layer. Calculated results are not necessarily highly sensitive to the value chosen for ENFRA, but a very inappropriate value can lead to

either instability (wild oscillations in entrainment rate and in boundary layer thickness) or inaccurate overall results. For typical boundary layer calculations, turbulent or laminar, a value of 0.005 frequently works well, but a fine grid near the outer edge may suggest a value as low as 0.001. On the other hand, for a free-convection boundary layer or any case where free-stream velocity is at or near zero (for example, a jet) ENFRA should be very much larger, 0.01 to 0.05. One way to get a handle on ENFRA, in any case, is to plot the initial velocity profile, perhaps based on an appropriate analytic solution, and then superimpose the desired grid on the plot. The difference in velocity between the free-stream and the next adjacent grid line, divided by the maximum velocity difference for the whole boundary layer, is then usually a good value for ENFRA.

If there is no free-stream, as would be the case for pipe-flow, then ENFRA can be left blank.

GV is a gravity constant which should be either set at zero or left blank if gravity is not a relevant parameter. The only gravity effects that can be considered are those in the direction of flow (x-direction). Note that a positive value of GV represents a gravity force in the positive or flow direction; if simple free-convection on a vertical flat plate is being considered, remember that GV must be <u>negative</u>. Note also that gravity has no effect unless there are density gradients across the boundary layer; the free-convection boundary layer is a compressible flow boundary layer, and nothing will happen if FLUID = 1.

5.3 -Body Forces and Sources

The next card read concerns some integer indicators having to do with body forces in the momentum equation, and energy and other types of sources in the diffusion equations. BODFOR can be 0, 1, or 2. If 0, there is no body force present other than pressure. If BODFOR = 1, the body force is the result of a gravity force acting upon density, and of course a value for GV must also be specified.

If BODFOR = 2, an external body force is present, and this force is introduced through a specified set of auxiliary boundary conditions AUX1(M), which will be discussed later. Provision is made only for a body force that is a function of x, and independent of y. BODFOR = 2 also includes BODFOR = 1. A body force has the dimensions force per unit of volume. The source indicators, SOURCE(J), are not read unless there are one or more diffusion equations in addition to the momentum equation, i.e., unless NEQ is greater than 1, and NPH is greater than 0. The index J varies from 1 to NPH so that one value for SOURCE is read for each diffusion equation, reading across the card in integer fields of 5, after BODFOR.

If there is more than one diffusion equation it must be decided ahead of time which is which, and the designation of a source for each equation establishes what kind of a diffusion equation it is to be. Of course, the initial dependent variable profiles and the boundary conditions, both of which are discussed later, must be consistent with this choice.

If there is to be no source for a particular diffusion equation, set SOURCE = 0, or at least leave it blank. If SOURCE = 0, the equation could be the energy equation with viscous dissipation neglected, or it could be a mass diffusion equation with no chemical reaction. Only the initial and boundary conditions serve to make a distinction (together also with the Prandtl or Schmidt number), since the differential equations are identical.

SOURCE = 1 activates viscous dissipation as an energy source, as well as body-force work, and the equation is then definitely the energy equation.

Setting SOURCE = 2 for a particular diffusion equation has more extensive effects. It activates the source function for the turbulence energy equation (Production-Dissipation), but additionally it changes the method of calculation of eddy viscosity (and thus eddy conductivity) from the mixing-length method to the turbulent kinetic energy method, wherein eddy viscosity is proportional to the square root of the turbulent kinetic energy. However, the program still uses mixing-length in the Wall Function, and it still uses mixing-length out to the edge of the viscous sublayer if the Wall Function does not extend that far. If there is no wall, turbulent kinetic energy is used throughout.

SOURCE = 3 is the same as SOURCE = 1, except that an external energy source, as a function of x alone, may be introduced through AUX2(M). Such a source must have the dimensions (energy)/(volume * time).

SOURCE = 4 also implies that an external volume source is being introduced through AUX2(M), but viscous dissipation and body-force work are omitted, so this could be a source different from energy.

Note that all of these external body forces and sources which are introduced through the auxiliary functions AUX1(M) and AUX2(M) are functions of x only. This is obviously somewhat limiting, but the only practical way to introduce sources that vary in the y-direction is by modifications in the core of the program. However, this can be easily done in SUBROUTINE AUX, where some comments are given.

5.4 Fluid Properties

The next card is the one in which fluid properties are introduced. The amount of information actually read depends upon whether constant properties are to be used or whether the variable properties contained in a separate property subroutine are to be used. In any case the initial static pressure PO is always read, and for the variable property case this is all that is needed. For constant properties, density, RHOC, and viscosity, VISCOC, are next to be read; if only the momentum equation is to be solved this is all that is necessary. If one or more diffusion equations are to be solved, the only additional property is the Prandtl number for the energy equation, PRC(J), or a Schmidt number for each and every mass diffusion equation, making sure that they are read in the same order as has been established for designating each equation, i.e., J = 1 refers to a particular diffusion equation, and J = 2 to another, and this order must be maintained throughout the entire input routine. Note that although the symbol PRC(J) is used, this can be either a Prandtl or a Schmidt number. Finally, all units must comprise a consistent set. Note that the read statements are so arranged that it doesn't matter if there is a redundancy of information. Thus the program might be set up to solve both momentum and energy equations with constant properties; but if in the second card FLUID is changed to 2 the program will run with variable air properties and simply will not read the constant properties (except PO). Similarly, if NEQ is changed to 1, the program will not read Prandtl number or anything else having to do with a diffusion equation; it is not necessary to remove this input information if an abbreviated problem is to be run. As a word of caution, do not try to solve the momentum equation alone without setting FLUID = 1 and supplying the appropriate constant properties. There is no way to introduce variable properties without temperature or mass concentration distributions upon which to base them.

5.5 Boundary Conditions

The next card supplies some information about types of boundary conditions, and the number of entries read depends upon the number of differential equations to be solved. NXEC, an integer number, refers to the number of points along the boundaries at which boundary condition information is to be supplied. The cards following will contain that information. Internally, the program will determine boundary values at each XU position by linear interpolation between the x-positions of the input boundary data as specified here. Thus NXBC must have as a <u>minimum</u> a value of 2 so that there is something to interpolate between. If boundary values are varying with respect to x in other than a linear manner, many more than two boundary values may be required for an accurate representation. The program is dimensioned such that NXBC may be as large as 100. Free-stream velocity is evaluated from a cubic spline fit scheme rather than linear interpolation, except that when NXBC = 2 linear interpolation is used.

The other items read on this card refer to the type of boundary condition at a wall that is going to be supplied for any and all diffusion equations. If there is no wall nothing is read, and the same is true if only the momentum equation is to be solved. TYPBC(J) can be either 1 or 2, depending upon whether the boundary condition read is to be, respectively, a specification of the value of the dependent variable at the wall, or the flux of the dependent variable at the wall. In the case of the energy equation, the question is whether it is the enthalpy at the wall or the heat flux that is to be specified. For the turbulent kinetic energy equation set TYPBC(J) = 1. Of course a specification for every diffusion equation must be supplied, and in the proper order.

The following card continues boundary specifications. These items, all decimal numbers, are read in the form of a table. The number of lines in the table must be equal to NXBC. X(M) is the x location of the points where boundary information is to be supplied. The first entry, X(1), must be equal to or less than XU read earlier; the last entry, X(NXBC), must be equal to or greater than XL. For a variable velocity boundary condition, the value of XU must coincide with an X(M) in the table. Between the first and last point, the spacing of any other boundary condition points can be completely arbitrary. Discontinuities, for example, can be simulated by placing two points very close together. When free-stream velocity is changing rapidly, it is important to use a large number of points and not produce situations that a spline

fit will have difficulty accommodating; abrupt changes of velocity are troublesome and can lead to unwanted velocities between the specified points.

RW(M) is a geometry specification for an axi-symmetric body. It is the transverse radius of the body at each specified x-location. Note that RW is a function of x, distance measured along the surface, and <u>not</u> the projection onto the axis of symmetry. The boundary layer can be either on the inside or the outside of the body for GEOM = 1. GEOM = 2 and 3 are restricted in this regard. For a pipe, GEOM = 4, RW(M) is the pipe radius. For a boundary layer on a non-axisymmetric body, for example a flat plate or an airfoil, use GEOM = 1 and set all values of RW(M) equal to any constant number, such as 1.0. For an axi-symmetric stagnation point use GEOM = 1 or 2 and set RW(M) = X(M). For a flat duct, GEOM = 5; RW(M) is the duct half-width.

Two additional pieces of boundary condition information can, if desired, be read on this card, AUX1(M) and AUX2(M). It has already been noted that these auxiliary items can be used for specified body forces or specified internal heat sources, if proper indicators are activated. AUX1(M) can also be used to provide a control on DELTAX. These functions, however, are provided in general so that the user can conveniently introduce any kind of information that is a function of x, and then appropriately modify the core of the program to make use of the information. If there is a wall present, the program additionally calculates two more functions, AUXM1 and AUXM2, which are linearly interpolated values of AUX1(M) and AUX2(M), and are always available in the COMMON.

The primary boundary condition data are read on the next cards, again in the form of a table in which the number of lines must equal NXBC. UG(M) is the free-stream velocity which must always be supplied if there is indeed a free stream. (In the case of a pipe or duct flow this column can be left blank.) A particular feature of this version of the program is the fact that free-stream velocity is treated as an independent boundary condition rather than pressure or pressure gradient. A minor modification of the basic program is necessary if pressure is to be the independent boundary condition. Note that UG is zero for simple free convection, or for a jet in a stagnant environment.

The second column (second field of 10 spaces) is the mass flux at the wall, AM(M). If there is no wall this column is simply not read. AM is positive in the positive direction of the coordinate system. Thus, if the I boundary is a wall, positive AM is mass transfer <u>into</u> the boundary layer, but if the E

boundary is a wall (as in pipe-flow), <u>negative</u> AM is mass transfer <u>into</u> the boundary layer.

The next five columns are read only if there is a wall and if one or more diffusion equations are to be solved. FJ(J,M) is either the wall value of the dependent variable in a diffusion equation or it is the wall value of the dependent variable flux. Whether it is a wall value or a flux is determined by TYPBC(J), discussed above. Thus for the energy equation FJ is either a wall value of enthalpy or a wall value of heat flux. The sign of the flux is again positive in the positive direction of the coordinate system which goes in the direction from I to E. Thus, for flow in a pipe, a heat flux into the fluid results when FJ is negative. Care must be taken when FJ is a flux and there is mass transfer at the wall. FJ is then the product of the mass flux and the value of the property in question in a reservoir outside the wall. For example, for the energy equation with FJ as a flux, FJ is the product of AM and the enthalpy of the transferred fluid in an external reservoir. For the turbulent kinetic energy equation, FJ should be 0.0.

5.6 Initial Profiles

The next series of cards contains the initial or starting profiles for velocity and the dependent variables for each of the diffusion equations. These are read in the form of a table, as in the previous case. The number of entries in the vertical columns must be equal to N + 1. Each column again occupies 10 spaces.

The first column contains Y(I), the distance measured from the I-boundary for each of the grid points at which the other information is to be supplied. In Y(I), I is an integer which varies from 1 to NP3, but 2 and NP2 are omitted, since these are the slip positions which are evaluated within the program. Thus the table will contain N + 1 entries. Y(I) is always 0.0, since y is measured from the I-boundary.

The spacing of the various Y(I) is very important, since it establishes the cross-stream grid for the entire boundary layer calculation. First, the obvious fact should be noted that it is not possible to start finite-difference calculations with this program from a singularity; starting profiles are mandatory, but the boundary layer can be as thin as desired, although a very thin starting boundary layer may require a large number of calculations to progress very far in the x-direction. Generally, the starting profiles are where analyti boundary layer solutions can be used to great advantage. Typically, one knows something like momentum thickness Reynolds number at the start, and simple analytic solutions can then be used to establish initial total thickness and initia profile shapes. Actually, since boundary layers, and especially turbulent hounc ary layers, come to equilibrium relatively quickly, the initial profile shapes are often not at all critical; it <u>is</u> important that the initial integral parameters (such as momentum and enthalpy thickness) be close to correct. For example, a laminar boundary layer calculation could be started with a simple linear velocity profile, and within a few downstream steps the correct profile will be closely approximated. An exception to this discussion is flow in a pipe or duct where the "boundary layer thickness" is always the distance from the wall to the centerline. It is possible to start such calculations with a uniform velocity profile and thus calculate the velocity entry length, but for accuracy this does require using a relatively fine grid spacing near the wall.

Now, to get back to the Y(I) spacing, the reason it is so important is that the program reads the initial data, calculates the fluid flow in each flow tube, totals this for the entire region from I to E, and then calculates the fraction of the flow in each flow tube. As the boundary layer grows, the total flow in the region I to E may grow due to entrainment and/or mass transfer, and the distance from I to E may grow, but the fraction of the total flow in each flow tube is maintained constant. The fraction of the flow from the I-boundary to some Y(I) is given the symbol OM(I) (omega). Thus the flow between the I and the I + 1 grid point is OM(I+1) - OM(I). It is these initial values of OM(I) that remain the same throughout the calculation (with an exception to be discussed below). Now there is no requirement that the OM spacings be uniform; on the contrary, it is generally more efficient if they are not. But it is important that the OM spacing differences between adjacent flow tubes not be too large. As a rule of thumb, differences greater than a factor of about 3 should be avoided. A good way to set up the initial velocity profile is to lay it out on a piece of graph paper and then superimposlines for grid points, crowding them closer together in the regions where velocity is changing rapidly. A mental estimate of the relative flow rate between each pair of grid lines will usually suffice to make sure that large steps in

flow rates are avoided. This graphical procedure was also recommended as a guide for specifying entrainment fraction.

If there is a wall and the boundary layer is turbulent, a decision must be made whether to use a small number of grid points, along with "using the Wall Function", or to "bypass the Wall Function" and use a fine grid down to the wall. For a great many calculations the results will not differ much, and "using the Wall Function" is a little simpler and cheaper in computation time. For very high Reynolds numbers there is really no choice; a grid fine enough to allow "bypassing the Wall Function" may require an excessive number of grid points. "Bypassing the Wall Function" does become useful where pressure gradients are large, or boundary conditions are changing rapidly along the wall, or it is simply desirable to have a print-out of the variables near the wall. The accuracy question comes down to the adequacy of the Couette flow approximation, which is used in the Wall Function. For large adverse pressure gradients, for example, the Couette flow approximation begins to yield a substantial error in local shear stress in a typical case when y^+ becomes larger than about 15 or 20.

When "bypassing the Wall Function", it is necessary that U and y at the first grid point (I = 3 if $K^TN = 1$, or I = NP1 if KEX = 1) be so chosen that y^+ is about 1.00, or less. This can be checked by multiplying U by y and dividing by kinematic viscosity, which gives the product U^+y^+ . In this region $U^+ = y^+$, approximately. The spacing of the grid points farther from the wall can then be gradually increased by steps of perhaps 20 percent out to about $y^+ = 20$, and 25-30 percent thereafter, i.e., $y^+ = 1.2$, 1.4, 1.7, 2.1, etc.

When "using the Wall Function" it is important that the first grid point be at a value of y^+ not less than about 20.0. The subsequent points can then be spaced at intervals that increase by 25 to 30 percent, i.e., 25.0, 31.0, 39.0, 49.0, etc.

For both cases, after y^+ becomes greater than about 200, quite large, equally spaced steps generally can be used because velocity is no longer changing rapidly. The important thing is to concentrate the grid where rapid changes are taking place.

It is important that the velocity at the free-stream edge of the boundary layer be precisely the same as the value of free-stream velocity introduced as a boundary condition earlier.

Having once established the initial velocity profile, the other columns are filled in with the corresponding initial dependent variable profiles for the diffusion equations, all in the same order as discussed earlier. Any of these can be totally zeros if desired, or all equal to the free-stream value, as would be the case for a heat transfer problem with an unheated starting length. For turbulent kinetic energy it is possible to start with all zeros and the program will generate its own kinetic energy. In any case, the wall value of turbulent kinetic energy should be 0.0. In the case of the energy equation the dependent variable is always stagnation enthalpy, <u>not</u> temperature.

The value of the dependent variable in the diffusion equations at the outer edge of the boundary layer is always constant, and is established by the value specified in the initial profiles.

5.7 <u>Turbulence Constants</u>

Some of the turbulence constants are read in the next cards. If the flow is laminar, dummy turbulent values can be used, or these entries can be left blank. If there is no wall, some of the constants are also redundant. AK is the wall region mixing-length constant, kappa. There is not total agreement on the value of kappa, but 0.41 is extensively used. ALMGG is lambda, the outer region mixing-length constant (or outer region length-scale constant when turbulent kinetic energy is used). There is also a constant eddy diffusivity option available (see below) in which case ALMGG becomes a dummy. For boundary layers a value of 0.085 appears reasonable; for flow in a pipe 0.07 is suggested, but the constant diffusivity option is recommended for pipe-flow. For a boundary layer the value for ALMGG is overridden at momentum thickness Reynolds numbers below about 5500 by an internal correlation that yields a higher value. This override can be suppressed by setting K2 = 3 (see below).

ALMGG is a non-dimensional constant which yields a mixing-length when multiplied by boundary layer thickness. But "boundary layer thickness" must be defined, and FR provides this definition. If FR is set equal to 0.01, the boundary layer thickness upon which ALMGG is based is the distance from the wall to the point where the velocity is within 1 percent of free-stream velocity. The suggested values for ALMGG given above are based on FR = 0.01.

AQ and BQ are turbulence constants which are used for the turbulence energy equation, but also for the constant eddy diffusivity option. In the former case AQ is the eddy diffusivity constant while BQ is the dissipation constant. Of the three constants, AK, AQ, BQ, only two are independent. The three are related by the equation:

If AK = 0.41, some reasonable values for AQ and BQ are 0.22 and 0.38.

When the constant eddy diffusivity option is used (set K2 = 2, see below), eddy diffusivity in the outer region is evaluated from the equation:

 $\frac{\varepsilon_{M}}{v}$ = AQ * (Reynolds number) ** BQ

For an external boundary layer, momentum thickness Reynolds number is used; for flow in a pipe or duct, diameter Reynolds number is used. Reasonable values for the pipe case are AQ = 0.005, BQ = 0.9.

YPMAX and YPMIN are controls on the values of y^+ at the outer edge of the Wall Function. They are operable whether the flow is laminar or turbulent, but are meaningless if there is no wall. Routine LAMSUB provides a scheme whereby extra grid points can be automatically inserted between the wall and the next point out, or grid points can be removed from the same region. In ∞ other words, the grid number N is changed. YPMAX sets a maximum limit on the value of y^+ at the outer edge of the Wall Function. If this limit is exceeded an extra grid point will be inserted. YPMIN sets a minimum limit on the value of y^+ at the outer edge of the Wall Function. If y^+ at the outer edge is less than this limit, the grid point nearest the wall will be removed.

When using the Wall Function, a typical procedure is to set YPMIN = 20.0 and YPMAX = 50.0 to 100.0. When bypassing the Wall Function, set YPMIN = 0.0 and YPMAX = 1.0. This scheme is also useful in setting up the initial profiles when it is desired to bypass the Wall Function. For example, a rather coarse grid can be introduced in which y^+ at the innermost point is, say, 50.0. Then if YPMIN = 0.0 and YPMAX = 1.0, the program will insert a series of points down to near y^+ = 1.0, with optimal spacing.

The damping function constant for the viscous sublayer is read in the next card. Two options are available, together with some variations. APL refers to A⁺ in the Van Driest exponential damping function scheme; BPL refers to B^{\dagger} in the Evans linear damping function scheme. The program will use the scheme for which the larger number is indicated, i.e., if APL is larger than BPL, the Van Driest scheme will be used, and vice versa. In either case an empirical internal correlation is used to modify the value of APL or BPL to account for the effects of pressure gradient and transpiration. For the Van Driest scheme. $A^{\dagger} = 25.0$ is suggested for external boundary layers, and $A^+ = 26.0$ for flow in a circular pipe. $B^+ = 35.0$ appears to be about correct for the Evans scheme. In any event, the user is urged to experiment with the constants and compare results against proven experimental data. If it is desired to not use the internal correlation for transpiration and pressure gradient, SIGNAL should be set to 1.0; otherwise SIGNAL may simply be left blank. For example, the internal equation for the effects of pressure gradient is probably not valid for a free-convection boundary layer, or for any boundary layer involving body forces in the flow direction, so in such a case set SIGNAL = 1.0.

The next card contains a lag constant, PPLAG, to account for the time required for the sublayer to adjust to different externally imposed conditions, such as pressure gradient or transpiration. PPLAG = 4000.0 has been found to be reasonably satisfactory.

Also in this card is read the turbulent Prandtl number, PRT(J), for each of the diffusion equations. PRT(J) is not read if the flow is laminar, nor is it read if only the momentum equation is being solved. The program contains an internal calculation for turbulent Prandtl number near a wall, based on a conduction model. The value of turbulent Prandtl number read here is the value for a region far removed from the wall. However, this value is used in the near-wall analysis and does affect it directly and importantly. Right at the wall, turbulent Prandtl number is computed to be twice the value far removed from the wall. For the energy equation it has been found that PRT(J) = 0.86 gives reasonable results for air, and is also quite satisfactory for liquid metals. In the latter case the internal analysis yields a turbulent Prandtl number over the entire region of interest considerably greater than the value of PRT(J)read in the input. For the turbulent kinetic energy equation the internal correlation is not used, and a value of PRT(J) = 1.7 may be about right, although there is great uncertainty about this figure.

If it is desired to suppress the internal calculation for turbulent Prandtl number and thus use a constant turbulent Prandtl number (or turbulent Schmidt number) throughout, set K3 = 3, as described later.

5.8 Other Constants and Output

The dimensioning system used is established in the next card. GC is the constant in Newton's Second Law (g_c) . If SI units are being used, GC = 1.0. If English Engineering units are used GC = $32.2 (1b_m ft)/(1b_f sec^2)$, etc. CJ is the proportionality factor in the First Law of Thermodynamics (J). Again, if SI units are used, CJ = 1.0; but with English Engineering units, J = 778 ft-1b_f/Btu. The other quantities read on this card, AXX, etc., are merely auxiliary constants which may be employed by the user for special purposes, after making appropriate adjustments inside the program.

The final card reads some integer numbers concerned with a number of different things. The first, NUMRUN, is the number of sets of DATA that are to be read. Ordinarily this would be 1, but DATA sets may be stacked if desired. SPACE designates the number of integrations between output prints, i.e., if SPACE = 10, the program will print out a complete set of results every 10 integrations in the x-direction. There are two special cases. If SPACE = -11, a one-line set of abbreviated results will be printed out for every integration; if SPACE = 21, a complete set of results will be printed every 20 integrations, and a one-line abbreviated set will be printed for every integration.

OUTPUT is a number designating the particular output format to be used. Three are presently available, designated by the integer numbers 2, 4, 6.

OUTPUT 6 is a general-purpose routine usable for any kind of problem. -Complete profiles of all dependent variables are printed, together with numerous other pieces of information such as shear stress at a wall, heat flux, entrainment rates, eddy viscosity, etc. This routine is the only one which is usable for KEX = 1, as well as KIN = 1, and it is the only one which should be used when free-stream velocity is at or near zero.

OUTPUT 2 is especially designed for external boundary layers when the I-boundary is a wall. U^+ and y^+ are printed, as well as the dimensional

profiles; and the non-dimensional parameters $C_f/2$, St, momentum thickness Reynolds number, enthalpy thickness Reynolds number, are all printed.

OUTPUT 4 is a routine for flow in a pipe or duct. Parameters peculiar to this type of problem, such as mean velocity, mixed-mean enthalpy, and diameter Reynolds number, are printed along with the pertinent profiles.

The options SPACE = 11 and 21 are available only for output routines 2 and 4.

Some additional data may be printed with any of the output routines by setting the indicator Kl (see below) to any number greater than 10. Five specially designated pieces of information, SP(1), ... SP(5), will be printed, but they must first be assigned at some point in the body of the program. This option simply provides the user with a simple method of capturing additional information of his own choosing.

The integer indicators Kl, K2, K3, have been mentioned several times in this chapter. These indicators provide the user with a convenient scheme for causing particular things to happen within the program. They have already been used for a number of purposes, but the user still has the option for other uses. The uses already programmed are as follows:

, 1915	Kl	greater than 10:	Five specially defined pieces of information will be printed in all of the output routines.
	Кl	equal to 9 or 20:	DELTAX becomes equal to AUX1(M), and the input value of DELTAX is overridden.
	К2	equal to 2:	Program will use the constant eddy diffusivity option in the outer region, rather than mixing- length.
	К2	equal to 3:	An internal empirical equation for ALMGG will be suppressed, and the input value of ALMGG will be used throughout.
Ţ,	K3	equal to 3:	An internal calculation for turbulent Prandtl num- ber will be suppressed, and the input values of turbulent Prandtl number will be used as a constant throughout.

Chapter 6

PROGRAM ORGANIZATION

6.1 Structure of the Program

Program STAN5 consists of a driver program and six subroutines.

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The driver program, MAIN, sets all boundary conditions and conducts the integration. In addition, fluid properties, entrainment, DX stepsize, and integral parameters are calculated in this routine.

SUBROUTINE STEP is a package containing five subsections. In STEP(1), the initial slip points and β and γ near the I and E surfaces are computed. STEP(2) computes the initial radii and converts the initial y's to ψ 's and then to ω 's. These two routines are required only at the start of integration or if LAMSUB readjusts the profiles. STEP(3) computes y's from the velocity profile, and the ψ distribution and the radii associated with these y locations. Also, the velocity profile is searched for its maximum and minimum values, and the boundary layer thickness is determined. In STEP(4), all finite-difference coefficients are formed and the resulting FDE's are solved. STEP(5) is used to initialize variables at the start of integration.

If one of the bounding surfaces is a wall, SUBROUTINE WALL computes wall shear stress and heat flux, along with $C_f/2$ and St. The internal correlation for A^+ or B^+ as a function of V_0^+ , P^+ , and BF^+ , and LAMSUB, are contained in this subroutine.

Effective viscosities and effective Prandtl numbers for turbulent flow calculations are computed in SUBROUTINE AUX, and, in addition, all source terms for the ϕ -equations, e.g., viscous dissipation or TKE production and dissipation.

Printing during integration is via SUBROUTINE OUT, which contains three subsections, with the first designed primarily for external boundary layers, the second for pipe flows, and the third for a general output.

SUBROUTINE PROP2 is a variable-properties table for air at moderate temperatures, to be used with compressible flow calculations.

SUBROUTINE INPUT reads and prints all input variables. In addition, it performs diagnostics on these variables to look for "pitfalls" associated with setting up a problem or incompatibilities among the variables.

6.2 <u>MAIN</u>

The driver of any program is generally the most complex routine, and the one contained in STAN5 is no exception. Therefore, it has been diagrammed and is given in Figure 6.1. Since the flow chart presents the sequence of events straightforwardly, no further discussion is felt necessary.

6.3 <u>STEP</u>

Five sections comprise STEP(K), with STEP1, STEP3, and STEP4 very similar in content to that found in Patankar and Spalding [1,2].

STEP1 computes slip-point quantities near the I and E surfaces and β and γ (see Section 4.3). This routine is used only for the initial profiles and for profiles readjusted by LAMSUB (see Section 3.5).

STEP2 has two functions, and is used only for the initial profiles and for profiles readjusted by LAMSUB. It computes the radii that correspond to initial values of y in the velocity profile. It also converts the initial y table to ψ , using equation (4.1), and finally to ω , OM(I), using equation (4.4), with $\psi_{\rm I}$ arbitrarily set to zero. Note that integration of equation (4.1) between the I and E surfaces gives mass flow rate per radian (or unit depth for two-dimensional flows). The variable PEI is this quantity. For internal flows, PEI remains constant (unless there is mass transfer at the wall), and for external flows PEI is increased at each integration step due to entrainment or wall mass transfer.

STEP3 has three functions; it is called at each integration step. This routine computes y locations of the nodes by integrating the velocity profile using equations (4.1) and (4.4) and the mass flow rate per unit radian, PEI. The radii are then calculated from the y's. Finally, the velocity profile is searched to obtain maximum and minimum velocities, UMAX and UMIN, and the input variable FR is multiplied times (UMAX - UMIN). The y table is then interpolated to obtain the location for this product, YL; this variable is the boundary layer thickness, defined as delta sub (1.000 - FR). For pipe flows YL is the wall radius.

STEP 4 has two functions; it is called at each integration step. It computes the velocity finite-difference coefficients AU(I), BU(I), and CU(I), and those for the ϕ equations, A(J,I), B(J,I), and C(J,I). The FDE's are then assembled and solved to obtain profiles for velocity, U(I), and ϕ -dependent variables, F(J,I).


Figure 6.1. Flow chart of the driver routine in STAN5.

STEP5 is called at the beginning of the program to zero the arrays and initialize parameters.

6.4 <u>WALL</u>

SUBROUTINE WALL performs the functions described in Sections 3.1 through 3.5 to determine friction factor and Stanton number. It is called one or more times per integration (depending on whether LAMSUB is invoked) providing one surface is a wall.

The first part of the routine sets up the join point conditions for velocity and stagnation enthalpy: $y_{2.5}$ is YI; $U_{2.5}$ is UI; $I_{2.5}^{\star}$ is FI(J); and Re_{2.5} is REW. The shear velocity U_{τ} , UTAUW, is also computed using the wall shear stress from the previous integration step.

The second part of the routine sets up various source terms for the stagnation enthalpy Wall Function equation (3.14). The variable C3 is W, C4 is $W \cdot X^+/2$, and C5 is the term in equation (3.4k) to convert s to S⁺. Since the non-dimensionalizations contain $q_0^{"}$ in the denominator; an adiabatic wall should be simulated with a very small but non-zero heat flux.

In the third section Couette flow quantities are formed: PPL is P^+ ; GPL is V_0^+ ; and BFPLUS is X^+ . These quantities are then converted into effective values by solving a lag equation (2.25) for $V_{0,eff}^+$, GPLE; and for $(P^+-X^+)_{eff}$, PPLE. The constant in equation (2.25) is the input variable PPLAG. Finally, the A^+ or B^+ equation (2.24) is evaluated using these effective values. If transition from laminar to turbulent flow is in progress, A^+ or B^+ is modified according to equation (2.38).

The fourth section examines the join-point Reynolds number. If it is less than 4 (which is synonymous with setting the input variable YPMAX < 2), the Wall Function is bypassed (section six below); otherwise section five is used.

The fifth section of SUBROUTINE WALL is "using the Wall Function". Here equation (3.9) is solved for U^+ and equation (3.14) is solved for I^{*+} . Both equations are numerically integrated by a trapezoidal rule using progressively larger Δy^+ steps, DYPL. In the output from this section $y^+_{2.5}$ is YPL, $U^+_{2.5}$ is UPL, and $I^{*+}_{2.5}$ is HPS(J). When the U^+y^+ product equals Re_{2.5}, control is transferred to section seven, described below. During integration τ^+ and y^+ are continuously monitored, and if τ^+ becomes less than 0.1 or y⁺ becomes greater than YPMAX, control is transferred to LAMSUB to insert a new point near the wall.

The Wall Function bypass option is contained in the sixth subsection of WALL. Here equations (4.18a-c) are solved for $y_{2.5}^+$, with $U_{2.5}^+$ computed from the definition of $\text{Re}_{2.5}^-$.

Outputs from either section five or six are used in section seven to compute wall shear stress, TAUW, using equation (3.11a). The friction factor, CF2, is then formed following equation (3.11b). If there are no ϕ equations being solved, control is passed to section ten of WALL.

If ϕ equations are being considered, section eight is used, providing the Wall Function is being bypassed, and equation (3.20) is solved for $I_{2.5}^{*+}$.

Section nine uses $I_{2.5}^{\star+}$ from either section five or eight to compute wall heat flux, QW(J), and Stanton number, ST(J). If there is a total flux boundary condition, the wall value of ϕ is computed (see Section 3.3.2).

Routine LAMSUB is contained in the tenth section. It is invoked in accordance with equation (3.21), which is fully described in Section 3.5.

6.5 AUX

In the first part of subroutine AUX, the turbulent viscosity and conductivity for each node is computed and added to its laminar counterpart to obtain an effective viscosity and conductivity.

Computation of the turbulent viscosity at each node begins with evaluating the damping function, DV(I), as described by equation (2.22) or (2.23). Then the $\lambda \delta_{.99}$ mixing-length, AL, is evaluated according to equation (2.26), with λ , ALMG, obtained from equation (2.27). If the flow is in the near-wall region, the mixing-length is switched to KyD, equation (2.21)

Once a mixing-length for the node is established, the turbulent viscosity μ_t , EMUT, is evaluated using either the Prandtl mixing-length model, equation (2.19), or the constant eddy viscosity model, equation (2.36), or the turbulent kinetic energy model, equation (2.28). The turbulent viscosity is added to the laminar viscosity to form an effective viscosity, EMU(I), as defined by equation (2.6).

If the stagnation entahlpy equation is being solved, the turbulent Prandtl number, PRTJ, is set either to its input value, PRT(J), or to a value calculated using the variable turbulent Prandtl number model, equation (2.37). For TKE the input variable is the turbulent Schmidt number. An effective Prandtl/Schmidt number, PREF(J,I), is formed according to equation (2.14). In the second part of subroutine AUX all source terms for the ϕ -equations are formulated. The sources are defined as all terms to the right of the equal sign after a ϕ -equation is transformed using equation (4.7), and finite-differenced according to equation (4.11).

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Appendix I

PROGRAM NOMENCLATURE

- A(J,I) Finite-difference coefficient for ϕ -equations.
- A2 Integral term in Couette flow form of momentum equation.
- AJE(J) Linear-interpolated value of FJ(J,M) if flux type boundary condition and E-surface is a wall.
- AJI(J) Linear-interpolated value of FJ(J,M) if flux type boundary condition and I-surface is a wall.
- AK Kappa in Prandtl mixing-length model.
- ALMG Outer layer constant in Prandtl mixing-length constant, modified if low Reynolds number (K2≠3).
- ALMGG Input value of outer layer constant in Prandtl mixing-length model.
- AM(M) Wall mass flux boundary condition, positive in direction of increasing y.
- AME Linear-interpolated value of AM(J) if wall mass flux and E-surface is a wall.
- AMI Linear-interpolated value of AM(J) if wall mass flux and I-surface is a wall.
- APL Van Driest damping coefficient in mixing-length model, input value SIGNAL=1.) or computed from internal correlation (SIGNAL=0.).
- AQ Production constant in TKE model or constant in eddy diffusivity model.
- AU(I) Finite-difference coefficient for velocity equation.
- AUX1(M) Generalized x-direction body force for momentum equation (BODFOR=2) in units of force/unit volume, specified at each X(M).
- AUX2(M) Generalized energy equation source [SOURCE(J)=2,3] in units of energy rate/unit volume, specified at each X(M).
- AUXM1 Linear-interpolated value of AUX1(M).
- AUXM2 Linear-interpolated value of AUX2(M).

AXX Not used by program.

B(J,I) Finite-difference coefficient for ϕ -equation.

BETA Power of y in slip scheme, near-wall region.

- BF(I) Body force term for momentum equation (gravity, AUXM1 for BODFOR#0).
- BFPLUS Body force in "wall coordinates" (X^{+}) .
- BODFOR Type of body force for momentum equation.
- BPL Evans damping coefficient in mixing-length model, input value (SIGNAL=1.) or computed from internal correlation (SIGNAL=0.).
- BQ Dissipation constant in TKE model or constant in eddy diffusivity model.

BU(I) Finite-difference coefficient for velocity equation.

- BXX Not used by program.
- C(J,I) Finite-difference coefficient for ϕ -equation.
- CAY Acceleration parameter, $(v/U_{\infty}^2) dU_{\infty}/dx$.
- CF2 Wall friction coefficient, $C_{\epsilon}/2$.
- CJ Conversion factor, mechanical to thermal energy.
- CSALFA Cosine α, to relate y and r.
- CU(I) Finite-difference coefficient for velocity equation.
- CXX Not used by program.
- DEL1 Boundary layer displacement thickness.
- DEL2 Boundary layer momentum thickness.
- DEL3 Boundary layer enthalpy thickness.
- DELTAX Maximum integration stepsize (DELTAX * YL).
- DPDX Pressure gradient due to free-stream velocity variation and freestream body force (pressure gradient to conserve continuity and momentum if pipe/channel flow).
- DX Integration stepsize (computed by program).

DXX Not used by program.

EMU(I) Effective dynamic viscosity, sum of laminar and turbulent contribution

ENFRA Entrainment fraction to control boundary layer entrainment.

- EXX Not used by program.
- F(J,I) ϕ -dependent variable in ϕ -equations (e.g., stagnation enthalpy or TKE equations) at Y(I).
- FI(J) Join-point value of F(J,I).
- FJ(J,I) Boundary value of F(J,I), specified at each X(M) [level if TYPBC(J)=1 and flux if TYPBC(J)=2].
- FLUID Type of free-stream fluid.
- FMEAN Bulk-mean stagnation enthalpy for pipe flow, to adjust Stanton number

FR Defines boundary layer thickness.

- FRA Fraction to determine DX stepsize.
- GAMA(J) Power of y in slip scheme, near-wall region.

GC Proportionality constant, Newton's 2nd Law.

GEOM Geometry descriptor.

GPL Blowing parameter in "wall coordinates" (V_{1}^{\dagger}) .

GV Gravity constant for momentum body force.

H Boundary layer shape factor.

I Cross-stream index for dependent variable (I = 1 at y = 0).

INDE(J) Type of boundary condition at E-surface (TYPBC(J)).

INDI(J) Type of boundary condition at I-surface (TYPBC(J)).

INTG Integration step counter.

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ITKE I index value at edge of mixing-length model/TKE model boundary.

J Index for ϕ -equations (all J loops bypassed if only solving velocity equation).

- KASE Flag to identify if one surface is a wall.
- KD Flag to determine how damping coefficient will be determined for Prandtl mixing-length model.
- K1 Flag to control print of SP(I) and changes in DELTAX.
- K2 Flag to suppress corrections to ALMGG or to use eddy diffusivity model.
- K3 Flag to suppress use of internal correlation of turbulent part of PREF(J,I).
- KENT Flag to control the entrainment calculation.
- KERROR Flag to terminate program if input data error detected.
- KEX Type of E-surface.
- KIN Type of I-surface.
- KRAD Flag to identify if transverse radius effects are to be included in equations.
- LSUB Flag to activate the LAMSUB routine in subroutine WALL.
- LVAR Flag to prematurely terminate program (e.g., if dimensioning exceeded, negative pressure, etc.).
- M Index for boundary condition location.
- MODE Flag to signal laminar or turbulent flow.
- N Number of initial stream tubes (which requires specification N + 1 initial profile points).
- NEQ Number of equations to be solved.
- NIND Counter for number of data sets executed.
- NPH Number of ϕ -equations to be solved (NEQ-1).
- NP1 N+1.
- NP2 N+2.
- NP3 N + 3.

NUMRUN Number of consecutive data sets to be processed.

NXBC Number of boundary condition locations (X(1) < X(M) < X(NXBC)).

- OM(I) Non-dimensional stream function.
- OMD(I) OM(I+1) OM(I).

OUTPUT Flag to signal type of print format, related to GEOM.

- PEI Boundary layer mass flow rate per unit radian (or per unit depth if transverse radius not considered).
- PO Initial free-stream static pressure.
- PPLAG Lag constant for changing P^+ , X^+ , V_2^+ .
- PPL Pressure gradient parameter in wall coordinates (P⁺).
- PR(J,I) Laminar Prandtl number.
- PRC(J) Constant property laminar Prandtl/Schmidt number.
- PRE Pressure at X = XD.
- PREF(J,I) Effective Prandtl number, combining the laminar and turbulent Prandtl numbers.
- PRO Pressure at X = XU.
- PRT(J) Initial value of turbulent Prandtl number for ϕ -equation (asymptote if variable turbulent Prandtl number model used).
- QW(J) Flux of ϕ -equation at a wall (positive in positive y-direction).

QWF(J) Flux of ϕ -equation at a wall / [F(J,wall) - FI(J)].

R(I) Transverse radius of finite-difference node at Y(I).

RBOM(I) 1./[OM(I+1) - OM(I-1)].

REH Enthalpy thickness Reynolds number.

REM Momentum thickness Reynolds number (diameter Reynolds number for pipe flow)

RETRAN Reynolds number for laminar-to-turbulent transition.

RHO(I) Fluid density.

RHOC Constant property fluid density.

RHOM Fluid density at location of FMEAN for pipe flow.

ROMD(I) = 1./[OM(I+1) - OM(I)].

- RW(M) Distance from axis of symmetry to body surface, specified at each X(M).
- RWO Wall radius for pipe flows.
- SC(I) Diffusion term for velocity equation (small c).

SD Source term at X = XD, not used by program.

SOURCE(J) Type of source function for ϕ -equation.

SP(I) Special print array, user supplied.

SPACE Print spacing.

ST(J) Wall Stanton number (based on FMEAN if pipe flow).

- SU(J,I) Source term for ϕ -equation.
- T(I) Static temperature if stagnation enthalpy equation (FLUID = 2); shear stress if no \$\phi\$-equations.

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TAU Shear stress at join-point location.

TAUW Wall shear stress.

TYPBC(J) Type of boundary condition for ¢-equations (level or flux).

- U(I) Velocity-dependent variable in momentum equation at Y(I).
- UG(M) Free-stream velocity, specified at each X(M), except for pipe/channel flows.
- UGD Free-stream velocity at XD, obtained using 3rd order spline fit to UG(M).
- UGU Free-stream velocity at XU, obtained using 3rd order spline fit to UG(M).
- UI Join-point velocity.

UMAX Maximum U(I) in velocity profile.

UMIN Minimum U(I) in velocity profile.

VISCO(I) Laminar dynamic viscosity.

VISCOC Constant property laminar dynamic viscosity.

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X(M)	Location along wall (centerline if no wall) where boundary values are given.
XD	Downstream value of x where differential equations are solved.
XL	Value of x where integration terminated.
XU	Value of x where integration begins; during integration the upstream value of x.
Y(I)	Independent variable, perpendicular to x, measured from I-surface.
YEM	Location for (1 - FR) · UMAX.
YIP	Location for (1 - FR) · UMIN.
YPMAX	Maximum y^+ at outer edge of Wall Function.
YPMIN	Minimum y at outer edge of Wall Function.

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Appendix II

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OUTPUT NOMENCLATURE

AME	$m_{\rm E}^{\prime\prime}$, wall mass flux, Figure 4.1, or entrainment, equation (4.15).
AMI	m ^{''} _I , wall mass flux, Figure 4.1.
APL	A^+ , Van Driest damping constant, equation (2.22).
BETA	β , slip constant, equation (4.13a); or $-H * \text{Re}_M * K/C_f/2$, acceleration parameter, OUTPUT = 2.
BPL	B^+ , Evans damping constant, equation (2.23).
CF2	$C_{\rm F}^{/2}$, friction factor, equations (3.11b) or (3.24).
EDR	μ_{eff}/μ , effective/laminar viscosity, equation (2.6).
EMU(I)	μ_{eff} , effective viscosity at y location, equation (2.6).
F	$m''_{(wall)}/\rho U$ (free stream), blowing fraction.
F(1,I)	dependent variable at y location for first ϕ -equation.
F(2,1)	dependent variable at y location for second ϕ -equation.
F(1,wall)	dependent variable, wall value.
FM	\overline{I}^* , mean stagnation enthalpy, equation (3.27).
FW	I at wall, stagnation enthalpy.
G	Clauser parameter, $(H-1.)/(H\sqrt{C_f/2})$, OUTPUT = 2.
GAMA(J)	γ , slip constant, equation (4.13b).
Н	δ_1/δ_2 , shape parameter, equations (3.22a-b).
HPLUS(I)	I^{*+} at y location, equation (3.4i).
I	y location.
INTG	integration number.
к	acceleration parameter, $(v/v_{\infty}^2) dv_{\infty}/dx$.
NU	Nu, Nusselt number, equation (3.26).

PEI	$(\psi_{\rm E}-\psi_{\rm I})$, boundary layer mass flow rate/radian (on unit depth), equation (4.4).
PPLUS	P^+ , pressure gradient parameter, equation (3.4g).
PRESS) PRESSURE)	fluid thermodynamic pressure.
QWALL	q_o'' , wall heat flux, equation (3.15a).
R(I)	r, radius at y location.
RE	Reynolds number, equation (3.29) , OUTPUT = 4.
REM	Rem, momentum thickness Reynolds number, $\delta_2 U_{\infty} / v$, equation (3.22b)
REH	Re _H , enthalpy thickness Reynolds number, $\Delta_2 U_{\infty}/v$, equation (3.22c
RHO(1)	ρ, fluid density at I-surface.
RHO (NP 3)	ρ, fluid density at E-surface.
SP(I)	special output array, user supplied.
SQRT(K)/UG	$\sqrt{q^2/2}/U_{\infty}$, turbulent kinetic energy equation.
ST(J)	St, Stanton number, equation (3.15b).
T(I)	static temperature, degrees Rankine; or τ^+ , equation (3.4f), if NEQ = 1 and OUTPUT = 2.
TAUPLUS	τ^+ , equation (3.4f).
TAUWALL	τ , wall shear stress, equation (3.11a).
U(I)	U, velocity at y location.
UGU	U_{∞} at print location.
UM	\overline{U} , mean velocity equation (3.28).
UPL, UPLUS(I)	V^+ at y location, equation (3.4b).
VWPLUS	V_o^+ , equation (3.4c).
XU	x at print location.
Y(I)	y, dependent variable location.
YPL,) YPLUS(1)	y at y location, equation (3.4e).

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Appendix III

STAN5 PROGRAM

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	AUXHZ#AU)	208-139	* 1.8UX21	1917 - AL	UNC (H-71		-v-A								MAIN0480
	IF IKEX.	W.11 A!	₹₽₽₽₽₽₽₽ ₹₽₽₽₽₽₽₽													MAIN0490
_	IF TKIN.E	Meti Vi	-1-4416	5									. ST	F01 -		MAIN 0500
C																MAIN0510
10	CALL STEP	P(1)														MAINO520
15	CONTINUE									E 111	TO			tes -		MATN0530
C					* **		TO 1	110		LU 474	10	rnur	EU 1			MAIN0540
C	FLUID PRO	PERTIES	S FILH	EK SE	1 24	UAL	1 U 3 8 8 9 9	1871	JI UI	n i A				• -		MATNOSSO
C	OR COMPUT	TED BY (ALLIN	j A V	AK I Å	ØLE	7700	FEKI	TE2							

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C	SUBROUTINE SUPPLIED BY USER.	MAIN0560
	IF(FLUID.NE.1) GO TO 115	MAIN0570
	IF(INTG.GT.0) GO TO 205	PATNOSBO
	DO 110 I=1,NP3	NA IN 0590
	VISCO(I)=VISCOC	PATN0600
	RHO([]=RHOC	HATNO610
	T(I)=1.	WATNO620
	IE (NPH_EQ_0) 60 TO 110	MATNOLZO
•		MATNOLA
		MATNOCO
105	CONTINUE	TAINUODU
110		PAINUBBU
110		MAIN0670
115		PAINU680
442		MAIN0690
		MAIN0700
	GU 10 (120,122,124), IPRUP	MAIN0710
120		MAIN0720
	IF (SUURCE(J] .EQ.2)J=2	MAIN0730
	CALL PROPZEI, FEJ, I), TEIJ, VISCOLIJ, PRE1, IJ, RHO(I))	MAIN0740
	IF (LVAR.EQ.7) GC TO 1000	MAIN0750
	GO TO 130	MAIN0760
Ç	CALLS FOR OTHER PROPERTY SUBROUTINES CAN BE INSERTED HERE. IT IS	MAIN0770
C	ALSO NECESSARY TO CHANGE PROPERTY CALLS IN SUBROUTINE WALL.	MAIN0780
122	CONTINUE	MAIN0790
124	CONTINUE	MAINO800
130	CONTINUE	MAINOBID
C	WALL RADIUS	MAIN0820
Č	WALL RADIUS AT EACH & LOCATION EVALUATED BY	MAIND830
C	BY LINEAR INTERPOLATION OF INPUT DATA	MATNOR40
205	IF (LSUB.GT.O) GC TO 35	MATNORSO
	R12=RW(M)	MATHORAD
	R11=RW(M-1)	MATNO870
	x2=x(H)	VATNORRO
	X1=X(M=1)	MATNORGO
	R(1)=R11+(R12-R11)+(X)-X1)/(X2-X1)	MATNO900
	IE(GEOM - EQ. 7)60 TO 225	MATMODIO
		MATNO910
		MATN 0020
		MAINU930
	USALT A ISANI (ACSULAZIAI) $(AZ - AL) (AZ - A$	MAINU940
	IFICTAL COLOR CONTINUARUUTIANSI CALTA	FAIP 0950
		#41NU960
220		FAIN0970
220		FAINU980
		PAIN0990
		MAIN1000
225		MAIN 1010
	IF (INTG.ED.O)PI=D.S=RUU=RJU=U(1)=RHU(1)	#AIN1020
	IF(INTG,EG,O)GO TC 30	MAIN 1030
	PI=PI-AMI#RUU#CX	MAIN1040
	IF(PI_LE.0.0)RUU=0.0	MAIN1050
	IF{PI.LE.0.0)GEOP=6	MAIN1060
	IF(GEDM.EQ.6)KIN=3	MAIN1070
	IF(GEOM.EQ.6)WRITE(6,220)	MAIN 1080
	IFIGEOM.EQ.6JGO TO 30	MAIN 1090
	RUU=SQRT(PI+2./(U(1)+RHO(1)))	MAIN1100
	GO TO 30	MAIN1110
230	CSALFA=1.00	MAIN1120
	IF(INTG.EQ.0)EN=0.0	MAIN 1130
	[F(]NTG_EQ.0]RWG=0.0	MAIN1140
	IF(INTG.E0.0)60 TO 30	MAIN1150

• • • • ·

		EN=EN+ANI+RUU+CX	MAIN1160
		RWD=EN/(RUU+U(1)+RHO(1))	MAIN1170
	30	R(1)=RUU	MAIN1180
С		STEP2	MAIN1190
	35	IF (INTG.EQ.O.CR.LSUB.GT.O) CALL STEP(2)	MAIN1200
		IF (LSUB.GT.O) GC TO 58	MAIN 1210
С			MAIN1220
		CALL STEP(3)	MAINIZJU
с-		ENTRAINMENT CONTROL	MAIN 1240
		IF (GEON.EQ.4.OR.CEOM.EQ.5) GD TD 340	MAINIZOU
		$IF (INTG_{\bullet}EQ_{\bullet}O) GC TO 345$	MAIN 1200
		UMAEUMAX-UNIN	MAIN1270
		PEIE=PEI/(R(NP3)+Y(NP3))	MATE 1200
		PEI1=PEIE*R(NP3)/R(1)	MATN1300
		UDIFF=ENFRA=UMP	MATN 1310
			WAIN1320
			MAINEBBO
		AMEN#AME + (ENFRA-UALIEJ#PEIE	MAIN1340
		IF (ENFRA, G), 2. TURCTEIARENTARC/2.	MAIN1350
		IF (ABS(U(NPI)=0(N))+LE+UU(FF/2+)AACA+AAC/2+	MATN 1 360
		APINEUS Te Juan en 21 antigant - (enera-uactiveri)	MAIN1370
		IF (KIN-50-2) ANIMAANI - (LIFRA-00-11) (LIF	MAIN1380
		$I \in (I \cap I \cap I) = I \cap I$	MAIN1390
		$\frac{1}{1} \left(\frac{1}{1} \right) \left(1$	MAIN1400
			MAIN1410
			MAIN1420
			MAIN1430
			MAIN1440
			MAIN1450
		15/1 - 50 - 102/10 TE 305	MAIN1460
		TE(E(1,1),GT,EPAX)EMAX=E(1,1)	MAIN1470
		TE (I, I), LT, FMIN) FMIN=F(J,I)	MAIN1480
		IF (SOURCE(J) .EC. 2) FMAX=1.	MAIN1490
	305	CONTINUE	MAIN1500
		FMM=FMAX-FMIN	PAIN1510
		FDIFF=ENFRA#FMM	MAIN1520
		IF(FMM.LT.0.1)GD TO 310	MAIN1530
		FACTI=ABS(F{J,1)-F{J,3}}/FMM	PAIN1540
		FACTE=ABS(F(J+NP3)-F(J+NP1))/FMM	MAINISSU
		AMEF(J)=AME + (ENFRA-FACTE)=PEIE	MAINISSU
		AM1F(J)=0.	MAIN 1770
		IF (KIN.EQ.2) AM1F(J)=AMI - (ENFRA-FACTI)#PELI	MAIN 1500
	310	CONTINUE	NAIN1600
		IF(INDI(J).EQ.2.AND.ABS(AJI(J).LTDODIAREF(J)=0.0	MAIN1610
		IF(INDE(J).EC.2. AND.ABS(AJE(J)).L1DUDIAHIP(J)-0.0	MATN 1620
		IF (FMM, LT.O. 1)AMEF(J)=0.0	MAIN1630
		IF(FAM.LT.0.1)AM1F(JT=0.0	MATN 1640
	312	CONTINUE	MAIN1650
			MAIN1660
		IF(J-G1-IJGU (U 31)	MAIN 1670
		AMEMAATEN Telvin en stanimateamin	PAIN1680
	315	ITININ•EN+6748778878878787 TECCOMPCECI).60.2108 TO 320	MAIN1690
	212	IFI SUURUELUI +EN +EN +EN ANFNA X+ANFF (.))	MAIN1700
		TE (FIN. BO. 2. AND. AN IF(.)). GT ANINJANI NA X*ANIF(.))	FAIN1710
	220	TELEST, BO. 21 AND AND AN THAT	MAIN1720
	320	TF/YIN_FO.23ANT=APTNAX	MAIN1730
	325		MÁIN1740
	رعد	GO TO 335	MAIN1750
		** * * ***	

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	330	IF(KEX.EQ.2)AME=AMEN	MAIN1760
		IF(KIN.EQ.2)API=APIN	MAIN1770
	335	IF(KEX.EQ.2.AND.AHE.GT.O.)AHE=0.	MAIN1780
		IF(KIN.EQ.2.ANC.AMI.LT.O.)ANI=O.	MAIN1790
		AMMAX=PEIE+0.1	MAIN 1800
		IF(KEX.EQ.2.AND.AME.LTAMMAX)AME=-AMMAX	MAIN1810
		IF (KIN. EQ. 2. ANC. AMI. GT.ANMAX)AMI=AMMAX	MAIN1820
	340	IF(KIN.EQ.3)AMI=O.	MAIN1830
		IF (KEX. EQ.3) APE=0.	MAIN1840
C		DX STEPSIZE	MAIN1850
-		IF(K1.EQ.20.CR.K1.EQ.9)DELTAX=AUXM1	MAIN1860
	345	IF(AMI = 0.0)42.40.42	MAIN 1870
	40	IF(AME - 0.0)42.44.42	MAIN1880
	42	CX=FRA+PE1/(ABS(R(1)+AMI-R(NP3)+AME))	MATN1890
		IF (DX - GT - DEL TAX+YL) DX=DEL FAX+YL	MATN 1900
			MATN1910
	44		MATN 1920
	46	1F(INTG-F0-0)60 10 49	MATN1930
		16 (DX- GT - 20 - #DX0) D WR ITE (6 - 48)	MATNIGLO
	40	$T = (T \times T_G + T_{-1,0}) \otimes T = 0.2 \pm 0.7$	MATN 1950
	~ /		MATNIGAD
			MATN 1970
			MATNIORO
		TC/DEW CT DETBANINGNESS	NATNI 1000
		$\frac{1}{1} \frac{1}{1} \frac{1}$	MAIN1 770
		15 (ADOUG (AINADUF 1030A/) AD AINADUF 10370A	MAIN 2010
			MATH 2010
c.			MAIN 2020
- U'		ADDY EASTERATE THAN BEESSIDE COADIENTS SUCH AS	PAIN2030
		BOUT FURCE (FIFER THAN PRESSURE GRADIENT) SUCH AS	MAINZUTU
L.	• • • • •	BOUTANCY UK A BEDT FURCE PER UNIT VULUNET FUR THE	MAIN 2000
L	• • • • •	FUNENIUM EQUATION, POSITIVE IN THE PUSITIVE A-DIR.	FAIN 2000
		IF (BODFOR-EC.0) GL TO 410	MAIN 2070
•			MAIN2080
	2-	BF([)=GV=RHD([]/GC	MAIN2090
		1F(BODFOR,EQ.2)B+(1)=B+(1)+AUXM1	MAIN2100
	405	CONTINUE	TAIN2110
		BFG=BF(1)	PAINZIZO
_		IF (KEX.EQ.2) BFG=BF(NP3)	FAIN 2130
C.	-	PRESSURE GRADIENT - EXTERNAL FLOW	MAIN2140
C		PRESSURE GRADIENT FOR EXTERNAL FLOW COMPUTED BY	MAIN 2150
C		FITTING A BRC GROER SPLINE-FIT TO FREE-STREAM VELOCITY	MAINZIBU
С		INTRODUCED IN THE INPUT DATA.	MAINZ170
	410	IF (INTG.EQ.I) DPSUM=0.0	₩AIN 2180
		IF (GEOM.EQ.4)GO TO 435	MAIN2190
		IFIGEOM.EQ.51GO TC 440	FAINZ200
		IF (INTG.NE.1) GO TO 415	MAINZ210
		M=1	MAIN2220
		IF(KEX.EQ.2)UGUICE=U(NP3)	MAIN2230
		1F(KIN.EQ.2.AND.KEX.NE.2)UGUIDE=U(1)	MAIN2240
		RHOLD=RHO(1)	MAIN2250
		IF (KEX.EQ.2) RHCLD=RHO(NP3)	MAIN2260
		RHO2=RHOLD	MAIN2270
		BFG≠BF(1)	MAIN 2280
		IF (KEX.EQ.2) BFG=BF(NP3)	MAIN2290
		FPP(1)=0.	HAIN2300
		FPP(NXBC)=0.	MAIN 2310
		NXBCM1=NXBC-1	MAIN2320
		IF (NX8C.EQ.2) GO TO 425	MAIN 2330
		DEL I=X(2)-X(1)	MAIN2340
		DO 411 I=2,NX8CM1	MAIN 2350

	DELN=DELI	MAIN2360
	DEL I=X(I+1)-X(I)	MAIN2370
	DELSUM=DELI+CELM	MAIN2380
	AFPP(I)=-DEL1/DELSUM/2.	MAIN2390
	EFPP(I) DELM/DELSUM/2.	MAIN 2400
411	CFPP(I)=3.+{UG(I-1)+DELI-UG(I)+DELSUN+UG(I+1)+DELM)/{DELI+DELM	PAIN2410
1	+DELSUM)	PAIN2420
	BFPP(2)=BFPP(2)=FFP(1)+CFPP(2)	MAIN 2430
	IF (NXBC-EQ.3) GO TO 414	MAIN244D
	00 412 I=3,N>BCM1	MAIN2450
	TRATIO=1./(10FPP(I)=AFPP(I-1))	FAIN 2400
	AFPP(I)=AFPP(I)#TRATIO	PAIN 2410
412	BFPP(I)=(BFPP(I)=EFPP(I-1)+CFPP(I))=(RAII)	MAIN2480
414		MATN 2500
	J=NX8UH1-1+2	MAIN 2510
413	PPP(J)=APPP(J)+PP(J+1)+BPPP(J)	WATN 2520
<i>c</i>	GU IU 920	MATN 2530
L	AUJUSINENI UF PRESSURE FUR CONRECT DENSITY	NATN 2540
415	$\frac{1}{1} + \frac{1}{1} + \frac{1}$	WATN 2550
	RNU2*RNU11/ Te (vev eg 3) Buf3-Bunin03)	NATN 2560
		MATN 2570
		MAIN 2580
		MAIN 2590
		MAIN 2600
418		MAIN 2610
440	DXH=X(M)-X(M-1)	MAIN2620
	AA=0.1666666+FFP(F-1)/DXN	MAIN2630
	88=0.1666666+FPP(F)/DXM	MAIN 2640
	CC=UG(M-1)/DXM-0.166666647XM#FPP(M-1)	MAIN 2650
	D=UG(M)/DXM-0.1666666#DXN#FPP(M)	MAIN 2660
425	CONTINUE	MAIN 2670
	FRO=PRE	MAIN 2680
	IF (XD-GT-X(P)) GC TO 418	MAIN 2690
	IF (INTG.EQ.1) UGC=AA+(X(M)-XU)+(X(M)-XU)+(X(M)-XU)	MAIN2700
1	[+BB#(XU-X(M-1))#(XU-X(M-1))#(XU-X(M-1))+CC#(X(M)-XU)+D#(XU-X(M-1))	MAIN 2710
	IF(INTG.Eg.1.AND.AES(UGUIDE-UGD).GT.0.001+UGUIDE)LVAR=5	MATN 2720
	UGU=UGD	MAIN2730
	XMXD=X(M)=XD	MAIN 2740
	xDMX=X0-X(M-1)	MAIN2750
	UGD=AA+XMXD+XMXD+XMXD+BB+XDMX+XDMX+XDMX+CC+XMXD+U+XDMX	MAIN 2 100
C • • • • •	IF IT IS DESIRED TO INTRODUCE THE FREE-SIREAM VELOCITY AS AN	WAIN2770
C	ANALYTIC FUNCTION, RATHER THAN A TABULATION, THIS IS THE PLACE	-AIN2100
C	TO PUT IT IN. IT THEN OVERKIDES THE PRECEDING STATEMENT.	MAIN 2900
C	THE FOLLOWING IS SPECIAL FOR EQUILLERIUM RUVERSE FO FLOWS.	MATN 2810
C	, IF (XD.6].8XX.AND.KI.E4.101000 AAAAT(XD-CAAF) (DAAF) (TTOAA	WATN 2820
-	$DPDX = \{UGU+UGU+UGU+UGU+UGU+UGU+UGU+UGU+UGU+UGU$	MATN 2830
C	NOTE THAT THIS PRESSURE GRADIENT IS RECORDED THE TRUE	MAIN 2840
	PRESSURE GRALIENT TIMES & SUB C	MATN 2850
		MATN 2860
C	THIS PRESSIRE IS USED ONLY IN THE PROPERTY SUBROUTINE. AND THERE	MAIN 2870
	INIY TO EVALUATE CENSITY.	MAIN 2880
~ • • • • •	GO TO 451	MAIN 2890
C	PRESSURE GRADIENT - INTERNAL FLOW	MAIN 2900
435	CONTINUE	MAIN 2910
	PRO=PRE	4A1N 2920
	IF(INTG.EQ.1)RHOF=RHO(1)	MAIN 2930
	UGU=2.*PE1/(R(NP3)*R(NP3)*RHOM)	MATN 2940
	DPDX=-PE[#UGU#{R{NP3]-RWQ}/{RWD#RWJ#RWJ#RD#DX}-2.#CF2#RHOM#	MAIN 2950

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	1UGU+UGU/R(NP3)+GC+EF(1)	N& TN 2960
	DP SUH= DPD X+D X+DP SUM	MAIN 2970
	PRE ≠PO+DPSUP/GC	MAIN 2980
	GO TO 445	MATN 2990
440) CONTINUE	MAIN 3000
	PRO=PRE	MATN 3010
	IF(INTG.EQ.1)RHOP=RHO(1)	#6 TN 3020
	UGU=PEI/(R(NP3)+Y(NP3)+RHDA)	#ATN 3030
	DPDX=-PEI+UGU+(Y(NP3)-RHJ)/(2,+RHJ+RHD+RHD+RH)+(X)-CF2+PHOMet(CI#UCU/	WA TN 3040
	1Y(NP3)+GC+BF(1)	MATN 2050
	DP SUM=DP DX + DP SUM	MAIN 3060
	PRE =PO+OPSUM/GC	MAIN 3070
445	IF (XD.LE.X(#)) GC TO 451	MATN 3080
	M=M+1	MAIN 3090
	GD TO 445	MATN 3100
451	CONTINUE	MAIN 3110
	IF(LVAR.EQ.5) GO TC 1020	HATN 3120
	IF (PRE-LT-0.) LVAR=4	MAIN3130
	IF (LVAR.EQ.4) GC TO 1010	MAIN 3140
55	IF(KASE-EQ-2) GO TO 65	MAIN 3150
C		-MAIN 3160
58	CALL WALL	#ATN 3170
	IF (LVAR.EQ.6) GC TO 1000	MAIN3180
	IF(N.LT.12) CO TO 1030	MAIN3190
	IF(LSU8+GT-0)GO TC 10	MAIN 3200
C	INTEGRAL PARAMETERS - EXTERNAL FLOW	- MAIN 3210
<u>C</u>	-CALCULATION OF CISPLAGEMENT THICKNESS, MIMENTUM THICKNESS,	MAIN 3220
C	SHAPE FACTOR, MOPENTUN THICKNESS REYNOLDS NUMBER, AND THE ENTHALP	YMAIN3230
C	THICKNESS REYNOLCS NUMBER.	MAIN 3240
	GD TO (500,500,500,538,538,560,560,560,560), GEOM	MAIN 3250
500	VISG=VISCO(NP3)	MAIN3260
	RHG=RHD(NP3)	MAIN 3270
	IF(KIN-EQ.I)GO TC 505	MAIN 3280
	KNG=RHD(1)	MATN 3290
EAE		MAIN 3 300
202		MAIN 3310
	2041-0.	PAIN 3320
610	UU 210 1-21072 CIMI-21072	MA1N 3 3 30
510	JUMI-JUMIY((())-(()-1)/*((()/*(()-1)//2, DE()-SUMIY(()-AU(-)/())	MAIN 3340
	CINAA	PAIN 3350
	507-50 00 515 1#3-MD7	FAIN 3 300
515		MAINSSIU
222		#A1N 3 35U
r	CODECTION OF INTEGRAL BARAMETERS FOR TRANSVERSE CHRVATURE	MAIN 3590
~ • • • • •	IF (KRAD.NE.1) CC TO SIG	MAIN 3400
		MAIN 2420
	OFI = B H H = 1 + SOBT (1 + 2) = C SA(EA + DE) 1/PHO(1)/C SA(EA	MAIN 3420
		MAINJAJU
		PAIN 3450
517	DEL 1=RW0+(+1,S0RT(1,2,+CSA) FA4DF(1/RW0))/(SA) FA	MATN 3460
	DEL2=RWO+(+1,-SORT(1,-2,+CSALFA+DEL2/RWO))/CSALFA	#ATN3470
519	CONTINUE	MATNRARA
~~ *	H=DEL1/DEL2	NATNRAGA
	REM=DEL 2+UGU+RHG/VISG	MAIN 3500
520	CONTINUE	MAIN 3510
	IF(NPH.EQ.0) GO TC 560	MAIN 3520
	REH=0.	MAIN 3530
	IF(SOURCE(1).EQ.2.AND.NPH.EQ.1)GO TO 535	MAIN3540
	.j=1	MAIN 3550

• • •

	IF(SDURCE(1).EQ.2)J=2		MAIN
	FW=F(J,1)		PAIN
	FG≠F(J.NP3)		MAIN
	IF(KIN.EQ.1)GO TO 525		MAIN
	FW=F(J.NP3)		MAIN
	FG=F(J.1)		MAIN
525	SUM=0.		MAIN
	DO 530 1=3.NP2		MAIN
	DF1 =0MD(1-1) +0.5+(f(J.1)+F(J.1-1)-2.+FG)		MAIN
530	S(IM=S(IM+DF)		MAIN
224	TETARS(1)(1)*(FM-E(1), T.O. 00001)G0 TU 535		MATN
	DEL 3=DE TASIIN / (RWCARHGAUGUA (FW-EG))		MAIN
	TE (KRAD.NE.1) GT TO 534		MATN
			MAIN
	1^{-1} (KINEQUEZ) GO TO 3^{-2} er sai faedfi $3/84011/7$ sai fa		MAIN
			HATN
573	GU 10 229 DEL2-DUD4(1)CODT(12 ACCALEARDEL3/PHOL1/CCALEA		PAIN
234	UEL JEKRUFITI - JUKITI - ZOFUJALFATUEL JIKRUTTI UJALIA		HATN
534	KENTDEL STOPOTKER / AI 20		MATN
535	CONTINUE		MATN
_	GO TO 560		MATH
C		FLOW	MATN
538	FMEAN=0.0		
	VISCOM=VISCO(1)		
	RHOM=RHO(1)		TAIN
	IF (NEQ.EQ.1) GO TC 555		PAIN
	IF(SOURCE(1).EQ.2.AND.NPH.EQ.1)GO TU 555		PAIN
	1 = ل		MAIN
	IF(\$QURCE(1).EQ.2)J=2		MAIN
	IF(ABS((F(J,1)-F(J,NP3))).LT0001)ST(J)=0.0		MAIN
	IF(ABS((F(J,1)-F(J,NP3))).LT0001)GD TO 555		MAIN
	DO 540 I=3,NP2		MAIN
	DEL=(ON(I)-OF(I-1))*(F(J,I)+F(J,I-1))/2.		MAIN
540	FMEAN=FMEAN+DEL		MAIN
	¥M≖0		MAIN
545			MAIN
	RATIO=1.0		MAIN
	IF(INTG.EQ.1)GD TE 550		MAIN
	IF(MM.EQ.NP2)GO TE 550		MAIN
	IF(ABS(F(J.MM)-FMEAN).GT.ABS(F(J.MM)-F(J.MM+1)))GD TO 545	i -	MAIN
	RATIO=(F(J,MH)-FHEAN)/(F(J,MH)-F(J,MH+1))		MAIN
550	RHOM=RHO(MM)-(RHO(MM)-RHO(MM+1))+RATIO		MAIN
	VISCON=VISCO(PH)-(VISCO(MH)-VISCO(NM+1))+RATIO		MAIN
C .	STANTON NUMBER AND CE2 ARE CALCULATED HERE BY SINPLY		MAIN
C	WODIEVING THE VALLES CALCULATED IN THE WALL FUNCTION		MAIN
C	WHERE FREE-STREAM IL AND F ARE USED.		MAIN
	ST(1)+ST(1)+(RHO(1)/RHOM)+(F(1,1)-F(1,NP3))/(FMFAN-F(1,NP	311	MATN
	DEMAL #DET//V/ND31#VISCOM)		MAIN
333	NEN-Y0-FEL/111NF3/F148990/ /E9=/E94840(11)//BNAN)		MATN
E L A			MAIN
200			MATN
_ O7	CUNITAUE	ALIX	MAIN
C		~~~	MATN
_	CALL AUX		MAIN
C		100	
	CALL OUT		
	IF(LVAR.GT.1)GO TO 1000		
C	. THE TERMINATION CONDITION		
	IF(XD.GT.XL) GO TC 1000		MAIN
	IF (KASE.EQ.2) GO TO 70		FAIN
-		<i>KEED</i>	MA 1 N

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 CBODY FORCE SOURCE DATA, AND ENERGY SOURCE DATA	MAIN4190
CFROM INPUT DATA.	MAIN 4200
AM1E=AH(M—1)+(AM(H)-AH(H-1))+(XD-X(H-1))/(X(N)-X(H-1))	MAIN4210
IF (KEX-EQ.1) AME=AMIE	MATNA220
IF (KIN-EQ-1) AMI=AMIE	NATN 4230
AUXM1 = AUX1 (M-1) + (AUX1(M) - AUX1(M-1)) + (XD-X(M-1)) / (X(M) - X(M-1))	MATN4250
$A (1) \times M = A (1) \times C (M - 1) + C A (1) \times C (M - 1) + M (1) $	MAIN 4240
IE IT IS DESIDED TO INTRODUCE THE HALL ADVADADE CONDITION AS	MAIN4230
Charles AN ANALYTIC FUNCTION, BATHED THEN ALL BUDDART CONDITION AS	MAIN4200
C OLARSTA OUT IT IN IT THEN OVER ALLS THE OF	MAIN4270
Compression of the the the deck-Rives inc Preceding Statement.	MAIN4280
LINEAR INTERROLATION OF WALL PRIMO FOR ALL F BOUNDARY CONDITION	- MAIN4290
 CONTRACTOR INTERPOLATION OF WALL BUUNDARY DATA	MAIN4300
CITIERON INPUT DATA	MAIN4310
	MAIN4320
1F (NEG-EG-1) GD 10 70	MAIN4330
 00 710 J=1,NPH	MAIN4340
FQ = FJ(J, M-1) + (FJ(J, N) - FJ(J, H-1)) + (XD - X(M-1))/(X(M) - X(M-1))	MAIN4350
CNOTE THAT FO IS EITHER A SURFACE PROPERTY, SUCH AS ENTHALPY,	MAIN4360
COR IT IS A SURFACE FLUX, SUCH AS HEAT FLUX.	MAIN4370
CIF IT IS DESIRED TO INTRODUCE THE WALL BOUNDARY CONDITION AS	MAIN 4380
CAN ANALYTIC FUNCTION, RATHER THAN A TABULATION. THIS IS THE	HATN4390
CPLACE TO PUT IT IN. IT THEN OVER-RIDES THE PRECEDING STATEMENT.	MATNALOO
GO TO (701.704.704). KIN	WAINGAID
701 NIND.(=)NDT(.)	MATNAADO
 GO TO (702.703). NIND.	MATN/4720
702 E(1,1) = E0	MAIN 4430
	MAIN4440
	PA1N4450
701 AD 1131-TH 744 744 744 744	MAIN 4460
704 GU 10 (705,708,708), KEX	MAIN4470
105 NINDJ=INDE(J)	MAIN4480
GO 10 (706,7C7), NINDJ	MAIN4490
706 F(J_NP3)=FQ	MAIN4500
GO TO 708	MAIN 4510
707 AJE(J)=FQ	MAIN 4520
2708 CONTINUE	MAIN4530
710 CONTINUE	PAIN4540
C STEP4	MAIN 4550
70 CALL STEP(4)	MATN 4560
 XU=XD	MAIN4570
PEI=PEI+DX+(R(1)+AHI-R(NP3)+AHE)	MATNA 590
GQ TQ 15	WATN4500
 1000 TEININD IT NUMBURIO TO 5	
 RETIRN	MATN 6610
1010 NRITE (6-455)	MATNA 4010
	HAIN402U
	TAIN 4030
1020 WRITE (014307	MAIN 4640
	MAIN4650
1030 WRITE (6,64)	MAIN 4660
GU TO 1000	MAIN4670
228 FORMAT(//* PROGRAM HAS SHIFTED TO GEDM=6 *//)	MAIN4680
64 FORMAT(//" PROGRAF TERMINATED BECAUSE THE NUMBER OF SPACES"/	MAIN 4690
1' IN THE GRID (N) GOT BELIW 12. AND MORE GRID POINTS TO'/	MAIN4700
24 THE CUTER PART OF THE BOUNDARY LAYER+//)	MAIN 4710
 450 FORMAT(// PROGRAM MAY HAVE TERMINATED BECAUSE INITIAL VELOCITY /	MAIN4720
1' PROFILE IS INCEMPATIBLE AT EITHER YINPAL OR YILL WITH 1/	MAIN 4730
2' THE INPUT FREE-STREAM VELOCITY PROFILE 4//)	MATN4740
455 FORMAT (/10X. PRESSURE HAS GOVE NEGATIVE DEDGE AN TERMINATENIA	MATNA750
48 FORMAT(// DX HAS TAKEN & LARGE STED CODUCT LEGITING CONTACT LEGITING	MATHATAN
14 ITE NOTHING BUT TODIG - DECADE FINARY HILDE LUTROT	
ENC NUMBER OF THOUSE FERRARS TIMPST HAS BLUMN UP."//)	HAIN4770
	MAIN4780

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SUBROUTINE STEP(KSTEP)	STEP0000
C	STEP0010
IN TEGER GEOM,FLUIC,SOURCE(5),SPACE,BODFOR,OUTPUT,TYPBC	STFP0020
COMMON/GEN/PEI,API,AME,DPDX,XU,XD,XL,DX,INTG,CSALFA,TYPBC(5),	STEP0030
1MODE,PRT(5),PRE,NXBC,X(10)],RW(100),FJ(5,100),GC,CJ,AM(100),PRO,	STEP0040
ZUG(100),PO,SOURCE,RETRAN,NUMRUN,SPACE,RWD,PPLAG,OUTPUT,DELTAX,GV	STEP0050
3/E/N,NP1,NP2,NP3,NEQ,NPH,KEX,KIN,KASE,KRAD,GEOM,FLUID,BODFOR,YPMIN	STEP0060
4/GG/BETA,GAMA(5),AJI(5),AJE(5),INDI(5),INDE(5),TAU,QWF(5)	STEP 0070
5/V/U(54),F(5,54),R(54),DN(54),Y(54),UGU,UGD,UI,FI(5),FMEAN,TAUW	STEP0080
6/W/SC(54]+AU(54)+BU(54)+CJ(54)+A(5+54)+B[5+54)+C(5+54)+SU(5+54)+SD	STEP 0090
7/L/AK;ALMG;ALMGG;FRA;APL;BPL;AQ;BQ;ENU(54);PREF(5;54);AUXM1	STEP 0100
<pre>B/L1/YL,UMAX,UMIN,FR,YIP,YEM,ENFRA,KENT,AUXM2</pre>	STEP0110
9/P/RH0(54),VISCO(54),PR(5,54),RH0C,VISCOC,PRC(5),T(54),RH0M,BF(54)	STEP0120
1/0/H,REM,CF2,ST(5),LSUB,LVAR,CAY,REH,PPL,GPL,QW(5),KD	STEP0130
2/CN/AXX, BXX, CXX, DXX, EXX, K1, K2, K3, SP(54), AUX1(100), AUX2(100), YPMAX	STEPO140
3/ADD/R80P(54),CMC(54),ROAD(54),ITKE	STEP 0150
	ST2P0100
GO TO (100,200,300,400,500), KSTEP	STEP0170
	STEP 0100
	STEP 0190
Commented and the second second and the second seco	STEP 0200
C BEGINNING UF INIEGRATAUN UK AFTER LANSUD HAS	STED0210
C	STEP0220
	STEPOZO
	STEP0250
	STEP0260
DE (A-(U(4)/U(5)-10//((4//)(5)-10/) 33 (/3)-(/3)/(1 A3 ABETAL	STEP0270
	ST-P0280
	STEP 0290
	STEP 0300
	STEP0310
	STEP 0320
	STEP 0330
50=84, +111-12, +113+9, +133	STEP0340
U(2)=(16,+U11-4,+U13+U35)/(2,+(U(1)+U(5))+SQRT(SQ))	STEP0350
$Y(2) = Y(3) = \{U(2) + U(3) - 2 = U(1) \} = 5/(U(2) + U(3) + U(1))$	STEP0360
GO TO 30	STEP0370
26 IF(KRAD-NE-0) GO TC 28	STEP 0 380
C SYMMETRY LINE, PLANE FLOW	STFP0390
U(2)=(4.+U(1)-U(3))/3.	STEP0400
¥(2)=0.	STEP0410
GO TO 30	STEP0420
C SYMMETRY LINE, AXIALLY SYMMETRICAL FLOW	STEP0430
28 U(2)=U(1)	S15P0440
¥(2)=¥(3)/3.	STEP0450
C SAME AS ABOVE BUT FOR KEX	STEP 0460
30 GO TO (32,34,36),KFX	STEP0470
C WALL	51590450
32 IF(LSUB.GT.0)GO TC 33	51590490
BETA={U(N}/U(NPI)-1.)/((Y(NP3)-Y(N))/(Y(NP3)-Y(NPI))-1.)	51280200 STEDAE10
33 U(NP2)=U(NP1)/(1.+2.*BETA)	31280310 STEDAE30
Y(NPZ]=Y(NP3)-(Y(NP3)-Y(NP1))#BE(A/(2.+BE(A)	STEDDE30
GO TO 38	31280750
34 UII=U(NPI)=U(NPI)	STEDASSA
	STEPOSA
USS=UINPS)=UINPS)	STEP0570
20=24*±032-14*±012±2**±011	STEPOSAO
U + + + + + +	STEPOSO
UTINE 21 #110*4033=4*013701147446*1011641*0141777*344149*7	

Y(NP2]=Y(NP3)-(Y(NP3)-Y(NP1))*(U(NP2)+U(NP1I-2.*U(NP3))*.5/	STEP 0600
1(U(NP2)+U(NP1)+U(NP3))	STEP0610
GC TO 38	STEP0620
C SYMMETRY LINE	STEP0630
36 U(NP2]=(4.+U(NP3)-U[NP1])/3.	STEP0640
Y(NP2)=Y(NP3)	STEP0650
38 CONTINUE	STEP 0660
IF(NEG.EG.1) GC TC 58	STEP0670
CCALCULATION OF SLIP VALUES FOR OTHER DEPENDENT VARIABLES	STEP 0680
DO 56 J=1,NPH	STEP0690
IF (LSUB-EQ-0)GAMA(J)=0.0	STEP0700
GQ TQ (42,44,46),KIN	STEP 0710
42 IF(SOURCE(J).EQ.2.0R.ABS(F(J,3)-F(J,1)).LE001)GO TO 43	ST5P0720
IF{LSUB.GT.0]G0 TC 43	STEP0730
GAMA(J)=((F(J,4)-F(J,1))/(F(J,3)-F(J,1))-1.}/(Y(4)/Y(3)-1.)	STEP0740
43 F(J+2)=F(J+1)+(F(J+3)-F(J+1))+(1+8ETA-GAMA(J))/(1+8ETA+GAMA(J))	STEP0750
GG TO 48	STEP 0 760
44 G={U{2}+U{3}-8**L{1}}/{5**{U{2}+U{3}}+8**U{1}}	ST=P0770
GF=(1PRT(J))/(1.+PRT(J))	ST5P0780
GF = (G+GF)/(1.+C+G+GF)	STEP0790
F(J,2)=F(J,3)+GF+(1GF)+F(J,1)	STEP 0800
GO TO 48	STEP0810
46 F(J+2)=F(J+1)	STEP0820
[F[KRAD.EQ.0}F[J,2]={4.*F[J,1]-F[J,3]}/3.	STEP0830
48 GG TO (50,52,54),KEX	STEP0840
50 IF(SOURCE(J).EC.2.CR.ABS(F(J,NP1)-F(J,NP3)).LE001)GO TO 51	STEP 0850
IF(LSUB.GT.0JGO TC 51	STEP0860
GAMA(J)=((F(J,N)-F(J,NP3))/(F(J,NP1)-F(J,NP3))-1.)/((Y(NP3)-Y(N))	/ STEP 0870
1(Y(NP3) - Y(NP1)) - 1.)	STEPOBRO
51 F(J,NP2)=F(J,NP3)+(F(J,NP1)-F(J,NP3))*(1+BETA-GAMA(J))/(1+BETA+	STEP 0890
1GAMA(J))	ST5P0900
GO TO 58	STEP0910
52 G=(U(NP2)+U(NP1)+8.*U(NP3))/(5.*(U(NP2)+U(NP1))+8.*U(NP3))	STEP0920
GF=(1PRT(J))/(1.+PRT(J))	STEP0930
$-GF = (G+GF)/(1_0+GPGF)$	STEP 0940
<pre>A F(J,NP2)=F(J,NPL)=GF+(1,-GF)=F(J,NP3) A F(J,NP2)=F(J,NP2)</pre>	SIEP0950
	SIEP0450
54 F[J,NP2]=(4.*F(J,KP3]-F[J,NP1]]/3.	21500470
	STEP 0 980
	STEP 1000
REIDEN STER 3	STEP 1000
	STEP 1010
CONSISTER CUMPUTES UPIT AKRATS AND PET	STEP1020
CARDEAN DEGINNING UF INTEGRALIUN UR AFTER LANGUD MAG	STEP 1050
C BEEN ALTIVATEL.	STEP 1040
LANNA CHIATTON CE AARTI	STEP1060
200 Is (WAD So A) (P A D 20)	STEP 1070
	STEPIORO
	STEPIAGA
CIU RIII-RIIITTIITCIALFA	STEP1100
220 DC 230 Ez2.NP3	STEP1110
C	STEP1120
220 PITIZPILI	STEP 1130
	STEP1140
CONTRACT ON OF OFFICE VALUES. THESE VALUES ARE ESTARISSIED BY THE	STEP1150
C INITIAL VELOCITY PROFILE AND REMAIN HACHANGED THEREAFTER.	STEP1160
	STEP1170
CH(2)=0.0	STEP 1180
DO 250 1=3.NP2	STEP 1190

ORIGINAL PAGE IS OF POOR QUALITY

C FOLLOWING EQUATION RESULTS FROM CONTINUITY	STEP 1200
250 CM(I)=OM(I-1)+.5*(RHO(I)+J(I)*R(I)+RHO(I-1)+U(I-1)*R(1-1))*	STEP1210
1(Y(I)-Y(I-1))	STEP L 220
PEI=CM(NP2)	STEP 1230
C OMEGA IS NCRPALIZED AT THIS POINT	STEP1240
DC 260 I=3,NP1	STEP 1250
260 [M(I)=DM(I)/FEI	STEP 1260
CM(NP2)=1.0	STEP 1270
CM(NP3)=1.0	STEP 1280
CO 270 1=2-NP1	STEP1290
BRGM(T) = 1 - ((CM(T+1) - GM(T-1)))	STEP 1300
	ST=P1310
	STEP 1320
	STEP 1330
	STEP 1340
	STEP 1350
	STEP 1360
	STED 1370
OMRAT = (OM(1) - (F(1-1))/(OM(1-1)) - OM(1-2))	CTE01290
IF (OMRAT.GT. 4. O. CR.OMRAJ.LI.G. 2) KACKK = 1	ČŤEG 1 200
IF (KXERR.EQ. 7) WRITE(6,27) L	31EF 1370 8TE61400
IF(KXERR.EQ.7)LVAR=8	51291400
IF (LVAR.EQ.8) DLTPUT=6	51691410
280 CONTINUE	51691420
275 FORMAT(/+37H PROGRAM TERNINATED BECAUSE THE OMEGA+/	STEP 1430
121H SPACING BETWEEN I = ,I2,1X,17HAND THE PRÉCEDING,/	STEP 1440
249H NODE IS EITHER MORE THAN FOUR TIMES OR LESS THAN,/	STEP 1450
234H ONE QUARTER THE PRECEDING SPACING)	STFP 1460
RETURN	STEP1470
C STEP 3	STEP 1480
CSTEP3 CCMPUTES Y'S,R'S	STEP 1490
C AND COMPUTES UMAX, UMIN, AND YL	STEP 1500
Ganna	STEP 1510
300 IF (INTG.EQ.0) GD TO 360	STEP 1 5 2 0
CARAGEY NEAR THE I BOUNCARY	STEP 1530
GD TO (312-314-316).KIN	STEP 1540
	STEP 1550
312 Y{2}={1.+BETA)+0+(3)+4./{(3.+RH0(2)+RH0(3))+(U(2)+U(3))}	STEP 1 560
312 Y(2)=(1.+BETA)+0+(3)+4./((3.+RHO(2)+RHO(3))+(U(2)+U(3))) GO TO 320	
312 Y(2)=(1.+BETA)+0+(3)+4./((3.+RHO(2)+RHO(3))+(U(2)+U(3))) GO TO 320 314 Y(2)=12.+OM(3)/((3.+RHO(2)+RHO(3))+(U(2)+U(3)+4.+U(1)))	STEP 1570
312 Y(2)=(1.+BETA)=0>(3)=4./((3.=RHO(2)+RHO(3))=(U(2)+U(3)) GO TO 320 314 Y(2)=12.=OM(3)/((3.=RHO(2)+RHO(3))=(U(2)+U(3)+4.=U(1))) GO TO 320	STEP 1570 STEP 1580
312 Y(2)=(1.+BETA)*0+(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3)) GO TO 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) GO TO 320 314 Y(2)=.5#OM(3)/(RHC(1)+U(1))	STEP 1570 STEP 1580 STEP 1590
<pre>312 Y(2)=(1.+BETA)*0+(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3))) GO TO 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) GO TO 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 y(3)=Y(2)+.2**CM(3)*(1./(RHO(3)*U(3))+2./(RHO(3)*U(3)+RHO(2)*</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600
<pre>312 Y(2)=(1.+BETA)*0+(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3))) GO TO 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) GO TO 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RHO(3)*U(3))+2./(RHO(3)*U(3)+RHO(2)* 10(2)))</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610
312 Y(2)=(1.+BETA)=0>(3)=4./((3.=RHO(2)+RHO(3))=(U(2)+U(3)) GO TO 320 314 Y(2)=12.=OM(3)/((3.=RHO(2)+RHO(3))=(U(2)+U(3)+4.=U(1))) GO TO 320 316 Y(2)=.5=OM(3)/(RHC(1)=U(1)) 320 Y(3)=Y(2)+.25=CM(3)=(1./(RHO(3)=U(3))+2./(RHO(3)=U(3)+RHO(2)= 1U(2))) TE(RETA.CE.0.9.ANC.KIN.E0.1)Y(3)=3.()=OM(3)/(RHO(3)=U(3)+RHO(2)=	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1610
312 Y(2)=(1.+BETA)=0>(3)=4./((3.*RHO(2)+RHO(3))=(U(2)+U(3))) GO TO 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))=(U(2)+U(3)+4.*U(1))) GO TO 320 316 Y(2)=.5=OM(3)/(RHC(1)=U(1)) 320 Y(3)=Y(2)+.25=CM(3)=(1./(RHO(3)+U(3))+2./(RHO(3)=U(3)+RHO(2)= 1U(2))) IF (BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0=OM(3)/(RHO(3)=U(3)+RHO(2)= 1=U(2))	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630
<pre>312 Y(2)={1.+BETA}*0+(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3)) GO TO 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) GO TO 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RHO(3)+U(3))+2./(RHO(3)*U(3)+RHO(2)* 1U(2))) IF (BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0*OM(3)/(RHO(3)*U(3)+RHO(2)* 1*U(2))</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630 STEP 1640
<pre>312 Y(2)={1.+BETA}*0P(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3)) GO TO 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) GO TO 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RHO(3)*U(3))+2./(RHO(3)*U(3)+RHO(2)* 1U(2))) IF(BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0*OM(3)/(RHO(3)*U(3)+RHO(2) 1*U(2)) CY 'S FOR INTERMECIATE GRID POINTS DO 320 I=4MQ1</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630 STEP 1640 STEP 1650
<pre>312 Y(2)={1.+BETA}*0P(3)*4./((3.*RH0(2)+RH0(3))*(U(2)+U(3)) G0 T0 320 314 Y(2)=12.*0M(3)/((3.*RH0(2)+RH0(3))*(U(2)+U(3)+4.*U(1))) G0 T0 320 316 Y(2)=.5*0M(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RH0(3)*U(3))+2./(RH0(3)*U(3)+RH0(2)* 1U(2))) IF(BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0*OM(3)/(RH0(3)*U(3)+RH0(2)* 1*U(2)) CY 'S FOR INTERMECIATE GRID POINTS D0 330 I=4.NP1 330 Y(1)=Y(1=1)A2 *0*0/(1=1)/(RH0(1)*U(1)*RH0(1=1)*U(1=1))</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630 STEP 1640 STEP 1650 STEP 1660
<pre>312 Y(2)={1.+BETA}*0P(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3)) GO TO 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) GO TO 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RHO(3)*U(3))+2./(RHO(3)*U(3)+RHO(2)* 1U(2))) IF(BETA.GE.O.9.ANC.KIN.EQ.1)Y(3)=3.0*OM(3)/(RHO(3)*U(3)+RHO(2)* 1*U(2)) IF(BETA.GE.O.9.ANC.KIN.EQ.1)Y(3)=3.0*OM(3)/(RHO(3)*U(3)+RHO(2)* 1*U(2)) CY 'S FOR INTERMECIATE GRID POINTS DO 330 I=4,NP1 330 Y(I)=Y(I-1)+2.*OPD(I-1)/(RHO(I)*U(I)*RHO(I-1)*U(I-1)) Y MEAP THE E ACUNCARY</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630 STEP 1640 STEP 1640 STEP 1660 STEP 1660
<pre>312 Y(2)={1.+BETA}*0P(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3)) GO TO 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) GO TO 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RHO(3)*U(3))+2./(RHO(3)*U(3)+RHO(2)* 1U(2))) IF(BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0*CM(3)/(RHO(3)*U(3)+RHO(2)* 1*U(2)) IF(BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0*CM(3)/(RHO(3)*U(3)+RHO(2)* 1*U(2)) CY 'S FOR INTERMECIATE GRID POINTS DO 330 I=4,NP1 330 Y(I)=Y(I-1)+2.*OPD(I-1)/(RHO(I)*U(I)*RHO(I-1)*U(I-1)) CY NEAR THE E BGUNCARY</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630 STEP 1640 STEP 1650 STEP 1650 STEP 1650 STEP 1670 STEP 1680
<pre>312 Y(2)={1.+BETA}*0P(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3)) GO TO 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) GO TO 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RHO(3)*U(3))+2./(RHO(3)*U(3)+RHO(2)* 1U(2))) IF(BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0*CM(3)/(RHO(3)*U(3)+RHO(2)* 1*U(2)) IF(BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0*CM(3)/(RHO(3)*U(3)+RHO(2)* 1*U(2)) CY 'S FOR INTERMECIATE GRID POINTS DO 330 I=4,NP1 330 Y(I)=Y(I-1)+2.*OPD(I-1)/(RHO(I)*U(I)*RHO(I-1)*U(I-1)) CY NEAR THE E BGUNCARY Y(NP2)=Y(NP1)*.25*CMD(NP1)*(1./(RHD(NP1)*J(NP1))+2./ 1/(NP2)+V(NP1)*D(NP1)*D(NP1)*J(NP1))+2./</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630 STEP 1640 STEP 1660 STEP 1660 STEP 1680 STEP 1690
<pre>312 Y(2)={1.+BETA}*0P(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3)) GO TO 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) GO TO 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RHO(3)*U(3))+2./(RHO(3)*U(3)+RHO(2)* 1U(2))) IF(BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0*OM(3)/(RHO(3)*U(3)+RHO(2)* 1*U(2)) CY 'S FOR INTERMECIATE GRID POINTS DO 330 I=4,NP1 330 Y(I)=Y(I=1)+2.*OPD(I=1)/(RHO(I)*U(I)*RHO(I=1)*U(I=1)) CY NEAR THE E BCUNCARY Y(NP2)=Y(NP1)*.25*CMD(NP1)*(1./(RHD(NP1)*J(NP1))+2./ 1(RHO(NP1)*U(NP1)*RHO(NP2)*U(NP2)))</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630 STEP 1640 STEP 1640 STEP 1660 STEP 1680 STEP 1690 STEP 1690
<pre>312 Y(2)={1.+BETA}*0P(3)*4./((3.*RH0(2)+RH0(3))*(U(2)+U(3)) G0 T0 320 314 Y(2)=12.*OM(3)/((3.*RH0(2)+RH0(3))*(U(2)+U(3)+4.*U(1))) G0 T0 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RH0(3)*U(3))+2./(RH0(3)*U(3)+RH0(2)* 1U(2))) IF(BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0*OM(3)/(RH0(3)*U(3)+RH0(2)* 1*U(2)) CY 'S FOR INTERMECIATE GRID POINTS D0 330 I=4,NP1 330 Y(I)=Y(I-1)+2.*OPD(I-1)/(RH0(I)*U(I)*RH0(I-1)*U(I-1)) CY NEAR THE E BCUNCARY Y(NP2)=Y(NP1)*.25*CM0(NP1)*(1./(RHD(NP1)*J(NP1))+2./ 1(RH0(NP1)*U(NP1)*RH0(NP2)*U(NP2))) G0 T0 (332,334,336),KEX 330 Y(100000000000000000000000000000000000</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630 STEP 1640 STEP 1650 STEP 1650 STEP 1670 STEP 1690 STEP 1720 STEP 1730
<pre>312 Y(2)={1.+BETA}*0P(3)*4./((3.*RH0(2)+RH0(3))*(U(2)+U(3)) G0 T0 320 314 Y(2)=12.*OM(3)/((3.*RH0(2)+RH0(3))*(U(2)+U(3)+4.*U(1))) G0 T0 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RH0(3)*U(3))+2./(RH0(3)*U(3)+RH0(2)* 1U(2))) IF(BETA.GE.0.*ANC.KIN.EQ.1)Y(3)=3.0*OM(3)/(RH0(3)*U(3)*RH0(2)* 1*U(2)) CY 'S FOR INTERMECIATE GRID POINTS D0 330 I=4,NP1 330 Y(I)=Y(I-1)+2.*OPD(I-1)/(RH0(I)*U(I)*RH0(I-1)*U(I-1)) CY NEAR THE E BGUNCARY Y(NP2)=Y(NP1)*.25*CM0(NP1)*(1./(RHD(NP1)*J(NP1))+2./ 1(RH0(NP1)*U(NP1)*RH0(NP2)*U(NP2))) G0 T0 (332,334,36),KEX 332 Y(NP3)=Y(NP2)*(1.*BETA)*OND(NP1)*4./((RHD(NP1)*3.*RH0(NP2)))</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630 STEP 1640 STEP 1650 STEP 1660 STEP 1660 STEP 1690 STEP 1720 STEP 1730 STEP 1740
<pre>312 Y(2)={1.+BETA}*0P(3)*4./((3.*RH0(2)+RH0(3))*(U(2)+U(3))* GO TO 320 314 Y(2)=12.*OM(3)/((3.*RH0(2)+RH0(3))*(U(2)+U(3)+4.*U(1))) GO TO 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RH0(3)*U(3))+2./(RH0(3)*U(3)+RH0(2)* 1U(2))) IF(BETA.GE.0.*ANC.*KIN.EQ.1)Y(3)=3.0*OM(3)/(RH0(3)*U(3)*RH0(2)* 1*U(2)) CY 'S FOR INTERMECIATE GRID POINTS DO 330 I=4,NP1 330 Y(I)=Y(I-1)+2.*OMD(I-1)/(RH0(I)*U(I)*RH0(I-1)*U(I-1)) CY NEAR THE E BGUNCARY Y(NP2)=Y(NP1)*.25*CM0(NP1)*(1./(RHD(NP1)*J(NP1))+2./ 1(RH0(NP1)*U(NP1)*RH0(NP2)*U(NP2))) GO TO (332,334,336),KEX 332 Y(NP3)=Y(NP2)*(1.*BETA)*OND(NP1)*4./((RHD(NP1)*3.*RH0(NP2))) 1)*(U(NP1)*U(NP2))]</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630 STEP 1640 STEP 1650 STEP 1650 STEP 1660 STEP 1680 STEP 1680 STEP 1730 STEP 1740 STEP 1741
<pre>312 Y(2)=(1.+BETA)*0P(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3))* GO TO 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) GO TO 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RHO(3)*U(3))+2./(RHO(3)*U(3)+RHO(2)* 1U(2))) IF(BETA.GE.O.9.ANC.KIN.EQ.1)Y(3)=3.0*OM(3)/(RHO(3)*U(3)+RHO(2)* 1*U(2)) CY 'S FOR INTERMECIATE GRID POINTS DO 330 I=4.NP1 330 Y(I)=Y(I=1)+2.*OPD(I=1)/(RHO(I)*U(I)*RHO(I=1)*U(I=1)) CY NEAR THE E BGUNCARY Y(NP2)=Y(NP1)+.25*CMO(NP1)*(1./(RHD(NP1)*U(NP1))+2./ 1(RHO(NP1)*U(NP1)*RHO(NP2)*U(NP2))) GO TO (332,334,336],KEX 332 Y(NP3)=Y(NP2)+(1.*BETA)*OND(NP1)*4./((RHD(NP1)*3.*RHO(NP2) 1))*(U(NP1)*U(NP2)) IF (BETA.GE.O.9) Y(NP3)=Y(NP1)+1.5*(OM(NP2)=OM(NP1))/ 10 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630 STEP 1640 STEP 1640 STEP 1650 STEP 1660 STEP 1680 STEP 1680 STEP 1740 STEP 1741 STEP 1741
<pre>312 Y{2}={1.+BETA}*0+(3)*4./((3.*RH0(2)+RH0(3))*(U(2)+U(3))) G0 T0 320 314 Y(2)=12.*0M(3)/((3.*RH0(2)+RH0(3))*(U(2)+U(3)+4.*U(1))) G0 T0 320 316 Y(2)=.5*0M(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RH0(3)+U(3))+2./(RH0(3)*U(3)+RH0(2)* 1U(2))) IF (BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0*0M(3)/(RH0(3)*U(3)+RH0(2)* 1*U(2)) CY 'S FOR INTERMECIATE GRID POINTS D0 330 I=4,NP1 330 Y(I)=Y(I-1)+2.*0*D*D(I-1)/(RH0(I)*U(I)+RH0(I-1)*U(I-1)) CY NEAR THE E BCUNCARY Y(NP2)=Y(NP1)+.25*CM0(NP1)*(1./(RH0(NP1)*U(NP1))+2./ 1(RH0(NP1)*U(NP1)+RH0(NP2)*U(NP2))) G0 T0 (332,334,336),KEX 332 Y(NP3)=Y(NP2)+(1.*BETA)*OMD(NP1)*4./((RH0(NP1)+3.*RH0(NP2))) IF (BETA.GE.0.9) Y(NP3)=Y(NP1)+1.5*(OM(NP2)-OM(NP1))/ 1 (0.5*(RH0(NP1)*U(NP1)+RH0(NP2)*U(NP2)))</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630 STEP 1640 STEP 1640 STEP 1660 STEP 1660 STEP 1680 STEP 1680 STEP 1740 STEP 1742 STEP 1742 STEP 1742
<pre>312 Y(2)=(1.+BETA)*0P(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3))) G0 T0 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) G0 T0 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RHO(3)+U(3))+2./(RHO(3)*U(3)+RHO(2)* 1U(2))) IF(BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0*OM(3)/(RHO(3)*U(3)+RHO(2)* 1*U(2)1 CY 'S FOR INTERMECIATE GRID POINTS D0 330 I=4.NP1 330 Y(I)=Y(I=1)+2.*OPD(I=1)/(RHO(I)*U(I)*RHO(I=1)*U(I=1)) CY NEAR THE E BGUNCARY Y(NP2)=Y(NP1)*.25*CMO(NP1)*(1./(RHO(NP1)*U(NP1))+2./ 1(RHO(NP1)*U(NP1)*HO(NP2)*U(NP2))) G0 T0 (332,334,336),KEX 332 Y(NP3)=Y(NP2)*(1.*BETA)*OND(NP1)*4./((RHO(NP1)*3.*RHO(NP2)*U(NP2))) IF (BETA.GE.0.9) Y(NP3)=Y(NP1)+1.5*(OM(NP2)=OM(NP1))/ 1 (0.5*(RHO(NP1)*U(NP1)*RHO(NP2)*U(NP2))) G0 T0 340 </pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1630 STEP 1640 STEP 1640 STEP 1650 STEP 1660 STEP 1680 STEP 1680 STEP 1740 STEP 1740 STEP 1740 STEP 1740 STEP 1742 STEP 1750
<pre>312 Y(2)=(1.+BETA)*0P(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3))) G0 T0 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) G0 T0 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RHO(3)+U(3))+2./(RHO(3)*U(3)+RHO(2)* 1U(2))) IF(BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0*OM(3)/(RHO(3)*U(3)+RHO(2)* 1*U(2)] CY 'S FOR INTERMECIATE GRID POINTS D0 330 I=4.NP1 330 Y(I)=Y(I=1)+2.*OMD(I=1)/(RHO(I)*U(I)*RHO(I=1)*U(I=1)) CY NEAR THE E BGUNCARY Y(NP2)=Y(NP1)*.25*OMO(NP1)*(1./(RHO(NP1)*J(NP1))+2./ 1(RHO(NP1)*U(NP1)*RHO(NP2)*U(NP2))) G0 T0 (332,334,336),KEX 332 Y(NP3)=Y(NP2)+(1.+BETA)*OND(NP1)*4./((RHO(NP1)*3.*RHO(NP2)*U(NP2))) IF (BETA.GE.0.9) Y(NP3)=Y(NP1)+1.5*(OM(NP2)=OM(NP1))/ 1 (0.5*(RHO(NP1)*U(NP1)*RHO(NP2)*U(NP2))) G0 T0 340 334 Y(NP3)=Y(NP2)+12.*OMD(NP1)/((RHO(NP1)*3.*RHO(NP2))*{U(NP2)})</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1640 STEP 1640 STEP 1640 STEP 1660 STEP 1660 STEP 1680 STEP 1680 STEP 1740 STEP 1740 STEP 1740 STEP 1740 STEP 1760 STEP 1760
<pre>312 Y(2)=(1.+BETA)+0P(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3))* GO TO 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) GO TO 320 316 Y(2)=.5+OM(3)/(RHC(1)+U(1)) 320 Y(3)=Y(2)+.25+CM(3)*(1./(RHO(3)+U(3))+2./(RHO(3)+U(3)+RHO(2)* 1U(2))) IF(BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0+OM(3)/(RHO(3)+U(3)+RHO(2)* 1+U(2)) CY 'S FOR INTERMECIATE GRID POINTS DO 330 I=4.NP1 330 Y(I)=Y(I-1)+2.*OPD(I-1)/(RHO(I)+U(I)+RHO(I-1)*U(I-1)) CY NEAR THE E BCUNCARY Y(NP2)=Y(NP1)+.25*CMD(NP1)*(1./(RHD(NP1)*J(NP1))+2./ 1(RHO(NP1)*U(NP1)+RHO(NP2)*U(NP2))) GO TO (332,334,336),KEX 332 Y(NP3)=Y(NP2)+(1.+BETA)*OND(NP1)*4./((RHO(NP1)+3.*RHO(NP2 1))*(U(NP1)+U(NP2))) IF (BETA.GE.0.9) Y(NP3)=Y(NP1)+1.5*(OM(NP2)-OM(NP1))/ 1 (0.5*(RHO(NP1)*U(NP1)+RHO(NP2)*U(NP2))) GO TO 340 334 Y(NP3)=Y(NP2)+12.*OMD(NP1)/((RHO(NP1)+3.*RHO(NP2))*(U(NP2))) 334 Y(NP3)=Y(NP2)+12.*OMD(NP1)/((RHO(NP1)+3.*RHO(NP2))*(U(NP2))) 334 Y(NP3)=Y(NP2)+12.*OMD(NP1)/((RHO(NP1)+3.*RHO(NP2))*(U(NP2))) 334 Y(NP3)=Y(NP2)+12.*OMD(NP1)/((RHO(NP1)+3.*RHO(NP2))*(U(NP2)))</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1640 STEP 1640 STEP 1640 STEP 1660 STEP 1660 STEP 1680 STEP 1690 STEP 1740 STEP 1740 STEP 1742 STEP 1740 STEP 1760 STEP 1760
<pre>312 Y(2)={1.+BETA)*0+(3)*4./((3.*RHO(2)+RHO(3))*(U(2)+U(3))* GO TO 320 314 Y(2)=12.*OM(3)/((3.*RHO(2)+RHO(3))*(U(2)+U(3)+4.*U(1))) GO TO 320 316 Y(2)=.5*OM(3)/(RHC(1)*U(1)) 320 Y(3)=Y(2)+.25*CM(3)*(1./(RHO(3)+U(3))+2./(RHO(3)*U(3)+RHO(2)* 10(2)) IF (BETA.GE.0.9.ANC.KIN.EQ.1)Y(3)=3.0*OM(3)/(RHO(3)*U(3)+RHO(2)* 1*U(2)) CY 'S FOR INTERMECIATE GRID POINTS DO 330 I=4.NP1 330 Y(I)=Y(I-1)+2.*OPP(I-1)/(RHO(I)*U(I)+RHO(I-1)*U(I-1)) CY NEAR THE E BCUNCARY Y(NP2)=Y(NP1)*.25*CMO(NP1)*(1./(RHO(NP1)*J(NP1))+2./ 1(RHO(NP1)*U(NP1)+RHO(NP2)*U(NP2))) GO TO (332,334,336),KEX 332 Y(NP3)=Y(NP1)*(1.+BETA)*OND(NP1)*4./((RHO(NP1)*3.*RHO(NP2))) IF (BETA.GE.0.9) Y(NP3)=Y(NP1)+1.5*(OM(NP2)-OM(NP1))/ 1 [0.5*(RHO(NP1)*U(NP1)*RHO(NP2)*U(NP2))) GO TO 340 334 Y(NP3)=Y(NP2)+12.*OMD(NP1)/((RHO(NP1)*3.*RHO(NP2))*(U(NP2))) GO TO 340</pre>	STEP 1570 STEP 1580 STEP 1590 STEP 1600 STEP 1610 STEP 1620 STEP 1640 STEP 1640 STEP 1640 STEP 1660 STEP 1660 STEP 1680 STEP 1690 STEP 1740 STEP 1740 STEP 1740 STEP 1760 STEP 1760 STEP 1780

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	340 IF (KRAD.EQ.0) GO TO 344	STEP 1 800
	DO 342 [=2,NP3	STEP 1810
	342 Y(I)=2.*Y(I)+PEI/(R(1)+SQRT(R(1)+R(1)+2.*Y(I)+PEI+CSALFA))	STEP1820
	GO TO 350	STEP 1830
	344 DO 346 1=2,NP3	STEP 1840
	346 Y(I)=PEI+Y(I)/R(1)	STEP 1850
	350 Y(2)=2.+Y(2)-Y(3)	STEP 1860
	IF(BETA.GE.0.9.AND.KIN.EQ.1)Y(2)=Y(3)/3.	STEP1870
	IF (BETA.GT.O.9.AND.KEX.EQ.1)GD TO 351	STEP1880
	Y(NP2)=2.4Y(NP2)-Y(NP1)	STEP 1890
	GO TO 352	STEP 1900
	351 Y(NP2)=(2.+Y(NP3)+Y(NP1))/3.	STEP 1910
	CCALCULATION OF RADII	STEP 1920
	352 DO 355 [=2,NP3	STEP1930
	IF(KRAD.EQ.0)R(I)=R(1)	STEP 1940
	1F(KRAD_NE_0)R(I)=R(1)+Y(I)#CSALFA	STEP1950
- · ·	355 CONTINUE	STEP1960
	CCALCULATION OF THE BOUNDARY LAYER THICKNESS	STEP 1970
	C BASED ON THE FR CRITERION USED IN 'INPUT'. I.E., IF FR	STEP 1980
	Connects D.DI. THIS ROLTINE CALCULATES YE WHICH IS THE 99 PER-	STEP 1990
	CONTRACTOR THICKNESS OF THE BOUNDARY LAYER. YE IS THEN A DISTANCE UPON	STEP 2000
	C LHICH A TURBUL ENCE I FIGTH SCALE IS BASED.	STEP 2010
	C SEARCH FOR THE MAXIPUN AND MINIMUM VELOCITIES	STEP 2020
	360 (MAX=U(1)	STEP 2030
		STEP 2040
	CO 375 133.NP3	STEP 2050
	TELL-EQ-NP21 GO TO 375	STEP 2060
		STEP 2070
		STEP 2080
		STEP 2090
		STEP 2100
	C	STEP 2110
	TEITIN NEAD TE 3 86	STEP 2120
	1/1 = 1/2	STEP 2130
		STEP 2140
	$v_{10} = c_{10} r_{10} r_{10$	STEP 2150
		STEP 2160
		STEP 2170
	300 J-2	STEP 2180
		STEP 2190
		STEP 2 200
		STEP 2210
		STEP 2220
	JCT AI-10 TC(M11) T A 111-1	STE0 2230
	1F10J20210003A2-70 V10-V10-112-V10-010-010-010-010-0000000000	STEP 2240
		STEP 2250
		STEP 2250
	STO TIPEU.	STEP 2200
	CSEARCH NEAR IFE E DUUNDART	SIEF2210
	388 [FIKEX.NE.2] GU 10 396	STEP 2200
		STEP 2270
	IFTUZICLIAUIFJ GL TU 370 Mena o nevište nijalna i catavinetla visiosil svinesila vinesi	5107 2 30V
	TEM=SUKILULP/ULL/+1.341TLNPLI+TLNPLI/TLNPS//TTLNPS/	STER 2310
	GU 1U 348	31072320
	540 J=NP2	STEP 2330
	342 J=1	STED 3350
	UJ1=U(J)-U(NP3)	31272370
	IF (ABS(UJI).GE.DIF) GU TU 394	51EF 2300
	GO TO 392	SIEP 23/0
	394 Al=1.	51645340
	If(UJ1.LT.O.JA1=-1.	21645340

YEM=Y(J+1}+(Y(J)-Y(J+1))+(U(NP3)+A1+DIF-U(J+1))/(U(J)-	·U(J+1))	STEP 2400
GO TO 398		STEP 2410
356 YEM=Y(NP3)		STEP 2420
398 YL-YEH-YIP		STEP 2430
RETURN		STEP 2440
C	STEP 4	STEP 2450
CSTEP4 CALCULATES ALL OF THE COEFFICIENTS FOR THE		STEP 2460
CFINITE DIFFERENCE EQUATIONS.		STEP 2470
CTHE FDE'S ARE THEN INJEGRATED.		STEP 2480
C		STEP 2490
CSOURCE TERMS, SU(J,I), AND SMALL C'S ARE CONPUTED IN		STEP 2500
CSUBROUTINE AUX.		STEP 2510
CTHE CONVECTION TERM		STEP 2520
400 KXX=0		STEP 2530
KXXX=O		STEP 2540
401 RFDX=1./4./DX		STEP 2550
SA=R(1) +AHJ/PEI		STEP 2000
SBDF=(R(NP3)+AME-R(1)+AMI)/PEI/4.		51272510
P2=3. #RFDX		STEP 2000
DO 420 I=3,NP1		51272390
Pl=OMD(I)#RFCX#R8CM(I)		51592000
P3=OMD(I-I)*RFCX*R60#(I)		51EP 2010
G1=P1+(SA+SBCF#(UM([+1]+3,*UM([))/*RBUM([]		51272020
		31EF 2030
63=P3-15A+580F=(UM11-17=3.=UM11)]=R00R117		STEP 2640
AU(1)=3((1)=KCPU(1)=2+=KCUP(1) au(1)=FC(1)=3+=BCAP(1)=1)+3==BBCA(1)		STEP 2000
DU(1)=3((1~1)+KUHU(1~1)+2.+KUHU(1) C///1)=-01+//(1+1)=D2+//1)=D2+//1=11		STEP 2670
$C(1) = P_1 + U(1 + 1) - P_2 + U(1 + P_2 + U(1 + 1))$		STEP 2680
IFINEQ.EQ.17 00 10 410		STEP 2690
C((, T)==01=E((, T+1)=02=E((, T)=03=E((, [-1))		STEP 2700
		STEP 2710
A(1. T) = A((T) / PREF(.). T)		STEP 2720
B(1, 1) = B(1(1) / PRFF(J, 1-1))		STEP 2730
405 CONTINUE	-	STEP 2740
410 CONTINUE		STEP 2750
COMPACE TERM FOR VELOCITY EQUATION		STEP 2760
S1=DPDX+DX-GC+8F(I)+DX		STEP 2770
S2=P2*S1/(RHC(I)+U(I))		STEP 2780
S3=P3+S1/(RHC(I-1)+U(I-1))		STEP 2790
S1=P1*S1/(RHO(I+1)*U(I+1))		STEP 2800
$CU(I) = -CU(I) - 2_0 = (S1 + S2 + S3)$		STEP 2810
S1=S1/U(I+1)	•	STEP 2820
S2=S2/U(I)		STEP 2830
S3=S3/U(I-1)		STEP 2840
CCOEFFICIENTS IN THE FINAL FORM		STEP 2850
RL=1./(G2+AU(I)+BU(1)-S2)		STEP 2860
AU(I)=(AU(I)+S1-G1)+RL		51542010
BU(I)=(BU(I)+S3−G3)≠RL		SI 27 2000
CU(I)=CU(I)#RL		31EF 2090
IF (NEQ. EQ.1) GO TO 420		31572700
DD 415 J=1,NPH		31272710
RL=1./(G2+A(J,1)+U(J+1)-50)		5167 2720
A(J, I)=(A(J, I)=GI)=RL		3167273U
D[J+]/4(D[J+]/-UJ/-KL		STED 2050
910 U(J+17=U(J+17=KL 200 CONTINUE		STEP 2930
920 LUNIINUE C SI TO COEFFICEINTS MEAD THE I DOUNDARY FOR VELOCITY FO	ATTON	57592970
CHARACTER CONTRACTION AND AND AND AND AND AND AND AND AND AN		STED 2980
		STEP 2590

• . . .

	GO TO (422,424,426),KIN	
422	2 BU(2)=0.	STEP 3000
	AU(2)=1./(1.+2.+0ETA)	STEP 3020
	GO TO 430	STEP 3030
	• SQ=84•*U(1)*L(1)-12•*U(1)*U(3)+9•*U(3)*U(3)	STEP 3040
	BU(2)=8.#(2.#U(1)+U(3))/(2.#U(1)+7.#U(3)+SQRT(SQ))	STEP 3050
	IF(U(5).LE.U(1))eu(2)=1.	STEP 3060
	AU(2)=1BU(2)	STEP 3070
	GO TO 430	STEP 3080
420	6U(2)=0.	STEP 3090
	AKI#1./DZ-(DPDX-GC#8F(2))/(RHO(1)+U(1)+U(1))	ST5P 3100
٠.	$A_{2} = 0(1) + A_{1} + 0 + 0 + -G(2 + B + (2)) / (R + O(1) + O(1))$	STEP 3110
	AJ-KHU(1)-U(1)*.2=*(*(2)**(3))**2/EMU(2)	STEP 3120
	1////1-2/-2/-2/-2/-2/-2/-2/-2/-2/-2/-2/-2/-2/-	STEP 3130
		STEP 3140
		STEP 31 50
428	$C(1(2)\pi) - f(2, 43, 44, 144K)$	S1 EP 3160
	AU(2) = CU(2) + (2 - A) + AU(3)	STEP 3170
	CU(2)=-CU(2)+4.+AJ+AK2	STED 3100
c	SLIP COEFFICIENTS NEAR THE E BOUNDARY FOR VELOCITY FOUNTION	STEP 3190
430	GO TO (432,434,436). KEX	STEP 3200
432	AU(NP2)=0.	STEP 3210
	BU(NP2)=1./(1.+2.+BETA)	STEP 3220
	GO TO 440	STEP 3240
434	SQ=84.#U(NP3)#U(NP3)-12.#U(NP3)#U(NP1)+9.#U(NP1)#U(NP1)	STEP 3250
	AU(NP2)=8.*(2.*U(NP3)+U(NP1))/(2.*U(NP3)+7.*U(NP1)+SORT(SO))	STEP 3260
	BU(NP2)=1AL(NP2)	STEP 3270
	GO TO 440	STEP 3280
436	AU(NP2)=0.	STEP 3290
	BK1=1./DX-(DPDX-GC+BF(NP2))/(RHD(NP3)+U(NP3)+U(NP3))	STEP 3300
	8K2=~U[NP3]=8K1+(DPDX-GC#8F(NP2))/(RHO(NP3)=U(NP3))	STFP 3310
	BJ#KHU(NP3)#U(NP3)#, 25#(2, #Y(NP3)-Y(NP1)-Y(NP2))##2/EHU(NP1)	STEP 3320
•	UUUNYEJ=1./12.45.40J+BK1J BUINDD1_CUINDD14/DDUADV1.	STEP 3 3 3 0
		STEP 3340
440	IF(NF0.F0.1) GO TO A71	STEP 3350
C	SI IP COEFFICIENTS NEAR THE I ADUNDARY FOR OTHER COUNTIONS	51EP 3360
	DO 470 J=1.NPH	5127 5570
	C(J.2)=0.	STEP 3300
	C(J,NP2)=0.	STEP 3400
	GO TO (452,454,456),KIN	STEP 3410
452	IF (INDI(J).EQ.1) GO TO 453	STEP 3420
	VA=GAMA(J)/((1.+BETA)+(QWF(J)+AMI))	STEP 3430
••	A(J+2)=(1VA+AMI)/(1.+VA+AMI)	STEP 3440
	B(J,2)=0.	STEP 3450
	$C(J,Z)=Z_+AJI(J)+VA/(1_+VA+ANI)$	STEP 3460
		STEP 3470
923	A(J)(2)=(1.+BETA+GAMA(J))/(1.+BETA+GAMA(J)) P(1.2)=1.=A(1.2)	STEP 3480
	D(J)2)=10-74(J)2) 16(COUDCE(1) NE 3)CO TO 440	-STEP 3490
	1 1.2 1	STEP 3500
		SIEP 3510
		5167 5520
	60 TO 460	31 CF 3330
454	A(J,2)=(U(2)+U(3)-8.+U(1))/(5.+(U(2)+U(3))+A.+U(1))	STEDISEN
	GF=(1PREF(J,2))/(1.+PREF(J.2))	STEPSSO
	A(J,2)=(A(J,2)+GF)/(1.+A(J,2)+GF)	STEP 3570
	B(J,2)=1,-A(J,2)	STEP 358D
	GO TO 460	STEP 3590

- · -

	456	B(.1.2)=0.	STEP 3600
			STEP 3610
			STEP 3620
		AR = 1.0/ UA= UJ	STEP 3630
			STEP 3640
		AK2=-AK1++(J,1)-US	STEP 3650
		AJF=AJ=PR=F{J,z}	STE03440
		IF(KRAD.EQ.0) GO 10 457	3167 3000
		A(J+2)=2+/(2++AJF+AK1)	5164 3010
		((J.2)=5+AJF+AK2+A(J.2)	STEP 3680
			STEP 3690
		(1) (2) (2) (3) (4)	STEP 3700
	421	U(J)2J-20/(20*30*70)*70*7	STEP 3710
		$A[J_{2}] = [J_{2}] = [J_{2}] = [J_{2}] = [J_{2}] = [J_{2}] = [J_{2}]$	STEP 3720
		((J)2)=-((J)2)+++AJ++AK2	STEP 3730
C • ·		SLIP COEFFICIENTS NEAR THE E BUUNDART FUR UTHER LOOATTONS	STEP 3740
	460	GO TO (462,464,466),KEX	CTE0 2750
	462	IF (INDE(J).EQ.1) GO TO 463	STE- 3730
		VA=GAMA(J)/((1.+8ETA)*(QWF(J)-AME))	5169 5700
		B(J.NP2)=(1.+VA+AHE)/(1VA+AHE)	STEPSTIO
		A(J-NP2)=0.	STEP 3780
		(1, ND2) = -2, +A = F(1) + VA/(1, -VA + AHE)	STEP 3790
			STEP 3800
		GU TU 470	STEP 3810
	463	B(J,NP2) = (I. TELA-GARALJ///II. OLIA - GARACO/	STEP 3820
		$A(J_{3},NPZ) = 1 B(J_{3},NPZ)$	STEP 3830
		IF(SOURCE(J).NE.2)GO TD 4/0	CTED 3840
		A(J,NP2)=0.	STED 2950
		B{J,NP2}=−1.	SIEP 3030
		C(J.NP2)=2.4FI(J)	SIEP 3000
		60 10 470	STEP 3870
		B(1,ND2)=(U(NP2)+U(NP1)-8,+U(NP3))/(5,+(U(NP2)+U(NP1))+8,+U(NP3))	STEP3880
	707	C = 11 = 00 E E (1 = N0 1) 1 / (1 = 00 E E (1 = N0 1) 1	STEP 3890
		Gratis-recreation fill (1. NoiteGF)	STEP 3900
			STEP 3910
		A(J,NP2)=1B(J,NP2)	STEP 3920
		GO TO 470	STEP 3930
	466	A(J,NP2)=0.	STEP 3940
		05=0•	STEP 3050
		BK1=1./DX-DS	SIEP 3730
		CS=0.	2164 3400
		BK7=-BK1+F(J.NP3)-CS	STEP 3910
		AIF=BIAPRFF(J, KP1)	STEP 3980
		C(1) ND(2) = 1 - / (2 + 3 + 4R) F + 8K1)	STEP 3990
		$a_1 + b_2 + c_1 + b_2 + b_2 + a_1 + b_2 + b_1 + b_2 $	STEP 4000
		D(J) N(Z) = CJ (N(Z)) + C (Z) = CJ (Z) + C (Z) = CJ (Z) + C	STEP4010
			STEP 4020
	470		STEP 4030
с.		SETTING UP VELOCITIES AT A FREE BOODAAT	STEP4040
	471	IF(KEX.EQ.2)U(NP3)=SQRT(U(NP3)=U(NP3)-2.+DX+(UP0X-GC+BP(NP3))	STEPADSO
		1/RHO(NP3)}	STEDADAD
		IF(KIN.EQ.2)U(1)=SQRT(U(1)+U(1)-2.+DX+(DPUX-GC+BF(1))/RHU(1))	STEP 4000
с.		THIS IS THE TRI-DIAGONAL ROUTINE WHERE THE FINITE	31274010
č.		INTEFERENCE EQUATIONS ARE ACTUALLY SOLVED.	STEP 4080
č.		INTEGRATE VELOCITY	STEP 4090
		$P_{11} = P_{11} = P$	STEP4100
			STEP4110
			STEP 4120
			STEP4130
		AU(I) = AU(I)=II	STEP4140
	472	BU(I) = (BU(I) + BU(I-1) + CU(I) + I)	STEDAISA
		DO 474 I=2,NP2	31277430 CTED4140
		JJ=NP 2- I +2	3127 9100
	674	{ LL JUA+ (1 L L) U4+ (1 + LL J) U4+ (1 + LL J) U4+ (1 - L)	STEP 4170
		DO 476 1#3.NP1	STEP4180
			STEP4190

1177 h-1177 h		
		STEP 4200
		STEP 4210
476 CONTINUE		STEP 4220
KXXX=KXXX+1		STEP 4230
IF(KXX_EQ.0)GO TO 478		STEP4240
IF(KXXX.GT.2)G0 T0 478		CTEDA JEA
C ATTEMPT TO RE-SOLVE TE NEGATI	IVE VELOCITY ADDEADS	31EF4230
TELVEN EN SLAME-ANELS S	IVE TELOUITT AFFERRS	31EP4200
TINEALEWACIANC-ANC/143		STEP 4270
1F(KIN+EU+27AH1=AP1/163		STEP4280
DO 4777 I=2,NP1		STEP 4290
RAVG=0.5*(R(I+1)+R(I))		STEP 4300
RHOAV=0.5#(RHO(I+1)+RHO(I)}		STEPASIO
CARAGADJUSTNENT OF ENU AT 2.5 AND	N+1.5	STED 4330
IF (1.61.2) 60 TO 4777		3167 4320
15 (VIN ME 1) CO TO 4772		SIEP4330
IF (KIM+ME+1) GU (U 4//0		STEP4340
IF IBEIA-LI-U-02-UK-BEIA-GI-G	0.91 GD TO 4777	STEP4350
EMU(2)=TAU#(Y(2)+Y(3))/(BETA	F(U(2)+U(3)))	STEP 4360
4778 IF (KEX.NE.1) GO TO 4777		STEP 4370
IF (BETA.LT.0.02.DR.BETA.GT.C	0.9) GO TO 4777	STEP4380
EMU(NP1)=TAU+(Y(NP3)-0.5+(Y(N	4P13+Y(NP2)11/	STEDA 200
1 (BETA+0.5+(1)(NP1)+1)(NP2)))		512F 4370
CCOMPUTE SMALL CIS		STEP 4400
A777 CCTTLEANCABANCABUGANAG CHINA		STEP4410
	[1+1]+U[]]]+EWU[]]/(PE]+PE]}	STEP 4420
WRITE (6,477) INTG		STEP 4430
477 FORMAT (/10X, VELOCITY NEGATI	VE, RE-SULVE, INTG=',14/)	STEP4440
GO TO 401		STEP4450
478 CONTINUE		STEDALLA
CARAN-SETTING UP VELOCITIES AT A SY	MMETRY INC	STED 4470
TE/KIN.NE.31 60 10 400		51674470
		21664480
		STEP 4490
IF IKKAU. EV. 0 JULI J=0. 75=U(2)+.	2540(3)	STEP4500
480 IF (KEX.EQ.3) U(NP3]=.75#U(NP2))+.25+U(NP1)	STEP4510
IF(NEQ.EQ.1) GO TO 494		STEP 4520
CINTEGRATE F EQUATIONS		STEP4530
00 492 J=1+NPH		57504540
00 482 1=2.NP2		57504560
		31694770
		STEP 4560
		STEP 4570
482 CU([]=C(J+[]		STEP 4580
IF (SOURCE(J).NE.21 GO TO 48	186	STEP 4581
IF (ITKE.EQ.1) GC TO 4886		STEP 4582
IF (KEX.EQ.1) GO TO 4884		STEP4583
DQ 4882 I=1.ITKE		STEDASQA
AU(1)=0.		51674304
		3167 4383
6892 CHITLES 1 TTNES		STEP 4586
ADDZ CUTITERT		STEP 4587
GU 10 4880		STEP4588
4884 DO 4885 I=ITKE,NF3		STEP 4589
AU(I)=O.		STEP 4590
BU([}=0.		STEP 4591
4885 CU(I)=F(J.ITKE)		STEDA 502
4886 CONTINUE		57604503
A11(2) = A11(2)+5(1.1) + FUT 21		31284343
DOLES - DULESTRIJIIS F CULES DO 444 1-3 MD3		STEP 4594
UU 707 1730NF2		STEP 4600
$IT = I \cdot / II \cdot - BU(I) = AU(I-1)$		STEP 4610
AU(I) = AU(I)+TT		STEP 4620
	}}≠TT	STEP 4630
00 486 I=2,NP2		STEP 4640
JJ=NP 2- I+2		STEDALEA
486 F(.1.1.1.4.1)(1.1.4.5.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.		31 CF 703U
	J 1	21544000

	SETTING HE SUBMETRY-LINE VALUES OF F		STEP 4680
	TELKIN.NE.3) GO TO 490		STEP4690
	F(1.1)=F(J.2)		STFP 4700
•	IF (KRAD.EQ.0)F(J.1)=.75+F(J.2)+.25+F(J.3)		STEP 4710
490	IF(KEX.EQ.3)F(J.NP3)=.75+F(J.NP2)+.25+F(J.NP1)		STEP4720
492	CONTINUE		STEP 4730
494	RETURN		STEP 4740
		STEP 5	STEP 4750
	STEP5 INITIALIZES PARAMETERS AND SETS UP INITIAL C	ONDITIONS+	5128 4 100 CTED& 770
			STEP4770
500	XD=XU		STEP 4790
	PRE=PO		STEP 4800
	AME=0.		STEP 4810
			STEP4820
	INTG=0		STEP 4830
	BETA=0.	·	STEP 4840
			STEP4850
			STEP 4860
			STEP 4870
			STEP 4880
			STEP 4890
			STEP 4900
			STEP 4910
	14UW=U.UZ 15/NDH 50 0150NP(511)=0		STEP 4920
	171NFR-E440/3000000117-0		STEP4930
	UU 240 1=1;472		ST F P 4 9 4 0
	ERU(1)=0.0		STEP 4950
	Br(1)=0.0		STEP4960
	371130.0		STEP 4970
	17 (NPH.52.07 00 10 540		STEP 4980
			STEP 499(
	04/1)=0.0		STEP 5000
	TE (SOURCE(1), EQ.2) PR[J, []=1.0		STEP 5010
530	CONTINUE		STEP 5020
540	CONTINUE		STEP 5030
240	EMEAN=0.0		STEP 504(
			STEP 5050
			STEP 506(
	AL MG#AL MGG		STEP 5070
	KRAD = 1		STEP 508
	IF (GEOH.EQ.1)KRAC=0		STEP 509(
	IF (GEOM.EQ.5) KRAD=0		STEP 5100
	IF (GECM.EQ.B)KRAC=0		STEP5110
	IF (GEON.EQ.9)KRAC=0		51595120
	IF(NEQ.EQ.1) GC TC 560		51545130
	DO 550 J=1,NPH		51525140
	0.0=(L)]LA		5168514
	AJE(J)=0.0		5127210
	INDI(J)=0		5157210
	INDE(J)=0		STED 510
	IF (KIN.EC.1) INDI (J)=TYPBC(J)		STEP 520
	IF(KEX+EQ+1)INDE(J)=TYPBC(J)		5750521
550	CONTINUE		STED 5221
560	CONTINUE		STEP 523
	RETURN		STEP 5240
	END		
			WALLOOD
	SUBRUUIINE RALL		

ORIGINAL' PAGE IS OF POOR QUALITY

C				
Channel				WALLOUID
INTEGER GEON-ELUID.SOURCE	SI SPACE BOOM		V005	#ALL0020
DIMENSION HH/SI LC(S) DOH	1 31 137 AUC10UU		TPBC	WALLUUJU
COMMON/CEN/DET ANT AME ODD		5(5)+UHT(5)		WALL 0040
INCOR DOTIEL DOT NUMBER VILLA	X+XJ+XU+XL+U	GINIG, CSALF	A. I YP BC (51,	WALL 0050
	JJ, RH(100), FJ	5,100, GC,C	J.AM(100),PRO,	WALL 0060
20011001 PU, SCURCE, RETRAN,	UMRUN, SPACE, F	RWJ, PPLAG, DU	TPUT, DELTAX, GV	WALL 0070
3/E/N, NP1, NP2, NP3, NEQ, NPH, I	(EX+KIN+KASE+	(KAD,GEDM,FL	UID,BODFOR,YPMIN	IWALL OOBO
4/GG/8ETA,GAMA(5),AJI(5),A.	/E(5),INDI(5),	INDE(5),TAU	,QWF(5)	WALL 0090
5/V/U(54),F(5,54),R(54),O4(54),Y(54),UGL	J,JGD,UI,FIC	51, FMEAN, TAUW	WALLO100
7/L/AK,ALNG,ALNGG,FRA,APL,E	BPL, AQ, BQ, EMU(54), PREF(5,	54),AUXM1	WALL0110
8/L1/YL, UMAX, UMIN, FR, YIP, YE	M, ENFRA, KENT,	AUXN2		WALL0120
9/P/RH0(54),VISCO(54),PR(5)	54), RHOC, VI SC	OC, PRC(5),T	(54), RHOM, BF (54)	WALLO130
1/0/H,REM,CF2,ST(5),LSUB,L	/AR,CAY,REH,PF	L, GPL, QW(5)	•KD	WALLOI40
2/CN/AXX,BXX,CXX,CXX,EXX,K1	L,KZ,K3,SP154)	,AJX1(100),	AUX2(100), YP MAX	WALLO150
C • • • • •		•		WAL1 0170
IF(INTG.GT.1.CR.LSUB.GT.0)	GO TO 8			WALL DI BO
KSTART=1				WALL 0190
MARKER=0				HALL 0200
C3=0.0				WALL 0210
(4=0.0				WALL 0720
C3N#O.				HALL 0220
C5=0.0				WALL0230
				WALL 0240
				WALL0250
				WALL0260
				WALL0270
				WALL 0280
				WALL 0290
IPLUS=1.				WALL0300
CLOOPX=0.0				WALL0310
DUDY=1.				WALL 0320
APLO=APL				WALL0330
BPLO=BPL				WALL 0340
EE=0.04				WALL0350
IF(NPH.LT.1)GO TC 8				WALL 0360
00 6 J=1,NPH				WALL0370
DHY(J)=1.				WALLO380
6 QW(J)=100.				WALL 0390
8 LSUB=0				WALL0400
LTPL=0				WALL 0410
	*	5	SECTION ONE	WALL 0420
CTHE JOIN POINT CONDITIONS	ARE SET UP HE	RE		WALL 0430
IF(KEX.NE.1)GO TC 20				WALL 0440
RHH=RHO (NP3)				WALL 0450
VISG=VISCO(1)				WALL 0460
VISH=VISCO(NP3)				WAT 1 0470
RHG=RHO(1)				WALL 0480
RHI=0.5+(RH0(NP1)+RH0(NP2)	3			WALL 0490
VIST=0.5+(VISCO(NP1)+VISCO	(NP2))			WA11 0500
BFOR=(BF (NP2)+BF (NP1))/2.				
VI				4411 0520
12-1111-27-82-111407474117474741174 117=_511114074411140744	••			HALLUJJU Hati Aeaa
	3-V/MD3114/V4	NI- EATVINAT	SAMENDONSS -	WALLUJ4U
IE/MODE.CO. 1306-017	a - 1 t Ar 4 7 7 7 1 1	17~42+LTINP1		
ITANUUSAEVAITUS=UI Istasta ce a gausait				MALLU 700
1 - 10E (A + VE + V + 77VE = V1 11 - 7417 4116) 73				FALLUD/U
				HALLUSOU
ANUAME				HALLUDYO
ART = "ARC 15(NEA EA 1100 TA (A				HALLU600
IPINEY.EY.IJGU IC 40			1	HALL0610

00 10 J=1.NPH	WALL0620
$H_{K}(J) = F(J, NP3)$	WALL 0630
HG(J) = F(J, 1)	WALL0640
PRW(J) = PR(J, R3)	WALL 0650
PRI(J)=0.5=(PR(J,NP1)+PR(J,NP2))	WALL 0.660
FI(J}=.5+(F(J,NP2)+F(J,NP1))	WALL 0670
FE=F(J+N)-(F(J+N)-F(J+NP1))/(Y(N)-Y(NP1))*(Y(N)5*(Y(NP1)+Y(NP2)	WALL 06BO
1))	WALL 0690
IF(MODE.EQ.1)FE=FI(J)	WALL 0700
IF (GAMA{J).GE.O.9.AND.GAMA(J).LE.1.1} FC=FI(J)	WALL 0710
If(SOURCE(J).EC.2)FE=FI(J)	WALL 0720
10 FI(J)=(FI(J)+FE)/2+	WALLO730
GO TO 40	WALLO740
20 IF(KIN+NE+1)RETURN	WALLU/SU
RHW=RHO(1)	WALL 0760
VISH=VISCO(1)	WALLUTTO
VISG=VISCD(NP3)	HALL0700
RHG=RHO(NP3)	
RHI=0.5+(RHO(2)+RHO(3))	WALL USUU
VISI=0.5*(VISCO(2)+VISCO(3))	WALLOBIO
8FDR=(8F(2)+8F(3))/2.	WALL 0020
UGG = UGU	WALLUBSU
$\mathbf{Y}_{\mathbf{I}} = 0 \rightarrow \mathbf{V}(\mathbf{Y}_{\mathbf{I}}) + \mathbf{V}(\mathbf{S}_{\mathbf{I}})$	WALL 0850
	WALL 0860
	WALL 0870
	WALL OBSO
	WALL 0890
$\mathbf{U} = \{\mathbf{U}\} + \mathbf{U} = \{\mathbf{U}\} + \mathbf{U} = \{\mathbf{U}\} + \mathbf{U} = \{\mathbf{U}\}$	WALL 0900
KC₩-KD3\UITTIKKNW/¥13W/	WALL 0910
$\frac{1}{100} = \frac{1}{100} = \frac{1}$	WALL 0920
	WALL 0930
	WALL0940
HG(1)=F(1.NP3)	WALL 0950
PR(J,I) = PR(J,I)	WALL 0960
PRI(J)=0.5+(PR(J,2)+PR(J,3))	WALL 0970
F(J) = .5 + (F(J, 2) + F(J, 3))	WALL 0980
FE=F(J,3)+0.5+(Y(2)-Y(3))+(F(J,4)-F(J,3))/(Y(4)-Y(3))	WALL 0990
IF(MODE.EQ.1)FE=FI(J)	WALL 1000
If $(GAMA(J) \cdot GE \cdot O \cdot 9 \cdot AND \cdot GAMA(J) \cdot LE \cdot 1 \cdot 1) FE = FI(J)$	WALL1010
IF(SOURCE(J).EQ.2)FE=FI(J)	WALL 1020
30 FI(J)=(FI(J)+FE)/2.	WALL1030
40 UTAUH=SQRT(GC#TAUH/RHW)	WALL 1040
UTAUG=SQRT(GC+TAUh/RHG)	WALL 1050
IF(REW.LT.4. IGC TC 160	WALL 1060
C	- WALL 1070
CSOURCE TERMS FOR COUETTE FLOW STAG ENTHALPY EQUATION	WALL 1000
S=0.0	WALL 1090
IF(NEQ.EQ.1)G0 TC 180	WALL 1100
	WALL 1120
	WALL 1130
LV IV ISV IL/DAAKES/10EA010EK010EA0010A IA TAA	WALL 1140
130 16(HCG.) T. 0. 011GE TO 140	WALL 1150
TENUNTOR TARACTAR A TAR	WALL 1160
TELARS(DENON), 1 T.0.00001168 TO 140	WALL 1170
COMMOTE: IF WALL HEAT FLUX IS NEAR ZERO, VISCOUS DISSIPATION	WALL 1180
C IS NOT PROPERLY HANDLED. ALWAYS USE AT LEAST A SHALL	WALL 1190
C HEAT FLUX. SAME TRUE OF HEAT SOURCE, S.	WALL 1200
	WALL 1210

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	C4=VISW+BFOR/(2.+DENCH+RHW)	WALL1220
	C5N=VISW+CJ/(RHW+DENON+UTAUW)	WALL 1230
140	C3=(C3+C3N)/2.	WALL 1240
	C5=(C5+C5N)/2.	WALL 1250
	IF(INTG_LT.5)C3=0.0	WALL 1260
	IF(TYP8C(J).EQ.1)GO TO 150	WALL 1270
	(L) BLA=NLA	WALL 1280
	IF(KIN.EQ.1)AJN=AJI(J)	WALL 1290
9 .1	IF (ABS(AJN) - GT - APS(1 - 1 + AJD) KKK = INTG	WALL 1300
	IF(INTG_LE_(KKK+1))C3=0.0	MALL 1310
	AJQ=AJE(J)	WALL 1320
		HALL 1320
150	CONTINUE	WALL 1350
C		WALL 1340
č	MIETTE EI DH EMIATION TERMS ARE COMPUTED HERE	WALL 1370
140	TE (TWE IT 2) ALADY-A	WALL 1300
100		WALLIS/U
		WALL 1380
145		F WALL 1 390
103		WALL 1400
		WALL 1410
	BFPLUS=BFUR=VISW/(TAUM=RHH=UTAUM)	WALL1420
	BFPLUS={BFPLUS+BFDLDJ/2.	WALL 1430
	BFOLDEBFPLUS	WALL1440
	IF (KSTART.EQ.1)PPL=0.	WALL1450
	IF (KSTART.EQ.1)BFPLUS=0.	WALL 1460
	IF(KSTART.EQ.1)GPL=0.	WALL 1470
		WALL 1480
_	IF(MODE.EQ.1)AKK=0.0	WALL 1490
C	JURBULENT FLOW DAMPING TERMS ARE COMPUTED HERE	WALL 1500
	IF(KD_EQ.1)GO TO 180	WALL 1510
	IF(KD.EQ.3)GC TO 180	WALL 1520
	IF(INTG.EQ.1)PPLE=PPL-BFPLUS	WALL 1530
	IF(INTG.EQ.1)GPLE=GPL	WALL 1540
	IF (PPLAG-LT-400-1 PPLE=PPL-BFPLUS	WALL 1550
.,	IF (PPLAG.LT. 400.)GPLE=GPL	WALL 1560
	IF(PPLAG.LT.400.JGD TO 170	WALL 1570
	IF(MARKER.EQ.1)GC TO 170	WALL 1580
	DIR=1.0	WALL 1590
	IF{{PPL-BFPLUS}.GT.PPLE}DIR=0.3	WALL 1600
	PPLE=PPL-BFPLUS-(PPL-BFPLUS-PPLE)+EXP(-{RHW+DX+UTAUG}/	WALL 1610
	1(VISW#PPLAG#DIR))	WALL 1620
	GPLE=GPL+{GPL-GPLE}+EXP{-{RHW+DX+UTAUG}/	WALL 1630
	1(VISW#PPLAG))	WALE 1640
170	CONTINUE	HALL 1650
C	THE FOLLOWING ARE ENPIRICAL CORRELATIONS FOR THE DAMPING TERM	WALL 1660
C	IN THE MIXING-LENGTH EXPRESSION.	WALL 1670
		LAL 1 1680
	RC = 4 - 25	HALL 1400
		HALL 1090
	$F(P) = F(T_0, A) = 2 - 9$	WALL 1700
		WALL 1710
		WALL1720
	ADI 3ADI A/IACAICOI FARCEIDDI F//), ACCACDI 513141-1	WALL 17/0
	ADI = 8 DI A// AC#/(D) EAR/#/DOI E//) A//#/DI E/////	WALL 1/40
	07L-07L0/1804107LC7004177LC/11+400407LC///41+/	WALL 1750
	IC (AC L + L T + T + UU L T AC L = 1000	WALL 1760
	17 (DYL+L).***UU1/ DYL+LUUU.	WALL1770
~	IFTINIG-EW-1-UK-KEH-GI-Z-FKETKANJGO TO 180	WALL 1780
	THE FULLUWING IS A GINNICK TO SINULATE A GRADUAL TRANSITION.	WALL 1790
-	IF(KD.LE.1.AND.HCCE.EQ.2)APL=APL+(300APL)+(1SIN(1.57	WALL 1800
1	L+ (REM-RETRAN)/RETRAN)]++2	WALL1810

IF(KD.GE.2.AND.MODE.EQ.2)BPL=BPL+(400BPL)+(1SIN(1.57	WALL 1
1+ (REM-RETRAN)/RETRAN))++2	WALLIG
	MATI 1
ISU FIREWALLATA AND INTERCOLOUNTIE (6,900)	MÁLI 1
AND COMMENTAL AND COMPANIES AVANCE THE MALL FUNCTIONS AT LEAST AT	MALLI
THE INTERATION IA	WALL 1
	HALL 1
IF CREATE THE TOTAL STOCE THE SECTION FIVE	-MALL 14
THIS IS THE BEGINNING OF A LOOP IN HHICH THE NOMENTUM	WALL 19
AND ANY MUNERS OF DESIGN COUPTE FLOW ORDINARY DIFFERENTIAL	WALL 1
C SALAND AND AND ADER OF OFFICIENCE COLLECTED AND AND AND AND AND AND AND AND AND AN	MALL 1
LETTERE AND	WALL I
ITING.EU.Z.OKINGEU.Z.IKIICGEU.Z.IKIICGEU.Z.IKIICGEU.Z.	MALE 1
TUTE INTERATION (/)	MALL 1
THIS INTEGRATION. "//	WALL 1
	WALE 19
IF (DTPL.G(.0.25) DTPL=0.25	
UPL=0.0	LALL 2
DUDY=1.	
A2=0.0	WALL 2
IF(NPH.LT.IJGO TC 200	WALL Z
DO 190 J=1,NPH	WALL 2
HPS(J)=0.0	HALL 2
190 DHY(J)=PRW(J)	WALLZ
200 KCHECK=0	WALLZ
210 IF(YPL.GT.2.5)0YPL=YPL/10.	WALL2
220 TPLUS={].0+GPL+{UPL+DUDY+DYPL/2.}+{PPL-BFPLUS}+{YPL+DYPL/2.}-	WALL 2
1(PPL-BFPLUS)#CF2#A2/RHG)	WALL Z
IF{TPLUS.LT.0.0}TPLUS=0.0	HALL 2
IF(TPLUS.LT.0.1)LTPL=1	WALL 2
IF(TPLUS.LT.0.1)LSUB=2	WALL 2
RR=1.+((RHI/RHW)-1.)+(UPL+UTAUW/UI)	WALL 2
IF{RR.LE.O.IRR=1.	WALLZ
VR=1.+{(VISI/VISh)-1.)+(UPL+UTAUW/UI)	WALL 2
IF(VR.LE.O.)VR=1.	WALL 2
IF(KD.GT.1)60 TO 230	WALL 2
YLOAP=(YPL+DYPL/2.1/APL/LVR/SQRT[RR])	WALL 2
IF (YLOAP.GT.10.) EE=1.	WALL 2
IF (YLOAP.GT.10.)GC TO 240	WALL 2
EE=11./EXP(YLOAP)	WALL 2
GO TO 240	WALL 2
230 EE=(YPL+DYPL/2.)/8PL/(VR/SQRT(RR))	WALL 2
$IF(EE_{\bullet}GT_{\bullet}1_{\bullet})EE=1_{\bullet}$	WALL 2
240 DD=1.+4.+TPLLS+AKK+AKK+EE+EE+(YPL+DYPL/2.)+(YPL+DYPL/2.)*	WALL2
1(RR/(VR+VR))	WALL 2
DUDY= (2.+TPLLS/(1.+SQRT()))/VR	WALL 2
	WALL 2
DI2=RR+RHW+, 5+((UPL-DUDY+DYPL)+(UPL-DUDY+DYPL)+UPL+UPL)+DYPL	WALL 2
A2=DI2+A2	WALL 2
TEINED.EQ.1)GC TC 260	WALL 2
EDR= (RR/VR) + AKK+AKK+ (YPL+DYPL/2.) + (YPL+DYPL/2.) +EE +EE+DUDY	WALL 2
FORT=FOR+1.0	WALL 2
	WALL 2
DBD=1.+((DBT(J)/DBW(J))+),)+(UP)+UTAUM/UI)	WALL 2
THE EDITORIAL IS THE EREE CONSTANT IN THE TURBILENT PRANDTL	WALL 2
CONTRACT FOLLOWING IS THE THE CONTRACT A DISERT A DISERT VALUE.	WALL 2
COMMONIC EQUALINA EXPERIENCE ANT DUDGET & DITTERCAT TREDET	WALL 2
$C_1 = U_0 Z$	WALL 2
PRIJ=PKIJJ	WALL 2
YE (U=EUK+U + FKK+ FK #1 J)	

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IF(PETC.LT001)PETC=.001	WALL 2420
IF{PETC.GT.100CR.MODE.EQ.1)GO TO 245	WALL 2430
ALPHA=SQRT(1./PRTJ)	WALL 2440
AOP=ALPHA/PETC	WA11 2450
IF{AOP.GT.10.}AOP=10.	MALL 2460
PRTJ=1+/(1+/(2+#PRTJ)+ALP+A+PETC-PETC+PETC+(1+-EXP(+AMP)))	WALL 2470
IF (K3-EQ-3-OR-SOURCE(J) EQ-2)PRT $J = PRT (J)$	
245 PREFW=EORT/(1./(FRR+PRW(J))+EDR/PRTJ)	LAL 2400
$DHY(J) = (PREF b / (ECRT f VR)) \neq (1_2 + GP(f + GP(f)) + OHY(f) + OHY(f)) \neq (1_2 + OHY(f))$	
1YPL+C4+UPL+YPL+C3+	WALL 2500
	WALL 2010
	WALL 2520
	WALL 2530
	WALL 2540
	WALL 2550
	WALL 2560
	¥ALL 2570
	WALL 2590
	WALL 2620
270 IF (KCHECK.E0.1) GC TO 280	WALL 2630
*****AT THIS POINT THE PRODUCT UPLEYPL IS COMPARED TO UEYERHO/MU AT	THEWALL 2640
•••••JUIN-PUINT IN THE MAIN PROGRAM GRID.	WALL 2650
IF(REL.LT.REH)GO TO 210	WALL 2660
280 ERR=REL-REW	WALL 2670
AERR=ABS(ERR)	WALL 2680
ER2=AERR/REW	WALL 2690
IF(ER2.LT.0.01)G0 T0 300	WALL 2700
KCHECK=1	WALL 2710
[F(ERR-LT-0.0]DYFL=ABS(DYPL/2.0)	WA11 2720
IFIERR.GT.O.OJDYPL=-ABS(DYPL/2.0)	WALL 2730
GO TO 220	WALL 2740
;	WAL1 2750
THIS SECTION IS USED IF THE NUMERICAL INTEGRATION	WALL 2760
OF THE COUETTE FLCW EQUATIONS IS BYPASSED	WALL 2770
290 YPL=SQRT(REW)	WALL 2780
YPL=SQRT(ABS(REW/(1++(PPL-BEPLUS)+YPL/2+GPL+YPL/2)))	WALL 2790
YPL=SQRT(ABS(REW/(1.+(PPL-BFPLUS)+YPL/2.+GPL+YPL/2.1))	WALL 2170
UPL=REW/YPL	WALL 2000
TPLUS=1 + GPL +UPL + (PPL + REPLIES) # YPL	WALL 2010
	WALL 2020
	WALL 2030
	WALL 2840
	WALL 2850
	WALL 2860
HALL SHEAR STRESS AND EDICTION CASES OF ADDRESS SECTION SEVEN -	WALL 2870
AND TELEVILLE YOR AND AND AND TRUCTION ARE COMPUTED HERE	WALL 2880
JUU IFITFLOLIOTPFINOANCOAUUESE4021LSUB=1	WALL 2890
IF TYPL . GT. YP FAXILSUB=2	WALL 2900
IFILSUB.NE.2JCLDCFX=DPDX	WALL 2910
BETA=DUDY+YPL/UPL	WALL 2920
THE FOLLOWING IS AN APPROXIMATE CORRECTION FOR USE	WALL 2921
OF PLANE WALL FUNCTION EQUATIONS FOR AXI-SYMMETRIC PROBLEMS	WALL 2922
RADRAT=(R(NP2)+R(NP1))/(2. +R(NP3))	WALL 2923
IF (KIN-EQ.1) RACRAT=(R(2)+R(3))/(2.+R(1))	WALL 2924
TAUW=ABS(RADRAT+RHW+UJ+UI/(UPL+UPL+GC))	WALL 2930
TAU=TAUN+TPLUS+GC	MAL 1 2940
IF(UGG.LT.0.001)60 TO 310	WALL 2740
CF2=GC+TAUW/(RHG+UGG)	WALL 2770 VALL 2040
310 CONTINUE	HALL 2400
	WALL 2970
AT THE WOE WOE TO THE JACK	WALL 2980
	WALL 2990
IF (REW.GE.4.) GC TO 320	WALL 3010
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	WALL 3020
CTHIS SECTION IS USED IF THE NUMERICAL INTEGRATION	WALL 3030
C OF THE COUETTE FLOW EQUATIONS IS BYPASSED	WALL 3040
HPS(J)=PRW(J)=(YPL+GPL=YPL+Z+J)	WALL 3050
DHY(J)=PRW(J)=(1.+GPL=HPS(J))	WALL 3000
PREFWEPRW(J)	WALL 3070
C HALL HEAT TO ANGE OF AND STANTON NUMBER AND STANTON	HALL 3080
230 CAMAL HEAT IKANSFER AND STANTUN HUNDER ARE CONFOLD HERE	WALL 3100
320 GARA(J/-DIT(J/-TC/N/3/3/	WALL 3110
	WALL 3120
IF (SOURCE (J)) = Co. 2 + AND + MOF = FO(2) F (J) = (AKK+AKK+EE+BETA+UI/AQ) + 2	WALL 3130
1F(SOURCE(J)-E0-2)G0 TO 328	WALL 3140
IF(INDI(J).EQ.1.(R.INDE(J).EQ.1)GO TO 325	WALL 3150
1F(KEX-EQ-1)6C TO 322	WALL 3160
F(J,1)=(FI(J)+AJI(J)/QWF(J))/(1.+AMI/QWF(J))	WALL 3170
$HW(J) = F(J_{T})$	WALL 3180
{L}WH+IMA-{L}ILA={L}WQ	WALL 3190
IF(FLUID.EQ.2)CALL PROP2(1,F(J,1),T(1),VISCO(1),PR(J,1),RHO(1))	WALL 3200
CIF VARIABLE PROPERTY ROUTINE OTHER THAN 2 IS USED, CHANGE THIS	WALL 3210
CCALL AS APPROPRIATE. ALSO AFTER STATEMENT 325	WALL 3220
GO TG 326	WALL 3230
322 F(J,NP3)=(F(J)-AJE(J)/QWF(J))/(1AME/QUF(J))	WALL 3240
LEAN,	WALL 3260
GREAT A DE CATARETRE DA DE CALANDE A CANDER TENDER VISCO (NP3) . PR(1. NP3).	WALL 3270
	WALL 3280
	WALL 3290
325 CONTINUE	WALL 3300
QW(J)=QWF(J)+(HW(J)-FI(J))	WALL 3310
326 IF (ABS(HG(J)-HW(J)).LT.0.000001.DR.UGG.LT001)ST(J)=0.0	WALL 3320
IF(ABS(HG(J)-HW(J)).LT.0.000001.OR.UGG.LT001)G0 TD 328	WALL 3330
ST(J)=QW(J)/(RHG+U6G+(HW(J)-HG(J)))	WALL 3340
IF(KEX.EQ.1.AND.INDE(J).EQ.1)QH(J)=-QH(J)	WALL 3350
328 IF(KIN.EO.1)PREF(J,2)=PREFM	WALL 3 300
IF(REX.EQ.1)PREF(J,NP1)=PREFN	MALE 3380
330 CONTINUE	MAL 1 3390
240 W CTARTAK CTARTAL	WALL 3400
JETTITG FO.1. AND. KSTART.LT.4JGO TO 40	WALL 3410
MARKER=0	WALL 3420
IF (L SUB_GT . 0)MAR KEA=1	WALL 3430
IF (LSU8-EQ-0) RETURN	WALL 3440
C	WALL 3450
CLAMSUB ROUTINE	WALL 3460
CIF LSUB EQUALS 1, (SEE CONDITIONS IN MAIN PROGRAM),	WALL 34/0
CTHIS ROUTINE HAS AS ITS FUNCTION THE DELETION OF THE FIRST	WALL 3400
C GRID LINE NEAREST THE WALL. IN EFFELI II CUNDINES THE	WALL 3490
C	WALL 3510
CONTRACTOR I AND 1	WALL 3520
TNTCESINTCHI AND 30 INTCESINTCHI	WALL 3530
MRITE(6.930)	WALL 3540
930 FORMAT(/' ROUTINE LAMSUB HAS BEEN CALLED')	WALL 3550
IF(LSUB.GT.1) 60 TO 390	WALL 3560
N=N-1	WALL 3570
WRITE(6,920)N, INTGE	WALL 3580
NP1=N+1	WALL 3590
NP Z=N+2	WALL 3600

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	NP3=N+3	WALL 3610
	IF(KIN.EQ.1)GO TO 360	WALL 3620
	U(NP3I=U(N+4)	WALL 3630
	U(NP2)=U(N+3)	VALL JAAA
	Y(NP3)=Y(N+4)	HALL 3460
	Y(NP2)=Y(N+3)	MALI 3440
	IFINED-ED-116D TC 460	WALL 3600
	00 350 J=1 NPH	WALL SGIU
		WALL 3000
350		WALL 3090
		WALL 3700
360	CONTINUE	WALL 3710
		WALL 3/20
		WALL 3730
		WALL 3740
		WALL 3750
		WALL 3760
370		WALL 3770
200		WALL 3780
200		WALL 3790
ànă		WALL 3800
340		WALL 3810
~	WKIJE (0,920JN,INIGE	WALL 3820
	CHANGE IF PREGRAP DIMENSIONING IS CHANGED. *********************	WALL 3030
	IF(N-61-50)6C TO 470	WALL 3840
	NP I= N+ 1	WALL 3850
	NPZ=N+2	WALL 3860
	NP3=N+3	WALL 3870
	IF(KIN.EQ.1)GO TC 420	WALL 3880
	Y(NP3)=Y(NP2)	WALL 3890
	Y(NP2)=Y(NP1)	WALL 3900
	U(NP3)=U(NP2)	WALL 3910
*	U(NP2)-U(NP1)	WALL 3920
Š.,	YI=0.5+(Y(NP2)+Y(N))	WALL 3930
· · ·	Y(NP1}=0.5*(Y(N}+YI)	WALL 3940
	U(NP1)=0.5+(U(N)+UI)	WALL 3950
	IF(NEQ.EQ.1)GO TO 410	WALL 3960
	00 400 J=1,NPH	WALL 3970
	F(J,NP3)=F(J,NP2}	WALL 3980
	F(J,NP2)=F(J,NP1)	WALL 3990
400	F(J,NP1)=0.5+(F(J,N)+FI(J))	WALL 4000
410	CONTINUE	WALL 4010
	GO TO 455	WALL 4020
420	00 440 K=1+N	WALL 4030
	I=NP3+(1-K)	WALL 4040
	U(I)=U(I-1)	WALL 4050
	A(I)=A(I-T)	WALL 4060
	IF(NEQ-EQ.1) GG TO 440	WALL4070
	DO 430 J=1,NPH	WALL 4080
430	F(J,I)=F(J,I-1)	WALL4090
440	CONTINUE	WALL 4100
	YI=0.5+(Y(2)+Y(3))	WALL 4110
	Y{3}=0.5*(YI+Y{3})	WALL 4120
	U(3)=0.5*(UI+U(3))	WALL 4130
	IF(NEQ.EQ.1) GO TO 455	WALL 4140
	DO 450 J=I,NPH	WALL4150
450	F(J,3)=0.5+(FI(J]+F(J,3))	WALL 4160
455	ENU(NP1)=EMU(N)	WALL 4170
	6F (NP3)=8F (NP2)	WALL 418A
	VISCO(NP3)=VISCO(NP2)	WALL ATOA
	RH0(NP3)=RH0(NP2)	WALL 4170

T(NP3)=1.	WALL 4210
IF (NPH-E0-0) G0 T0 460	WALL4220
DO 458 J=1.NPH	WALL 4230
458 PR(J.NP3)=PR(J.NP2)	WALL 4240
	WALL 4250
$IF(1 TP) = FO_{-1} HRITF(6_{-6}2)$	WALL 4260
	WALL 4270
470 MD 17E (6.940)	WALL 4280
	WALL 4290
A COMMATCH I SUB-2 WAS INVOKED RECAUSE SHEAR STRESS RATIO"/	WALL 4300
TA TH MALL EUROTICH OT LESS THAN 0.1. DUE PROBABILY!	WALL 4310
TH WALL FORCE DESCRIPT OF SIGNATION ()	WALL 4320
2 TO ECCENTIVE PROCEDUM TERMINATER RECAUSE N HAS EXCEEDED THE!/	MAL1 4330
THE PORTATION PROGRAM TERMINATED DECADE IN THE PROGRAM TERMINATED	WALL4340
I NUMBER OF FLOW TODES FOR WIGH THE FROM TS STRATSOND FF	WALL 4350
YZU FURMATIIATIIA MAS SHIFTED TU TIZTIAT TATO TITT	4411 4360
RE I UKN	UA11 4370
END	BALL 4370

	AUX00000
SUDKUUTINE AUA	AUX00010
L	AUX00020
INTEGER GEUMFFLUTUTSGURGETSTASTACETBURGETOTTETTET	AUX00030
	AUX00040
1PUDE, PRT (5), PRE, NABC, & (10) /, RW(100), FJ(3), 100/, GC, CJ, AN(100), FW(10)	
2UG(100), PO, SOURCE, RETRAN, NUMRUN, SPALE, RHU, PPLAG, DU JPUT, DELTAA, GV	AUXUUUJU
3/E/N,NP1,NP2,NP3,NEQ,NPH,KEX,KIN,KASE,KRAD,GEOM,FLUID,BUDFUR, PMI	AUXUUU60
4/GG/BETA,GAMA(5),AJI(5),AJE(5),INDI(5),INDE(5),TAU,OWF(5)	AUX00070
5/V/U(54),F(5,54),R(54),DN(54),Y(54),UGU,UGD,UI,FI(5),FHEAN,TAUW	AUX00080
6/w/SC(54),AU(54),BU(54),CU(54),A(5,54),B(5,54),C(5,54),SU(5,554),SU(5,554),SU(5,58),SU(5,54),SU(5,54),SU(5,54),SU(5,54),SU(5,54),SU(5,54),SU(5,54),SU(5,54),SU(5,54),SU(5,56),SU(5,56),SU(5,56),SU(5,56),SU(5,56),SU(5,56),SU(5,56),SU(5,56),SU(5,56),SU(5,56),SU(5,56),SU(5,56),SU(5,56),SU(5,56),SU(5,56),SU(5,56),SU(5,56)	JAUX00090
7/L/AK,ALMG,ALMGG,FRA,APL,BPL,AQ,BQ,EMU(54),PREF(5,54),AUXMl	AUX00100
8/L1/YL.UMAX.UMIN,FR.YIP,YEM,ENFRA,KENT.AUXM2	AUX00110
9/P/RH0(54).VISCO(54).PR(5,54).RH0L,VISCOC,PRC(5),T(54).RH0M.BF(54)	AUX00120
1/0/H. REM.CF2.STI51.LSUB.LVAR.CAY.REH.PPL.GPL.QW(5).KD	AUX00130
2/CN/AXX-BXX-CXX-CXX-EXX-K1-K2-K3-SP(54)-AUX1(100)-AUX2(100)-YPMAX	AUX00140
3/ADD/880M(54). [MC(54).80MD(54).1TKE	AUX00150
	AUX00160
	AUX00170
	AUX00175
	AUX00180
	AUX00190
	AUX00200
	AUX00230
	AUY00220
VISH=VISCO(NP3)+FLOAT(KEX-LI=(VISCO(L)-VISCO(NP3))	40400220
UTAU=SQRT(GC+TAUb/RHW)	AUX00230
Abnt=RHM=UTAU/VISh	AUX00240
IF (INTG.GT.I) GC TO LO	AUX00250
KOUNT=0	AUX00260
IF (MODE.EQ.2) KCLNT=1	AUX00270
1 RAVG=R(1)	AUX00280
RHOAV=RHO(1)	AUX00290
VI SAV=VI SCO(1)	AUX00300
KTURB=0	AUX00310
IF (NPH.EQ.O.AND.PODE.EQ.2.AND.K2.NE.2)WRITE(6,6)	AUX00320
IF (K2.EQ.2.AND.MCDE.EQ.2)WRITE(0,9)	4UX00330
IF ANPH.ED.D.AND.PODE.EQ.2.AND.KD.LT.2) WRITE(6,7)	AUX00340
TE INPH-ED.D.AND.MODE.EQ.Z.AND.KD.GE.21 WRITE(6.8)	AUX00350
TE (NPH-E0-0) 60 TC 10	AUX00360
	AUX00370
	AUX00380
UU J J-IINFN Is /souperink ro 31 (TKE=1	AUX00390
D.	
OH IGTAT.	
$OP \rightarrow VAU P$	
-4	

IF (J.EQ.JTKE.ANC.MODE.EQ.2) WRITE (6.4)	AUX00400
IF (J.EQ.JTKE.AND.MODE.EQ.2.AND.K2.EQ.2) WRITE (6.3)	AUX00410
3 FORMAT(//* K2 SHCULD NOT BE SET EQUAL TO 2 1//)	AUX00420
4 FORMAT(FLOW IS TURBULENT AND PROGRAM IS USING TURBULENT (AUX00420
1/ KINETIC-ENERGY TO EVALUATE EDDY VISCOSTAY EVCEDT IN THEFT	4000430
14 WALL FUNCTION SHERE MITINGS ENGINE TO USED SHOTE THAT THEY	40200440
I DINTED-OUT WANTER DE THE MARKE DE GAMME TO THE MART HEY	AUX00450
I PERINE OUT VALUES OF THE HAVE NU HEANING IN THE NEAR-WALL'	AUX00460
1 REGION, 1-2-, FCR YE LESS (AN B+, OR 2#A+, */)	AUX00470
> 17 (SUUKCE(J].EQ.2) KTUR3=1	AUX004R0
IF (MODE-EQ-1) GC TO 10	AUX00490
IF (KTURB-EQ-0-ANC-K2-NE-2)WRITE (6,6)	AUX00500
IF (KD.LT.2) WRITE (6,7)	AUX00510
IF (KD.GE.2) WRITE (6,8)	AUX00520
6 FORMAT(" FLOW IS TURBULENT AND PROGRAM IS USING THE PRANDT! MIX-+	AUX00530
1/' ING-LENGTH HYPOTHESIS TO EVALUATE EDDY-VISCOSITY//	AUX00330
7 FORMAT(THE VAN DRIEST SCHEME IS BEING USED TO EVALUATE.	AUX00540
1/1 THE MIXING FIENCTH OF LENGTH SCALE DAMATES THE PARCATE	AUX00550
A FORMATION THE EVANGE COMMENTS CALE DAMPING NERK THE WALL '')	AUX00560
1/1 MIXING EVANS SCHEME IS DEING USED IJ EVALUATE THE	AUX00570
CONTRACTOR LENGTH ON LENGTH-SCALE DAMPING YEAR THE WALL. //	AUX00580
FURMATI FLUE IS FURBULENT AND PRUGRAM IS USING THE CONSTANT!/	AUX00590
I' EDDY DIFFUSIVITY OPTION IN THE OUTER REGION //	AUX00600
	AUX00610
10 DO 100 I=2,NP1	AUX00620
YM=0+5+(Y(I+1)+Y(I))	AUX00630
IF (KEX.EQ.1) AM=Y(NP3)-YM	4UX00640
IF (FLUID.EQ.1) GC TO 12	AUX00650
RAVG=0.5+{R(1)+R(1+1)}	AUX00660
RHOAV=0.5¢(RHO(I)+RHO(I+1)}	AUX00670
VISAV=0.5*(VISCO(I)+VISCO(I+1))	AUX00680
12 EMUT=0.	00000000
CV([)=1.	AUX00700
IF (MODE.EQ.1) GC TO 50	AUX00710
KOUNT=KOUNT+1	AUX00720
IF (KOUNT-EO-1) CC TO 1	AUX00720
IF (KASE-E0.2) GO TO 25	AUXOUTSU
C	- 411200750
Canada VAN ORIEST DAMPING FUNCTION	AUX00750
CAPL BPL COMPLETED IN MALL	AUX00700
IF (FLUID-NE-1) VEUTESOPT(PHOAVETAULECCAVETAV	AUXUU770
	AUXU0780
	AUX00790
	AUX00800
AV ITEUE/AFE0014 AUD / DU IU 20 DV/II-1 _ / 2007UTAF/AD	AUX00810
0 TO 22	AUX00820
	AUX00830
Construction	AUX00840
15 DV(I)=VLCC/BPL	AUX00850
20 [F(DV(I).GT.1.) DV(I)=1.	AUX00860
CLOHER LIMIT VALUE DAMPING TERM	AUX00870
22 IF (DV(I).LT.0.0001) DV(I)=0.0001	AUXOORRO
25 CONTINUE	AUX00890
C PRANDTL MIXING LENGTH	AUX00900
IF (1.GT.2) GO TO 30	AUX00910
IF (GEOM-EQ.4.OR.GEOM-EQ.5) GO TO 30	AUX00920
IF (REM.LE.1000R.KZ.EQ.3) GD TD 30	AUX00930
CEMPIRICAL CORRELATION FOR ALMS FOR MALL FLOWS	AUXODOAD
CTHIS CORRELATION THEN OVERRIDES THE INDUIT AN MGG	AUXONGEN
AHOR=AHE/RHO(1)	AUYOAGLA
IF (KIN, EQ. 1) ANDR AN MI/RHO (NP3)	AUX00700
	AUX00970
IF (ALMGALT_ALMGG) ALMGGALMGG	AUX00980

CONDUTE NEXTAG LENCTH	AUX01000
C UMPUTE FIXING LENGTH	AUX01010
JU ALTAINGTIL Thurse En 1 and VM (T A) /AKE AI HAKEYM	AUX0 1020
$\begin{bmatrix} I \\ A \\ A \end{bmatrix} = \begin{bmatrix} A \\ A \end{bmatrix} = $	AUX01030
	AUX01040
IF (KIURB-EQ.I.ANL-NASE-EQ.27 GD TO TO	AUX01050
IF(KASE.EQ.2)GU 1C 35	AUX01502
YTKE=YIIJ=YPUT	AUX0 1054
IF (KEX.EQ.1) YTKE=(Y(NP3)-Y(1+1))=TPU1	AUX01060
IF (KTURB-EQ. 1. ANC-KD-LE-1. AND YTKE GE-2. APE TO TO TO	AUX01070
IF(KTURB.EQ.1.AND.KD.GE.2.AND.VIKE.GE.BPLIGUID 40	AUX01080
35 EMUT=RHOAV+AL+AL+ABS((U(I+1)-U(I))/(Y(I+1)+T(I)))=0(I)+0(I)+0(I)+0(I)+0(I)+0(I)+0(I)+0(I)+	AUX01000
IF(K2-NE+2+OR+KASE+EQ+2)GD TO 36	AUX01070
EMUTC=(AQ+REH++BG)+VISAV	AUX01100
IF (EMUT.GT.EMUTC)EMUT=EMUTC	AUXOIIIO
IF(YM.GT.0.4+YL)EMUT=EMUIC	AUXU1120
36 IF(KTURB.NE.1)60 TO 50	AUX01150
CADJUSTMENT OF THE IN NEAR-WALL REGION	BUXU1140
FJJAVE=((AK*EHUT)/(AQ#RHQAV#AL#DV(I)))##2	AUX01150
F(JTKE, I)=FJJAVE	AUX01160
ITKF=1	AUX01161
TE (KEX_ED.1.AND.ITKE.EQ.1) ITKE=I	AUX01162
	AUX01170
COMPUTE FORY VISCOSITY USING TURBULENT KINEFIC ENERGE EON	AUX01180
$40 = (1 \text{ average} (0.5 \pm (FL) \text{ KE}, 1 + 1) + F(J \text{ KE}, 1))$	AUX01190
EMIT-ADADHDAVAALADVIT 1450RT(FJJAVE)/AK	AUX01200
EFFECTIVE VISCOSITY	AUX01210
	AUX01220
SU EMULTITEMUTVILLAND KASE, EQ. 1) $T(T)$ = ABS(EMU(T)+(U(T+1)-U(T))/	AUX01230
	AUX01240
1(Y(1+1)-Y(1))/(GC-TADR)	AUX01250
IF (NPH.EQ.0) GO TO 100	AUX01260
IF (NPH.EQ.0) GO TO 100 C	AUX01260
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01290 AUX01290
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01310
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01310 AUX01320
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01290 AUX01300 AUX01310 AUX01310 AUX01330
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01300 AUX01310 AUX01330 AUX01330
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01310 AUX01310 AUX01320 AUX01340 AUX01350
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01310 AUX01310 AUX01330 AUX01340 AUX01350 AUX01350
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01310 AUX01310 AUX01330 AUX01340 AUX01350 AUX01360
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01310 AUX01310 AUX01330 AUX01340 AUX01350 AUX01360 AUX01370 AUX01370
IF (NPH.EQ.0) GO TO 100 C	
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01300 AUX01310 AUX01330 AUX01340 AUX01350 AUX01360 AUX01360 AUX01380
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01300 AUX01310 AUX01330 AUX01330 AUX01350 AUX01360 AUX01360 AUX01380 AUX01400
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01290 AUX01300 AUX01300 AUX01310 AUX01320 AUX01330 AUX01340 AUX01350 AUX01360 AUX01360 AUX01390 AUX01400 AUX01410
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01290 AUX01300 AUX01300 AUX01310 AUX01320 AUX01330 AUX01340 AUX01350 AUX01360 AUX01360 AUX01390 AUX01400 AUX01410 AUX01420
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01290 AUX01300 AUX01300 AUX01310 AUX01310 AUX01330 AUX01330 AUX01350 AUX01360 AUX01360 AUX01370 AUX01390 AUX01400 AUX0140 AUX01420 AUX01430
IF (NPH.EQ.O) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01290 AUX01300 AUX01300 AUX01310 AUX01310 AUX01330 AUX01330 AUX01350 AUX01360 AUX01360 AUX01370 AUX01390 AUX01400 AUX0140 AUX0140 AUX01440 AUX01440
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01300 AUX01310 AUX01310 AUX01330 AUX01350 AUX01350 AUX01360 AUX01360 AUX01370 AUX01390 AUX01400 AUX0140 AUX0140 AUX01430 AUX01430 AUX01440
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01290 AUX01300 AUX01300 AUX01310 AUX01310 AUX01330 AUX01330 AUX01340 AUX01350 AUX01360 AUX01360 AUX01390 AUX01400 AUX0140 AUX0140 AUX01450 AUX01460
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01290 AUX01300 AUX01300 AUX01310 AUX01310 AUX01330 AUX01330 AUX01340 AUX01350 AUX01360 AUX01360 AUX01390 AUX01400 AUX0140 AUX01450 AUX01450 AUX01470
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01300 AUX01300 AUX01300 AUX01330 AUX01330 AUX01350 AUX01360 AUX01360 AUX01400 AUX01400 AUX01400 AUX01440 AUX01450 AUX01460 AUX01460 AUX01470 AUX01460 AUX01470
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01300 AUX01300 AUX01300 AUX01330 AUX01330 AUX01360 AUX01360 AUX01360 AUX01400 AUX01410 AUX01440 AUX01450 AUX01460 AUX01460 AUX01460 AUX01460 AUX01460 AUX01460
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01300 AUX01300 AUX01300 AUX01330 AUX01330 AUX01360 AUX01360 AUX01360 AUX01360 AUX01400 AUX01410 AUX01440 AUX01450 AUX01460 AUX01460 AUX01460 AUX01460 AUX01460 AUX01490 AUX01500
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01280 AUX01290 AUX01300 AUX01300 AUX01310 AUX01310 AUX01330 AUX01330 AUX01350 AUX01360 AUX01360 AUX01360 AUX01400 AUX0140 AUX01440 AUX01450 AUX01460 AUX01460 AUX01460 AUX01460 AUX01470 AUX01480 AUX01490 AUX01500 AUX01510
IF (NPH.EQ.0) GO TO 100 C	AUXO1260 AUXO1270 AUXO1280 AUXO1280 AUXO1290 AUXO1300 AUXO1300 AUXO1300 AUXO1310 AUXO1330 AUXO1330 AUXO1340 AUXO1360 AUXO1360 AUXO1360 AUXO1360 AUXO1400 AUXO1410 AUXO1440 AUXO1450 AUXO1460 AUXO1460 AUXO1460 AUXO1460 AUXO1460 AUXO1450 AUXO1450 AUXO1510 AUXO1520
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01290 AUX01300 AUX01300 AUX01310 AUX01310 AUX01330 AUX01330 AUX01340 AUX01360 AUX01360 AUX01360 AUX01360 AUX01400 AUX01440 AUX01450 AUX01440 AUX01450 AUX01450 AUX01450 AUX01500 AUX01510 AUX01520 AUX01530
IF (NPH.EQ.0) GO TO 100 C	AUX01260 AUX01270 AUX01280 AUX01290 AUX01300 AUX01300 AUX01300 AUX01300 AUX01330 AUX01330 AUX01350 AUX01360 AUX01360 AUX01370 AUX01390 AUX01390 AUX01490 AUX0140 AUX01450 AUX01460 AUX01460 AUX01450 AUX01450 AUX01500 AUX0150 AUX01530 AUX01530 AUX01540

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90 CONTINUE	AUX01560
	AUX01570
DO 110 [=2.NP1	AUX01580
RHDAV=(RHD(IT)+RHD(IT+I))/2.	AUX01600
RAVG = (R(1) + R(1 + 1))/2	AUX01610
CADJUSTMENT OF FHU AT 2.5 AND No.1.5	AUX01620
IF (I.GT.2) GO TC 110	AUX01630
IF (KIN.NE.1) GD TO 105	AUX01640
IF (BETA-LT-0-02-CR-BETA-GT-0-94 G3 T0 110	AUX01650
EMU(2) = TAU = [Y(2) + Y(3)]/(BETA = (11/2) + 11/(3)])	AUXU1560
105 IF (KEX.NE.1) GO TO 110	AUX01670
IF (BETA-LT-0-02-OR-BETA-GT-0.9) GO TO 110	AUX01680
EMU(NP1)=TAU+(Y(NP3)-0.5+(Y(NP1)+Y(NP2)))/	AUX01090
1 (BETA+0.5+(U(NP1)+U(NP2)))	AUX01710
CCOMPUTE SMALL C'S	AUX01720
110 SC(I)=RAVG=RAVG=RHOAV=0.5=(U(I+L)+U(I))=EHU(I)/(PEI=PEI)	AUX01730
[F (NEQ.EQ.1) 60 TO 300	AUX01740
C SOURCE TERM	S AUX01745
UU 200 I=3,NF1	AUX01750
CO 150 J=1,NPH	AUX01760
SU(J,I)=0, and $SU(J,I)=0$	AUX01770
	AUX01780
IF ISUCKLE(J).EQ.07 GD TO 150	AUX01790
	AUX01800
G0 10 (115,130,115,120), NSOR	AUX01810
15 IE (1 50 2) REE(1) PRESIDENT STAGNATION ENERGY EON SOURC	E AUX01820
DEFET (DEFET) INFERT (J) JAPAT	AUX01830
	AUX01840
	AUX01850
CS=(1,=)/000000 (1100(1-1))(1-1)(0(1-1))(0(1-1))	AUX01860
	AUX01870
120 [F ($\mu(1)$) + T ($\mu(0)$) (0 to 125	AUX01980
	AUX01890
IF (SDURCE(J), F0.4) SU(J, I) = AU(M)// FAU(H)// TAU(H)//	AUX01900
125 SD=0.	10X01913
GO TO 150	AUX01920
C TURBULENT KINETIC ENERGY FOUNTION SOURCE	
130 AL=ALMG*YL	AUX01960
IF (KASE.EQ.2) GO TO 140	AUX01950
YMQ=Y(I)	40101970
IF (KEX.EQ.1) YMQ=Y(NP3)-Y(I)	AUX01980
IF (YMQ.LT.AL/AK) AL=AK+YMQ	AUX01990
140_0U2DOM=.5*((U(I+1)+U(I+1)-U(I)+U(I))+RJND(I)+	AUX02000
1 (U(I)+U(I)-U(I-1)+U(I-1))+ROMD(I-1))	AUX0 2010
DVO=.5+(DV(I)+CV(I-1))	AUX02120
FJ2=ABS(F(J,I))	AUX02030
PRUD=AQ#AL#DVQ#SCRT[FJ2]#[RHO(]]#R(]]/PE]]##2/(U(]]#AK#4.]#	AUX()2040
	AUX0 2050
UI33=8474K#FJ27#1.3/(AL#DVQ#U(1))	AUX0 2060
121112340X+01+FJ210135#FJ2/DX	AUX0 2070
JUIJIII=PRUU+U133	4UX0208J
ГОЧ-ГЦЈЛРЈЈ 161710 БЛ ЭЗБЛТ-ЕЈ (1)	AUX02090
IFIKIN-FO.7)FCT=A.A	AUX02100
TE(ELL, T), IT, EGTISH(L, T)=DDAA	AUX0 2110
SD=0_0	AUX02120
GO TO 150	AUX02130
C ADD OTHER SOURCE FUNCTIONS HERE	AUXUZI40
	AUX02150

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CCHANGE "COMPUTED GD TO" STATEMENT TO INCLUDE	AUX02160
C COMPCE ENACTICA STATEMENT ANIMAERS I IVENISE.	AUX02170
C SUURCE FUNCTION STATEMENT NUMBERS. LIKENISCI	
CCHANGE TURBULENT PR/SC NUMBER "COMPUTED GD TO "	AUX02180
C CTATEMENT NUMBER C	AUX02190
C	AUKO2170
150 CONTINUE	AUX02200
	AUX02210
200 CONTINUE	40402210
300 CONTINUE	AUX02220
BE THON	AUX0 2 2 30
	40402230
END	AUXUZZ40
	•
	DUTOODO
SOBROUTINE OUT	00700000
	00.00010
NTHENSTON (1011/5(54), VPLUS(54), HP[54), GRAT(54)	00100020
	01700000
INTEGER FLAG;FLAG2	06000100
INTEGER GEOM-FLUID-SOURCE(5)-SPACE-BODEOR-DUTPUT-TYPBC	00100040
COMPANY OF ANT AND DRAY WIND VINTO CEALEA THREE (5)	011700050
CUMPUN/GEN/PEI;API;APE;DPDA;AU;AD;AL;DA;INIG;CSALPA;IFDCID;	
1MODE,PRT(5),PRE,AXBC,X(100),RH(100),FJ(5,100),GC,CJ,AM(100),PRO,	00100060
246 (100), DO, SOUDE E RETRAN, NUMPUN, SPACE PHO, DOLAG, OUTDUT, DELTAY, GV	00700070
3/E/N+NP1+NPZ+NP3+NEQ+NPH+KEX+KIN+KASE+KKAD+GEUM+FLUIU+BODFOR+YPMIN	
A/GG/BETA.GAMA(5).AJT(5).AJE(5).INDI(5).INDE(5).TAU.OWE(5)	00000100
ending and the set and a meril and a stranger of the end and the	011700100
5/4/U[54];F[5;54];K[54];UR[54];Y[54];UGU;UGU;UI;FI[5];FRCAN;IAUW	COLOOTO0
7/1/AK.ALHG.ALHGG.FRA.APL.BPL.AQ.BQ.EMU(54).PREF(5.54).AUXM1	OUT00110
A PROPERTY WITCOLEAN ADDE SAN SHOT WITCOT ADTIEN TIEAN AND RELEAN	CHT00120
9/P/RHU(54), VISCU(54), PR(5), 541, RHUC, VISCUC, PRC(5), (154), RHCH, DF(54)	00120
1/0/H.REM.CF2.ST(5).LSUB.LVAR.CAY.REH.PPL.GPL.QW(5).KD	00100130
3/CH / A VY BYY FYY FYY FYY H1 H2 H3 CO (54) A 191 (100) AUY2(100) YDMAY	01700160
C	00100150
CD TO (100, 200, 300, 600, 500, 600) . OUTPUT	00100160
100 CONTINUE	20100110
GT TO 1000	DUT00180
	001700100
200 CONTINUE	00100190
200 CONTINUE	0UT00190 0UT00200
200 CONTINUE C	OUT00190 OUT00200 OUT00210
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED	0UT00190 0UT00200 0UT00210
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS;	0UT00190 0UT00200 0UT00210 0UT00220
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CDITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK	00100190 00100200 00100210 00100220 00100220
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK	00100190 00100200 00100210 00100220 00100230 00100230
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT PUST BE THE LAST EQUATION SOLVED.	00100190 00100200 00100210 00100220 00100220 00100230 00100240
200 CONTINUE C C C C PRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, C NITH OR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK C PROPERLY, IT PUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600	00100190 00100200 00100210 00100220 00100230 00100240 00100250
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IE(LINC.NE.1)GC TC 205	00100190 00100200 00100210 00100220 00100230 00100240 00100250 00100250
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205	00100190 00100200 00100210 00100220 00100230 00100240 00100250 00100250 00100250
200 CONTINUE C C C C PRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, C NITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK C PROPERLY, IT PUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE	00100190 00100200 00100210 00100220 00100230 00100240 00100250 00100250 00100260 00100270
200 CONTINUE C C C C PRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, C WITH OR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK C PROPERLY, IT PUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.SQ.1)KSPACE=SPACE IF(KSPACF-EQ.1).CR.KSPACE=EQ.21)SPACE=1	00100190 00100200 00100210 00100220 00100230 00100240 00100250 00100250 00100260 00100280
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH OR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT PUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 600 IF(INTG.RE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NOW EC O)STILLED	00100190 00100200 00100210 00100220 00100230 00100240 00100250 00100250 00100260 00100280
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL HOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WDRK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EC.0)ST(1)=0.0	QUT00190 QUT00200 DUT00210 GUT00220 DUT00230 DUT00240 DUT00250 CUT00260 DUT00270 DUT00280 CUT00290
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT PUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(2)=0.	QUT00190 QUT00200 DUT00210 GUT00220 DUT00230 DUT00240 QUT00250 CUT00260 QUT00270 QUT00280 CUT00290 QUT00290 QUT00300
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL HOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH OR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT PUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.RE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.1)ANC.SCURCE(1).EU.21ST(1)=0.	00100190 00100200 00100210 00100220 00100230 00100240 00100250 0000050 000000000 0000000000
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL HOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WDRK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 600 IF(INTG.RE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.1.ANC.SCURCE(1).EQ.21ST(1)=0.	QUTOD190 QUTOD200 DUTOD210 GUTOD220 DUTOD230 DUTOD230 DUTOD240 DUTOD250 CUTUD260 DUTOD250 CUTUD260 DUTOD280 CUTOD290 QUTOD290 QUTOD310
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHGUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT PUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)REH=0.	QUT00190 QUT00200 DUT00210 GUT00220 DUT00230 DUT00240 GUT00250 CUT00260 GUT00270 GUT00280 CUT00290 GUT00290 GUT00290 GUT00310 GUT00320
200 CONTINUE 200 CONTINUE C THIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL HOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.0)BEF=0.0	QUT00190 QUT00200 DUT00210 GUT00220 DUT00230 DUT00240 QUT00250 CUT00260 QUT00260 QUT00280 CUT00280 CUT00290 QUT00300 CUT00310 QUT00320 CUT00330
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL HOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WDRK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 600 IF(INTG.RE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)REH=0. IF(NPH.EQ.0.0REH=0.0	QUTOD190 QUTOD200 DUTOD210 GUTOD220 DUTOD230 DUTOD230 DUTOD240 DUTOD250 CUTUD260 DUTOD270 DUTOD280 CUTUD280 CUTOD290 DUTOD290 DUTOD300 CUTOD320 CUTOD320 CUTOD340
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 600 IF(INTG.RE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)REH=0. IF(NPH.EQ.0)F(1,1)=0.	QUT00190 QUT00200 DUT00210 GUT00220 DUT00230 DUT00240 GUT00250 CUT00260 GUT00270 DUT00280 CUT00290 GUT00290 GUT00300 CUT00310 DUT00320 CUT00330 GUT00340
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.NE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)REH=0. IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.1) FLAG=1	QUT00190 QUT00200 DUT00210 GUT00220 DUT00230 DUT00240 QUT00250 CUT00260 QUT00260 QUT00280 CUT00290 QUT00390 CUT00390 CUT00310 QUT00320 CUT00330 QUT00330 QUT00350
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL HOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WDRK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 600 IF(INTG.RE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)REH=0. IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1	QUTO0190 QUTO0200 DUT00210 GUT00220 DUT00230 DUT00240 DUT00250 CUTU0260 DUT00270 QUT00280 CUT00290 QUT00290 QUT00290 QUT00300 CUT00320 CUT00330 CUT00350 CUT00350 CUT00360
200 CONTINUE 200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EC.0)ST(1)=0. IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1	QUTOD190 QUTOD200 DUTOD210 GUTOD220 DUTOD230 DUTOD230 DUTOD240 QUTOD250 CUTUD260 QUTOD250 CUTUD260 QUTOD290 QUTOD290 QUTOD300 CUTUD310 QUTOD320 CUTOD320 CUTOD350 CUTUD360 CUTUD360
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL HOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH OR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0. IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.0)REH=0.0 IF(NPH.EQ.0)F(1,1)=0. IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 Z05 FAM=AMI/(RHO(NP3)+U(NP3))	QUT00190 QUT00200 DUT00210 GUT00220 DUT00230 DUT00240 QUT00250 CUT00260 QUT00260 QUT00280 CUT00290 QUT00390 CUT00390 CUT00310 QUT00330 QUT00350 CUT00360 CUT00370
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH OR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.RE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPM.EQ.0)ST(1)=0. IF(NPM.EQ.0.ST(2)=0. IF(NPM.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPM.EQ.0)F(1,1)=0. IF(NPM.EQ.0)F(1,1)=0. IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 205 FAM=AMI/(RHO(NP3)+U(NP3))	QUTOD190 QUTOD200 DUTOD210 GUTOD220 DUTOD230 DUTOD230 DUTOD240 QUTOD250 CUTUD260 QUTOD250 CUTUD260 QUTOD270 QUTOD280 CUTUD280 CUTOD290 QUTOD290 QUTOD390 CUTUD310 CUTOD300 CUT00330 CUT00330 CUT00350 CUTUD360 CUT00370 QUT00380
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.RE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EC.0)ST(1)=0.0 IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.0)REH=0.0 IF(NPH.EQ.0)F(1,1)=0. IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 C	QUT00190 QUT00200 DUT00210 GUT00220 DUT00230 DUT00240 QUT00250 CUT00260 DUT00270 DUT00280 CUT00290 QUT00290 QUT00390 CUT00310 CUT00320 CUT00350 CUT00360 CUT00370 DUT00390
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH OR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.0)RET=0.0 IF(NPH.EQ.0)RET=0.0 IF(NPH.EQ.0)F(1,1)=0. IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 STA=ST(1) G=(H-1.)/(H#SQRT(CF21)	QUT00190 QUT00200 DUT00210 GUT00220 DUT00230 DUT00240 QUT00250 CUT00260 QUT00260 QUT00280 CUT00290 QUT00390 CUT00310 QUT00320 CUT00330 QUT00350 CUT00360 CUT00370 QUT00380 QUT00380 QUT00390
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.RE.1)GC TC 205 IF(INTG.RE.1)GC TC 205 IF(INTG.RE.1)GC TC 205 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.0)REH=0.0 IF(NPH.EQ.0)REH=0.0 IF(NPH.EQ.0)F(1,1)=0. IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=21 205 FAM=AMI/(RHO(NP3)+U(NP3)) STA=ST(1) G=(H-1.)/(H+SQRT(CF2)) BTA=-H+REM+CAY/CF2	QUTOD190 QUTOD200 DUTOD210 GUTOD210 GUTOD220 DUTOD230 DUTOD240 QUTOD240 QUTOD250 CUTUD260 QUTOD260 QUTOD280 CUTUD280 CUTOD290 QUTOD300 CUTOD300 CUTOD300 CUTOD300 CUTOD300 CUTOD300 CUTOD350 CUTUD360 CUTOD370 QUTOD390 DUTOD390 DUTOD400
200 CONTINUE 200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.RE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.0)REH=0.0 IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 Z05 FAM=AMI/(RHO(NP3)+U(NP3)) STA=ST(1) G=(H-1.)/(H#SORT(CF2)) BTA=-H#REM*CAY/CF2 IE(SOURCE(1).EQ.1)STA=ST(2)	QUT00190 QUT00200 DUT00210 GUT00220 DUT00230 DUT00240 DUT00240 DUT00250 CUT00260 DUT00280 CUT00290 QUT00290 QUT00390 CUT00310 CUT00350 CUT00350 CUT00360 CUT00370 DUT00390 DUT00390 QUT00400 CUT00410
200 CONTINUE C CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH OR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CWITH OR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.RE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(NPH.EQ.0)ST(1)=0. IF(NPH.EQ.0)ST(1)=0. IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.0)REH=0.0 IF(NPH.EQ.0)REH=0.0 IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=2 205 FAM=AMI/(RHO(NP3)+U(NP3)) STA=ST(1) G=(H-1.)/(H*SQRT(CF2)) BTA=-H*REM*CAY/CF2 IF(SOURCE(1).EQ.2.AND.NPH.GT.1)STA=ST(2)	QUT00190 QUT00200 DUT00210 GUT00220 DUT00230 DUT00240 QUT00250 CUT00260 QUT00260 QUT00280 CUT00290 QUT00390 CUT00310 QUT00320 CUT00330 QUT00350 CUT00350 CUT00360 CUT00370 QUT00390 QUT00390 QUT00390 QUT00390 QUT00400 QUT00400
200 CONTINUE 200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL HOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH DR WITHGUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 600 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.1).CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 205 FAM=AMI/(RHO(NP3)+U(NP3)) STA=ST(1) G=(H-1.)/(H*SQRT(CF2)) BTA=-H*REM*CAY/CF2 IF(SOURCE(1).EQ.2AND.NPH.GT.L)STA=ST(2) IF(ND.GE.XL)GC TC 210	QUTO0190 QUT00200 QUT00210 QUT00210 QUT00230 QUT00240 QUT00250 QUT00260 QUT00270 QUT00280 QUT00280 QUT00310 QUT00320 QUT00330 QUT00340 QUT00420
200 CONTINUE 200 CONTINUE C CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH OR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT PUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG2=1 205 FAM=AMI/(RHO(NP3)+U(NP3)) STA=ST(1) G=(H-1.)/(H*SORT(CF2)) BTA=-H*REM*CAY/CF2 IF(SOURCE(1).E0.2.AND.NPH.GT.1)STA=ST(2) IF(NTG.NE.FLAG)G TO 210 IF(INTG.NE.FLAG)G TO 210	QUTOD190 QUTOD200 QUTOD200 QUTOD210 QUTOD200 QUTOD230 QUTOD230 QUTOD250 QUTOD250 QUTOD260 QUTOD260 QUTOD290 QUTOD290 QUTOD290 QUTOD290 QUTOD300 QUTOD300 QUTOD300 QUTOD300 QUTOD300 QUTOD360 QUTOD360 QUTOD360 QUTOD360 QUTOD390 QUTOD400 QUTOD420 QUTOD420 QUTOD420
200 CONTINUE 200 CONTINUE C CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.NE.1)GC TC 205 IF(INTG.EQ.1)KSPACE=SPACE IF(NPH.EQ.1)KSPACE=SPACE IF(NPH.EQ.0)ST(1)=0. IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.0)REF=0.0 IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(INTG.EQ.1)FLAG2=1 205 FAM=AMI/(RHO(NP3)+U(NP3)) STA=ST(1) G=(H-1.)/(H*SORT(CF2)) BTA=-H#REM#CAY/CF2 IF(SOURCE(1).EQ.2.AND.NPH.GT.1)STA=ST(2) IF(ND.E.FLAG) GC TO 278 CONTINUE	QUT00190 QUT00200 DUT00210 GUT00220 DUT00230 DUT00240 QUT00250 CUT00260 QUT00270 DUT00280 CUT00290 QUT00290 QUT00290 QUT00300 CUT00310 QUT00310 CUT00310 CUT00350 CUT00350 CUT00360 CUT00370 DUT00360 CUT00370 DUT00360 CUT00370 DUT00400 CUT00420 GUT00420
200 CONTINUE C CPRIMARILY FOR EXTERNAL MOMENTUM AND THERMAL BOUNDARY LAYERS, CWITH OR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.EQ.1)KSPACE=SPACE IF(KIN.RE.1)GC TC 205 IF(INTG.EQ.1)LCR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(2)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)REH=0. IF(NPH.EQ.0)REH=0.0 IF(NPH.EQ.0)REH=0.0 IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=2 IF(SURCE(1).EQ.2AND.NPH.GT.1)STA=ST(2) IF(NTG.NE.FLAG) GO TO 278 210 CONTINUE	QUTO0190 QUT00200 QUT00210 QUT00210 QUT00230 QUT00240 QUT00250 QUT00260 QUT00270 QUT00280 QUT00280 QUT00280 QUT00320 QUT00330 QUT00340 QUT00370 QUT00340 QUT00340 QUT00340 QUT004400 QUT004400 QUT004400 QUT004400
200 CONTINUE 200 CONTINUE 210 CONTINUE	QUTO0190 QUTO0200 DUT00210 QUT00220 DUT00230 DUT00240 QUT00250 QUT00260 QUT00260 QUT00280 QUT00280 QUT00290 QUT00290 QUT00300 CUT00320 CUT00300 QUT00300 QUT00350 CUT00370 QUT00360 CUT00370 QUT00360 CUT00370 QUT00390 DUT00400 QUT00420 SUT00420 SUT00450
200 CONTINUE C CTHIS ROUTINE WORKS PROPERLY ONLY FOR KIN=1. IT IS DESIGNED CPRIMARILY FOR EXTERNAL MOMENTUM AND THEMAL BOUNDARY LAYERS, CWITH OR WITHOUT THE TURBULENT KINETIC ENERGY EQUATION. TO WORK CPROPERLY, IT MUST BE THE LAST EQUATION SOLVED. IF(KIN.NE.1)GC TC 600 IF(INTG.EQ.1)KSPACE=SPACE IF(KSPACE.EQ.11.CR.KSPACE.EQ.21)SPACE=1 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.0)ST(1)=0.0 IF(NPH.EQ.1.ANC.SCURCE(1).EQ.2)ST(1)=0. IF(NPH.EQ.0)REH=0.0 IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(NPH.EQ.0)F(1,1)=0. IF(INTG.EQ.1)FLAG=1 IF(INTG.EQ.1)FLAG=1 205 FAM=ANI/(RHO(NP3)*U(NP3)) STA=ST(1) G=(H-1.J)/(H*SQRT(CF2)) BTA=-H*REM*CAY/CF2 IF(SOURCE(1).EQ.2.AND.NPH.GT.1)STA=ST(2) IF(NTG.HE.FLAG) GC TO 278 210 CONTINUE NINTG=INTG-1 IE(INTG.ED.1.AND_KSPACE.NE_11160 TO 215	QUT00190 QUT00200 DUT00210 GUT00220 DUT00230 DUT00240 QUT00250 CUT00260 QUT00260 QUT00280 CUT00290 QUT00390 CUT00310 QUT00390 CUT00330 CUT00350 CUT00360 CUT00370 QUT00360 CUT00370 QUT00380 QUT00390 QUT00390 QUT00390 QUT00400 CUT00420 SUT00420 SUT00420 CUT00420 CUT00420
200 CONTINUE 200 CONTINUE 20	QUTO0190 QUT00200 QUT00210 QUT00210 QUT00230 QUT00240 QUT00250 QUT00260 QUT00270 QUT00280 QUT00280 QUT00280 QUT00320 QUT00330 QUT00340 QUT00340 QUT00340 QUT003400 QUT004400 QUT004400 QUT004400 QUT004400 QUT004400
200 CONTINUE 200 CONTINUE 20	QUT00190 QUT00200 DUT00210 QUT00220 DUT00230 DUT00240 QUT00250 QUT00260 QUT00260 QUT00280 QUT00290 QUT00290 QUT00290 QUT00290 QUT00300 CUT00300 CUT00300 CUT00300 CUT00350 CUT00370 QUT00360 CUT00370 QUT00400 QUT00420 SUT00420 SUT00420 CUT00420 CUT00420 CUT00420 CUT00420 CUT00420

	IF(INTG.EQ.2.AND.KSPACE.EQ.21)WRITE(6.282)		CUT00490
	IFISPACE.NE.11GO TO 215		CUT00500
	IF(KSPACE.EQ.1)GO TO 215		00700510
	CPL=APL		OUT00520
	IF(KD.GT.1)CPL=BPL		20100530
	WRITE(6,204)NINTG,XU,UGU,CAY,FAM,REM,CF2,H,	REH, STA, F(1, 1), CPL, AME	CUT00540
	IF (KSPACE.EQ.11.AND.XD.LT.XL/GD TU 279		CUT00550
	IF(INTG.EO.FLAG2)GO TO 215		CUT00560
	IF (KSPACE.EQ.21. AND. XD.LT. XLIGO TO 279		CUT00570
	IF(XD_GE_XL) UGU=UGO		CUT00580
215	CONTINUE		CUT00590
~ • • •	\$RTTE(6.280)		CUT 00600
	LPITE(A.2A2)		DUT00610
			00100620
	TELED.GT.11CP(#88)		10100630
	- LETROIGISLIGHE-OFE - MOTTELA, 28AININTC, YH, HGH,CAY,EAM,DEM,CE2,H.(EHASTA ELLA TA CPL ANE	CUT00640
	TEIVI.CT TATUTTEIA. 2861(\$0/1).1=1.51.6.814		01100650
284		X . 64501 21= . F. 9. 3. 1 X. 6450	
200	1/31- EG 3.1V.4400/41+.50 2.1V.4450/51+.50.2.	. 1 Y . 2HG=-	001000000
	1137-1676391A(0)37141-1626391A(0)3713713746963	1 4 72110-1	00100680
200	CTD+C+LA+DTDCTA-+FJ+C+ CTD+C+LA+DTDCTA-+FJ+C+		000000
, ۵۵ع) FURMATY/JOAJOHN 1		001000700
	1 NELUGII//DA/10000//////////////////////////////		00100100
	15(NEQ 80) 01/HR1(E(0)200)		00100720
200	171NEWsEWsIJERIIE1092703 N 206matij 29 446 t		00100120
290	TAUDIAL ()	PEUSICI OPEUSICI	011700760
202	1	9 . 9 ¥. 69 . 4. 5¥ . 67. 4 .	CUT00760
272	; FURMAI(0A)[2;7A;F0;0;2A]F1;2;JA;F0;2;UA;FJ; 187 84 3 57.87 3)		01700770
	174170+2164171+21 	(1)	CUT00790
	I DIIT+1 . //!!/NG21 ± CCGT/CE2±0 MD/NG31/DHC[111]		01700790
	TEINDH EN NICH TE 202		00100100
	- 1F(NFN+EV+U/UU (U 275 - TE/ABČŽŽČŽI IVEC// ND3VV+ST/1)V (T - 0001)CO	70 293	01100810
	TE INEA OF 1 ANA CONDECT13 NE 2140 H_{\pm} CORT(C)	2 + PHO(1)/PHO(NP3)//	00100820
,	1 (15/1.1)_5(1.ND2))#CT(1))		CUTOOR30
	1 ////////////////////////////////////		00100831
~	- CHANCE MILTE DIMENSIONING CHANGED EXERTERET	**********	CUT00832
201	NI-EA		00100833
r 273	FU-24		CUT00834
			00700840
· •	NeT		CUT00850
			OUT00860
			CUT00870
	16/1 NE.2100 TO 245		CUT00880
	CO TO (340, 335, 350, 255, 251, NED		00100890
220	00 10 1240922392209223922092239122391224		00700900
. 220	ICICONDECTIVECECTOD TO 235		01000010
	[F[]]UKUELZ/0NE0Z/0U (U 22)		01700920
	QKAI(HUJ=3QKI(#D3(FI(2))// UNF3/		00100920
225	0 1F(SUUKCE(1).EQ.2)GU TU 233		00100940
		TO 230	00100950
	- /F(ADS((F(1,1)=F(1,NF3/)*3)(1/).(1.0001/30)	10 200	04200100
	TT1 MULETIAL		01100970
230	CO TO 340		CUTDO980
335	UU TU 27U 2 AD AT/MUL-CADT/ABC/CT/11141/11/ND23		00100990
230	V WERTERNISON (1003121171)/ ALULASI V MULLA BAINITIANIAN		00101000
240	TLMU/-V#D-TTTT///		CUT01010
	ULTU/TUI Varuežmit_a salv/stav/stavbit		RUTO 1020
	TPLUDIAUJ=U.J=IT(LIFTIJIJ=TPU) UNIUCINUL-UT4UNUT		CUT01030
			00701040
			1 11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
	HENU Tritten Norten To 374		00101040

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	GO TO (250,255,265,255,255),NEQ	OUT01060
250	TAUPL=1.0	00101070
	IF(I.NE.1.ANC.P.NE.MU)TAUPL=0.5*(1(H)+1(H-1))	00101080
	IF(M.EQ.MU)TAUPL=TAU/(GC+TAUH)	00101090
	IF(I.EQ.NP3)TAUPL=0.0	00101100
	WRITE(6,292) M,Y(M,U(M),YPLUS(M),UPLUS(H),TAUPL	
	GO TO 274	00101120
255	IF(SOURCE(1).EG.2)GO TO 272	00101130
	HP(I)=0.0	00101140
	IF(ABS((F(1,1)-F(1,NP3))+ST(1)).LT3001)GD TO 260	CU101150
	HP(I)=(F(1,1)-F(1,I))+HPUT	00101160
260	WRITE(6,292) M, Y(M),U(M),YPLUS(M),UPLUS(M)	CUT01170
	1,HP(M)	00101180
	GO TO 274	0101190
265	IF(SOURCE(1).EQ.2)GO TO 272	00101200
	IF(SOURCE(2) NE-21GO TO 255	00101210
	QRAT([]=SQRT(ABS(F(2,1)))/U(NP3)	00101220
	HP(I)=0.0	00101230
	IF(ABS((F(1,1)-F(1,NP3))).LT0001)GD TJ 270	00101240
	HP(I)=(F(1,1)-F(1,I))+HPUT	OUT01250
270	WRITE(6,292) M+Y(M),U(M),YPLUS(N),UPLUS(N),HP(M),QRAT(M)	00101260
	GD TO 274	00101270
272	QRAT(I)=SQRT(A8S(F(1,1)))/U(NP3)	OUT01280
	CUMM Y=0.0	OUT01290
	WRITE(6,292}#,Y(#),U(M),YPLUS(M),UPLUS(M),DUMMY,QRAT(M)	JUT01300
274	CONTINUE	OUT01310
	WRITE(6,280)	OUT01320
	IF(XD.GT.XL)GO TC 276	OUTO 1330
	IF(INTG.EQ.1)GO TC 276	OUT01340
	IF(KSPACE.EQ.11.OR.KSPACE.EQ.21)WRITE(6,282)	00101350
276	CONTINUE	OUT01360
280	FORMAT(//)	OUT01370
	FLAG2=FLAG2+KSPACE-1	00101380
279	FLAG=FLAG + SPACE	CU101390
278	CONTINUE	00101400
282	FORMAT(7,115H INTG XJ UGU K F REM	00101410
	1 CF2 H REH ST F(1,WALL) APL OR BPL AME)	00101420
284	FORMAT(3X,13,2X,F7.4,2X,F7.2,1X,E10.3,2X,F6.4,1X,F7.1,2X,F8.6,2X,	00101430
	1F5.3, 3X, F7.1, 2X, F8.6, 2X, F8.2, 2X, F6.2, 2X, F6.4)	
_	RETURN	00101450
C	•	CUTU1460
300	CONTINUE	00101470
	GO TO 1000	00101480
_ 400	CONTINUE	00101490
C		01101500
C • • • •	THIS OUTPUT ROUTINE IS DESIGNED PRIMARILY FUR FLUW IN A TUDE.	00101510
	IF(INTG.NE.IJGO TO 404	00101520
	KSPACE= SPACE	00101030
	IF (NPH. GT. OFGU TU 403	00101540
	51(1)=0.0	00101550
		00101500
	P11)7731#U+U	01101570
		01101500
403		00101270
	FLAGETI TELEGARE EN 11 DE VERARE EN 311504/5-1	00101000
404	12/40 72 4/170 70 402 17/170 72 4/170 70 402	011701620
	ITTAU-UC-ALIGU TU TV7 TE/INTC NE SLACICA TA 425	00101620
ANE	[T11NID0NE0FLA0100 10 767	OUT01640
407	ципі іпус Барміт/Эх. Бытитсь, Га. 1 У. 24 ўйн. БК. 2°1 У. 240 Бн. БО. 1.	01170 1450
400	TUNNA I I GAJ JNAN I V-31J JAAJ JNAV-31 VA J34A 339RG-31 7887	20.01030

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11X,4HCF2=,F7.5,1X,3HST=,F7.5,1X,3HNU=,F7.2,1X,3HUM=,F7.2,1X,	OUT01660
13HFM=,F9.2,1%,6HPRESS=,F10.3,1%,3HFW=,F8.2)	OUT01670
NINTG=INTG-1	OUT01680
<u>1</u> هـل	OUT01690
IF(SOURCE(J), EQ. 2, AND_NPH, EQ. 2) J=2	OUT01700
IF (SOURCE(J), EQ. 2, AND, NPH, EQ. 1) ST(1)= $0, 0$	00101710
ANU=ST(J)+PR(J.7)+REN	DUT01720
CNOTE THAT NUSSELT HERE IS CALCULATED FROM 1=7 PR. WHEREAS THE	CUT01730
CARLE OTHER PARAMETERS ARE RASED ON MIXED MEAN TEMPERATURE	DUTO 1740
 UPITE (A.AAANTATC. VI. DEM. CE2.ST/L. MULLIC. EMEAN. DO. C/ 1. NO3)	00101750
	CUT01760
A = COMAT(1) + 2A + COTO(1) + COTO(1) = COT(1) = COT(1) + COTO(1) = COT(1) + COTO(1) + COTO(1) = COTO(1) + COTO(1)	CUTO1780
$\frac{1}{1000}$	00101770
15/5/-1510-5114/511/510/14/-1510-51/4/005/51/-1510-57	00101780
	00101190
	00101800
	010101010
	00101820
404 FURMAIL/,224,427 1 T(1) V(1) F(1,1) F(2,1)	0101830
1,5X,*YPL*,5X,*UPL*,7X,*EDK*,6X,*!(11*7)	00101840
410 WRITE(6,484)	CUT01850
486 FURMAT16X, 12, 3X, F9.6, 2X, F7.2, F10.2, F10.2, 3X, F8.2, 2X, F6.2,	00101860
14x,F6.2,4x,F7.2)	OUT01870
	CUT01880
YPUT=UGU+SQRT(CF2)	DUT01890
DO 415 I=1,NP3	CUT01900
IF(KEX_EQ.1)YPL=(Y{NP3)-Y{[]}*RH0(NP3)*YPUT/VISCO(NP3)	OUT01910
IF(KIN.EQ.1)*PL=(*(I)-*(1)*RHO(1)*YPUT/VISCO(1)	DUT01920
UPL=U(I}/YPUT	OUT01930
IF(NPH-EQ.1)F(2,1)=0.0	CUT01940
[F{[.GT.2.ANC.I.LT.NP2}EDR={EMU([]+EMU([-1))/(2.#VISCO(1))	OUT01950
IF(1.LT.3.OR.I.GT.NP1#EDR=1.0	CUT01960
IF (NPH. EQ.O) #RITE (6.486) [.Y(I).U(I).DUM.DUM.YPL.UPL.EDR.T(I)	00101970
IF(NPH-GT-O) WRITE(6.446) I. Y(1). U(1). F(1.1). F(2.1). YPL. UPL. EDR. T(1	00701980
415 CONTINUE	CUT01990
WRITE(6.488)	OUT 0 2000
488 FORMAT(//)	00702010
FLAG2=FLAG2+KSPACE-1	00102020
420 CONTINUE	CUT0 2030
	00102040
425 CONTINUE	01110 2050
OFTION	00102060
for an and the second	011702070
500 CONTINUE	00102010
	DUTO 2000
	00102090
C THE IS A CENERAL BURRASE OUTDUT DOUTING	00102100
C THIS IS A GENERAL FUNFUSE DUIFUI RUUTINE	00102113
	00102120
	00102130
	00:02140
IFIND GEALINED TO GOD	00102150
IF(IN(G.NE.FLAG)GL TO 620	00102160
	00102170
NINIGEINTGEI	00102180
680 FURMAT(//,2X,5HINTG=,13,2X,3HXU=,F8.5,2X,4HPEI=,F8.5,2X,4HAMI=,	00102190
1r8+4+2X+4HAME=+F8+4+2X+9HPRE55URE=+F9+3+2X+5HBETA=+F7+4+2X+	00102200
22HK=,E10.3)	0102210
682 FORMAT(12X,4HREM*,F9.1,2X,4HREH=,F9.1,1X,4HCF2=,F8.6,2X,9HA OR BP	LUUT02220
1=,F6.2,2X,2HH=,F6.3,2X,7H3HO(1)=,F7.4,2X,9H3HO(NP3)=,F7.4)	CUT02230
684 FORMAT(12X,28HCISPLACEMENT OF I-SURFACE = +F7.5)	TUT02240
686 FORMAT(12X,9HST(J)= ,5F9.61	CUT02250

1 T(1) $F(1,1)$ $F(2,1)$ $F(3,1)$ $F(4,1)$ $F(5,1)'/)$	
	00702270
690 FORMAT(4x.12.1X.F8.6.2X.F7.4.3X.F7.5.1X.F7.2.2X.F10.7.2X.F6.1.2X.	OUT02280
15510-31	CUT02290
402 EDBMAT (41, 12, 14, FR. 4, 24, F7, 4, 34, F7, 5, 14, F7, 2, 24, F10, 7, 24, F6, 3)	CUT02300
UPITCIA ADDITITC YIL DELLANI, AME, DEG. AFTA, CAY	00102310
	011702320
TELATE EA DI CA TA 410	00102330
IFINASCIEVIZI DU LU DU	00102350
IF(KU+GI+IICEUFDE) Techter folluntter((anitem DSU (Et (D)) u (amo/1) (bmo/ND3)	00102350
IF(KASE.EV.I IKKI IE(0,002/KEM;KEM;KEY)(F2, ()KUULI; KUULF)	
694 FORMAT(12X,2FF=,F6.3,2X,74VWPLUS=,F7.4,2X,6HPPLUS=,F7.4,2X,6H) AUMA	00102300
1LL±,F9.6)	00102370
IF(KASE.NE.1)GO TO 610	10102380
[F(KIN.EQ.1.AND.U(NP3).GT.O.OO1)FAM=AHI/(J(NP3)=RHD(NP3))	00102390
IF{KEX.EQ.1.AND.U(1).GT.0.001}FAM=AME/(U(1)*RHO(1))	CUT0 2400
WRITE(6,694)FAM,GPL,PPL,TAUW	DUT02410
610 IF(GEOM.EQ.9)WRITE(6,684)RWO	OUT0 2420
EMU(1)=0.0	NUTO2430
IF(KASE.EQ.1.AND.NPH.NE.O)WRITE(6,686)(ST(J),J=1,NPH)	OUT0 2440
IF(KASE.EQ.1.AND_NPH.NE.D)WRITE(6,696)(Qw(J),J=1,NPH)	DUT02450
696 FORMAT(12X,8HQWALL= ,5F10.5)	ULLO 2460
658 FORMAT(12X,9MGAMA(J)= ,5F9.5)	QUT02470
IF (KASE.EQ.1.AND.APH.NE.D) WRITE (6,698) (GANA(J), J=1, NPH)	CUTO 2480
IF(K1, GT, 10) = RITE(6, 699)(SP(I), I=1, 5)	CUTO 2490
699 FORMAT(12X.23HSPECIAL OUTPUT - SP(1)=,E10.3,1X.6HSP(2)=,E10.3,1X.6	5 CUTO 2 500
1HSP(3) = F10.3.1X.6HSP(4)=.F10.3.1X.6HSP(5)=.E10.3)	CUT02510
	00702520
	OUTO 2530
	QUT0 2 540
	OUT02550
TE (NOH E0.0) - DETTE (A.492) T. Y(1). B(1). UM(1). U(1). FMU(1).T(1)	CUT0 2 560
T = T = T = T = T = T = T = T = T = T =	CUT0 2570
1 (I I I I I I I I I I I I I I I I I I	CUT02580
	CUT02590
	OUTO 2600
	CUT0 2610
CZU CUNTINUE BETTION	00102620
	CUT0 2630
	04702640
REIORN	0010 2650
5ND	
END	
END	PROPAGO
SUBROUTINE PROPZ(K,FX,TI,VISCOI,PRA,RHDA)	PROP 0000
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C	PROP 0000 PROP 0010 PROP 0010
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC	PROP 0000 PROP 0010 PROP 0010 PROP 0020
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERFINED FROM F(J,I) AND U(I). IT IS ESSENTIALLY A CENTHALPY DETERFINED FROM F(J,I) AND U(I). IT IS ESSENTIALLY A	PROP 0000 PROP 0010 PROP 0020 PROP 0030 PROP 0041
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERFINED FROM F(J,I] AND U(I). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED DISTURBULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED	PROP 0000 PROP 0010 PROP 0020 PROP 0030 PROP 0041 P20P 0050
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERFINED FROM F(J,I] AND U(I). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CIN USING THIS SUPROUTINE THAT THE DEPENDENT VARIABLE IN THE	PROP 0000 PROP 0010 PROP 0020 PROP 0030 PROP 0044 PROP 0050 PROP 0050
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERFINED FROM F(J,I] AND U(I). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CIN USING THIS SUPROUTINE THAT THE DEPENDENT VARIABLE IN THT CTHERMAL ENERGY EQUATION IS STAGNATION ENTHALPY.	PROP 0000 PROP 0010 PROP 0020 PROP 0030 PROP 0030 PROP 0050 PROP 0050 PROP 0050
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERPINED FROM F(J,I) AND U(I). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CIN USING THIS SUBROUTINE THAT THE DEPENDENT VARIABLE IN THT CTHERMAL ENERGY EQUATION IS STAGNATION ENTHALPY. C HERE:	PROP 0000 PROP 0010 PROP 0020 PROP 0030 PROP 0030 PROP 0050 PROP 0050 PROP 0050
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERPINED FROM FLJ,IJ AND ULI). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CIN USING THIS SUPROUTINE THAT THE DEPENDENT VARIABLE IN THT CTHERMAL ENERGY EQUATION IS STAGNATION ENTHALPY. C HERE: C K=1 IMPLIES START WITH LOWEST TABULATED STATIC ENTHALPY	PROP 0000 PROP 0010 PROP 0020 PROP 0030 PROP 0030 PROP 0030 PROP 0030 PROP 0030 PROP 0030
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERPINED FROM FLJ,IJ AND ULI). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CIN USING THIS SUPROUTINE THAT THE DEPENDENT VARIABLE IN THT CTHERMAL ENERGY EQUATION IS STAGNATION ENTHALPY. C HERE: C K=1 IMPLIES START WITH LOWEST TABULATED STATIC ENTHALPY C =2 IMPLIES START WITH PREVIDUSLY USED TABULATED STATIC	PROP 0000 PROP 0010 PROP 0020 PROP 0030 PROP 0030 PROP 0030 PROP 0030 PROP 0030 PROP 0030 PROP 0030
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERPINED FROM FLJ,IJ AND ULI). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CIN USING THIS SUPROUTINE THAT THE DEPENDENT VARIABLE IN THT CTHERMAL ENERGY EQUATION IS STAGNATION ENTHALPY. C HERE: C K=1 IMPLIES START WITH LOWEST TABULATED STATIC ENTHALPY C ENTHALPY C ENTHALPY	PROP 0000 PROP 0010 PROP 0020 PROP 0030 PROP 0030 PROP 0030 PROP 0030 PROP 0030 PROP 0030 PROP 0030 PROP 0100 PROP 0110
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERFINED FROM F(J,I) AND U(I). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CIN USING THIS SUPROUTINE THAT THE DEPENDENT VARIABLE IN THT CTHERMAL ENERGY EQUATION IS STAGNATION ENTHALPY. C HERE: C K=1 IMPLIES START WITH LOWEST TABULATED STATIC ENTHALPY C ENTHALPY C HI=ABSOLUTE STATIC ENTHALPY(G/LBM)	PROP 0000 PROP 0010 PROP 0020 PROP 0030 PROP 0030 PROP 0030 PROP 0050 PROP 0050 PROP 0050 PROP 0050 PROP 0050 PROP 0100 PROP 0110
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERPINED FROM FLJ,IJ AND ULI). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CIN USING THIS SUPROUTINE THAT THE DEPENDENT VARIABLE IN THT CTHERMAL ENERGY EQUATION IS STAGNATION ENTHALPY. C HERE: C K=1 IMPLIES START WITH LOWEST TABULATED STATIC ENTHALPY C ENTHALPY C HI=ABSOLUTE STATIC ENTHALPY(B/LBM) C HI=ABSOLUTE STATIC ENTHALPY(B/LBM) C PRE-STATIC PRESSURE (LBF/SQ.FT.I)	PROP 0000 PROP 0010 PROP 0020 PROP 0030 PROP 0030 PROP 0030 PROP 0030 PROP 0030 PROP 0030 PROP 0100 PROP 0110 PROP 0120 PROP 0120
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C C C C C C C ENTHALPY DETERFINED FROM F(J,I) AND U(I). IT IS ESSENTIALLY A C ENTHALPY DETERFINED FROM F(J,I) AND U(I). IT IS ESSENTIALLY A C TABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED C IN USING THIS SUPROUTINE THAT THE DEPENDENT VARIABLE IN THT C THERMAL ENERGY EQUATION IS STAGNATION ENTHALPY. C HERE: C K=1 IMPLIES START WITH LOWEST TABULATED STATIC ENTHALPY C ENTHALPY C HI#A@SOLUTE STATIC ENTHALPY(G/LBM) C RHDA=CALCULATED DENSITY (LBM/(CU.FT.)) HIFCOLOCALCULATED DENSITY (LBM/(CU.FT.))	PROP0000 PROP0010 PROP0020 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0100 PROP0110 PROP0120 PROP0120
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERFINED FROM F(J,I) AND U(I). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CTHERMAL ENERGY ECUATION IF THAT THE DEPENDENT VARIABLE IN THT CTHERMAL ENERGY ECUATION IS STAGNATION ENTHALPY. C HERE: C K=1 IMPLIES START WITH LOWEST TABULATED STATIC ENTHALPY C ENTHALPY C HI=ABSOLUTE STATIC ENTHALPY(G/LBM) C PRE=STATIC PRESSURE (LBF/SQ.FT.I) C RHDA=CALCULATED DENSITY (LBM/(SEC.FT.I)) C VISCOI=CALCULATED DYNAMIC VISCOSITY (LBM/(SEC.FT.I))	PROP0000 PROP0010 PROP0020 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0100 PROP0100 PROP0120 PROP0140 PROP0140
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PRDPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERPINED FROM F(J,I) AND U(I). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CIN USING THIS SUBROUTINE THAT THE DEPENDENT VARIABLE IN THE CTHERMAL ENERGY EQUATION IS STAGNATION ENTHALPY. C HERE: C K=1 IMPLIES START WITH LOWEST TABULATED STATIC ENTHALPY C ENTHALPY C HISSOLUTE START WITH PREVIDUSLY USED TABULATED STATIC C HI=ABSOLUTE STATIC ENTHALPY(G/LBM) C PRE=STATIC PRESSURE (LBF/SQ.FT.)) C VISCOI=CALCULATED DYNAMIC VISCOSITY (LBM/(SEC.FT.)) C PRA=CALCULATED PRANDTL NUMBER	PROP0000 PROP0010 PROP0020 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0130 PROP0120 PROP0130 PROP0140 PROP0150 PROP0150
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERPINED FROM F(J,I) AND U(I). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CIN USING THIS SUBROUTINE THAT THE DEPENDENT VARIABLE IN THT CTHERMAL ENERGY EQUATION IS STAGNATION ENTHALPY. C HERE: C K=1 IMPLIES START WITH LOWEST TABULATED STATIC ENTHALPY C ENTHALPY C HITAESOLUTE START WITH PREVIDUSLY USED TABULATED STATIC C HITAESOLUTE STATIC ENTHALPY(8/LBM) C PRE-STATIC PRESSURE (LBF/SQ.FT.)) C VISCOI=CALCULATED DYNAMIC VISCOSITY (LBM/(SEC.FT.)) C PRA=CALCULATED TEMPERATURE (DEG. RANKINE)	PROP0000 PROP0010 PROP0020 PROP0030 PROP0030 PROP0030 PROP0050 PROP0050 PROP0050 PROP0050 PROP0100 PROP0100 PROP0120 PROP0130 PROP0140 PROP0160 PROP0160
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERFINED FROM F(J,I) AND U(I). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CIN USING THIS SUPPOUTINE THAT THE DEPENDENT VARIABLE IN THT CTHERMAL ENERGY EQUATION IS STAGNATION ENTHALPY. C HERE: C K=1 IMPLIES START WITH LOWEST TABULATED STATIC ENTHALPY C ENTHALPY C ENTHALPY C HI=ABSOLUTE START WITH PREVIDUSLY USED TABULATED STATIC C HI=ABSOLUTE STATIC ENTHALPY(B/LBM) C PRE-STATIC PRESSURE (LBF/SQ.FT.)) C VISCOI=CALCULATED DENSITY (LBM/(CU.FT.)) C PRA-CALCULATED DRANDTL NUMBER C TI=CALCULATED TEMPERATURE (DEG. RANKINE)	PROP0000 PROP0010 PROP0020 PROP0030 PROP0030 PROP0030 PROP0050 PROP0050 PROP0050 PROP0050 PROP0080 PROP0100 PROP0120 PROP0120 PROP0150 PROP0160 PROP0160 PROP0170
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PRDPERTIES OF AIR AT ABSOLUTE STATIC CTHIS PROGRAM CALULATES THE PRDPERTIES OF AIR AT ABSOLUTE STATIC CTHIS PROGRAM CALULATES THE PRDPERTIES OF AIR AT ABSOLUTE STATIC CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CTHOUSING THIS SUPROUTINE THAT THE DEPENDENT VARIABLE IN THT CTHERMAL ENERGY EQUATION IS STAGNATION ENTHALPY. C HERE: C K=1 IMPLIES START WITH LOWEST TABULATED STATIC ENTHALPY C HERE: C K=1 IMPLIES START WITH PREVIDUSLY USED TABULATED STATIC C ENTHALPY C HI=ABSOLUTE STATIC ENTHALPY(8/LBM) C PRE=STATIC PRESSURE (LBF/SQ.FT.)) C PRA=CALCULATED DENSITY (LBM/(CU.FT.)) C PRA=CALCULATED TEMPERATURE (DEG. RANKINE) C TI=CALCULATED TEMPERATURE (DEG. RANKINE)	PROP0000 PROP0010 PROP0020 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0130 PROP0120 PROP0120 PROP0120 PROP0140 PROP0140 PROP0140 PROP0160 PROP0160
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERPINED FROM F(J,I) AND U(I). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CIN USING THIS SUPROUTINE THAT THE DEPENDENT VARIABLE IN THT CTHERMAL ENERGY EQUATION IS STAGNATION ENTHALPY. C K=I IMPLIES START WITH LOWEST TABULATED STATIC ENTHALPY C ENTHALPY C HERE: C ENTHALPY C HI=ABSOLUTE STATIC ENTHALPY(G/LBM) C PRE-STATIC PRESSURE (LBF/SQ.FT.I) C VISCOI=CALCULATED DENSITY (LBM/(CJ.FT.I)) C PISCOI=CALCULATED DENSITY (LBM/(SCOSITY (LBM/(SEC.FT.I))) C TI=CALCULATED TEMPERATURE (DEG. RANKINE) C TI=CALCULATED TEMPERATURE (DEG. RANKINE)	PROP0000 PROP0010 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0130 PROP0130 PROP0130 PROP0140 PROP0140 PROP0160 PROP0160 PROP0160
END SUBROUTINE PROP2(K,FX,TI,VISCOI,PRA,RHDA) C CTHIS PROGRAM CALULATES THE PROPERTIES OF AIR AT ABSOLUTE STATIC CENTHALPY DETERPINED FROM F(J,I) AND U(I). IT IS ESSENTIALLY A CENTHALPY DETERPINED FROM F(J,I) AND U(I). IT IS ESSENTIALLY A CTABULATION OF THE ECKERT AND DRAKE TABLES. IT IS ASSUMED CTN USING THIS SUPROUTINE THAT THE DEPENDENT VARIABLE IN THE C THERMAL ENERGY EQUATION IS STAGNATION ENTHALPY. C HERE: C K=I IMPLIES START WITH LOWEST TABULATED STATIC ENTHALPY C ENTHALPY C ENTHALPY C FILLES START WITH PREVIDUSLY USED TABULATED STATIC ENTHALPY C PRE-STATIC PRESSURE (LBF/SQ.FT.I) C PRE-STATIC PRESSURE (LBF/SQ.FT.I) C VISCOI=CALCULATED DENSITY (LBM/(CJ.FT.I)) C TI=CALCULATED TEMPERATURE (DEG. RANKINE) C TI=CALCULATED TEMPERATURE (DEG. RANKINE)	PROP0000 PROP0010 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0030 PROP0130 PROP0130 PROP0130 PROP0140 PROP0140 PROP0140 PROP0140 PROP0140
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THREED DEAN FLUTD FOUDEFLEN FALLS DOOF DUS TRANT THREE	
INTEGER GEOM, FLUTU, SUURCETST, SPACE, BUDFUR, USTPUT, TYPEC	PROPOINO
COMMON/GEN/PEI;API;AME;DPJX;XJ;XD;XL;DX;IATG;CSALFA;TYPBC(5);	PP]P 0 1 90
1MODE, PRT(5), PRE, NXBC, X(13)), Ra(100), FJ(5,100), GC, CJ, AM(100), PRO,	PRCP 0 200
2UG (100) • PO • SGURCE • RETRAN • NUNRUN • SPACE • RWD • PPI AG• OUTPUT • DELTAX • GV	PR0210
5/V/11/54) - E/5 - 541 - 8/54) - 00/ 541 - 9/541 - 4/61- 120- 4/7 - E/7 51 - EMEAN - TAUM	00000220
	000000000
1707H;REF;CF2;S1157;CSUB;CVAR;CAT;REH;PPC;GPL;QPC;UW(5);RU	0230
 D[MENSIGN HA(34),TA(34),VS(34),PA(34)	PR0P0240
DATA HA(1),HA(2),HA(3),HA(4),HA(5),HA(6),HA(7),HA(8),HA(9),HA(10)	, PROP 0 250
1MA(11) •HA(12) •PA(13) •HA(14) •HA(15) •HA(16) •HA(17) •HA(18) •HA(19) •	PROP 0260
744/201 44/211 44/221 44/221 44/24 4/24 4/26 44/26 4/26 4/26 4/26 4/	00000270
$\sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{i=1}^{n} \sum_{i=1}^{n} \sum_{i=1}^{n} \sum_{i=1}^{n} \sum_{i$	PP.0= 0273
JFA(291, HA(301, FA(31), HA(321, HA(331, HA(341/42.09, 04.43, 85.97)	PRUPUZHU
4107.50,129.06,150.68,172.39,194.25,216.26,238.50,260.97,283.68,	PROPOZOO
🔬 5306.65,329.88,253.37,377.11,401.09,425.29,449.71,499.17,549.35, 👘	PP.0P.0300
6600.16.651.51.703.35.755.61.808.28.861.28.914.61.968.21.	PROP0310
71022-09-1076-20-1130-56-1185-11-1/76-47/	PP-1P-0-320
	. 00000330
	PROP0330
ITALII, TALIZI, TALISI, TALI47, TALISI, TALISI, TALI7, TALI81, TALI97,	PROPUSAU
2TA(20), TA(21), TA(22), TA(23), TA(24), TA(25), TA(26), TA(27), TA(28),	PROP 0 350
3TA(29), TA(30), TA(31), TA(32), TA(33), TA(34)/180.0, 270.0, 360.0, 450.0	, PROP 0360
4540.0.630.0.720.0.810.0.900.0.990.0.1000.0.11170.0.1260.0.1350.0.	PROP 0370
51440-0-1530-0-1620-0-1710-0-1800-0-1980-0-2160-0-2360-0-2520-0-	PR090380
	00000000
/4320+0,4620+0/	PROP 0400
GATA VS(1), VS(2), VS(3), VS(4), VS(5), VS(6), VS(7), VS(8), VS(9), VS(10)	, PROP0410
1VS(11),VS(12),VS(13),VS(14),VS(15),VS(16),VS(17),VS(18),VS(19),	PROP 0420
2VS(20), VS(21), VS(22), VS(23), VS(24), VS(25), VS(26), VS(27), VS(28),	PROP 0430
3VS(29).VS(30).VS(31).VS(32).VS(33).VS(34)/46.53.69.10.89.30.107.4	• PROP 0440
 4124 1 . 139 4 . 153 4 . 166 9 . 179 5 . 191 4 . 202 8 . 213 5 . 223 9 . 233 9 . 243 6	PR00 0450
	88000440
	PROP 0400
6391.5,402.9,416.8,430.1,439.8,451.3,461.1,475.0/	PRCP0470
DATA PA(1),PA(2),PA(3),PA(4),PA(5),PA(6),PA(7),PA(8),PA(9),PA(10)	, PROP0480
1PA(11),PA(12),PA(13),PA(14),PA(15),PA(16),PA(17),PA(18),PA(19),	PROP 0490
2PA(20) • PA(21) • PA(22) • PA(23) • PA(24) • PA(25) • PA(26) • PA(27) • PA(28) •	PROP 9500
* 3PA (29) . PA (30) . PA (31) . PA (32) . PA (33) . PA (34) /0. 770.0. 753.0. 739.0. 722	PR000510
$ \begin{array}{c} \mathbf{A} \\ \mathbf$	00000520
	PROP 0520
50.692.0.696.0.699.0.702.0.706.0.714.0.722.0.726.0.734.0.741.0.749	PRUP 0530
60. 759 ,0.76 7,0.783,0.803,0.831,0.863,0.916,0.972/	PROPO540
HI=FX-{U{K}+U{K}}/{2_0+GC+CJ}	PROP 0 5 5 0
IF(HA(34).LT.HI.CR.HA(1).GT.HI)LVAR=7	PROP 0560
IF (LVAR-EQ.7) WRITE (6.6)	PROP 0 570
[F (HA (3A) . L T . HT) HT #HA (3A)	PROPOSED
	00000500
	PP 3P 0 370
O FURMATI//' ENIMALYT IS UUI UF INE KANGE UF'/	
1º VALUES TABULATEC IN PROP2"//J	PROPO610
1F(K.EQ.1) L=1	PR 0 P 0 6 2 0
00 l I=L,34	PROP 0630
IF(HA(I).GT.FI) GO TO 2	PR DP 0640
1 CONTINUE	PROP0650
	00000460
	PR0P0000
IF(HA(H)+LE+FI) GL (U)	PRUPU6/U
DG 3 J=1,M	PROP 0680
MB=M-J	PROP 0690
IF(HA(NB).LE.HI) GO TO 4	PROP 0700
3 CONTINUE	PROP0710
	0000720
	00000770
J=n+1	PROPUTSU
5 L=1	PRUPU740
TI=TA(M)+(TA(I)-TA(M))+(HI-HA(M))/(HA(I)-HA(M))	PROP 0 750
VISCOI=(VS(M)+(VS(I)-VS(N))+(HI-HA(N))/(HA(I)-HA(M)))+0.0000001	PROP 0 760
PRA=PA{M}+{PA{I}-PA{M}}+(HI-HA{M})/{HA{I}-HA{M}}	PROP 0770
· · · ································	

		00000700
	PRES=PRE	PROPUTOU
	IF(LSUB.GT.O) PRES=PRO	PROPOTAD
	BH(A=08F5/(53-344T1)	PROP 0800
		PROPORTO
	RETORN	00000020
	END	PRUPUOZU
		•
		INPU0000
-	SOBKOUTINE INFOTTEENNON	INPUDDID
C		1000010
	INTEGER GEOM, FLUIC, SOURCE(5), SPACE, BODFOR, JUIPUT, TYPEC, TITLE(18)	INPUUUZU
	COMMON/GEN/PEI.AFI.AME.DPDX.XU.XD.XL.DX,INTG.CSALFA,TYPBC(5).	INPU0030
1	HODE OPTIST, EPE, NVAC, VIIOT, BUILDAL, F. 15, 1001, GC. C. J. AM(100) . PRO.	INPU0040
-		TNPHO050
2	UG(100), PU, SUURLE, RETRAN, NUARUN, SPALE, RHU, FFLAG, UTFOTTOELTAN	INFUDDIO
3	3/E/N,NP1,NP2,NP3,NEQ,NPH,KEX,KIN,KASE,KRAD,GEDM,FLUID,BUDFUR,YPHIN	INPUUUBU
4	A/GG/AFTA.GANA(5).AJI(5).AJE(5).INDI(5).INDE(5).TAU.QWF(5)	[NPU0070
		INPU0080
2		TNDUODOO
6	5/W/SC(54), AU(54), EU(54), LU(54), A(5, 54), B(5, 54), C(5, 54), SU(5, 54),	
7	7/l/AK,ALMG,ALMGG,FRA,APL,BPL,AQ,BQ,EMU(54),PREF(5,54),AUXML	INPUOLUU
8	R/L1/YL . UMAX . UMIN . FR. YIP. YEM. ENFRA . KENT. AJXM2	INPUO110
	(P (BUO (EA) , MISCO (EA) , PR(5, 54) , PHOC, VISCOC, PRC (5) , T (54) , RHCM, BE (54)	INPU0120
7		110110120
1	L/G/H, REM, CF2, ST (5), LSUB, LVAR, LAY, KEH, PPL, GPL, GPL, WIDI, KU	INFUUISU
2	2/CN/AXX, BXX, CXX, CXX, EXX, K1, K2, K3, SP(54), AJX1(100), AUX2(100), YPMAX	INPU0140
r		INPU0150
C	CACH INCANA CTATEMENT IS INDICATED BY THE SHIND IS CARAGAGAGAGAGAGAGAGAGAGAGAGAGAGAGAGAGAGA	INPU0160
C	EACH REAU STATEMENT IS INDICATED OF THE SCHOOL TO HETTER TO	TNDU0170
C	ALL INTEGERS ARE IN FIELDS OF 5 SPACES. BE SURE TO JUSTIFY TO	INFUOLIG
C	RIGHT. ALL DECIPAL NUMBERS ARE IN SUCCESSIVE FIELDS OF 10 SPACES.	INPUO180
r +++4	DATATATATATATATATATATATATATATATATATATAT	INPU0190
•	DEADLE EASTINE	INPUD200
_	READ(5),50577116C	TND00210
C		1000210
	hRITE(6,506)TITLE	INPUOZZO
C	THE DUANTIES READ AT THIS POINT ARE DEFINED:	INPU0230
<i>c</i>	CEON- CENEDAL STATEMENT OF THE SYSTEM GEOMETRY	INPU0240
	GEGAT GENERAL STATERANT OF THE DODUCT DADIUS NOT INCLUDED IN	INPUD250
C	= IMPLIES AKI-STANCIKIC BUDT-RADIUS ADT INCLUED TO TITUED	11000200
C	BOUNDARY LAYER EQUATIONS, APPLICABLE TO EITHER	INPUU20U
C	INTERNAL OR EXTERNAL BOUNDARY LAVERS WHERE	INPU0270
r	ADUNDARY LAYER THICKNESS IS SHALL RELATIVE TO	INPU0280
		TNPU0290
C		THRU0300
C	GEOMETRY (SIMPLY SEI RATH) CONSTANTI	1NP00300
C	=2 IMPLIES AXI-SYMMETRIC BODYRADIUS INCLUDED IN	1000320
(BOUNDARY LAYER EQUATIONS, APPLICABLE ONLY TO	INPU0330
	EVIEDUAL BOUNDARY LAVERS (KIN=1-KEX=2)	INPU0340
	A THE TERME DUTING ANTERS TO THE TREE AND	TNPI A 35A
C	- TAPLIES ANT-STARETALL OUNVART LATER, APPLICABLE UNLT	11000320
C	TO INTERNAL BOUNDARY LAYERS (KIN=2, KEX=1)	100000
Casses	=4 IMPLIES CIRCULAR TUBE-FLOW PROBLEM (KIN=3,KEX=1)	INPU0370
C	=5 IMPLIES FLOW BETWEEN PARALLEL PLANES. SYMMETRICAL	INPU0380
		INPU0390
6		TNDIINANN
C	. =6 IMPLIES AXIALLY-SYMMETRIC JEIS	1000400
C	_ =7 IMPLIES AXIALLY-SYMMETRIC FREE SHEAR FLOW	INPUOATO
Č	-R INDITES THO-DINENSIONAL SYMMETRIC JET	INPU0420
	THOLLES THO DIMENSIONAL EREE SHEAR FLOW	INPU0430
6		INDIALA
C	. MODE= TYPE CF FLOW SYSTEM LUNSIDERED INITIALLY	
C	IPPLIES LAMINAR FLOW	INPUD450
C	=2 INPLIES TURBULENT FLOW	INPU0460
	NOTES TE MORE - 1 THE POGRAM ANTOMATICALLY CHANGES	INPU0470
6	NUTE: IF NUE - I THE PROGRAM AUTOMATICALLY CHANGES	INDUAAA
C	TO TURBULENI FLUW WHEN THE RURENTUM THICKNESS KE	TNDUA400
C	NUMBER EXCEEDS VALUES INSERTED AS 'RETRAN' BELOW.	14600440
C	FLUID- TYPE OF HAINSTREAM FLUID/SELECTS APPROPRIATE SUBROU-	INPU0500
~	TINEC	INPU0510
	- TINGS - The tree constant donded ty finita	TNPU0520
C	-1 IPPLIES CONSIGNI PROPERIT PLOTO	TNDUAEZO
C	. =2 IMPLIES AIR AT MODERATE TEMPERATURES	14600230

. ... **.**

=310R HIGHER) IMPLIES OTHER FLUIDS NOT YET SPECIFIED. INPU0540 Ç.... NEG= NUMBER OF CONSERVATION EQUATIONS CONSIDERED INPU0550 C INPU0560 INCLUDING MOMENTUM EQUATION C N= NUMBER OF STRIPS ACROSS LAYER (LIMITED TO 50, THIS VERSION) INPU0570 C.... KEX= DEFINES TYPE OF BOUNDARY AT ARBITRARILY NOMINATED INPU0580 C EXTERNAL BOUNDARY **INPU0590** C.... KIN= DEFINES TYPE OF BOUNDARY AT ARBIRARILY NOMINATED C INPU0600 INTERNAL BOUNDARY INPU0610 C KIN, KEX= 1 IPPLIES WALL BOUNDARY **INPU0620** C C = 2 IMPLIES FREE BOUNDARY INPU0630 INPU0640 = 3 IMPLIES LINE OF SYMMETRY C KENT= O IF ENTRAINMENT IS BASED ON MOMENTUM EQUATION ONLY. INPU0650 C.... = 1 IF ENTRAINMENT IS BASED ON ALL EQUATIONS. **INPU0660** C C (INTEGERS) INPUD680 READ(5,585) GEON, PCDE, FLUID, NEQ, N, KEX, KIN, KENT INPU0690 **INPU0700** C INPU0710 WRITE(6,510) IF(N.GT.40)WRITE(6,980) INPU0720 WRITE(6,520) GEON, MODE, FLUID, NEQ, N, KEX, KIN **INPU0730** IF(GEOM.EQ.4.OR.GECM.EQ.5)GO TO 20 **INPU0740** IF(KENT_EQ_O)WRITE(6,525) INPU0750 INPU0760 IF (KENT.GT.O] HRITE(6,526) C.... THE QUANITIES READ AT THIS POINT ARE DEFINED: INPU0770 XU= INITIAL VALUE OF X CHOSEN TO DEFINE POSITION OF INITIAL **INPU0780** C PROFILES. TYPICALLY XU=0.0, BUT NEED NOT BE. INPU0790 C XL= VALUE CF X WHERE COMPUTATIONS ARE TERMINATED INPUOBOO DELTAX= MAXIMUM STEP IN X-DIRECTION, EXPRESSED AS FRACTION OF INPUOBIO C C POUNCARY LAYER THICKNESS (SUGGEST 0.5, BUT CAN BE MADEINPUO820 C MUCH LARGER FOR CONSTANT PROPERTY FLOWS AND LAM FLOWSLINPUO830 C C RETRAN = MOMENTUM THICKNESS REYNOLDS NUMBER (OR DIAMETER INPU0840 REYNCLDS NUMBER IN TUBE-FLOW PROBLEM) AT WHICH INPU0850 C TRANSITION FROM LAHINAR TO TURBULENT BOUND-**INPU0860** C ARY LAYER IS DESIRED (USE DUNHY NUMBER IF **INPU0870** C PROBLEM IS ALL TURBULENT.) (SUGGEST 200.0) C INPU0880 FRA= FRACTION FOR DETERMINATION OF DX TO NEXT POSITION (SUG-C INPU0890 INPU0900 GESTED VALUE=0.051. C ENFRA- DESIRED FRACTIONAL DIFFERENCE BETWEEN FREE-STREAM AND INPU0910 C NEXT-TC-LAST GRID PUINT. CONTROLS ENTRAINMENT RATE. INPU0920 C THIS VALUE IS RELATED TO THE INPU0930 (SUGGESTED VALJE=0.005). C..... CHOSEN GRID SPACING. IN SOME CASES 0.01 WORKS BETTER, C INPU0940 BUT WITH A FINE GRID IT MAY BE NECESSARY TO GO AS LOW INPU0950 C AS 0.001. IF THERE IS NO FREE-STREAM **INPU0960** C LEAVE ENFRA BLANK, OR USE ANY DUNNY NUMBER. C.... INPU0970 GV= GRAVITY CONSTANT, POSITIVE IN POSITIVE X DIRECTION. INPU0980 C.... LEAVE 0.0 OR BLANK IF GRAVITY IS NOT CONSIDERED. INPU0990 C C (DECIMAL NUMBERS) INPU1010 20 READ(5,580)XU,XL,CELTAX,RETRAN,FRA,ENFRA,GV INPU1020 C INPU1030 hRITE(6,540) INPU1040 WRITE(6,550) XU, XL, DELTAX, RETRAN, FRA, ENFRA, GV INPU1050 INPU1060 NPH=NEQ-1 INPU1070 KASE=1 IF(KIN.NE.1.AND.KEX.NE.1)KASE=2 INPU1080 C....THE QUANITIES READ AT THIS POINT ARE DEFINED: INPU1090 C....BCDFOR= TYPE OF BCCY-FORCE (OTHER THAN PRESSURE GRADIENT) INPUT 100 =0 IMPLIES NO EXTRA BODY FORCES **INPU1110** C.... =1 IMPLIES FREE-CONVECTION BODY-FORCE. INPU1120 C =2 IMPLIES AN EXTERNAL BODY-FORCE (IN ADDITION TO FREE INPU1130 C

INPU1140 CONVECTION), INTRODUCED THRU AUXI(H). C C SOURCEIJI - TYPE OF SOURCE FUNCTION IN THE DIFFUSION EQUATIONS. INPU1150 IMPLIES NO SOURCE FUNCTION. INPU1160 . 0 C IMPLIES VISCOUS DISSIPATION, PLUS WORK OF ANY BODY INPU1170 = 1 C INPU1180 FORCES. IN THE ENERGY EQUATION. C.... IMPLIES THE SOURCE FUNCTION FOR THE TURBULENT ENERGY INPULL90 C • 2 EQUATION. SETTING SOURCE EQUAL TO 2 FOR ANY DIFFUS- INPUI200 C ION EQUATION AUTOMATICALLY MAKES THAT EQUATION BE THE INPU1210 C TURBULENT KINETIC ENERGY EQUATION, AND AT THE SAME INPU1220 C TIME THE EDDY VISCOSITY AND EDDY CONDUCTIVITIES WILL INPU1230 C BE CALCULATED BY THE TURBULENT KINETIC ENERGY METHOD INPUI240 C **INPU1250** INSTEAD OF FROM THE MIXING LENGTH. C IPPLIES VISCOUS DISSIPATION PLUS AN EXTERNAL VOLUME **INPU1260 =** 3 C SOURCE, INTRODUCED THROUGH AUX2(M), PLUS BODY FORCE INPU1270 C.... WORK, IN THE ENERGY EQUATION. AUXZ(M) HAS DIMENSIONSINPUL280 C.... (ENERGY)/(VOLUME+TIME). INPU1290 C IMPLIES AN EXTERNAL VOLUME SDURCE, INTRODUCED THROUGHINPU1300 C AUX2(M). DIMENSIONS, (QUANTITY)/(VOLUME*TIME). **INPU1310** C INPU1320 C.....SOURCE WILL NOT BE READ UNLESS NEQ IS GREATER THAN 1. **INPU1330 INPU1340** C (INTEGERS) IF(NEQ.GT.1)READ(5,585) BODFOR, (SOURCE(J], J=1, NPH) INPU1350 INPU1360 IF(NEQ.EQ.1)READ(5,585)800FOR INPU1370 C INPUI380 WRITE(6, 820) IF(NEQ.GT.1)WRITE(6, 830) BODFOR,(SOURCE(J), J=1, NPH) INPU1390 INPU1400 IF(NEQ.EC.1) MRITE(6,830) BDDFOR **INPU1410** C..... THE QUANITIES READ AT THIS POINT ARE DEFINED: PD= INITIAL FREESTREAM STATIC PRESSURE INPU1420 C • • **INPU1430** RHOC=DENSITY OF CONSTANT PROPERTY FLUID C VISCOC=VISCOSITY OF CONSTANT PROPERTY FLUID(IF ENGLISH UNITS, INPU1440 C **INPU1450** USE DYNAMIC VISCOSITY, LBM/(SEC-FT)). C PRC = PRANDTL NUMBER OF CONSTANT PROPERTY FLUID (FOR TURBULENTINPU1460 C INPU1470 KINETIC ENERGY EQUATION USE PRC=1.00) C C (THE CONSTANT PROPERTIES MAY BE UMITTED IF FLUID NOT EQUAL 1) **INPU1480** INPU1490 IF(FLUID.EQ.2)WRITE(6,800) INPU1500 IF(FLUID.EQ.1)#RITE(6,750) C ********************** READ UNLY ONE OF THE FOLLOWING THREE INPU1510 INPU1520 C (DECIMAL NUMBERS) INPU1530 IF(FLUID.NE.1)REAC(5,580)PO IF (FLUID.EQ. 1. AND.NEQ.GT.1)READ (5,580) PO, RHOC, VISCOC, (PRC(J), J=1, INPU1540 INPU1550 INPH) **INPU1560** IF(FLUID.EO.1.ANC.NEQ.EQ.1)READ(5,580)PD,RHDC,VISCOC INPU1570 C INPU1580 WRITE(6,700) INPU1590 WRITE(6, 900) PD INPU1600 IF(FLUID.NE.1)GO TO 50 INPU1610 WRITE(6,680) IF (NPH.EQ.0) GC TC 40 INPU1620 INºU1630 WRITE(6,690) RHOC, VISCOC, (PRC(J), J=1, NPH) **INPU1640** GO TO 50 40 WRITE(6, 870) RHCC, VISCOC INPU1650 INPU1660 **50 CONTINUE** INPU1670 WRITE(6,770) C BOUNDARY CONDITIONS ALONG I AND E BOUNDARIES (ONLY ONE MAY BE **INPU1680** 1NPU1690 C.... WALL C THE QUANITIES READ AT THIS POINT ARE DEFINED: [NPU1700 NXBC= NUMBER CF POINTS USED TO SPECIFY BOUNDARY CONDITIONS AT INPU1710 C INPU1720 EITHER INTERNAL DR EXTERNAL BOUNDARY C TYPBC(J) = IMPLIES TYPE OF BOUNDARY CONDITION GIVEN FOR THE INPU1730 C Chieffan Hern

J-TH CONSERVED QUANTITY AT A WALL SURFACE =1 IMPLIES LEVEL SPECIFICATION C INPU1740 C INPU1750 C =2 IMPLIES FLUX SPECIFICATION INPU1760 C.... NOTE: FOR THE TURBULENT KINETIC ENERGY EQUATION INPU1770 C USE TYPBC(J)=1 INPU1780 (TYPBC WILL NOT BE READ UNLESS NEQ IS GREATER THAN 1) C INPU1790 C +++++++++++++++ READ ONLY ONE OF THE FOLLOWING THREE INPU1800 C....NOTE: KASE=1 MEANS A WALL: KASE=2 MEANS THERE ARE NO WALLS. INPU1810 C (INTEGERS) INPU1820 IF(KASE.EQ.1.AND.NEQ.GT.1)READ(5,585) NXBC,(TYPBC(J),J=1,NPH) INPU1830 IF(KASE-EQ.1.AND.NEQ.EQ.1) READ(5,585) NXBC **INPU1840** IF (KASE.EQ.2)REAC (5,585) NXBC **INPU1850** C INPU1860 IF (KASE.EQ. 2. OR. NEQ. EQ. 1)GO TO 70 INPU1870 WRITE(6,570) INPU1880 #RITE(6,590) NX8C,(TYP8C(J),J=1,NPH) **INPU1890** GO TO 80 INPU1900 70 WRITE(6, 890) INPU1910 WRITE(6, 585) NXBC INPUL920 C.... THE QUANITIES READ AT THIS POINT ARE DEFINED: INPU1930 C X(M)= POSITION AT WHICH THE BOUNDARY VALUES ARE GIVEN. NOTE **INPU1940** C.... THAT X(1) MUST BE LESS THAN (OR EQUAL TO) XU, AND THE INPU1950 C LARGEST VALUE OF X(M) MUST BE GREATER THAN INPU1960 (OF EQUAL TO) XL. INPU1970 C RW(N)= DISTANCE FROM AXIS OF SYMMETRY TO BODY SURFACE. C INPU1980 C SET= CENSTANT IF PLANE BUUNDARY LAYER. (SUGGEST 1.0) INPU1990 FOR GECM=4, RW(M) IS THE PIPE RADIUS, MAY VARY WITH X. INPUZOOD C FOR GEON= 5, RW(M) IS THE HALF-WIDTH OF THE DUCT, WHICH INPU2010 C MAY BE A FUNCTION OF X. C INPU2020 C.... FOR GEOM=6,8, OR,9, RW(M) IS TOTALLY A DUMMY. **INPU 2030** C FOR GEON=7, RH(M) IS THE INITIAL RADIUS OF THE I-INPU2040 C.... BCUNDARY, BUT IS A DUMMY THEREAFTER. INPU2050 AUX1(M), AUX2(M)= AUXILIARY FUNCTIONS, FOR SPECIAL PURPOSES: C INPU2060 INTERPOLATED VALUES WILL APPEAR IN THE COMMON AS AUXMI INPU2070 C Cesses & AUXM2 IF THERE IS A WALL. LEAVE COLUMN BLANK IF **INPU 2080** C NOT USED. INPU2090 **80 CONTINUE** INPU2100 IF(NXBC.LT.2)WRITE(6,920) INPU2110 DO 90 M=1,NX8C **INPU2120** (DECIMAL NUMBERS, IN THE FORM OF A TABLE.) **INPU2140** C 90 READ(5,580) x(M),RW(M),AUX1(N),AUX2(N) INPU2150 C INPU2160 C....THE QUANITIES READ AT THIS POINT ARE DEFINED: INPU2170 C....UG(M)= FREESTREAM VELOCITY AT POSITION X(M). IF BOTH THE INPU2180 I AND E SURFACES ARE FREE-STREAM BDUNDARIES. UG(M) IS C INPU2190 THE FREE-STREAM VELOCITY ON THE E-SIDE AND MUST START C INPU2200 OUT THE SAME AS U(NP3). **INPU2210** C C (IF THERE IS NO FREE-STREAM READ IN A DUMMY INPU2220 NUMBER FOR UG, OR ELSE LEAVE A BLANK) C **INPU2230** C....AM = MASS FLUX AT WALL, POSITIVE IN THE POSITIVE DIRECTION OF Y INPU2240 (AM WILL NOT BE READ UNLESS THERE IS A WALL.) **INPU2250** C.... C....FJ(J, M) = VALUE OF PROPERTY OR FLUX OF PROPERTY AT BOUNDARY INPU2260 C.... NOTE THAT IF FJ IS A PROPERTY AT THE **INPU2270** WALL (SUCH AS ENTHALPY), TYPBC(J) , ABOVE, MUST BE EQUAL INPU2280 C.... TO 1. IF FJ IS A FLUX AT THE WALL (SUCH AS HEAT FLUX), TYPBC(J) HUST BE SET EQUAL TO 2. IN THE LATTER CASE, FJ C INPU2290 **INPU2300** C IS THE TOTAL FLUX OF THE PROPERTY IN QUESTION, I.E., THAT C INPU2310 EVALUATED AT THE 'T-STATE' CONTROL SURFACE. THIS BECOMES OF **INPU2320** C PARTICULAR SIGNIFICANCE WHEN THERE IS HASS TRANSFER AT THE **INPU2330** C

INPU2340 SURFACE. IF FJ IS A WALL FLUX. IT SHOULD BE POSITIVE C IN THE POSITIVE DIRECTION OF THE COORDINATE SYSTEM. INPU2350 C INPU2360 FOR THE TURBULENT KINETIC ENERGY EQUATION SET FJ=0.0 C (FJ WILL NOT BE READ UNLESS THERE IS A WALL, AND WILL NOT INPU2370 INPU2380 BE READ IF NEC IS 1) C NOTE: IF FJ IS A HALL FLUX, AND IS ZERD (ADIABATIC WALL), SOME INPU2390 C ERROR MAY BE INTRODUCED BECAUSE THE DEPENDENT VARIABLE IN THE INPU2400 C **INPU2410** WALL FUNCTION IS NORMALIZED WITH RESPECT TO THE WALL FLUX. C INPU2420 IT IS BETTER TO INTRODUCE A SMALL WALL FLUX. (SUGGEST 0.0001) C C..... (NOTE THAT M IS AN INTEGER VARYING FROM 1 TO NXBC.) INPU2430 INPU2440 WRITE(6,600) **INPU2450** DO 110 M=1.NX8C **INPU 2460** C (DECIMAL NUMBERS, IN THE FORM OF A TABLE) INPU2470 IF(KASE.EQ.1.AND.NEQ.GT.1)READ(5,580)UG(N),AM(M),(FJ(J,M),J=1,NPH)INPU2480 INPU2490 IF (KASE.EQ.1.AND.NEQ.EQ.1) READ (5,580) UG(H), AN(M) INPU2500 IF (KASE.EQ. 2)REAC(5, 580)UG(M) INPU2510 C **INPU2520** IFIKASE.EQ.1.AND .NEQ.GT.11WRITE(6,610) N,X(MJ,RW(M),UG(M),AM(M), INPU 2 530 1AUX1(M),AUX2(M),(FJ(J,M),J=1,NPH) INPU2540 IF (KASE.EQ.1.AND.NEQ.EQ.1) WRITE (6,610) M.X(M), RW(M), UG(M), AM(M), INPU 2 5 50 1AUX1(M),AUX2(P) INPU2560 110 IF (KASE.EQ.2) WRITE (6,610) H.X(4), RW(M), UG(4), AUX1(M), AUX2(M) INPU2570 NP1=N+1 INPU2580 NP2=N+2 **INPU 2590** NP 3=N+3 INPU2600 C....INITIAL PROFILE SPECIFICATION INPU2610 THE INITIAL VELOCITY PROFILE ESTABLISHES THE GRID SPACING C AND THUS SOME CARE SHOULD BE EXERCISED IN LAYING IT OUT. **INPU2620** C THE PROGRAM IS NOT PARTICULARLY SENSITIVE TO UNEVENNESS INPU 2630 C IN THE Y-INCREMENTS, BUT BIG CHANGES IN DELTA-Y SHOULD INPU2640 C INPU2650 BE AVOIDED. C INPU2660 FOR TURBULENT FLOW NEAR A WALL THE VALUE OF C.... U+Y+DENSITY/VISCOSITY AT THE FIRST PDINT NEXT TO THE INPU2670 C WALL SHOULD BE NOT LESS THAN ABOUT 200, UNLESS IT IS DESIREDINPU2680 C TO BY-PASS THE WALL FUNCTION. IN THAT CASE THIS VALUE INPU2690 C SHOULD BE LESS THAN 1.0, AND ABOUT 20 PDINTS RATHER EVENLY INPU2700 C INPU2710 SPACEDSHOULD BE USED OUT TO YPLUS EQUAL ABOUT 20.0. C INPU2720 Y(I)= DISTANCE ALONG NORMAL TO BOUNDARY C INPU 2730 NOTE THAT Y IS MEASURED FROM THE I-BOUNDARY, C.... INPU2740 I.E., Y(1)= 0.0. C INPU2750 U(I) = VELOCITY IN X-DIRECTION AT Y(I) C INPU2760 F(J,T)= VALUE OF CONSERVED QUANTITY AT Y(I) C NOTE: FOR THE TURBULENT KINETIC ENERGY EQUATION USE INPU2770 C INPU2780 THE REMAINDER OF F(J, I)=0.0 AT THE WALL (IF ANY). C THE INITIAL TURBILENT KINETIC PROFILE DEPENDS ON THE INPU2790 C PROBLEM SPECIFICATIONS. IT CAN BE ALL ZERO. INPU2800 C INPU 2810 WRITE(6,760) INPU2820 WRITE(6,630) C ******************** READ IN A TABLE OF Y AND U. OR Y. U. AND F'S. INPUZ830 INPU2840 C (DECIMAL NUMBERS) INPU2850 IF(NEQ.EQ.1)G0 T0 240 INPU2860 READ(5,580) Y(1),U(1),(F(J,1),J=1,NPH) INPU2870 DO 220 1=3,NP1 INPU2880 220 READ(5,580) Y(I),U(I),(F(J,I),J=1,NPH) INPU2890 READ(5,580) Y(NP3),U(NP3),(F(J,NP3),J=1,NPH) INPU 2900 GO TO 255 INPU2910 1 240 #EAD(5,580) Y(1),U(1) INPU2920 DO 250 I=3,NP1 INPU 2930 250 READ(5,580) Y(1),U(1)

READ(5,580) V(NP3),U(NP3)	INPU2940
C	INPU 2950
255 NDUMB=1	INPU 2960
IF(NEQ.EQ.1)60 TO 265	INPU2970
WRITE(6, 850)NDUMB,Y(1),U(1),(F(J,1),J=1,NPH)	INPU2980
DO 230 I=3,NP1	INPU 2990
230 WRITE(6, 850)1,Y(I),U(I),(F(J,I),J=1,NPH)	INPU 3000
WRITE(6, 850)NP3,Y(NP3),J(NP3),(F(J,NP3),J=1,NPH)	INPU 3010
GO TO 270	INPU 3020
265 WRITE(6. 850) NDUMB.Y(1).U(1)	INPU 3030
DO 260 I=3.NP1	INPU 3040
260 WRITE(6. 850) I.V(I).U(I)	INPU 30 50
WRITE(6. 850) NP3.V(NP3).U(NP3)	INPU3060
270 CONTINUE	INPU 3070
Constants	INPU 3080
CONTRACTOR AND A CNEY READ IN DUNNY DATA.	INPU3090
CALLE THERE IS NO WALL PEAD IN DUMMY VALUES FOR AK, APL, BOI	INPUSION
THE ANANTITIES DEAD AT HIS DOINT ARE DEFINED:	INPU3110
AKE NYYING I ENGTH CONSTANT KAPDA (SUGGESTED VALUE-0.41)	INDI 3120
	TN0113130
CONTRACT ENTER ON A WALL THIS VALUE IS STERNIDER AT EUR	
CONTROLOS NOMERS LOLUM AFRUATATLEL DUGUT EACET WHEN RE-S.	
C CONTRACTOR INTO UNIT AND A CONSTANT EDT	
COLOR DIFFUSIVITY LFILM IS USED THIS NUMBER IS A DUMMY	
C FRE DEFINES DUMUARY LATER INICKNESS (998 PUINIEU.01/ USED IN	
C THE DEFINITION OF ALMS (SUGSESTED VALUE=0.01).	1NPU 3190
Comment and a second and a seco	INPU 3200
C CONSTANTS IN THE EDDY DIFFUSIVITY EQUATION. WHEN THE	INPUSZIU
C CONSTANT EDDY DIFFUSIVITY OPTION IS USED,	INPU 3220
C SET $R_2=2$. (FUR PIPE-FLOW IRV $R_2=2$, $A_2=.005$, $B_2=0.9$)	INPU 3230
C NOTE: TO BE CONSISTENT FOR TURBULENT K.E., AK HOST BE	INPU3240
C EQUAL TO 140**.75//180**.25)	INPU3250
C (SUGGEST 0.22 AND 0.377 FUR TKE. ALSO SUGGEST USE	INPU 3260
C PRT(J)=1.7 FDR THE TURBULENT KINETIC ENERGY EQUATION.)	INPU 3270
C YPMAX= MAXIMUM VALUE OF YPLUS TO BE ALLIMED AT OUTER EDGE OF	INPU 3280
C WALL FUNCTION (SAY 50.0 FOR TURBULENT BL; USE 1.0 IF	INPU3290
C DESIRED TO BYPASS WALL FUNCTION, BUT THEN SET	INPU3300
C YPMIN = 0.0. FOR STRONG PRESSURE GRADIENTS IT IS MORE	INPU 3310
C ACCURATE TO SET YPNAX NO GREATER THAN 15 SINCE THE DE-	INPU 3320
C PARTURE FROM COUETTE FLOW OCCURS AT VERY LOW Y+. BEST	INPU3330
C ACCURACY IS BEFAINED WHEN YMAX+1.0 AND YPMIN=0.0, BUT	INPU3340
C THE NUPBER OF FLOW TUBES MAY THEN BE VERY LARGE.)	INPU3350
C YPMIN= MINIMUM VALUE OF YPLUS TO BE ALLIWED AT DUTER EDGE	INPU 3360
C OF WALL FUNCTION FOR A TURBULENT BL (CAN BE 0.0)	INPU3370
C ************************************	INPU3380
C (DECIMAL NUMBERS)	INPU3390
READ(5,580) AK,ALNGG,FR,AQ,BQ,YPMAX,YPMIN	INPU 3400
C • • • • •	INPU3410
C READ IN A+ OR 8+. IF A+ IS GREATER THAN 8+. PROGRAM WILL USE VAN	INPU3420
C DRIEST SCHEME FOR SUCLAYER, AND B+ IS READ AS MERELY A DUMMY NUM-	INPU3430
C BER. IF B+ IS GREATER THAN A+, PROGRAM WILL USE THE EVANS SCHEME.	INPU3440
C THE PROGRAM WILL USE AN INTERNAL EMPIRICAL CORRELATION FOR EFFECTS	INPU 3450
C OF PRESSURE GRADIENT, TRANSPIRATION, ETC., BUT THIS ADDITIONAL COR-	ENPU 3 460
C RECTION CAN BE SUPPRESSED IF DESIRED BY SETTING "SIGNAL" AT ANY NUM-	INPU3470
C BER EQUAL TO 1.0. SUGGEST A+=25 FUR FLAT SURFACE, 26 FOR FLOW	INPU3480
C INSIDE A CIRCULAR TLEE.	INPU3490
· C · *********************************	INPU 3500
C (DECIMAL NUMBERS)	INPU 3510
READ(5,580)APL.BFL.SIGNAL	INPU 3520

INPU3540 KD=0 INPU3550 IF(APL.GE.BPL.ANC.SIGNAL.GE.1.0)KD=1 INPU 3560 IF(BPL.GE.APLIKD=2 [NPU3570 IF [BPL.GE.APL.ANC.SIGNAL.GE.I.O]KD=3 C....THE QUANTITIES READ AT THIS POINT ARE DEFINED: INPU3580 PPLAGE & LAG CONSTANT IN THE EFFECTIVE VALUE OF PPLUS, GPLUS, INPU3590 C INPU3600 USED IN THE EVALUATION OF APL, OR SPL. C INPU3610 (SUGGESTED VALUE = 4000.) C INPU3620 PRT(J) = TURBULENT TRANSFER RATIO FOR F(J) (TRY .86) C NEAR A WALL THIS VALUE IS OVERRIDEN INSIDE THE INPU3630 C INPU3640 PROGRAM UNLESS K3 IS SET EQUAL TO 3. C SEE INFORMATION ON K3 BELOW. INPU3650 C INPU3660 **INPU3670** (DECIMAL NUMBERS) IF(NEO.GT.1)READ(5,580) PPLAG, (PRT(J),J=1,NPH) INPU 3680 **INPU3690** IF (NEQ.EQ.1)READ (5,580)PPLAG INPU3700 C INPU3710 #RITE(6,780) INPU3720 WRITE(6,640) WRITE(6,650) AK, ALMGG, FR, PPLAG, AQ, BQ, YPMAX, YPMIN INPU 3730 INPU3740 IF (PPLAG.LT. 400.) WRITE(6,990) INPU3750 IF(BQ.LE.0.0)G0 TC 275 **INPU3760** IF(NPH.LT.1)GO TC 275 INPU 3770 AKCHEC={AQ++.75}/[8Q++.25] **INPU3780** AKERR=ABS(AK-AKCHEC) INPU3790 K20=0 INPU3800 DO 274 J=1,NPH **INPU3810** 274 IF(SOURCE(J).EQ.2)K20=1 INPU 3820 IF(AKERR/AK.GT.0.01.AND.K20.EQ.1)#RITE(6,710) INPU3830 275 HRITE(6,930) INPU3840 WRITE(6,940) APL, BPL, SIGNAL INPU3850 IF(KD.EQ.0)WRITE(6,950) INPU3860 IF{KD.EQ.2}wRITE(6,955) INPU3870 IF (NEQ. GT.1) WRITE(6,660) INPU3.890 IF (NED.GT.1) WRITE(6,650) (PRT(J), J=1, NPH) C.....READ IN CONVERSION CONSTANTS, AND ANY OTHER ARBITRARY DECIMAL CON-INPUSBOO INPU3900 C....STANTS THAT ARE CESIRED. INPU3910 GC= 32.2 IN BRITISH SYSTEM C INPU 3920 CJ= 778.0 IN BRITISH SYSTEM C C....IF YOU USE A SYSTEM SUCH AS MKS, GC=1.0 AND CJ=1.0. JUST USE C....A CONSISTENT SYSTEM. THE PROGRAM WURKS IN REAL WORLD DIMEN-INPU3930 **INPU3940** C SIONS, NOT NONDIMENSIONAL VARIABLES. BE CAREFUL ABOUT THE **INPU 3950** INPU3960 C DIMENSIONS OF VISCOSITY -- IN ENGLISH UNITS USE LBM/(SEC-FT). C.... THE CONSTANTS AXX, BXX, ETC., MAY BE LEFT BLANK IF THEY ARE NOT INPU3970 C....BEING EMPLOYED FOR SOME SPECIAL PURPOSE INSIDE THE PROGRAM. INPU3980 * INPU 3990 **INPU4000** C (DECIMAL NUMBERS) INPU4010 READ(5,580) GC.CJ.AXX.BXX.CXX,DXX.EXX INPU4020 C INPU 4030 wRITE(6,790) INPU 4040 WRITE(6.720) INPU4050 WRITE(6, 910) GC+CJ+AXX+BXX+CXX+DXX+EXX C READ IN THE NUMBER OF RUNS OF DATA THAT YOU WANT USED (NUMRUN), INPU4060 C....AND THE SPACING (NUMBER OF INTEGRATIONS) OF THE OUTPUT DATA THAT INPU4070 C....YOU WANT PRINTED (SPACE). IF YOU SET SPACE=11, AN ABBREVIATED INPU4080 C....DATA SET WILL BE PRINTED DUT, OMITTING ALL PROFILES, BUT INCLUDING INPU4090 C....ALL OTHER DATA AT EACH INTEGRATION. SETTING SPACE=21 WILL CAUSE INPU4100 C A COMPLETE DATA SET TO BE PRINTED EVERY 20 INTEGRATIONS, AS WELL INPU4110 C AS AN ABBREVIATED SET EVERY INTEGRATION. (THESE OPTIONS LIMITED **INPU4120 INPU4130** C....TO DUT2, DUT4).

J.

C....READ IN DESIRED CUTPUT SUBROUTINE (2, 4, 6, ETC.) INPU4140 C....SOME ADDITIONAL ARBITRARY INTEGERS, K1, K2, K3, MAY BE READ IN HERE INPU4150 C....IF DESIRED - OTHERWISE LEAVE BLANK. IF KL IS SET GREATER THAN 10, INPU4160 C....ALL OUTPUTS WILL PRINT OUT ONE TO FIVE SPECIALLY DESIGNATED PIECESINPU4170 C.... OF INFORMATION, CESIGNATED AS SPILL. IF K3 IS SET EQUAL TO INPU4180 C.... 3 A VARIATION OF TURBULENT PR NEAR A WALL WILL BE SUPRESSED, SEE INPU4190 C....PRT(J) ABOVE. SETTING K2 EQUAL TO 3 WILL DO THE SAME THING FOR INPU4200 C....ALMGG. **INPU4210** C....IF KZ IS SET EQUAL TO 2, PROGRAM WILL USE A CONSTANT EDDY DIF-**INPU4220** C....FUSIVITY IN THE DUTER REGION, INSTEAD OF A CONSTANT MIXING-INPU4230 C....LENGTH. IT WILL BE EVALUATED FROM THE EQUATION, EDR=AQ=REM++BQ, INPU4240 C WHERE REM IS MCMENTUM THICKNESS REYNOLDS NUMBER, OR PIPE DIAMETER INPU4250 C REYNOLDS NUMBER. DONT USE THIS OPTION IF FREE-STREAM VELOCITY INPU4260 C....IS ZERO (SEE COMMENT ON AQ, BQ). **INPU4270** C....IF KI IS SET EQUAL TO 9 DR 20, DELTAX BECOMES EQUAL TO AUXI(M), INPU4280 C AND THE ORIGINAL INPUT VALUE OF DELTAX IS OVERRIDDEN. THIS ALLOWSINPU4290 C....DELTAX TO VARY WITH X. INPU4300 C....ISEE PRESSURE GRADIENT CALCULATION IN MAIN FOR K1=15) INPU4310 C (INTEGERS) **INPU4330** READ(5,585) NUMRUN, SPACE, DUTPUT, K1, K2, K3 INPU4340 C INPU4350 WRITE(6,730) INPU4360 HRITE(6,740) NUMRUN, SPACE, OUTPUT, K1, K2, K3 INPU4370 IF(GEOM.EQ.4.OR.GECM.EQ.5)GO TO 11 INPU4380 IF(K2.NE.3.AND.KASE.EQ.1.AND.K2.NE.2.AND. YODE.EQ.2 WRITE(6,960) **INPU4390** 11 CONTINUE INPU4400 K10=0INPU4410 IF(K3.NE.3.ANC.KASE.EQ.1)K10=1 **INPU4420** IF (K10.EQ.1.AND.NEQ.GT.1.AND.MODE.EQ.2) WRITE(6,970) INPU 4430 IF(K1.EQ.20.CR.K1.EQ.9)WRITE(6,992) INPU4440 C INPU4450 C INPUT DATA ERROR CHECK **INPU4460** C **INPU4470** IF (XU.LT.X(1).OR.XL.GT.X(NXBC) | WRITE(6,50)) INPU4480 IF(XU.LT.X(1).OR.XL.GT.X(NXBC))KERROR=3 **INPU4490** IF(XU.GE.XL)WRITE(6,500) INPU4500 IF(XU.GE.XL)KERROR=3 INPU4510 IF(Y(NP3).G1.0.1*(X(2)-X(1)))#RITE(6,522) INPU4520 IF(BQ.LT.O.)KERRCR=5 INPU4540 IF (GC.LT.0.5)KERRCR=5 INPU4550 IF (OUTPUT.LT.1)KERROR=5 **INPU4560** IF(KIN.EQ.1.AND.U(1).GT.O.UJKERROR=5 **INPU4570** IF(KEX.EQ.1.AND.U(NP3).GT.O.O)KERRUR=5 INPU4580 IFINEQ.GT.01GO TO 13 **INPU4590** IF(TYPBC(1).LT.1)KERROR=5 **INPU4600** 13 IF (GEOM.LT.6.AND.RW(1).EQ.0.0) KERROK=5 INPU4610 IF(GC.EQ.0.0.0R.CJ.EQ.0.0)KERROR=5 INPU4620 IF(SPACE.EQ.0)KERPOR=5 INPU4630 IF(KERROR.EQ.5)WRITE(6,502) **INPU4640** IF(MODE.EQ.1)GO TO 15 INPU4650 IF (AK-LT..25.OR.AK.GT..6) WRITE (6, 504) **INPU4660** IF (AK.LT..25.OR.AK.GT..6)KERROR=4 INPU 4670 15 DO 16 M=2,NXEC INPU4680 16 IF(X(M).LT.X(M-1))KERROR=1 **INPU4690** IF(Y(3).LT.Y(1))KERROR=1 **INPU4700** CO 18 I=4.NP1 INPU4710 18 IF(Y(I).LE.Y(I-1))KERROR=1 **INPU4720** IF(Y(NP3).LT.Y(NP1))KERROR=1 INPU4730 IF(KERROR.EQ.1)WRITE(6,507) INPU4740

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TELCEON EO. 4. AND. KIN. NE. 3. KERROR=2	INPU4750
IF (GEONEGA FAND, KIN, NE, 3) KEDBAB#2	INPU4760
IF (GEUM-EQ. 3 AND WIN-NE 3) KENON-2	INPU 4770
IF (GEUN-EQ. 3 AND THIN NE 1) KERADE-2	INPU4780
	INPI14790
IF (KIN, EQ. 1. AND, REASE QUI)KERNOR ²	TNDILA ROO
IF (MODE.GV.2.OK.GEUM.LV.I)KERKUK=2	IN0//4000
IF(KERROR.EO.2)WRITE(6,508)	INFU 4010
IF((YPMAX-YPMIN) LE.O.O)KERRDR=6	111704020
IF ((YPMAX-YPMIN) »LE» YPMIN) KERROR=6	INPU4030
IF(KERROR.EQ.6)WRITE(6,527)	INPU4640
500 FORMAT(//* PROGRAM TERMINATED BECAUSE EITHER XU DR XL WERE*/	
1º OUTSIDE OF THE RANGE OF THE INPUT DATA, OR ELSE XU"/	INPU4000
2º WAS INPUT AS GREATER THAN XLº//)	11904070
502 FORMAT(// PROGRAM TERMINATED BECAUSE OF INSUFFICIENT OR TOU "	INPUSCO
1' MANY CATA CARDS, OR SOME OTHER INPUT ERROR 7/7	INPU4890
504 FORMATL// PROGRAM TERNINATED BECAUSE AK HAS ASSUMED AN ABSURD'	INPU4900
1. VALUE, CAUSED EITHER BY WRONG INPUT OR IMPROPER ATTENTION 10.7	INPU4910
24 FORMATING OF SCME OF THE INPUT DATA4//)	INPU4920
505 FORMAT(18A4)	INPU4930
506 FORMAT(1H1,1X,18A4)	INPU4940
507 FORMAT(// PROGRAP TERMINATED BECAUSE THE INPUT VALUES OF EITHER /	INPU4950
1 X(N) OR Y(I) ARE NOT IN MONOTONIC SEQUENCE, OR ELSE THERE IS'	INPU4960
2. SOME OTHER INPUT FORMATING ERROR THAT HAS FORCED THESE!/	INPU4970
3. QUANTITIES OUT OF ORDER!//)	INPU4980
508 FORNATI // PROGRAM TERNINATED BECAUSE IT IS EITHER NOT' /	INPU4990
1. YET COMPLETELY SET UP TO HANDLE THIS PARTICULAR /	INPU 5000
2. GEOMETRY, OR ELSE THE CONBINATION OF KEX AND KIN'/	INPU5010
3. IS NOT POSSIBLE IN THIS VERSION OF THE PROGRAM 1/1	INPU 5020
SIG FORMATI/SOH GECMETRY MODE FLUID NEW N KEX KIN	INPU5030
520 FORMAT(4X, 12, 5X, 11, 4X, 12, 4X, 12, 2X, 12, 3X, 11, 4X, 11)	INPU 5040
522 FORMAT(// THE INITIAL BOUNDARY LAYER IS RATHER THICK RELATIVE'/	INPU 5050
1. TO THE SPACING OF THE BOUNDARY CONDITION POINTS. THIS MAY!/	INPU 5060
21 LEAD TO TROUBLES. ESPECIALLY WITH PRESSURE GRADIENT."//)	INPU 5070
525 FORMATI// ENTRAINMENT BASED ON MOMENTUM EQUATION ONLY.")	INPU5080
526 FORMATI / ENTRATEMENT BASED ON BEHAVIOR OF ALL EQUATIONS.")	INPU 50,90
527 CORMATI// PROGRAM TERMINATED RECAUSE YPMAX IS TOO SMALL+'/	INPU5100
I OP THEFE IS SOME OTHER RELATED INPUT ERROR . //)	TNPU5110
540 EDEMAT(107H XIL XL DELTAX TRANSITION REVNOLDS NO.	INPU5120
1 EPA ENTRAINMENT FRACTION GRAVITY CONSTANT	INPU5130
550 500MAT(2X, F6, 3, 3X, F7, 3, 4X, F5, 2, 9X, F7, 1, 12X, F5, 3, 8X, F7, 4, 11X, F7, 2)	INPU5140
	INPU5150
570 SODMATISON NXBC TYPECI TYPEC2 TYPEC3 TYPEC4 TYPE	INPU5160
	INPU5170
107 / 500 500 MAT (7510.0)	INPU5180
	INPU5190
262 FURMAILCI2/	INPU5200
290 FORMATI 1410A M (M) KW(M) UG(M) AH(M)	INPU5210
COC FURMAT(7,1207 F 1(1,M) FJ(2,N) FJ(3,M) FJ(4,M) FJ(5,M)	INPU5220
	INPU5230
(10 FORMAT(3) 12.47 57.3.17.59.3.17.510.3.510.3.510.3.510.3.510.3.510.3.	INPU5240
1010 2 E10 2 E10 2 E10 21	INPU5250
$\frac{1}{1} \frac{1}{1} \frac{1}$	INPU5260
CSU PURMAILBUM I TILI OLI TILI CLUT TILI	INPU 5270
LL) FLAFLJ FLOFLJ ///	INPU 5280
CAU PURMAIL//YON NAFFA LANDDA FA CAU CONSTANT AN	INPU 5290
189 MAX, TELUS IN HE MING TELUS IN HEF	
650 FURMAISIXstf.44;5Xstf.44;3Xstf.44;3Xstf.42;3Xstf.444;3Xstf.444;3Xstf.44;3	INPU5300
	INPU5300 INPU5310
111X,F7.4,/)	INPU5300 INPU5310 INPU5320
111X,F7.4,/) 660 FORMAT(/,50H PRT(1) PHT(2) PHT(3) PRT(4) PRT(5)) 760 FORMAT(/,50H PRT(1) PHT(2) PHT(3) PT(3) PT(INPU5300 INPU5310 INPU5320 INPU5330
111X,F7-4,/) 66D FORMAT(/,50H PRT(1) PKT(2) PKT(3) PRT(4) PRT(5)) 68D FORMAT(/68H DENSITY VISCOSITY PRC(1) PRC(2) PRC(3) PF	INPU5300 INPU5310 INPU5320 INPU5330 INPU5340

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	690 FORMAT(1X,F8.4,3X,F9.7,3X,F8.3,3X,F0.3,3X,F6.3,3X,F6.3,3X,F6.3,1/)	INPU5350
	700 FORMAT(7+ INITIAL STATIC PRESSURE +)	INPU5360
	710 FORMAT(//' WARNING: THE INPUT VALUES OF AK, AQ, AND 80, ARE'/	INPU5370
	1º INCONSISTENT (//)	INPU5380
	720 FORMAT(/-107F G-SUB-C J AXX	INPU5390
		INPU5400
	730 FORMAT(/-81H NC. OF RUNS OF DATA PRINTOUT SPACING OUTPU	INPU5410
	1T OPTION K1 K2 K3)	INPU 5420
	740 FORMAT(13X.12.22X.12.15X.12.10X.15.15.15.15.1)	INPU5430
	750 FORMAT(/ CONSTANT FLUID PROPERTIES ARE BEING USED)	INPU5440
	760 FORMAT(/* INITIAL PROFILES*/)	INPU5450
	770 FORMAT(/' BOUNCARY CONDITIONS ALONG I- AND C-SURFACES')	INPU 5460
	780 FORMATI/ TURBULENCE CONSTANTS ')	INPU 5470
	790 FORMAT(/ DIMENSIONING SYSTEM CONSTANTS ARBITRARY	INPU5480
	1CONSTANTS')	INPU5490
	ROO FORMAT(/ THE FLUID IS AIR (KEENAN AND KAYE GAS TABLES))	INPU5500
	820 FORMAT(/63H BODY-FERCE SUURCE(1) SUURCE(2) SUURCE(3) SOURCE(4) SOU	INPU5510
	1RCF(5))	INPU 5520
	A30 E00WAT(5Y,1),9Y,11,9Y,1),9X,11,9X,11,9X,1),/)	INPU5530
	950 FORMAT(3Y, 12, 7Y, F7, 5, 2X, F7, 2, F10, 3, (X, F10, 3, [X, F	[NPU5540
	1.31	[NPU5550
	ATO ECONMAT(1), ER. 4.33, ER. 7./)	INPU 5560
	ADD FORMATIZAN NYAF (NIMARA DE SPECIFIED BE POINTSI)	INPU 5570
	and commarting Ela. 2)	INPUSSAD
	700 FURMAILLANGTIU-27 010 EODMATL2Y EA 1 7Y EE 1.189.5515 (4)	INPU5590
	THE FURNALLY ATTALY ATT	INPU 5600
	12 DIAMATTY - PREGRAF TERMINALED BECAUSE TADE TAS A TA A TATA A T	INPU5610
	T NUMBER LESS THAN 27 WHICH IS NOT ALLOWED 777	INPU5620
	300 FORMATIAN EA 3 AN EA 3 AN EA 3 AN EA 3 AN	INPU 5630
	340 FURNALLAST COLUMN TO CLARAST COLUMN AN INTERNAL CUEDESATION TO $1/$	INPU5640
	TH ACCOUNT ON THE INCLUENCE OF DESCUIDE CONTENTION TO AN SPIR-1/	INPU 5650
	1' AUGUNN FUR THE INFLUENCE OF FRESSURE GRAVIENT AND TRACT IN T	TN9115660
	CER COMMENT // THE DODOGAM IS USING AN INTERNAL CODELATION TO //	INPH5670
	THE FURNER TO STAND AN INTERNAL CONCENTION TO AN STRAIGHT AND TRANSFIR-1/	INPU15680
	1° ALLOUN' FUR THE INFLUENCE OF FRESSURE STABLET, AND TRASSLIK /	INPU5690
	2' UN OFLUS'I CAD FORMATIN TE BEN IS LESS THAN AROUT 6003-1/	INPUS700
	TOU FURNATION IF REF 13 CESS HANN ADDUD DUDY''	IN0115710
	I' LAMDUA IS ELING CUMPULED DI AN INTERNAL LEGATIONS //	INPU5720
	THE EVALUATED BY AN INTERNAL EQUATION, EVCEDT WHEN DET IS FOR!/	IN9115730
	1° EVALUATED DI AN INTERNAL EQUATIONY EXCETT WHEN THE 13 FOR 7	INPU5740
·	2" THE TURBULENT RE EMMATUNG "/ COAR ECONATION OF THE BUNK OUT BECAUSE & IS CREATER THAN 40."/)	INPU5750
	TOU FURNATIVE TR THE LAC CONSTANT IS LESS THAN ADD. IT IS TREATED /	INPUS760
	THE AC TE TE UEDE TEOR 1/1	INDUS 770
	IT AD IT II WERE LERUAT// Tead converting deltar to betake overatousn av Aivi/Mi //i	INDUS780
	SYZ FURMANNY' UCLIGA IS DEING UVERRIUDER DI RUALATIO'''	INDUKTOO
	KEIUKN	TNDU SEGA
	END	14-0.2030

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Appendix IV

SAMPLE DATA SETS

1.	EXTERNAL	LAMERAE	BOUNDARY LA	YER, NO	PRESSURE GI	PARIENT CR.	TRANSPIPATION
2.	1	1 1	1 24	2 1	0 (F	0 007	
3.	0.023	0.320	1.	300.	0.05	0.005	
4.	2117	0 075	0.000012				
5. 6	211/.	0.075	0.000011				
7.	0.023	1.					-
8.	0.320	1.					
9.	50.						
10.	50.						
11.	0.0	0.0					
12.	0.000062	3.1					
13.	0.000125	b. 2					
14.	0.000185	9.) 10 z					
15.	0.000247	12.5					
10.	0.000370	18 3					
18	0 000432	21.1					
19.	0.000493	23.9					
20	0.000555	26.7					
21.	0.000617	29.2					
22.	0.000678	31.7					
23.	0.000740	34.3					
24.	0.000802	36.4					
25.	0.000865	28.2					
20.	0.000925	40.7					
27.	0.001050	43.9					***
29	0.001110	45.6					,
30.	0.001170	46.7					
31.	0.001230	47.8					
32.	0.001300	48.9					Ž.
33.	0.001360	49.3					
34.	0.001420	49.7					• •
35.	0.001480	50.0	D 01	0	0	· · •	0
36. 77	0.41	0.085	0.01	υ.	v.	± •	• • •
)/. zo	22.	0.					
30. 30	32.2	778.					
40.	1	21 2					
L1	-						
42.							
43.							
44.	NOTE: M	OMENTUM	EQUATION ONL	Y IS BEI	NG SOLVED.	A TRANSIT	ION TO A
45.	т	URBULENT	BOUNDARY LA	YER WILL	OCCUR WHE	N REN REACH	ES 300.
46.	А	N ENTRAL	NMENT FRACTI	ON OF U.	003 IS REC	ONENDED FOR	LAMINAR
47.	В	DUNDARY	LAYER FLOWS.				

ORIGINAL PAGE IS OF POOR QUALITY

$\frac{1}{2}$	EXTERNA 1	L TURBULENT	BOUNDARY	LAYER, NO	PRESSURE	GRADIENT OR	TRANSPIRATION	
Ĵ.	0.0	μ. O	1 0		10 05	005		
6	0.0	0	2.0	•.•				
5	2117	0.075	0 000012	07				
6.	2	1	0.000011					
7	0 0	10						-
8	L 0	1.0						
Ğ.	110	1.0	100					
10	110		100					
11	0 0	0 0	100.					
12	0.0	73	173					
12.	0.0024	81	181					
11	0.0004	85	195					
14.	0,0044	02.	100					
12.	0.0050	00.	100.					
10.	0.0000	91.	191.					
1/.	0.0078	95.	195.					
18.	0.0088	90,	196.					
19.	0.01	98.	198.					
20.	0.0112	99.	199.					
21.	0.0122	101.	201.					
22.	0.0134	102.	202.					
23.	0.0144	104.	204.					
24.	0.0166	106.	206.					
25.	0.0188	108.	208.					
27.	0.0232	110.	210.					
28.	0.41	0.085	.01	0.0	0.0	1.0	0.0	
29.	25.							
30.	4000.	0.86						
31.	32.2	778.0						
32.	1	21 2						
33.								
34.								
35.								
36.	NOTE:	THIS DATA IS	5 SET UP F	OR CONSTAN	IT PROPERT	TIES; IF FLU	ID IS CHANGED	
37.		TO 2, VARIAE	BLE PROPER	TIES OF AI	R WILL BE	USED, CONS	ISTANT WITH	
38.		THE SPECIFIE	ED PRESSUR	E AND ENTH	ALPIES.			
39.								
40.	ł	WITH YPMAX S	SET TO 1.0	, THE WALL	FUNCTION	IS BEING B	YPASSED AND	
41.	•	THE PROGRAM	WILL INSE	RT A NUMBE	R OF ADDI	TIONAL GRID	POINTS, IF	
42.		IT IS DESIRF	D TO USE	THE WALL F	UNCTION C	PTION, CHAN	GE YPMAX.	
43.						•	· •	
44.		THE MIXING-L	ENGTH SCH	EME, WITH	VAN DRIES	T DAMPING 1	S USED THROUGH	

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1.	EXTERNAL	TURBULENT	BOUNDARY L	AYER, USING	TURBULENT	KINETIC	ENERGY
2.	1	2 1	2 15	2 1 1			
3.	0.0	4.0	1.0	300.	.05	.005	
4.	0	2					
5.	2117.	0.075	0.000012	1.0			
6.	2	1					
7.	0.0	1.0					
8.	4.0	1.0					
9.	110.		0.				
10.	110.		0.				
11.	0.0	0.	0.				
12.	0.0024	73.	73.				
13.	0.0034	81.	71.				
14.	0.0044	85.	67.				
15.	0.0056	88.	62.				
16.	0.0066	91.	57.			· ·	
17.	0.0078	93.	52.				
18.	0.0088	96.	47.				
19.	0.01	98.	41.				
20.	0.0112	99.	36.				
21.	0.0122	101.	31.		-		
22.	0.0134	102.	26.				
23.	0.0144	104.	21.				
24.	0.0166	106.	13.				
25.	0.0188	108.	5.				
26.	0.0232	110.	0.				_
27.	0.41	0.085	.01	.22	.377	1.0	0.0
28.	25.0						
29.	4000.	1.7					
30.	32.2	778.0					
31.	1 2	21 2					
32.							
33.							
34.							
35.	NOTE: MC	DMENTUM AND	TURBULENT	KINETIC EN	ERGY EQUAT	TON ARE B	EING SOLVED.
56.	TH	E THERMAL	ENERGY EQU	ATION CAN B	E ADDED AS	A THIRD	EQUATION AS
51.	DE	ESIRED. SEI	E PREVIOUS	NOTE ON YPI	MAX.		

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3. 0.0 20. 1.0 2000. .05 4. 0 0.0075 0.000012 0.7 5. 21.17 0.0075 0.000012 0.7 6. 0.1 0.1 0.1 8. 0.5 0.1 0.5 9. 2.0 0.1 2.0 11. 10.0 0.1 5.0 12. 20. 0.1 5.0 13. 20.1 5.0 14. 240. 14. 20. 20.2 8.1 15. 240. 120. 16. 240. 120. 17. 240. 120. 21. 0.053 8.1 22. 0.053 8.1 23. 0.047 8.1 24. 0.047 8.1 25. 0.051 8.1 26. 0.053 8.1 27. 0.054 8.1 28.	1.		FLOW IN A	CIRCULAR PII	PE, ENTRY	LENGTH	PROBLEM	
<pre>4. 0 0 0 5. 21.17 0.00075 0.000012 0.7 6. 6 1 7. 0.0 0.1 0.1 8. 0.5 0.1 0.5 9. 2.0 0.1 1.0 10. 4.0 0.1 2.0 11. 10.0 0.1 5.0 12. 20. 0.1 5.0 12. 20. 0.1 5.0 13. 240. 14. 240. 15. 240. 16. 240. 16. 240. 16. 240. 17. 240. 18. 240. 18. 240. 18. 240. 19. 0.0 8. 120. 21. 0.034 8. 120. 22. 0.039 8. 120. 22. 0.045 8. 120. 24. 0.047 8. 120. 25. 0.045 8. 120. 26. 0.055 8. 120. 27. 0.058 8. 120. 28. 0.064 8. 120. 29. 0.064 8. 120. 30. 0.066 8. 120. 31. 0.076 8. 120. 31. 0.076 8. 120. 33. 0.076 8. 120. 33. 0.076 8. 120. 33. 0.076 8. 120. 33. 0.076 8. 120. 33. 0.076 8. 120. 33. 0.076 8. 120. 33. 0.076 8. 120. 33. 0.076 8. 120. 33. 0.076 8. 120. 33. 0.080 8. 120. 34. 0.080 8. 120. 35. 0.080 8. 120. 35. 0.080 8. 120. 36. 0.088 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 39. 0.086 8. 120. 39. 0.086 8. 120. 30. 0.086 8. 120. 31. 0.090 8. 120. 33. 0.090 8. 120. 34. 0.090 8. 120. 35. 0.080 8. 120. 36. 0.085 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 39. 0.086 8. 120. 30. 0.086 8. 120. 31. 0.099 8. 120. 32. 0.099 7. 100. 33. 0.099 7. 100. 34. 0.099 7. 120. 35. 0.0 0.0 35. 0.0 0.0 35. 0.0 0.0 35. 0.0 0.0 35. 0.0 0.0 35. 0.0 0.0 35. 0.0 0.0 35. 0.0 0.0 35. 0.0 0.0 35. 0.0 0.0 35. 0.0 0.0 35. 0.0 0.0 35.</pre>	3.	0.0	20.	1.0	2000.	.05		
3. 21.17 0.0075 0.00012 0.7 6. 6 1 0.1 0.7 7. 0.0 0.1 0.1 8. 0.5 0.1 0.5 9. 2.0 0.1 1.0 10. 4.0 0.1 2.0 11. 10.0 0.1 5.0 12. 20.0 0.1 5.0 13. 240. 14. 240. 14. 240. 14. 240. 15. 240. 12. 120. 21. 0.033 8. 120. 22. 0.039 8. 120. 23. 0.047 8. 120. 24. 0.061 8. 120. 25. 0.055 8. 120. 26. 0.055 8. 120. 27. 0.064 8. 120. 28. 0.064 8. 120. 29. 0.073 8. 120. 30. 0.076 8.	4.	0	0					
0.0 0.1 0.1 0.5 8. 0.5 0.1 0.5 9. 2.0 0.1 2.0 10. 4.0 0.1 2.0 11. 10.0 0.1 5.0 12. 20. 0.1 5.0 13. 240. 14. 240. 15. 240. 16. 240. 17. 240. 18. 240. 19. 0.0 8. 120. 21. 0.034 8. 120. 22. 0.047 8. 120. 23. 0.047 8. 120. 23. 0.064 8. 120. 23. 0.067 8. 120. 24. 0.064 8. 120. 23. 0.076 8. 120. 23. 0.076 8. 120. 25. 0.088 8. 120. <t< th=""><th>5.</th><th>21.17</th><th>0.00/5</th><th>0.000012</th><th>0./</th><th></th><th></th><th></th></t<>	5.	21.17	0.00/5	0.000012	0./			
s: 0.5 0.1 0.5 9. 2.0 0.1 1.0 10. 4.0 0.1 2.0 11. 10.0 0.1 5.0 12. 20. 0.1 5.0 13. 240. 1 240. 14. 240. 1 240. 15. 240. 1 240. 16. 240. 1 240. 16. 240. 1 1 20. 0.022 8. 120. 21. 0.039 8. 120. 22. 0.043 8. 120. 23. 0.047 8. 120. 24. 0.064 8. 120. 25. 0.055 8. 120. 26. 0.067 8. 120. 27. 0.064 8. 120. 26. 0.068 8. 120. 27. 0.084 8.	7.	0.0	0.1	0.1				
9. 2.0 0.1 1.0 10. 4.0 0.1 2.0 11. 10.0 0.1 5.0 12. 20. 0.1 5.0 13. 240. 14. 240. 15. 240. 16. 240. 16. 240. 17. 240. 18. 0.0 8. 120. 20. 0.022 8. 120. 21. 0.034 8. 120. 22. 0.039 8. 120. 23. 0.043 8. 120. 24. 0.047 8. 120. 25. 0.051 8. 120. 26. 0.058 8. 120. 27. 0.058 8. 120. 28. 0.064 8. 120. 29. 0.064 8. 120. 30. 0.067 8. 120. 31. 0.070 8. 120. 33. 0.076 8. 120. 33. 0.076 8. 120. 33. 0.076 8. 120. 33. 0.078 8. 120. 33. 0.078 8. 120. 33. 0.078 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 35. 0.080 8. 120. 35. 0.080 8. 120. 35. 0.086 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 39. 0.088 8. 120. 39. 0.088 8. 120. 40. 0.099 8. 120. 41. 0.092 8. 120. 42. 0.094 6. 120. 42. 0.094 6. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.098 8. 120. 46. 0.0988 8. 120. 47. 0.0994 7. 120. 48. 0.0994 7. 120. 44. 0.0994 7. 120. 45. 0.0994 7. 120. 46. 0.0988 8. 120. 57. 1 21 4 9 56. 57. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE 15 HERE BEING VARIEL USING K1 = 9 APPT A TABLE OF AUX1(M).	8.	0.5	0.1	0.5				
10. 4.0 0.1 2.0 11. 10.0 0.1 5.0 12. 20. 0.1 5.0 13. 240. 14. 240. 15. 240. 16. 240. 17. 240. 18. 240. 19. 0.0 8. 120. 21. 0.034 8. 120. 22. 0.043 8. 120. 23. 0.043 8. 120. 24. 0.047 8. 120. 25. 0.051 8. 120. 26. 0.055 8. 120. 27. 0.058 8. 120. 28. 0.061 8. 120. 28. 0.061 8. 120. 28. 0.064 8. 120. 30. 0.067 8. 120. 31. 0.070 8. 120. 32. 0.073 8. 120. 33. 0.076 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 39. 0.088 8. 120. 39. 0.088 8. 120. 30. 0.067 8. 120. 31. 0.076 8. 120. 32. 0.073 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 40. 0.099 8. 120. 41. 0.092 8. 120. 42. 0.094 5. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 45. 0.0985 8. 120. 46. 0.0987 4. 180. 50. 0.100 0.0 0.40 0.0 0.0 1.0 0.0 51. 0.0 0.0 0.40 0.0 52. 0.0 0.0 0.41 0.0 0.0 1.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE 15 HERE BEING VARIEL USING KI = 9 APT 50. 51. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE 15 HERE BEING VARIEL USING KI = 9 APT 54. 55. NOTE: THE FOREWARD STEP SIZE 15 HERE BEING VARIEL USING KI = 9 APT 54. 55. NOTE: THE FOREWARD STEP SIZE 15 HERE BEING VARIEL USING KI = 9 APT 54. 55. NOTE: THE FOREWARD STEP SIZE 15 HERE BEING VARIEL USING KI = 9 APT 54. 55. NOTE: THE FOREWARD STEP SIZE 15 HERE BEING VARIEL USING KI = 9 APT 55. NOTE: THE FOREWARD STEP SIZE 15 HERE BEING VARIEL USING KI = 9 APT 55. NOTE: THE FOREWARD STEP SIZE 15 HERE BEING VARIEL USING KI = 9 APT 56. 57.	9.	2.0	0.1	1.0				
11. 10.0 0.1 5.0 13. 20. 0.1 5.0 14. 240. 15. 240. 15. 240. 16. 240. 16. 240. 17. 240. 17. 240. 18. 120. 21. 0.034 8. 120. 22. 0.039 8. 120. 23. 0.043 8. 120. 24. 0.047 8. 120. 25. 0.051 8. 120. 26. 0.055 8. 120. 27. 0.058 8. 120. 28. 0.064 8. 120. 29. 0.664 8. 120. 30. 0.678 8. 120. 31. 0.076 8. 120. 32. 0.080 8. 120. 33. 0.086 8. 120. 44. 0.092 8. 120. 45. 0.0985 8. 120.	10.	4.0	0.1	2.0				
1. 240. 14. 240. 15. 240. 16. 240. 17. 240. 18. 240. 19. 0.0 8. 20. 0.022 8. 21. 0.034 8. 22. 0.039 8. 23. 0.043 8. 24. 0.047 8. 25. 0.051 8. 26. 0.055 8. 27. 0.058 8. 28. 0.064 8. 29. 0.064 8. 20. 0.067 8. 21. 0.073 8. 28. 0.067 8. 29. 0.064 8. 20. 120. 3. 31. 0.076 8. 32. 0.073 8. 33. 0.086 8. 34. 0.090 8. 35. 0.086 8. 36. 0.092 8. </th <th>12.</th> <th>20</th> <th>0.1</th> <th>5.0</th> <th></th> <th></th> <th></th> <th></th>	12.	20	0.1	5.0				
14. 240. 15. 240. 16. 240. 17. 240. 18. 240. 19. 0.0 8. 120. 21. 0.034 8. 120. 22. 0.039 8. 120. 23. 0.043 8. 120. 24. 0.047 8. 120. 25. 0.051 8. 120. 26. 0.055 8. 120. 27. 0.064 8. 120. 28. 0.064 8. 120. 29. 0.064 8. 120. 30. 0.067 8. 120. 31. 0.070 8. 120. 33. 0.076 8. 120. 34. 0.080 8. 120. 35. 0.080 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120.	13.	20.	0.1	240.				
15. 240. 16. 240. 17. 240. 18. 240. 19. 0.0 8. 20. 0.022 8. 21. 0.034 8. 22. 0.039 8. 22. 0.039 8. 22. 0.039 8. 22. 0.043 8. 23. 0.043 8. 24. 0.047 8. 22. 0.055 8. 24. 0.047 8. 25. 0.051 8. 26. 0.055 8. 27. 0.658 8. 28. 0.064 8. 29. 0.664 8. 20. 31. 0.078 31. 0.078 8. 32. 0.078 8. 33. 0.068 8. 34. 0.078 8. 32. 0.064 8. 34. 0.090 8. 34.	14.			240.				
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17. 240. 19. 0.0 8. 120. 20. 0.022 8. 120. 21. 0.034 8. 120. 22. 0.039 8. 120. 22. 0.043 8. 120. 23. 0.047 8. 120. 24. 0.047 8. 120. 25. 0.051 8. 120. 26. 0.055 8. 120. 27. 0.064 8. 120. 28. 0.061 8. 120. 30. 0.067 8. 120. 31. 0.070 8. 120. 32. 0.073 8. 120. 33. 0.076 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 40. 0.092 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 44.	16.			240.				
13. 0.0 8. 120. 20. 0.022 8. 120. 21. 0.034 8. 120. 22. 0.039 8. 120. 22. 0.043 8. 120. 22. 0.043 8. 120. 23. 0.047 8. 120. 24. 0.047 8. 120. 25. 0.051 8. 120. 26. 0.055 8. 120. 27. 0.058 8. 120. 28. 0.061 8. 120. 30. 0.067 8. 120. 31. 0.070 8. 120. 32. 0.078 8. 120. 33. 0.060 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 40. 0.090 8. 120. 42. 0.094 8. 120. 43. 0.0928 8. 120. <th>19</th> <th></th> <th></th> <th>240.</th> <th></th> <th></th> <th></th> <th></th>	19			240.				
20. 0.022 8. 120. 21. 0.034 8. 120. 22. 0.043 8. 120. 23. 0.043 8. 120. 24. 0.047 8. 120. 25. 0.051 8. 120. 26. 0.055 8. 120. 27. 0.064 8. 120. 28. 0.061 8. 120. 30. 0.067 8. 120. 31. 0.070 8. 120. 32. 0.076 8. 120. 33. 0.076 8. 120. 34. 0.080 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 40. 0.092 8. 120. 41. 0.092 8. 120. 44. 0.098 8. 120. 45. 0.0988 120. 46. 0.0994 7. 120.	19.	0.0	8.	120.				
21. 0.034 8. 120. 22. 0.039 8. 120. 23. 0.043 8. 120. 24. 0.047 8. 120. 25. 0.051 8. 120. 26. 0.055 8. 120. 27. 0.058 8. 120. 29. 0.064 8. 120. 30. 0.067 8. 120. 31. 0.070 8. 120. 32. 0.073 8. 120. 33. 0.076 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 39. 0.088 8. 120. 40. 0.099 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0994 7. 120. 46. 0.0998 8. 120. 47. 0.0994 7. 120. 48. 0.0994 7. 120. 49. 0.0994 7. 120. 48. 0.0994 7. 120. 48. 0.0994 7. 120. 48. 0.0994 7. 120. 49. 0.0995 8. 120. 40. 0.0 0.0 0.0 1.0 0.0 1.0 0.0 51. 0.0 0.0 0.0 1.0 0.0 1.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING K1 = 9 ANT A TABLE OF AUX1(M).	20.	0.022	8.	120.				
22. 0.039 8. 120. 23. 0.043 8. 120. 24. 0.047 8. 120. 25. 0.051 8. 120. 27. 0.058 8. 120. 28. 0.061 8. 120. 29. 0.064 8. 120. 30. 0.067 8. 120. 31. 0.070 8. 120. 32. 0.073 8. 120. 33. 0.076 8. 120. 34. 0.080 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 39. 0.086 8. 120. 41. 0.092 8. 120. 41. 0.092 8. 120. 41. 0.098 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 45. 0.0985 8. 120. 45. 0.0988 8. 120. 45. 0.0988 8. 120. 45. 0.0994 7. 120. 46. 0.0998 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.0 52. 0.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING K1 = 9 ANT 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING K1 = 9 ANT 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING K1 = 9 ANT 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING K1 = 9 ANT 50. A TARLE OF AUX1(M).	21.	0.034	8.	120.				
23. 0.043 6. 120. 24. 0.047 8. 120. 25. 0.051 8. 120. 26. 0.055 8. 120. 28. 0.061 8. 120. 30. 0.067 8. 120. 31. 0.070 8. 120. 33. 0.076 8. 120. 33. 0.076 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 39. 0.088 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 42. 0.094 6. 120. 44. 0.098 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 44. 0.0984 8. 120. 45. 0.0985 8. 120. 45. 0.0985 8. 120. 46. 0.0985 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 48. 0.0994 7. 120. 48. 0.0994 7. 120. 48. 0.0994 7. 120. 50. 0.100 0.0 240. 51. 0.0 0.0 0.0 53. 0.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING K1 = 9 AUT 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING K1 = 9 AUT 51. A TABLE OF AUX1(M).	22.	0.039	8.	120.				
25. 0.051 8. 120. 26. 0.055 8. 120. 27. 0.058 8. 120. 28. 0.064 8. 120. 30. 0.067 8. 120. 31. 0.070 8. 120. 32. 0.073 8. 120. 33. 0.076 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 45. 0.0981 8. 120. 46. 0.0991 8. 120. 47. 0.0991 8. 120. 48. 0.0991 7. 120. 49. 0.0991 8. 120. 40. 0.0991 8. 120. 41. 0.000 0.0 0.0 0.0 1.0 0.0 50. 0.100 0.0 240. 51. 0.0 0.0 0.0 52. 0.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 50. 0. THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 50. 0. ATABLE OF AUX1(M).	23. 24	0,045	8. 8	120.				
26. 0.055 8. 120. 27. 0.058 8. 120. 28. 0.064 8. 120. 29. 0.064 8. 120. 30. 0.067 8. 120. 31. 0.070 8. 120. 32. 0.073 8. 120. 33. 0.076 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 44. 0.098 8. 120. 45. 0.0988 8. 120. 45. 0.0991 8. 120. 47. 0.0991 8. 120. 48. 0.0997 4. 180. 50. 0.100 0.0 0.0	25.	0.051	8.	120.				
27. 0.058 8. 120. 28. 0.061 8. 120. 30. 0.067 8. 120. 31. 0.070 8. 120. 33. 0.076 8. 120. 33. 0.076 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 45. 0.0985 8. 120. 45. 0.0985 8. 120. 45. 0.0985 8. 120. 45. 0.0988 8. 120. 45. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.0 0.0 1.0 0.0 52. 0.0 0.0 0.0 53. 0.0 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 60. A TARLE OF AUX1(M).	26.	0.055	8.	120.				
28. 0.061 8. 120. 29. 0.064 8. 120. 30. 0.067 8. 120. 31. 0.070 8. 120. 33. 0.076 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 46. 0.0988 8. 120. 46. 0.0998 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.0 0.0 1.0 0.0 52. 0.0 0.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 ANT A TABLE OF AUX1(M).	27.	0.058	8.	120.				
23. 0.004 0. 120. 31. 0.070 8. 120. 32. 0.073 8. 120. 33. 0.076 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 46. 0.0988 8. 120. 46. 0.0991 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.0 1.0 0.0 52. 0.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 ANT A TABLE OF AUX1(M).	28.	0.061	8.	120.				•
31. 0.070 8. 120. 32. 0.073 8. 120. 33. 0.076 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 39. 0.088 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 45. 0.0991 8. 120. 46. 0.09938 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 0.0 0.0 51. 0.0 0.0 0.0 0.0 0.0 52. 1	30	0.064	o. 8	120.				
32. 0.073 8. 120. 33. 0.076 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 46. 0.0988 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 48. 0.0994 7. 120. 48. 0.0994 7. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING K1 = 9 ANT A TABLE OF AUXI(M).	31.	0.070	8.	120.				
33. 0.076 8. 120. 34. 0.078 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 39. 0.088 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 45. 0.0985 8. 120. 46. 0.0988 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.01 0.0 0.0 1.0 0.0 52. 0.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING K1 = 9 AMT 60. A TABLE OF AUX1(M).	32.	0.073	8.	120.				
34. 0.078 8. 120. 35. 0.080 8. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 39. 0.088 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 45. 0.0985 8. 120. 45. 0.0991 8. 120. 46. 0.0994 7. 120. 48. 0.0994 7. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.0 1.0 0.0 52. 0.0 0.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIEL USING K1 = 9 ANT <th>33.</th> <th>0.076</th> <th>8.</th> <th>120.</th> <th></th> <th></th> <th></th> <th></th>	33.	0.076	8.	120.				
35. 0.000 0. 120. 36. 0.082 8. 120. 37. 0.084 8. 120. 38. 0.086 8. 120. 39. 0.088 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 45. 0.0985 8. 120. 46. 0.0988 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 51. 0.0 0.0 0.0 1.0 0.0 52. 0.0 0.0 0.0 1.0 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. </th <th>34.</th> <th></th> <th>8.</th> <th>120.</th> <th>-</th> <th></th> <th></th> <th></th>	34.		8.	120.	-			
37. 0.084 8. 120. 38. 0.086 8. 120. 39. 0.088 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 45. 0.0985 8. 120. 45. 0.0988 8. 120. 46. 0.0991 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.0 1.0 0.0 52. 0.0 0.0 0.0 1.0 0.0 0.0 53. 0.0 0.0 0.0 0.0 1.0 0.0 54. <td< th=""><th>36</th><th>0.080</th><th>8.</th><th>120.</th><th></th><th></th><th></th><th></th></td<>	36	0.080	8.	120.				
38. 0.086 8. 120. 39. 0.088 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 45. 0.0988 8. 120. 45. 0.0991 8. 120. 47. 0.0994 7. 120. 48. 0.0994 7. 120. 49. 0.0994 7. 120. 49. 0.0994 7. 120. 50. 0.100 0.0 240. 51. 0.0 0.0 0.0 1.0 0.0 52. 0.0 0.0 0.0 1.0 0.0 0.0 53. 0.0 0.0 0.0 0.0 1.0 0.0 54. 32.2 778.0 0.0 0.0 0.0 <t< th=""><th>37.</th><th>0.084</th><th>8.</th><th>120.</th><th></th><th></th><th></th><th></th></t<>	37.	0.084	8.	120.				
39. 0.088 8. 120. 40. 0.090 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 46. 0.0988 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.01 0.0 0.0 1.0 0.0 52. 0.0 0.0 0.01 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND A TABLE OF AUX1(M).	38.	0.086	8.	120.				
40. 0.090 8. 120. 41. 0.092 8. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 46. 0.0988 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.01 0.0 0.0 1.0 0.0 52. 0.0 0.0 0.01 0.0 0.0 1.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING K1 = 9 AND A TABLE OF AUX1(M).	39.	0.088	8.	120.				
41. 0.032 0. 120. 42. 0.094 8. 120. 43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 46. 0.0988 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.01 0.0 0.0 1.0 0.0 52. 0.0 0.0 0.01 0.0 0.0 1.0 0.0 53. 0.0 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING K1 = 9 AND 60. A TABLE OF AUX1(M).	40.	0.090	8. 9	120.				
43. 0.096 8. 120. 44. 0.098 8. 120. 45. 0.0985 8. 120. 46. 0.0988 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.01 0.0 0.0 52. 0.0 0.0 0.01 0.0 0.0 53. 0.0 0.0 0.0 0.0 0.0 54. 32.2 778.0 0 0.0 0.0 55. 1 21 4 9 0.0 0.0 56. 57. 58. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 50. A TABLE OF AUX1(M). 0.	42.	0.094	8. 8.	120.				
<pre>44. 0.098 8. 120. 45. 0.0985 8. 120. 46. 0.0988 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.01 0.0 0.0 1.0 0.0 51. 0.0 0.0 0.01 0.0 0.0 1.0 0.0 52. 0.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 60. A TABLE OF AUX1(M).</pre>	43.	0.096	8.	120.				
45. 0.0985 8. 120. 46. 0.0988 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.01 0.0 0.0 1.0 0.0 52. 0.0 0.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 60. A TABLE OF AUX1(M).	44.	0.098	8.	120.				
46. 0.0998 8. 120. 47. 0.0991 8. 120. 48. 0.0994 7. 120. 49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.01 0.0 0.0 1.0 0.0 52. 0.0 0.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 60. A TABLE OF AUX1(M).	45.	0.0985	8.	120.				
48. 0.0994 7. $120.$ 49. 0.0997 $4.$ $180.$ 50. 0.100 0.0 $240.$ 51. 0.0 0.0 0.0 1.0 0.0 52. 0.0 0.0 0.0 1.0 0.0 53. 0.0 0.0 $54.$ 32.2 778.0 55. 1 21 4 9 56. $57.$ $58.$ $58.$ $59.$ NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND $59.$ NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND	40. 47	0.0988	ð. 8	120.				
49. 0.0997 4. 180. 50. 0.100 0.0 240. 51. 0.0 0.0 0.0 1.0 0.0 52. 0.0 0.0 0.0 1.0 0.0 53. 0.0 0.0 0.0 $53.$ 0.0 0.0 54. 32.2 778.0 $55.$ 1 21 4 9 56. $57.$ $58.$ $59.$ NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND $60.$ A TABLE OF AUX1(M). $4.$	48.	0.0994	7.	120.				
50. 0.100 0.0 240. 51. 0.0 0.0 0.01 0.0 0.0 1.0 0.0 52. 0.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 60. A TABLE OF AUX1(M).	49.	0.0997	4	180.				
51. 0.0 0.0 0.01 0.0 0.0 1.0 0.0 52. 0.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 60. A TABLE OF AUX1(M).	50.	0.100	0.0	240.				
52. 0.0 0.0 53. 0.0 0.0 54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 60. A TABLE OF AUX1(M).	51.	0.0	0.0	0.01	0.0	0.0	1.0	0.0
54. 32.2 778.0 55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 60. A TABLE OF AUX1(M).	22. 53	0.0	0.0					
55. 1 21 4 9 56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 59. A TABLE OF AUX1(M).	54.	32.2	778.0					
56. 57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 60. A TABLE OF AUX1(M).	55.	1	21 4	9				
57. 58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 60. A TABLE OF AUX1(M).	56.							
58. 59. NOTE: THE FOREWARD STEP SIZE IS HERE BEING VARIED USING KI = 9 AND 60. A TABLE OF AUX1(M).	57.							
60. A TABLE OF AUX1(M).	58.	NOTE	THE EOREWA	RD STEP SIZE	TS HERE	BEING V	ARTED USTHG	KI = 9 AND
	59. 60.	NUICI	A TABLE OF	AUX1(M).				

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. 1.	TURBULE	NT FLOW IN	A CIRCULAR	PIPE			
4. z	0 0 4	2 1 h ()	1 0	ົ້າດດດ້	05		
J .	v. u	4. V	1.0	2000.	• • • •		
4. F	2117	0 075	0 000012	07			
2.	211/.	2.075	0.000012	0.7			
р. 7	0 0 4	- 1					
/.	0.0	0.1					
ð. 0	9.	0.1	- 2				
9.			-2.				
10.			-2.				
11.	0.0	115.	137.				
13.	0.010	112.	159.				
15.	0.020	103.	145.				
17.	0.030	106.	148.				
18.	0.035	105.	149.				
19.	0.040	105.	151.				
20.	0.045	102.	155.				
21.	0.050	100.	155.				
22.	0.055	99.	158.				
23.	0.060	95.	162.				
24.	0.065	94.	164.				
25.	0.070	91.	168.				
26.	0.075	89.	172.				
27.	0.080	87.	1/5.			2 · · ·	
28.	0.085	84.	179.				
29.	0.090	80.	185.				
30.	0.095	73.	193.				
31.	0,10	0.	200.			L.A	0 0
32.	0.41	0.075	0.01	0.005	0.9	40.	0.0
33.	26.						•
34.	4000.	0.86					
35.	32.2	778.0	_				
36.	1	21 4	2				
37.			·			• •	
38.							
39.							
40.	NOTE:	HERE EDDY V	ISCOSITY IN	THE OUTER	R REGION I	S BEING CU	MPUTED
41.		AS A CONSTA	NT BASED ON	REYNULDS	NUMBER RA	THER THAN	
42.		A MIXING-LE	NGTH. HEAT	FLUX IS	SPECIFIED A	AI INE WAL	L LAS A
43.		CONSTANT VA	LUE) RATHER	THAN WAL	L ENTHALPY	AS IN THE	PREVIOUS
44.		EXAMPLES.	WALL FUNCTI	ON 15 BEI	NG USED IN	NEAK-WALL	. REGIUN.

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1.	LAMINA	R FREE CONVEC	TION FROM	A VERTICAL	FLAT PLATE	1	
2.	1	1 2	2 31	2 1	U		
3.	0.0	3.0	.5	1.0	.01	.01	-32.2
4.	1	0					
5.	2117.						
6.	2	1					
7.	0.0	4.0					
8.	3.0	4.0					
9.	.0001	υ.Ο	138.66				
10.	.0001	0.0	138.60				
11.	0.0	0.0	138.66				
12.	. 25258	E-03 .0165	138.47				
13.	4208	E-03 .0276	138.34				
14.	.50498	E-03 .0331	138.26				
15.	63508	F-03 .041	138,16				
16	76516	F=03 0507	138.06				
17	1 0176	E = 0.3 0.672	137 87				
19	1 2705		137 66				
10.	1 5305		137 66				
13.	1.700	E = 0.3 1170	127.90				
20.	2 0755	E-03 175	137.06				
21.	2.0320	E-UJ .1944 E-03 1E91	136 76				
22.	2.2320	E-03 1696	136 67				
23.	2.3400	E = 03 1851	136 46				
24.	3 0600		136 14				
25.	2 2120		136 07				
20.	3.5450		135 86				
21.	3 9269	E=03 2000	135 66				
20.	1 2085		135 36				
23.	4.2001		135 06				
Z 1	4.JJIC	L-03 2865	134 46				
22.	5 1 2 1 6		133 09				
22.	7 6616	-0J .25/J	132 00				
2). 71.	0 1910		172.30				
24.	3.1010	C-UJ .237J	120 20				
JJ. 76	12.240		170.20				
JU. 77	10.070		107 74				
J/. 70	13.030		107 76				
20.	23.740		127.20				
29.	2/.340		127,02				
40.	JI.J/0		126.00				
41.	20.190		126.66				
42.	0 0		01	0.0	0 1)	1 0	0 0
43.	0.0	0.0	.01	0.0	0.0	1.0	0.0
44.	0.0	0 0					
43.	22 2	778 0					
40.	32.2	20 5					
4/.	1	20 0					
40. 20							
43. 50							
50.	NOTE	A LADCE ENTO	ALMMENT EDA		SED AS DI	SCHSSED IN	1
JI. 50	NUILI	THE TEYT A	EINITE EDI	EF-STDEAM V	JELOCITY IS	LISED RUT	ТНЕ
52			CENEDALLY	ADEBATE C	TISEACTOD	, 5525, 501 IV WITH A	1116
シリ。 ちル		7FPO VALUE I	E THE ENTER	LINMENT ED/	LOTION IS N		.1.1
57.		AN F-FORMAT	IS HERE US	D FOR THE	Y-DISTANCE	S. FOR CON	VFN-
56		LENCE (IT OV	FRRIDES TH	F F-FORMAT	SPECIFICAT	TION. BUT T	ΉE
57		NUMBERS MUST	BE JUSTIE	ED TO THE	RIGHT OF T	HE 10 SPAC	E
59		FIFID) SFT	RETRAN=1) FOR LAMIN	NAR ERFE CC	NVECTION F	LOWS
- O +		TILLU/A JEI	NET 0007-44	- TON LANGT	WAR INCL OU		

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1.	FLOW	A SUPERSON	IC NOZZLE,	PRESCRIBE	D CORE	VELOCITY D	ISTRIBUTION
3.	-0.1783	1.6358	0.25	200.	0.01	0.01	
4.	0	1					
5.	2980.8	-					
6.	40	1					
7.	1783	0,2085					
8.	0.0208	0.2085					
9.	0.0416	0.2085					
10.	0.1092	0,1004					
12	0.2000	0.1503					
13	0.5707	0 1385					
14.	0.4994	0.1291					
15.	0.5443	0.1213					
16.	0.5805	0.1150					
17.	0.61	0.1098					
18.	0.6356	0.1054					
19.	0.658	0.1015					
20.	0.6952	0.0951					
21.	0.7249	0.089					
22.	0.7491	0.0857					
23.	0.7691	0.0822					
24.	0.7951	0.0761					
25.	0.8261	0.0723					
27.	0.8457	0.0689					
28.	0.8545	0.0674					
29.	0.8603	0,0664					
30.	0.8616	0.0664					
31.	0.8655	0.0671					
32.	0.8731	0.0684					
55.	0.8882	0.071					
24.	0.90/1	0.0745					
35.	0.9500	0.0798					
37	1.0229	0.0944					
38.	1.0751	0.1035					
39.	1.1038	0.1085					
40.	1.1341	0.1137					
41.	1.1999	0.1251					
42.	1.2726	0.1378					
43.	1.3524	0.1516					
44 <u>.</u> .E	1.4394	0.100/					
45.	1 6358	0.165					
40.	0123 78	0,2000	150.69				
48.	0123.78		150.69				
49.	0123.78		150.69				
50.	0151.85		150.69				
51.	0189.74		150.69				
52.	0227.59		150,69				
53.	0265.38		150.69		-		
54.	0505.13		120.03				
22. 56	0340.//		150.05				
57.	0415.85		150.69				
58.	0453.25		150.69				
59.	0490.53		150.69				
60.	0564.75		150.69				

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61	0638.4	2		150.69					
62	0711 5/	6		150 69					
63	0784 0	ž		150 69					
64	0901 3	R		150 69					
65	0005100	<u> </u>		150 69					
65. 66	1100 7	2		150.69					
67	1201 7			150.05					
D/.	1501.7			150.09					
DB .	1440.2			150.69					
69.	1651.			120.09				4	
70.	1805.2			150.69					
/1.	1969.			120.69					
/2.	2122.2			120.69					
73.	2310.7			150.69					
74.	2471.4			150.69					
75.	2663.2			150,69					
76.	2831.4			150.69					
77.	2978.6			150.69					
78.	3107.4			150,69					
79.	3165.7			150,69					
80.	3220.1			150.69					
81.	3318.6			150.69					
82.	3405.3			150.69					
83.	3481.4			150.69					
84	3548.5			150.69					
85.	3607.8			150.69					
86.	3660.4			150.69					
87.	0.00000	0 12	3.780	369.17					
88.	0.0037	3 12	2.31	369.17					
89	0.00746	5 12	0.73	369.17					
90.	0.0112	11	9.02	366.42					
91.	0.0149	3 11	7.14	363.02					
92.	0.0186	7 11	5.07	359.26					
93.	0.0205	3 11	3.94	357.21					
94	0.0224	11	2.74	355.04					
95	0.0242	7 11	1.46	352.72					
96	0 0261	. ii	0 08	350 22					
97	0 028	10	8 59	347.52					
98	0.02983	7 10	6 97	341.52					
50.	0.0230	, 10 h 10	5 19	361 35					
100	0.0336/	• 10 n 10	Z 2	337 7h					
100.	0.0356	7 10	0 05	171 67					
101.	0.0774		251	329 06					
102.	0.03/3	+ 30 05	250	202 27					
105.	0.0532	7 01	432	316 42					
104.	0.0410	, oc	205	707 00					
105.	0.0429	4 00 70	.200	207.09		•			
100.	0.0448	7 0 0	.172	232.33					
107.	0.04007	/ 00	.000	120.03	0.0	0.0	1 0	0 0	
108.	0.41	υ.	005	0.01	0.0	0.0	1.0	0.0	
109.	25.	•	a.c.						
110.	4000.	U.	0 D 0						
111.	52.2	_ //	ð.						
112.	1	5	0						
112.									
114.	NOTE -			ADEDTICE A					. E
115.	NOTE:	VAKIA	DLE PK	CREATES U	- AIK AR	E DEING LUM	FUIED USI	NG SUBRUUII ED AND THE	I.C.
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