CALCULATION OF THE INTERACTION BETWEEN A COMPLEX TURBULENT SHEAR LAYER AND AN EXTERNAL INVISCID STREAM

by

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بسم الله الرحمن الرحيم

الحمد لله رب العالمين على اتمام هذا العمل الذى هو سوى
نطفة من علمه سبحانه و تعالى

In the name of God, the Merciful,
the Compassionate

Thanks to God the one and only for the
completion of this work.

C O N T E N T S

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NOMENCLATURE

(i) List of Abbreviations Used in the Text

AMOS	A.M.O. Smith (Smith and Hess).
BFA	Bradshaw-Ferriss-Atwell.
BL	Boundary layer.
C-F-L	Courant-Friedrichs-Lewy.
K-Z	Kutta-Zhukovskii.
LE	Leading Edge.
MS	Matching Surface.
PF	Potential Flow.
RS	Real Surface.
SL	Shear Layer.
TE	Trailing Edge.
TSL	Thin Shear Layer.

(ii) List of Definitions

Initial	: Initial conditions refer to conditions just before the first viscous/inviscid iteration is performed.
Starting	: Starting conditions denote conditions at the first station ($s = s_o$) (or start) of the turbulent shear layer calculation.
Iteration (or Iteration Cycle)	: This refers to one complete viscous/inviscid interaction cycle, including potential flow, shear layer and matching calculations.
Sweep	: This refers to one streamwise calculation of the shear layer only.
Run	: This denotes one potential flow calculation (program AMOS), one application of the matching procedure (program MATCH), one execution of the smoothing program (SMOOTH) or one execution of the mass flow calculation program for the duct (TRAVERS).
Nodes	: These refer to either real-surface or matching surface nodes.

Shear Layer Calculation Stations	: These denote calculation stations (at constant s) for the shear layer.
Traverse Stations	: These denote stations along the duct, at which the velocity profile and mass flow rate are calculated.
Smoothing Points	: These denote points picked off the p'(s) distribution, through which a cubic spline is fitted (which is used to smooth the p'(s) distribution).
Knots	: These are the s-values of points at which two segments of a cubic spline fit are matched in first and second derivative.

(iii) List of Symbols

A	The advection term in the turbulent kinetic energy equation.
A',F',G',K',H'	Functions of the coefficients of partial differential equations.
$A_1,B_1,C_1,D_1,E_1,$ A_2,B_2,C_2,D_2,E_2	Coefficients of partial differential equations.
A_{pn}	A matrix of coefficients of the source elements; this is known as the matrix of influence coefficients. Its elements represent the normal velocity induced by a unit source density at the nth. element, on the pth. element and at the mid point of the pth. element.
A'_{pn}	A matrix of coefficients of the source elements.
a_1	This is equal to $\frac{(-\overline{uv})}{\overline{q^2}}$ for the shear layer. (See equation 2.1.5a).
a^i	A general contravariant tensor of order one.
a_i	A general covariant tensor of order one.
a(i)	The physical component of a first order tensor.
a^{ij}	A general contravariant tensor of order two.
a_{ij}	A general covariant tensor of order two.
B'	Defined as $\alpha-\beta$ for the ingoing characteristic.
B_{pn}	A matrix of coefficients of the source elements; its elements represent the tangential velocity induced by a unit source density at the nth. element, on the pth. element

	and at the mid point of the pth. element.
b_p	The normal velocity induced by the undisturbed stream velocity U_∞ at the mid point of the pth. element.
b_p^*	Value of b_p for $U_\infty = 1$.
C	The additive constant in the logarithmic law for the inner layer of the turbulent shear layer.
C_n, D_n	Coefficients depending on the (MS) geometry.
C'_p	The integral of $\frac{1}{\rho}\frac{\partial p}{\partial s}$ across the SL from the wall to the MS. (See §A3.5).
$C_{\overline{u^2}}$	The integral of $\overline{u^2}$ across the SL from the wall to the MS. (See §A3.5).
C_{UV}	The integral of UV across the SL from the wall to the MS. (See §A3.5).
C_τ	The integral of $\frac{\tau}{\rho}$ across the SL from the wall to the MS. (See §A3.5).
c	A constant in the equation of the normal to the RS.
c_1	A constant used in representing $\rho\overline{u^2}$; $c_1 = \dfrac{\overline{u^2}}{-\overline{uv}}$.
c_2	A constant used in representing $\rho\overline{v^2}$; $c_2 = \dfrac{\overline{v^2}}{-\overline{uv}}$.
c_f	The skin friction coefficient, defined as $c_f = \dfrac{\tau_w}{\frac{1}{2}\rho U_e^2}$.
c_p	The pressure coefficient.

D	A function of R_θ used in the Spalding-Chi skin friction formula.
dS	Element of arc length in transformed co-ordinate system.
$\hat{e}$	Extra strain rate correction in turbulent kinetic energy equation.
F	A function used in the logarithmic law for wall transpiration.
F_1, F_2, F_3	Functions used in applying the wall boundary condition for the shear layer calculation.
f_p	The tangential velocity induced by the undisturbed stream velocity U_∞ at the mid point of the pth. element.
f_p^*	Value of f_p for $U_\infty = 1$.
G	An empirical function for the shear layer calculation; defined as $\frac{(\overline{\frac{p'v}{\rho}} + \frac{1}{2}\overline{q^2 v})}{(-\overline{uv}).(-\overline{uv})^{\frac{1}{2}}_{max}}$.
$\hat{G}$	$G(\frac{\tau_m}{\rho})^{\frac{1}{2}}$.
G^{ij}	The Generation of Reynolds stress.
g_{RS}	The slope of the MS at any point (also at a node).
g_{RS_J}	Approximated slope of the RS at the Jth. node.
g_{ij}	The covariant metric tensor.
g^{ij}	The contravariant component of the metric tensor.
H	The shape parameter $\frac{\delta^*}{\theta}$ for the laminar BL and also for the turbulent SL.

H_D	Duct width.
H_{MS}	Height of the MS from the RS in the normal n-direction.
h, h_1	This is equal to $(1 + \frac{n}{R})$ for the s-n co-ordinate system.
h_i	A factor related to the physical component of a tensor of first order. Defined as $(g_{ii})^{\frac{1}{2}}$.
I_1, I_2	Integrals resulting from the fifth power law U velocity profile (see §A3.4).
K	Von Kármán's constant.
k	General node index.
k_m	Index of node on MS where the <u>speed</u> (total velocity magnitude) is a minimum.
L	Empirical length scale defined as $(-\overline{uv})^{3/2}/\varepsilon$ used to model ε in the turbulent kinetic energy equation.
l_{ref}	A reference length used in scaling all lengths.
M	Source strength of point source.
Ma	Mach number.
M^{ij}	The mean transport of Reynolds stress.
m	Source strength density distribution on MS, (i.e. source strength per unit length).
m_n	Source density of the nth. element for the case of unit stream velocity only.
m'_n	Source density of nth. element for the case of vorticity distribution only.
m_p	Source density of the pth. element for the case of unit stream velocity only.

N	The total number of source elements.
n	The coordinate direction normal to the real surface, in the s-n coordinate system (equal to y in plane flow).
$\underline{\hat{n}}$	Unit vector normal to the MS.
P	The production of turbulent kinetic energy.
P'	Total pressure.
P_e	Total pressure outside SL (on the MS).
P^{ij}	The turbulent transport of Reynolds stress by pressure fluctuations.
p or p(s,n)	The two dimensional mean pressure field.
$\tilde{p}$	The instantaneous pressure field.
p'	The fluctuating pressure.
p'(s)	The shifted pressure distribution in the SL, at a constant normal distance from the RS; it is given by: $p(s,n)\|_{n=const} + p_{e,new} - p_{e,old}$.
p_1	The value of p at the first mesh point in the SL calculation.
p_e	External pressure on the matching surface at SL calculation station or at MS nodes.
p_e^*	External pressure on MS at the element mid points.
p_{e_1}	Value of p_e on the old MS.
p_{e_2}	Extrapolated value of p_e on the new MS.
$p_{e,new}$	The current sweep value of p_e at the SL calculation stations.
$p_{e,old}$	The previous sweep value of p_e at the SL calculation stations.

p_{ref}	A reference pressure.
p_w	The wall pressure.
q	Tangential velocity on MS.
$q^{(1)}$	Tangential velocity distribution for flow case (1) of unit stream velocity.
$q^{(2)}$	Tangential velocity distribution for flow case (2) of unit vorticity distribution.
q_p	The nett velocity tangential to the pth. element at its mid point.
q'_p	The tangential velocity induced by all elements at the mid point of the pth. element.
$q_p^{(1)}$	The value of q_p for flow case (1), $U_\infty = 1$.
$q_p^{(2)}$	The value of q_p for flow case (2) of unit vorticity distribution.
q'_{np}	The tangential velocity induced by the nth. element at the mid point of the pth. element.
R	The radius of curvature of the body surface (the real surface).
Re_θ	The Reynolds number based on momentum thickness, defined as $Re_\theta = \frac{U_e \theta}{\nu}$.
$Re_{\theta,tran}$	The value of Re_θ at transition.
R^{ij}	Re-distribution of Reynolds stress by pressure fluctuations.
r	Radial distance.
S	The total arc length around the MS.
S^{ij}	The turbulent transport of Reynolds stress by the velocity fluctuations.
s	The streamwise coordinate direction (arc

	length on RS) in the s-n coordinate system (equal to X in plane flow).
s'	Arc length measured along the MS, starting from the LE.
$\underline{\hat{s}}$	Unit vector tangential to the matching surface.
s_o	The value of s at the start of the turbulent SL calculation (i.e. at the first station).
s_1', s_2'	Values of s' at which tangents drawn to the tangential velocity curve with s', intersect the s'-axis.
s_{max}	The value of s at the end of the turbulent SL calculation.
T	The total turbulent transport of turbulent kinetic energy.
T^{ij}	The total turbulent transport of Reynolds stress.
t	Time variable.
U	The streamwise component (in the s-direction) of the mean velocity.
U_∞	The undisturbed stream velocity (external flow only).
U_1	The value of U at the first mesh point from the surface for the SL calculation.
U_e	The value of the U-velocity (parallel to the RS) on the matching surface, from the turbulent SL calculation. It is also used to describe the "free-stream" velocity for the laminar BL calculation.
U_{exit}	Duct exit velocity.

U_{fut}	The value of U at the future station s+Δs in the U,τ calculation.
U_{in}	Duct inlet velocity.
U_{int}	The value of U interpolated at the position where the characteristic intersects a turbulent SL calculation station.
U_{mid}	The value of U at the mid point of a characteristic segment.
U_{ref}	The reference velocity used in scaling all velocities.
U^i	The mean velocity tensor in the i direction.
$\tilde{U}^i$	The instantaneous velocity tensor in the i direction.
u	The streamwise component (in the s-direction) of the turbulent fluctuating velocity.
u_τ	The "friction velocity", defined as $(\frac{\tau_w}{\rho})^{\frac{1}{2}}$.
u^i	The turbulent fluctuating velocity tensor in the i-direction.
V	The normal component (in the n-direction) of the mean velocity.
V_1	The value of V at the first mesh point from the surface in the SL calculation.
V_{1n}	Velocity induced by nth. source element, in the direction parallel to the nth. element.
V_{2n}	Velocity induced by the nth. source element, in the direction normal to the nth. element.
V_B	Normal velocity distribution on the bottom matching surface of the duct.
V_e	The value of the V-velocity (normal to the RS) on the matching surface, from the turbulent SL

	calculation. It is also used to describe the "external" V velocity for the laminar BL calculation.
V_{mid}	The value of V at the mid point of the characteristic segment.
V_{MS}	Velocity normal to the MS.
V_p	Nett velocity normal to the pth. element at its mid point.
$V_p^{(1)}$	The value of V_p for flow case (1), $U_\infty = 1$.
$V_p^{(2)}$	The value of V_p for flow case (2) of unit vorticity distribution.
V_T	Normal velocity distribution on the top surface of the duct.
V_W	Wall transpiration velocity.
V_X	The nett off-body velocity in the X-direction.
$V_X^{(1)}$	The value of V_X for flow case (1), $U_\infty = 1$.
$V_X^{(2)}$	The value of V_X for flow case (2) of unit vorticity distribution.
V_Y	The nett off-body velocity in the Y-direction.
$V_Y^{(1)}$	The value of V_Y for flow case (1), $U_\infty = 1$.
$V_Y^{(2)}$	The value of V_Y for flow case (2) of unit vorticity distribution.
V^{ij}	The viscous destruction of Reynolds stress.
v	The normal component (in the n-direction) of the turbulent fluctuating velocity.
v'_{np}	The velocity induced by the nth. element at the mid point of the pth. element and in the direction normal to the pth. element.
v'_p	The velocity induced by all the elements at the mid point of the pth. element and normal to it.

v_r	Radial velocity induced by a point source.
v_t	Tangential velocity induced by a line vortex.
W	The z-direction component of the mean velocity (for three dimensional flow only).
w	The z-direction component of the turbulent fluctuating velocity.
X,Y	X,Y axes fixed with their origin at a specified point on the RS. For external flows, the X-axis is made to pass through the leading and trailing edges of the aerofoil.
X_J, Y_J	Coordinates of the Jth. node on the RS, relative to the (X,Y) axes.
X_{MS}, Y_{MS}	Coordinates of a point (and also a node) on the MS, relative to the (X,Y) axes.
X_n, Y_n	Coordinates of the mid point of the nth. element relative to the (X,Y) axes.
X_{RS}, Y_{RS}	Coordinates of a point (and also a node) on the RS, relative to X,Y axes.
x	Streamwise coordinate direction for plane flow.
$\overline{x}, \overline{y}$	Axes parallel and perpendicular to the nth. element.
x^i	Coordinate distance tensor.
y	Normal coordinate direction for plane flow.
z	The coordinate direction normal to the s-n plane (for three dimensional flow only).
α	This is equal to $a_1\{\hat{G} + \frac{(\overline{u^2} - \overline{v^2})}{U}\}$.
α'	Angle of incidence; this is the angle made by the undisturbed stream velocity to the X-axis.

α_o	This is equal to $\frac{\tau_1 - \tau_w}{\rho \Delta n}$, which is a finite difference form of $\frac{\partial \tau}{\partial n}$ at the wall.
α_{MS}	Angle made at a point (and also a node) on the MS, to the X-axis.
α_{RS}	Angle made at a point (and also a node) on the RS, to the X-axis.
β	This is equal to $\surd\{\alpha^2 + 2a_1[\frac{\tau}{\rho} + (\overline{u^2}-\overline{v^2})\frac{V}{U}]\}$.
Γ	The total circulation around the MS.
Γ'	The strength of a line vortex.
γ	Vorticity distribution on MS. Also vorticity of a line vortex.
γ_n	Vorticity of the nth. element.
Δ	An arbitrarily defined surface $n=\Delta$ for the laminar BL.
Δn	The spacing between grid points (mesh points) in the n-direction for the shear layer calculation.
Δq	Nett tangential velocity difference at the TE.
$\Delta q^{(1)}$	The tangential velocity difference at the TE for flow case (1).
$\Delta q^{(2)}$	The tangential velocity difference at the TE for flow case (2).
Δs	The calculating step between stations in the s-direction, for the shear layer calculation. Also referred to as the s-step.
Δs_{max}	The maximum permissible value of Δs, given by the C-F-L criterion.
Δs_n	Length of the nth. MS element.
Δu	Correction velocity for corner elements, in the axial direction.

Δv	Correction velocity for corner elements, in the transverse direction.
Δx	Axial corner element length.
Δy	Transverse corner element length.
δ	The normal distance of the matching surface from the real (body) surface (in the n-direction).
δ^*	The displacement thickness of the laminar BL and an integral for the turbulent shear layer (see equation (A3.41)).
δ_o	The initial guess for the matching surface height, $n = \delta_o$.
δ_{05}	The value of n (the height from the surface) at which τ falls to .05 of its maximum value in the SL: roughly equal to δ_{995}.
δ_{Coles}	The boundary layer thickness obtained from the Coles velocity profile family for the start of the turbulent SL calculation.
δ_{exit}	MS height at exit from the duct.
δ_{in}	MS height at entry to the duct.
δ_{pn}	The Kroenecker delta in cartesian tensor notation.
δ_i^j	The Kroenecker delta in generalised tensor notation.
ε	The viscous dissipation of turbulent kinetic energy.
ζ_+	The tangent of the "outgoing" characteristic angle.
ζ_-	The tangent of the "ingoing" characteristic angle.

η	This is $\left\|\frac{g_{RS}}{\sqrt{1+g_{RS}^2}}\right\|$.
θ	The momentum thickness of the laminar BL and an integral for the turbulent SL (see equation (A3.42)).
θ_o	The value of θ at the start of the turbulent SL calculation (at $s = s_o$).
θ_n	The angle made by the nth. element to the X-axis.
θ_p	Angle made by the pth. element to the X-axis.
κ	The curvature of the body surface.
ν	The kinematic viscosity of air.
ξ	This is $\left\|\frac{g_{RS}\ H_{MS}}{\sqrt{1+g_{RS}^2}}\right\|$.
ρ	The mean density (assumed constant for incompressible flow).
σ_{np}	Acute angle between the nth. and pth. elements.
τ	Reynolds shear stress = $-\rho\overline{uv}$ (in s-n coordinates).
τ_1	The value of τ at the first mesh point from the surface for the SL calculation.
τ_{fut}	The value of τ at the future station, in the U,τ calculation.
τ_{int}	The value of τ interpolated at the position where the characteristic intersects a station.
τ_m, τ_{max}	Maximum Reynolds shear stress at given s.
τ_{mid}	The value of τ at the mid point of the characteristic segment.
τ_w	The wall shear stress.

τ^{ij}	The Reynolds stress tensor (second order).
υ_p	Specified velocity normal to the pth. element at its mid point.
υ_p^*	The value of υ_p normalised with the free stream velocity; i.e. $\upsilon_p^* = \upsilon_p/U_\infty$.
Φ	A function used in the momentum integral check for the SL calculation (see equation (2.2.7)).
Φ'	A function used in the logarithmic law for a solid wall.
ϕ	A general characteristic angle denoting one of the inclined characteristics.
ϕ_{in}	The angle made by the "ingoing" characteristic, with the s-direction.
ϕ_{new}	The "ingoing" characteristic angle at the first mesh point from the surface.
ϕ_{out}	The angle made by the "outgoing" characteristic, with the s-direction.
Ψ	A complicated function which is the coefficient of ds in the equations along the inclined characteristics, for the shear layer calculation (see equation (A3.16)).
Ω	An under-relaxation factor.

S U M M A R Y

The present method is concerned with the calculation of the complete flow field over highly curved surfaces and can be extended to the calculation of highly curved free shear layers as well as boundary layers.

The flow field is divided into two parts: (i) The curved turbulent shear layer, which is called a "complex" shear layer because of the extra rates of strain imposed by the curvature of the streamlines. The shear layer calculation method is based on that of Bradshaw, Ferriss and Atwell with the addition of the solution of the full normal momentum equation. (ii) The external inviscid flow, which is solved by a suitable potential flow method. In the present case of incompressible flow the Hess and Smith surface source distribution method is used. The two flows are then matched on an arbitrarily defined "matching surface", which is nominally just outside the shear layer. There are two versions of the method; one for internal flows such as the flow in ducts and the other for external flows such as the flow around aerofoils. The method has been applied to a test case which consists of the flow in a duct which curves through 30° and good agreement with measurements was obtained. It has also been applied to the flow over a NACA 0012 aerofoil with the exception of the trailing edge region.

CHAPTER 1

INTRODUCTION

The classical approach to solving the complete flow around an aerofoil in two dimensional, steady, incompressible flow has been that of matching an external inviscid solution with a solution of the boundary layer on the aerofoil and the wake behind it. The boundary layer is calculated by solving Prandtl's boundary layer equations (see Cebeci and Bradshaw (1977)) in which the approximation $\frac{\partial p}{\partial y} = 0$ is inherent. Henceforth, these will be termed the "thin-shear-layer equations" (or TSL equations for brevity). The viscous/inviscid matching is usually done on the displacement surface, which is assumed to be a streamline of the external flow with an equivalent transpiration velocity V_w^* (see Fig. (1)). The calculation is then iterated between the potential flow solution and the TSL solution until convergence is reached. See, for example, Lock, Wilby and Powell (1970) for incompressible flow and also Lock (1975) for compressible flow. Fig. (1) shows a flow chart which outlines the usual steps followed in the displacement-surface matching procedure.

The conventional displacement surface matching procedure outlined above breaks down once the normal pressure gradient $\frac{\partial p}{\partial y}$ across the BL becomes significant, so that $\frac{\partial p}{\partial y}$ cannot be set to zero (as assumed by the TSL equations). In that case, the definition of the displacement surface itself becomes ambiguous, since by Bernoulli's equation the "free-stream" velocity outside the BL varies with normal distance from the surface. Examples of where this occurs are the trailing edge region of an aerofoil (where the streamline curvature is high) and also in flows over highly curved surfaces, which include the flow through highly curved ducts and the flow over highly cambered aerofoils. In the present work, the duct flow is supposed to have a potential flow core; if it did not, the calculation would degenerate to a double shear layer solution.

The object of the present work is to compute the complete flow over such highly curved bodies. The large centrifugal force exerted on the flow due to the large streamline curvature, causes the normal pressure gradient $\frac{\partial p}{\partial y}$ to be significant and hence

(a) the conventional displacement surface matching procedure cannot be used for this type of flow, and

(b) the TSL equations do not adequately or correctly describe the behaviour of the BL.

Thus for such flows we have a twofold problem:

(i) The Boundary Layer problem: since $\frac{\partial p}{\partial y} \neq 0$ we cannot use the TSL equations. We will refer to this type of BL as a shear layer (denoted by SL), since BL would imply use of the TSL equations; for the <u>SL</u> we additionally need to solve the full normal component of momentum equation. The equations describing the behaviour of this SL are thus the full Navier-Stokes equations.

(ii) The Matching problem: since we cannot match the SL calculation to the external inviscid calculation on the displacement surface, we have to search for an alternative "matching surface". We shall consider how the present method tackles each of the above mentioned problems in turn:

(i) The shear layer problem: The present method basically uses the Bradshaw, Ferriss and Atwell (1967) method (henceforth referred to as the BFA method) for calculating the turbulent shear layer, using the TSL equations, with the addition of solving the full normal momentum equation. The BFA method was found convenient since the V calculation uncouples from the U and τ calculations (this is helpful if p, rather than V, is specified at y = 0 and δ) but other methods can also be used. The only other difference is that the present method solves the equations of continuity, streamwise momentum, normal momentum and turbulent shear stress (henceforth referred to as the "SL equations"). These are written in (s-n) orthogonal curvilinear coordinates, so that the coordinate directions are as nearly as possible parallel to the streamlines of the flow in order to reduce what are termed "artificial viscosity errors". Artificial viscosity errors are numerical truncation errors which appear due to the finite difference representation of the convective terms (the acceleration terms) present in the momentum equations. For a demonstration of the form of the artificial viscosity error see Roache (1972b) p. 46. For a more detailed analysis of artificial viscosity see Roache (1972a). Now, the SL equations mentioned above are used to solve for U, V, τ and p across the shear layer. They are effectively the full time-averaged Navier-Stokes equations in the shear layer but with the neglect of viscous stress gradients (since turbulent Reynolds stress gradients are much larger) and the inclusion of a crude approximation for the normal Reynolds stresses. For a full discussion see Chapter 2. The SL equations are thus elliptic. However, due to the form of these equations, especially the equation for τ, it was found that they can be divided into two distinct sets: (a) A pair of equations for U and τ with p(x,y) assumed known, which are hyperbolic and can thus be solved by the method of characteristics, as in the conventional BFA method (in which p(x) is known). (b) A pair of equations for V and p, which are solved by a line relaxation method across the shear layer, at each station of the flow field. It is this "uncoupling" of the V and p calculation from the U and τ calculation which renders the shear layer calculation simple and economical, permitting the solution to proceed by means of streamwise sweeps of the flow field rather like a conventional BL calculation marching technique (as in the BFA method). However, since the full set of SL equations is nevertheless elliptic, in order to obtain a complete solution of the flow field, the shear layer calculation has to be iterated by streamwise sweeps. At the same time one such sweep also constitutes part of one complete viscous/inviscid iteration cycle, since the shear layer calculation has to be matched with the external flow. These viscous/inviscid iterations proceed until convergence is attained. (Even the displacement surface matching approach requires iteration so that the present method is no more costly, except for the solution of the normal momentum equation). Moreover, due to the elliptic nature of the equations, a downstream boundary condition for the pressure has to be applied at the last calculation station downstream, in order that the effect of the pressure can propagate upstream to satisfy the physical nature of the elliptic problem. The pressure field within the shear layer is stored as a two-dimensional array for use from sweep to sweep of the SL calculation; during a given iteration we use only the pressures calculated in the previous sweep and not the newly-calculated values. This is termed a Gauss-Jacobi iteration, as opposed to the Gauss-Seidel iteration method which would use the newly-calculated values of pressure as soon as available during a streamwise sweep. The latter would lead to gross errors in the evaluation of streamwise derivatives of the pressure array, because the gradient $\frac{\partial p}{\partial s}$ at given s would be formed partly from old, partly from new pressure values.

(ii) The matching problem: In the present method we have overcome the problem of not being able to match the shear layer and inviscid calculations on a "displacement surface" by defining an arbitrary "matching surface" (henceforth referred to as MS) which is nominally just outside the shear layer. This is the most obvious way of matching the flows in the two regions; Prandtl's elegant idea of matching on the displacement surface avoided the definition of the boundary layer thickness. We solve the shear layer equations mentioned above, inside the MS, and outside it (actually on the MS) we solve for the inviscid flow by a potential flow method and match both sets of solutions on the MS. The potential flow method, for incompressible flow, used is the surface source singularity method of Hess and Smith (1967) which has the advantage that it is very simple to use.

It is interesting to compare the present method with a similar one, namely that due to MacCormack (1976). Whereas MacCormack solves the complete N-S equations for the whole flow field, the present method, although effectively solving the Navier-Stokes equations, distinctly divides the flow field into a shear layer and a potential flow region (with its corresponding simplifications, especially at Ma = O where a surface singularity method can be used for inviscid flow). Thus it recognises the presence of two distinct domains of the flow field and solves the equations pertinent to each domain in turn. The purpose of the matching procedure is then to obtain a complete solution of the flow field in which the separate solutions in each of the two distinct domains match on the MS. The method can therefore not be classified as a N-S solver in the same way as MacCormack's method. The efficiency of MacCormack's method (which is a time-dependant method applicable only to compressible flows at Ma $\not\ll$ 1) lies in the numerical ingenuity of splitting the equations at a given point into a hyperbolic and a parabolic part; the full N-S equations are written down in such a way that the "hyperbolic" terms and "parabolic" terms are gathered separately. Each of these sets of terms is then written as one equation (thus splitting them into <u>two</u> equations). Each of the equations is then solved separately, one using a hyperbolic solution technique and the other using a parabolic technique, thus saving considerably on computation time (in comparison with an elliptic method of solution). The present method (for the shear layer part of the calculation) uses splitting in an analogous but unconnected way; the U,τ calculation is hyperbolic and is uncoupled from the V,p calculation which is parabolic (if $\frac{\partial p}{\partial s}$ is assumed known).

Upstream influence is transmitted by evaluating $\partial p/\partial s(s)$ for the U,τ calculation by central differences, thus incorporating information from further downstream (from the previous sweep of course).

Another interesting N-S solver that is different in approach is due to Murphy (1977). It uses line relaxation for the solution at streamwise stations which is probably the only similarity it has with the present method.

The present method also is similar to the procedure of Pratap and Spalding (1975) and Patankar and Spalding (1971) in that it is in the same class of "partially parabolic" flows where a weakly elliptic system of equations is iterated to convergence by several streamwise sweeps. The weak ellipticity of the SL equations in both cases stems from the fact that the upstream propagation of information occurs through the pressure field predominantly by means of the external inviscid flow, if any, rather than through the shear layer itself, although of course there is upstream propagation through the shear layer. The details of the two methods are, however, different, in that Pratap and Spalding calculate a correction to the pressure (using the full normal momentum equation) in order to satisfy continuity, whereas in the present method the full normal momentum equation is solved together with an equation in which continuity is inherent in order to obtain the pressure directly. These two equations are used to solve for V and p. Pratap and Spalding's method is also for three dimensional flows so that they solve an additional z-component momentum equation in the cross flow plane.

Tassa, Reshotko and Anderson (1976) have developed a method of solution for supersonic flows over curved surfaces. In this case, they solve for U, V, τ, p and T, the temperature and have an additional energy equation. The full normal momentum equation is retained. The authors claim that this elliptic system of equations can be solved by a parabolic marching technique, by reducing the system of partial differential equations to a set of linear algebraic equations solving the latter by a block tri-diagonal matrix method. Their matching procedure involves matching the external supersonic flow (which is obtained by the method of characteristics, the relevant equations being hyperbolic) to the locally subsonic (parabolic) flow along the sonic line (where the Mach number is locally equal to unity). This provides a neat and efficient matching procedure, although the solution of the elliptic set of equations for U, V, τ, p and T in the shear layer is obtained only by one streamwise sweep. This one-sweep cannot possibly be a converged elliptic solution. For an account of the characteristics method in the supersonic flow region see Tassa, Reshotko and Anderson (1976).

An integral method approach is given by Nakayama, Patel and Landweber (1976a,b) which proves the importance of carefully treating the trailing edge region even in the case of bodies of revolution. This utilises an integral form of the normal momentum momentum equation and is an interesting application of integral methods to this class of flows in which $\frac{\partial p}{\partial y}$ is significant.

A very different approach to the problem of matching the shear layer calculation and the external inviscid calculation is given by Brune, Rubbert and Nark (1975) together with an equally interesting approach to viscous/inviscid matching by Brune, Rubbert and Forester (1975), although the latter is mainly for separated flows. The approach they use is applied to the displacement surface matching technique; a linearised functional relationship between an increment $\Delta\delta^*$ in the displacement thickness and an increment ΔU_e in the free stream velocity, for each of the BL and inviscid flow calculations, is obtained from the equations describing the flow for each case. The converged solution for δ^* and U_e is obtained by using Newton's iterative method, in order to reduce $\Delta\delta^*$ and ΔU_e to zero. One difficulty envisaged in applying this procedure would be the formulation of the required functional relationships (with the MS replacing δ^*) to obtain a solution, collectively, for U, V, τ and p, using the equations (and especially the turbulence model equation) of the present method.

Another difficulty might be the computation time taken in inverting a matrix whose size depends on the number of grid points used in the calculation. One advantage is, however, the higher speed of convergence as compared with the conventional δ^* matching procedure.

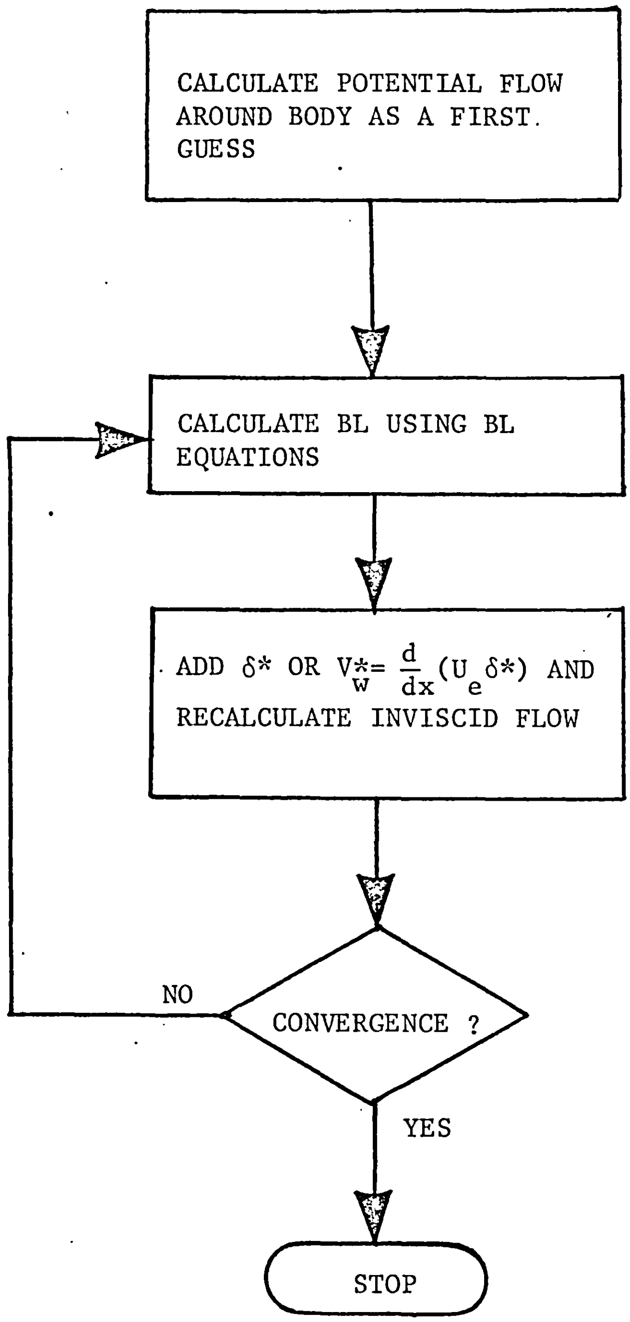
In addition to the problems presented above, we will find problems associated with the turbulence structure of the highly curved shear layer. Turbulent flows with extra rates of strain (e.g. $\frac{\partial V}{\partial x}$ in addition to $\frac{\partial U}{\partial y}$) are one example of "Complex turbulent flows". The extra rates of strain can be due to surface curvature, flow rotation, lateral divergence, etc. For a full and comprehensive discussion of the effect of streamline curvature on the structure of turbulent flows and how it affects turbulent SL calculations, the reader is referred to Bradshaw (1973). Further discussions of how to approach the problem of calculating "Complex" turbulent flows can be found in Bradshaw (1975). An example of the type of turbulence structure encountered in highly curved shear layers is found in the highly curved mixing layer of Castro and Bradshaw (1976). A good account of the numerical difficulties encountered in calculating such flows is given by Castro (1977). In the present method, we have not accounted for the effect of extra strain rates on the structure of the turbulence; the turbulence model is unchanged from that given by the original Bradshaw, Ferriss, Atwell (1967) method. An extra strain rate correction to the turbulence model, for small curvature, was made by Ferriss and Bradshaw (1968) and this has provided good predictions for mildly curved flows such as the flow of Meroney and Bradshaw (1975). The computational results for this flow can be found in Bradshaw (1973).

Transonic flows are of great practical importance. They pose several problems which do not lie entirely outside the limits of the present discussion. Most important of all, they provide large scope for viscous/inviscid interaction work. Lock and Collyer (1977) have solved the complete flow around an aerofoil in transonic flow in the presence of shock waves on the aerofoil surface. Once again one feels the need here for an improved solution in the trailing edge region where the normal pressure gradient is large. The method is not dissimilar to that of Melnik, Chow and Mead (1977), employing the Bauer, Garabedian and Korn (1971) potential flow calculation method, which uses a conformal mapping of the flow field into the interior of a circle and is based on Sells' (1968) method. Smith and O'Mahoney (1977) map the flow field around the aerofoil and its wake into the upper half plane. They also compare their results with those of Bauer, Garabedian and Korn. A comprehensive review of the present state of Finite Difference methods in calculating transonic flows is given by Lock (1975). Seginer and Rose (1976) produce a solution in the case of strong shock induced separation in a transonic flow. Although the present method as it stands is incapable of dealing with such flows, since they represent quite a strong flow interaction, yet the ideas behind it may provide a simplified approach to the solution of what are after all the Navier-Stokes equations with the embodiment of a discrete shear layer and a potential flow region, and with the subsequent viscous/inviscid matching necessary to achieve compatibility between the two discrete flow domains.

The extension of the present method to solve compressible flows would be relatively simple; the shear layer becomes genuinely "hyperbolic" if Ma > 1 locally, but this should not affect the SL calculation method since it is hyperbolic in any case. The external inviscid solution is easily obtained and matching this to the shear layer calculation, using the present matching procedure, would be just as easy.

FIG (1)

FLOW CHART OF DISPLACEMENT SURFACE MATCHING PROCEDURE



CHAPTER 2

THE SHEAR LAYER CALCULATION

In this Chapter the equations used in the shear layer calculation of the present method will be stated and described, their derivation being left to the appropriate Appendices. The description of the present method will be presented separately for the shear layer (this Chapter) and potential flow calculations (Chapter 3) and in Chapter 4 a description will be given of the overall strategy of the viscous/inviscid matching procedure. The figures corresponding to each Chapter will be given at the end of the relevant Chapter.

2.1 THEORETICAL DESCRIPTION AND EQUATIONS FOR THE SHEAR LAYER CALCULATION

(a) The Basic Set of Equations to be Solved

As mentioned in the Introduction, the equations of flow for the two dimensional shear layer are written in orthogonal curvilinear s-n coordinates (see Fig. 2). Bradshaw (1973) states these equations, and their derivation using generalised tensor analysis is given in Appendices (A1) and (A2). The position of any point P in the flow field (see Fig. 2) is prescribed by the distance s along the real surface and the distance n normal to the real surface. The local radius of curvature of the surface is R which, in general, is a function of s only. κ $(= \frac{1}{R})$ is the corresponding surface curvature.

The equation of continuity thus becomes

$$\frac{\partial U}{\partial s} + (1 + \frac{n}{R}) \frac{\partial V}{\partial n} + \frac{V}{R} = 0 \qquad (2.1.1)$$

The equation of momentum in the s coordinate direction becomes

$$\frac{U\partial U}{\partial s} + (1 + \frac{n}{R})\, V\frac{\partial U}{\partial n} + \frac{UV}{R} = -\frac{1}{\rho}\frac{\partial p}{\partial s} - \frac{\partial \overline{u^2}}{\partial s} + (1 + \frac{n}{R})\frac{\partial}{\partial n}(-\overline{uv})$$
$$+ 2\,\frac{(-\overline{uv})}{R} + \nu h\frac{\partial}{\partial n}\left[\frac{\frac{\partial}{\partial n}(hU) - \frac{\partial V}{\partial s}}{h}\right] \qquad (2.1.2)$$

Since normal pressure gradients are significant, we need to use the full normal momentum equation which in (s-n) coordinates becomes

$$U\frac{\partial V}{\partial s} + (1 + \frac{n}{R})\, V\frac{\partial V}{\partial n} - \frac{U^2}{R} = -(1 + \frac{n}{R})\frac{1}{\rho}\frac{\partial p}{\partial n} + \frac{1}{\rho}\frac{\partial}{\partial s}(-\overline{uv})$$
$$-(1 + \frac{n}{R})\frac{\partial \overline{v^2}}{\partial n} + (\frac{\overline{u^2} - \overline{v^2}}{R}) - \nu h\frac{\partial}{\partial s}\left[\frac{\frac{\partial}{\partial n}(hU) - \frac{\partial V}{\partial s}}{h}\right] \qquad (2.1.3)$$

Now, the turbulent kinetic energy equation in (s-n) coordinates can be written (see Appendix A2) as

$$U\frac{\partial}{\partial s}(\tfrac{1}{2}\overline{q^2}) + (1 + \frac{n}{R})\, V\frac{\partial}{\partial n}(\tfrac{1}{2}\overline{q^2}) = -\overline{u^2}\,(\frac{\partial U}{\partial s} + \frac{V}{R})$$
$$-(1 + \frac{n}{R})\,\overline{v^2}\,\frac{\partial V}{\partial n} - \overline{uv}\,\{(1 + \frac{n}{R})\frac{\partial U}{\partial n} + \frac{\partial V}{\partial s} - \frac{U}{R}\} - \frac{\partial}{\partial s}(\frac{\overline{p'u}}{\rho} + \tfrac{1}{2}\overline{q^2 u})$$
$$-\frac{\partial}{\partial n}\{(1 + \frac{n}{R})(\frac{\overline{p'v}}{\rho} + \tfrac{1}{2}\overline{q^2 v})\} - \varepsilon \qquad (2.1.4)$$

where ε is the viscous dissipation of turbulent kinetic energy.

We shall now discuss the assumptions made in solving the complete set of equations (2.1.1) to (2.1.4). Since we shall solve these equations outside the viscous sublayer, the viscous terms in the two momentum equations, as well as the viscous diffusion term in the turbulent kinetic energy equation, have been neglected. In the momentum equations the viscous terms take the form of viscous stress gradients which are much smaller than the turbulent Reynolds stress gradients outside the viscous sublayer. In all the equations we have included the normal Reynolds stresses and their gradients (in addition, of course, to the Reynolds shear stress and its gradients) since they may be expected to be significant for flows with large variations in the streamwise direction (rapidly changing flows), such as occur in highly curved flows. It is usually sufficient to make a crude approximation to the normal Reynolds stresses since their gradients are usually small (but not negligible) in comparison with the Reynolds shear stress gradients. In the present case we assume that the normal stresses are a constant multiple of the Reynolds shear stress.

We shall now consider the turbulence modelling of equation (2.1.4); using the turbulence model of Bradshaw, Ferriss, Atwell (1967) we define an empirical function $a_1 = \frac{(-\overline{uv})}{\overline{q^2}}$, so that $\frac{1}{2}\overline{q^2}$ on the left hand side of (1.1.4) becomes $\frac{-\overline{uv}}{2a_1}$. The turbulent diffusion term $(\frac{\overline{p'v}}{\rho} + \frac{1}{2}\overline{q^2 v})$ (in the n-direction) is modelled as $G(-\overline{uv})^{\frac{1}{2}}.(-\overline{uv})_{max}$ where G is another empirical function which is supplied in the calculation of the shear layer. The turbulent kinetic energy dissipation term ε (which has dimensions of $(\text{velocity})^3/(\text{length})$) determines the rate of energy transfer to the dissipating eddies and is modelled as $\varepsilon = (-\overline{uv})^{3/2}/L$ where L is a length scale of the large or energy containing eddies of the turbulence. L/δ is also a supplied empirical function of n/δ.

According to our crude assumption for the normal Reynolds stresses, we set $\rho\overline{u^2} = c_1.(-\rho\overline{uv})$ and $\rho\overline{v^2} = c_2.(-\rho\overline{uv})$ where c_1 and c_2 are constants, which would be supplied empirically.

Thus, we have the following empirical functions:

$$a_1 = \frac{-\overline{uv}}{\overline{q^2}} \quad (2.1.5a)$$

$$G = (\frac{\overline{p'v}}{\rho} + \tfrac{1}{2}\overline{q^2 v})/[(-\overline{uv}) \, . \, (-\overline{uv})^{\frac{1}{2}}_{max}] \quad (2.1.5b)$$

$$L = (-\overline{uv})^{3/2}/\varepsilon \quad (2.1.5c)$$

$$c_1 = \overline{u^2}/(-\overline{uv}) \quad (2.1.5d)$$

$$c_2 = \overline{v^2}/(-\overline{uv}) \quad (2.1.5e)$$

With the above assumptions and empirical substitutions, the equations of continuity, s-momentum, n-momentum and Reynolds shear stress transport (turbulence model equation) can be written in the (s-n) coordinate system as

$$\frac{\partial U}{\partial s} + h\frac{\partial V}{\partial n} + \frac{V}{R} = 0 \quad (2.1.6)$$

$$U\frac{\partial U}{\partial s} + hV\frac{\partial U}{\partial n} + \frac{UV}{R} = -\frac{1}{\rho}\frac{\partial p}{\partial s} + \frac{h}{\rho}\frac{\partial \tau}{\partial n} - \frac{c_1}{\rho}\frac{\partial \tau}{\partial s} + \frac{2\tau}{\rho R} \quad (2.1.7)$$

$$U\frac{\partial V}{\partial s} + hV\frac{\partial V}{\partial n} - \frac{U^2}{R} = -\frac{h}{\rho}\frac{\partial p}{\partial n} + \frac{1}{\rho}\frac{\partial \tau}{\partial s} - \frac{hc_2}{\rho}\frac{\partial \tau}{\partial n} + (\frac{c_1 - c_2}{R})(\frac{\tau}{\rho}) \quad (2.1.8)$$

$$U\frac{\partial}{\partial s}(\frac{\tau}{2a_1\rho}) + hV\frac{\partial}{\partial n}(\frac{\tau}{2a_1\rho}) = \frac{\tau}{\rho}(h\frac{\partial U}{\partial n} + \frac{\partial V}{\partial s} - \frac{U}{R})$$
$$- c_1 . \frac{\tau}{\rho}(\frac{\partial U}{\partial s} + \frac{V}{R}) - hc_2 . \frac{\tau}{\rho} . \frac{\partial V}{\partial n} - \frac{\partial}{\partial n}\{hG(\frac{\tau_m}{\rho})^{\frac{1}{2}} . \frac{\tau}{\rho}\}$$
$$- \frac{(\tau/\rho)^{3/2}}{L} \quad (2.1.9)$$

where $\tau = -\rho\overline{uv}$ (the Reynolds shear stress), and where $h = 1 + \frac{n}{R}$, R being a function R(s) of s only. Comparison of this set of equations with those of the original BFA method shows that the differences in the equations solved for the two cases are that (i) in the present method we have added the normal momentum equation (2.1.8), and (ii) that we have written the equations in (s-n) coordinates, thus producing extra curvature dependent terms which, of course, did not appear in the original BFA set of equations.

(b) Solution Procedure for the Basic Set of Equations

The complete set of equations (2.1.6) to (2.1.9) is elliptic if we require a solution for U, τ, V and p simultaneously. However, if we consider the continuity equation, the s-momentum equation and the τ-transport equation alone, we find that if the pressure p(s, n) is given (together with $\overline{u^2}$, $\overline{v^2}$, $\frac{\partial \overline{u^2}}{\partial s}$ and $\frac{\partial \overline{v^2}}{\partial n}$) then this set of equations is hyperbolic in U, τ and V, so that we can solve for U,τ using the same characteristics procedure as in the original BFA method. We find (see Appendix A3) that there are three characteristic directions; one is normal to the surface (i.e. in the n-direction)

$$\frac{dn}{ds} = \infty \qquad (2.1.10)$$

and the other two are defined by the equations

$$\frac{dn}{ds} = \frac{V + \alpha \pm \beta}{U} \qquad (2.1.11)$$

where $\hat{G} = G(\frac{\tau_m}{\rho})^{\frac{1}{2}}$, $\alpha = a_1 \{\hat{G} + \frac{(\overline{u^2} - \overline{v^2})}{U}\}$

$$= a_1 \{\hat{G} + \frac{(c_1 - c_2)}{U} \cdot \frac{\tau}{\rho}\}$$

and $\beta = \surd\{\alpha^2 + 2a_1 [\frac{\tau}{\rho} + \frac{V}{U} (\overline{u^2} - \overline{v^2}]\}$

$$= \surd\{\alpha^2 + 2a_1 \frac{\tau}{\rho} [1 + (c_1 - c_2)\frac{V}{U}]\}$$

We can therefore write equations (2.1.6), (2.1.8) and (2.1.9) along the three characteristic directions given above (see Appendix A3). This yields the following set of equations

$$hV\ dU - hU\ dV = -\frac{1}{\rho}\frac{\partial p}{\partial s}\ .\ dn + \frac{h}{\rho}\ d\tau - \frac{c_1}{\rho}\ (\frac{\partial \tau}{\partial s})\ .\ dn + \frac{2\tau}{\rho R}\ .\ dn \tag{2.1.12}$$

along the vertical characteristic, and

$$[\frac{\tau}{\rho} + (\overline{u^2} - \overline{v^2})\ \frac{V}{U}].dU - \frac{1}{2a_1}\ (\alpha \pm \beta)\ d\tau =$$

$$\frac{1}{U}\ \{\frac{\tau}{\rho} + \frac{V}{U}\ (\overline{u^2} - \overline{v^2})\}\{-\frac{1}{\rho}\frac{\partial p}{\partial s} - \frac{UV}{R} + \frac{2\tau}{\rho R} - \frac{\partial \overline{u^2}}{\partial s}\}\ ds$$

$$+ \frac{1}{U}\ (\alpha \pm \beta)\{\frac{(\tau/\rho)^{3/2}}{L} + h(\frac{\tau}{\rho})\ (\frac{\tau_m}{\rho})^{\frac{1}{2}}\ \frac{dG}{dn}$$

$$- \frac{\tau}{\rho}\ (\frac{\partial V}{\partial s} + \hat{e}) + \frac{\tau U}{\rho R} + \frac{G}{R}\ (\frac{\tau_m}{\rho})^{\frac{1}{2}}\ .\ \frac{\tau}{\rho}$$

$$+ (\overline{u^2} - \overline{v^2})(\frac{2\tau}{\rho R} - \frac{1}{\rho}\frac{\partial p}{\partial s} - \frac{\partial \overline{u^2}}{\partial s})\}\ ds \tag{2.1.13}$$

along the inclined characteristics, where $\hat{e}$ is an extra rate correction to the turbulence model equation (see Bradshaw (1973)).

If we put $\frac{1}{R}$, $\overline{u^2}$, $\overline{v^2}$, $\frac{\partial \overline{u^2}}{\partial s}$ all equal to zero, equations (2.1.10) to (2.1.13) reduce to the equations for the three characteristic directions and the corresponding equations along these directions in the solution for U, τ and V as used in the original BFA method.

If we take equation (2.1.8) which is the normal momentum equation and given U, τ and V, we can solve this equation for the pressure p. This amounts to a "line relaxation" solution for p in two-dimensional flow. The above procedure can be looked upon as consisting of two distinct steps:

(A) A solution for U, τ, V given p.

(B) A solution for p, having obtained U, τ and V.

We can further isolate the V calculation from the U, τ calculation and obtain:

(A) A solution for U and τ given V and p.

(B) A solution for V and p, having obtained U and τ.

We have thus uncoupled the U, τ calculation from the V, p calculation, and it is this feature of the shear layer calculation which provides a simple and quick solution; the original U, τ calculation, and the subsequent calculation for V are basically the same as in the original BFA method, and the new addition is a line relaxation solution of the normal momentum equation to obtain p. Since the first step in the solution procedure is to solve for U, τ with V and p known, we need an initial guess for the whole of the pressure field p(s,n).

We will now firstly consider the boundary and initial conditions necessary for the shear layer calculation:

(a) An <u>initial</u> guess for the pressure field p(s,n) ($s_o \leqslant s \leqslant s_{max}$; $0 \leqslant n \leqslant \delta(s)$) (for details of how this is supplied see §2.2). Note that "<u>initial</u>" conditions will be used to denote conditions which apply at the beginning of a streamwise sweep of the calculation.

(b) <u>Starting</u> profiles for U, τ, V and p at the first streamwise calculation ($s = s_o$) station. Note that "starting" conditions will be used to denote conditions at the first streamwise calculation station $s = s_o$. The U, τ starting profiles are usually supplied while the V, p starting profiles are calculated; the V profile is calculated using equation (2.1.12) along the vertical characteristic at $s = s_o$. The initial pressure profile is usually taken as $p(s_o, n) = p_e(s_o)$ for $0 \leqslant n \leqslant \delta(s_o)$, since we normally <u>start</u> the calculation in a region of zero or very small $\frac{\partial p}{\partial n}$. For the more complicated case of $\left.\frac{\partial p}{\partial n}\right|_{s=s_o}$ not equal to zero, see §2.2 (h).

(c) Wall boundary conditions ($n = 0$; $s_o \leqslant s \leqslant s_{max}$); these are the usual conditions $U = 0$, $V = V_w$ (a given wall transpiration velocity which is zero in all the work reported here although the program contains a transpiration option).

(d) An external boundary condition ($n = \delta(s)$; $s_o < s < s_{max}$); in our present case we prescribe the external pressure distribution $p_e(s)$ on some defined matching surface at $n = \delta(s)$, which lies just outside the shear layer (a full description of this is deferred to §2.3).

(e) A downstream boundary condition ($0 \leqslant n \leqslant \delta(s_{max})$; $s = s_{max}$). This can be quite arbitrary; in the present method we have chosen the following boundary condition: $\frac{\partial p}{\partial s}$ at the last streamwise station $= \frac{dp_e(s)}{ds}$ at the last station (for all values of n). Since for flows which exhibit large normal pressure gradients the calculation must necessarily proceed streamwise until such gradients have become small and ordinary BL calculation methods can be used, this provides a simple and sufficient downstream boundary condition which also satisfies continuity of the streamwise pressure gradient everywhere across the shear layer (since $\frac{dp_e(s)}{ds}$ is continuous).

The boundary conditions at $s = s_o$ and $s = s_{max}$ are supplied assuming that we normally start the calculation and end it in regions where the normal pressure gradient $\frac{\partial p}{\partial n}$ is zero (or very small).

We shall now consider the calculation procedure for one streamwise sweep (henceforth just referred to as sweep) of the shear layer calculation for $s_o \leqslant s \leqslant s_{max}$ and $0 \leqslant n \leqslant \delta(s)$; with the above mentioned boundary and initial conditions, the calculation proceeds as follows:

(i) Given U, τ, V, p at $s = s_o$ and an <u>initial</u> guess for p(s,n) everywhere, calculate U, τ for the next streamwise station $s = s_o + \Delta s$ from equations (2.1.13) (initially using upstream coefficients and then updating).

(ii) Calculate V, p at $s = s_o + \Delta s$ (having calculated U, τ) from equations (2.1.12) and (2.1.8), substituting the values of U, τ from (i).

(iii) Increment s and repeat steps (i) and (ii) above until the end of the sweep $s = s_{max}$ is reached.

It is important here to mention that although we have conveniently split the equations into distinct sets, the complete set of equations is elliptic, so that in seeking an overall solution we have to recognise the need for elliptic type boundary conditions. It is for this reason that for a thin shear layer we have supplied a downstream boundary condition, in addition to the usual starting, wall and external boundary conditions. We have chosen to impose the downstream boundary condition on the pressure (although there would be nothing to prevent us from imposing it on V) for simplicity and because the pressure is after all what we are seeking. In addition, in order to account for the upstream influence on the flow which is transmitted through the pressure field, we need to use a finite difference scheme for $\frac{\partial p}{\partial s}$ which would allow for that effect; we have therefore used central differences for $\frac{\partial p}{\partial s}$ (for a detailed description see §2.2(b)). Also, since a converged solution to an elliptic problem cannot be obtained using a "once through" marching procedure (see the discussion of Reshotko et al above), iteration is needed to improve the initial guess for p(s,n) (which, as we shall see later, may be quite crude). This iteration alternates with the iteration of the overall viscous/inviscid matching procedure which will be described in §4.1. It is sufficient here to note that the above mentioned steps (i) to (iii) constitute one streamwise sweep of the shear layer calculation.

2.2 NUMERICAL PROCEDURE FOR THE SHEAR LAYER CALCULATION

In this section we shall describe the various numerical schemes used in the main part of the shear layer calculation. After describing these we shall then explain in §2.3 the overall scheme for calculating one complete streamwise sweep of the shear layer calculation.

Since the shear layer calculation is based on the BFA method, we will mainly point out the changes made in the present method from the BFA method, but a brief explanation of the BFA method will also be given as needed. For full details of the numerical procedure and computer program for the BFA method the reader is referred to Bradshaw and Unsworth (1974).

(a) The Calculation Grid

Fig. (3) shows the domain of the shear layer calculation and the calculation grid in s-n coordinates. The flow field is divided by a series of lines normal to the body surface (constant s-lines). These are the s-stations. A series of constant n-lines are then drawn parallel to the body surface.

(i) The constant-s lines ("stations")

The index used for the grid points in the s-direction from $s = s_o$ to $s = s_{max}$ is i. The spacing of the stations is not generally constant; it is usually set to the maximum allowed by the Courant-Friedrichs-Lewy stability criterion and increases as the SL thickness increases. For details see §2.2 (f). The s-coordinate of any grid point P is denoted by s_i (see Fig. (3)) and the streamwise spacing between station s_{i-1} and station s_i is $\Delta s_i = s_i - s_{i-1}$. Δs_i is also referred to as the s-step.

(ii) The constant-n lines ("mesh lines")

For any given station the grid points in the n direction are termed "mesh points" and are equally spaced at a distance Δn. The mesh lines run from a height Δn above the "wall" (the body surface) up to and including the uppermost limit of the shear layer calculation, which is the "matching surface" ($n = \delta(s)$) on which the external boundary condition is supplied. The index used for mesh points is j, so that the n-coordinate of any grid point P is given by $n_j = j.\Delta n$ (see Fig. (3)); the wall would thus correspond to the mesh point $j = 0$. The matching surface height $n = \delta(s)$ is always taken to be an integer multiple of Δn in the calculation.

(b) The U, τ Calculation

As discussed in §2.1, the U, τ calculation is performed using the method of characteristics. The equations actually solved to obtain U, τ at any station given V and p(s,n) are equations (2.1.13) along the two inclined characteristics (see Fig. (4)). For a full description of the method see Bradshaw and Unsworth (1974, 1976). AP and BP represent segments of the "ingoing" and the "outgoing" characteristics, at any point P. The inclinations (ϕ_{in}, ϕ_{out}) of AP and BP to the s-direction are given by equations (2.1.11) where $\tan\phi_{out} = \frac{V+\alpha+\beta}{U}$ and $\tan\phi_{in} = \frac{V+\alpha-\beta}{U}$. C is the mid point of the "ingoing" characteristic segment AP and C' is that for the "outgoing" characteristic segment BP. Equations (2.1.13) are solved along AP and BP and can be written as:

$$\left[\frac{\tau}{\rho} + (\overline{u^2} - \overline{v^2})\frac{V}{U}\right]dU - \frac{1}{2a_1}(\alpha - \beta)\frac{d\tau}{\rho} - \frac{\Psi}{U}ds = 0 \qquad (2.2.1)$$

$$\left[\frac{\tau}{\rho} + (\overline{u^2} - \overline{v^2})\frac{V}{U}\right]dU - \frac{1}{2a_1}(\alpha + \beta)\frac{d\tau}{\rho} - \frac{\Psi}{U}ds = 0 \qquad (2.2.2)$$

Equation (2.2.1) is solved along AP while (2.2.2) is solved along BP. The normal stresses $\overline{u^2}$ and $\overline{v^2}$ are set equal to $c_1\frac{\tau}{\rho}$ and $c_2\frac{\tau}{\rho}$, respectively, as explained in §2.1. Therefore, we can write (2.2.1) and (2.2.2) in finite difference form (see Fig. (4)) as:

$$\{1 + (c_1 - c_2)\frac{V_{mid}}{U_{mid}}\}.\tau_{mid}.(U_{fut} - U_{int}) - \frac{1}{2a_1}(\alpha \pm \beta).$$

$$.(\tau_{fut} - \tau_{int}) - \frac{\Psi}{U}.\Delta s = 0 \qquad (2.2.3)$$

U_{int} and τ_{int} are values of U, τ at A, B obtained by parabolic interpolation at the previous station; since the values of U, τ are known at the previous station at the mesh points, the values of U, τ at A and B can be obtained by interpolation. Any terms appearing in equations (2.2.1) and (2.2.2) which are not in the form of derivatives are assigned values at the mid point of the characteristic segments C and C'. Thus U_{mid}, τ_{mid} and V_{mid} are the values of U, τ and V at the mid points of the characteristic segments, for each of the characteristic equations in turn. We note here that these values can only be obtained after a "predictor" calculation is performed which uses the known values at the previous station. We thus solve equations (2.2.3) along AP and BP as indicated to obtain U_{fut} and τ_{fut}, the values of U, τ at the point P. This procedure is repeated for each mesh point, starting at mesh point 1 (where U is matched with the logarithmic law in the inner layer) - see §2.2 (d).

The main changes made to the U, τ calculation in the present method from the original BFA method are as follows:

(i) Extra terms appear in the equations for the characteristic angles (2.1.11) and in the equations along the characteristics (2.1.13); these are terms due to the inclusion of the normal Reynolds stresses and extra curvature dependent terms which appear due to the use of the (s-n) coordinate system.

(ii) In the group of terms Ψ, $\frac{\partial V}{\partial s}$ appears explicitly, together with a term $\hat{e}$. These two terms together with the terms of order U/R represent the extra rates of strain. $\hat{e}$ is a mild curvature correction to the turbulence model (see Bradshaw (1973)). Although it is included in the coding of the program, it is actually set to zero in the present calculations, so that the turbulence model used does not have a curvature correction. As for the term $\frac{\partial V}{\partial s}$, this is merely the explicit extra strain rate which is present in the turbulent kinetic energy production term in addition to $\frac{\partial U}{\partial n}$. Backward differences are used to evaluate $\frac{\partial V}{\partial s}$ except at $s = s_o$ where forward differences are used.

(iii) In the group of terms Ψ, $\frac{\partial p}{\partial s}$ also appears. Now, as mentioned before in §2.1, upstream influence in the shear layer propagates through the pressure field by means of the $\frac{\partial p}{\partial s}$ term. Roache (1967) (p. 46) performed a simple analysis which showed that upstream influence cannot propagate at more than one s-step per sweep of the calculation. Therefore, in order to account for this, central differences are used in the finite difference representation of $\frac{\partial p}{\partial s}$. $\frac{\partial p}{\partial s}$ at P (see Fig. (4)) is obtained by fitting a parabola to points P_1, P and P_2. This yields (see Appendix A4) the following expression for the differenced form of $\frac{\partial p}{\partial s}$:

$$(\frac{\partial p}{\partial s})_{i,j} = (\frac{p_{ij} - p_{i-1,j}}{\Delta s_i}) \cdot \frac{\Delta s_{i+1}}{\Delta s_i + \Delta s_{i+1}} + (\frac{p_{i+1,j} - p_{ij}}{\Delta s_{i+1}}) \cdot \frac{\Delta s_i}{\Delta s_i + \Delta s_{i+1}} \quad (2.2.4)$$

Upstream influence will propagate from the last station (through the downstream pressure boundary condition) roughly at the rate of one boundary layer thickness for each sweep of the shear layer calculation. Note also that, as mentioned before, we use only the previous sweep values of the pressure p(s,n) at any given sweep to avoid inconsistencies in the evaluation of $\frac{\partial p}{\partial s}$.

(iv) Another change made to the original BFA calculation is termed the "edge clip" modification. In the original program, $U_e(x)$ was specified and whenever U becomes greater than U_e at any station due to finite difference or rounding errors, it was set to U_e. However, for the present type of flow, in which $\frac{\partial p}{\partial n}$ is significant, the edge velocity is not only unspecified ($p_e(s)$ being specified instead, on the matching surface), but U also varies with n, even outside the shear layer. Hence, in order to take account of this, the new condition applied is that if U becomes greater than $U_e(n) = 1-(\frac{p - p_{ref}}{\frac{1}{2}\rho U^2_{ref}})$ then it is set equal to that value. U_e as defined here is obtained from Bernoulli's equation

$$p + \tfrac{1}{2}\rho\ (U_e^{\ 2} + V_e^{\ 2}) = p_{ref} + \tfrac{1}{2}\rho U_{ref}^2 \qquad (2.2.5)$$

with $V_e^{\ 2}$ neglected in comparison with $U_e^{\ 2}$. This provides a smooth merging of the U profile calculated at any station, with the "inviscid" value of the U velocity given by the above expression (see Fig. (5)). There is thus no unique definition of the "edge velocity"; we have therefore defined it as being equal to U on the matching surface, i.e. $U_e = \{1-(\frac{p_e - p_{ref}}{\frac{1}{2}\rho U_{ref}^2})\}$.

(c) <u>The V, p Calculation</u>

As explained in §2.1, we use the equation along the vertical characteristic (2.1.12) (see Fig. (4)) together with the full normal momentum equation (2.1.8) to solve for V, p at any station, having calculated U, τ at that station. Thus (see Fig. (4)) having calculated U, τ at the "future" station, we calculate V(n) from the equation along the vertical characteristic WP and then p(n) from the normal momentum equation.

We will now discuss the finite difference scheme employed in solving the above two equations. Fig. (6) is to be used in conjunction with the explanation given below:

(i) The n-derivative of any quantity appearing in the equations is obtained by a backward difference. For example $\frac{\partial p}{\partial n}$ at P(i,j) is approximated as $\frac{p_{ij} - p_{i,j-1}}{\Delta n}$, so that n derivatives are effectively centred at the point B.

(ii) The s-derivative of any quantity is effectively centred at the point A in the middle of the shaded "cell" $s + \frac{1}{2}\Delta s$, so that $\frac{\partial \tau}{\partial s}$, for example, is approximated by $\frac{1}{2}\ \{(\frac{\tau_{ij} - \tau_{i-1,j}}{\Delta s_i}) + (\frac{\tau_{i,j-1} - \tau_{i-1,j-1}}{\Delta s_i})\}$.

The only exception to this rule is the term $\frac{\partial V}{\partial s}$ which is the dominant term in the normal momentum equation since it represents the extra rate of strain, which for highly curved flows is large compared to the usual rate of strain term $\frac{\partial U}{\partial n}$ (see Bradshaw (1973) for a full discussion). Therefore, for accuracy, a central difference form of $\frac{\partial V}{\partial s}$ is used, which is exactly the same as that used for $\frac{\partial p}{\partial s}$ in the U, τ calculation. Thus

$$\left(\frac{\partial V}{\partial s}\right)_{ij} = \left(\frac{V_{ij} - V_{i-1,j}}{\Delta s_i}\right) \cdot \frac{\Delta s_{i+1}}{\Delta s_i + \Delta s_{i+1}} + \left(\frac{V_{i+1,j} - V_{ij}}{\Delta s_{i+1}}\right) \cdot \frac{\Delta s_i}{\Delta s_i + \Delta s_{i+1}}$$

Since when calculating the pressure at any station $s = s_i$, $V_{i+1,j}$ is not yet known, the pressure calculation is performed one step upstream of the V calculation, so that after calculating V at the (i+1)th station, say, we then calculate p at the ith station.

(iii) Quantities which do not appear in the form of a derivative are centred at the point B, so that, for example U is approximated by $\frac{1}{2}(U_{ij} + U_{i,j-1})$.

(iv) In approximating the small term $hV\frac{\partial V}{\partial n}$ in the normal momentum equation, we have linearised the finite difference form by using V as the value given by the previous station, while using the correct local value of $\frac{\partial V}{\partial n}$. Thus $V\frac{\partial V}{\partial n}$ becomes $\frac{1}{2}(V_{i-1,j} + V_{i-1,j-1}) \cdot \left(\frac{V_{ij} - V_{i,j-1}}{\Delta n}\right)$, so that the differenced normal momentum equation is linear in V_{ij}.

After the new pressure profile is calculated, we apply under-relaxation to it, so that the new pressure is taken as a linear combination of the pressure just calculated and the pressure from the previous sweep, i.e. $p_{new} = \Omega p_{calculated} + (1 - \Omega)p_{old}$, where Ω is termed the under-relaxation factor.

The V profile at the first station is also calculated using equation (2.1.12), given the starting U, τ profiles, however here, of course, a forward difference form for $\frac{\partial p}{\partial s}$ is used. Thus, the solution procedure for V, p can be summarised as follows:

(i) V_1, the value of V at the first mesh point, is known from the wall boundary condition calculation (see §2.2 (d) below). Hence, using (2.1.12) we can calculate the V profile up to the last mesh point (i.e. the matching surface). The value of V on the matching surface is V_e and is the variable transferred to the potential flow calculation in the viscous/inviscid interaction scheme.

Here, again, $\frac{\partial p}{\partial s}$ is obtained <u>only</u> from the previous sweep values of the pressure array p(s,n).

(ii) Having calculated the V profile, we calculate the p profile from equation (2.1.8) starting at the matching surface (where $p = p_e$ is given from the potential flow calculation) and working downwards until we reach the first mesh point. We then need to calculate the wall pressure p_w from the pressure at the first mesh point p_1; this is done by inserting an approximate one-fifth-power-law U profile into the continuity and normal momentum equations and integrating those two equations from the wall to the first mesh point. This, then, allows us to evaluate $\frac{p_w - p_1}{\rho U_{ref}^2}$. (See Appendix A3 for a detailed derivation).

The main changes made from the original BFA method are as follows:

(i) Whereas in the original BFA method, only the equation along the vertical characteristic was solved (in x-y coordinates, of course) we now additionally solve the full normal momentum equation. We also solve the two equations for V, p in s-n coordinates, which introduces extra curvature dependent terms in the equation along the vertical characteristic.

(ii) The term $\frac{\partial p}{\partial s}$ appearing in the equations along the characteristics is evaluated using central differences to account for upstream influence, as explained earlier.

(d) <u>The Wall Boundary Condition</u>

As seen in the previous sections, the U, τ and V calculations start at the first mesh point $n = \Delta n$ taking the values of U_1, $\frac{\tau_1}{\rho}$ and V_1. So the purpose of the wall boundary condition calculation is to obtain the values of $U_1, \frac{\tau_1}{\rho}, \frac{\tau_w}{\rho}$ and V_1 (where the suffix "1" denotes the first mesh point and "w" denotes the wall) given U at the wall (which is zero) and $V = V_w$, which may or may not be zero.

This is achieved in the following stages:

(i) Three equations are written down and solved for U_1, $\frac{\tau_1}{\rho}$ and $\frac{\tau_w}{\rho}$. These three equations are:

(A) The logarithmic law for the inner layer of the turbulent shear layer written at the first mesh point (with an extra term (Townsend (1961)) in cases where $\frac{\partial \tau}{\partial n}$ is significant).

(B) The equation along the segment of the "ingoing" characteristic which ends at the first mesh point (see Fig. (7)).

(C) The s-component momentum equation integrated in the n-direction between the wall and the first mesh point, with a one-fifth-power-law variation for the U velocity profile in that region.

These equations are non-linear and are solved iteratively using Newton's method. Since the value of V_1 and the angle of the ingoing characteristic are needed in this calculation, the values at the previous station are used as a first guess, as in the main U, τ calculation.

(ii) When the solution to the equations in (i) above has converged, V_1 and the angle of the ingoing characteristic are then evaluated by integrating the continuity equation in the n-direction from the wall to the first mesh point again using the one-fifth-power-law for U in the $\frac{\partial U}{\partial s}$ term. The values of $U_1, \frac{\tau_1}{\rho}$ and $\frac{\tau_w}{\rho}$ already calculated are used. But since these were evaluated using a guess for V_1 and the characteristic angle ϕ_{new} (see Fig. (7)), a better estimate for U_1, $\frac{\tau_1}{\rho}$ and $\frac{\tau_w}{\rho}$ using the newly calculated values of V_1 and ϕ_{new} is then made by going back to (i) above.

The above procedure is repeated until convergence of $\frac{\tau_1}{\rho}$ is achieved, so that the values of U_1, $\frac{\tau_1}{\rho}$ and $\frac{\tau_w}{\rho}$ are consistent with the value of V_1 (and tan ϕ_{new} as well). Details of the equations solved and of their method of solution are given in Appendix A3.

The solution procedure itself is unchanged from that of the original BFA method. The only changes made are in the form of extra curvature dependent terms appearing in the equations, in addition to the terms $\frac{\partial p}{\partial s}$, $\frac{\partial V}{\partial s}$ and normal Reynolds stress terms. These, although considerably affecting the mathematical complexity of the equations, did not affect the rate of convergence of the calculation procedure. Convergence is reached in three or four iterations at the most, unless $\frac{\tau_w}{\rho}$ is changing rapidly.

(e) The Momentum-Integral Check

As a check on the overall calculation, the momentum integral check compares the value of the momentum thickness obtained by integration of the U velocity profile, with that obtained by integrating the s-component momentum equation in the n-direction (thus obtaining the s-component momentum integral equation). The derivation and definitions are given in Appendix A3. It can be written exactly as:

$$\frac{d}{ds}(U_e^2\theta) = \frac{\tau_w}{\rho} + U_e\frac{dU_e}{ds}(\delta-\delta^*) + \frac{C_{UV}}{R} - \frac{C_\tau}{R} + V_w U_e + C_p' + \frac{dC_{\overline{u^2}}}{ds} \qquad (2.2.6)$$

where
$$C_{UV} = \int_0^\delta UV\,dn$$
$$C_\tau = \int_0^\delta \frac{\tau}{\rho}\,dn$$
$$C_p' = \int_0^\delta \frac{1}{\rho}\frac{\partial p}{\partial s}\,dn$$
$$C_{\overline{u^2}} = \int_0^\delta \overline{u^2}\,dn$$

where the integrals in δ^* and θ are evaluated from $n = 0$ to δ, like the explicit integrals in (2.2.6).

The only extra terms present here in addition to those of the original BFA method are dependent on curvature, normal Reynolds stress and streamwise pressure gradient; namely $\frac{C_{UV}}{R}$, $\frac{C_\tau}{R}$, C_p' and $\frac{dC_{\overline{u^2}}}{ds}$. The term in $\overline{v^2}$ sometimes found in formulation of the momentum integral equation is hidden in the pressure which is, of course, a function of n.

The solution of this equation for θ proceeds in much the same way as in the BFA method; we can write (2.2.6) as

$$\frac{d}{ds}(U_e^2\theta) = \Phi + \frac{dC_{\overline{u^2}}}{ds} \qquad (2.2.7)$$

where Φ can be evaluated for any given station. The $\frac{\partial p}{\partial s}$ term here is also evaluated using central differences, for consistency with the main calculation. If we use simple backward differences for the derivative terms in equation (2.2.7) we obtain a relation between values at s and s + Δs:

$$(U_e^{\,2}\theta)\big|_{s+\Delta s} = (U_e^{\,2}\theta)\big|_s + \tfrac{1}{2}.\Delta s.\left(\Phi\big|_s + \Phi\big|_{s+\Delta s}\right) + \left(C_{\overline{u^2}}\big|_{s+\Delta s} - C_{\overline{u^2}}\big|_s\right) \qquad (2.2.8)$$

Thus, given $U_e^{\,2}\theta$ at s we can evaluate it at s + Δs. The solution proceeds in the same way as for the BFA method in that we evaluate $U_e^{\,2}\theta$ (and hence θ) at station s + Δs from the previous station value at s. At the first station θ is taken to be the value obtained by integrating the starting U profile. The corresponding value of Φ is then computed using that value of θ. The procedure for subsequent downstream stations is then as outlined above.

(f) <u>Modification of the Courant-Friedrichs-Lewy Criterion</u>

The hyperbolic part of the calculation (in which U, τ are calculated) utilises the method of characteristics. Therefore, there is an upper limit to the permissible size of the s-step taken in the s-direction. This criterion is known as the Courant-Friedrichs-Lewy Criterion (see Roache (1972) p. 47, and also Courant, Friedrichs, Lewy (1967)). In the original BFA method it is used in the form of the statement:

$$\frac{\Delta x}{\Delta y} < \frac{1}{|\tan \phi|_{max}}$$

where $|\tan\phi|_{max}$ is the magnitude of the maximum characteristic angle at any given station (the characteristic angles vary, of course, across the shear layer).

For added security and in order to allow for small variations in the CFL value of the s-step from sweep to sweep, the right hand side of the above equation is multiplied by a factor of 0.9 so that

$$\frac{\Delta x_{max}}{\Delta y} = \frac{0.9}{|\tan\phi|_{max}} \tag{2.2.9}$$

determines the size of the x-step for any given station.

In the present method we have inserted an extra factor $(1 + \frac{\delta_{05}}{R})$ to account for the change to the s-n coordinate system. If we look at Fig. (8) we see that if Δs is the streamwise step at the wall, then at a height n above the wall, the step will be $\Delta s\ (1 + \frac{n}{R})$. Now, at the shear layer edge, this factor will be a maximum and equal to $\Delta s\ (1 + \frac{\delta_{05}}{R})$ so that we have to insert this in place of Δs in equation (2.2.9). We thus have a modified criterion governing the Δs at the wall:

$$\frac{\Delta s_{max}}{\Delta n} = \frac{0.9}{\left||\tan\phi|\,(1+\frac{n}{R})\right|_{max}} = \frac{0.9}{|\tan\phi|_{max}\cdot(1+\frac{\delta_{05}}{R})} \tag{2.2.10}$$

(g) The Initial Guess for the Pressure Field p(s,n)

As we have seen in previous sections, we need an initial guess for the pressure field p(s,n), in order to start the calculation. Now, a reasonable guess would be the "centrifugal force" approximation which is sometimes used when the full normal momentum equation is not solved. This would mean ignoring all the terms in the normal momentum equation except for the terms $\frac{U^2}{R}$ and $\frac{h}{\rho}\frac{\partial p}{\partial n}$. Thus, we would have

$$\frac{h}{\rho}\frac{\partial p}{\partial n} = \frac{U^2}{R} \tag{2.2.11}$$

where $h = 1 + \frac{n}{R}$ and R is a function of s.

We can write this equation more precisely as:

$$\frac{1}{\rho}\frac{\partial p(s,n)}{\partial n}\bigg|_{s=const.} = \frac{U^2\ (n)}{(n + R(s)|_{s=const.})} \tag{2.2.12}$$

for $s_o \leqslant s \leqslant s_{max}$; $0 \leqslant n \leqslant \delta(s)$ where we have actually used the starting U velocity profile (given at the first station) for all stations. Alternatively, one can merely start with the boundary layer assumption

$$\frac{\partial p(s,n)}{\partial n} = 0 \tag{2.2.13}$$

everywhere. As it turns out, the use of this fairly crude guess, rather than the centrifugal approximation, does not affect the rate of convergence for the cases presented here. We have therefore used (2.2.13) for simplicity and for numerical reasons (which will be discussed in Chapter 5 when the test cases are considered), although the option exists in the program to use (2.2.12).

(h) <u>The Starting Velocity and Pressure Profiles for the Case in which the Calculation is started in a Region of large $\frac{\partial p}{\partial n}$</u>

This section deals with the starting velocity and pressure boundary conditions necessary only if the calculation is started in a region of significant $\frac{\partial p}{\partial n}$. In such cases, for highly curved flows, the U velocity profile has non-zero velocity gradient at the edge of the shear layer, although the total pressure profile asymptotes to a constant value P_e, say, as in a plane BL. If we consider a plane BL with static pressure p_w and velocity profile

$$\frac{U}{U_e} = f(n) \qquad (2.2.14)$$

where $P_e = p_w + \frac{1}{2}\rho U_e^2$, then a plausible mean velocity profile for a curved flow is

$$U = \left[(P' - p)/\tfrac{1}{2}\rho\right]^{\frac{1}{2}} \qquad (2.2.15)$$

Therefore,

$$U = \left[(p_w + \tfrac{1}{2}\rho U_e^2 f^2(n) - p)/\tfrac{1}{2}\rho\right]^{\frac{1}{2}}$$

$$= \left[\{(P_e - p_w)f^2(n) - (p - p_w)\}/\tfrac{1}{2}\rho\right]^{\frac{1}{2}} \qquad (2.2.16)$$

The velocity profile (for the curved flow) given by (2.2.14) is termed an "unrealistic" profile, while that given by (2.2.16) is termed a "realistic" profile. Fig. (9) shows typical "realistic" profiles for the two cases $p_e > p_w$ and $p_e < p_w$.

In artificial test cases f(n) is chosen to give the required BL thickness and, via the logarithmic law, the required surface shear stress. The starting static pressure profile can be derived from the centrifugal approximation (2.2.12), say, by solving

$$\frac{1}{\rho}\frac{\partial p}{\partial n}\bigg|_{s=s_o} = \frac{U^2}{(n + R_o)} \qquad (2.2.17)$$

Substituting for U from (2.2.16) this becomes

$$\left.\frac{\partial p}{\partial n}\right|_{s=s_o} = 2\left[\frac{(p_e - p_w)\ f(n) - (p - p_w)}{(n + R_o)}\right] \qquad (2.2.18)$$

with $p = p_w$ when $n = 0$. Equations (2.2.16) and (2.2.17) can be solved iteratively to obtain the starting U and p profiles.

The facility also exists in the program to input a starting pressure profile but only in the case of a "realistic" U starting profile also being supplied; this provides an alternative to the above, in the case in which the starting profiles are known in the region of large $\frac{\partial p}{\partial n}$.

(i) The Downstream Pressure Boundary Condition

As mentioned earlier, we usually end the shear layer calculation in a region of zero (or very small) $\frac{\partial p}{\partial n}$, so that the downstream boundary condition mentioned in §2.1 would be acceptable; this is applied in the form

$$p(s_{max}, n) - p(s_{max} - \Delta s, n) = p_e(s_{max}) - p_e(s_{max} - \Delta s)$$

for all values of n. The facility also exists of supplying the pressure profile at $s = s_{max}$ via input, for cases in which the calculation is terminated in a region of large $\frac{\partial p}{\partial n}$, just as in the case of the starting pressure profile.

2.3 PROCEDURE FOR ONE STREAMWISE SWEEP OF THE SHEAR LAYER CALCULATION AS PART OF ONE VISCOUS/INVISCID INTERACTION CYCLE

We shall describe below the procedure adopted in performing one streamwise sweep of the shear layer calculation and how it forms a part of one complete viscous/inviscid interaction cycle or iteration. For a description of the viscous/ inviscid interaction procedure itself the reader is referred to

Chapter 3; here we shall only describe the shear layer part of the interaction with as little reference as possible to the details of the viscous/inviscid interaction procedure itself.

(a) Adjustment of the Matching Surface

We have previously discussed the various boundary conditions needed for the shear layer calculation in §2.1.

Here, we shall only consider the external boundary condition ($p = p_e(s)$ at $n = \delta(s)$ for $s_o \leqslant s \leqslant s_{max}$) in more detail. These values of external pressure are supplied by the potential flow calculation at certain s-positions or "nodes" on a "matching surface" $n = \delta(s)$ (the surface on which the viscous/inviscid matching is performed). Furthermore, since for the first sweep of the shear layer calculation, we do not know where the edge of the shear layer lies, we guess an arbitrary position for the matching surface, $n = \delta_o(s)$ say. After the first sweep of the shear layer calculation we determine the actual edge of the shear layer by determining the smallest value of n at which U is greater than .999 of the "potential velocity" $\sqrt{\{1 - 2(\frac{p - p_{ref}}{\rho U^2_{ref}})\}}$ and $\frac{\tau}{\rho U^2_e}$ less than 10^{-6}. We then multiply this height by a factor (usually 1.1) to allow for further changes in the actual shear layer thickness, thus obtaining a new matching surface position $n = \delta(s)$ which is then fixed for the remaining sweeps of the calculation. In the following sections we describe how the above interaction procedure is applied to the shear layer calculation in the form of two distinct interaction schemes, one for internal and one for external flows.

(b) Interaction Scheme for Internal Flow

Fig. (11) shows the interaction scheme used in calculating two dimensional flows; for simplicity we have just shown the calculation of the shear layer on the bottom wall of a duct. Now, since we have to store the two dimensional pressure array p(s,n) for use in the next sweep of the shear layer calculation and since the MS position during the first sweep has also changed we have a twofold problem:

(i) We need to increase the pressure profiles at all stations by an amount equal to $p_{e,new} - p_{e,old}$ at each station; if we consider a fixed MS, say (see Fig. (12a)),then if $p_{e,old}$ is the value of p_e at any given station and $p_{e,new}$ is its value at the same station for the next sweep of the shear layer calculation, then the currently calculated pressure profiles have to be "shifted" by an amount equal to $(p_{e,new} - p_{e,old})$ (see Fig. (12a)) so that the p profile should pass through $p_{e,new}$ on the next sweep. Thus, we have kept $\frac{\partial p}{\partial n}$ the same but have simply altered the origin of p for consistency. This pressure profile shift is necessary for all sweeps of the calculation.

(ii) For all sweeps after the first, the pressure profile shift of (i) above is all that is required, since the MS will be fixed. However, in going from the first to the second sweep only, we additionally change the MS position, so that care is needed in shifting the pressure profiles; if we extrapolate the pressure profile from the old MS (where $p_e = p_{e_1}$) to the new one (see Fig. (12b)), we arrive at a different external pressure p_{e_2} on the new MS. Now, we take p_{e_2} to be the value of $p_{e,old}$ in (i) above and shift the pressure profiles accordingly, since the new MS now forms our fixed MS to be used for all subsequent sweeps. It turns out that the pressure profiles are almost linear near the MS so that a linear extrapolation of the pressure profiles would be sufficiently accurate.

(c) Interaction Scheme for External Flow

Fig. (13) shows the interaction scheme for the case of external flow which is typically an aerofoil; only the upper half of the aerofoil is shown for clarity. Now in this case we adopt a simple laminar flow calculation, which is an integral method due to Thwaites (see Duncan, Thom and Young (1970), p. 273) from the stagnation point to a position where a simple transition criterion is applied. We enforce the crude transition condition that if Re_θ becomes equal to or greater than some transition Reynolds number $Re_{\theta,tran}$ (which we have chosen to be 600), then the laminar BL calculation stops and we immediately start the turbulent shear layer calculation, assuming $\frac{\partial p}{\partial n} = 0$ up to and including this station. In the laminar BL calculation region I (see Fig. (13)), the external pressure distribution is given on the old MS at certain "nodes". Hence the free stream velocity distribution and its gradient are known and we can calculate the momentum thickness distribution $\theta(s)$ from the Thwaites formula (see A3.7):

$$\theta^2(s) = \frac{0.45\nu}{U_e^6(s)} \int_0^s U_e^5 (\xi)\, d\xi \qquad (2.3.1)$$

where ξ is a dummy variable denoting distance along the aerofoil surface. At the end of region I we generate starting U and τ profiles for use in the turbulent shear layer calculation region II. Thus, this station will constitute the "first" station for the turbulent calculation. We generate the starting U and τ profiles having obtained the value of θ at the first station from the Thwaites laminar BL calculation, and using Coles' velocity profile family (this part is unchanged from the BFA method ; for a discussion of this the reader is referred to Bradshaw and Unsworth (1974)). The starting U, τ profile calculation results in a BL thickness of δ_{Coles} at the start of the turbulent shear layer calculation. This would usually be smaller than the initial guess $n = \delta_o$ for the matching surface so that the U and τ profiles would need to be extended up to the old MS just by putting $\frac{U}{U_e} = 1$ and $\frac{\tau}{\rho U_e^2} = 10^{-8}$ in the region $\delta_{Coles} \leqslant n \leqslant \delta_o$, at the first station(assuming $\frac{\partial p}{\partial n} = 0$). The _shape_ of the _new_ MS in region I is taken to be proportional to $\theta(s)$ in that region. After the turbulent shear layer has been calculated and the position of the new MS $n = \delta$ established for the turbulent region II (in exactly the same way as in (b) above for internal flow), the new MS for the laminar region I is obtained by making it proportional to $\theta(s)$ with the constant of proportionality obtained by making the MS continuous at the first station (see Fig. (13)), so that the constant is then δ/θ_o where θ_o is the value of θ at the first station. This new MS is then fixed for all subsequent sweeps of the calculation, as before.

It is necessary to calculate $V_e(s)$, the external velocity on the MS, as part of the interaction procedure, since this will be used in the potential flow part of the calculation (for a full discussion see Chapter 3). Now, in region I during the first sweep of the shear layer calculation the position of the new MS is not known in advance and therefore only during this sweep is $V_e(s)$ computed on the surface as shown in Fig. (13), which also has the same shape as $\theta(s)$ but passes through the point $n = \delta_{Coles}$ at the first station. For subsequent sweeps $V_e(s)$ is actually calculated on the new MS $n = \delta$. The calculation of V_e in region I on any surface $n = \Delta$ is achieved by integrating the continuity equation in the n direction. This gives approximately (see §A3.7)

$$V_e|_{n=\Delta} = V_w - \frac{d}{ds}\left[U_e(\Delta - \delta^*)\right] + U_e \frac{d\Delta}{ds} \qquad (1.3.2)$$

assuming that $\Delta >$ laminar BL thickness and that $\frac{d\Delta}{ds} << 1$. $\delta^*(s)$ is computed from an empirical formula for the shape parameter $H \ (= \frac{\delta^*}{\theta})$ as a function of the parameter $\frac{\theta^2}{\nu} \ \frac{dU_e}{ds}$ in the laminar region I.

Since the surface on which V_e is calculated during the first sweep cannot be determined until δ_{Coles} is calculated, the laminar calculation (for the first sweep only) proceeds in two stages:

(i) Firstly, $\theta(s)$ is calculated and δ_{Coles} is then computed.

(ii) Secondly, the surface $n \propto \theta(s)$ for the V_e calculation is determined (having computed δ_{Coles}) and $V_e(s)$ is calculated, so that two runs of the laminar calculation are performed (for the first sweep only).

As mentioned earlier, after the laminar calculation is completed we then use the value of θ at the first station ($s=s_o$) and calculate the starting U and τ profiles for the turbulent calculation as in the original BFA method from Coles' velocity profile family (assuming $\frac{\partial p}{\partial n} = 0$). For the turbulent calculation, the shift in the pressure profiles required from sweep to sweep as well as the adjustment necessary for the pressure profiles after the first sweep of the calculation, are exactly the same as in the internal flow case.

2.4 DESCRIPTION OF THE COMPUTER PROGRAM FOR THE SHEAR LAYER CALCULATION

The description given in the following sections will be of the shear layer calculation program alone. It should be used in conjunction with the relevant program listing, namelist and flow charts given in the Appendix. Constant reference will also be made to various parts of the preceding sections as well as to sections in the Appendices. In many places the program is unchanged, or little changed, from the basic BFA method; in such cases only a brief description will be given. For a full description of the BFA program the reader is referred to Bradshaw and Unsworth (1974).

It will be found more convenient to describe the main routine (called TURB) first and then to describe each of the subroutines (the main subroutines are arranged in the order in which they are called in the main routine, while subsidiary subroutines are described in alphabetical order). A flow chart (Fig. (14)) is also given, showing the calling sequence of the main subroutines and how they are linked. Note that the convention used is O to denote the letter O and Ø to denote zero.

(a) The Main Routine TURB

To save core space the shear layer program as run on the ICCC CDC machine has been divided into overlays; the main routine and its subroutines reside in the main overlay (OVTURB,Ø,Ø) (also called the zero overlay) while two other main blocks reside in two primary overlays. These are (i) the subroutines used only to start the calculation (subroutines STARTØ, START and SYNTH) which reside in overlay (OVTURB,2,Ø) and (ii) a subroutine called after the completion of one sweep of the calculation (subroutine PRLAST) which resides in overlay (OVTURB,1,Ø).

Firstly, after reading in some input variables, overlay (OVTURB,2,Ø) is loaded so that the starting subroutines STARTØ, START and SYNTH are brought into operation. These are responsible for initialising the calculation and computing the starting U, τ and p profiles, as well as computing any other starting parameters. In the case of an external flow, SYNTH also performs the Thwaites laminar BL calculation (see §2.3(c)).

On returning from this initialisation overlay the program prints out the starting pressure profile (at the first value of X, equal to s_o) as well as the profile at X + YSTP ($s_o + \Delta s$) for the first sweep only.

The calculation loop then starts (at statement number 12Ø) in the main routine by moving the stores UFUT and TFUT, which contain the U, τ profiles recently calculated for the current s (or, for $s = s_o$, the input profiles) into stores U, TAU. Similarly stores U, TAU (containing profiles for $s - \Delta s$) are moved into UOLD, TOLD. The FUT stores are unchanged until they are overwritten with values calculated at $s + \Delta s$. The maximum value of τ, τ_m is then calculated. τ_{05} is then calculated as the shear layer thickness at which the shear stress τ is $0.05\ \tau_m$. τ_m is used later in scaling the function G (§2.1(a)).

A call is then made to subroutine VPRESS which performs the V,p calculation at the current station. At the first station $s = s_o$ only the initial V profile is calculated, p(n) being input as a boundary condition. V_e, the value of V on the matching surface (which is used in the viscous/inviscid matching procedure) is stored in array VEXT after the call of VPRESS. INTGEQ is then called to provide a check on the calculation by comparing the values of momentum thickness (i) obtained by integrating the calculated U profile and (ii) obtained by solving the s-component momentum integral equation for the current station: at $s = s_o$ INTGEQ merely initialises its stores.

In order to proceed to the next station of the calculation $s + \Delta s$, subroutine CFL is then called to compute the maximum size of the s-step Δs_{max} according to the Courant-Friedrichs-Lewy Criterion. The CFL value of Δs_{max} is factored by the input variable A(6), so that the actual Δs used is A(6). Δs_{max}. After returning from CFL, the step Δs is stored in XSTEP. $s + \Delta s$ is stored in the array XCAL at each station and is fixed for all subsequent sweeps; even if the value of Δs_{max} given by CFL were to change slightly from sweep to sweep it would not matter, since the actual Δs used is smaller than Δs_{max}. If an extra strain rate correction (STRAIN) were inserted in the turbulence model, its value would be calculated next. However, we have not inserted any such correction in our turbulence model equation and so STRAIN has been set to zero. The next section of the main routine calls the output subroutine PRINT at pre-selected s-stations. If the end of the sweep has been reached, control is returned to statement number 27Ø.

Next, the boundary values at $n = 0$ and $n = \delta$ are applied.

Optionally, surface roughness, transpiration velocity or lateral divergence at $s + \Delta s$ are interpolated from input look-up tables as in the BFA program. A low-Reynolds number correction (negligible for $U_e\theta/\nu > 5000$ approx.) is then made to the parameter z_{01} in the evaluation of L. The curvature CURV at $s + \frac{1}{2}\Delta s$ is computed. This is for consistency with the way in which we centre variables in the middle of a cell in our finite difference scheme (see §2.3(c)).

We then find the external pressure p_e at $s + \Delta s$ and also fill up the "initial" guess for the pressure array $p(s,n)$ for the station $s + \Delta s$. Now, in order to obtain a smooth distribution of p_e, the external pressure boundary value at $s + \Delta s$ is interpolated, using cubic splines, from the boundary values given at the "nodes" on the matching surface (see §2.3). For sweeps after the first, the values of the pressure array calculated on the previous sweep are stored in the two dimensional array PRESS. Since the matching surface $n = \delta(s)$ is taken to be at the mesh point whose index j is equal to I62, the value of p_e at any station (for sweeps after the first) is the value of PRESS for j = I62. The initial filling up of the pressure array (for the first sweep only) is performed in the next section, using $\frac{\partial p}{\partial n} = 0$ if "unrealistic" starting profiles of U, τ are supplied; this applies to the case where we start the turbulent calculation in a region of zero $\frac{\partial p}{\partial n}$.

If the turbulent calculation is started in a region of significant $\frac{\partial p}{\partial n}$, the initial pressure array is filled up using the centrifugal approximation (see §2.2(h)). Moreover, if in this case pressure profiles at $s = s_o$ and $s = s_{max}$ are supplied (from input), then the "initial" pressure array is filled up by using a streamwise linear interpolation of the pressure profiles between s_o and s_{max}, to obtain $p(s + \Delta s, n = \text{const.})$ (for all values of n).

The wall boundary condition subroutine WALLBC is then called in order to obtain the values of $U_1, \frac{\tau_1}{\rho}, \frac{\tau_w}{\rho}$ and V_1 at s + Δs. After returning from WALLBC, subroutine NEWPRO is called to calculate U, τ at s + Δs.

The next section of the program is concerned with printing the pressure profiles calculated on the previous sweep NSWEEP-1 which are used in the current sweep. The station count (NCOUNT) is then incremented by one, s is set to s + Δs and control is returned to statement number 12Ø to begin the next s-step of the calculation.

When s reaches s_{max}, control is transferred to statement number 27Ø whence overlay (OVTURB,1,Ø) is loaded, which brings subroutine PRLAST into operation. This is the last subroutine called and it implements the downstream pressure boundary condition as well as other final operations (for a full discussion see (s) below).

Finally, NSWEEP is printed to signal completion of the sweep.

(b) Subroutine STARTØ

This is the first subroutine called when the primary overlay (OVTURB,1,Ø) is loaded. This subroutine firstly reads in variables used in the shear layer calculation from disc unit TAPE14, which has been written on by other programs in the viscous/inviscid calculation procedure. One of these is the distribution of p_e on the MS, which is given at the mid points between the "nodes" of the inviscid calculation (see §2.3) and is therefore interpolated at the nodes, again using cubic splines for smoothness, and stored in array PA.

Control parameters contained in the I and A arrays are then read in from TAPE5; for a full description of these control parameters see Chapter 4. Some initialisations of variables are then made before the call of subroutine START, which is the next subroutine used to start the calculation. The index NSTART refers to the "first station" ($s = s_o$) of the turbulent shear layer calculation.

(c) Subroutine START

Fig. (9) gives a flowchart for this subroutine.

The subroutine first tests for external or internal flow; according to the value of I(2) (see subroutine PRLAST above). SYNTH is called (for the case of external flow), in order to perform the Thwaites laminar BL calculation in the laminar flow region, and also to evaluate synthetic U and τ starting profiles (stored in arrays U and TAU on return from SYNTH).

The next section evaluates the starting values (at $s = s_o$) of roughness, curvature, divergence and transpiration velocity from the corresponding boundary values. It also prints out these boundary values together with the curvature distribution (CURVA), external pressure distribution (PA) and matching surface height (RNPNEW and RNP) and their corresponding s-values (XCURV, SSURF and SSURF, respectively. The other boundary values are assumed to be at a constant interval A2 (equal to the control parameter A(2)).

In the next small section XP is an integer array which if I(3) < Ø will contain station numbers at which PRINT is to be called in the main routine. If I(3) > Ø, then PRINT will be called every I(3) steps.

The next section reads in starting U and τ profiles if the flow is an internal one (in which case synthetic starting profiles of U, τ will not have been calculated since SYNTH would not have been called).

From statement number 43Ø to 532 the iteration calculation for obtaining a "realistic" velocity profile and a corresponding starting pressure profile is performed (see §2.2(h)). The equations solved are (2.2.16) and (2.2.17) in the manner described in that section. This assumes that the starting U profile supplied is an "unrealistic" (JOPT=1) one and that the turbulent calculation is started in a region of significant $\frac{\partial p}{\partial n}$.

Putting the input parameter A(1) equal to zero implies that the turbulent calculation is started in a region of <u>zero</u> $\frac{\partial p}{\partial n}$ and in that case the starting pressure profile is taken as $p(s_o,n) = p_e(s_o,n)$.

In the next two small sections allowance is made to input a "realistic" U (and τ) profile as well as corresponding starting and final pressure profiles at $s = s_o$ and $s = s_{max}$, respectively. For this case, JOPT=2.

We then fill in a pressure profile at a station Δn downstream of the first station. This pressure profile is obtained using the centrifugal approximation for $\frac{\partial p}{\partial n}$, only for the case JOPT=1 (where we have supplied an "unrealistic" starting U profile). For the case JOPT=2, this pressure profile is obtained by streamwise linear interpolation between the profiles supplied at $s = s_o$ and $s = s_{max}$.

The final section of START evaluates some parameters needed to start the calculation, as well as storing the starting U, τ profiles in UFUT, TFUT, respectively; UFUT now contains a "realistic" starting velocity profile.

(d) <u>Subroutine SYNTH</u>

This subroutine is called only in the case of external flow and performs a Thwaites laminar BL calculation from the stagnation point to a position where a transition criterion is applied. At this position, synthetic starting U and τ profiles for the turbulent calculation are then evaluated from Coles' velocity profile family (see §2.3(c) and also the flow chart Fig. (20)).

The first major section extends from statement number 25 to 1Ø5 and constitutes the laminar BL calculation using Thwaites' integral method (assuming $\frac{\partial p}{\partial n} = 0$). The integration of $U_e^5(s)$ in the Thwaites calculation is exact if $U_e(s)$ (and not U_e^5) is made to vary linearly with s. From statement number 25 to 9Ø certain parameters of the calculation are initialised. Starting at statement number 9Ø the integration loop for the laminar calculation proceeds in the streamwise direction with XF the "future" station and X the current one. The streamwise positions chosen for the calculation are at the "nodes" of the real surface (see Chapter 3) contained in the array SSURF. The value of θ at XF is stored in THETA and is calculated from equation (2.3.1). The value of the parameter $\frac{\theta^2}{\nu} \frac{dU_e}{ds}$ is then computed and the shape parameter (H1) is evaluated from an empirical formula. This then allows us to compute the V_e distribution (stored in array VEXT) from equation (2.3.2). A test is then made for transition; for demonstration purposes the transition criterion is $Re_\theta = 600$ independent of pressure gradient, so that if $Re_\theta > 600$ the laminar calculation is stopped and transfer is made to statement number 1Ø5. Now, for sweeps after the first of the complete shear layer calculation, we stop the laminar calculation at the same s-position at which it was stopped for the first sweep, so that the above transition criterion is only applied during the first sweep. It is found that Re_θ at the transition position does not vary much from sweep to sweep and as the laminar calculation is stopped at the "node" immediately after the transition position, it is found that this node would have been the same if the transition criterion ($Re_\theta > Re_{\theta tran}$) were allowed to decide the transition position for every sweep.

After the laminar BL calculation, in the next section down to statement number 12Ø, the ratio θ_o/δ_{Coles} is calculated iteratively in the same way as in the BFA program, (where θ_o is the value of θ at the start of the turbulent calculation). However, we have also included here the Spalding-Chi empirical formula in zero pressure gradient (simpler than Coles' implicit formula) for calculating $\frac{c_f}{2}$ at $s = s_o$. If A(5) is input as zero, this formula is used. However if A(5) is not zero, then its value is taken to be $\frac{c_f}{2}$.

The next section from statement number 12Ø to 125 is executed only once for the first sweep. As stated in §2.3(c) in describing the method of calculation, we perform the laminar calculation twice during the first sweep only. For the first "stage" mentioned in §2.3(c) the variable LOOP takes the value 1 and we do not calculate the V_e distribution on the MS for the laminar region then, since the new MS position is not yet known. After having gone through the laminar calculation once and having thus obtained the θ distribution and thus the turbulent shear layer thickness at transition, we can provisionally define a matching surface on which the V_e distribution is calculated (see §2.3(c) for details). We then carry out the laminar calculation a second time (stage (ii) mentioned in §2.3(c)) with LOOP=2, only this time we calculate the V_e distribution on the above mentioned matching surface. This section calculates the factor necessary to multiply the θ distribution in order to obtain this surface (by forcing it to pass through δ_{Coles} at the end of the laminar calculation). This process is more efficient than storing all the laminar information.

In the next section the synthetic starting profiles of U and τ are calculated in the same way as for the BFA program, from Coles' velocity profile family. The number of profile points for the turbulent calculation is then adjusted; for the first sweep we take I6 to be the number of profile points used to compute the starting U and τ profiles, so that the I6'th mesh point corresponds to a height of δ_{Coles} above the real surface. This number of points can be very small (as little as 5). However, if we use the same Δn, the value of I62 used in the turbulent calculation (on the old MS at a height RNP) will generally be much larger, since the thickness of the laminar BL is usually very small. This criterion governs the initial guess of the MS height; one can usually work backwards by firstly choosing a reasonable value of I62 for the turbulent calculation and then estimating the MS height RNP. A check on the value of I62 is included and if it exceeds 51 it is printed out and the program stops; its value will give an indication of the amount by which RNP (the initial MS height) is to be reduced. Finally, the starting U and τ profiles are continued from the height $n = \delta_{Coles}$ up to the MS height $n = \delta_o$ (for the first sweep) or $n = \delta$ for all subsequent sweeps.

(e) Subroutine VPRESS

This subroutine contains the V, p calculation and is the main addition to the original BFA program (see Fig. (17) for flow chart). It replaces what used to be just the calculation of V from the equation along the vertical characteristic. The first section of the subroutine is executed for $s = s_o$ only and is used to calculate the starting V profile from equation (2.1.12) along the vertical characteristic. Here, as mentioned before (see §2.2(c)) $\frac{\partial p}{\partial s}$ is obtained by forward differences between the first station ($s = s_o$) and a position given by $s = s_o + \Delta n$ since at the first station the s-step (Δs) is not yet known; we therefore, only obtain a localised value for $\frac{\partial p}{\partial s}$ near the first station, using Δn merely as a small distance in the s-direction. As for the U, τ calculation, $\frac{\partial p}{\partial s}$ is also obtained from the previous sweep values of the pressure array p(s,n)(stored in PRESS).

The next section of VPRESS contains the calculation of V at any station after the first (where Δs is now known), also from equation (2.1.12) along the vertical characteristic. The same rules apply for the calculation of $\frac{\partial p}{\partial s}$ except that for the first sweep only $\frac{\partial p}{\partial s}$ is obtained by backward differences as in the case of the U, τ calculation.

The normal momentum equation (2.1.8) is then solved to obtain the pressure profile. As mentioned in §2.2(c), we use central differences for $\frac{\partial V}{\partial s}$ so that the pressure profile calculated after V for station $s + \Delta s$ is actually that at the previous station s. Therefore, the p calculation lags one step behind the V calculation; thus VOLD contains V(s) (where p is being calculated), VOLDER $V(s - \Delta s)$ at the station before that and V contains the V-profile at the current station $s + \Delta s$ (see Fig. (14)). The pressure is calculated starting at the matching surface (where $p = p_e$ is given) down to the first mesh point (where $p = p_1$). The wall pressure p_w is then calculated from p_1 using equation (A3.27) for $\frac{p_w - p_1}{\rho U_{ref}^2}$ given in

Appendix A3.

The newly calculated pressure is then underrelaxed as described in §2.2(c). The next section is concerned with the calculation of p at $s_{max} - \Delta s$; since we do not have a V profile for the last station, we use backward differences for $\frac{\partial V}{\partial s}$ at $s = s_{max} - \Delta s$. Only at $s_{max} - \Delta s$ is the p calculation performed at the same station as the V calculation, since central differences for $\frac{\partial V}{\partial s}$ are not used.

Finally, the characteristic angles (TANA and TANB) at $s + \Delta s$ are calculated by calling subroutine TANCAL.

The control parameter IORIG is used to inform the subroutine of the origin of the call to VPRESS; if VPRESS is called from the main routine, then IORIG=1 and in that case the V and p calculations are performed (as well as the calculation of the characteristic angles). However, if IORIG=2, then VPRESS was called from NEWPRO, where the inner layer recalculation of U, τ is performed and in this case only V and the characteristic angles are calculated, as in subroutine VANGL of the original BFA program.

(f) Subroutine TANCAL

This calculates the characteristic angles from equations (2.1.11) at any station and stores them in arrays TANAFU and TANBFU.

(g) Subroutine INTGEQ

This subroutine provides the momentum integral check of §2.2(e). In the first section, the U velocity profile is integrated to obtain the values of δ^* and θ (which is called THETA in this case). Next, the term Φ of equation (2.2.7) is calculated for the first station ($s = s_o$).

The next section computes $U_e^2\theta$ (stored in THUS) at station $(s + \Delta s)$ from equation (2.2.8) which is the s-component momentum integral equation. The value of θ obtained from this equation is stored as SCHMET and is compared with THETA as a check on the calculation. Again, for consistency, $\frac{\partial p}{\partial s}$ is calculated in the same way as for the U, τ calculation. The momentum integral check is calculated up to the MS (i.e. the I62'th mesh point).

(h) Subroutine CFL

This subroutine evaluates the s-step (XSTEP) from the Courant-Friedrichs-Lewy Stability Criterion. It is little changed from that in the BFA program with the exception of introducing an extra factor $(1 + \frac{\delta_{05}}{R})$ (see §2.2(f)).

(i) Subroutine PRINT

This subroutine is only slightly changed from the BFA version; firstly, the various integral parameters are printed out including SCHMET. If the control parameter I(1) is greater than zero then the profiles of U, τ, V and the characteristic angles are also printed out up to $n = \delta$.

(j) Subroutine ROUGHC

This subroutine evaluates the value of the additive constant in the logarithmic velocity profile law for a rough surface. It is unchanged from the BFA version.

(k) Subroutine WALLBC

This is the subroutine which applies the wall boundary condition and essentially calculates $U_1, \frac{\tau_1}{\rho}, \frac{\tau_w}{\rho}$ and V_1 (at the first mesh point) at $s + \Delta s$, for use in the main part of the calculation (see §2.2(d) and also the flowchart Fig. (18)).

The first main section of the subroutine is executed only once for each station (ie. for each call of WALLBC) and performs the initial interpolations of U, $\frac{\tau}{\rho}$ and V where the in-going characteristic at the first mesh point of the future station s + Δs, intersects the current calculating station s (see Fig. (7)). (This interpolation is overwritten once an improved ingoing characteristic angle is obtained, as outlined below). It also evaluates $\frac{\partial p}{\partial s}$ at the first mesh point using backward differences for the first sweep and central differences for subsequent sweeps, exactly as in the main U, τ calculation.

The next main block is executed once for each overall iteration and applies for both the solid wall and transpiration cases (one overall iteration starts at statement number 2Ø and ends at statement number 16Ø). In this block various terms used in the wall boundary condition calculation, both for solid wall and transpiration, are evaluated.

In the next section, the calculation of U_1, $\frac{\tau_w}{\rho}$ and α_o for the solid wall case is performed by solving equations (A3.28, A3.29, A3.34) of Appendix A3 iteratively, using Newton's method. After completion of this section control is transferred to statement number 14Ø.

The next section, entered only in the case of transpiration, calculates U_1, $\frac{\tau_w}{\rho}$ and $\frac{\tau_1}{\rho}$ by solving equations (A3.35, A3.36 and A3.37) of Appendix A3 by Newton's method. An under-relaxation term equal to $-\frac{.05\ V_w}{|V_w|\bullet NIT}$ is added to the determinant of coefficients for stability of the Newton's method iteration (where NIT is the iteration number). At the end of this section transfer is made to statement number 14Ø.

Statement number 14Ø tests for convergence of $\frac{\tau_1}{\rho}$ within a certain tolerance limit since the value of V_1 used in the above calculations (for U_1, $\frac{\tau_1}{\rho}$, $\frac{\tau_w}{\rho}$) is that at the previous station s. If convergence of $\frac{\tau_1}{\rho}$ is not yet complete, then the next section is used to evaluate better values of V_1 and the ingoing characteristic angle. Transfer is then made to statement 2Ø for another "overall" iteration to be performed in order to improve on the values of U_1, $\frac{\tau_1}{\rho}$ and $\frac{\tau_w}{\rho}$ until the required convergence of $\frac{\tau_1}{\rho}$ is attained. Fig. (18) shows a flowchart outlining the main loops of the wall boundary condition calculation procedure.

(1) Subroutine NEWPRO

This subroutine calculates U, τ at s + Δs (see Fig. (16) for flowchart). After some initialising, the calculation, (which is contained in the main loop starting at statement number 11Ø down to statement number 16Ø) commences with the parabolic interpolation in n at station s to obtain the values of UINT, TINT and VINT (see §2.2(b)) where the ingoing and outgoing characteristics through the Kth mesh point at s + Δs intersect the n-axis at s. The two passes (I1 = 1 and I1 = 2) down to statement number 13Ø then solve the two equations (2.2.3) along the characteristics through the Kth mesh point, to obtain UFUT and TFUT (the values of U, τ at s + Δs). Note that $\frac{\partial p}{\partial s}$ is obtained by backward differences at the "future" station s + Δs for the first sweep only, since p at the station following the future one is not yet known. It is only after the first sweep (when the whole pressure array is stored) that central differences are used for $\frac{\partial p}{\partial s}$. As mentioned before, only the values of p(s,n) calculated on the previous sweep (NSWEEP-1) are used to compute $\frac{\partial p}{\partial s}$ for the current sweep.

The next group of statements from statement number 14Ø to 185 apply the edge clip condition on the U velocity (see §2.2(b), part (iv)), and also (for the first sweep only) find the edge of the shear layer as in the BFA method by finding where the conditions $U/U_e > 0.999$ and $\frac{\tau}{\rho U_e^2} < 10^{-6}$ are both satisfied (where $U_e = \sqrt{\{1 - 2\frac{(p_e - p_{ref})}{\rho U_{ref}^2}\}}$) in order to compute the position of the new matching surface (see §2.3). The new MS height is then calculated as 1.1 times this shear layer thickness and is stored in array RNPNEW.

The final section of NEWPRO is unchanged in principle from the BFA program and recalculates U, τ in the inner fifth of the shear layer by obtaining better estimates for V and the characteristic angles in that region, since for the main part of the calculation described above, the value of V and the characteristic angles are those for the previous station.

Thus WALLBC is iterated to convergence to calculate $\frac{\tau_w}{\rho}$, U_1 and $\frac{\tau_1}{\rho}$, while inner-layer values are obtained with one predictor and one corrector and outer layer values are obtained from one predictor (using upstream coefficients) only.

(m) Subroutine PRLAST

This is the main subroutine of the primary overlay (OVTURB,1,Ø) and is called when one sweep of the calculation is completed. The other utility subroutines VALUE and SPLINE are the same as before, but must be included in each overlay in which they are used.

Firstly, PRLAST retrieves the pressure profile calculated at $s_{max} - \Delta s$ in VPRESS from store P (the pressure profile at the last station s_{max} is supplied as the downstream boundary condition). Since central differences are used for $\frac{\partial p}{\partial s}$ in the U, τ and V calculations, we can only calculate U, τ and V up to and including $s_{max} - \Delta s$.

Having obtained the pressure profile at the station

$s_{max} - \Delta s$, the downstream boundary condition $\left.\frac{\partial p}{\partial s}\right|_{s=s_{max}} = \frac{dp_e}{ds}$ between the last station and the station before last is applied (see §2.2(i)).

Next, the pressure profiles calculated at various stations are printed out if the value of the control parameter I(14) is greater than zero. The pressure profiles are only printed out for the stations at which other information was printed out via subroutine PRINT.

The next section (down to statement number 36Ø) is executed only for the first sweep and used to obtain the new matching surface shape whose ordinate is 1.1 times the shear layer thickness (on the first sweep) and also to extrapolate the pressure profiles calculated from the old MS up to the new one (see §2.3(b) and (c)). The cases of internal and external flow are distinguished by the value taken by the control parameter I(2); if I(2) = Ø then synthetic initial U, τ profiles have been calculated in subroutine SYNTH and the flow in this case is an external one. If I(2) = 1 then the flow is an internal one and <u>input</u> starting U, τ profiles are assumed to have have been supplied.

The final section of PRLAST is used to transfer several variables to disc (on unit TAPE14) for use in the other programs in the viscous/inviscid calculation sequence. For a full description of the operation of the interaction procedure the reader is referred to Chapter 4. Finally, the distributions of V_e/U_e, $\frac{p_w - p_{ref}}{\rho U_{ref}^2}$ and $\frac{p_w - p_e}{\rho U_{ref}^2}$ are printed out for each station.

(n) <u>Function F</u>

This is an analytic function which is used in the logarithmic law for the case of transpiration. It is called in subroutine WALLBC, the wall boundary condition subroutine where the logarithmic law is applied in the inner layer of the turbulent shear layer.

(o) Function GRAD

This is used to obtain the gradient of a specified variable list FR(J) which is defined at equal intervals of its argument J.

(p) Function ORDIN

This function is used in the interpolation of a function FA defined at equal intervals. If DX (the function interval) is greater than zero in the call of ORDIN a linear interpolation is performed, while if it is set to less than zero (simply as a flag to ORDIN) the interpolation is quadratic. It is a special case of VALUE (see below).

(q) Function PHI

This is the equivalent of the function F (in section (n) above) except that it applies to the solid wall case.

(r) Subroutine PRINIT

This subroutine is used to fill up a list PR for the pressure using the centrifugal approximation $\frac{\partial p}{\partial n} = \frac{\rho U^2(n)}{(n+R)}$ where U(n) is given in array VEL. It is called in the main routine when the initial guess for the pressure array p(s,n) is made; this subroutine is called at every station to fill up the pressure profiles using this approximation. It is also called in subroutine START when the initial pressure profile (at the first station) is calculated using the centrifugal approximation. The subroutine fills PR starting at the given external pressure p_e (PRE) down to the pressure at the first mesh point PR(1). The corresponding value of the wall pressure (PRW) is then also approximately calculated by assuming that $\frac{\Delta n}{R} << 1$. For a detailed derivation see Appendix A3.

(s) Function SIMPSN

This is used to integrate a given function FR with equal intervals, using Simpson's rule.

(t) Function SPLINE

This subroutine is used for cubic spline interpolation of given function values. The function values are stored in arrays X (the coordinates) and Y (the ordinates). SPLINE calls the NAG library routine EØ1ADF (see References) which fits a cubic spline through the given function values. The X values of the function are called "knots" and the cubic spline fitted has continuous first and second derivative at these knots. The coordinate at which the spline is interpolated is given by XINT; the corresponding interpolated ordinate (on the spline) is returned as VAL. M is the total number of function values supplied. M-2 is sometimes referred to as the number of "interior knots" of the spline since it excludes the first and last function values. W and D are two working arrays required when calling EØ1ADF and should each have dimensions of M at least.

(u) Function VALUE

This is used in the interpolation of a function given at unequal intervals. If IOPT=1, a linear interpolation is performed, while if IOPT=2 a quadratic interpolation is performed using Lagrange's interpolation formula (see Hamming (1962) and Hayes (1970)). (See §A3.9).

(v) Block Data Subprogram

This contains tables of values of the empirical functions $\frac{G(n/\delta)}{(\tau_m/\rho U_e^{\,2})^{\frac{1}{2}}}$ (stored in GA), $\delta_{05}\,\frac{\partial}{\partial n}\{\frac{G(n/\delta)}{(\tau_m/\rho U_e^{\,2})^{\frac{1}{2}}}\}$ (stored in DGA) and the length scale $\frac{L(n/\delta)}{\delta_{05}}$ (stored in RLA). These are fixed and are given at intervals of $0.05\delta_{05}$ in the n direction out to $1.45\delta_{05}$.

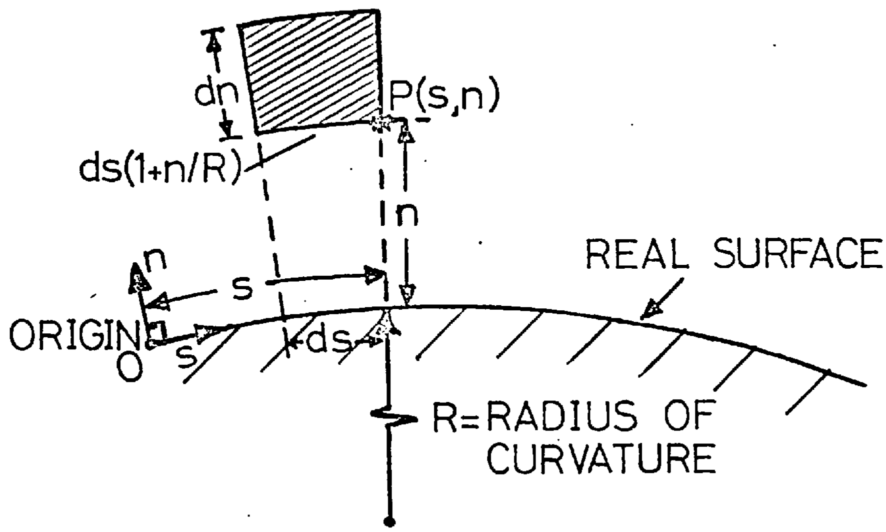


FIG (2)

s-n COORDINATE SYSTEM FOR SHEAR LAYER CALCULATION

"LAST MESH POINT"
(MATCHING SURFACE, MS)

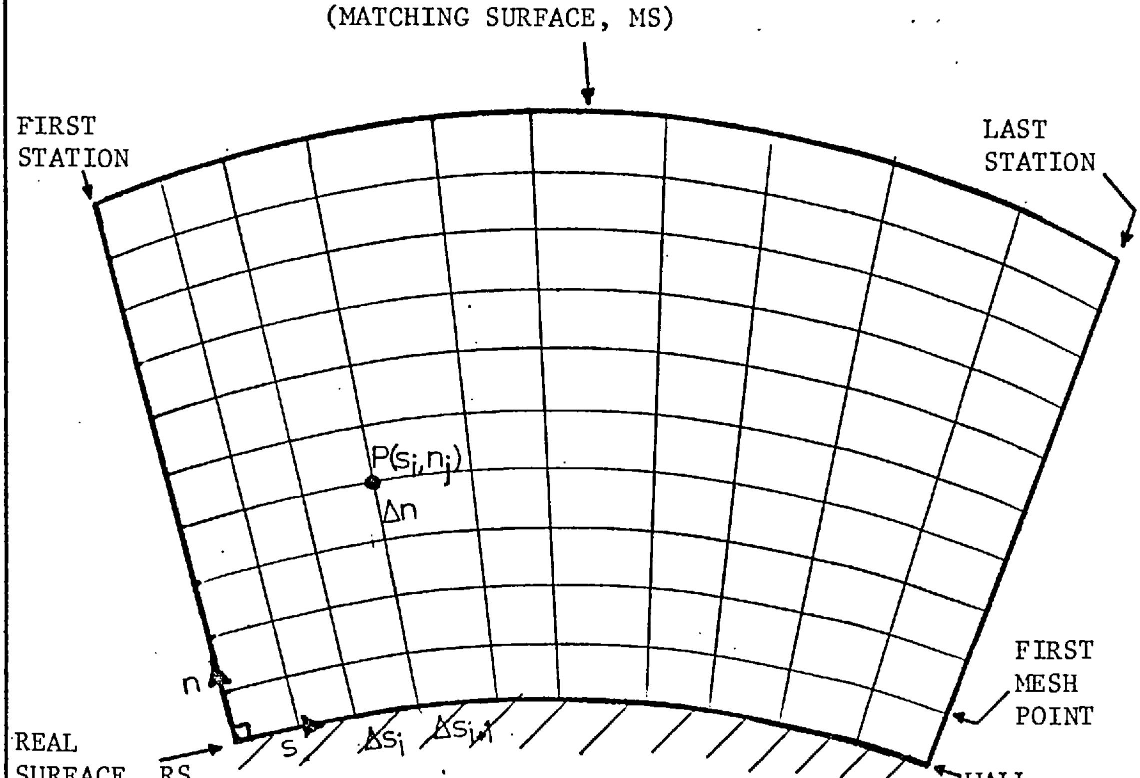


FIG (3)

CALCULATION GRID USING s-n COORDINATE SYSTEM

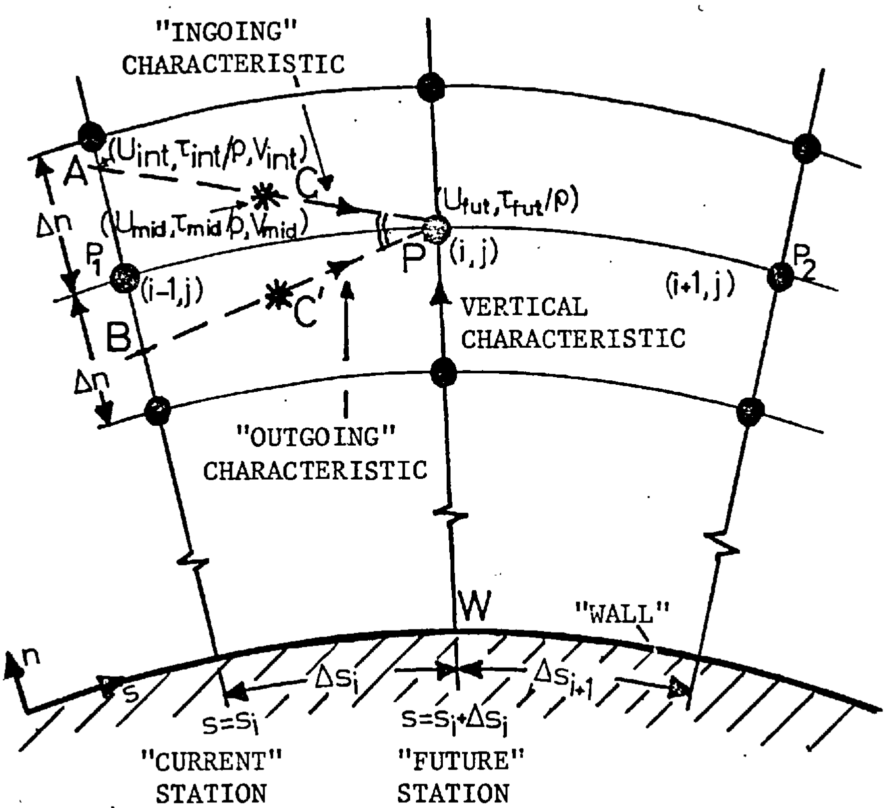


FIG (4)

U,τ CHARACTERISTICS
CALCULATION

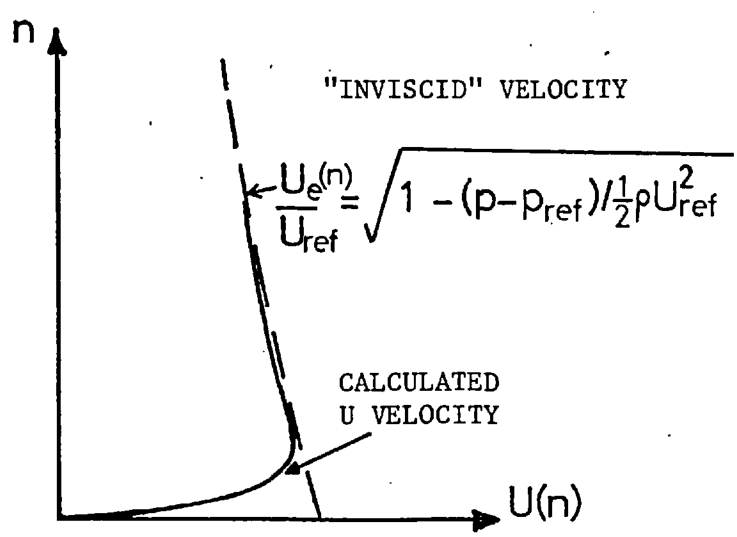


FIG (5)

U VELOCITY EDGE CLIP
CONDITION

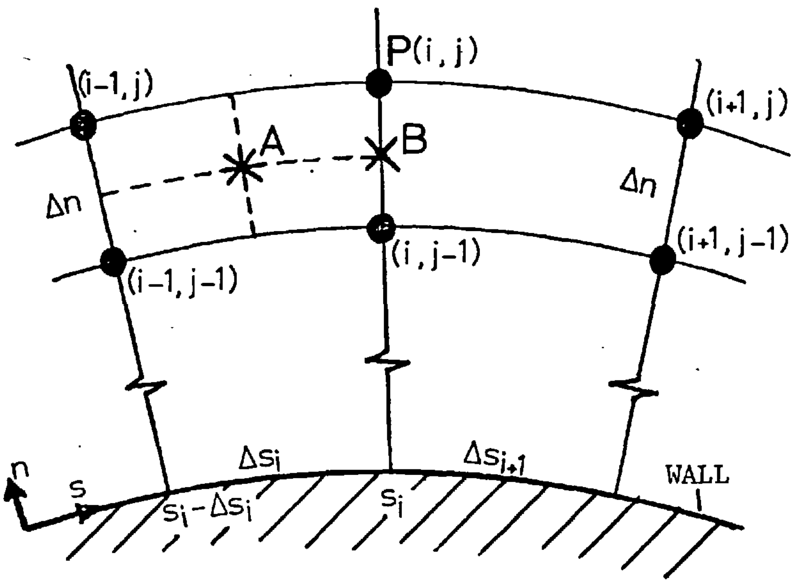


FIG (6)

FINITE DIFFERENCE SCHEME
FOR QUANTITIES IN THE V, p
CALCULATION

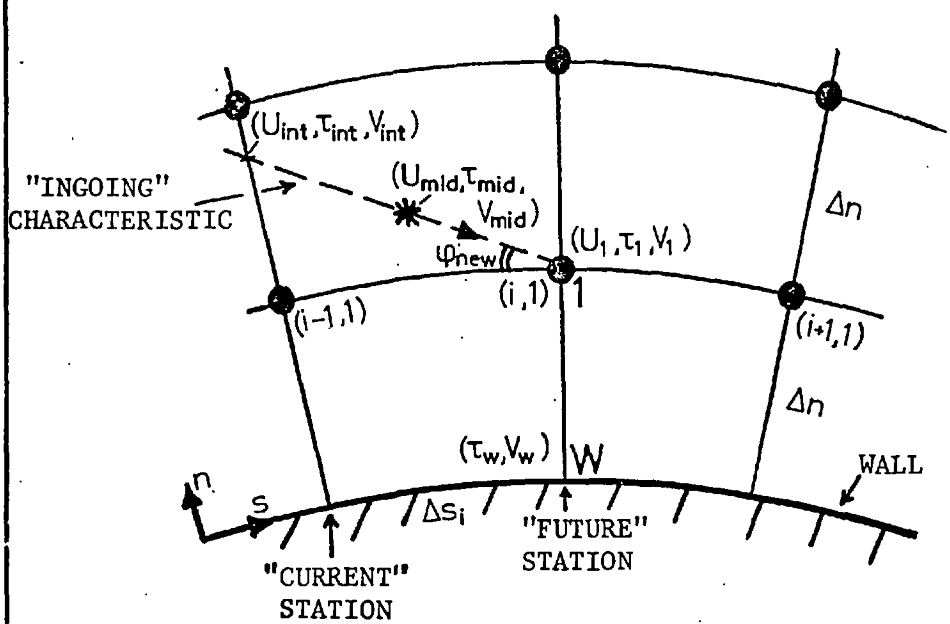


FIG (7)

SCHEME FOR WALL BOUNDARY
CONDITION CALCULATION

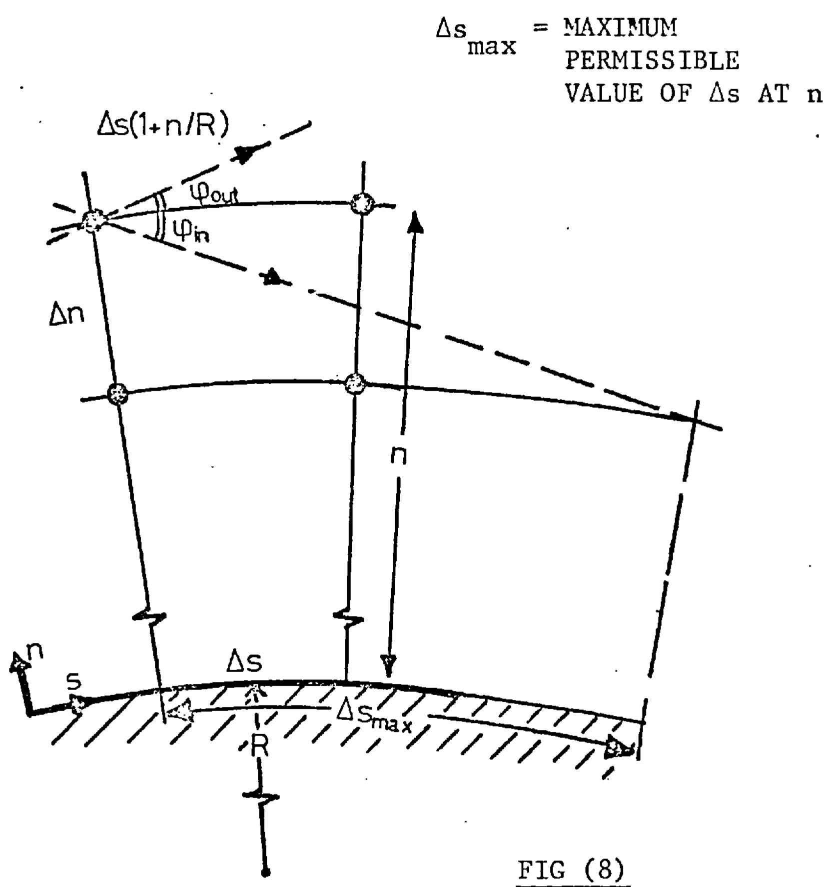


FIG (8)

THE COURANT-FRIEDRICHS-LEWY CRITERION IN s-n COORDINATES

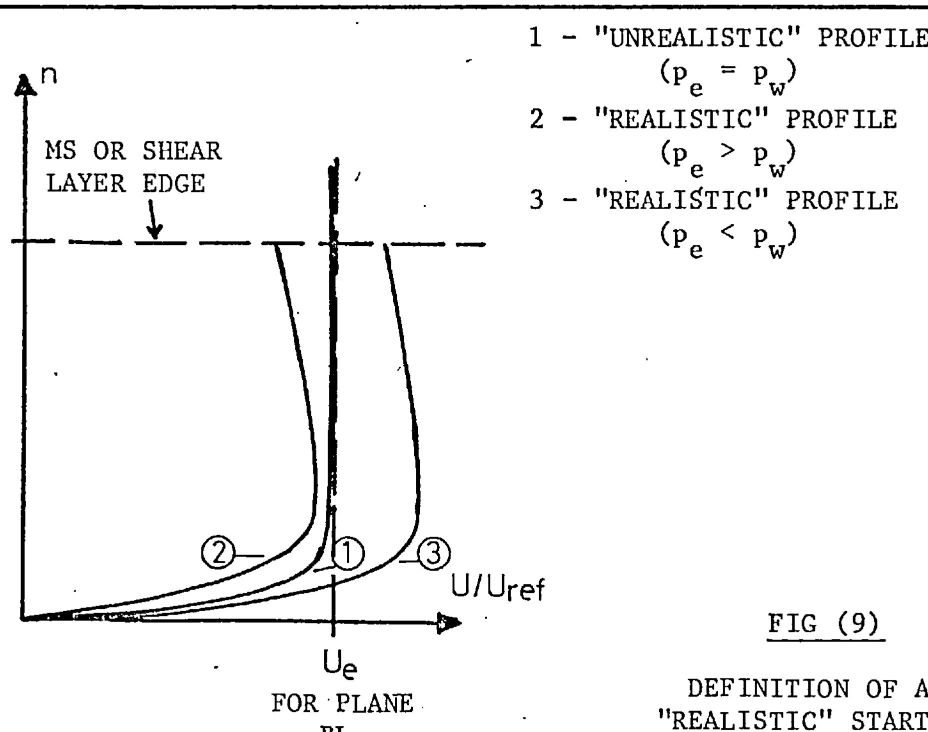


FIG (9)

DEFINITION OF A "REALISTIC" STARTING VELOCITY PROFILE

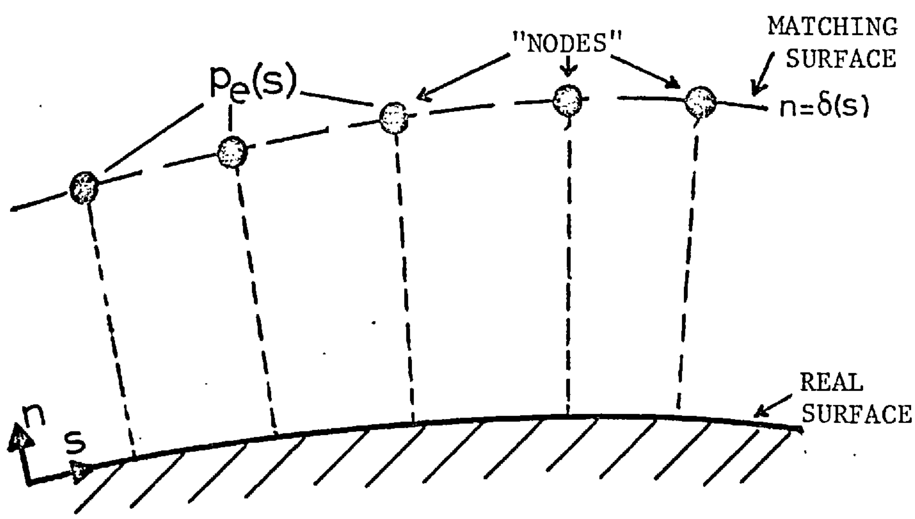


FIG (10)

THE MATCHING PROCESS FOR THE SHEAR LAYER CALCULATION

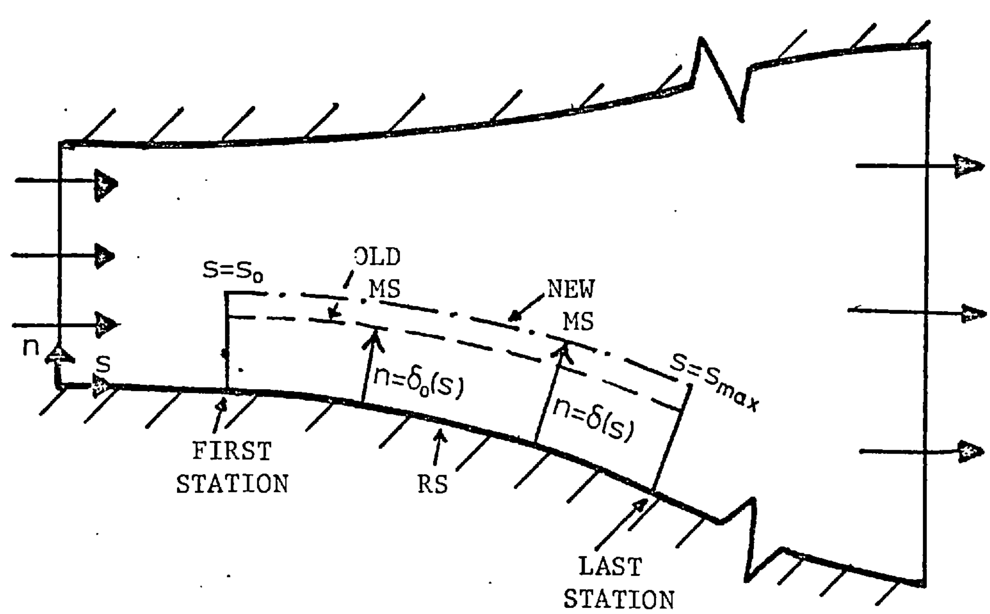


FIG (11)

INTERACTION SCHEME FOR INTERNAL FLOW

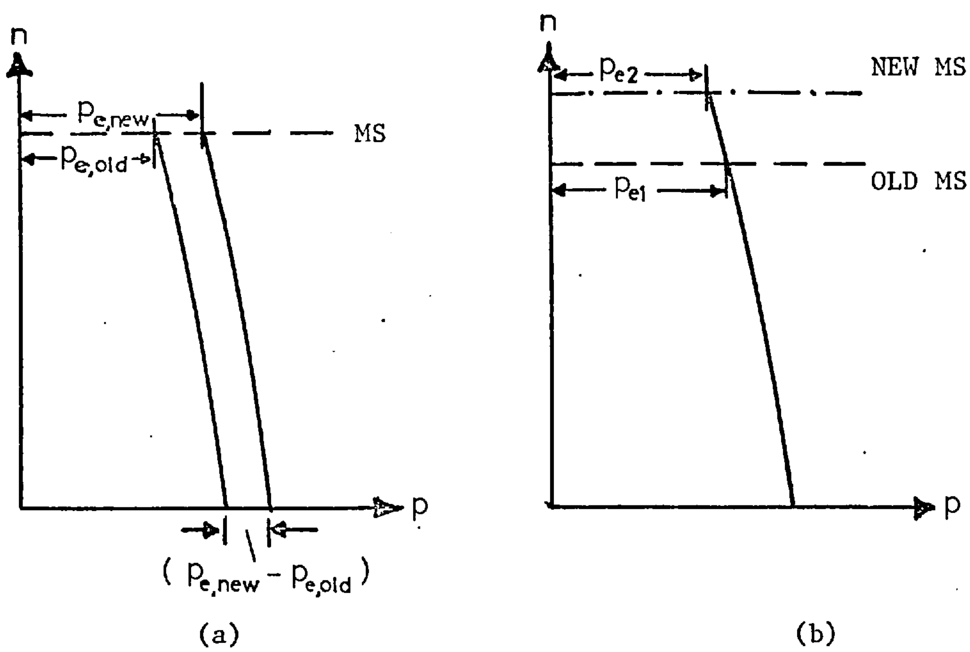
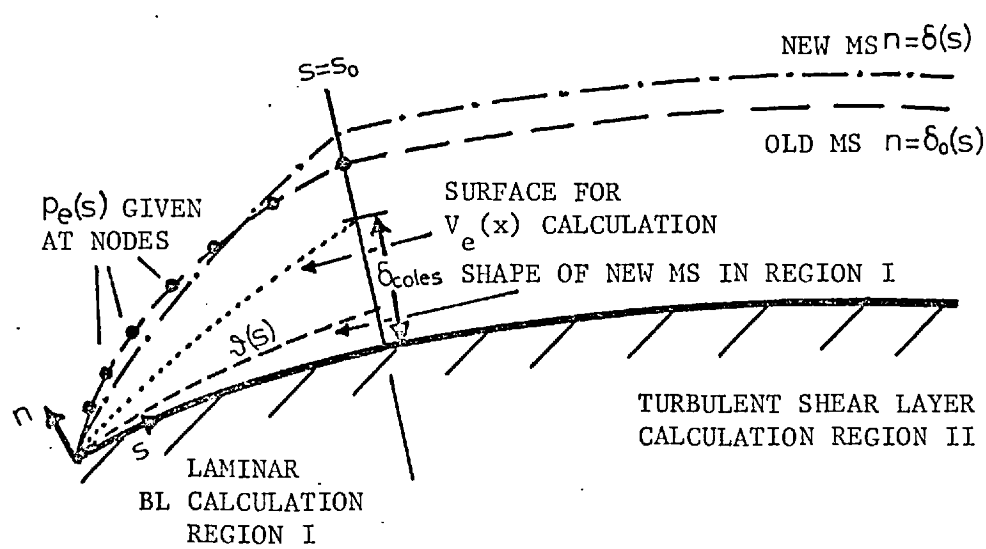


FIG (12)

PRESSURE PROFILE SHIFTING

FIG (13)

INTERACTION SCHEME
FOR EXTERNAL FLOW .



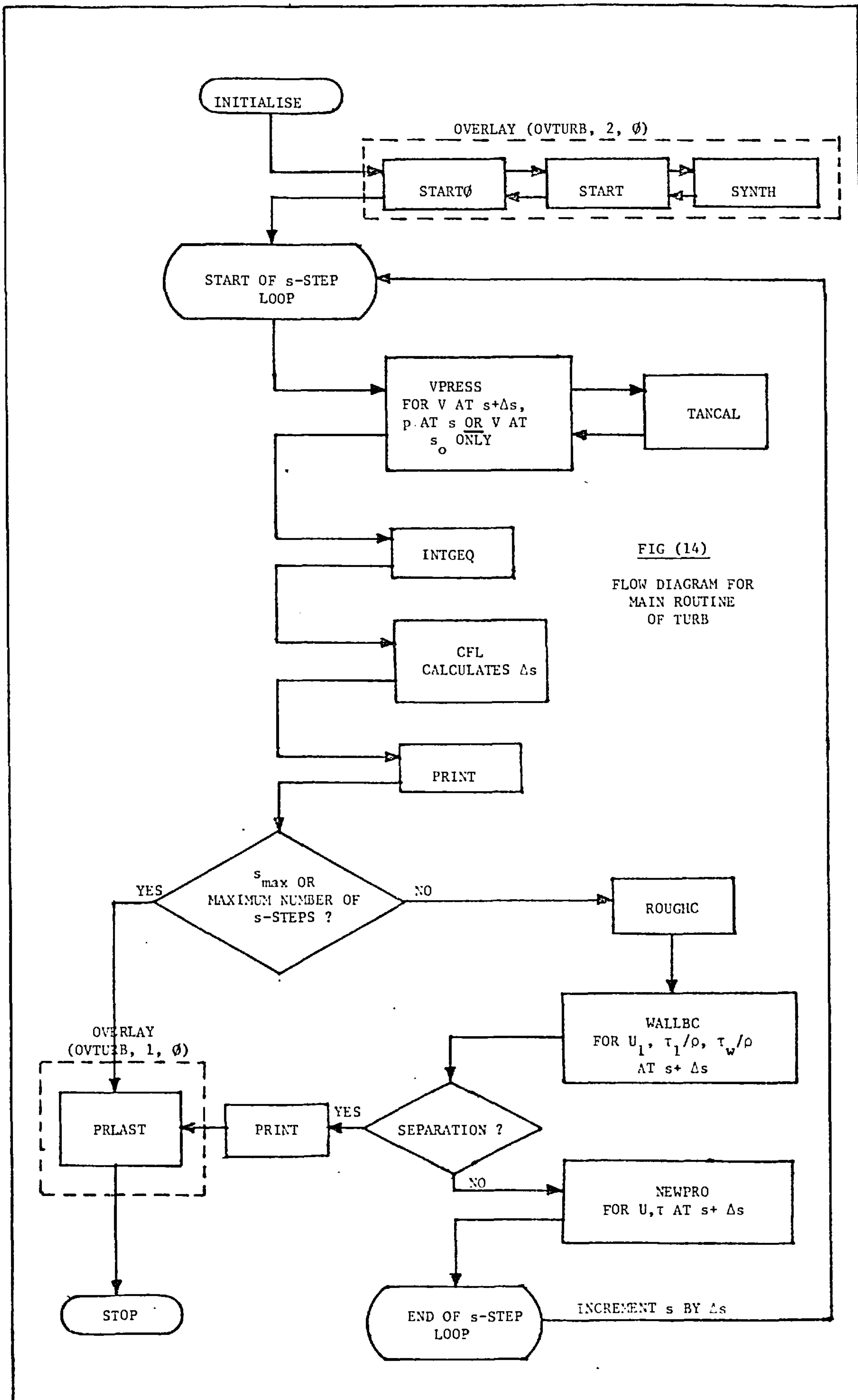


FIG (14)

FLOW DIAGRAM FOR MAIN ROUTINE OF TURB

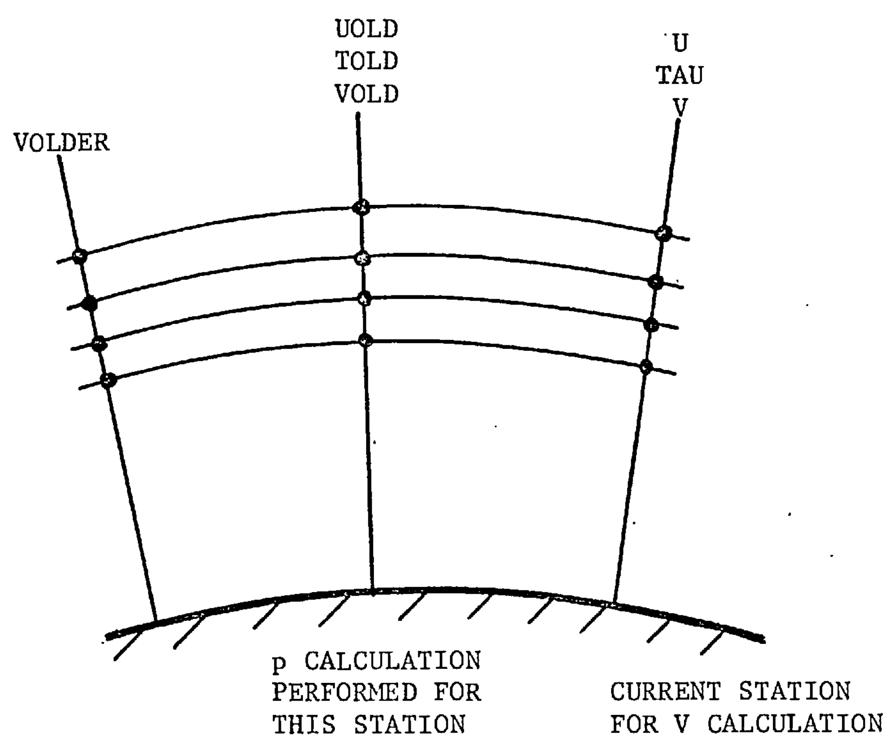


FIG (15)

ARRAY STORAGE FOR V,p CALCULATION

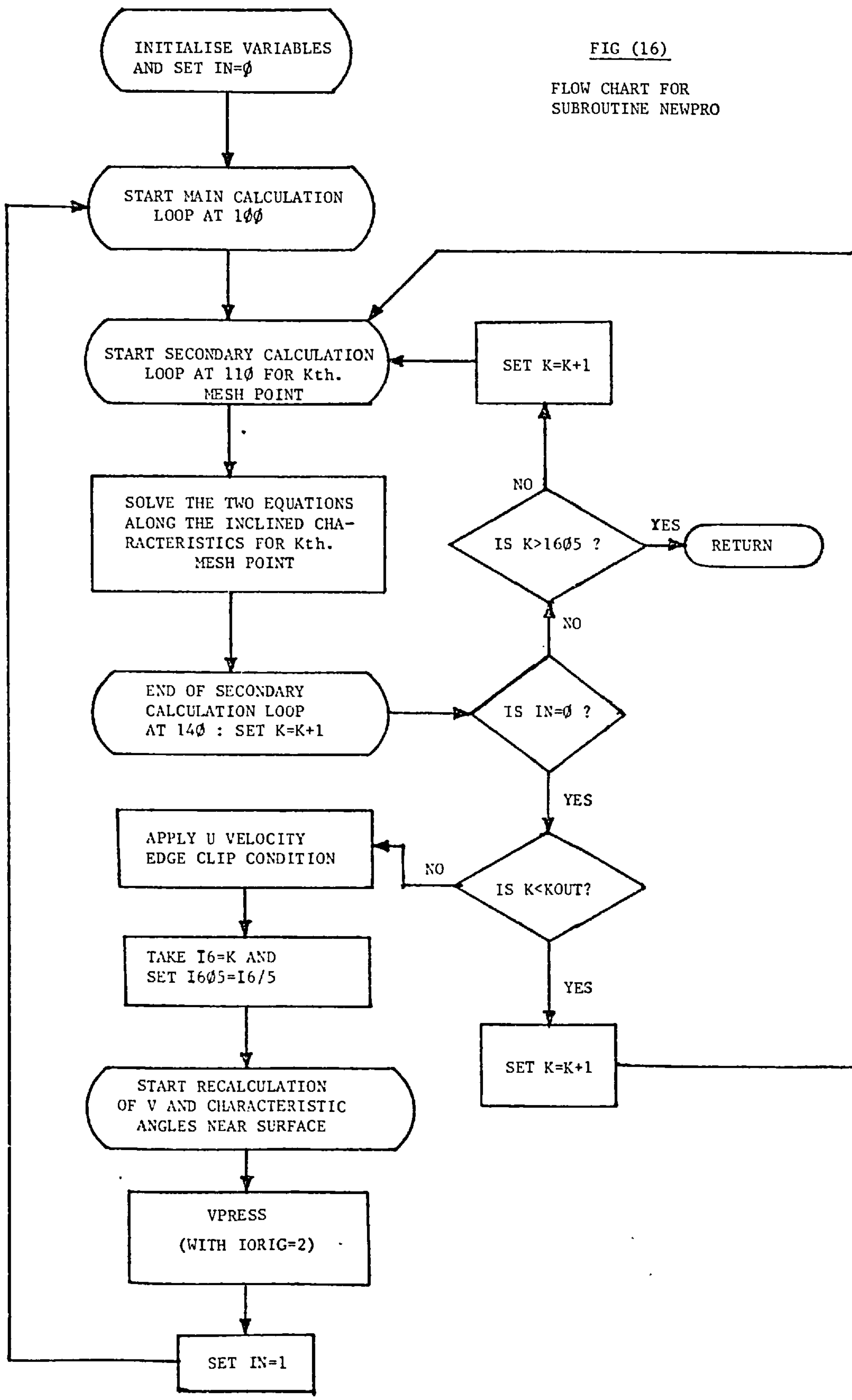


FIG (16)

FLOW CHART FOR SUBROUTINE NEWPRO

FIG (17)

FLOW CHART FOR SUBROUTINE VPRESS

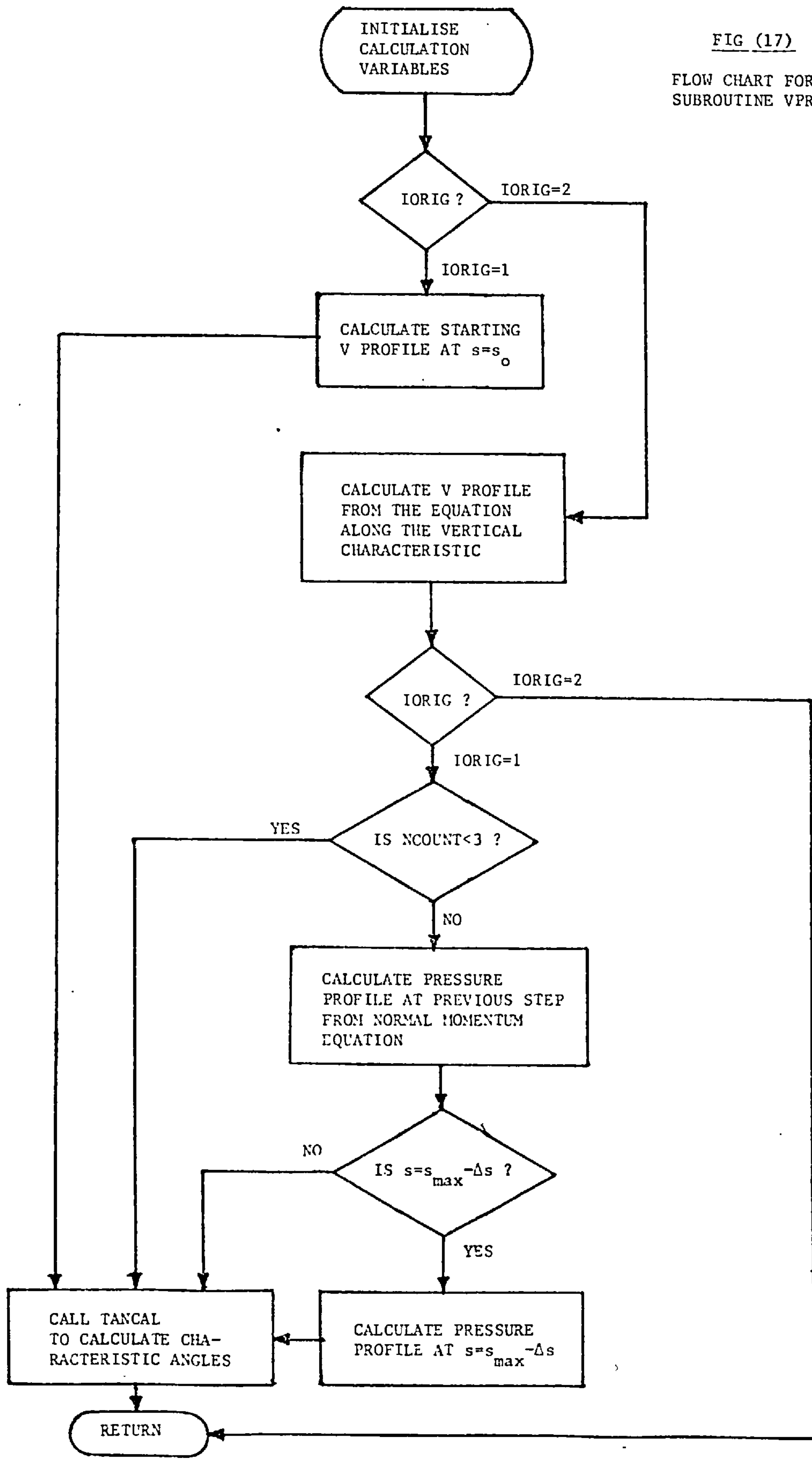
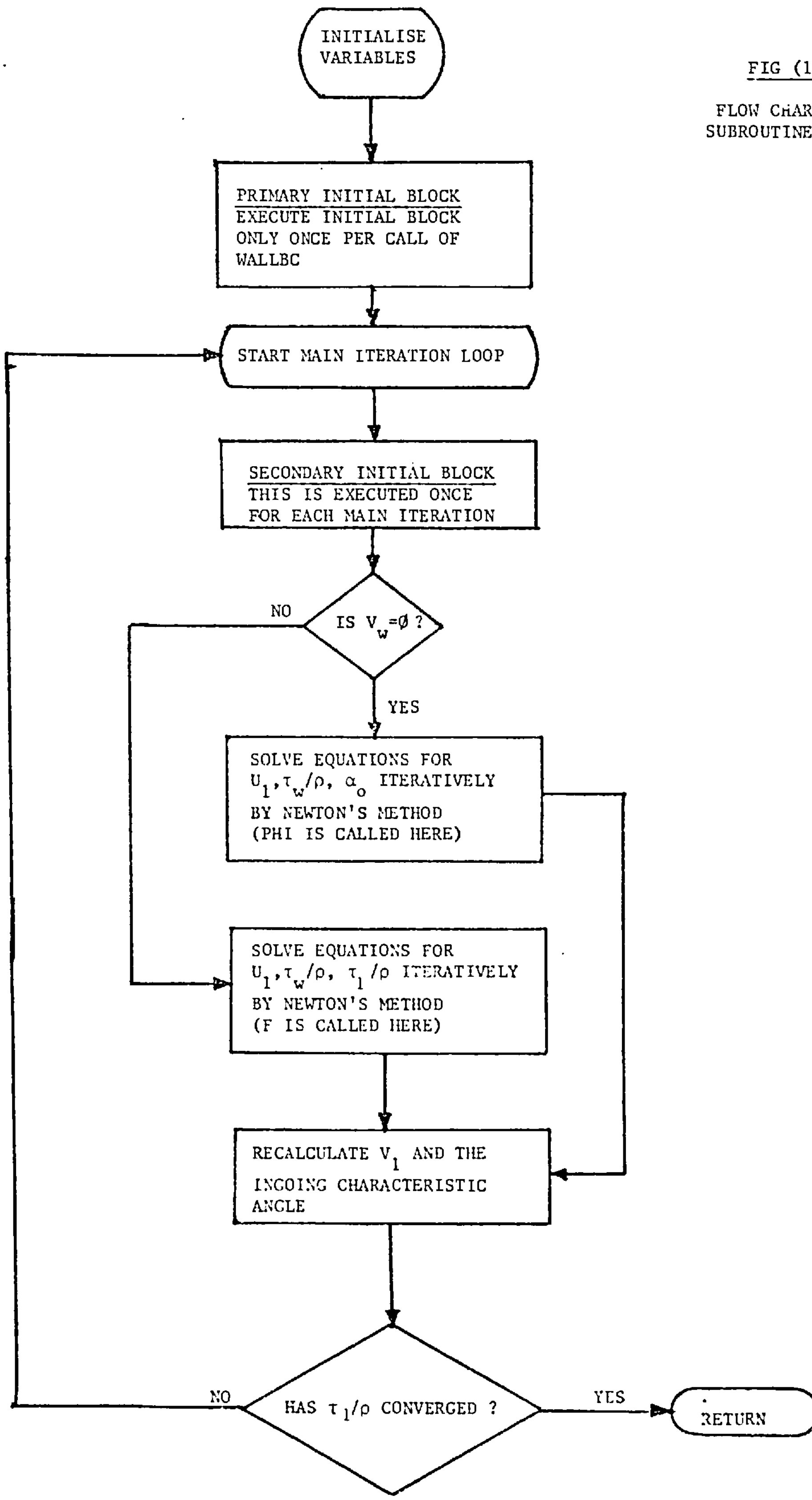


FIG (18)

FLOW CHART FOR SUBROUTINE WALLBC



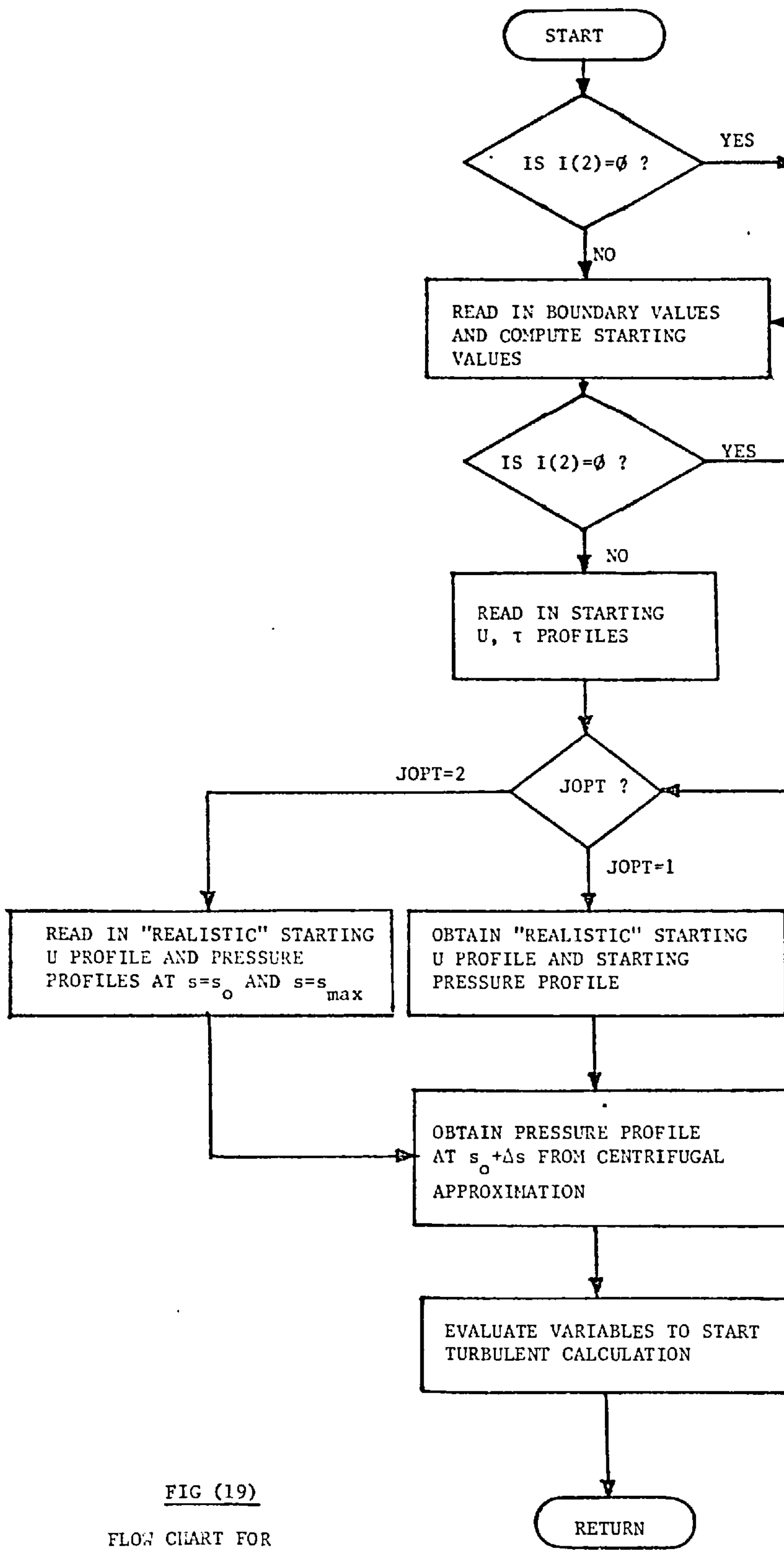


FIG (19)

FLOW CHART FOR SUBROUTINE START

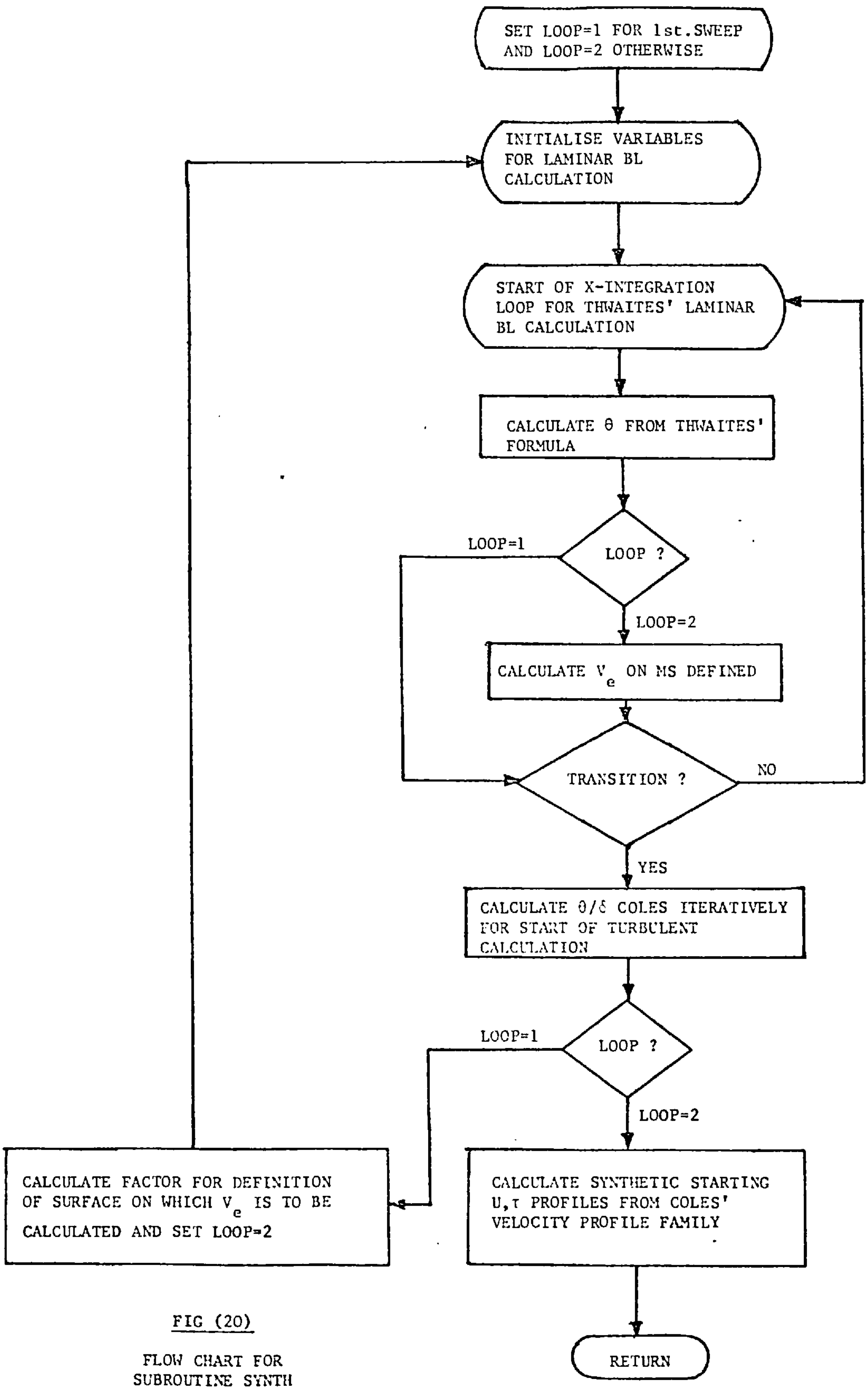


FIG (20)

FLOW CHART FOR SUBROUTINE SYNTH

CHAPTER 3

THE POTENTIAL FLOW CALCULATION

3.1 DESCRIPTION AND NUMERICAL PROCEDURE FOR THE POTENTIAL FLOW CALCULATION

The potential flow calculation method used to compute the external inviscid flow over the matching surface, for the incompressible case, is the surface source singularity method due to Hess and Smith (1967) and will be described first for external flow round an isolated body, ignoring any boundary layers. The flow around the body is approximated by an initially unknown distribution of sources (or vortices) on the MS. The solution for the velocity and pressure on the body surface is obtained by imposing the appropriate boundary condition normal to the body surface; the condition $V_p = \upsilon_p$ is specified, where V_p is the nett calculated velocity normal to the body surface at any point P and υ_p is the required normal velocity (both positive in the outward normal direction, say) (see Fig. (21a)). For a solid body $\upsilon_p = 0$: here the body is replaced by the MS, so $\upsilon_p \neq 0$ usually. The imposition of this boundary condition leads to an integral equation for the unknown source density distribution m(s') (the source strength per unit length) which is then solved in finite difference form. Having obtained this distribution we can then easily obtain the tangential velocity distribution q(s') on the MS and hence the pressure distribution p(s')from Bernoulli's equation (see Fig. (21)).

The basic Smith-Hess method will now be described, followed by a discussion of improvements made by the present author.

(a) The Normal Velocity Boundary Condition

In the present method we approximate the surface singularity distribution on the MS by a distribution of sources composed of straight line segments, where the source density of each segment is constant. Thus, the MS is divided into a series of straight line segments (source "elements") meeting at "nodes" (see Fig. (21b)). Corresponding to the MS nodes, the body surface (or real surface, denoted by RS) also has nodes; for details of the relation between the RS and MS nodes, the reader is referred to §4.1(a).

Firstly, we need to examine the effect of one MS element on another one in order to obtain the effect of all the elements on one particular element. The velocity induced by a single point source of strength M at a point P is given by $v_r = \frac{M}{2\pi r}$, in the radial direction (see Fig. (22)), where r is the radial distance from the source to the point P. Now, since our source elements consist of straight line segments, we must calculate the velocity field induced by a single straight line source element AB of constant source density m_n at a point P (see Fig. (23)); $(\overline{x},\overline{y})$ are the distances of P from the mid point of the element AB and in the directions parallel and perpendicular to AB, respectively. Let ξ denote the coordinate of a small element $d\xi$ on AB. The effect of the velocity induced by the small element $d\xi$ (which can be taken as a point source) at P must be integrated over AB in order to obtain the velocity field induced by the whole of element AB at P. The derivation of the expressions for the velocities (V_{1n}, V_{2n}) induced at P by the element AB, is given in Appendix A4, and we obtain

$$V_{1n} = \frac{m_n}{4\pi} \log\{\frac{(\bar{x} + \frac{1}{2}\Delta s_n)^2 + \bar{y}^2}{(\bar{x} - \frac{1}{2}\Delta s_n)^2 + \bar{y}^2}\} \qquad (3.1.1)$$

$$V_{2n} = \frac{m_n}{2\pi} \tan^{-1}\{\frac{\bar{y}\ \Delta s_n}{\bar{x}^2 + \bar{y}^2 - \frac{1}{4}(\Delta s_n)^2}\} \qquad (3.1.2)$$

where V_{1n} is in the direction of AB and V_{2n} is normal to it.

Having obtained the velocity field induced by a source element at a point, we will look at the more general problem of the MS around an aerofoil (see Fig. (21b)), which is divided into several such elements; consider the velocity field induced by the nth. element on the pth. element (see Fig. (24)): by the above analysis, the velocities induced by the nth. element on the pth. element are given by equations (3.1.1) and (3.1.2) above, where, again V_{1n} is in the direction of AB and V_{2n} is perpendicular to it. Note that we have aligned X and Y axes for the aerofoil in Fig. (24), such that the X-axis is defined by the line passing through the leading and trailing edges. The arc length around the MS is measured from the leading edge and is taken to be positive in the clockwise direction around the MS. The undisturbed stream velocity is U_∞ at an angle α' to the X-axis.

We now apply the normal velocity boundary condition $V_p = \upsilon_p$ at the mid point of the pth. element. Therefore, we have to consider <u>all</u> the contributions to the velocity normal to that element (see Fig. (25)):

(i) The normal component of velocity induced by all the other elements on the pth. element. Now, the normal velocity induced by the nth. element (in the outward normal direction shown in Fig. (25)) is given by

$$v'_{np} = V_{2n} \cos \sigma_{np} - V_{1n} \sin \sigma_{np} \tag{3.1.3}$$

where σ_{np} is the angle between the pth. and nth. elements. Therefore, the total normal velocity component induced by all the elements on the MS will just be a summation over all elements and can be written as:

$$v'_p = \sum_{n=1}^{N} (V_{2n} \cos \sigma_{np} - V_{1n} \sin \sigma_{np}) = \sum_{n=1}^{N} v'_{np} \tag{3.1.4}$$

(ii) The normal velocity component induced by the pth. element on itself; now, if we consider the values of V_m and V_{2n} in the limit as $(\overline{x},\overline{y}) \to (0,0)$ we find that $V_{1n} \to \frac{m_p}{4\pi} \log 1 = 0$ and $V_{2n} \to \frac{m_p}{2\pi} \tan^{-1} 0 = \pm \frac{m_p}{2}$. This velocity is $+\frac{m_p}{2}$ in the <u>outward normal</u> direction.

(iii) The component of the undisturbed velocity in the direction normal to the pth. element. If θ_p is the inclination of the pth. element to the X axis (see Fig. (25)) then this component is just $-U_\infty \sin (\theta_p - \alpha')$ in the outward normal direction.

Thus, the nett velocity normal to the pth. element (and in the outward normal direction) becomes:

$$V_p = \tfrac{1}{2}m_p + \sum_{\substack{n=1 \\ (n \neq p)}}^{N} (V_{2n} \cos \sigma_{np} - V_{1n} \sin \sigma_{np}) - U_\infty \sin (\theta_p - \alpha') \tag{3.1.5}$$

By substitution of the expressions for V_{1n}, V_{2n} from (3.1.1) and (3.1.2), this can be written as:

$$V_p = \sum_{n=1}^{N} (\tfrac{1}{2}\delta_{pn} + A'_{pn}) m_n - b_p \tag{3.1.6}$$

where δ_{pn} is the Kroenecker delta ($\delta_{pn} = 1$ for $p = n$, $\delta_{pn} = 0$ for $p \neq n$) and where $A'_{pp} = 0$ for all p. This equation can further be written in matrix/tensor notation as

$$V_p = A_{pn} m_n - b_p \tag{3.1.7}$$

where the tensor summation convention is applied.
Here we note that A_{pn} will be a two dimensional array or matrix of coefficients which will only depend on the geometry and not on α' or υ_p (as it only consists of distances and angles for the various elements). Moreover, the term $A_{pn} m_n$ represents the total normal velocity induced by all the elements on the pth. element (summing over n), including the normal velocity induced on the pth. element by itself. Thus, putting $m_n = 1$, we see that A_{pn} along represents the normal velocity induced by a unit source density (placed at the position of the nth. element) on the pth. element.

Now in order to solve for the values of source density m_n in equation (3.1.7) we need to apply the normal velocity boundary condition; if we are given that the velocity in the outward normal direction is υ_p at the mid point of the pth. element, we can write

$$A_{pn} m_n - b_p = \upsilon_p$$

or

$$\underline{A_{pn} m_n = b_p + \upsilon_p} \tag{3.1.8}$$

Hence, equation (3.1.8) can be solved for the m_n's by inversion of the matrix of coefficients A_{pn} (also called the "influence coefficient matrix") to obtain

$$m_n = A^{-1}_{pn} (b_p + \upsilon_p) \tag{3.1.9}$$

where A^{-1}_{pn} is the inverse of matrix A_{pn}.

(b) <u>Calculation of the Pressure Coefficient for the Non-Lifting Aerofoil Case</u>

If we refer to Fig. (25), we can see that the total tangential velocity induced at the centre of the pth. element is due to the following contributions:

(i) The tangential velocity induced by all the elements on the pth. element. From Fig. (25) we can see that the tangential velocity induced by the nth. element on the pth. element is

$$q'_{np} = (V_{1n} \cos \sigma_{np} + V_{2n} \sin \sigma_{np}) \qquad (3.1.10)$$

Therefore, the tangential velocity induced by all the elements at the mid point of the pth. element is

$$q'_{p} = \sum_{n=1}^{N} (V_{1n} \cos \sigma_{np} + V_{2n} \sin \sigma_{np}) \qquad (3.1.11)$$

We note here that the tangential component of velocity induced by the pth. element on itself (at its mid point) is zero, the source density being uniform over the element.

(ii) The tangential component of the undisturbed stream velocity: this is just $U_\infty \cos (\theta_p - \alpha')$ in the positive s'-direction.

Thus, the total <u>tangential</u> velocity component induced at the mid point of the pth. element is

$$q_{p} = \sum_{n=1}^{N} (V_{1n} \cos \sigma_{np} + V_{2n} \sin \sigma_{np}) + U_\infty \cos (\theta_p - \alpha') \qquad (3.1.12)$$

As before, this can be written in matrix/tensor notation as

$$q_p = B_{pn} m_n + f_p \qquad (3.1.13)$$

where the coefficient B_{pn}, here, is in effect the tangential velocity induced on the pth. element by a source element of unit source density placed at the position of the nth. element.

Thus, having solved for the m_n's from equation (3.1.9) we substitute for m_n in equation (3.1.13) to give

$$q_p = B_{pn} A^{-1}_{pn} (b_p + \upsilon_p) + f_p \tag{3.1.14}$$

To obtain the pressure coefficient c_p(at the mid point of the pth. element, we use Bernoulli's equation, so that

$$c_p = 1 - (\frac{q_p^{\ 2} + \upsilon_p^{\ 2}}{U_\infty^{\ 2}}) \tag{3.1.15}$$

where q_p is obtained from (3.1.14) and υ_p is the normal velocity specified. Usually $\upsilon_p < 0.1\ q_p$ so the error in c_p is only 1%. However, here we have taken it into account, for safety.

(c) <u>The Kutta-Zhukovskii Condition and the Lifting Aerofoil Case</u>

The preceding sections have described the application of the normal velocity boundary condition and the calculation of the pressure distribution around the MS for a non-lifting aerofoil. For a lifting aerofoil, the solution procedure is divided into two steps:

(i) Firstly, we calculate the tangential surface velocity distribution $q^{(1)}(s')$ on the MS for a stream velocity $U_\infty = 1$ at an angle of incidence α (see Fig. (26a)). This will, in general, result in a finite difference in tangential velocity (on the MS) at the trailing edge, between the upper and lower surfaces of the aerofoil; let this difference be $\Delta q^{(1)}$. In order to satisfy the condition at the TE (of zero tangential velocity difference), we need to apply a certain amount of circulation.

(ii) We then find the tangential surface velocity distribution $q^{(2)}(s')$ on the MS for a constant unit vorticity distribution ($\gamma_n = 1$ for nth. element) on each element around the MS (see Fig. 26b)). In general, this too will result in a finite tangential velocity difference at the TE equal to $\Delta q^{(2)}$, say. In this case, the total circulation around the aerofoil is given by $\oint \gamma ds = \sum_{n=1}^{N} \gamma_n \Delta s_n = \sum_{n=1}^{N} \Delta s_n$ (since $\gamma_n = 1$ everywhere). This is just the total arc length S, say, around the MS.

Thus, from sections (i) and (ii) above we see that, since the equations governing the calculation of the tangential velocity are linear, we can superimpose solutions and hence for the general case of undisturbed stream velocity U_∞ and circulation Γ we have

$$q(s') = U_\infty q^{(1)}(s') + \frac{\Gamma}{S} q^{(2)}(s') \qquad (3.1.16)$$

where $q(s')$ is now the total tangential velocity distribution. Now, in order to find the value of the circulation Γ we apply the K-Z condition; the total tangential velocity difference Δq is given from (i) and (ii) and is set equal to zero. Thus we have

$$\Delta q = U_\infty \Delta q^{(1)} + \frac{\Gamma}{S} \Delta q^{(2)} = 0 \qquad (3.1.17)$$

and this equation determines the amount of circulation Γ needed to satisfy the K-Z at the TE. We can then substitute for Γ in (3.1.16) to obtain the total tangential velocity $q(s')$.

We shall now show how the calculation of the tangential velocity distribution $q^{(2)}(s')$ is performed (the calculation for $q^{(1)}(s')$ being given in sections (a) and (b) above):

Fig. (27) shows the velocity v_t induced by a single line vortex of strength (circulation) Γ at the point P, where $v_t = \frac{\Gamma'}{2\pi r}$, and r is the radial distance from the vortex to the point P. If we compare this with the velocity induced by the point source (Fig. (22)) we see that the expressions are the same (with γ replacing M) and that the direction of velocity in the case of the vortex is rotated 90^o in the clockwise sense relative to that in the case of the source. Therefore, the expressions for the induced velocities V_{1n} and V_{2n} at the mid point of the pth. element, due to a vortex strength γ_n at the mid point of the nth. element (see Fig. (28)) are the same as those given by equations (3.1.1) and (3.1.2) except that m_n is replaced by γ_n and that the directions of these velocities are rotated clockwise through 90^o.

From Fig. (28) we can see that the total normal component of velocity induced on the pth. element due to the vorticity distribution is given by $-\sum_{n=1}^{N}(V_{1n} \cos \sigma_{np} + V_{2n} \sin \sigma_{np})$ in the outward normal direction. This is just $-B_{pn}\gamma_n$ where B_{pn} is defined by equation (3.1.13) and where all the γ_n's are equal to unity. Now, since we have already satisfied the normal velocity boundary condition in the first step of the solution, in the present step the normal velocity will be zero everywhere. Therefore, in order to achieve this, we need to counteract the normal velocity $-B_{pn}\gamma_n$ induced by the vortices; for that we need a source density (m_n' say at the nth. element). Now, by the analysis of the previous sections, we have seen that the normal velocity induced by this source density distribution is just $A_{pn}\, m_n'$ (where A_{pn} is defined by equation (3.1.7). Thus, for zero nett normal velocity at the mid point of the pth. element we must have

$$A_{pn}\, m_n' - B_{pn}\, \gamma_n = 0 \tag{3.1.18}$$

or

$$m_n' = A^{-1}_{pn}\, B_{pn}\, \gamma_n \tag{3.1.19}$$

If we also consider the total <u>tangential</u> component of velocity induced at the mid point of the pth. element due to the vorticity distribution γ_n (see Fig. (28)) we see that this is $\sum_{n=1}^{N} (V_{2n} \cos \sigma_{np} - V_{1n} \sin \sigma_{np})$, which is just $A_{pn}\, \gamma_n$. The tangential velocity due to the source distribution m_n' is (as before) just $B_{pn}\, m_n'$, so that the total tangential velocity at the pth. element for the case where we just have a vorticity distribution $\gamma_n = 1$ on all the elements is given by

$$q_p^{(2)} = B_{pn}\, m_n' + A_{pn}\, \gamma_n \tag{3.1.20}$$

Substituting for m_n' from (3.1.19) yields

$$q_p^{(2)} = A_{pn}\, \gamma_n + B_{pn}\, A^{-1}_{pn}\, [B_{pn}\, \gamma_n] \tag{3.1.21}$$

where, since all the γ_n's are equal to unity,

$$A_{pn}\, \gamma_n \equiv \sum_{n=1}^{N} A_{pn} \tag{3.1.22}$$

and

$$B_{pn}\, \gamma_n \equiv \sum_{n=1}^{N} B_{pn} \tag{3.1.23}$$

The solution for the tangential velocity component for the case in which $U_\infty = 1$ is given by equation (3.1.14) as

$$q_p^{(1)} = B_{pn}\, A^{-1}_{pn}\, (b_p^* + \upsilon_p^*) + f_p^* \tag{3.1.24}$$

where b_p^* and f_p^* are b_p and f_p as defined by equations (3.1.6) and (3.1.13) respectively, but with $U_\infty = 1$. Also υ_p^* is just

υ_p/U_∞. Hence, the complete solution for the tangential velocity at the mid point of the pth. element is given by

$$q_p = U_\infty\, q_p^{(1)} + \frac{\Gamma}{S}\, q_p^{(2)} \qquad (3.1.25)$$

so that

$$q_p = U_\infty\left[B_{pn}\, A^{-1}_{pn}(b_p^* + \upsilon_p) + f_p^*\right] + \frac{\Gamma}{S}\left[A_{pn}\,\gamma_n + B_{pn}\, A^{-1}_{pn}\cdot (B_{pn}\,\gamma_n)\right] \qquad (3.1.26)$$

As a check on the calculation, we can compute the total normal velocity component at the mid point of the pth. element: For case (1),

$$V_p^{(1)} = A_{pn}\, m_n - b_p^* = \upsilon_p^* \qquad (3.1.27)$$

For case (2),

$$V_p^{(2)} = A_{pn}\, m_n' - B_{pn}\,\gamma_n$$

(see equation (3.1.18).

Substituting for m_n', from (3.1.19) we obtain

$$V_p^{(2)} = A_{pn}.A^{-1}_{pn}\left[B_{pn}\,\gamma_n\right] - B_{pn}\,\gamma_n = 0 \qquad (3.1.28)$$

So that $\quad V_p = U_\infty\, V_p^{(1)} + \frac{\Gamma}{S}.V_p^{(2)}$

$$= U_\infty\,\upsilon_p^* = \upsilon_p \qquad (3.1.29)$$

which is the normal velocity specified on the pth. element. The value of $\frac{\Gamma}{S}$ obtained from equation (3.1.17) is

$$\frac{\Gamma}{S} = -\,U_\infty\,.\,\frac{\Delta q^{(1)}}{\Delta q^{(2)}} \qquad (3.1.30)$$

and the pressure coefficient c_p is, as before,

$$c_p = 1 - \left(\frac{q_p^{(2)} + \upsilon_p^2}{U_\infty^2}\right) \qquad (3.1.31)$$

(d) The Calculation of Velocities and the Pressure Coefficient at Off-Body Points

The previous sections have been concerned with the calculation of the tangential velocity and pressure coefficient on the MS (at the mid points of the source elements). We will now consider the calculation of the velocities and the pressure coefficient for points off the matching surface. Fig. (29) shows the point P with coordinates (X,Y), at which we wish to calculate the pressure. Consider the velocities induced by the nth. element (source strength m_n) at P. The expressions for the velocities V_{1n}, V_{2n} induced in the direction of AB and perpendicular to it, respectively, are given by equations (3.1.1) and (3.1.2) where

$$\bar{x} = (X-X_n) \cos \theta_n + (Y-Y_n) \sin \theta_n \qquad (3.1.32)$$

and

$$\bar{y} = - (X-X_n) \sin \theta_n + (Y-Y_n) \cos \theta_n \qquad (3.1.33)$$

and where (X_n,Y_n) are the coordinates of the mid point of the nth. element and θ_n its inclination to the X-axis. In order to obtain the complete solution for the lifting aerofoil, we consider the two flow cases of the previous section.

(i) Case 1: Here we have $U_\infty = 1$ at incidence α' but no circulation. The total velocity induced by all the elements, at P (including the component of the undisturbed stream velocity) and in the direction of the X-axis can be written

$$V_x^{(1)} = \sum_{n=1}^{N} (V_{1n} \cos \theta_n - V_{2n} \sin \theta_n) = C_n\, m_n + \cos \alpha' + \cos \alpha' \qquad (3.1.34)$$

where m_n is the solution for the source density of the nth. element, given by equation (3.1.9).

Similarly, for the velocity in the Y-direction, we can write

$$V_y^{(1)} = \sum_{n=1}^{N} (V_{1n} \sin \theta + V_{2n} \cos \theta_n) = D_n\, m_n + \sin \alpha' + \sin \alpha' \qquad (3.1.35a$$

(ii) Case 2: Here we have a line vortex of unit strength at the mid point of each element. As before, and since the direction of the velocity induced at P due to a vortex at the nth. element is at right angles to that induced due to a source we can write the expressions for the velocities induced at P in the X and Y directions as:

$$V_x^{(2)} = C_n\, m_n' + D_n\, \gamma_n \qquad (3.1.35b$$

$$V_y^{(2)} = D_n\, m_n' - C_n\, \gamma_n \qquad (3.1.36)$$

where m_n' is given by equation (3.1.19). Also since $\gamma_n = 1$ everywhere $C_n\, \gamma_n = \sum_{n=1}^{N} C_n$ and $D_n\, \gamma_n = \sum_{n=1}^{N} D_n$.

Hence, the complete solution for the velocities in the directions of the X and Y axes are given (in the same way as before) by:

$$V_x = U_\infty . V_x^{(1)} + \frac{\Gamma}{S} V_y^{(1)} = U_\infty (C_n\, m_n + \cos \alpha') + \frac{\Gamma}{S} (C_n\, m_n' + D_n\, \gamma_n) \qquad (3.1.37)$$

$$V_y = U_\infty . V_x^{(2)} + \frac{\Gamma}{S} V_y^{(2)} = U_\infty (D_n\, m_n + \sin \alpha') + \frac{\Gamma}{S} (D_n\, m_n' - C_n\, \gamma_n) \qquad (3.1.38)$$

The pressure coefficient is again obtained from Bernoulli's equation as

$$c_p = 1 - \left(\frac{V_x^2 + V_y^2}{U_\infty^2}\right) \qquad (3.1.39)$$

(e) Calculation of the Stagnation Point Position

The position of the stagnation point on the MS is found by first searching for the node (k_m say) at which the speed (velocity magnitude) is a minimum (see Fig. (30)). Now, the tangential velocity q (which is a vector) changes sign from the top to the bottom surface of the aerofoil, since on the top surface q is in the positive s'-direction and on the bottom surface it is in the negative s'-direction. Fig. (30) shows a typical plot of velocity q plotted against arc length in the region of minimum surface speed; we wish to obtain the value of s' at the point where the curve intersects the s'-axis, i.e. where q = 0. We find the intersection ($s' = s'_1$) of the straight line drawn through nodes k_m and $k_m + 1$ and also the intersection ($s' = s'_2$) of the straight line drawn through nodes $k_m - 1$ and k_m. An approximate position for the stagnation point is then given by taking the average of the above two positions, i.e. $\frac{1}{2}(s'_1 + s'_2)$.

(f) External and Internal Flow and the Shortcomings of the Method

Problems were encountered when the Hess and Smith method was applied to the calculation of internal flows. Thanks to invaluable advice given by John Hess (one of the originators of the method) we have managed to overcome these problems. There were two main problems:

(i) The first problem was how to distinguish between an external and an internal flow. This is not obvious from the formulation of the method, so a short explanation is given here. Fig. (31) shows part of a surface for which the flow is calculated; the unit vector $\underline{\hat{s}}$ is tangential to the body surface and the unit vector $\underline{\hat{n}}$ is normal to it. The direction of $\underline{\hat{s}}$ is defined by the order in which we input the coordinates of the nodes; it points in the direction from the node which is input first to that which is input second. The direction of $\underline{\hat{n}}$ is always to the left as seen by an observer looking in the direction of $\underline{\hat{s}}$ and it points into the flow field being considered. Thus, in the section of body shown in Fig. (31), if the nodes are input in the order k-2, k-1, k, k+1, k+2 etc. then $\underline{\hat{s}}$ and $\underline{\hat{n}}$ would be in the directions shown and it would be assumed that we are calculating the flow field above the body. If the order of the input points were reversed, $\underline{\hat{s}}$ and $\underline{\hat{n}}$ would be in the opposite directions to those shown and we would, in that case, be calculating the flow field below the body. The positive normal direction would always be in the direction of $\underline{\hat{n}}$. Therefore, when we are specifying the normal velocity υ_p (see equation (3.1.8)) care has to be taken in specifying the sign of υ_p; if υ_p is in the direction of $\underline{\hat{n}}$ it is taken to be positive and if it is in the opposite direction to $\underline{\hat{n}}$, it is taken to be negative, regardless of the direction in which $\underline{\hat{n}}$ points.

(ii) The second problem concerned the inaccuracy of the method near corners. For an analysis of the solution near a corner see Craggs, Mangler and Zamir (1973). This inaccuracy exists for external and internal corners. However for an internal corner the solution is more inaccurate, especially for the 90° corner which is of most interest in solving duct flows. If we consider the flow through the duct of Fig. (32) we will find that application of the Hess and Smith method to the calculation of the flow inside the duct BC leads to gross errors near the corners. The flow near the corner regions is confused and the streamwise velocity profile is not uniform. Moreover, the mass flow rate at station C is not the same as that at station B. There is an apparent "leakage" effect of mass flow through the corner regions. One solution is to extend the duct artificially to stations A and D as shown in Fig. (32). In this case, provided AB and CD are long enough, the mass flow rates at stations B and C will be approximately (but not exactly) the same; in doing this we have removed the effects of the corners from the region of interest BC. The flow in regions AB and CD will be confused and should be ignored. However, the streamwise velocity profiles at B and C will still be non-uniform since, no matter how long the extensions AB and CD are made, the total pressure of the flow emerging from the corner region is non-uniform. In order to overcome this source of error and the mismatch in mass flow rates at stations B and C, we have inserted extra velocities (Δu, Δv) at the mid points of all the corner elements for the corners of the artificial extensions (see Fig. (32)). The condition which has to be satisfied by these extra velocities is that there is no nett accumulation of mass inside the duct. The flow in regions AB and CD is still meaningless, but the mass flow rates at stations B and C can be made equal to within a specified tolerance level and the streamwise velocity profiles at these stations can be made more nearly uniform, so that the errors in the corner regions do not affect the flow in the region of interest BC. Fig. (32a) shows typical uncorrected and corrected velocity profiles across the duct. The above method of correction has been successfully applied to ducts and specifically for the case of the duct flow considered in §5.1. The values of Δu and Δv were found largely by trial and error. We have not yet found a simple "universal" method of finding these velocity increments. However, the magnitudes of Δu and Δv would probably depend on the distance between nodes (in both directions) and the number of nodes across the duct width. Attempts to formulate a simple relationship for Δu and Δv as a function of the ratio of the node spacings in both the axial and transverse directions, have failed. Typical values of Δu and Δv for the duct of §5.1 are shown in Fig. (42).

3.2 DESCRIPTION OF THE COMPUTER PROGRAM FOR THE POTENTIAL FLOW CALCULATION

As stated in Chapter 4, the potential flow calculation is performed for the inviscid region outside* the MS, so that this is the surface on which the velocities and pressures are calculated; the potential flow calculation has no information about the actual body surface (the RS).

In describing the program which performs the potential flow calculation, the reader is referred to the relevant program listing and namelist (see Appendix A5 and A6). We will firstly describe the main routine and then each subroutine in the order in which it is called in the main routine.

The program first obtained by the author was of

* We continue to use this word for convenience, whether the flow is external or internal.

uncertain provenance and inefficient construction; the worst inefficiencies have been removed but the program is still not optimal.

(a) The Main Routine AMOS

Firstly, subroutine COORD is called; it reads in the MS coordinates from disc file (TAPE12). Then, the arc length around the aerofoil is evaluated at the element mid points (all on the MS), assuming straight line source elements. The next section calculates the influence coefficient matrices A_{pn} and B_{pn} (defined by equations (3.1.7) and (3.1.13), respectively). These are purely a function of the geometry of the MS. Next, the inversion of the matrix A_{pn} is performed, by calling the matrix inversion subroutine MINV. Here the matrix is actually inverted only during the first and second runs of the potential flow calculation (we shall refer to one PF calculation as one "run"); this corresponds to the initial guess MS (during the first run) and to the newly calculated MS which is used for the second run onwards. Thus, after the second run of the calculation, since the MS is fixed, we need not invert A_{pn} again but simply read it from disc file (TAPE13), having stored it during the second run. We also read in the required incidence ALP, the variable CHD (which is used to normalise the chord length of the aerofoil) and the parameter NOFBDY. If the value of NOFBDY is zero, then no off-body coordinates are read in. If NOFBDY is ≥ 1, then we read in NOFBDY pairs of off-body coordinates for points at which we shall later require the velocities and pressure coefficient to be calculated. So far, the whole viscous/inviscid calculation procedure applies only to symmetrical aerofoils at zero incidence (so that only one sweep of the SL calculation is needed for each iteration). Then the total normal velocity (at the MS element mid points) is calculated; this is just the term $b_p + \upsilon_p$ in equation (3.1.8) (with $U_\infty = 1$) and is stored in array VC.

The next section firstly evaluates the source densities $m_n' = A^{-1}_{pn} [B_{pn} \gamma_n]$ (see equation (3.1.19)) and $m_n = A^{-1}_{pn} (b_p + \upsilon_p)$ (see equation (3.1.9)) and initially stores them in arrays POG and POS, respectively. Then the difference between the total tangential velocities at the TE is calculated; these are the tangential velocities at the mid points of the last MS element on the upper surface and the first on the lower surface (nearest to the TE) (see Fig. (33)): Firstly, the tangential velocities $q^{(1)}_{NTBE}$, $q^{(1)}_{NTE}$ flow case (1) of unit stream velocity are evaluated at the TE using equation (3.1.24). Fig. (33) shows the positive sense of the tangential velocities, so that the difference between the actual velocities at the TE (since the actual direction of the velocity on the lower surface element is reversed) is given by $\Delta q^{(1)} = q^{(1)}_{NTBE} + q^{(1)}_{NTE}$. Secondly, the tangential velocities $q^{(2)}_{NTBE}$, $q^{(2)}_{NTE}$, for flow case (2) of unit vorticity distribution, are evaluated at the TE from equation (3.1.20) and their difference $\Delta q^{(2)}$ is computed. The required circulation $\frac{\Gamma}{S}$ is then evaluated from equation (3.1.30) (with $U_\infty = 1$) and stored as GAP. Having obtained $\frac{\Gamma}{S}$, the total tangential velocity around the MS is computed from equation (3.1.26) and is stored in array SV. Also, as a check on the calculation, the total normal velocity around the MS is computed using equation (3.1.29) and should reduce to the values given by the specified input normal velocity υ_p (stored in array VC). The computed normal velocity is stored in array Y. The pressure coefficients at the MS element mid points are then computed using equation (3.1.31).

The next section of the program firstly evaluates the MS node at which the magnitude of the velocity is a minimum (node index JM) and stores this velocity as SM, for use later when finding the position of the stagnation point. Then the pressure coefficients on the MS at the element mid points are stored on disc file (TAPE13) for use in the shear layer calculation. The inverse of the influence coefficient matrix A_{pn} is also stored on TAPE13 for the second run of the potential flow calculation onwards (since it is unchanged for NORUN>2).

Next, the position of the stagnation point on the MS is obtained using the method of §3.1(e). The program then proceeds to print out the arc length around the MS (and the associated total velocity) measured from the stagnation point position. The arc lengths and velocities are those at the mid points of the elements.

The velocities V_x, V_y and the pressure coefficient are then calculated for any off body points whose coordinates (XX, YY) may have been read in earlier. The calculations for the off-body points are performed using the procedure described in §3.1(d).

We have distinguished between internal and external flows by means of the parameter NEXT; if NEXT=∅, the flow is an internal one and if NEXT=1, then we have an external flow. For internal flows, we specify the velocities at the inlet and outlet of, say, a duct by means of a specified normal velocity distribution at the element mid points, so that the "undisturbed stream" velocity part of the calculations is set to zero. Also, since the part of the calculation depending on lift (flow case (2)) would be meaningless (as would the application of the Kutta-Zhukovskii condition) for an internal flow, the value of the circulation $\frac{\Gamma}{S}$ calculated in the case of an aerofoil, is set to zero for the internal flow case.

We also note that the array SV contains the <u>total</u> velocity $\sqrt{q_p^2 + \upsilon_p^2}$ at the element mid points, since for internal flows the velocity υ_p may be the inlet or outlet velocity (so that υ_p cannot be neglected in comparison to q_p). Thus, we obtain the correct value for the pressure coefficient c_p from equation (3.1.31).

(b) <u>Subroutine COORD</u>

This subroutine reads in certain parameters, as well as the coordinates of the MS nodes and the normal velocities at the mid points of the MS elements, from disc file (TAPE12). The inclination (stored in TH) and lengths (stored in DS) of the MS elements are also computed.

(c) <u>Subroutine MINV</u>

This subroutine computes the inverse of a matrix stored in the array A. The inversion uses Gaussian elimination with row and column interchanges and is numerically the most accurate matrix inversion method. On return from the subroutine, the inverse matrix is stored in A by overwriting it. L and M are two working arrays used in the inversion and D is the determinant of A.

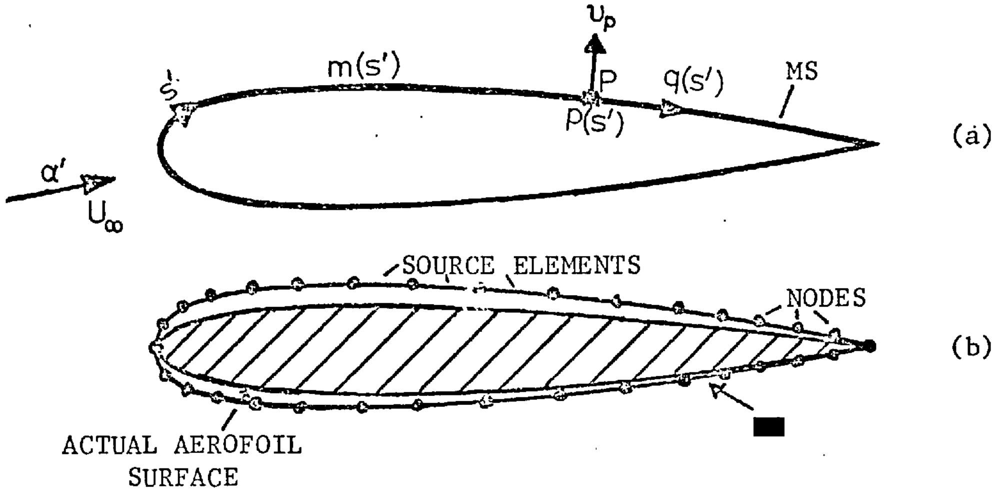


FIG (21)

HESS AND SMITH SURFACE SOURCE DISTRIBUTION METHOD

(a) CONTINUOUS SOURCE DISTRIBUTION

(b) DISCRETE SOURCE DISTRIBUTION

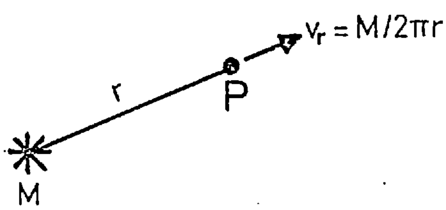


FIG (22)

VELOCITY INDUCED BY A POINT SOURCE

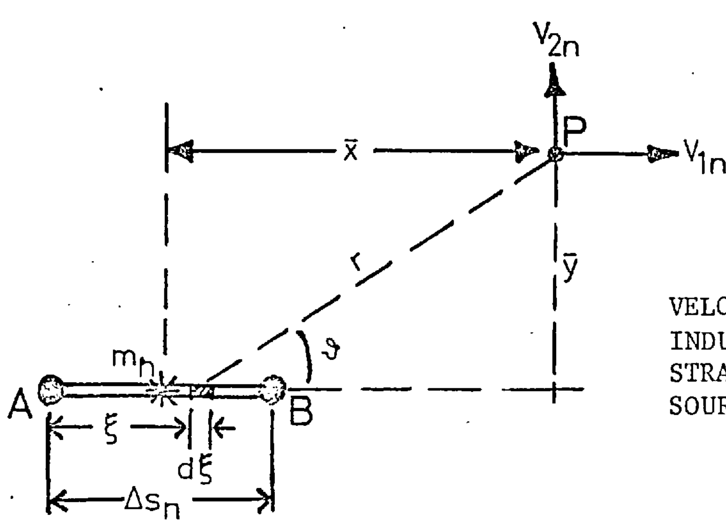


FIG (23)

VELOCITY FIELD INDUCED BY A STRAIGHT LINE SOURCE ELEMENT

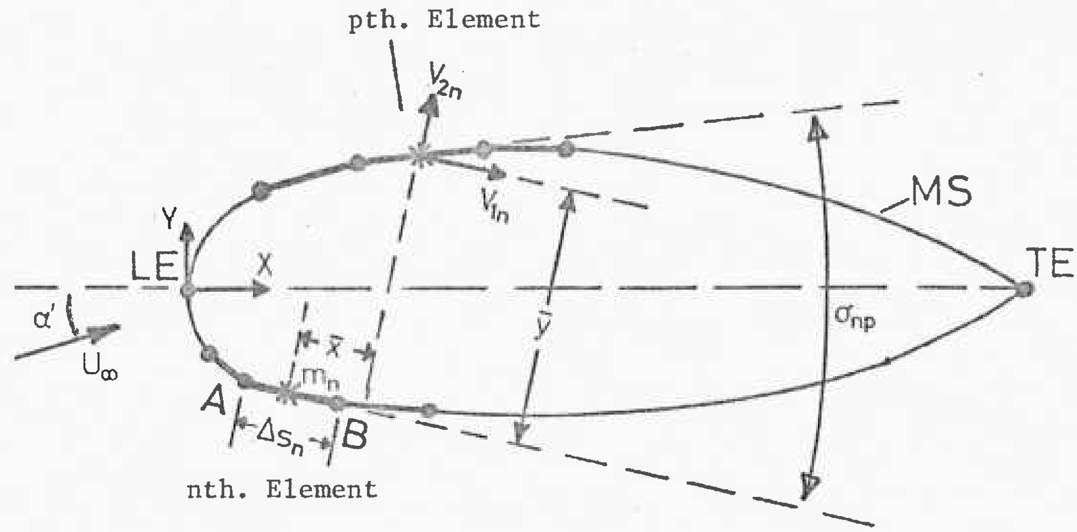


FIG (24)

VELOCITY FIELD INDUCED BY nth. ELEMENT ON THE pth. ELEMENT

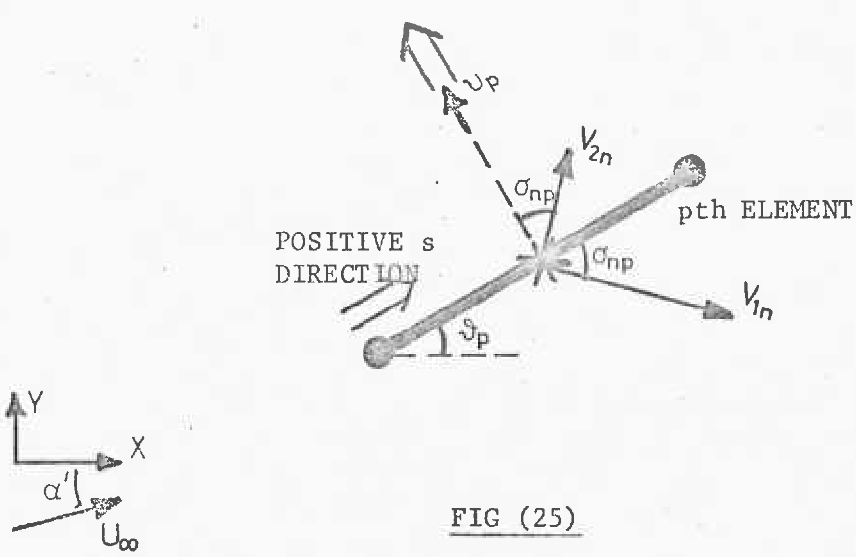


FIG (25)

VELOCITY INDUCED ON pth. ELEMENT DUE TO nth. SOURCE ELEMENT

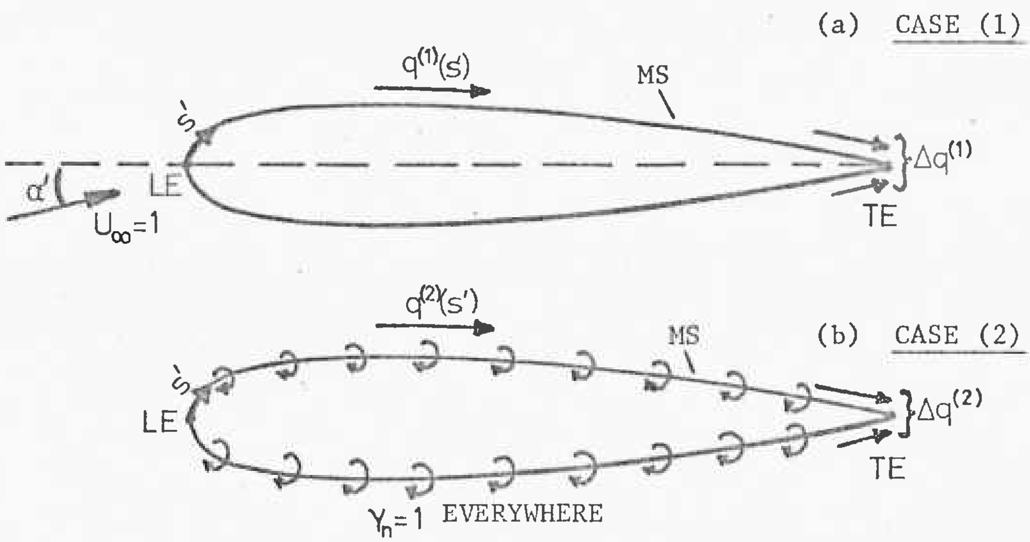


FIG (26)

SOLUTION PROCEDURE FOR
LIFTING AEROFOIL CASE

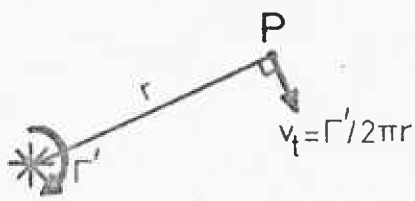


FIG (27)

VELOCITY INDUCED
BY A LINE VORTEX

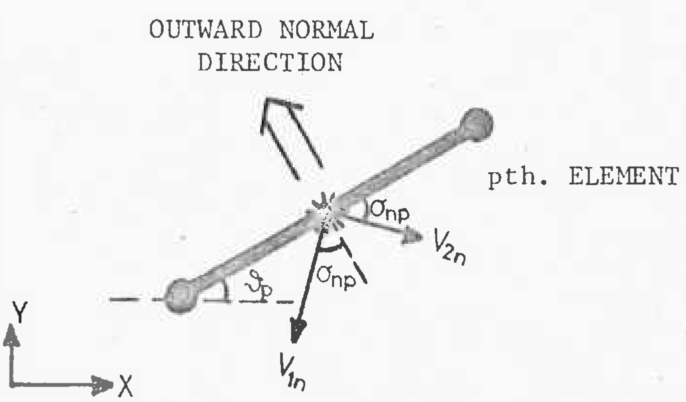


FIG (28)

VELOCITIES INDUCED ON
pth. ELEMENT DUE TO
VORTEX AT nth. ELEMENT

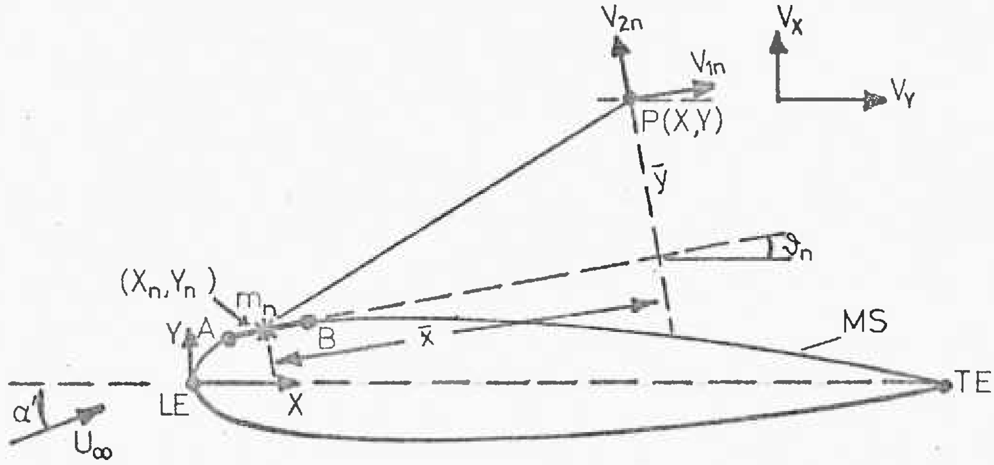


FIG (29)

CALCULATION AT OFF-BODY POINTS

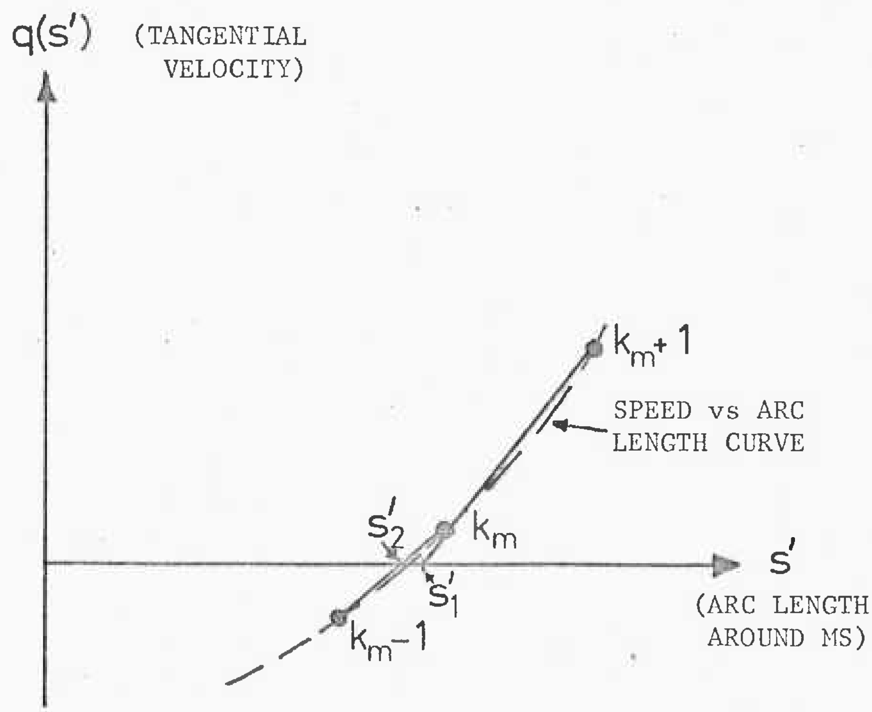


FIG (30)

CALCULATION OF STAGNATION POINT POSITION

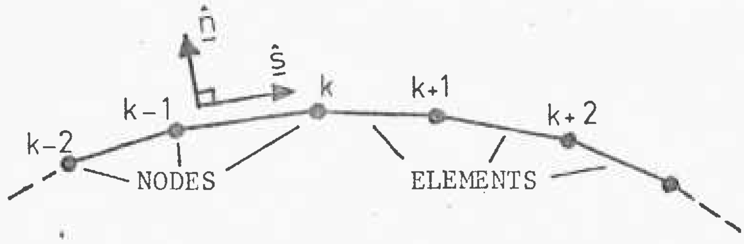
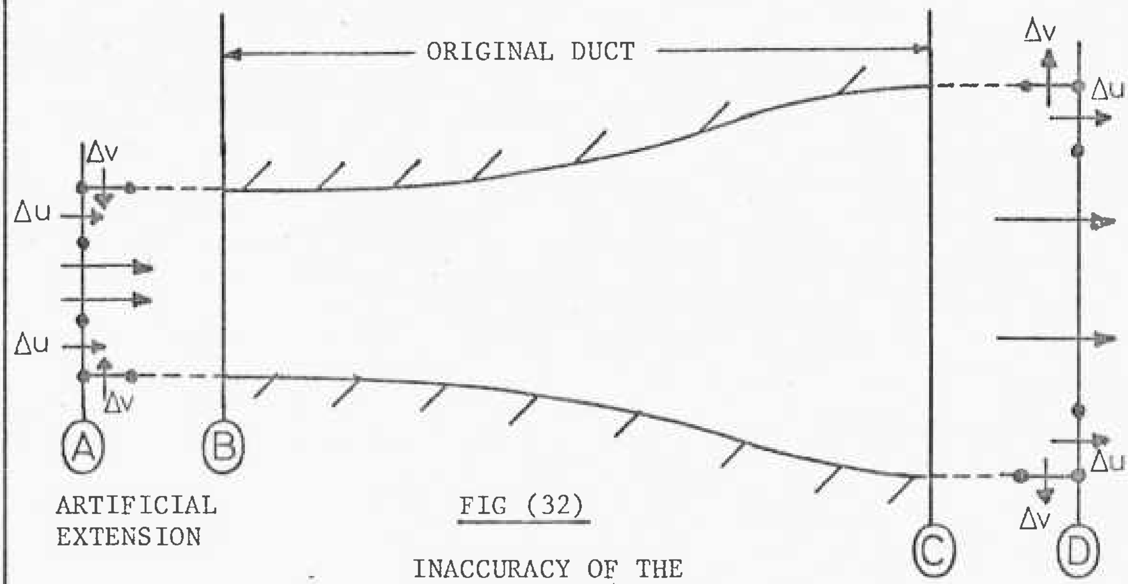


FIG (31)

DEFINITION OF EXTERNAL AND INTERNAL FLOW

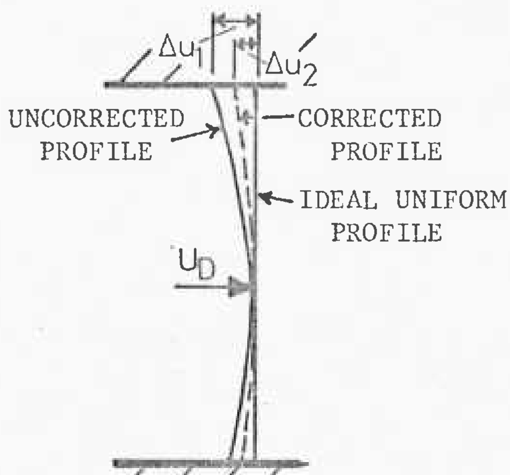


ARTIFICIAL EXTENSION

FIG (32)

INACCURACY OF THE HESS & SMITH METHOD NEAR CORNERS

ARTIFICIAL EXTENSION



$\Delta u_1/U_D$ TYPICALLY 10% - 15%

$\Delta u_2/U_D$ TYPICALLY 1% - 5%

FIG (32a)

CORRECTION OF DUCT VELOCITY PROFILES

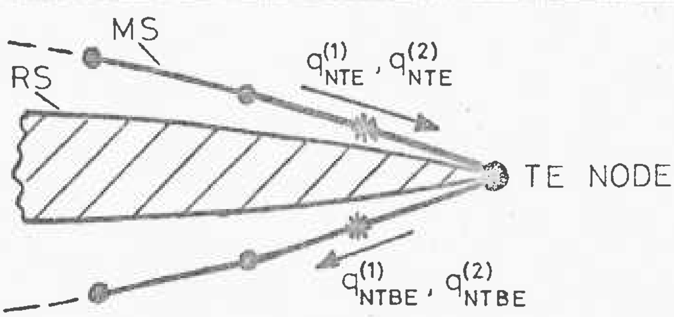


FIG (33)

APPLICATION OF KUTTA-ZHUKOVSKII CONDITION AT TRAILING EDGE

CHAPTER 4

THE VISCOUS/INVISCID MATCHING PROCEDURE

4.1 DESCRIPTION AND NUMERICAL DETAILS OF THE MATCHING PROCEDURE

As mentioned before, we divide the flow region of interest into two distinct domains: (i) A Shear Layer; where we solve the relevant shear layer equations according to the method of Chapter 2 and (ii) A Potential Flow region, where the flow is solved using the Hess and Smith surface source distribution method. In order to achieve a comprehensive and meaningful solution, the flows of (i) and (ii) above are matched on a matching surface (MS) dividing the two regions. The quantities which are matched on this surface are the velocity normal to it and the pressure on it; the normal velocity distribution $V_{MS}(s')$ is obtained from the shear layer calculation (where s' is the arc length on the MS, which is not to be confused with s, the arc length on the RS), which is performed in region I (see Fig. (34a)) from the real surface (RS) up to the MS and the pressure distribution $p_e(s')$ on the MS is obtained from the potential flow calculation which is nominally performed in region II from the MS outwards (in fact, of course, the Hess and Smith surface source singularity method does not use points within the field).

(a) Definition of the Matching Surface

As we are using an s-n coordinate system on the RS for the shear layer calculation, it is convenient to define the MS by specifying the height (value of n) $n = H_{MS}(s)$ of the

MS for any point on the RS; thus the MS is defined as a normal distance from the RS which is, in general, a function of s (the arc length along the RS). Therefore, if we draw the normal through any point P_{RS} (with coordinates X_{RS}, Y_{RS}) on the RS, we define the point P_{MS} (with coordinates X_{MS}, Y_{MS}) on the MS at the height H_{MS}. α_{RS} and α_{MS} are the inclinations of the RS and the MS, respectively, to the X-axis, as shown in Fig. (34b). We require the coordinates (X_{MS}, Y_{MS}) of P_{MS}, given the coordinates of P_{RS} (X_{RS}, Y_{RS}) on the RS. Firstly, we need to obtain the equation of the normal through the point P_{RS}; the slope of that normal is $-\frac{1}{g_{RS}}$, where g_{RS} is the RS slope at P_{RS} and is equal to tan α_{RS}. Therefore, the equation of the normal through P_{RS} is given by

$$Y = -\frac{1}{g_{RS}} X + c \qquad (4.1.1)$$

where c is a constant to be determined.

Now, $$H_{MS}^2 = (X_{MS} - X_{RS})^2 + (Y_{MS} - Y_{RS})^2 \qquad (4.1.2)$$

and since the normal P_{RS} passes through P_{RS} and P_{MS} we have

$$Y_{MS} = -\frac{X_{MS}}{g_{RS}} + c \qquad (4.1.3)$$

and $$Y_{RS} = -\frac{X_{RS}}{g_{RS}} + c \qquad (4.1.4)$$

If we subtract (4.1.4) from (4.1.3) and substitute for $Y_{MS} - Y_{RS}$ into (4.1.2) we obtain

$$g_{RS}^2 H_{MS}^2 = (1 + g_{RS}^2)(X_{MS} - X_{RS})^2$$

or $$X_{MS} = X_{RS} \pm \frac{g_{RS} H_{MS}}{\sqrt{1 + g_{RS}^2}} \qquad (4.1.5)$$

and subsequently $Y_{MS} = Y_{RS} \frac{\mp}{\sqrt{1 + g_{RS}^2}} \cdot H_{MS}$ (4.1.6)

or alternatively $X_{MS} = X_{RS} \pm \xi$ (4.1.7)

and $Y_{MS} = Y_{RS} \mp \eta$

The positive and negative signs in these equations distinguish the upper and lower surfaces of the aerofoil, for the case of external flow; for the upper surface we take the negative sign for equation (4.1.7) and the positive sign for equation (4.1.8), i.e. $X_{MS} = X_{RS} - \xi$ and $Y_{MS} = Y_{RS} + \eta$, while for the lower surface the converse applies, i.e. $X_{MS} = X_{RS} + \xi$ and $Y_{MS} = Y_{RS} - \eta$.

Thus, given the RS slope and the required height of MS from the RS (in the n-direction), we can find the coordinates of the MS (relative to the X and Y axes shown in Fig. (34b)) from those of the RS. Now, we consider the practical implementation of such a scheme numerically. Since the Potential Flow calculation divides the surface on which the pressure is calculated (in this case the MS) into discrete straight line elements (see Chapter 3) between defined "nodes", it is most convenient to define the RS by a series of nodes and then to define the nodes for the MS by means of the normal to the RS <u>at</u> the RS nodes (see Fig. (35)). The RS slope at the Jth. node is obtained by taking the average of the slopes of the two segments on the RS which meet at the Jth. node; i.e.

$$g_{RS_J} = \tfrac{1}{2}\{(\frac{Y_{J+1} - Y_J}{X_{J+1} - X_J}) + (\frac{Y_J - Y_{J-1}}{X_J - X_{J-1}})\} \qquad (4.1.9)$$

where the X and Y coordinates in this equation refer to the nodes on the RS. So, by specifying the MS height $H_{MS}(s_J)$ for all RS nodes, we define the MS nodes (as shown in Fig. (35))

by solving equations (4.1.5) and (4.1.6) at the nodes.

(b) The Initial Guess for the Matching Surface

As mentioned in §2.3(b) and §2.3(c), we have to guess an initial MS for the first iteration of the interaction calculation and then during the first sweep of the shear layer calculation a new MS will be computed (which is just outside the edge of the shear layer) and this new MS will be used for all subsequent sweeps. Now, the initial guess for the MS can be quite arbitrary and there are two different cases:

(i) Internal Flow Case

Since for internal flows we will be mainly concerned with short ducts, where the shear layers are turbulent but have not met near the centre line, there is no laminar BL calculation and for simplicity we define the initial MS height H_{MS} to be constant (see Fig. (36a)). Thus, the MS will be parallel to the RS and we choose H_{MS} to be about 1.2 times the thickness of the shear layer at the start of the turbulent shear layer calculation ($s = s_o$). H_{MS} will be defined at the RS nodes in the manner outlined in Section (a) above.

(ii) External Flow Case

In this case, the MS will be slightly more complicated due to the presence of a laminar boundary layer calculation as well. Fig. (36b) shows the general shape of the MS for an aerofoil; in region (A), where the laminar BL calculation is performed, the MS height is quadratic in s, starting with the value zero at the LE, the distribution of H_{MS} having zero slope at the end of region (A). In region (B) the turbulent shear layer calculation is performed and again, for simplicity, we define the MS height H_{MS} to be constant as in (i) above.

Now, when performing the complete calculation around an aerofoil, the wake should be taken into account. However, here, we end the shear layer calculation at the end of region B and close the MS at the TE in region C where H_{MS} is again quadratic in s. The start and end of region B are conveniently taken at the position of a RS (and hence a MS) node. So far, we have only considered symmetrical aerofoils, so that the MS distribution will also be symmetrical. Again, the MS is defined at the RS nodes (as in (a) above) for the entire region A, B and C. Work on wakes is in progress.

For both internal and external flow cases, we see from Figs. (36a) and (36b) that the shear layer calculation is performed in region I only and that the potential flow calculation is performed in region II, so that the latter only "sees" the MS.

(c) The Viscous/Inviscid Matching Procedure

Here, we describe how the matching procedure is applied, numerically. The reader is referred to the flow diagram Fig. (39) (which shows the viscous/inviscid iteration cycle) in conjunction with the descriptions given in this section onwards; this will aid to establish which position in the iteration cycle each section refers to. In addition to this, the flow diagram is annotated with the relevant section numbers in the text.

As mentioned in the introduction to this Chapter the external pressure distribution p_e is obtained from the potential flow calculation and is used in the shear layer calculation, while the shear layer calculation in turn produces a normal velocity distribution V_e (normal to the RS) and a component U_e parallel to the RS. From these, we obtain the component of velocity V_{MS} normal to the MS so that we can use this in calculating the potential flow over the MS. In general, the MS and RS are not parallel and in that case (see Fig. (34b)) V_{MS} is obtained from U_e and V_e through the expression

$$V_{MS} = V_e \cos(\alpha_{MS} - \alpha_{RS}) - U_e \sin(\alpha_{MS} - \alpha_{RS}) \qquad (4.1.10)$$

Now, the potential flow calculation calculates p_e^* at the centre of the MS elements (see Fig. (37)), while V_{MS} for the potential flow calculation is obtained at the MS nodes using (4.1.10), from the values of U_e and V_e at the nodes. In general, there will be more shear layer calculation stations (see Fig. (37)) than there are nodes, so that in order to obtain the values of U_e and V_e at the nodes, we need to interpolate from the values of U_e and V_e given at the shear layer stations. Moreover, since the potential flow calculation requires the values of V_{MS} at the mid points of the MS elements, we need to interpolate from the values of V_{MS} calculated at the nodes. Similarly, for the shear layer calculation we require the external pressure p_e at the MS nodes and so we interpolate from the values p_e^* given at the mid points of the MS elements.

In order to start the potential flow calculation we need an "initial" guess for V_{MS} (as well as that for H_{MS} given above) which can be quite arbitrary. We therefore choose a parabolic distribution with s in regions A and C (see Fig. (36b) and a constant value in region B, for the external flow case. For the internal flow case (see Fig. (36a)) we choose a constant value of V_{MS} everywhere.

We can now summarise the whole viscous/inviscid matching procedure as follows:

(i) Make an initial guess $H_{MS} = \delta_o(s)$ for the matching surface and an "initial" guess for the velocity V_{MS} normal to the MS.

(ii) Perform the potential flow calculation in region II (see Figs. (36a), (36b) and (37)) to obtain the external pressure distribution p_e* on the MS at the element mid points.

(iii) Using the p_e* external pressure distribution, obtain the values of p_e at the MS nodes and carry out one sweep of the shear layer calculation as described in §2.3 to obtain U_e and V_e. Then reassign the MS height $H_{MS} = \delta(s)$ to be just outside the shear layer.

(iv) Calculate the values of V_{MS} at the new MS nodes from the values of U_e and V_e at the shear layer calculation stations obtained from (iii). Interpolate from these values to obtain the values of V_{MS} at the mid points of the MS elements for use in the potential flow calculation. With these values of V_{MS} and with the new MS height $H_{MS} = \delta(s)$, go to (ii) to re-calculate the potential flow and repeat steps (ii), (iii) (without further reassignment of H_{MS}) and (iv) until convergence is achieved.

Steps (i) - (iv) above are termed one "iteration" of the viscous/inviscid calculation procedure.

It has been found convenient to write a separate program to perform the matching operations in (i) and (iv) above. This program (called MATCH) is described in §4.2.

(d) Under-Relaxation and Smoothing

As mentioned when describing the shear layer calculation, we apply under-relaxation to the two dimensional pressure array (see §2.2(c)) which contains the entire pressure field in the shear layer calculation region (I). We also apply under-relaxation to the values of V_{MS} calculated at the mid points of the MS nodes. Thus, if $V_{MS}^{(n-1)}$ is the value from the (n-1)th. sweep, and $V_{MS}^{(n)}$ the value calculated on the nth. sweep, then the actual value used is

$$V_{MS} = \Omega\, V_{MS}^{(n)} + (1 - \Omega)\, V_{MS}^{(n-1)} \qquad (4.1.11)$$

where Ω is the "under-relaxation factor". A value of $\Omega = 0.3$ was used for the two test cases of Chapter 5, which resulted in a reasonable rate of convergence of the viscous/inviscid interaction procedure (about ten iterations). The under-relaxation of V_{MS} is carried out in program MATCH (see Fig. (39)).

We have also encountered a numerical problem which caused a great amount of confusion since it was producing totally incorrect distributions of $V_e(s)$ and of $p(s,n)\big|_{n=const.}$ (i.e. pressure with s at constant n), which exhibited "spikes" at some positions. These distributions of $V_e(s)$ and $p(s,n)\big|_{n=const.}$ were the values obtained at the shear layer calculation stations. The reason for this behaviour was discovered to be merely the irregularity in any input data such as the $p_e(s)$ distribution or even the values of $p(s,n)\big|_{n=const.}$ itself calculated from one sweep of the shear layer calculation and used on the next sweep (since p(s,n) is, after all, the result of a finite difference calculation). This irregularity or "noise" in the original data leads to short wavelength "noise" when the gradients of such data are taken and used in the calculations. It is therefore necessary to have smooth distributions for $p_e(s)$ and $p(s,n)\big|_{n=const.}$ and for their streamwise gradients, especially in the case of rapidly changing flows in the streamwise direction. We therefore use cubic spline interpolation in interpolating the values of $p_e(s)$ used at the shear layer calculation stations from the values $p_e{}^*(s)$ given at the mid points of the MS elements, to ensure smoothness of the first derivative as well. As for the pressure array $p(s,n)$, after shifting the pressure profiles by the appropriate amounts $p_{e,new}(s) - p_{e,old}(s)$ as described in §2.3(b), we look at the distribution given by

$$p'(s)\Big|_{n=const.} = p(s,n)\Big|_{n=const.} + p_{e,new}(s) - p_{e,old}(s) \qquad (4.1.12)$$

and smooth it at each n, again using cubic spline interpolation. The smoothing is easily achieved by picking off a number of points (hereafter, the "smoothing points") on the distribution $p'(s)$ roughly equal to the number of RS nodes in the calculation region. The "smoothing points" are picked off from the $p'(s)$ distribution (which is given at the SL calculation stations) by parabolic interpolation. For flows with large changes of streamwise pressure gradient (like the duct in §5.1) it is best to choose these points manually by inspecting the pressure output from the shear layer calculation for each sweep, but in most cases equally-spaced smoothing points would suffice. We then use cubic spline interpolation to interpolate new, smooth values of $p'(s)$ at the shear layer stations, from the values picked off from the original distribution at the "smoothing points". This procedure ensures that the distribution $p'(s)$ is correctly smoothed and that loss of information due to smoothing is kept to an absolute minimum especially near regions containing sharp peaks of $p'(s)$. It has been found convenient to include this smoothing procedure in a separate small program called SMOOTH (see §4.2 for its description and Fig. (39)).

(e) Mass Flow Conservation for Internal Flows

In order to obtain the correct exit velocity for internal (duct) flows, given the entry velocity, we need to apply the conservation of mass flow rate to the duct, in the potential flow region II (see Fig. (38)). Let us consider, as an example, the internal flow test case (see §5.1) of the curved, constant width duct. In general, the MS height is $\delta(s)$ and the velocity distributions normal to the MS are $V_B(s)$ and $V_T(s)$ for the bottom and top surfaces, respectively (see Fig. (38)). The entry and exit velocities are U_{in} and U_{exit}, respectively and are taken to be constant with n. In what follows we shall only consider one shear layer at a time. For conservation of mass flow rate, we have

$$U_{in}\ (H_D - \delta_o) + \int_A^B V_B(s)\ ds + \int_C^D V_T(s)\ ds = U_{exit}\ (H_D - \delta_{exit}) \tag{4.1.13}$$

where H_D is the duct width, δ_{in} is the value of $\delta(s)$ at the entry to the duct and δ_{exit} its value at the exit. We can thus obtain the correct value of U_{exit}, given U_{in}. This is automatically computed in the matching program MATCH for internal flows. We can also obtain the correct mass flow rate at any station M, say, of the duct (see Fig. (38)). The mass flow rate at station M is

$$\dot{m} = U_{in}\ (H_D - \delta_{in}) + \int_A^E V_B(s)\ ds + \int_F^D V_T(s)\ ds \tag{4.1.14}$$

This provides a check on what the mass flow rate should be at any station of the duct. This is especially important when correcting for the mass flow through the duct due to the errors produced by the potential flow method (see §3.1(f) part (ii)). The velocity corrections at the mid points of the corner elements are input to the matching program MATCH, which takes them into account (by adding them onto the existing velocities normal to the corner elements) when producing V_{MS} (the normal velocity at the MS element mid points) for use in the potential flow calculation. Also, as a check on the mass flow rate (and in order to find the velocity corrections necessary to produce the correct mass flow rate), the mass flow rate and the streamwise velocity profile are computed at four stations (see Fig. (38)) near the entry and exit of the duct. This mass flow rate is obtained by integrating the velocity profile across the duct. This is performed by a separate small program called TRAVERS whose description is given in §4.2 (see also Fig. (39) for its position in the interaction cycle).

4.2 DESCRIPTION OF COMPUTER PROGRAMS USED IN THE MATCHING PROCEDURE

We shall describe in what follows the programs used in the viscous/inviscid matching procedure. The function of each has been outlined in §4.1. One execution of any of these programs (MATCH, TRAVERS, SMOOTH) in the viscous/inviscid "iteration" cycle is termed a "run" (as in the Potential Flow Calculation). The reader is referred to the relevant program listings (Appendix A6) and namelists (Appendix A5) in conjunction with the descriptions given below. The reader is also referred to Fig. (37), which shows the numerical implementation of the viscous/inviscid matching procedure, as this will aid in clarifying the various definitions used. As we use two similar but different matching programs for the cases of internal and external flow, we have kept the descriptions for those two cases separate, to avoid any confusion. As before, for each program we shall describe the main routine first, then the main subroutines in the order in which they are called in the main routine and finally any subsidiary subroutines in alphabetical order.

I. The Matching Program for External Flows (MATCH)

This program is responsible for effecting the correct matching procedure between the shear layer calculation and the potential flow calculation; its functions can be summarised as:

(i) To generate the coordinates of the MS at the nodes, given the RS coordinates at the nodes; this applies to the initial guess for the MS, as well as the final MS used for the second iteration onwards.

(ii) To obtain the component of velocity normal to the MS elements at their mid points, given the velocities parallel and normal to the real surface at the shear layer calculation stations. For the first run of the program, the initial guess for the above velocity is also made.

(a) The Main Routine MATCH

Firstly, some parameters are read in together with the RS coordinates at the nodes. Next, variables transferred from the shear layer calculation are read in from disc file (TAPE14); these are the positions of the shear layer calculation stations and for runs after the first, the normal distance H_{MS} for the new matching surface (which is calculated in the shear layer program).

The arc length along the RS is then calculated, measured from the LE around the aerofoil. Next, the gradients g_{RS} (see §4.1(a)) of the RS at the nodes, are calculated.

The next major section (which extends down to about statement number 444) is responsible for defining the MS height H_{MS} (see §4.1(a) and §4.1(b)-(ii)) for the three regions A, B and C (see Fig. (36b)) of the aerofoil, including the initial guess for the MS (for the first run of the calculation, denoted by NORUN=1); firstly, the MS height H_{MS} is defined for region A as a parabola with s (the arc length along the RS) and for this purpose subroutine PARAB is called. Now, for NORUN=1, the node numbers denoting the start and end of region B (NSTART and NEND, respectively) are input by the user, thus constituting an "initial" guess for region B. However, after the first "iteration", the values of NSTART and NEND are adjusted in the program at the positions where the laminar BL calculation ends and where the turbulent shear layer calculation ends, respectively. This information is, of course, transferred to the matching program from the shear layer program. The indices equivalent to NSTART and NEND for the bottom surface of the aerofoil are NSLOW and NENLOW. Next, the MS height H_{MS} is defined for region B as a constant; for NORUN=1 a guessed height is input while for runs after the first, the height evaluated by the shear layer calculation is used, so that H_{MS} will lie just outside the edge of the shear layer. In the present version of the program the MS height for the final region C is then defined as a parabola with s, again, going to zero at the TE. We then calculate the coordinates (X_{MS}, Y_{MS}) of the MS nodes, having defined the MS height $H_{MS}(s)$ for all the nodes, from equations (4.1.5) and (4.1.6).

Having completely defined the MS coordinates, we then proceed to the matching of the velocities as described in §4.1(c). Firstly, subroutine VMATCH is called, which evaluates the velocities normal to the MS at the nodes. We then interpolate from these values, to obtain the velocity V_{MS} (see §4.1(c)) at the mid points of the MS elements. These values of V_{MS} are then under-relaxed with an under-relaxation factor OMEGA (see equation (4.1.11). Finally, variables relevant to the potential flow calculation are written onto disc file (TAPE12). For a description of these variables see §4.3.

(b) Subroutine VMATCH

This subroutine is responsible for obtaining the velocities V_{MS} (see §4.1(c)) normal to the MS, at the MS nodes, given the velocities U_e (parallel) and V_e (normal) to the RS at the shear layer calculation stations. The first section provides the initial guess for V_{MS} in region B (see Fig. (36b)), which is a constant arbitrary velocity of -.Ø17 times the stream velocity (all velocities are normalised with respect to the stream velocity).

In the next section (extending down to statement number 1Ø5) V_{MS} is obtained from U_e and V_e for regions A and B of the aerofoil, which are read in from disc file (TAPE14). Firstly, the laminar BL calculation region A is dealt with and there U_e and V_e have been evaluated at the MS nodes in the shear layer calculation (note that this is only true for NORUN greater than 1). However, for region B, since U_e and V_e are evaluated at the shear layer calculation stations, interpolation of these values is needed first to obtain U_e and V_e at the MS nodes. Having obtained U_e and V_e at all the nodes, V_{MS} is calculated at the MS nodes using equation (3.1.10). This procedure is then performed for the lower surface of the aerofoil after the upper surface.

Next, the initial guess for V_{MS} is made for region A of the aerofoil and for NORUN=1 only. A parabolic variation of V_{MS} with s is assumed starting with zero at the LE (see §4.1(c)). Finally a parabolic variation is again made for V_{MS} in the last region C of the aerofoil.

(c) Subroutine PARAB

This subroutine fits a parabola through two points (whose coordinates are given), with zero slope specified at one of these points. The two points through which the parabola is passed have coordinates (X(1), Y1) and (X(NP), YNP), where NP is the total number of points on the parabola. X is a specified array and Y will contain values on the parabola, corresponding to X. If IOPT=1, the parabola is assumed to have zero slope at (X(1), Y1) and if IOPT=2, it has zero slope at (X(NP), YNP).

II. The Matching Program for Internal Flows

The purpose of this program is exactly the same as for the external flow case; differences in content include:

(i) The absence of a lower surface results in considerable simplification, as all sections concerned with the lower surface are removed; in the present state of the program the internal flow matching is carried out on one surface only for simplicity, although it need not necessarily be the case.

(ii) The inclusion of the calculation of the duct exit velocity by performing a mass flow rate balance (see §4.1(e)) and also the addition of "correction" velocities for the corner elements to correct the errors arising from the potential flow calculation.

(a) The Main Routine MATCH

As before we begin by reading in some parameters (more in this case) as well as the RS node coordinates. In the next sections of the program we calculate the RS arc length and the gradients at the RS nodes, as before.

The next section of the program down to statement number 444 is somewhat different from that for external flow, in that the MS height H_{MS} definition is only made for one surface. Also, the MS height for the regions upstream and downstream of the turbulent shear layer calculation region is set to a constant and equal to the MS height in the turbulent shear layer region. These two regions are the artificial extensions of §3.1(f)-(ii) necessary to reduce the errors resulting from the deficiencies of the potential flow calculation method near the corners. In these regions, the turbulent shear layer calculation is not performed. (We shall henceforth refer to the region in which the turbulent shear layer is calculated as the "turbulent" region). The coordinates (X_{MS}, Y_{MS}) of the MS nodes are then calculated as before, using equations (4.1.5) and (4.1.6).

Next, the velocities normal to the MS are calculated by calling subroutine VMATCH. We then interpolate, as before, to obtain the velocities V_{MS} normal to the MS at the MS element mid points and then under-relax these values of V_{MS}. In this case, we then perform the mass flow rate balance of §4.1(e) to obtain the correct value of the exit velocity from equation (4.1.13). The correction velocities normal to the corner elements of the MS and at their mid points are then read in and added to the normal velocities already specified.

Finally, the variables relevant to the potential flow calculation are written onto TAPE12, as before.

(b) <u>Subroutine VMATCH</u>

The purpose of this subroutine is exactly the same as in the external flow case. Firstly, the normal velocity at the MS nodes for the turbulent region is arbitrarily defined as a constant equal to -.018 only for the first run of the calculation (NORUN=1), and constitutes the initial guess.

In the next section down to statement number 6Ø, the velocities normal to the MS at the MS nodes are obtained as before for the turbulent region by interpolation from the values of U_e and V_e at the shear layer calculation stations (see Fig. (37)).

In the final two sections, the normal velocity at the MS nodes is defined as a constant equal to .002 for both the region upstream of the turbulent region and for the region downstream of the turbulent region.

For the internal flow case subroutine PARAB does not exist.

III. <u>Program SMOOTH (called for NORUN>1 only)</u>

This program is responsible for smoothing the pressure distribution (obtained from the shear layer calculation) at any given height above the surface, using cubic spline interpolation (see §4.1(d)). It also shifts the pressure profiles by the appropriate amount $p_{e,new}(s) - p_{e,old}(s)$, where $p_{e,old}(s)$ is the external pressure distribution for the previous sweep of the calculation and $p_{e,new}(s)$ is the newly calculated external pressure distribution from the potential flow calculation.

Firstly, the program reads in relevant variables from disc file (TAPE1). Then it reads in the s-positions at which the "smoothing points" of the p'(s) distribution are chosen (array XNODE) (see §4.1(d)). In the next two sections of the program, the distribution p'(s) is obtained (from equation (4.1.12)) for all the values of n from the RS to the MS, at the grid points. The values of the distribution picked off at the "smoothing points" (by parabolic interpolation from p'(s), which is given at the SL calculation stations) are then stored in array YNODE (see §4.1(d)). Cubic spline interpolation of the function values (XNODE, YNODE) is then used to obtain the smoothed values of p'(s) at the shear layer calculation stations; the coordinates XNODE, in this case, are the "knots" of the cubic spline (see §2.4(t)). Finally, we overwrite the data file containing the two dimensional pressure array p(s,n) with the smoothed and shifted array $p'(s)\big|_{n=\text{const.}}$ for all values of n, for input to the shear layer calculation.

IV. Program TRAVERS

This program computes the streamwise velocity profile and the mass flow rate at specified stations of the duct in internal flow. The mass flow rate is calculated by integrating the velocity profiles across the duct at specified "traverse" stations. Thus, the mass flow calculated in this manner is the mass flow actually produced as a result of the potential flow calculation and will, in general, not be the same as the correct mass flow obtained by applying continuity in the duct from the PF calculation. We therefore need to compute the mass flow actually obtained from the PF calculation in order to correct it by the insertion of extra velocities at the corner elements.

Firstly, the program reads in the relevant data (for details see §4.3). It then extracts the velocity profile across each "traverse" station of the duct and integrates it using Simpson's rule by calling subroutine SIMPSN. Since the velocity profile across the duct is, in general, not given at a constant spacing, we first need to interpolate to obtain the values of streamwise velocity at constant intervals since the Simpson's rule integration assumes constant intervals. The velocity profile and mass flow rate at each of the "traverse" stations along the duct are outputted.

4.3 DESCRIPTION OF THE OPERATION/USER'S GUIDE OF THE VISCOUS/INVISCID ITERATION CYCLE

In this section we shall describe the practical computer implementation of the Viscous/Inviscid interaction iteration described in §4.1(c). The flow diagram illustrating the iteration cycle is given by Fig. (39).

The way in which the iteration cycle has been arranged is as follows: Each of the separate calculation programs like the shear layer calculation program (TURB), the potential flow calculation program (AMOS) and the matching program (MATCH), together with any other subsidiary programs required (e.g. SMOOTH and TRAVERS), are executed in turn. The necessary data for each program is transferred from the previous program in the interaction cycle by storing it on disc files. Each disc file is given a unit number (e.g. TAPE12, TAPE13, TAPE14) for writing and subsequently reading the relevant data from within a program. These are also called local file names. The data disc files themselves are given permanent file names, which are the names by which the CDC computer system identifies them. Other computer systems have different names for "permanent files" but the Fortran TAPEn convention for local files is nearly universal, so the Fortran programs (as distinct from the "control cards" which issue instructions to the computer operating system) should be machine-independent as the BFA shear layer program is. It is of course possible to write to and read from arrays in core instead of disc files but the present system will be preferable on all time-sharing machines except the largest. As the data stored on these files changes from iteration to iteration, we shall call these temporary data stores "variable data files". In addition to these variable data files, each of the programs in the iteration cycle also requires data which are fixed for all iterations (e.g. the coordinates of the RS) and we call these "fixed data files". Again, these are identified by the system by permanent file names and are read in by assigning unit numbers in the form of local file names.

Fig. (40) gives a flow diagram showing the sequence of execution of the various programs in the viscous/inviscid iteration cycle, together with the relevant fixed and variable data files. The whole cycle is initialised by setting the iteration count NORUN to 1. This is done by writing the number 1 on the variable data file MATDAT. The flow diagram also shows the variables stored on the various data files. Double-headed arrows indicate the direction of flow of the iteration cycle, while single-headed arrows indicate the reading and/or writing of data. The reader is referred to the namelists in Appendix A5 for the meanings of the symbols used for the variables; the symbols used for the variable data files are the same as those used in the program which writes the data on the file, while the symbols used for the fixed data files are the same as those used in the program which reads the data from the file.

For operation of the iteration cycle, the user merely needs to create the fixed data files MATDAT1, AMOSDA1 and MATDAT1 (also TRAVDAT for internal flow) (see Appendix A8 for control cards needed to create these files on the Imperial College Computer System) and specify the relevant data for program SMOOTH from input. Firstly, we shall consider the data needed to create these fixed data files (which constitute all the input data required to run the interaction cycle) and then we shall show how the interaction cycle is run on the CDC computer system at Imperial College.

(a) Creation of Fixed Data File MATDAT1 (for program MATCH

As in the flow diagram of Fig. (40) each line of data (numbered below) refers to a card image in the creation of all the fixed data files. The reader is referred to the relevant namelists for an explanation of the symbols used.

(1) N, NTEL for external flow or N,NTEL, NSIDE, NTOP for internal flow. The format used is 16I5. N is the total number of RS node coordinates starting with the LE node and ending with it again. NTEL is the total number of elements from the LE node to the TE node. For internal flow, NSIDE is the number of elements on the sides of the duct (assumed the same for the entry and exit sides) and NTOP is the number of elements on the top surface of the duct, which is the surface on which the shear layer is not calculated.

(2) (X(J),Y(J),J=1,N) which are the RS node coordinates. The format used is 2F1Ø.Ø These are to be read in counter-clockwise around the body contour for external flows starting with the LE node and finishing with it again. For internal flows, they are to be read in clockwise around the contour of the duct, again reading the first point in once more at the end.

(3) RNPNST, OMEGA for external flow or RNPNST, UINF, OMEGA for internal flow, with format 8F1Ø.Ø. UINF is the entry velocity to the duct.

(4) NSTART, NEND with format 16I5. These will correspond to the start and end nodes of the turbulent shear layer calculation region only for the first run of the calculation (NORUN=1). For NORUN>1 they will be ignored and read in as dummies NS1,NEND1.

(5) (IEL(J),J=1,8) with format 16I5. These are the numbers of the eight corner elements at which correction velocities are applied. They are read in only if NEXT=Ø (internal flows).

(6) (VCORR(J),J=1,8) with format 8F1Ø.Ø. These are the correction velocities for the eight corner elements. Again they only apply for internal flows.

(b) <u>Creation of Fixed Data File AMOSDA1</u>
<u>(for program AMOS)</u>

(1) NEXT, with format I5; NEXT=1 for external flow and NEXT=Ø for internal flow.

(2) ALP,CHD, with format 2F1Ø.Ø, for external flow only; ALP is the angle of incidence α in <u>degrees</u> (which must be set to zero at present) and CHD is the chord of the aerofoil which should be set to 1. For internal flow ALP and CHD are ignored.

(3) NOFBDY, with format I5; this gives the number of off-body coordinates to be read.

(4) (XX(J),YY(J),J=1,NOFBDY) with format 2F1Ø.Ø; these

are the off-body coordinates at which the velocities and pressure coefficient are to be calculated. If NOFBDY=Ø this read statement is skipped.

(c) Creation of Fixed Data File BLDAT1 (for program TURB)

(1) NSTNS,NEXPTS, with format 16I5; these are the dimensions of arrays used in the shear layer calculation and are needed since we use variable dimensions in some subroutines. NSTNS should be at least equal to the total number of SL calculation stations. For internal flows NEXT can be made equal to NSTNS, while for external flows NEXT must be greater than NSTNS by an amount equal to at least the number of nodes in the laminar BL calculation region.

(2) (US(J),J=1,8) with format 8A1Ø; this is a title card for the shear layer calculation and is printed at the start. This assumes that the computer stores 10 A-format characters in one central memory word; for 8 characters per word use 1ØA8 format.

(3) (I(J),J=1,14) with format 14I5; these are controlling options or parameters for the shear layer calculation as follows, generally as in the BFA method except for the addition of I(13) and I(14);

(i) I(1): Its value is not used except for visual identification of the data set, however if I(1) is made negative then only the integral parameters and not the profiles of U, τ, V and the characteristic angles, will be printed out.

(ii) I(2): If I(2)=1 then the starting U, τ profiles are assumed supplied. If I(2)=Ø synthetic starting U, τ profiles will be generated for the start of the turbulent shear layer calculation after the laminar BL calculation is performed.

At present I(2)=∅ implies that we have an external flow and I(2)=1 implies an internal flow.

(iii) I(3): This is the number of calculation steps between each printout of integral parameters or U, τ, V, p profiles for a calculation station. If I(3) is negative then -I(3) station numbers are read into the Integer array XP(J). These station numbers denote stations at which information is to be printed.

(iv) I(4): This is the total number of s-steps to be executed. If I(4)=∅ the program resets it to 1∅∅∅ so that the calculation runs to the end of the data.

(v) I(5): The total number of boundary values, with a maximum of 51. This does not apply to the external pressure, matching surface height boundary values, which are supplied internally through variable data files. For curvature boundary value see (6) and (7) below.

(vi) I(6): This is two less than the number of points on the starting U, τ profiles supplied; its maximum value is 48. If the starting U, τ profiles are not supplied, then this is the number of points across the synthetically generated U, τ profiles up to δ_{Coles}.

(vii) I(7): Unused.

(viii) I(8): Set to 1 for the case of a rough surface, otherwise zero.

(ix) I(9): In the BFA program this is set to 1 if the extra strain rate (curvature) correction to the turbulence model is required, otherwise set to zero. In the present program it has no effect, as we do not have an extra strain rate correction.

(x) I(1∅): This is set to ∅ for no lateral divergence, 1 for (the divergence radius) input, 3 for $1/(x-x_o)$ input; in order to insert the divergence into the continuity equation while suppressing the extra strain rate correction, set to (-1) times the above values.

(xi) I(11): Not used.

(xii) I(12): Set to 1 if the suction/injection boundary values are supplied, otherwise set to zero.

(xiii) I(13): If I(13) is negative, an "unrealistic" starting U profile is supplied. If I(13) is positive a "realistic" U profile is supplied (in that case pressure profiles at $s = s_o$ and $s = s_{max}$ are also supplied).

(xiv) I(14): This controls the printout of pressure profiles. If I(14)=Ø no pressure profiles will be printed out. If I(14)=Ø the newly calculated pressure profiles, as well as the pressure profiles from the previous sweep of the calculation, are printed out according to the value of the control parameter I(3).

(4) (A(J),J=1,7) with format 7F1Ø.Ø; these specify scales and starting conditions for the shear layer calculation as follows: l_{ref} is an arbitrary length scale and U_{ref}, p_{ref} denote arbitrary reference conditions.

(i) A(1): If A(1)>Ø, this is the streamwise distance RLEND between the starting pressure profile (at $s = s_o$) and the final one if these are supplied (see (13) below). If If A(1)<Ø then pressure profiles may not be supplied. If A(1)=Ø, $\frac{\partial p}{\partial n}$ is set to zero everywhere, for the initial guess of p(s,n) and for the starting pressure profile. Otherwise, the centrifugal approximation is used.

(ii) A(2): This is the streamwise spacing of the boundary values/l_{ref}; where this does not apply to the external pressure on MS height boundary values (for curvature boundary value see (6) and (7) below).

(iii) A(3): s_o/l_{ref}.

(iv) A(4): The Reynolds number $\frac{U_{ref}\ l_{ref}}{\nu}$.

(v) A(5): This is the starting value of $\frac{c_f}{2}$ (for the start of the turbulent shear layer calculation). If A(5)=Ø (only for external flows) then $\frac{c_f}{2}$ is computed from the Spalding-Chi formula.

(vi) A(6): This is an s-step factor; it multiplies the s-step ($\frac{\Delta s}{l_{ref}}$) obtained from the Courant-Friedrichs-Lewy criterion to obtain a smaller step if desired. Necessarily O<A(6)<1.

(vii) A(7): This is the under-relaxation factor used for the two dimensional pressure array. O<A(7)<1.

Items (5) to (14) are all read in in 7F1Ø.Ø format:

(5) (ROUGHA(J),J=1,I5), starting at s = O, if I(8)=1; this boundary value is the (equivalent sand roughness height)/ l_{ref}; some zero values are permissible. Negative values are interpreted as $-z_o/l_{ref}$.

(6) (XCURV(J),J=1,I5); these are the $\frac{s}{l_{ref}}$ -positions for the curvature boundary value and at present are only supplied for internal flows. For external flows, the values of XCURV are set at the RS nodes by the program.

(7) (CURVA(J),J=1,I5), starting at s = O; this is the curvature boundary value $\kappa\ l_{ref}$ or $\frac{l_{ref}}{R}$. At present, for external flow it is to be supplied at the RS nodes, while for internal flow it is to be supplied at the positions of XCURV(J) in (6) above.

(8) (DIVA(J),J=1,I5), starting at s = O,if I(1Ø)≠ Ø;

this is the divergence origin x_o (a function of s in general) in l_{ref} units.

(9) (VWA(J),J=1,I5), starting at s = O, if I(12)=1; this is the transpiration velocity $\frac{V_w}{U_{ref}}$. It is positive for injection and negative for suction.

(10) (XP(J),J=1,NXP) with format 16I5; supplied if I(3)<O and then NXP=-I(3). This is an integer array giving the numbers of the stations at which information is to be printed out.

(11) (U(J),J=1,I62) with format 7F1Ø.Ø; this is the starting velocity profile U/U_e supplied, whether "unrealistic" or "realistic". It is only supplied if I(2)=1. The first value starts at the first mesh point n = Δn and the I62'th (last) value is on the MS. Δn is the initial MS height/I62.

(12) (TAU(J),J=1,I62); this is the starting $\frac{\tau}{\rho U_e^2}$ profile and is supplied (for I(2)=1 only) as for the starting velocity profile.

(13) PW,(PRESS(J,1),J=1,I62); this is the starting pressure profile at $s = s_o$ and is supplied only if I(3)>O. The pressures are input as $\frac{p - p_{ref}}{\rho U_{ref}^2}$, starting with the wall pressure and ending with the external pressure on the MS (I62th. value).

(14) PWEND,(PEND(J),J=1,I62); this is the downstream boundary condition pressure profile and is supplied (for I(13)>O only) in the same way as for the starting profile in (13) above. It is assumed to be at a distance $s = s_o$ + RLEND=A(3)+A(1).

(d) Creation of Fixed Data File TRAVDAT

This only applies to internal flows and gives program TRAVERS information about the geometry of the duct and the velocity profiles at the various "traverse" stations where the mass flow rate is to be computed by integration of these profiles. The data is supplied in the following way:

(1) WIDTH (Format 8F1Ø.Ø); this is the width of the duct H_D/l_{ref}.

(2) NTRAVS,NOFBDY (Format 3I5); NTRAVS is the number of "traverse" stations while NOFBDY is the number of velocity profile points across each "traverse" station (all assumed the same), where these do not include the lower and upper walls of the duct, i.e. just the number of points off the body (duct walls).

(3) NPTS,IBOT,ITOP (Format 3I5) } NTRAVS

(4) THETA,(DELT(J),J=2,NPTS+1) (Format 8F1Ø.Ø) } times

Both (3) and (4) are supplied for each "traverse" station in sequence and in the order shown; NPTS is the number of points on the velocity profile, again excluding the duct walls. IBOT, ITOP are the element numbers on the bottom and top surface of the duct at the "traverse" station. THETA is the inclination in degrees to the X-axis, of the duct at the station where the traverse is made. DEL(J) is an array giving the values of n across the duct at which the velocity profile is measured at the "traverse" station, excluding the duct walls,i.e. the values of n for the off-body points only.

(e) Input Data for program SMOOTH

ND, (XNODE(J),J=2,ND+1) in free format form for CDC machines; these data give the number and s-coordinates, respectively, of the "smoothing points" used in smoothing the distribution p'(s); they do not include the first and last values (at $s = s_o$ and $s = s_{max}$). These data have to be supplied for each "iteration" of the interaction cycle after the first, i.e. for NORUN=2,3,...

(f) Initialisation of Viscous/Inviscid Iteration Cycle

The iteration cycle is initialised by writing the number 1 using a binary WRITE statement, onto the variable data file MATDAT.

(g) Running the Interaction Calculation

We shall describe here how the iteration cycle was executed on the KRONOS operating system for the CDC machines at Imperial College. After creation of the fixed data files for the particular problem and the initialisation of the iteration cycle, as described in the above sections, a "control card record" or "procedure file" (called CYCLE) was created, which contained the relevant program executions and data file transfers in the correct sequence exactly as shown in Fig. (40). A listing of this procedure file is given in Appendix A8. Note also that programs MATCH, AMOS, TURB, TRAVERS and SMOOTH were first stored as compiled binary files (see Appendix A8). A small sequence of control cards (see Appendix A8) then instructed the execution of procedure file CYCLE as many times as required, according to the value of R1. R3=1 for external flows (so that the execution of TRAVERS is skipped) and R3=∅ for internal flows.

It has been found very convenient to execute the iteration cycle in this way rather than as one program, since the separate programs and their associated functions can be treated logically separate. This also avoids complex overlaying of the programs to reduce core size and, for operational speed and convenience, the core sizes and execution times can be kept to the lowest job category on the Imperial College Computer system, so that turnaround time is minimised.

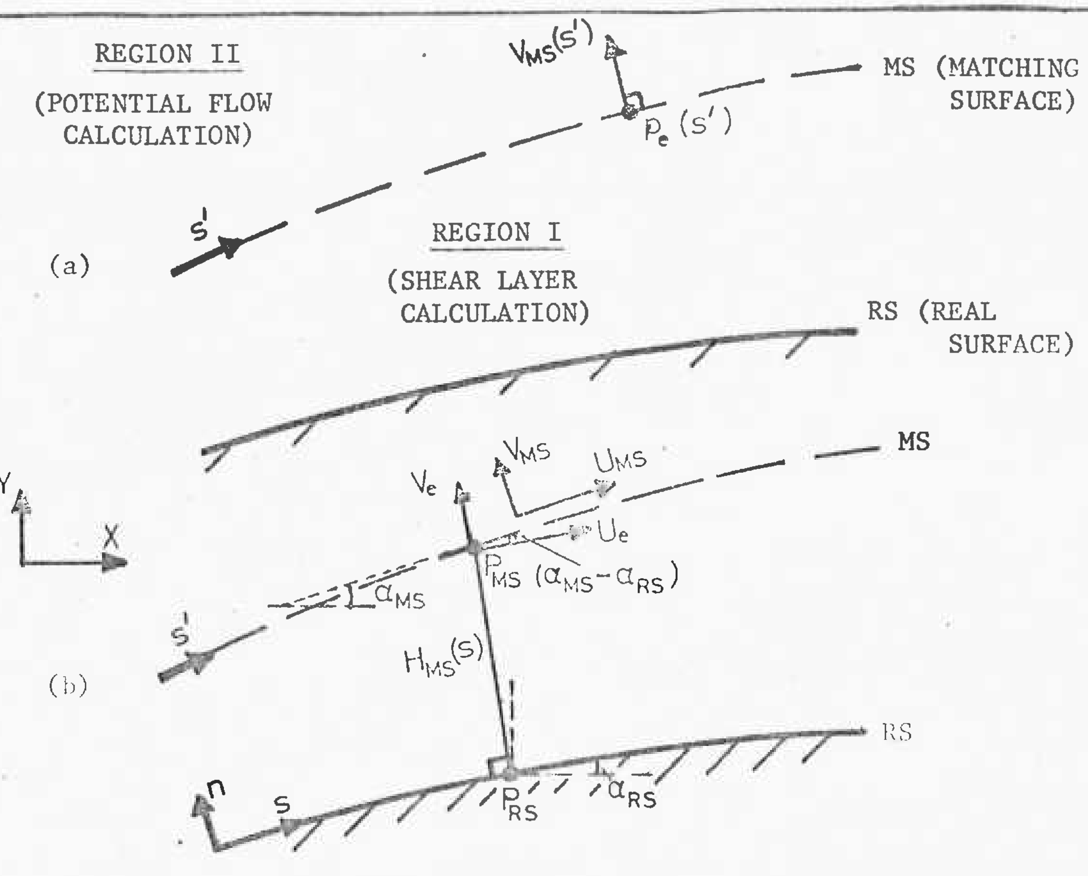


FIG (34)

VISCOUS/INVISCID MATCHING SCHEME

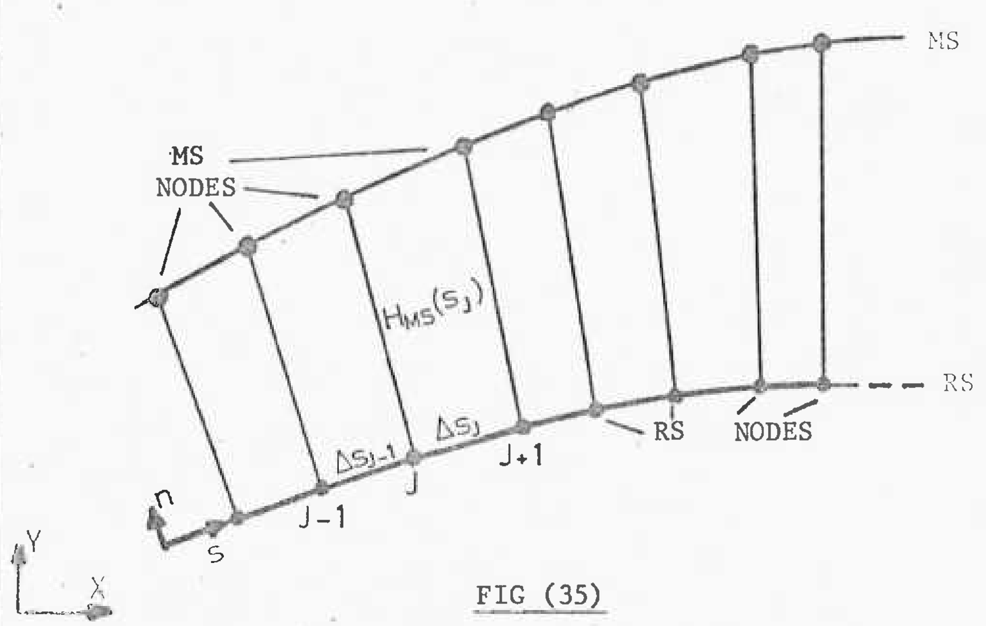
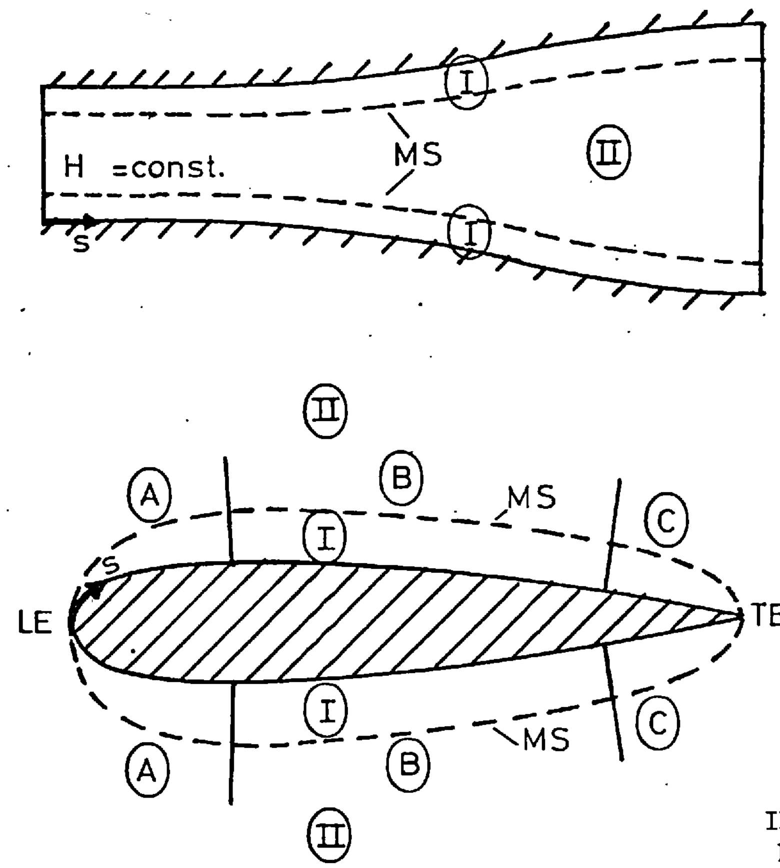


FIG (35)

NUMERICAL IMPLEMENTATION OF MATCHING SCHEME



(a)

INTERNAL FLOW

(b)

EXTERNAL FLOW

FIG (36)

INITIAL GUESS FOR MATCHING SURFACE

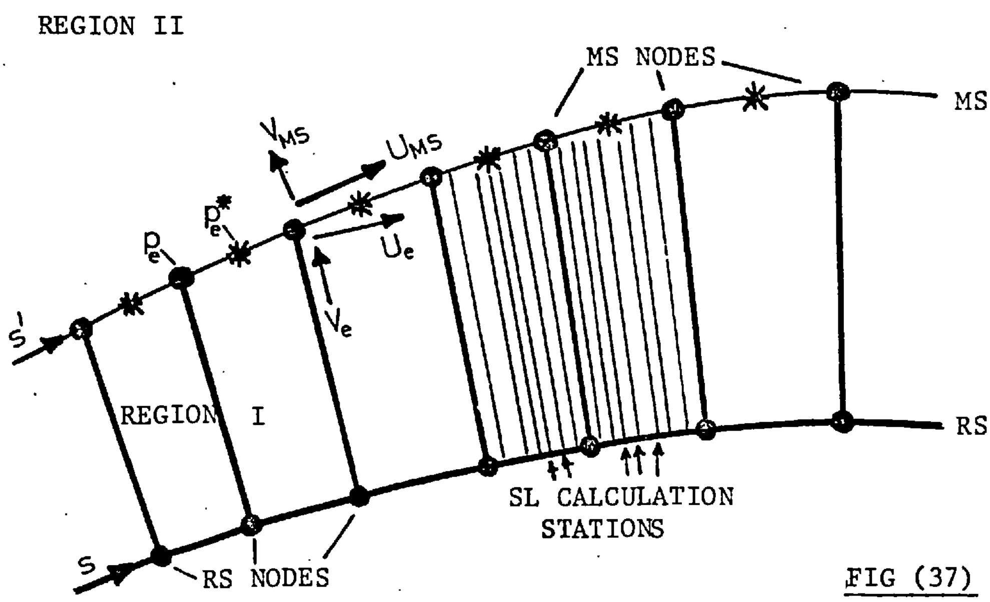


FIG (37)

NUMERICAL SCHEME FOR VISCOUS/INVISCID MATCHING

N.B. THE SL CALCULATION STATIONS NEED NOT NECESSARILY COINCIDE WITH NODES

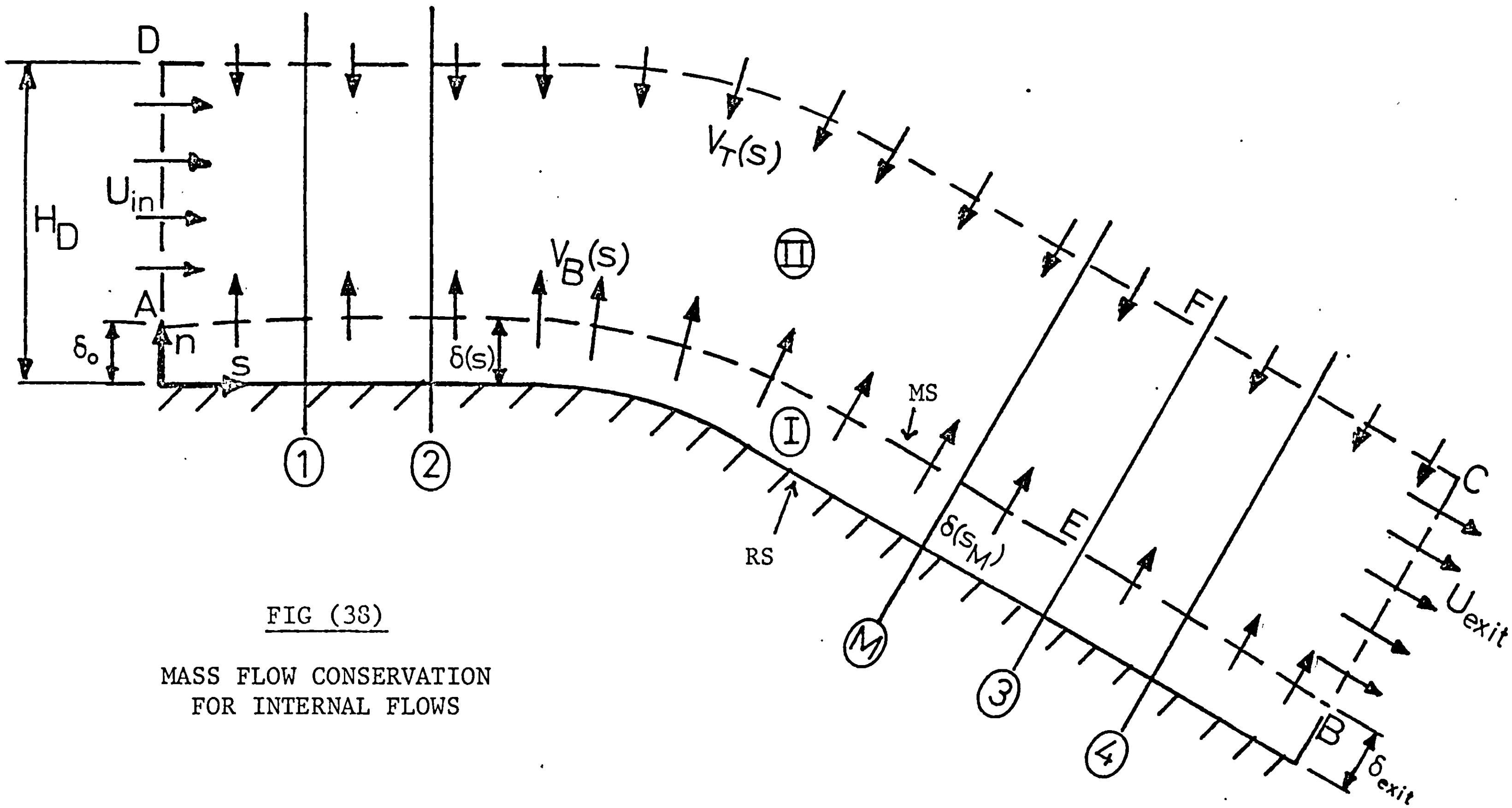


FIG (38)

MASS FLOW CONSERVATION
FOR INTERNAL FLOWS

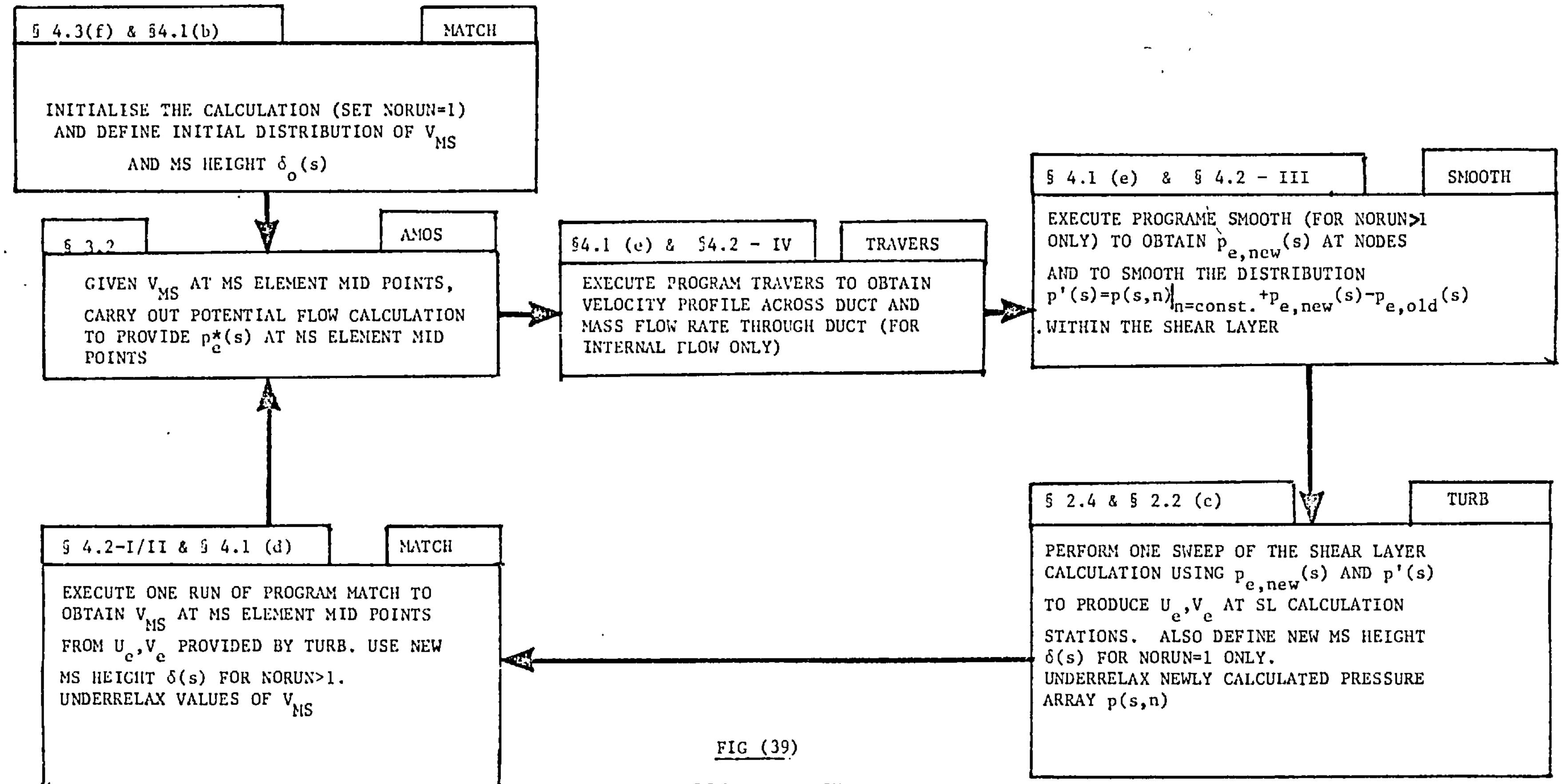


FIG (39)

FLOW DIAGRAM OF VISCOUS/INVISCID ITERATION CYCLE

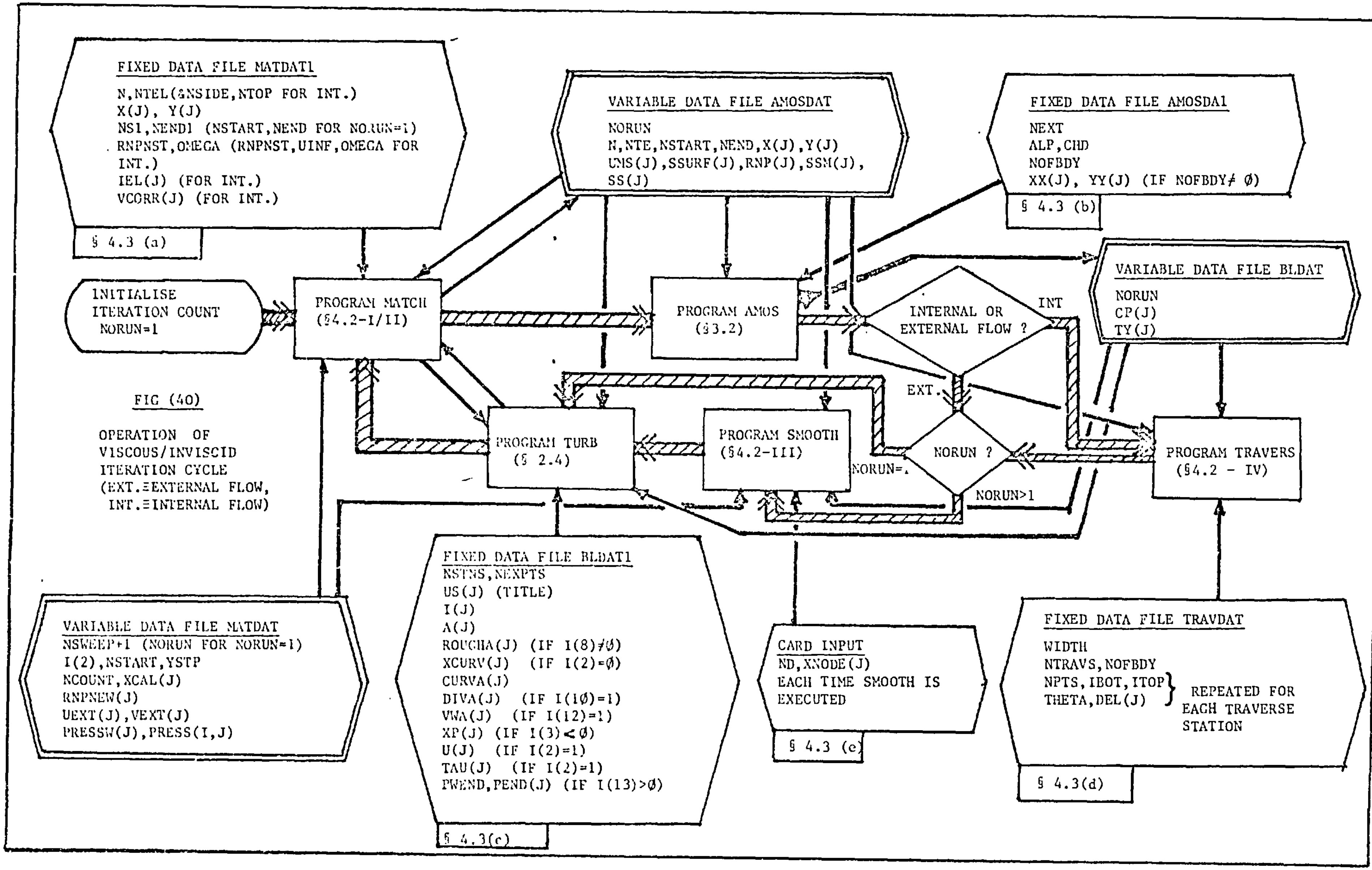


FIG (40)

OPERATION OF VISCOUS/INVISCID ITERATION CYCLE (EXT.≡EXTERNAL FLOW, INT.≡INTERNAL FLOW)

CHAPTER 5

TEST CASES

In the following sections we shall consider two test cases to which the present method has been applied. The first is the flow through a curved constant width duct and the second is the flow around a symmetrical NACA 0012 aerofoil at zero incidence and omitting the wake calculation. It must be stated that the real test of the present method is shown when applied to the curved duct case, since, as we shall see, this represents a severe test case due to the large rates of change present in the streamwise direction. The aerofoil test case is presented merely to demonstrate the ability of the method to deal with external flow problems. However, due to the absence of a wake calculation, the calculation for the aerofoil is as yet carried out only up to a distance of 60% of the chord from the leading edge. If one proceeded any further without a wake calculation, one would run into problems in the TE region.

5.1 TEST CASE (1) (INTERNAL FLOW): THE CURVED DUCT

(a) Geometrical Description, Starting and Boundary Values

The duct has parallel walls and consists of a straight section which curves through 30° and then becomes straight again (see Fig. (41)). The duct width is 5 in. and the radius of curvature of the bottom wall (the convex surface) is 5 in. The initial shear layer is fully turbulent and measurements of velocity and Reynolds shear stress profiles were made (Smits, Young and Bradshaw (1978), to be submitted to the Journal of Fluid

Mechanics) starting at a station (1) 3 in. upstream of the beginning of the bend on the convex side. We shall only be concerned here with the convex (bottom) wall of the duct, which is the surface on which the shear layer calculation has been performed. The initial shear layer thickness at station (1) was about 1 in.

Fig. (42) shows how the duct was divided into elements for use in the potential flow method. It also shows the initial guess for the MS, which was made at a constant height 1.2 in. from the convex surface, so that it was well outside the edge of the initial shear layer. The potential flow calculation is performed in region II and the shear layer calculation in region I. We shall now consider the potential flow and shear layer calculations separately.

(i) The Potential Flow Calculation

With the initial guess for the MS as shown in Fig. (42), the inlet and outlet velocities U_{in} and U_{exit}, respectively, were specified as normal velocities at the mid points of the elements in the entry and exit planes. We have also provided artificial extensions to the duct both upstream and downstream, so that the flow region of interest is well removed from the effects of the corners. The velocity corrections at the mid points of the corner elements were obtained by trial and error; the velocity profiles across the duct were calculated at "traverse stations" A, B, C and D shown in Fig. (42) and at the off-body points indicated. The mass flow rate at those stations was then computed by integrating the velocity profiles and was compared with what the mass flow rate should be (by performing the mass flow balance of §4.1(e)). The error in the mass flow rate was then corrected by applying the velocity corrections shown in Fig. (42). This figure also shows the lengths Δx and Δy of the corner elements. Since the MS height is changed during the first sweep of the shear layer calculation, we will, in general, need to perform the above procedure only once again for the second run of the potential flow calculation; with the new MS, the values of the correction velocities for the first run do not give the correct mass flow rate, so that new correction velocities need to be found for the second run onwards, using the same procedure outlined above. However, it is not necessary to perform this more than twice, since the MS height is kept fixed from the second run onwards. Although there is a slight drift in mass flow on subsequent runs (due to changes in υ_p affecting the required corner corrections), yet this is very small and can be neglected. The inlet velocity U_{in} is adjusted to obtain the correct starting value for the external pressure (see section (ii) below) to agree with the value obtained from the experiment.

The initial guess for the velocities normal to the elements is .002 for the regions upstream and downstream of the turbulent shear layer region and -.018 in the turbulent region. For the upper wall we have included a constant normal velocity .002 into the duct to account approximately for the effect of the shear layer on that surface: this is an adequate fit to the data but could be improved. In real problems both shear layers would be calculated.

(ii) The Shear Layer Calculation

The starting U and τ profiles are specified at the first station (1). The U profile is "unrealistic" since $\frac{U}{U_e}$ tends to the value 1 at the edge of the shear layer. The initial values of U_e and $\frac{c_f}{2}$ (at station (1)) are given as $\frac{U_e}{U_{ref}} = 1.11$ and $\frac{c_f}{2} = 1.375 \times 10^{-3}$, so that the initial value of $\frac{p_e - p_{ref}}{\frac{1}{2}\rho U_{ref}^2}$ is -.23 approximately. The Reynolds number $\frac{U_{ref}\, l_{ref}}{\nu}$ is 6.256×10^4 (where $l_{ref} = 1$ in.). The curvature boundary value is given as a ramp function (see Fig. (43)); the maximum value of the curvature $\kappa\, l_{ref}$ is 0.2. c_1, c_2 are both set to zero at present.

The initial guess for the two dimensional pressure array uses the approximation $\frac{\partial p}{\partial n} = 0$ everywhere. Although crude, the effect of this guess quickly disappears with the iterations performed. This approximation is quite adequate at $s = s_o$ and $s = s_{max}$ since $\frac{\partial p}{\partial n}$ there is small. In order to obtain small streamwise steps to cope with the large streamwise rates of change, we have chosen an s-step factor A(6) of 0.3. We have taken the number of steps for the shear layer calculation to be 99, thus yielding 100 SL calculation stations altogether. The value of the under-relaxation factor A7 chosen was 0.3.

(b) Results

The viscous/inviscid iteration cycle was arbitrarily run ten times for the curved duct test case. The computer program printouts for these ten runs are given in the relevant section of Appendix A7. Fig. (44) shows the wall pressure distribution $\frac{p_w - p_{ref}}{\frac{1}{2}\rho U_{ref}^2}$ on each sweep of the calculation. This is the wall pressure obtained directly from the shear layer calculation (without smoothing). We can see that the first calculated wall pressure distribution is quite close to the final converged result, so that the crudity of the initial guess

$\frac{\partial p}{\partial n} = 0$ quickly disappears. We can also see that convergence is achieved by about the eighth sweep and that the approach to convergence is monotonic.

Fig. (45) shows a comparison between several pressure distributions; the converged wall pressure distribution, the converged external pressure distribution, the experimental wall pressure distribution, the inviscid flow wall pressure distribution (obtained by using the RS as a boundary, on a separate run) and the pressure distribution obtained by making the crude centrifugal approximation $\frac{\partial p}{\partial n} = \frac{\rho {U_e}^2}{(n+R)}$ between the MS and the RS. It can be seen that the calculated wall pressure agrees well with the experimental one; especially in the suction peak region which corresponds to the middle of the convex bend. This is a region of rapid variation in pressure and has been predicted quite well by the method. We can also see that the suction peak is grossly over-estimated (c_p too low) by the purely inviscid flow and by the centrifugal approximation.

The assumption that the streamlines are all parallel to the surface, used in the centrifugal approximation, is quite inadequate in regions of rapidly changing curvature. We can see the extent of the pressure difference across the shear layer by observing the difference (especially in the bend region) between the external and wall pressures.

Fig. (46) shows the converged pressure profiles at specified shear layer calculation stations. These stations correspond to the stations at which all profiles for the shear layer calculation are printed out (see program printouts for sweep no. 10 of the shear layer calculation). We can see how $\frac{\partial p}{\partial n}$ increases rapidly through the bend, relaxing back to $\frac{\partial p}{\partial n} \simeq 0$

at the last station.

Fig. (47) shows the velocity vectors across the shear layer,for the same stations as Fig. (46). U is scaled with respect to the maximum value over all the stations shown and V is scaled with respect to its maximum value over all the stations shown. The V-velocity scale is stretched to demonstrate the extent to which the streamline angle changes near the edge of the shear layer. It can be seen that the streamlines converge very rapidly towards the wall just before the bend. Approximately in the middle of the bend, the streamlines start moving away from the wall until at approximately the end of the bend region they rapidly diverge away from the wall. Further downstream the streamlines become gradually more parallel until by the last station they are very nearly parallel. Fig. (48) shows the streamwise variation of the streamline angle on the MS, which confirms the very rapid changes involved, especially in the bend region.

In Fig. (49), the calculated (converged) skin friction distribution is compared with the experimentally obtained distribution (using a Preston Tube). We can see that the present method over-estimates the values of c_f. This may be mainly due to the inability of the turbulence model used in the calculation, to predict the turbulence structure for highly curved flows. We have not included any curvature (extra strain rate) correction to the turbulence model and from Castro and Bradshaw (1976) we see that the turbulence structure of highly curved shear layers exhibits an entirely different behaviour, so that a fair comparison of the skin friction distributions cannot be made in the absence of a reasonably reliable turbulence model.

Fig. (50) demonstrates the impossibility of using conventional displacement thickness matching for this type of problem, where $\frac{\partial p}{\partial n}$ is large; the calculated velocity profile is that for station (34) of Fig. (47) and we can see that $\frac{\partial U}{\partial n}$ near the shear layer "edge" is quite considerable, so that any attempt to use the displacement surface concept would lead to gross errors and would completely misrepresent the flow. This can be seen from the comparison, in Fig. (50), of the calculated velocity profile with two other "boundary layer" type profiles; one has the same total pressure as the calculated profile but with constant static pressure equal to the wall pressure and the other has the same total pressure but with a constant static pressure equal to the external pressure. These would be "unrealistic" velocity profiles in the context of the shear layer calculation method.

The approximate calculation times (for one iteration of the viscous/inviscid calculation cycle) on the CDC 6500 computer at Imperial College for 50 elements around the duct, 100 stations for the shear layer calculation and 39 grid points across the shear layer, are:

(i) 5 secs. for the potential flow calculation (including the execution of programs MATCH, AMOS and TRAVERS) but excluding the inversion of the influence coefficient matrix which takes approximately 7 secs.

(ii) 20 secs. for the shear layer calculation (program TURB).

(iii) 9 secs. for the cubic spline smoothing of the (100 x 39) pressure array (program SMOOTH).

The maximum amount of core needed was 25,000 decimal words.

Footnote

We have additionally included Figs. (47a) and (47b); Fig. (47a) shows the velocity vectors for the curved duct flow but with the normal velocity (V) scale unstretched, so that this presents a true picture of the flow. Fig. (47b) shows the velocity vectors with the same scale as Fig. (47a) only they have been presented in a straight line so that the true angle which the flow makes with the local surface can be seen.

5.2 TEST CASE (2) (EXTERNAL FLOW): THE AEROFOIL

(a) Geometrical Description, Starting and Boundary Values

The aerofoil in this test case was merely used to demonstrate the applicability of the method to external flows. It is a symmetrical NACA 0012 aerofoil (see Fig. (51a)) and the case considered is that of zero incidence. The coordinates of the aerofoil surface are given in Appendix A4. Fig. (51b) shows the nodes chosen for the RS (and also the initial MS guess) where the vertical scale has been exaggerated to show the shape of the initial MS. The initial guess for the height of the MS chosen was such that 22 profile points were obtained across the shear layer, which is well outside the very thin laminar BL. The initial guess for the end of the turbulent region was set at node number 16 on the upper surface (24 on the lower surface) and after 119 steps of the turbulent shear layer calculation were performed, this was then adjusted to node number 14 on the top surface (see relevant printouts of results in Appendix A7). Thus, the shear layer calculation was carried out to approximately 60% of the chord.

The laminar BL calculation was performed up to node number 8 on the upper surface, which is the first node after which the transition criterion was obeyed. The curvature distribution for the turbulent region is shown in Fig. (52), the curvature boundary value being supplied at the RS nodes. The curvature distribution for the aerofoil surface is given in Appendix A4. The Reynolds number $\frac{U_{ref}\, l_{ref}}{\nu}$ chosen was 7.5×10^6. U_{ref} was taken as the undisturbed stream velocity and l_{ref} the chord length of the aerofoil. Both were arbitrarily set to 1. The s-step factor A(6) was taken as 1 and the under-relaxation factor A7, for the pressure array, was again taken as 0.3. The values of c_1, c_2 were again taken to be zero.

(b) Results

Fig. (53) shows the convergence of the wall pressure distribution $\frac{p_w - p_{ref}}{\frac{1}{2}\rho U_{ref}^2}$ which can again be seen to be monotonic. We have, as for the curved duct case, chosen to execute ten runs of the viscous/inviscid calculation procedure. The curvature distribution (and the resulting pressure distribution) for this test case are mild in comparison with the violent flow of the curved duct case. The real test of the present method would be its application in the TE region of the aerofoil where normal pressure gradients are large; for the main part of the aerofoil (up to about 80% chord) an ordinary boundary layer/displacement thickness matching solution could be applied without any gross errors. However a complete calculation including the wake has not yet been performed, due to the absence of an appropriate wake calculation (which would be essential in such a case).

Fig. (54) shows the calculated (converged) wall pressure distribution compared to the inviscid flow distribution carried out on the actual aerofoil surface (the RS). Fig. (55) compares the inviscid wall pressure distribution, the calculated wall pressure distribution and the wall pressure distribution obtained from the centrifugal approximation. It can be seen here that the centrifugal approximation compares quite well with the calculated results, since $\frac{\partial p}{\partial n}$ for the calculation region considered, is very small. Finally, Fig. (56) shows the calculated skin friction distribution over the aerofoil surface; the irregularity in the region, 55% to 60% chord is probably due to the sudden "cut-off" of the MS from its value at 60% chord to the value zero at the TE.

Typical calculation times for one viscous/inviscid iteration cycle (on the CDC 6500 computer at Imperial College) for 38 elements around the aerofoil surface, 120 shear layer calculation stations and 21 grid points across the shear layer, are:

(i) Approximately 3 secs. for the potential flow calculation (including the execution of programs MATCH and AMOS) and excluding the inversion of the influence coefficient matrix (a 38 x 38 matrix), which takes about another 2.5 secs.

(ii) Approximately 15 secs. for the shear layer calculation (program TURB).

(iii) Approximately 5 secs. for the cubic spline smoothing of the (120 x 21) pressure array (program SMOOTH).

The maximum amount of core needed was 25,000 decimal words.

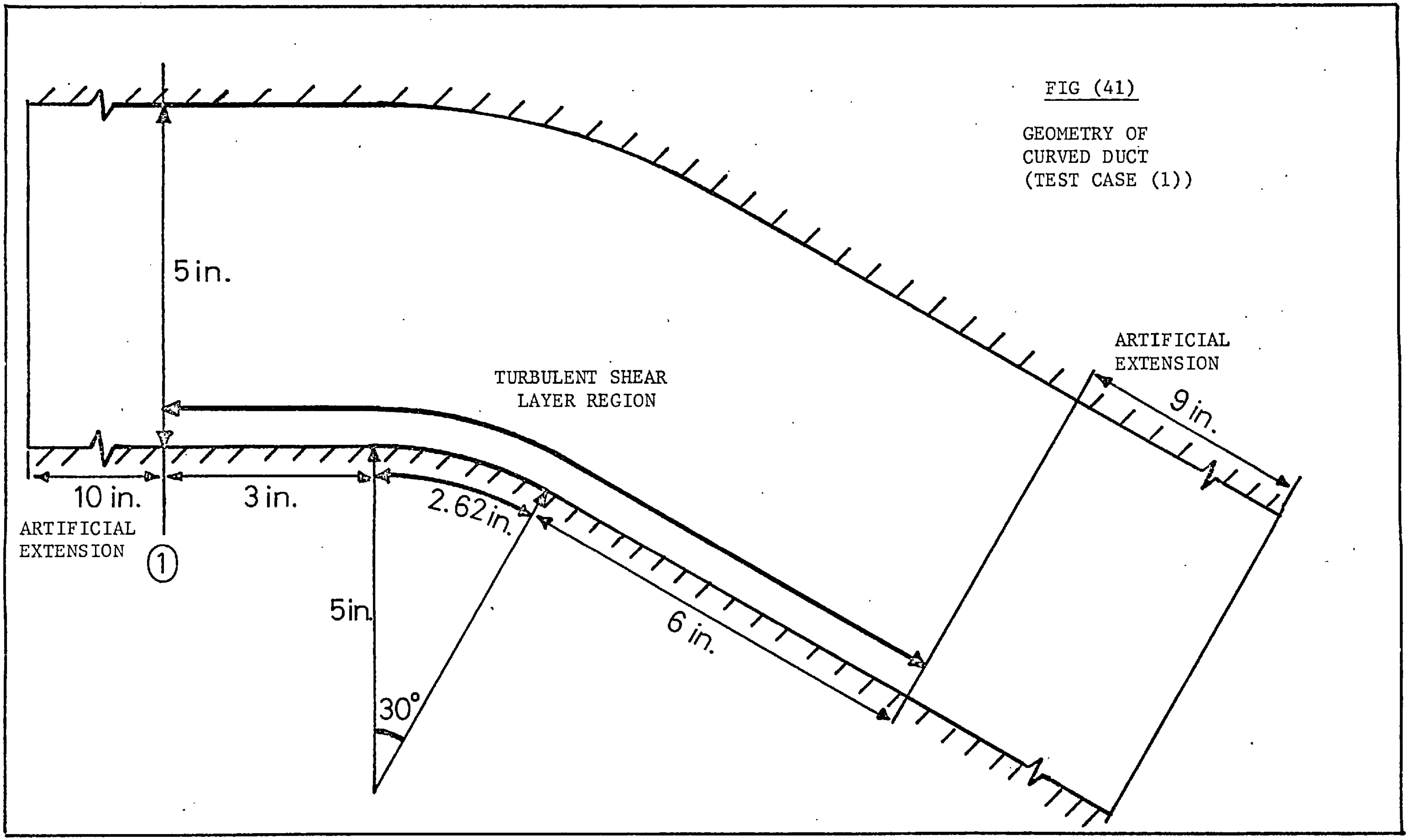


FIG (41)

GEOMETRY OF CURVED DUCT (TEST CASE (1))

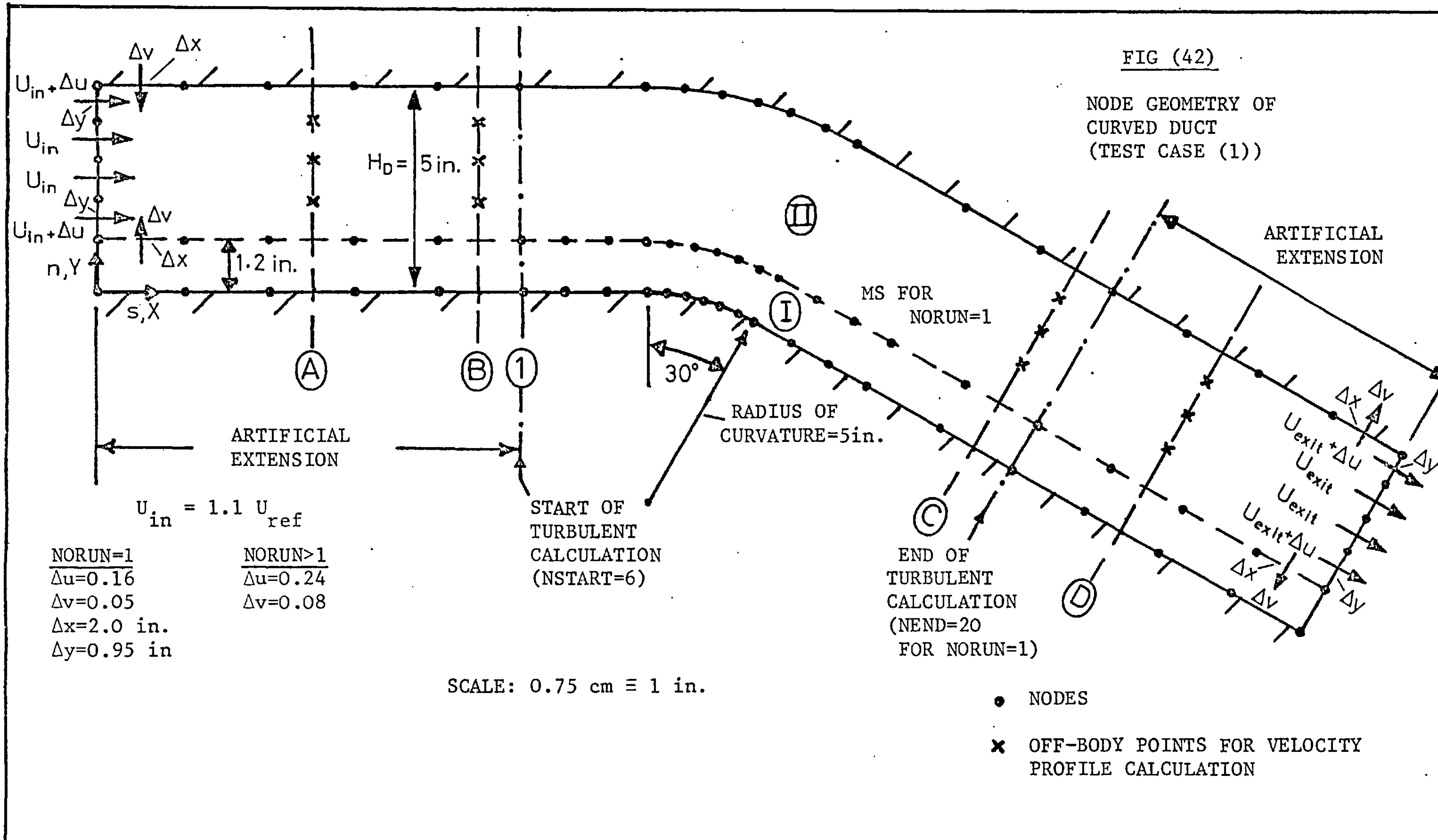


FIG (42)

NODE GEOMETRY OF CURVED DUCT (TEST CASE (1))

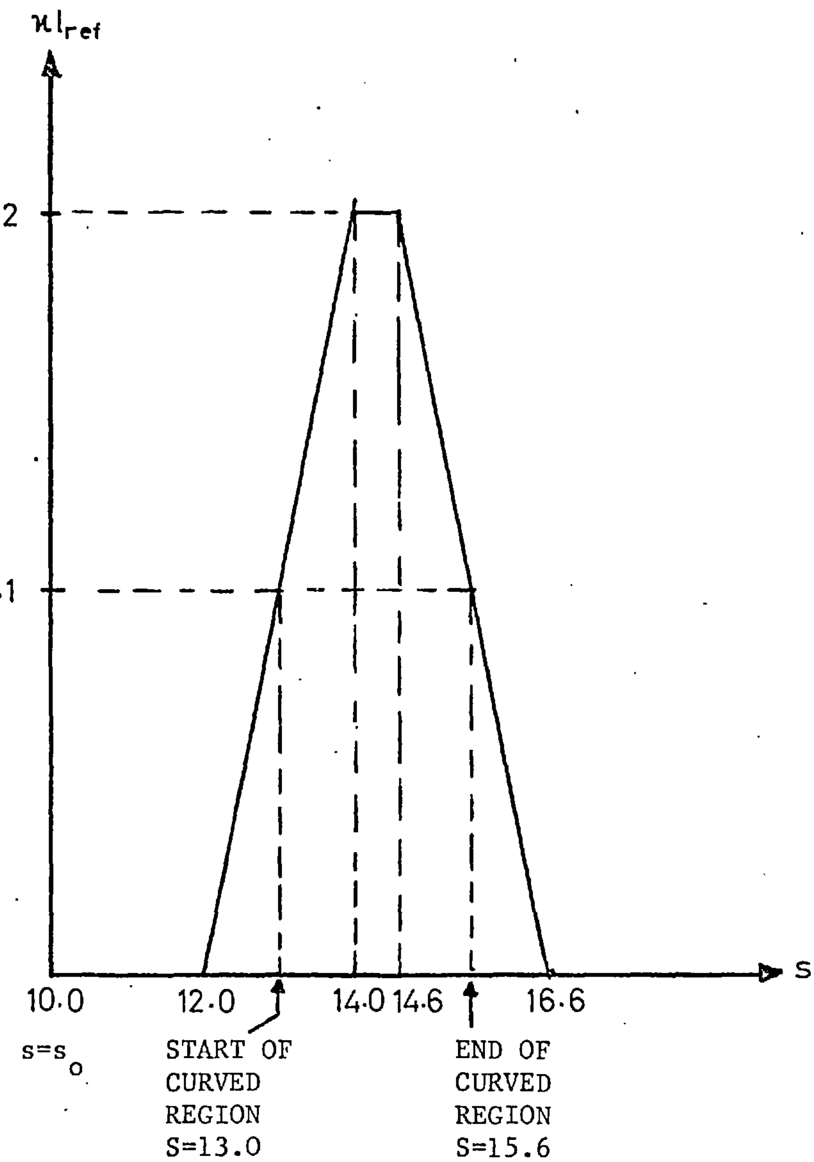


FIG (43)

CURVATURE DISTRIBUTION
FOR CURVED DUCT

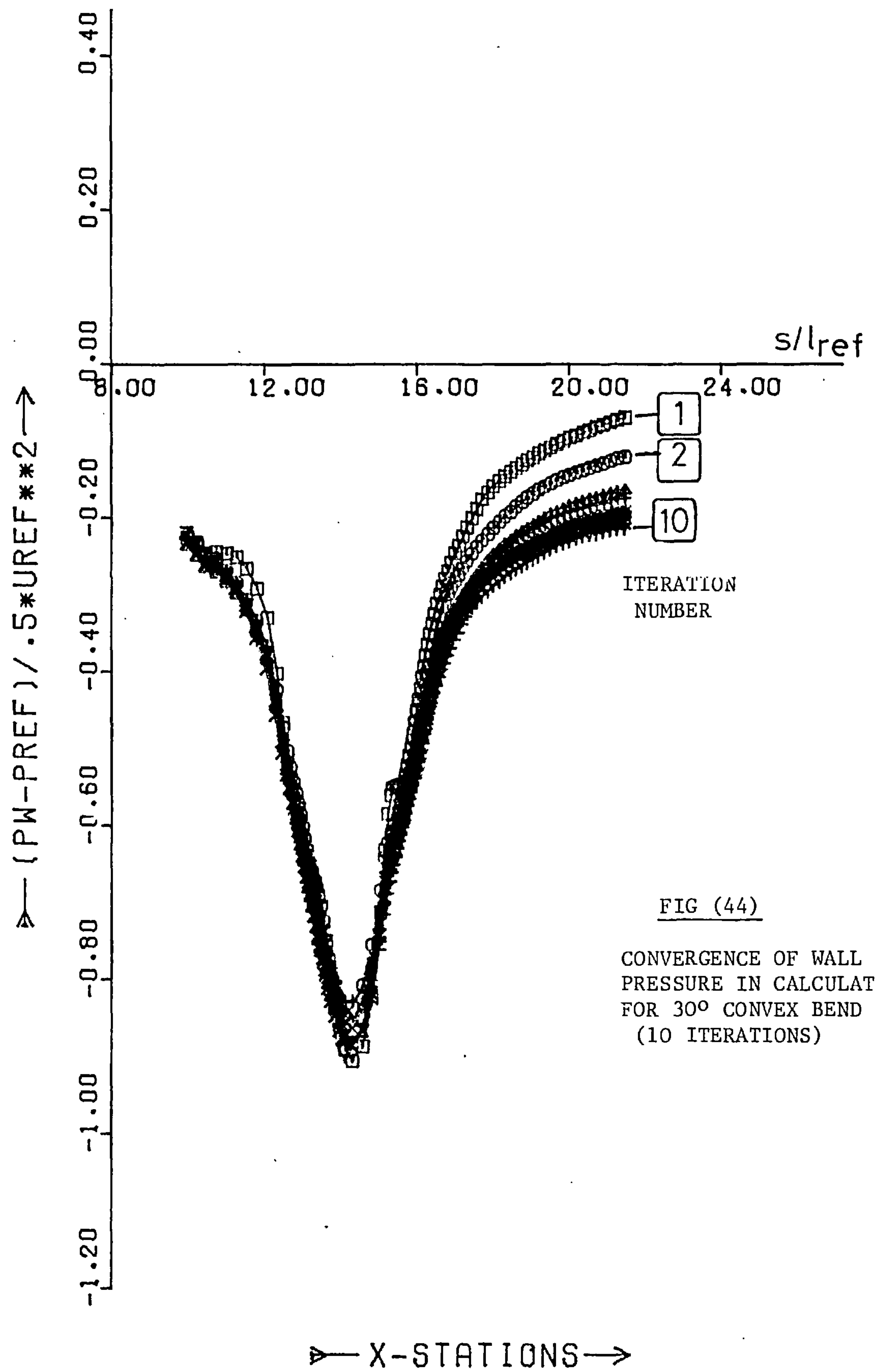


FIG (44)

CONVERGENCE OF WALL PRESSURE IN CALCULATION FOR 30° CONVEX BEND (10 ITERATIONS)

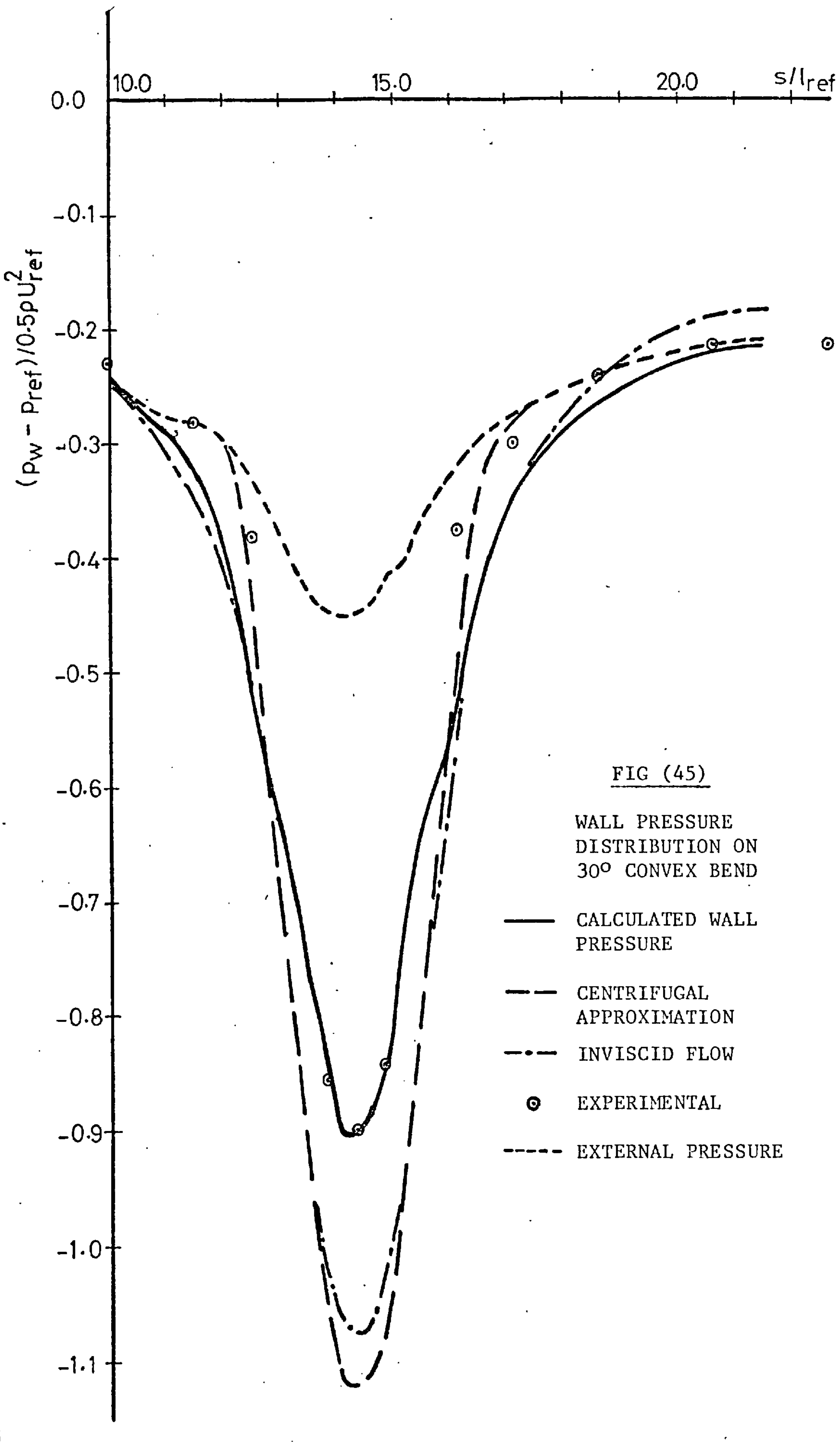


FIG (45)

WALL PRESSURE DISTRIBUTION ON 30° CONVEX BEND

CALCULATED WALL PRESSURE

CENTRIFUGAL APPROXIMATION

INVISCID FLOW

EXPERIMENTAL

EXTERNAL PRESSURE

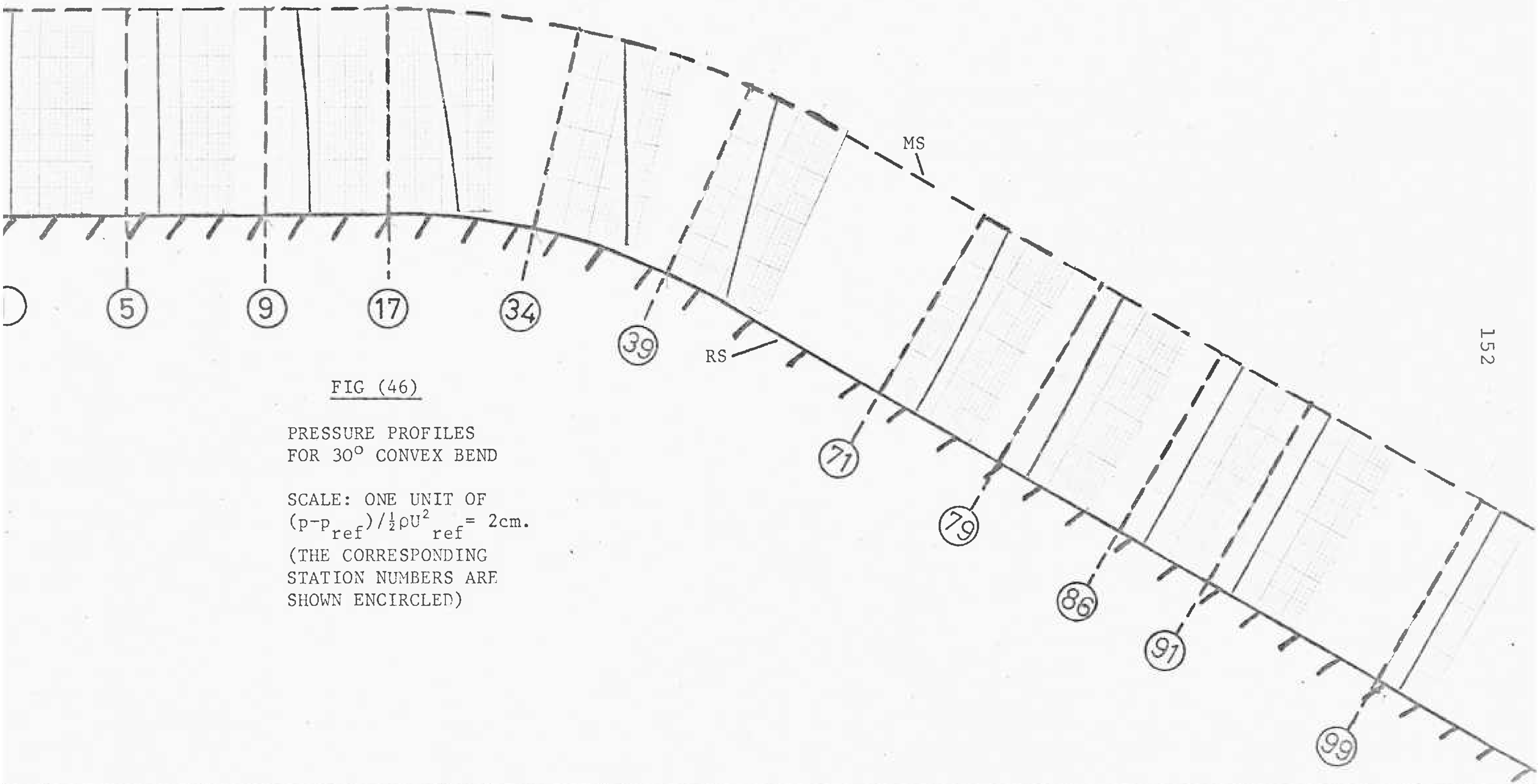


FIG (46)

PRESSURE PROFILES
FOR 30^{o} CONVEX BEND

SCALE: ONE UNIT OF
$(p-p_{ref})/\frac{1}{2}\rho U^2_{ref}$ = 2cm.
(THE CORRESPONDING
STATION NUMBERS ARE
SHOWN ENCIRCLED)

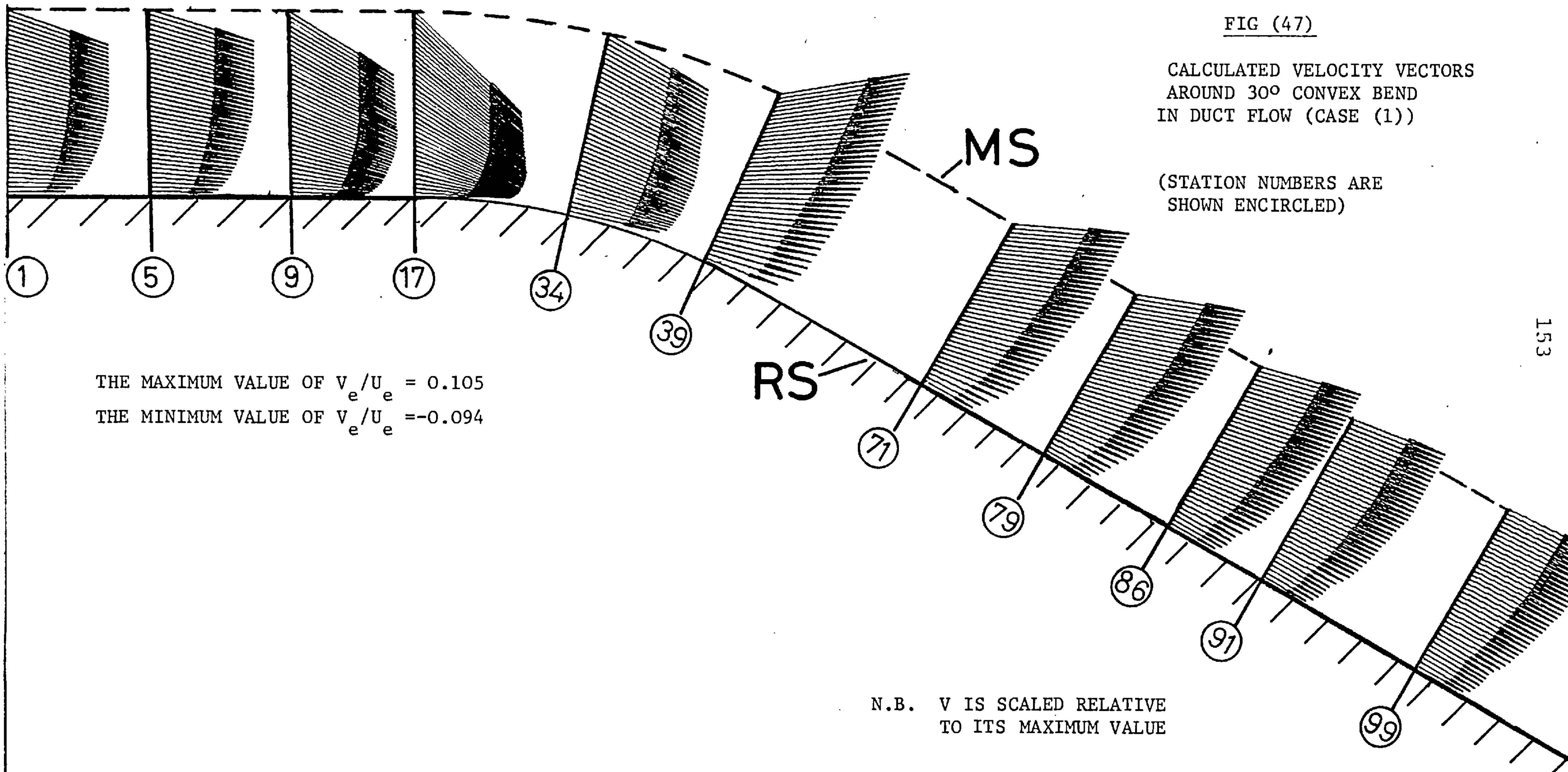


FIG (47)

CALCULATED VELOCITY VECTORS AROUND 30° CONVEX BEND IN DUCT FLOW (CASE (1))

(STATION NUMBERS ARE SHOWN ENCIRCLED)

THE MAXIMUM VALUE OF V_e/U_e = 0.105

THE MINIMUM VALUE OF V_e/U_e =-0.094

N.B. V IS SCALED RELATIVE TO ITS MAXIMUM VALUE

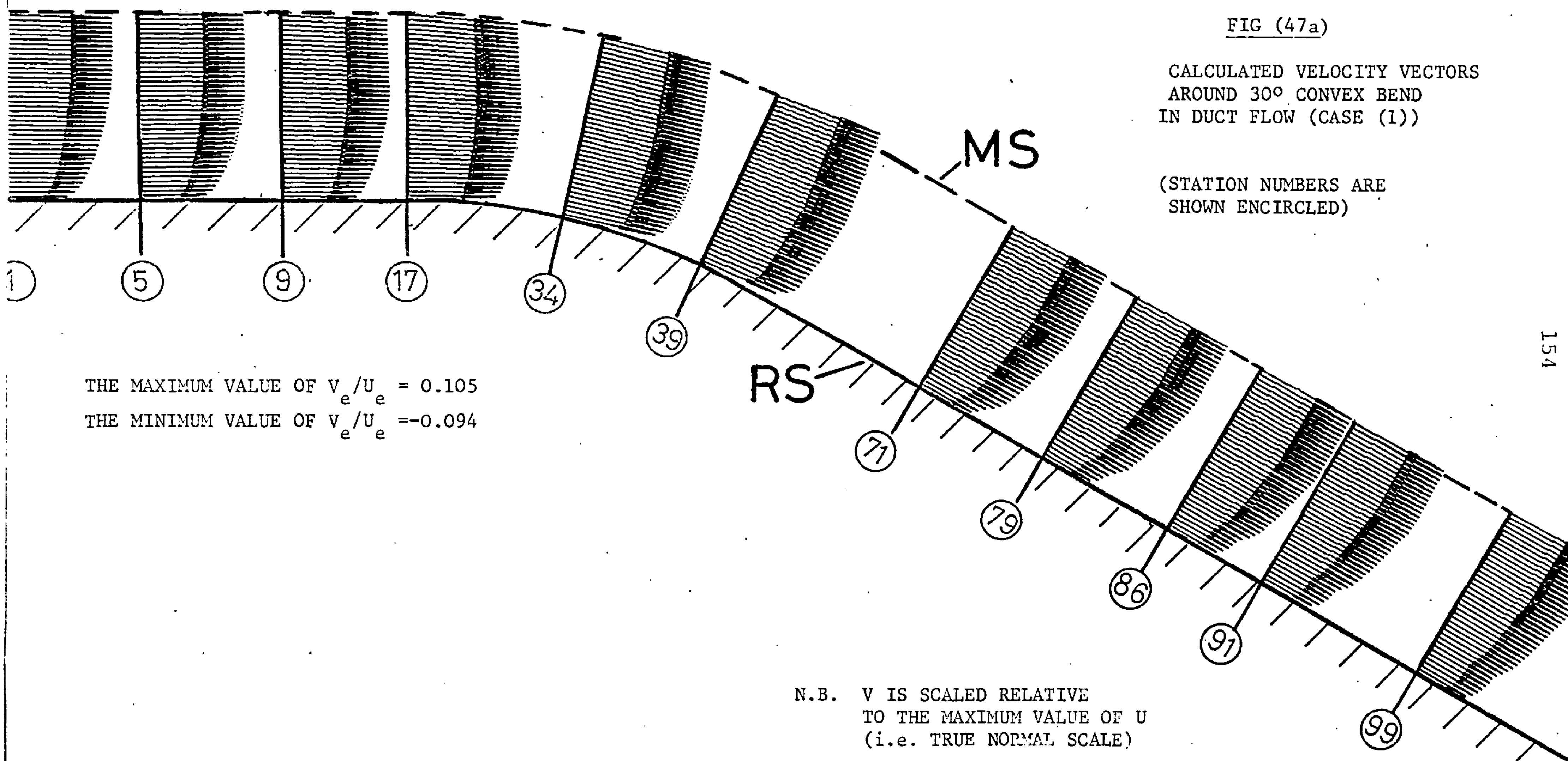


FIG (47a)

CALCULATED VELOCITY VECTORS AROUND 30° CONVEX BEND IN DUCT FLOW (CASE (1))

(STATION NUMBERS ARE SHOWN ENCIRCLED)

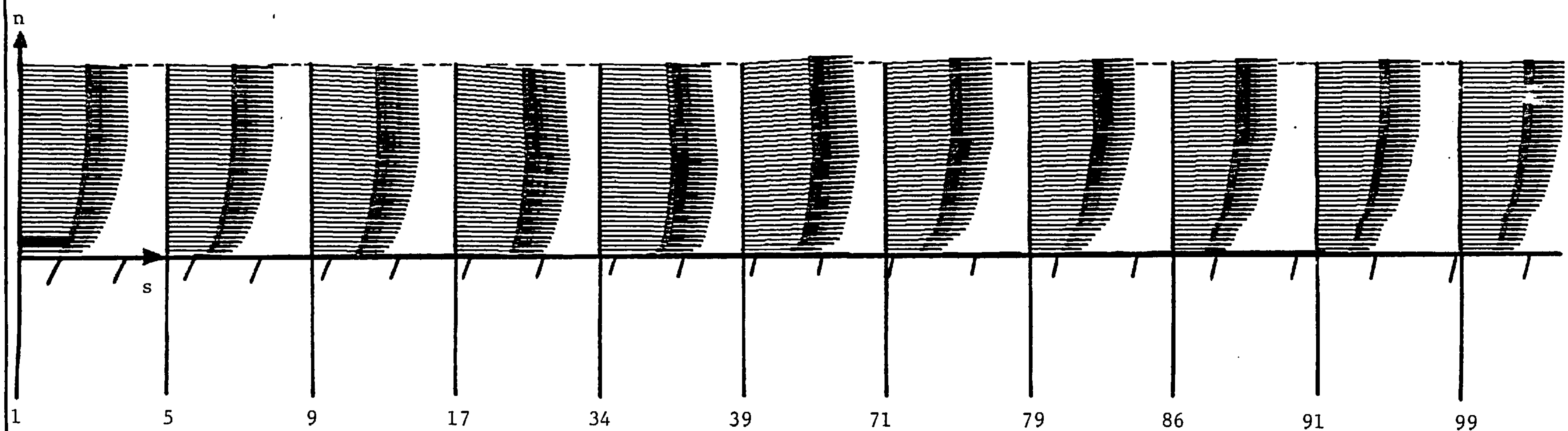
THE MAXIMUM VALUE OF V_e/U_e = 0.105

THE MINIMUM VALUE OF V_e/U_e =-0.094

N.B. V IS SCALED RELATIVE TO THE MAXIMUM VALUE OF U (i.e. TRUE NORMAL SCALE)

FIG (47b)

CALCULATED VELOCITY VECTORS OF FIG (47a)
DISPLAYED ON A STRAIGHT LINE
(STATION NUMBERS ARE SHOWN)



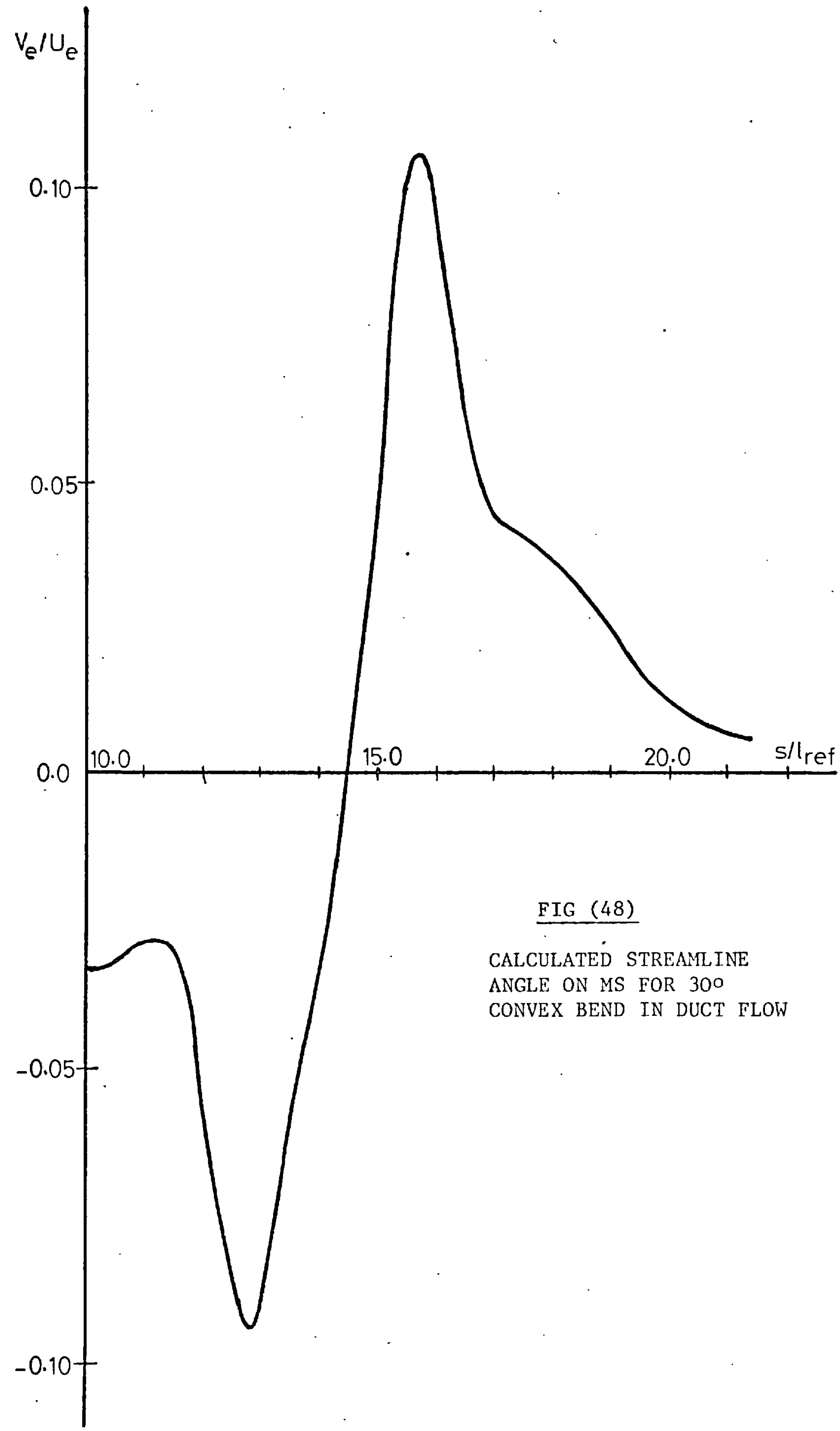


FIG (48)

CALCULATED STREAMLINE ANGLE ON MS FOR 30° CONVEX BEND IN DUCT FLOW

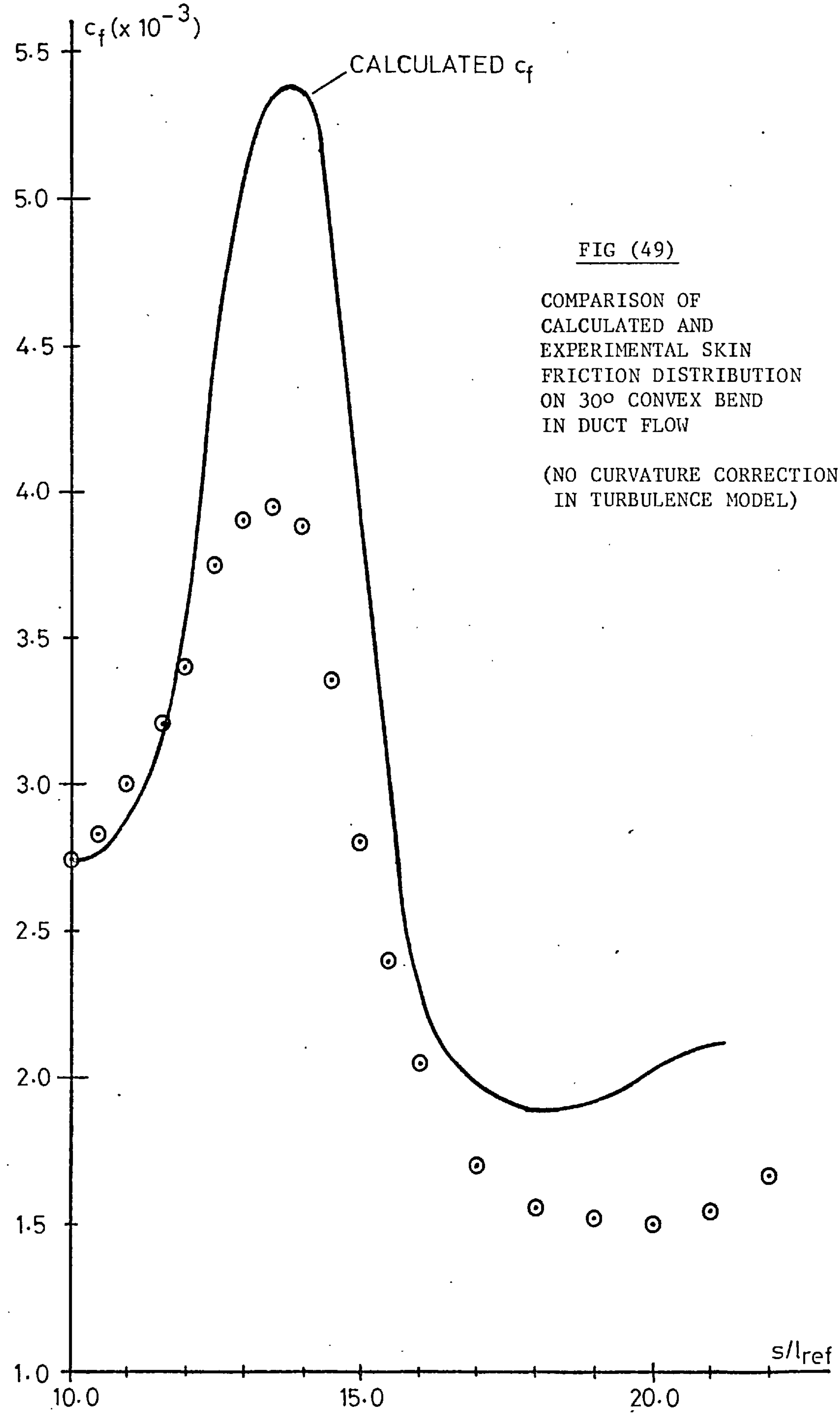


FIG (49)

COMPARISON OF CALCULATED AND EXPERIMENTAL SKIN FRICTION DISTRIBUTION ON 30° CONVEX BEND IN DUCT FLOW

(NO CURVATURE CORRECTION IN TURBULENCE MODEL)

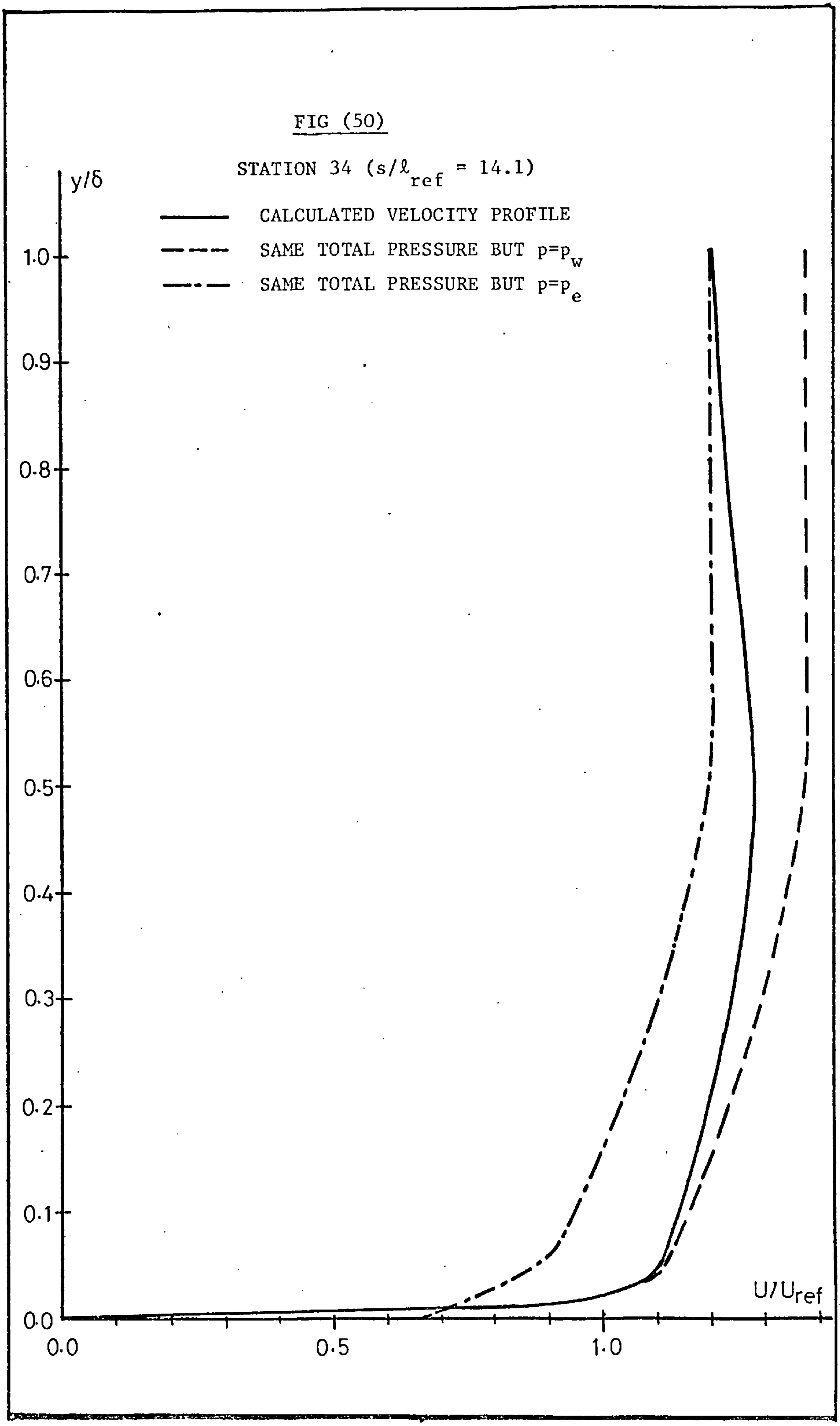
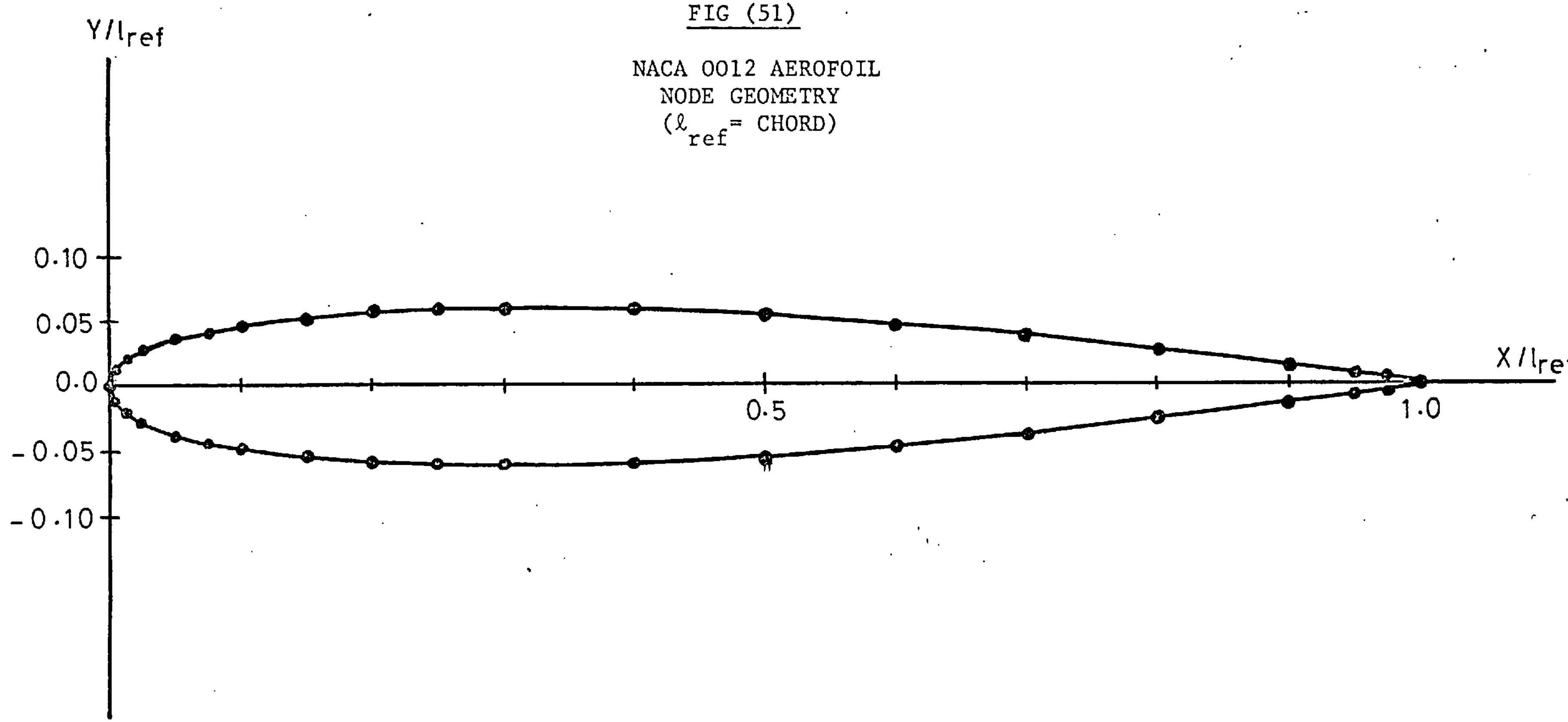


FIG (50)
STATION 34 (s/ℓ_{ref} = 14.1)
CALCULATED VELOCITY PROFILE
SAME TOTAL PRESSURE BUT $p=p_w$
SAME TOTAL PRESSURE BUT $p=p_e$
y/δ
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.5
1.0
U/U_{ref}

FIG (51)

NACA 0012 AEROFOIL
NODE GEOMETRY
(ℓ_{ref} = CHORD)



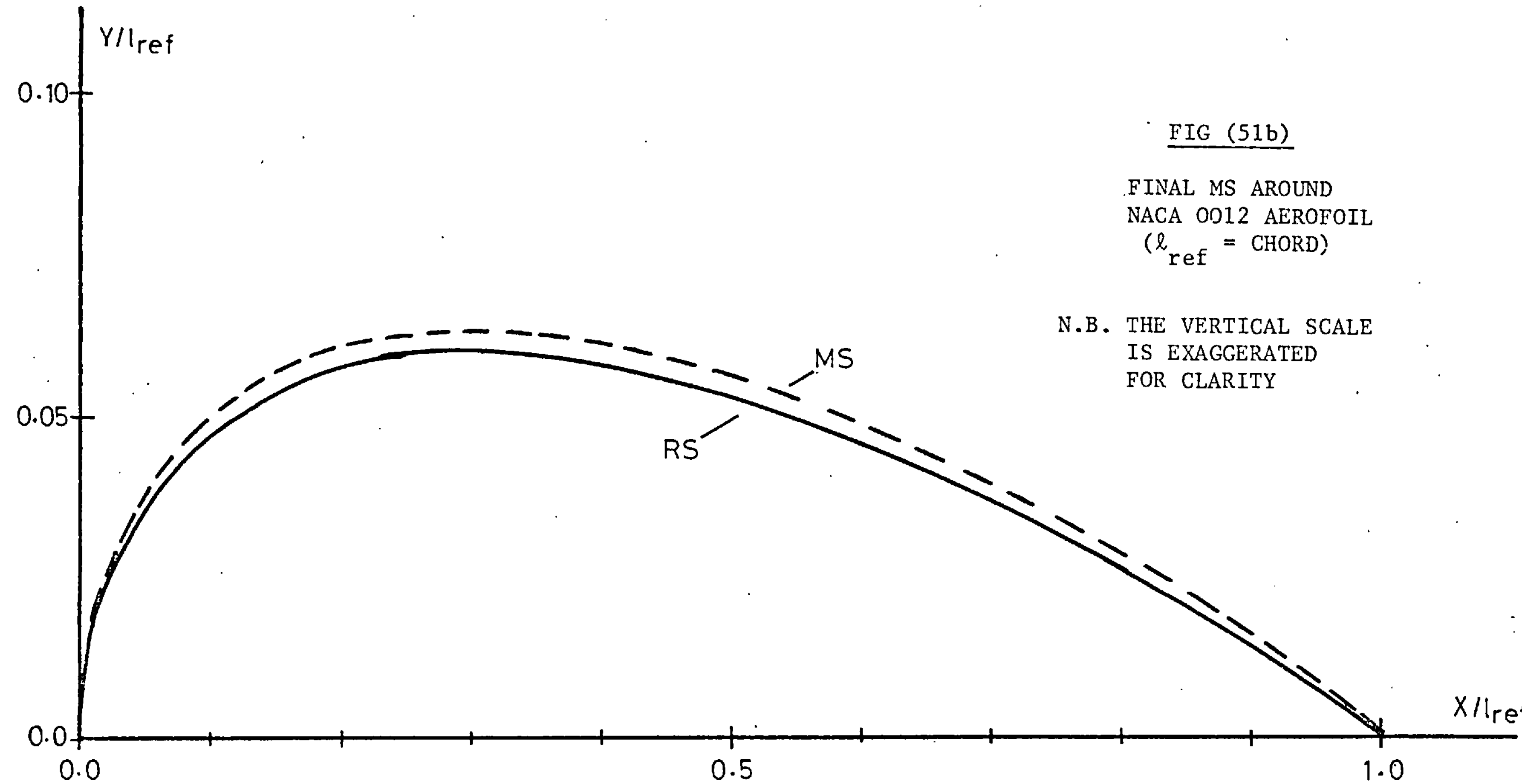


FIG (51b)

FINAL MS AROUND NACA 0012 AEROFOIL (ℓ_{ref} = CHORD)

N.B. THE VERTICAL SCALE IS EXAGGERATED FOR CLARITY

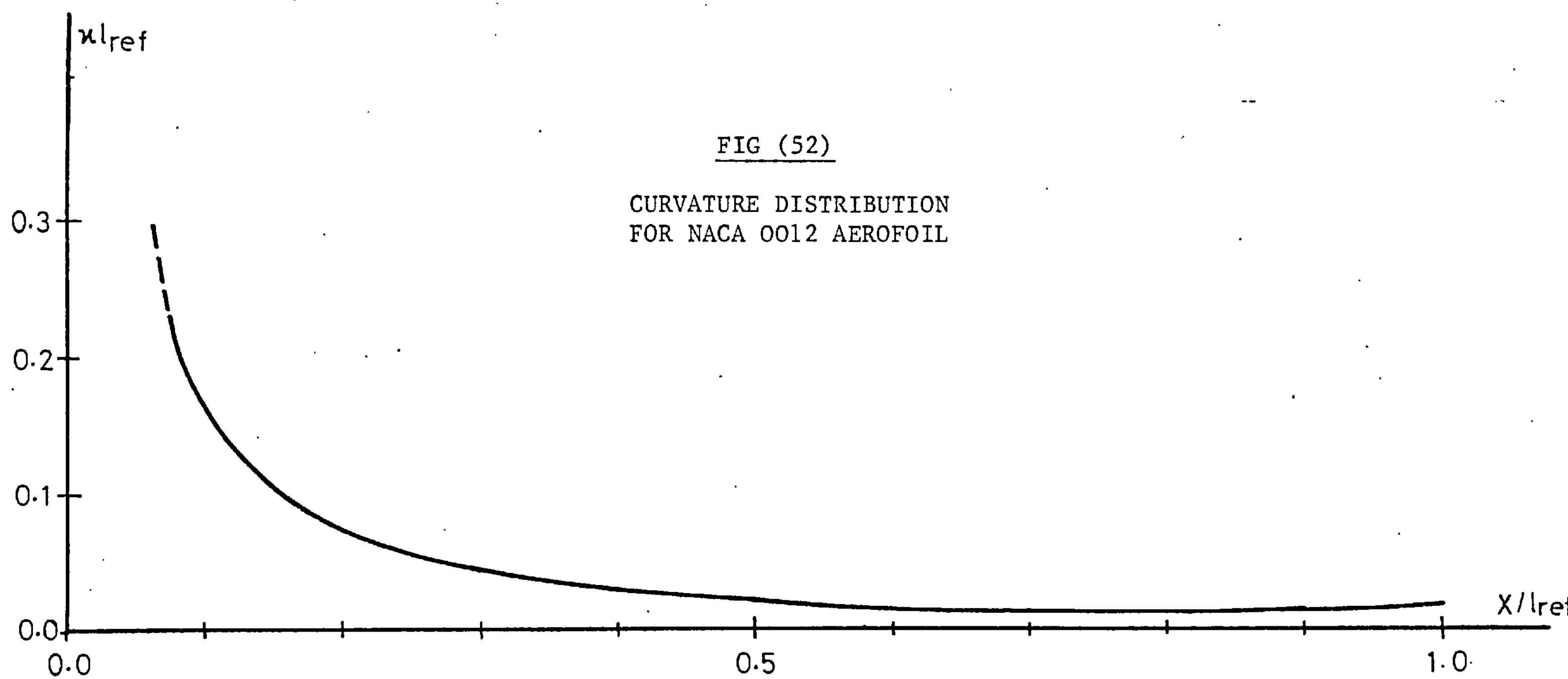


FIG (52)

CURVATURE DISTRIBUTION
FOR NACA 0012 AEROFOIL

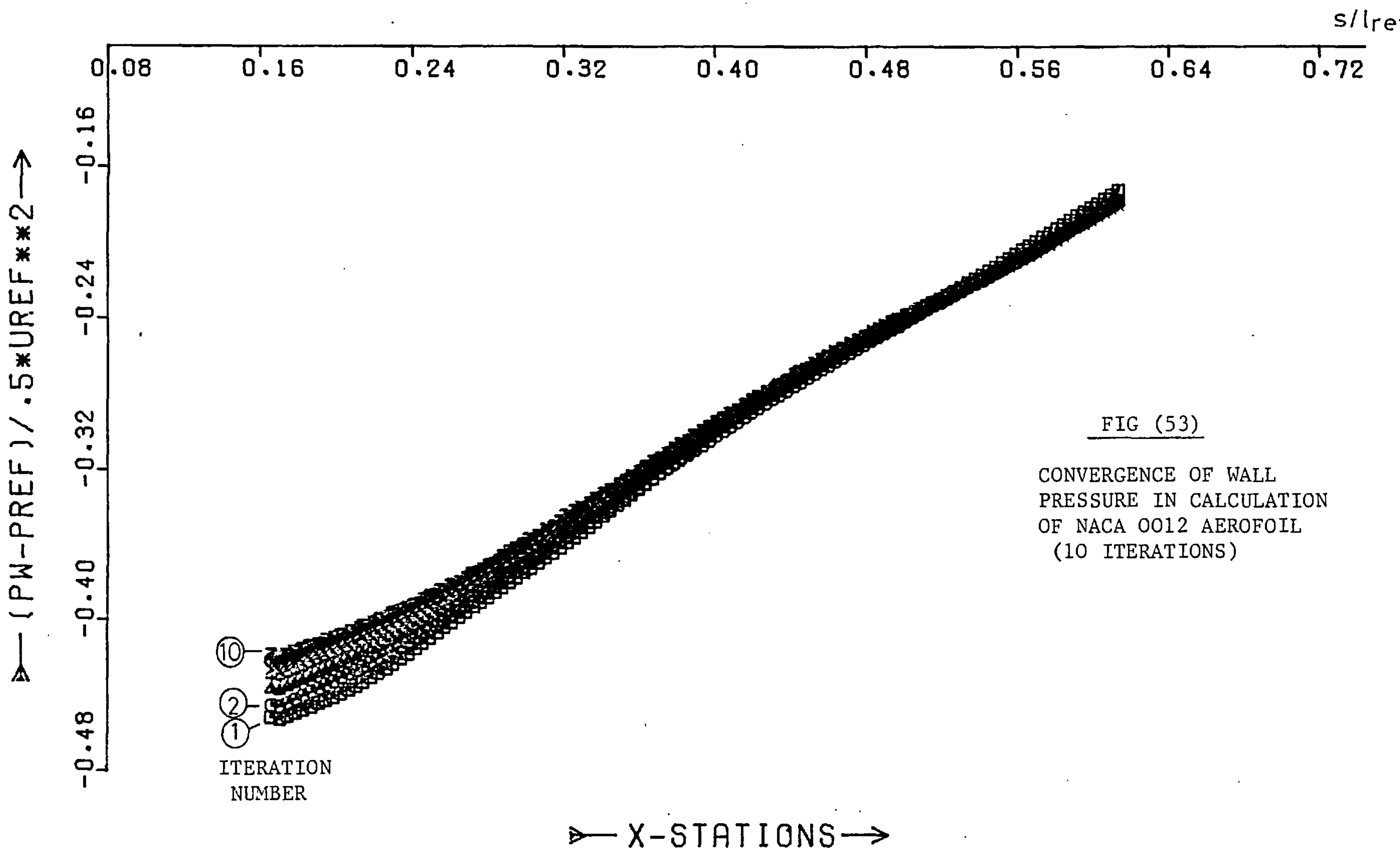


FIG (53)

CONVERGENCE OF WALL PRESSURE IN CALCULATION OF NACA 0012 AEROFOIL (10 ITERATIONS)

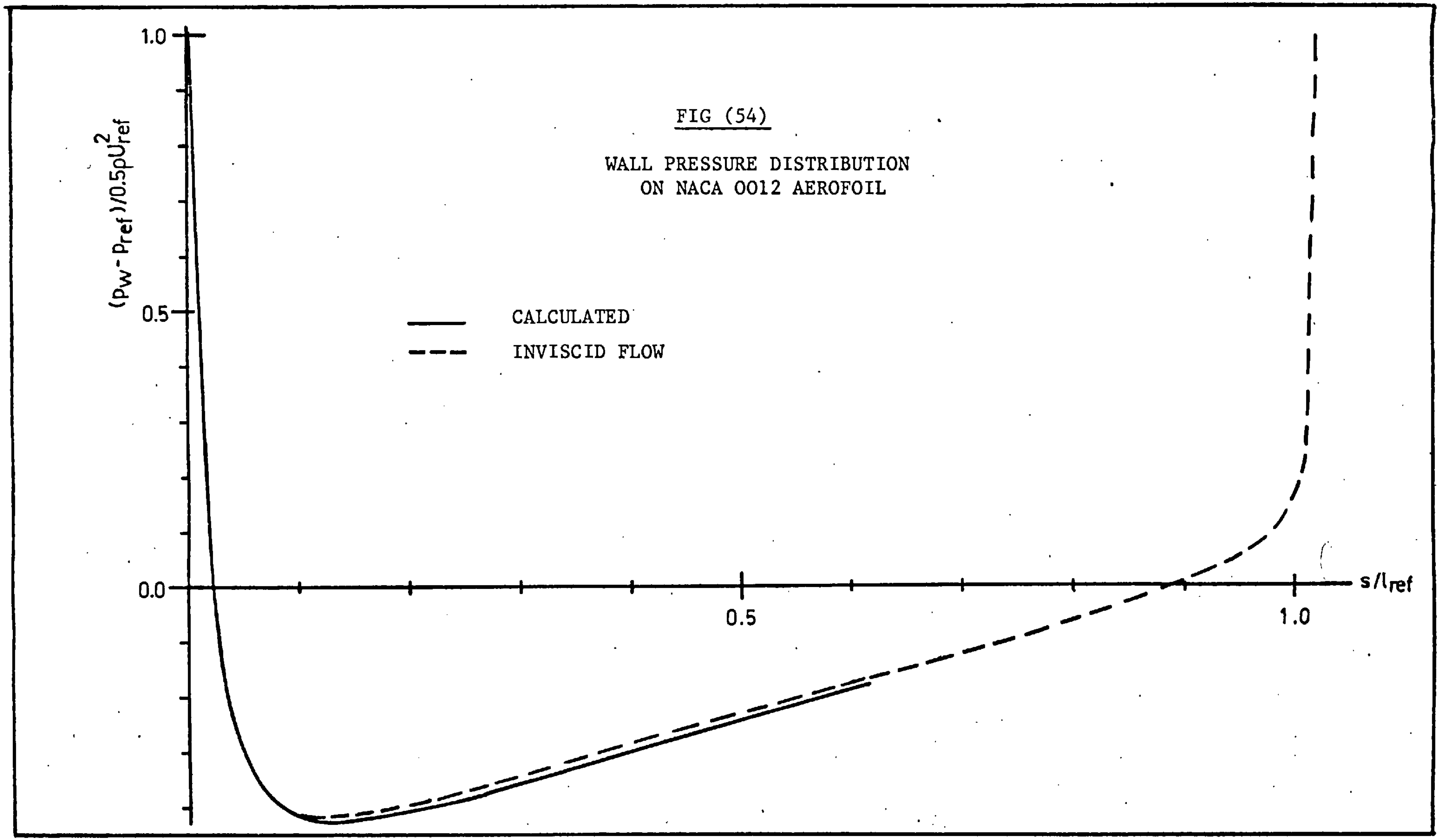


FIG (54)

WALL PRESSURE DISTRIBUTION
ON NACA 0012 AEROFOIL

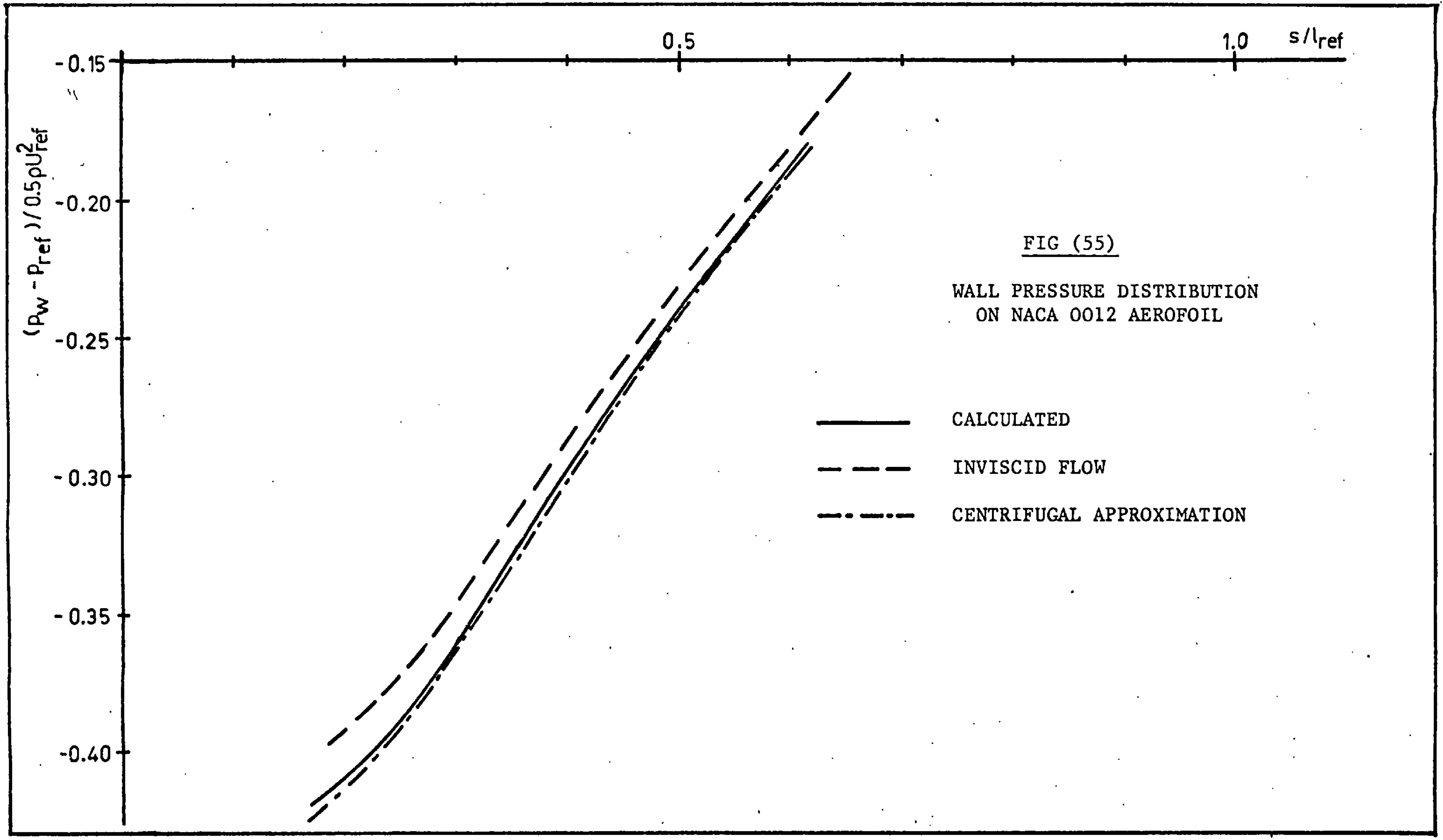


FIG (55)

WALL PRESSURE DISTRIBUTION ON NACA 0012 AEROFOIL

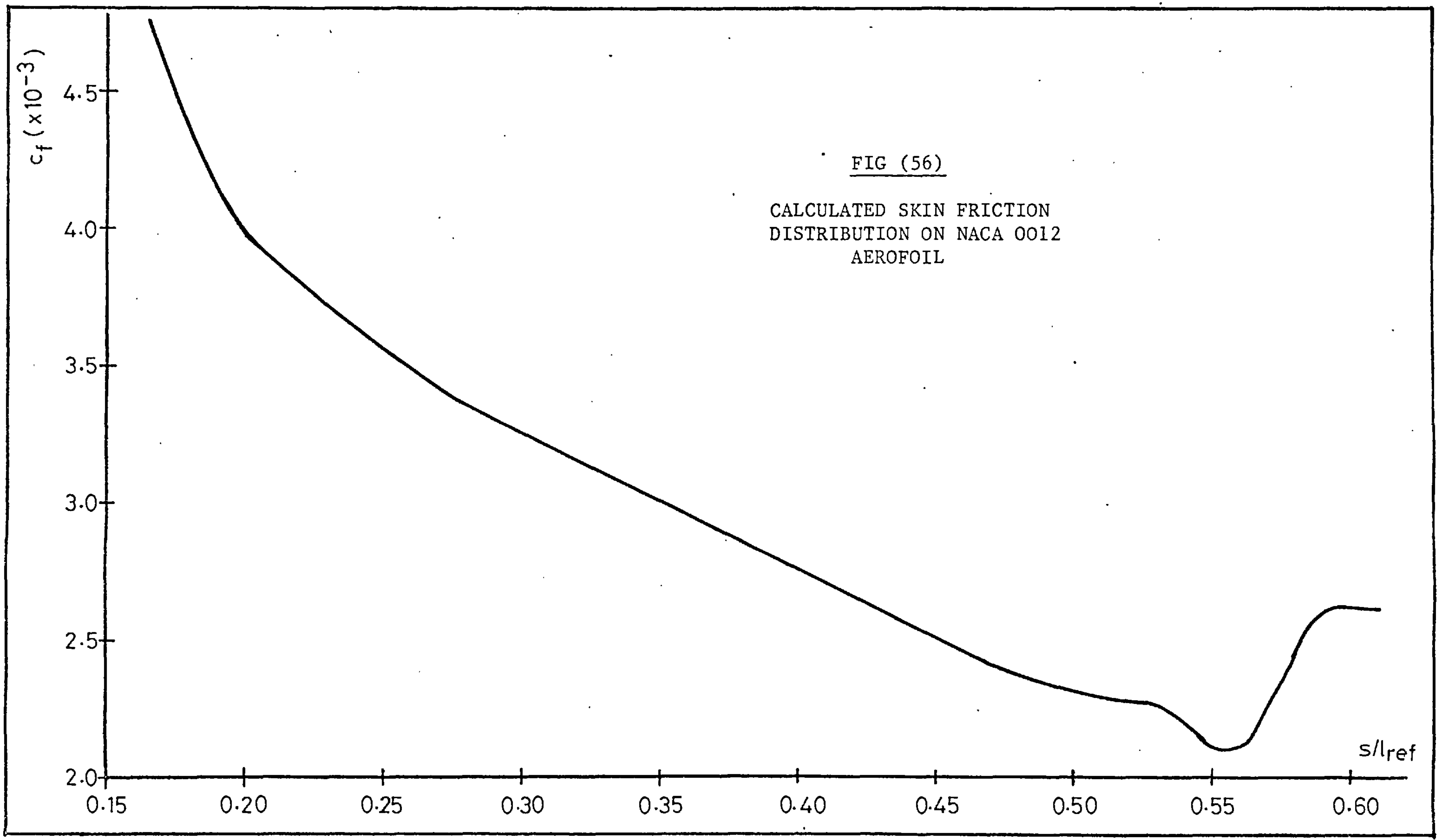


FIG (56)

CALCULATED SKIN FRICTION DISTRIBUTION ON NACA 0012 AEROFOIL

CONCLUDING REMARKS

(1) The conventional displacement thickness approach to matching an external inviscid flow calculation and a boundary layer calculation is inadequate for flows exhibiting large normal pressure gradients. This leads us to search for an alternative surface on which to match the inviscid and shear layer calculations.

(2) For such flows, Prandtl's boundary layer equations (which assume zero normal pressure gradient) do not adequately describe the behaviour of the shear layer, so that the full normal momentum equation has to be solved for the shear layer.

(3) For such turbulent shear layers, which possess extra rates of strain (for example due to longitudinal curvature), we face additional problems associated with finding an appropriate turbulence model which accurately represents the turbulence structure of the shear layer.

(4) The present method overcomes the problems outlined in (1) and (2) above by matching the inviscid and shear layer flows on an arbitrary matching surface lying just outside the shear layer and by solving the full normal momentum equation for the shear layer.

(5) The other advantages of the method can be summarised as follows:

(i) The application of the potential flow method both to internal and external flows is very simple. The problems associated with the errors obtained in mass flow rate for internal flows are simply overcome by the use of extra "correction velocities" at the corners of the duct.

(ii) The shear layer calculation method is fast and economical since it uses the hyperbolic marching technique of the original BFA method with the addition of only one extra routine for the pressure profile calculation from the normal momentum equation, whose solution algorithm is very simple and fast.

(iii) The equations for the shear layer are written in s-n coordinates which has the advantage of minimising artificial viscosity errors.

(iv) The matching procedure itself is relatively simple and straightforward to apply, with the external pressure for the shear layer calculation being supplied by the potential flow calculation and the normal velocity component for the potential flow calculation being supplied by the shear layer calculation. The matching surface need only be changed once, so that the inversion of the influence coefficient matrix in the potential flow calculation is only done twice, thus considerably saving on computation time.

(v) The convergence of the whole viscous/inviscid iteration cycle is monotonic and fairly rapid. Even the violent and rapidly changing curved duct flow converged with the same speed as the fairly uneventful flow over the aerofoil.

(vi) The method has demonstrated its ability in dealing with rapidly changing flows, where both the streamwise and normal pressure gradients are large and where the ratio of shear layer thickness to surface radius of curvature is also large (the maximum value of $\delta_{05}/R \simeq 0.2$).

(6) The present method predicts the violent duct flow fairly well, with the exception of the skin friction distribution. This is probably due to the lack of an adequate turbulence model for this type of flow to account for the

extra rates of strain imposed by the mean flow on the turbulence structure of the shear layer.

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APPENDIX A1

DERIVATION OF THE NAVIER STOKES EQUATIONS FOR INCOMPRESSIBLE FLOW IN s-n-z COORDINATES USING GENERALISED TENSOR ANALYSIS

In this Appendix we shall derive the Navier Stokes equations in s-n-z coordinates, starting with their generalised tensor form. For an excellent introduction to generalised tensor analysis from first principles the reader is referred to Tyldesley (1975), while for a more advanced treatment, especially as applied to fluid mechanics see Aris (1967). Spiegel (1959) provides many examples of the application of generalised tensor analysis including several solved problems.

A1.1 GENERAL DEFINITIONS AND DERIVATIONS FOR THE s-n-z COORDINATE SYSTEM

In performing coordinate transformations using generalised tensors there are two basic types of tensors whose properties are distinct. These are the contravariant tensor written with a superfix a^i and the covariant tensor which is written with a suffix as a_i. The main difference between these two types of tensor is that in conversion from the coordinate system x^i to the system $\overline{x^i}$, the transformation law for contravariant tensors is:

$$\overline{a^i} = \frac{\partial \overline{x}^i}{\partial x^j} . a^j \qquad (A1.1)$$

while for covariant tensors it is:

$$\bar{a}_i = \frac{\partial x^i}{\partial \bar{x}^j} \cdot a_j \qquad (A1.2)$$

The coordinate lengths themselves are contravariant tensors since they transform according to the contravariant law i.e.

$$d\bar{x}^i = \frac{\partial \bar{x}^i}{\partial x^j} . dx^j \qquad (A1.3)$$

by the chain rule for partial differentiation.
Similarly, velocity is a contravariant tensor being the time derivative of a coordinate.

The covariant "metric tensor" g_{ij} of the transformation is defined by

$$dS^2 = g_{ij}\, dx^i dx^j \qquad (A1.4)$$

where dS is the element of arc length and g_{ij} can be shown to be a covariant tensor. The contravariant component of the metric tensor can be defined by

$$g_{ij}\, g^{jk} = \delta_i^k \qquad (A1.5)$$

where $\delta_i^k = 1$ if $i = k$ and $\delta_i^k = 0$ if $i \neq k$.
In the same way we can obtain the contravariant component of a covariant tensor a_i as

$$a^j = g^{ij} a_i \qquad (A1.6)$$

Conversely, the covariant component of a contravariant tensor can be obtained; if we multiply both sides of (A1.6) by g_{jk} we obtain

$$g_{jk}a^j = g_{jk}g^{ij}a_i = \delta^i_k a_i = a_k \quad (A1.7)$$

Now, if we consider the partial derivative $\frac{\partial a^i}{\partial x^j}$ of any contravariant tensor quantity a^i, it can be shown that this partial derivative does not transform under the tensor rules of (A1.1) or (A1.2). We therefore have to define what is termed the "covariant derivative" of a^i as

$$a^i_{,j} = \frac{\partial a^i}{\partial x^j} + \left\{ {i \atop k\ j} \right\} a^k \quad (A1.8)$$

and similarly for a covariant tensor

$$a_{i,j} = \frac{\partial a^i}{\partial x^j} - \left\{ {k \atop j\ i} \right\} a_k \quad (A1.9)$$

where the symbol $\{{s \atop p\ q}\}$ is known as the Christoffel symbol of the second kind and is defined by

$$\left\{ {s \atop p\ q} \right\} = \frac{1}{2} g^{sr} \left(\frac{\partial g_{pr}}{\partial x^q} + \frac{\partial g_{qr}}{\partial x^p} - \frac{\partial g_{pq}}{\partial x^r} \right) \quad (A1.10)$$

The derivatives defined by equations (A1.8) and (A1.9) are tensor quantities and they can be shown to transform under the tensor rules. Similarly, covariant derivatives of higher order tensors can be defined

$$a^{ij}_{,k} = \frac{\partial a^{ij}}{\partial x^k} + \left\{ {i \atop \ell\ k} \right\} a^{\ell j} + \left\{ {j \atop \ell\ k} \right\} a^{i\ell} \quad \text{(A1.10a)}$$

$$a_{ij,k} = \frac{\partial a_{ij}}{\partial x^k} - \left\{ {\ell \atop k\ i} \right\} a_{\ell j} - \left\{ {\ell \atop k\ j} \right\} a_{i\ell} \quad \text{(A1.10b)}$$

We also have to distinguish between a tensor and its physical component, since tensors may represent physical quantities other than lengths. The physical j-component of a contravariant tensor a^j is defined as

$$a(j) = (g_{jj})^{\frac{1}{2}} a^j = h_j a^j \quad \text{(A1.11)}$$

where summation over the index j is not performed. Similarly, the physical j-component of a covariant tensor a_i is defined as

$$a(j) = (g_{jj})^{\frac{1}{2}} g^{ij} a_i = h_j g^{ij} a_i \quad \text{(A1.12)}$$

The tensor analysis rules outlined above apply for transformations in general non-orthogonal coordinate systems. However, for orthogonal coordinate systems certain simplifications apply:

(i) The metric tensor $g_{ij} = 0$ for $i \neq j$, so that only components $g_{ii} \equiv h_i^2$, say, are non-zero. Similarly, $g^{ij} = 0$ for $i \neq j$ and in this case $g^{ii} = 1/h_i^2$.

(ii) This results in simplifications for the Christoffel symbol of the second kind as follows:

If $$\left\{ {s \atop p\ q} \right\} = \frac{1}{2} g^{sr} \left(\frac{\partial g_{pr}}{\partial x^q} + \frac{\partial g_{qr}}{\partial x^p} - \frac{\partial g_{pq}}{\partial x^r} \right)$$

then,

if $$p = q = s, \quad \left\{ {p \atop p\ p} \right\} = \frac{1}{2g_{pp}} \frac{\partial g_{pp}}{\partial x^p} = \frac{1}{h_p} \frac{\partial h_p}{\partial x^p} \qquad (A1.13)$$

If $$p = q \neq s, \quad \left\{ {s \atop p\ p} \right\} = -\frac{1}{2g_{ss}} \frac{\partial g_{pp}}{\partial x^s} = -\frac{h_p}{h_s^2} \frac{\partial h_p}{\partial x^s} \qquad (A1.14)$$

If $$p = s \neq q, \quad \left\{ {p \atop p\ q} \right\} = \frac{1}{2g_{pp}} \frac{\partial g_{pp}}{\partial x^q} = \frac{1}{h_p} \frac{\partial h_p}{\partial x^q} \qquad (A1.15)$$

If p, q, s are all different $\left\{ {s \atop p\ q} \right\} = 0$.

Note also that in general $\left\{ {s \atop p\ q} \right\} = \left\{ {s \atop q\ p} \right\}$ so that the Christoffel symbol of the second kind is symmetric in p and q.

(iii) The physical j-component of a contravariant tensor a^i is as before $a(j) = h_j a^i$. For a covariant tensor, the physical j-component given by equation (A1.12) can be simplified since $g^{ij} = 0$ for $i \neq j$, so that

$$a(j) = (g_{jj})^{\frac{1}{2}} g^{jj} a_j = h_j \cdot \frac{1}{h_j^2} \cdot a_j = \frac{a_j}{h_j} \qquad (A1.16)$$

We now apply the above rules to our s-n coordinate system (in two dimensions). The element of arc length in this system (see Fig. (2)) can be written

$$dS^2 = \left(1+\frac{n}{R}\right)^2 ds^2 + dn^2 \qquad (A1.17)$$

Here the components of x^i are s and n, so that $x^1 \equiv s$, $x^2 \equiv n$. If we compare (A1.17) with (A1.4) we see that the components of the metric tensor are given by

$$g_{11} = h_1^2 = \left(1 + \frac{n}{R}\right)^2$$

and $\quad g_{22} = h_2^2 = 1$ for the s-n coordinate system

so that $\quad h_1 = 1 + \frac{n}{R}$ and $h_2 = 1$.

Using the rules for the Christoffel symbols in orthogonal coordinate systems given by equations (A1.13) to (A1.15), the Christoffel symbols of the second kind for the (s-n) system can be written as

$$\left\{ {1 \atop 1\ 1} \right\} = \frac{1}{h_1}\frac{\partial h_1}{\partial x^1} = \frac{1}{h_1}\frac{\partial h_1}{\partial s}$$

$$\left\{ {2 \atop 2\ 2} \right\} = \frac{1}{h_2}\frac{\partial h_2}{\partial x^2} = 0$$

$$\left\{ {1 \atop 1\ 2} \right\} = \left\{ {1 \atop 2\ 1} \right\} = \frac{1}{h_1}\frac{\partial h_1}{\partial n} = \frac{1}{h_1 R}$$

$$\left\{ {2 \atop 2} {\ \atop 1} \right\} = \left\{ {\ \atop 1} {2 \atop 2} \right\} = \frac{1}{h_2}\frac{\partial h_2}{\partial x^1} = 0$$

$$\left\{ {1 \atop 2} {\ \atop 2} \right\} = -\frac{h_2}{h_1^2}\frac{\partial h_2}{\partial x^1} = 0$$

$$\left\{ {2 \atop 1} {\ \atop 1} \right\} = -\frac{h_1}{h_2^2}\frac{\partial h_1}{\partial n} = -\frac{h_1}{R}$$

If we additionally consider the s-n-z system (in three dimensions) and let the third axis be z (normal to the s-n plane), then the element of arc length in this case is

$$dS^2 = h_1^2 ds^2 + dn^2 + dz^2$$

so that $h_3 = 1$ and $x^3 \equiv z$. From the equations for the Christoffel symbols we see that all Christoffel symbols with a 3 anywhere in them are equal to zero, since

$$\frac{\partial h_3}{\partial x^1} = \frac{\partial h_3}{\partial x^2} = \frac{\partial h_1}{\partial x^3} = \frac{\partial h_2}{\partial x^3} = \frac{\partial h_3}{\partial x^3} = 0$$

A1.2 DERIVATION OF THE NAVIER STOKES EQUATIONS in s-n-z COORDINATES

Firstly, we have to define the mean velocity tensor U^i as a contravariant tensor (and similarly the turbulent fluctuating velocity u^i), since it transforms according to the contravariant tensor rule (being just the rate of change of distance, which is a contravariant tensor). Stress is also a contravariant tensor. If we define the turbulent Reynolds stress tensor as

$$\tau^{ij} = \tau^{ji} = -\overline{u^i u^j}$$

(where $\tau^{ij} = \tau^{ji}$) then the i-component mean momentum equation for incompressible flow can be written (see Aris (1967) and Bradshaw (1973)) as:

$$\frac{\partial U^i}{\partial t} + U^j U^i_{,j} = -\frac{1}{\rho} g^{ij} p_{,j} + \tau^{ij}_{,j} + \nu g^{jk} U^i_{,jk} \qquad \text{(A1.19)}$$

where p is the mean pressure (which is a scalar, i.e. a tensor of order zero) and ν is the kinematic viscosity.
The mean continuity equation for incompressible flow can also be written as

$$U^i_{,i} = 0 \qquad \text{(A1.20)}$$

Note that using the instantaneous continuity equation

$$\tilde{U}^j_{,j} = 0 \,, \quad \tilde{U}^j \tilde{U}^i_{,j} = (U^j U^i)_{,j}$$

Now, if $\tilde{U}^i = U^i + u^i$, the time mean of $\tilde{U}^j \tilde{U}^i_{,j}$ is $(U^j U^i)_{,j} + (\overline{u^j j^i})_{,j}$, which agrees with the definition of τ^{ij}.

In the following sections we shall derive the above two equations term by term in s-n coordinates from their generalised tensor forms given above. We note, however, that the equations will be derived in terms of the physical components of the quantities in question, which are defined as follows:

Physical Component	Tensor Quantity
s, n, z	x^1, x^2, x^3
U, u	$U^1 = \frac{U}{h_1}, \; u^1 = \frac{u}{h_1}$
V, v	$U^2 = \frac{V}{h_2} = V, \; u^2 = \frac{v}{h_2} = v$
W, w	$U^3 = \frac{W}{h_3} = W, \; u^3 = \frac{w}{h_3} = w$
p	p
$-\overline{u^2}$	$\tau^{11} = -\frac{\overline{u.u}}{h_1 h_1} = -\frac{\overline{u^2}}{h_1^2}$
$-\overline{v^2}$	$\tau^{22} = -\frac{\overline{v^2}}{h_2^2} = -\overline{v^2}$
$-\overline{w^2}$	$\tau^{33} = -\frac{\overline{w^2}}{h_3^2} = -\overline{w^2}$
$-\overline{uv}$	$\tau^{12} = \tau^{21} = -\frac{\overline{uv}}{h_1 h_2} = -\frac{\overline{uv}}{h_1}$
$-\overline{uw}$	$\tau^{13} = \tau^{31} = -\frac{\overline{uw}}{h_1 h_3} = -\frac{\overline{uw}}{h_1}$
$-\overline{vw}$	$\tau^{23} = \tau^{32} = -\frac{\overline{vw}}{h_2 h_3} = -\overline{vw}$

(I) The Continuity Equation

From (A1.20) the continuity equation is $U^i_{,i} = 0$ and using the definition (A1.8) of the covariant derivative of a contravariant tensor, this can be written as:

$$\frac{\partial U^i}{\partial x^i} + \left\{ {i \atop i\ m} \right\} \cdot U^m = 0$$

Writing this directly in terms of the physical components, we obtain:

$$\frac{\partial}{\partial s}\left(\frac{U}{h_1}\right) + \left\{ {1 \atop 1\ 1} \right\} \frac{U}{h_1} + \left\{ {2 \atop 2\ 1} \right\} \cdot \frac{U}{h_1} + \frac{\partial}{\partial n}\left(\frac{V}{h_2}\right)$$
$$+ \left\{ {1 \atop 1\ 2} \right\} \cdot \frac{V}{h_2} + \left\{ {2 \atop 2\ 2} \right\} \frac{V}{h_2} + \frac{\partial}{\partial z}\left(\frac{W}{h_3}\right) = 0$$

Using the values of the Christoffel symbols given by equations (A1.18) this reduces to

$$\frac{\partial}{\partial s}\left(\frac{U}{h_1}\right) + \frac{\partial V}{\partial n} + \frac{V}{h_1 R} + \frac{U}{h_1^2}\frac{\partial h_1}{\partial s} + \frac{\partial W}{\partial z} = 0$$

or $$\frac{\partial U}{\partial s} + h_1 \frac{\partial V}{\partial n} + \frac{V}{R} + h_1 \frac{\partial W}{\partial z} = 0$$

since $\frac{\partial h_1}{\partial n} = \frac{1}{R}$, we can write the equation as:

$$\frac{\partial U}{\partial s} + \frac{\partial}{\partial n}(h_1 V) + h_1 \frac{\partial W}{\partial z} = 0 \quad \text{(A1.21)}$$

(II) The Momentum Equation

We shall derive each of the terms of the momentum equation (A1.19) separately, for clarity.

(a) The Acceleration Term

This is the term

$$A^i = \frac{\partial U^i}{\partial t} + U^j U^i_{,j} = \frac{\partial U^i}{\partial t} + U^j \frac{\partial U^i}{\partial x^j} + \left\{ {i \atop j\ell} \right\} U^j U^\ell$$

(i) <u>For i = 1 (the s-direction)</u>:

$$A^1 = \frac{\partial U^1}{\partial t} + U^j \frac{\partial U^1}{\partial x^j} + U^j U^\ell \left\{ {1 \atop j\ell} \right\}$$

$$= \frac{\partial}{\partial t}\left(\frac{U}{h_1}\right) + \frac{U}{h_1} \cdot \frac{\partial}{\partial s}\left(U/h_1\right) + V \frac{\partial}{\partial n}\left(\frac{U}{h_1}\right)$$

$$+ \left(\frac{U}{h_1}\right)^2 \cdot \frac{1}{h_1} \frac{\partial h_1}{\partial s} + 2\left(\frac{U}{h_1}\right) \cdot V \cdot \frac{1}{h_1 R} + W \frac{\partial}{\partial z}\left(U/h_1\right)$$

This reduces to

$$A^1 = \frac{1}{h_1^2}\left[h_1 \frac{\partial U}{\partial t} + U \frac{\partial U}{\partial s} + h_1 V \frac{\partial U}{\partial n} + h_1 W \frac{\partial U}{\partial z} + \frac{UV}{R}\right] \qquad (A1.22)$$

(ii) <u>For i = 2 (the n-direction)</u>:

$$A^2 = \frac{\partial U^2}{\partial t} + U^1 \frac{\partial U^2}{\partial x^1} + U^2 \frac{\partial U^2}{\partial x^2} + U^3 \frac{\partial U^2}{\partial x^3} + \left\{ {2 \atop j\ell} \right\} U^j U^\ell$$

$$= \frac{\partial V}{\partial t} + \frac{U}{h_1} \cdot \frac{\partial V}{\partial s} + V \cdot \frac{\partial V}{\partial n} + W \cdot \frac{\partial V}{\partial z} + \left(-\frac{h_1}{R}\right) \cdot \left(\frac{U}{h_1}\right)^2$$

which reduces to

$$A^2 = \frac{1}{h_1}\left[h_1 \frac{\partial V}{\partial t} + U \frac{\partial V}{\partial s} + h_1 V \frac{\partial V}{\partial n} + h_1 W \frac{\partial V}{\partial z} - \frac{U^2}{R}\right]$$

(iii) For i = 3 (the z-direction):

$$A^3 = \frac{\partial U^3}{\partial t} + \frac{U}{h_1}\frac{\partial W}{\partial s} + V\frac{\partial W}{\partial n} + W\frac{\partial W}{\partial z}$$

$$= \frac{1}{h_1}\left[h_1\frac{\partial W}{\partial t} + U\frac{\partial W}{\partial s} + h_1 V\frac{\partial W}{\partial n} + h_1 W\frac{\partial W}{\partial z}\right]$$

(A1.24)

(b) The pressure gradient term

This is the term

$$\Pi^i = -\frac{1}{\rho}g^{ij}p_{,j} = -\frac{1}{\rho}g^{ii}\frac{\partial p}{\partial x^i} = -\frac{1}{h_i^2}\cdot\frac{1}{\rho}\frac{\partial p}{\partial x^i}$$

since the covariant derivative of a scalar is just its partial derivative and since $g^{ij} = 0$ for $i \neq j$.

(i) For i = 1 (s-direction):

$$\Pi^1 = -\frac{1}{h_1^2}\cdot\frac{1}{\rho}\frac{\partial p}{\partial s} \qquad \text{(A1.25)}$$

(ii) For i = 2 (n-direction):

$$\Pi^2 = -\frac{1}{h_2^2}\cdot\frac{1}{\rho}\frac{\partial p}{\partial n} = -\frac{1}{\rho}\frac{\partial p}{\partial n} \qquad \text{(A1.26)}$$

(iii) For i = 3 (z-direction):

$$\Pi^3 = -\frac{1}{h_3^2}\cdot\frac{1}{\rho}\frac{\partial p}{\partial z} = \frac{1}{\rho}\frac{\partial p}{\partial z} \qquad \text{(A1.27)}$$

(c) The Reynolds Stress Gradient Term

This is

$$T^i = \tau^{ij}_{,j} = \left[\frac{\partial \tau^{ij}}{\partial x^j} + \left\{{i \atop \ell\ j}\right\}\tau^{\ell j} + \left\{{j \atop \ell\ j}\right\}\tau^{i\ell}\right]$$

from the expression for the covariant derivative of a second order tensor, equation (A1.10)(a).

(i) For i = 1 (s-direction):

$$T^1 = \frac{\partial \tau^{1j}}{\partial x^j} + \left\{ {1 \atop \ell\ j} \right\} \tau^{\ell j} + \left\{ {j \atop \ell\ j} \right\} \tau^{1\ell}$$

Now
$$\left\{ {1 \atop \ell\ j} \right\} \tau^{\ell j} = \left\{ {1 \atop 1\ 1} \right\} \tau^{11} + 2\left\{ {1 \atop 1\ 2} \right\} \tau^{12} + \left\{ {1 \atop 2\ 2} \right\} \tau^{22}$$

$$= \frac{1}{h_1}\frac{\partial h_1}{\partial s} . \tau^{11} + \frac{2}{h_1 R} . \tau^{12}$$

and
$$\left\{ {j \atop \ell\ j} \right\} \tau^{1\ell} = \left\{ {1 \atop 1\ 1} \right\} \tau^{11} + \left\{ {1 \atop 2\ 1} \right\} \tau^{12} + \left\{ {2 \atop 1\ 2} \right\} \tau^{11} + \left\{ {2 \atop 2\ 2} \right\} \tau^{22}$$

$$= \frac{1}{h_1}\frac{\partial h_1}{\partial s} . \tau^{11} + \frac{1}{h_1 R} . \tau^{12}$$

$$\therefore\ T^1 = \frac{\partial \tau^{11}}{\partial s} + \frac{\partial \tau^{12}}{\partial n} + \frac{\partial \tau^{13}}{\partial z} + \frac{2}{h_1} . \frac{\partial h_1}{\partial s} . \tau^{11} + \frac{3}{h_1 R} . \tau^{12}$$

$$= -\left[\frac{\partial}{\partial s}\left(\frac{\overline{u^2}}{h_1^2}\right) + \frac{\partial}{\partial n}\left(\frac{\overline{uv}}{h_1}\right) + \frac{\partial}{\partial z}(\overline{uw}) + \frac{2}{h_1} . \frac{\partial h_1}{\partial s} . \frac{\overline{u^2}}{h_1^2} + \frac{3}{h_1 R} . \left(\frac{\overline{uv}}{h_1}\right) \right]$$

which reduces to:

$$T^1 = -\frac{1}{h_1^2}\left[\frac{\partial \overline{u^2}}{\partial s} + h_1 \frac{\partial}{\partial n}(\overline{uv}) + h_1 \frac{\partial}{\partial z}(\overline{uw}) + 2\frac{\overline{uv}}{R} \right] \qquad (A1.28)$$

(ii) <u>For i = 2 (n-direction)</u>:

$$T^2 = \frac{\partial \tau^{2j}}{\partial x^j} + \left\{ {2 \atop \ell\ j} \right\} \tau^{\ell j} + \left\{ {j \atop \ell\ j} \right\} \tau^{2\ell}$$

Now $$\left\{ {2 \atop \ell\ j} \right\} \tau^{\ell j} = \left\{ {2 \atop 1\ 1} \right\} \tau^{11} + 2\left\{ {2 \atop 1\ 2} \right\} \tau^{12} + \left\{ {2 \atop 2\ 2} \right\} \tau^{22}$$

$$= -\frac{h_1}{R} . \tau^{11}$$

and $$\left\{ {j \atop \ell\ j} \right\} \tau^{2\ell} = \left\{ {1 \atop 1\ 1} \right\} \tau^{21} + \left\{ {2 \atop 1\ 2} \right\} \tau^{21} + \left\{ {1 \atop 2\ 1} \right\} \tau^{22} + \left\{ {2 \atop 2\ 2} \right\} \tau^{22}$$

$$= \frac{1}{h_1} \frac{\partial h_1}{\partial s} . \tau^{21} + \frac{\tau^{22}}{h_1 R}$$

$$\therefore T^2 = \frac{\partial \tau^{12}}{\partial x^1} + \frac{\partial \tau^{22}}{\partial x^2} + \frac{\partial \tau^{23}}{\partial x^3} - \frac{h_1}{R} . \tau^{11} + \frac{1}{h_1} \frac{\partial h_1}{\partial s} . \tau^{21} + \frac{\tau^{22}}{h_1 R}$$

which reduces to

$$T^2 = -\frac{1}{h_1} \left[\frac{\partial \overline{uv}}{\partial s} + h_1 \frac{\partial \overline{v^2}}{\partial n} + h_1 \frac{\partial \overline{vw}}{\partial z} + \frac{\overline{v^2} - \overline{u^2}}{R} \right] \qquad (A1.29)$$

(iii) <u>For i = 3 (z-direction)</u>:

$$T^3 = \frac{\partial \tau^{3j}}{\partial x^j} + \left\{ {3 \atop \ell\ j} \right\} \tau^{\ell j} + \left\{ {j \atop \ell\ j} \right\} \tau^{3\ell}$$

since $\left\{ {3 \atop l\ j} \right\} = 0$ for all l, j, this becomes

$$T^3 = \frac{\partial \tau^{3j}}{\partial x^j} + \left\{ {j \atop \ell\ j} \right\} \tau^{3\ell}$$

Now $$\left\{ {j \atop \ell\ j} \right\} \tau^{3\ell} = \left\{ {1 \atop 1\ 1} \right\} \tau^{31} + \left\{ {2 \atop 1\ 2} \right\} \tau^{31} + \left\{ {1 \atop 2\ 1} \right\} \tau^{32} + \left\{ {2 \atop 2\ 2} \right\} \tau^{32}$$

$$= \frac{1}{h_1} \frac{\partial h_1}{\partial s} \cdot \tau^{31} + \frac{1}{h_1 R} \cdot \tau^{32}.$$

$$\therefore\ T^3 = \frac{\partial \tau^{31}}{\partial x^1} + \frac{\partial \tau^{32}}{\partial x^2} + \frac{\partial \tau^{33}}{\partial x^3} + \frac{1}{h_1} \frac{\partial h_1}{\partial s} \cdot \tau^{31} + \frac{\tau^{32}}{h_1 R}$$

$$= -\left[\frac{\partial}{\partial s}\left(\frac{\overline{uw}}{h_1} \right) + \frac{\partial}{\partial n}(\overline{vw}) + \frac{\partial}{\partial z}(\overline{w^2}) + \frac{1}{h_1} \frac{\partial h_1}{\partial s} \cdot \frac{\overline{uw}}{h_1} + \frac{\overline{vw}}{h_1 R} \right]$$

$$= -\frac{1}{h_1} \left[\frac{\partial \overline{uw}}{\partial s} + h_1 \frac{\partial \overline{vw}}{\partial n} + h_1 \frac{\partial \overline{w^2}}{\partial z} + \frac{\overline{vw}}{R} \right] \qquad \text{(A1.30)}$$

(d) <u>The Viscous Stress Gradient Term</u>

The ith component of this term is given by

$$V^i = \nu g^{jk} U^i_{,jk}$$

and since $g^{jk} = 0$ for $j \neq k$ for an orthogonal coordinate system, then

$$V^i = \nu g^{kk} U^i_{,kk} = \nu \left[\frac{U^i_{,11}}{h_1^2} + \frac{U^i_{,22}}{h_2^2} + \frac{U^i_{,33}}{h_3^2} \right]$$

where $h_2 = h_3 = 1$.

Firstly, we shall deduce a general expression for the quantity $U^i_{,jk}$.

Now, by the definition of covariant differentiation

$$U^i_{,jk} = (U^i_{,j})_{,k} = \frac{\partial U^i_{,j}}{\partial x^k} - \left\{ {l \atop k\,j} \right\} U^i_{,l} + \left\{ {i \atop l\,k} \right\} U^l_{,j}$$

$$= \frac{\partial}{\partial x^k}\left[\frac{\partial U^i}{\partial x^j} + \left\{ {i \atop j\,l} \right\} U^l \right] - \left\{ {l \atop k\,j} \right\} \left[\frac{\partial U^i}{\partial x^l} + \left\{ {i \atop l\,m} \right\} U^m \right]$$

$$+ \left\{ {i \atop l\,k} \right\} \left[\frac{\partial U^l}{\partial x^j} + \left\{ {l \atop j\,m} \right\} U^m \right]$$

which reduces to

$$U^i_{,jk} = \frac{\partial^2 U^i}{\partial x^j \partial x^k} + \left\{ {i \atop j\,l} \right\} \frac{\partial U^l}{\partial x^k} - \left\{ {l \atop k\,j} \right\} \frac{\partial U^i}{\partial x^l}$$

$$+ \left\{ {i \atop l\,k} \right\} \frac{\partial U^l}{\partial x^j} + U^m \frac{\partial}{\partial x^k} \left\{ {i \atop j\,m} \right\} - U^m \left\{ {l \atop k\,j} \right\} \left\{ {i \atop l\,m} \right\}$$

$$+ U^m \left\{ {i \atop l\,k} \right\} \left\{ {l \atop j\,m} \right\} \qquad \text{(A1.31)}$$

Now, for j = k this becomes

$$U^i_{,kk} = \frac{\partial^2 U^i}{\partial x^k \partial x^k} + 2 \left\{ {i \atop l\,k} \right\} \frac{\partial U^l}{\partial x^k} - \left\{ {l \atop k\,k} \right\} \frac{\partial U^i}{\partial x^l}$$

$$+ U^m \frac{\partial}{\partial x^k} \left\{ {i \atop k\,m} \right\} - \left\{ {l \atop k\,k} \right\} \left\{ {i \atop l\,m} \right\} U^m + \left\{ {i \atop l\,k} \right\} \left\{ {l \atop k\,m} \right\} U^m$$

$$\text{(A1.32)}$$

(i) For i = 1 (the s-direction):

$$V^1 = \nu \left[\frac{U^1_{,11}}{h_1^2} + U^1_{,22} + U^1_{,33} \right]$$

Putting i = 1 in (A1.32) and using the definitions of the Christoffel symbols given by equations (A1.18) we find after some algebra that

$$U^1_{,11} = \frac{\partial^2 U^1}{\partial x^1 \partial x^1} + \frac{\partial}{\partial x^1}\left(\frac{U^1}{h_1}\frac{\partial h_1}{\partial s}\right) + \frac{2}{h_1 R}\frac{\partial U^2}{\partial x^1} + U^2 \frac{\partial}{\partial x^1}\left(\frac{1}{h_1 R}\right) + \frac{h_1}{R}\cdot\frac{\partial U^1}{\partial x^2}$$

and

$$U^1_{,22} = \frac{\partial^2 U^1}{\partial x^2 \partial x^2} + \frac{2}{h_1 R}\cdot\frac{\partial U^1}{\partial x^2} + U^1 \frac{\partial}{\partial x^2}\left(\frac{1}{h_1 R}\right) + \frac{U^1}{(h_1 R)^2}$$

while $U^1_{,33} = \dfrac{\partial^2 U^1}{\partial x^3 \partial x^3}$

Therefore

$$\frac{V^1}{\nu} = \frac{1}{h_1}\left[\frac{U^1_{,11}}{h_1} + h_1 U^1_{,22} + h_1 U^1_{,33} \right]$$

$$= \frac{1}{h_1}\left[\frac{1}{h_1}\frac{\partial^2}{\partial s^2}\left(\frac{U}{h_1}\right) + h_1 \frac{\partial^2}{\partial n^2}\left(\frac{U}{h_1}\right) + \frac{3}{R}\frac{\partial}{\partial n}\left(\frac{U}{h_1}\right) \right.$$

$$+ \frac{1}{h_1}\frac{\partial}{\partial s}\left(\frac{U}{h_1^2}\frac{\partial h_1}{\partial s}\right) + \frac{2}{h_1^2 R}\frac{\partial V}{\partial s} + \frac{V}{h_1}\frac{\partial}{\partial s}\left(\frac{1}{h_1 R}\right)$$

$$\left. + U \frac{\partial}{\partial n}\left(\frac{1}{h_1 R}\right) + \frac{U}{h_1^2 R^2} + \frac{\partial^2 U}{\partial z^2} \right]$$

After much algebra and using the continuity equation, this reduces to

$$V' = \frac{\nu}{h_1}\left[\left(\frac{\partial^2 U}{\partial n^2} + \frac{1}{h_1 R}\frac{\partial U}{\partial n} - \frac{U}{h_1^2 R^2}\right) - \frac{1}{h_1}\frac{\partial^2 V}{\partial s \partial n} + \frac{1}{h_1^2 R}\frac{\partial V}{\partial s} + \frac{\partial^2 U}{\partial z^2} - \frac{1}{h_1}\frac{\partial^2 W}{\partial s \partial z}\right]$$

$$= \frac{\nu}{h_1}\frac{\partial}{\partial n}\left[\frac{\frac{\partial}{\partial n}(h_1 U) - \frac{\partial V}{\partial s}}{h_1}\right] + \frac{\nu}{h_1^2}\frac{\partial}{\partial z}\left(h_1\frac{\partial U}{\partial z} - \frac{\partial W}{\partial s}\right) \quad \text{(A1.33)}$$

(ii) <u>For i = 2, 3 (the n-direction and z-direction)</u>:

$$V^2 = \nu\left[\frac{U^2_{,11}}{h_1^2} + U^2_{,22} + U^2_{,33}\right]$$

$$V^3 = \nu\left[\frac{U^3_{,11}}{h_1^2} + U^3_{,22} + U^3_{,33}\right]$$

These terms have not been derived here due to the complexity of the algebra but their derivation follows exactly the same procedure as that outlined for the s-component of the viscous stress gradient.

Thus, to obtain the complete Navier-Stokes equations we add the various terms for each of the three coordinate directions s, n and z to obtain:

The Continuity Equation:

$$\frac{\partial U}{\partial s} + \frac{\partial}{\partial n}(h_1 V) + h_1\frac{\partial W}{\partial z} = 0 \qquad \text{(A1.34)}$$

The s-component Mean Momentum Equation:

$$h_1 \frac{\partial U}{\partial t} + U\frac{\partial U}{\partial s} + h_1 V\frac{\partial U}{\partial n} + \underline{h_1 W\frac{\partial U}{\partial z}} + \frac{UV}{R}$$

$$= -\frac{1}{\rho}\frac{\partial p}{\partial s} - \frac{\partial \overline{u^2}}{\partial s} - h_1\frac{\partial \overline{uv}}{\partial n} - \underline{h_1\frac{\partial \overline{uw}}{\partial z}} - \frac{2\overline{uv}}{R} \tag{A1.35}$$

The n-component Mean Momentum Equation:

$$h_1 \frac{\partial V}{\partial t} + U\frac{\partial V}{\partial s} + h_1 V\frac{\partial V}{\partial n} + \underline{h_1 W\frac{\partial V}{\partial z}} - \frac{U^2}{R}$$

$$= -\frac{h_1}{\rho}\frac{\partial p}{\partial n} - \frac{\partial \overline{uv}}{\partial s} - h_1\frac{\partial \overline{v^2}}{\partial n} - \underline{h_1\frac{\partial \overline{vw}}{\partial z}} - \frac{(\overline{v^2} - \overline{u^2})}{R} \tag{A1.36}$$

The z-component Mean Momentum Equation:

$$h_1 \frac{\partial W}{\partial t} + U\frac{\partial W}{\partial s} + h_1 V\frac{\partial W}{\partial n} + h_1 W\frac{\partial W}{\partial z}$$

$$= -\frac{h_1}{\rho}\frac{\partial p}{\partial z} - \frac{\partial \overline{uw}}{\partial s} - h_1\frac{\partial \overline{vw}}{\partial n} - h_1\frac{\partial \overline{w^2}}{\partial z} - \frac{\overline{vw}}{R} \tag{A1.37}$$

These are the mean Navier-Stokes equations for three dimensional, unsteady turbulent flow and neglecting the viscous stress gradient terms. For two dimensional flow, the terms underlined in (A1.34), (A1.35) and (A1.36) are deleted as well as the z-component equation, and the equations then reduce to those given by Bradshaw (1973).

APPENDIX A2

DERIVATION OF THE TRANSPORT EQUATIONS FOR THE REYNOLDS STRESSES AND THE TURBULENT KINETIC ENERGY EQUATION IN s-n-z COORDINATES, FOR THREE DIMENSIONAL INCOMPRESSIBLE FLOW, USING GENERALISED TENSOR ANALYSIS

The instantaneous i-component momentum equation can be written in generalised tensor form as:

$$\frac{\partial \tilde{U}^i}{\partial t} + \tilde{U}^l \tilde{U}^i_{,l} = -g^{il}\frac{\tilde{p}_{,l}}{\rho} + \nu g^{kl}\tilde{U}^i_{,kl} \quad (A2.1)$$

From this equation, by inserting $\tilde{U}^i = U^i + u^i$ and $\tilde{p} = p + p'$ and taking the time mean, we obtain equation (A1.19) which is the time average (or mean) i-component momentum equation. However, if we multiply (A2.1) by the fluctuating velocity component u^j and multiply the instantaneous j-component momentum equation by u^i then add, we obtain the following transport equation for the Reynolds stress tensor $\tau^{ij} = -\overline{u^i u^j}$ (with some use of the continuity equation (A1.20)):

$$\underset{\text{I}}{U^l(-\overline{u^i u^j})_{,l}} = \underset{\text{II}}{(\overline{u^i u^l}\, U^j_{,l} + \overline{u^j u^l}\, U^i_{,l})}$$

$$\underset{\text{III}}{-\overline{\frac{p'}{\rho}(g^{il}u^j_{,l} + g^{jl}u^i_{,l})}}$$

$$+\left[g^{il}(\overline{p'u^j})_{,l}+g^{jl}(\overline{p'u^i})_{,l}\right]+(\overline{u^iu^ju^l})_{,l}$$

IV

$$-\nu g^{kl}(\overline{u^iu^j_{,kl}}+\overline{u^ju^i_{,kl}}) \quad \text{(A2.2)}$$

V

The terms denoted by I, II, III, IV and V are the mean transport, generation, redistribution by pressure fluctuations, turbulent transport and viscous transport/destruction of the Reynolds stress, respectively. Thus, we can write (A2.2) in the form

$$M^{ij}=G^{ij}+R^{ij}+T^{ij}+V^{ij} \qquad \text{(A2.3)}$$

where M^{ij}, G^{ij}, R^{ij}, T^{ij}, V^{ij} denote terms I, II, III, IV, V, respectively.

Now, if we multiply both sides of (A2.2) by g_{ij} and sum over the indices i and j, we obtain:

$$\underset{A}{U^l(\tfrac{1}{2}\overline{u^iu_i})_{,l}}=\underset{B}{-g_{ij}\,\overline{u^iu^l}\,U^j_{,l}}-\underset{C}{\left(\frac{\overline{p'u^l}}{\rho}+\tfrac{1}{2}\overline{u^iu_iu^l}\right)_{,l}}-\underset{D}{\epsilon} \qquad \text{(A2.4)}$$

This is the conservation equation for the quantity $\frac{1}{2}q^2 \equiv \frac{1}{2}\overline{u^iu_i}$, which is the turbulent kinetic energy which is also equal to $\frac{1}{2}(\overline{u^2}+\overline{v^2}+\overline{w^2})$. Terms A, B, C, D denote the advection, production, turbulent transport (or diffusion) and viscous dissipation of turbulent kinetic energy.

The viscous transport (diffusion) of turbulent kinetic energy has been neglected. If we use A, P, T to denote terms A, B, C respectively, then we can write (A2.4) as

$$A = P + T - \epsilon \qquad (A2.5)$$

We shall now derive the Reynolds stress transport equations and the turbulent kinetic energy equation in s-n-z coordinates.

A2.1 DERIVATION OF THE REYNOLDS STRESS TRANSPORT EQUATIONS IN s-n-z COORDINATES

We shall consider each term of equation (A2.2) (and (A2.3)) separately:

I The Mean Transport Term

This term represents the transport of Reynolds Stress by the mean velocity field. We can write it as

$$M^{ij} = U^k(-\overline{u^i u^j})_{,k} = U^k\left[\frac{\partial}{\partial x^k}(-\overline{u^i u^j}) + \left\{{i \atop m\ k}\right\}(-\overline{u^m u^j}) + \left\{{j \atop m\ k}\right\}(-\overline{u^i u^m})\right] \quad (A2.6)$$

using equation (A1.10a) for the covariant derivative of a second order contravariant tensor. For simplicity, let $\tau^{ij} \equiv -\overline{u^i u^j}$ (and $\tau^{ij} = \tau^{ji}$ is a symmetrical tensor in i and j). We can then write (A2.6) as:

$$M^{ij} = U^k\left[\frac{\partial \tau^{ij}}{\partial x^k} + \left\{{i \atop m\ k}\right\}\tau^{mj} + \left\{{j \atop m\ k}\right\}\tau^{im}\right]$$

$$= U^1\frac{\partial \tau^{ij}}{\partial x^1} + U^2\frac{\partial \tau^{ij}}{\partial x^2} + U^3\frac{\partial \tau^{ij}}{\partial x^3}$$

$$+ U^1 \left\{ {i \atop m\ 1} \right\} \tau^{mj} + U^2 \left\{ {i \atop m\ 2} \right\} \tau^{mj} + U^1 \left\{ {j \atop m\ 1} \right\} \tau^{im}$$
$$+ U^2 \left\{ {j \atop m\ 2} \right\} \tau^{im} \qquad (A2.7)$$

Now, if i = j (A2.7) becomes

$$M^{ii} = U^k \left[\frac{\partial \tau^{ii}}{\partial x^k} + 2 \left\{ {i \atop m\ k} \right\} \tau^{im} \right]$$
$$= U^1 \frac{\partial \tau^{ii}}{\partial x^1} + U^2 \frac{\partial \tau^{ii}}{\partial x^2} + U^3 \frac{\partial \tau^{ii}}{\partial x^3}$$
$$+ 2 \left[U^1 \left\{ {i \atop m\ 1} \right\} + U^2 \left\{ {i \atop m\ 2} \right\} \right] \tau^{im} \qquad (A2.8)$$

(i) <u>For i = 1, j = 1</u>:

From (A2.8)

$$M^{11} = U^1 \frac{\partial \tau^{11}}{\partial x^1} + 2U^1 \left\{ {1 \atop m\ 1} \right\} \tau^{m1} + U^2 \frac{\partial \tau^{22}}{\partial x^2}$$
$$+ 2U^2 \left\{ {1 \atop m\ 2} \right\} \tau^{m1} + U^3 \frac{\partial \tau^{11}}{\partial x^3}$$

$$\therefore -M^{11} = \frac{U}{h_1} \frac{\partial}{\partial s} \left(\frac{\overline{u^2}}{h_1^2} \right) + 2 \frac{U}{h_1} \cdot \frac{1}{h_1} \frac{\partial h_1}{\partial s} \cdot \left(\frac{\overline{u^2}}{h_1^2} \right) + 2 \frac{U}{h_1} \cdot \frac{1}{h_1 R} \cdot \frac{\overline{uv}}{h_1}$$

$$+ V \frac{\partial}{\partial n} \left(\frac{\overline{u^2}}{h_1^2} \right) + 2V \cdot \frac{1}{h_1 R} \cdot \left(\frac{\overline{u^2}}{h_1^2} \right) + W \frac{\partial}{\partial z} \left(\frac{\overline{u^2}}{h_1^2} \right)$$

This can be reduced to

$$M^{11} = -\frac{1}{h_1^3} \left[U \frac{\partial \overline{u^2}}{\partial s} + h_1 V \frac{\partial \overline{u^2}}{\partial n} + \frac{2U}{R} \cdot (\overline{uv}) + h_1 W \frac{\partial \overline{u^2}}{\partial z} \right]$$
$$(A2.9)$$

(ii) <u>For i = 2, j = 2</u>:

Using (A2.8) again, we obtain:

$$M^{22} = U^1 \frac{\partial \tau^{22}}{\partial x^1} + 2U^1 \left\{ {2 \atop m\,1} \right\} \tau^{m2} + U^2 \frac{\partial \tau^{22}}{\partial x^2} + 2U^2 \left\{ {2 \atop m\,2} \right\} \tau^{m2} + U^3 \frac{\partial \tau^{22}}{\partial x^3}$$

$$\therefore -M^{22} = \frac{U}{h_1} \frac{\partial}{\partial s}(\overline{v^2}) + 2 \cdot \frac{U}{h_1}\left(-\frac{h_1}{R}\right) \cdot \tau^{12} + V \frac{\partial}{\partial n}(\overline{v^2}) + W \frac{\partial}{\partial z}(\overline{v^2})$$

$$\therefore M^{22} = -\frac{1}{h_1}\left[U \frac{\partial \overline{v^2}}{\partial s} + h_1 V \frac{\partial \overline{v^2}}{\partial n} + h_1 W \frac{\partial \overline{v^2}}{\partial z} - \frac{2U}{R} \cdot (\overline{uv}) \right] \qquad (A2.10)$$

(iii) <u>For i = 1, j = 2</u>:

Using (A2.7) we obtain:

$$M^{12} = M^{21} = U^1 \frac{\partial \tau^{12}}{\partial x^1} + U^2 \frac{\partial \tau^{12}}{\partial x^2} + U^3 \frac{\partial \tau^{12}}{\partial x^3} + U^1 \left\{ {1 \atop m\,1} \right\} \tau^{m2} + U^1 \left\{ {2 \atop m\,1} \right\} \tau^{m1} + U^2 \left\{ {1 \atop m\,2} \right\} \tau^{m2} + U^2 \left\{ {2 \atop m\,2} \right\} \tau^{m1}$$

$$\therefore -M^{12} = \frac{U}{h_1} \frac{\partial}{\partial s}\left(\frac{\overline{uv}}{h_1}\right) + V \frac{\partial}{\partial n}\left(\frac{\overline{uv}}{h_1}\right) + W \frac{\partial}{\partial z}\left(\frac{\overline{uv}}{h_1}\right) + \frac{U}{h_1} \cdot \frac{1}{h_1}\frac{\partial h_1}{\partial s} \cdot \frac{\overline{uv}}{h_1} + \frac{U}{h_1} \cdot \frac{1}{h_1 R} \cdot \overline{v^2} + \frac{U}{h_1}\left(-\frac{h_1}{R}\right)\left(\frac{\overline{u^2}}{h_1^2}\right) + V \cdot \frac{1}{h_1 R} \cdot \frac{\overline{uv}}{h_1}$$

which reduces to

$$M^{12} = -\frac{1}{h_1^2}\left[U\frac{\partial \overline{uv}}{\partial s} + h_1 V\frac{\partial \overline{uv}}{\partial n} + h_1 W\frac{\partial \overline{uv}}{\partial z} + \frac{U}{R}(\overline{v^2} - \overline{u^2})\right] \qquad (A2.11)$$

(iv) For i = 3, j = 3:

From (A2.8):

$$M^{33} = U^k \frac{\partial \tau^{33}}{\partial x^k}$$

since all Christoffel symbols with a 3 in them are zero.

$$\therefore -M^{33} = \frac{U}{h_1}\frac{\partial \overline{w^2}}{\partial s} + V\frac{\partial \overline{w^2}}{\partial n} + W\frac{\partial \overline{w^2}}{\partial z}$$

or $$M^{33} = -\frac{1}{h_1}\left[U\frac{\partial \overline{w^2}}{\partial s} + h_1 V\frac{\partial \overline{w^2}}{\partial n} + h_1 W\frac{\partial \overline{w^2}}{\partial z}\right] \qquad (A2.12)$$

(v) For i = 1, j = 3:

From (A2.8):

$$M^{13} = M^{31} = U^k\frac{\partial \tau^{13}}{\partial x^k} + U^1\left\{{1 \atop m\ 1}\right\}\tau^{m3} + U^2\left\{{1 \atop m\ 2}\right\}\tau^{m3}$$

$$\therefore -M^{13} = \frac{U}{h_1}\frac{\partial}{\partial s}\left(\frac{\overline{uw}}{h_1}\right) + V\frac{\partial}{\partial n}\left(\frac{\overline{uw}}{h_1}\right) + W\frac{\partial}{\partial z}\left(\frac{\overline{uw}}{h_1}\right)$$
$$+ \frac{U}{h_1}\cdot\frac{1}{h_1}\frac{\partial h_1}{\partial s}\cdot\left(\frac{\overline{uw}}{h_1}\right) + \frac{U}{h_1}\cdot\frac{1}{h_1 R}\cdot(\overline{vw}) + V\cdot\frac{1}{h_1 R}\cdot\left(\frac{\overline{uw}}{h_1}\right)$$

which reduces to

$$M^{13} = -\frac{1}{h_1^2}\left[U\frac{\partial \overline{uw}}{\partial s} + h_1 V\frac{\partial \overline{uw}}{\partial n} + h_1 W\frac{\partial \overline{uw}}{\partial z} + \frac{U}{R}(\overline{vw})\right] \qquad (A2.13)$$

(vi) For i = 2, j = 3:

$$M^{23} = M^{32} = U^k \frac{\partial \tau^{23}}{\partial x^k} + U^1 \left\{ {2 \atop m\ 1} \right\} \tau^{m3} + U^2 \left\{ {2 \atop m\ 2} \right\} \tau^{m3}$$

$$\therefore -M^{23} = \frac{U}{h_1} \frac{\partial}{\partial s}(\overline{vw}) + V \frac{\partial}{\partial n}(\overline{vw}) + W \frac{\partial}{\partial z}(\overline{vw}) + \frac{U}{h_1}\left(-\frac{h_1}{R}\right) \frac{\overline{uw}}{h_1}$$

$$\therefore M^{23} = -\frac{1}{h_1}\left[U \frac{\partial \overline{vw}}{\partial s} + h_1 V \frac{\partial \overline{vw}}{\partial n} + h_1 W \frac{\partial \overline{vw}}{\partial z} - \frac{U}{R}(\overline{uw}) \right]$$

(A2.14)

II Generation Term

This is the term representing the generation of Reynolds stress by the mean flow and is written

$$G^{ij} = \tau^{il} U^j_{,l} + \tau^{jl} U^i_{,l} = \tau^{il}\left[\frac{\partial U^j}{\partial x^l} + \left\{ {j \atop l\ m} \right\} U^m \right] + \tau^{jl}\left[\frac{\partial U^i}{\partial x^l} + \left\{ {i \atop l\ m} \right\} U^m \right]$$

$$= \tau^{il} \frac{\partial U^j}{\partial x^l} + \tau^{jl} \frac{\partial U^i}{\partial x^l} + \tau^{il} \left\{ {j \atop l\ m} \right\} U^m + \tau^{jl} \left\{ {i \atop l\ m} \right\} U^m$$

(A2.15)

where here $\tau^{ij} = u^i u^j$.

For i = j this reduces to

$$G^{ii} = 2\tau^{il} U^i_{,l} = 2\tau^{il} \frac{\partial U^i}{\partial x^l} + 2\tau^{il} \left\{ {i \atop l\ m} \right\} U^m$$

(A2.16)

(i) <u>For i = 1, j = 1</u>:

Using (A2.16) we obtain:

$$G^{11} = 2\tau^{1\ell}\frac{\partial U^1}{\partial x^\ell} + 2\tau^{1\ell}\left\{{}_{\ell}{}^{1}{}_{m}\right\}U^m$$

$$\therefore \frac{G^{11}}{2} = \tau^{11}\frac{\partial U^1}{\partial x^1} + \tau^{12}\frac{\partial U^1}{\partial x^2} + \tau^{13}\frac{\partial U^1}{\partial x^3} + \tau^{11}\left\{{}_{1}{}^{1}{}_{1}\right\}U^1$$
$$+ \tau^{12}\left\{{}_{2}{}^{1}{}_{1}\right\}U^1 + \tau^{11}\left\{{}_{1}{}^{1}{}_{2}\right\}U^2 + \tau^{12}\left\{{}_{2}{}^{1}{}_{2}\right\}U^2$$

$$\therefore \frac{G^{11}}{2} = \frac{\overline{u^2}}{h_1^2}\cdot\frac{\partial}{\partial s}\left(\frac{U}{h_1}\right) + \frac{\overline{uv}}{h_1}\frac{\partial}{\partial n}\left(\frac{U}{h_1}\right) + \frac{\overline{uw}}{h_1}\frac{\partial}{\partial z}\left(\frac{U}{h_1}\right)$$
$$+ \frac{\overline{u^2}}{h_1^2}\cdot\frac{1}{h_1}\frac{\partial h_1}{\partial s}\cdot\frac{U}{h_1} + \frac{\overline{u^2}}{h_1^2}\cdot\frac{1}{h_1 R}\cdot V + \frac{\overline{uv}}{h_1}\cdot\frac{1}{h_1 R}\cdot\frac{U}{h_1}$$

which reduces to

$$G^{11} = \frac{2}{h_1^3}\left[\overline{u^2}\left(\frac{\partial U}{\partial s} + \frac{V}{R}\right) + h_1(\overline{uv})\frac{\partial U}{\partial n} + h_1(\overline{uw})\frac{\partial U}{\partial z}\right] \tag{A2.17}$$

(ii) <u>For i = j = 2</u>:

$$\frac{G^{22}}{2} = \tau^{2\ell}\frac{\partial U^2}{\partial x^\ell} + \tau^{2\ell}\left\{{}_{\ell}{}^{2}{}_{m}\right\}U^m$$
$$= \tau^{21}\frac{\partial U^2}{\partial x^1} + \tau^{22}\frac{\partial U^2}{\partial x^2} + \tau^{23}\frac{\partial U^2}{\partial x^3} + \tau^{21}\left\{{}_{1}{}^{2}{}_{1}\right\}U^1$$
$$+ \tau^{21}\left\{{}_{1}{}^{2}{}_{2}\right\}U^2 + \tau^{22}\left\{{}_{2}{}^{2}{}_{1}\right\}U^1 + \tau^{22}\left\{{}_{2}{}^{2}{}_{2}\right\}U^2$$

$$= \frac{\overline{uv}}{h_1}\cdot\frac{\partial V}{\partial s} + \overline{v^2}\frac{\partial V}{\partial n} + \overline{vw}\frac{\partial V}{\partial z} + \frac{\overline{uv}}{h_1}\left(-\frac{h_1}{R}\right)\cdot\frac{U}{h_1}$$

$$\therefore\ G^{22} = \frac{2}{h_1}\left[h_1\overline{v^2}\frac{\partial V}{\partial n} + \overline{uv}\left(\frac{\partial V}{\partial s} - \frac{U}{R}\right) + h_1\overline{vw}\frac{\partial V}{\partial z}\right] \qquad (A2.18)$$

(iii) <u>For i = j = 3:</u>

$$\frac{G^{33}}{2} = \tau^{3l}\frac{\partial U^3}{\partial x^l} = \frac{\overline{uw}}{h_1}\frac{\partial W}{\partial s} + \overline{vw}\frac{\partial W}{\partial n} + \overline{w^2}\frac{\partial W}{\partial z}$$

$$\therefore\ G^{33} = \frac{2}{h_1}\left[\overline{uw}\frac{\partial W}{\partial s} + h_1\overline{vw}\frac{\partial W}{\partial n} + h_1\overline{w^2}\frac{\partial W}{\partial z}\right] \qquad (A2.19)$$

(iv) <u>For i = 1, j = 2:</u>

$$G^{12} = \tau^{1l}\frac{\partial U^2}{\partial x^l} + \tau^{1l}\left\{{2 \atop l\ m}\right\}U^m + \tau^{2l}\frac{\partial U^1}{\partial x^l} + \tau^{2l}\left\{{1 \atop l\ m}\right\}U^m$$

$$\therefore\ G^{12} = \frac{\overline{u^2}}{h_1^2}\frac{\partial V}{\partial s} + \frac{\overline{uv}}{h_1}\cdot\frac{\partial V}{\partial n} + \frac{\overline{u^2}}{h_1^2}\left(-\frac{h_1}{R}\right)\cdot\frac{U}{h_1} + \frac{\overline{uv}}{h_1}\frac{\partial}{\partial s}\left(\frac{U}{h_1}\right)$$

$$+ \overline{v^2}\frac{\partial}{\partial n}\left(\frac{U}{h_1}\right) + \frac{\overline{uv}}{h_1}\cdot\frac{1}{h_1}\frac{\partial h_1}{\partial s}\cdot\frac{U}{h_1} + \frac{\overline{uv}}{h_1}\cdot\frac{1}{h_1 R}\cdot V + \overline{v^2}\cdot\frac{1}{h_1 R}\cdot\frac{U}{h_1}$$

$$+ \frac{\overline{uw}}{h_1}\frac{\partial V}{\partial z} + \overline{vw}\cdot\frac{\partial}{\partial z}\left(\frac{U}{h_1}\right)$$

which reduces to

$$G^{12} = \frac{1}{h_1^2}\left[\overline{u^2}\left(\frac{\partial V}{\partial s} - \frac{U}{R}\right) + h_1 \overline{v^2}\frac{\partial U}{\partial n} + h_1 \overline{uw}\frac{\partial V}{\partial z} + h_1 \overline{vw}\frac{\partial U}{\partial z}\right]$$

(A2.20)

(v) <u>For i = 1, j = 3</u>:

$$G^{13} = \tau^{1\ell}\frac{\partial U^3}{\partial x^\ell} + \tau^{3\ell}\frac{\partial U^1}{\partial x^\ell} + \tau^{3\ell}\left\{{1 \atop \ell\ m}\right\}U^m$$

$$\therefore G^{13} = \frac{\overline{u^2}}{h_1^2}\frac{\partial W}{\partial s} + \frac{\overline{uv}}{h_1}\frac{\partial W}{\partial n} + \frac{\overline{uw}}{h_1}\frac{\partial W}{\partial z} + \frac{\overline{uw}}{h_1}\frac{\partial}{\partial s}\left(\frac{U}{h_1}\right)$$
$$+ \overline{vw}\frac{\partial}{\partial n}\left(\frac{U}{h_1}\right) + \overline{w^2}\frac{\partial}{\partial z}\left(\frac{U}{h_1}\right) + \frac{\overline{uw}}{h_1}\cdot\frac{1}{h_1}\frac{\partial h_1}{\partial s}\cdot\frac{U}{h_1}$$
$$+ \frac{\overline{uw}}{h_1}\cdot\frac{1}{h_1 R}\cdot V + \overline{vw}\cdot\frac{1}{h_1 R}\cdot\frac{U}{h_1}$$

which reduces to:

$$G^{13} = \frac{1}{h_1^2}\left[\overline{u^2}\frac{\partial W}{\partial s} + h_1\overline{uv}\frac{\partial W}{\partial n} + \left(h_1\frac{\partial W}{\partial z} + \frac{\partial U}{\partial s} + \frac{V}{R}\right)\overline{uw}\right.$$
$$\left. + h_1\overline{vw}\frac{\partial U}{\partial n} + h_1\overline{w^2}\frac{\partial U}{\partial z}\right]$$

By continuity $\quad \frac{\partial U}{\partial s} + \frac{V}{R} + h_1\frac{\partial V}{\partial n} + h_1\frac{\partial W}{\partial z} = 0$

$$\therefore G^{13} = \frac{1}{h_1^2}\left[\overline{u^2}\frac{\partial W}{\partial s} + h_1\overline{uv}\frac{\partial W}{\partial n} + h_1\overline{w^2}\frac{\partial U}{\partial z} - h_1\overline{uw}\frac{\partial V}{\partial n}\right.$$
$$\left. + h_1\overline{vw}\frac{\partial U}{\partial n}\right] \qquad \text{(A2.21)}$$

(vi) For i = 2, j = 3:

$$G^{23} = \tau^{2\ell}\frac{\partial U^3}{\partial x^\ell} + \tau^{3\ell}\frac{\partial U^2}{\partial x^\ell} + \tau^{3\ell}\left\{ {2 \atop \ell\ m} \right\} U^m$$

$$\therefore G^{23} = \frac{\overline{uv}}{h_1}\frac{\partial W}{\partial s} + \overline{v^2}\frac{\partial W}{\partial n} + \overline{vw}\frac{\partial W}{\partial z} + \frac{\overline{uw}}{h_1}\frac{\partial V}{\partial s} + \overline{vw}\frac{\partial V}{\partial n}$$
$$+ \overline{w^2}\frac{\partial V}{\partial z} + \frac{\overline{uw}}{h_1}\left(-\frac{h_1}{R}\right)\left(\frac{U}{h_1}\right)$$

which reduces to

$$G^{23} = \frac{1}{h_1}\cdot\left[\overline{uv}\frac{\partial W}{\partial s} + h_1\overline{v^2}\frac{\partial W}{\partial n} + h_1\overline{vw}\left(\frac{\partial W}{\partial z} + \frac{\partial V}{\partial n}\right)\right.$$
$$\left. + h_1\overline{w^2}\frac{\partial V}{\partial z} + \overline{uw}\left(\frac{\partial V}{\partial s} - \frac{U}{R}\right)\right] \quad (A2.22)$$

III Pressure Re-Distribution Term

This term re-distributes the Reynolds stress over the three coordinate directions, thus tending to make the turbulence more isotropic. We can write it as:

$$R^{ij} = -\overline{\frac{p'}{\rho}\left(g^{i\ell}u^j_{,\ell} + g^{j\ell}u^i_{,\ell}\right)}$$

Now, for orthogonal coordinates $g^{il} = 0$ for $l \neq i$

$$\therefore R^{ij} = -\overline{\frac{p'}{\rho}\left(g^{ii}u^j_{,i} + g^{jj}u^i_{,j}\right)} = -\overline{\frac{p'}{\rho}\left(\frac{u^j_{,i}}{h_i^2} + \frac{u^i_{,j}}{h_j^2}\right)}$$

(A2.23)

For i = j, $R^{ii} = -2\overline{\frac{p'}{\rho}\left(\frac{u^i_{,i}}{h_i^2}\right)}$ (A2.24) and $$u^i_{,j} = \frac{\partial u^i}{\partial x^j} + \left\{ {i \atop j\ m} \right\} u^m$$

In the above let r^{ij} be defined by $R^{ij} = -\overline{\frac{p'}{\rho} r^{ij}}$

(i) <u>For i = j = 1</u>:

$$r^{11} = 2\frac{u^1_{,1}}{h_1^2} = \frac{2}{h_1^2}\left[\frac{\partial u^1}{\partial x^1} + \left\{ {1 \atop 1\ m} \right\} u^m\right]$$

$$= \frac{2}{h_1^2}\left[\frac{\partial}{\partial s}\left(\frac{u}{h_1}\right) + \frac{1}{h_1}\frac{\partial h_1}{\partial s}\cdot\frac{u}{h_1} + \frac{1}{h_1 R}\cdot v\right]$$

$$= \frac{2}{h_1^3}\left(\frac{\partial u}{\partial s} + \frac{v}{R}\right)$$

$$\therefore \quad R^{11} = -\frac{2}{h_1^3}\overline{\frac{p'}{\rho}\left(\frac{\partial u}{\partial s} + \frac{v}{R}\right)} \qquad (A2.24)$$

(ii) <u>For i = j = 2</u>:

$$r^{22} = 2\frac{u^2_{,2}}{h_2^2} = 2\left[\frac{\partial u^2}{\partial x^2} + \left\{ {2 \atop 2\ m} \right\} u^m\right] = 2\frac{\partial v}{\partial n}$$

$$\therefore \quad R^{22} = -2\overline{\frac{p'}{\rho}\frac{\partial v}{\partial n}} \qquad (A2.25)$$

(iii) <u>For i = j = 3</u>:

$$r^{33} = 2\frac{u^3_{,3}}{h_3^2} = 2\left[\frac{\partial u^3}{\partial x^3} + \left\{ {3 \atop 3\ m} \right\} u^m\right] = 2\frac{\partial w}{\partial z}$$

$$\therefore \quad R^{33} = -2\overline{\frac{p'}{\rho}\frac{\partial w}{\partial z}} \qquad (A2.26)$$

(iv) For i = 1, j = 2:

$$\tau^{12} = \frac{u^2_{,1}}{h_1^2} + \frac{u^1_{,2}}{h_2^2} = \frac{1}{h_1^2}\left[\frac{\partial u^2}{\partial x^1} + \left\{ {2 \atop 1\ m} \right\} u^m\right] + \frac{\partial u^1}{\partial x^2} + \left\{ {1 \atop 2\ m} \right\} u^m$$

$$= \frac{1}{h_1^2}\left[\frac{\partial v}{\partial s} + \left(-\frac{h_1}{R}\right)\left(\frac{u}{h_1}\right)\right] + \frac{\partial}{\partial n}\left(\frac{u}{h_1}\right) + \frac{1}{h_1 R}\left(\frac{u}{h_1}\right)$$

$$= \frac{1}{h_1^2}\left(\frac{\partial v}{\partial s} + h_1\frac{\partial u}{\partial n} - \frac{u}{R}\right)$$

$$\therefore R^{12} = -\frac{1}{h_1^2}\cdot\overline{\frac{p'}{\rho}\left(\frac{\partial v}{\partial s} + h_1\frac{\partial u}{\partial n} - \frac{u}{R}\right)} \qquad (A2.27)$$

(v) For i = 1, j = 3:

$$\tau^{13} = \frac{u^3_{,1}}{h_1^2} + \frac{u^1_{,3}}{h_3^2} = \frac{1}{h_1^2}\left[\frac{\partial u^3}{\partial x^1} + \left\{ {3 \atop 1\ m} \right\} u^m\right] + \frac{\partial u^1}{\partial x^3} + \left\{ {1 \atop 3\ m} \right\} u^m$$

$$\therefore \tau^{13} = \frac{1}{h_1^2}\cdot\frac{\partial w}{\partial s} + \frac{\partial}{\partial z}\left(\frac{u}{h_1}\right)$$

$$\therefore R^{13} = -\frac{1}{h_1^2}\cdot\overline{\frac{p'}{\rho}\left(h_1\frac{\partial u}{\partial z} + \frac{\partial w}{\partial s}\right)} \qquad (A2.28)$$

(vi) For i = 2, j = 3:

$$\tau^{23} = \frac{u^3_{,2}}{h_2^2} + \frac{u^2_{,3}}{h_3^2} = \frac{\partial u^3}{\partial x^2} + \frac{\partial u^2}{\partial x^3}$$

$$\therefore R^{23} = -\overline{\frac{p'}{\rho}\left(\frac{\partial w}{\partial n} + \frac{\partial v}{\partial z}\right)} \qquad (A2.29)$$

since all Christoffel symbols with 3 in them are zero.

IV Turbulent Transport Term

This term represents the transport of Reynolds stress by the turbulence via the pressure and velocity fluctuations. We shall represent the transport by pressure fluctuations by P^{ij} and that by velocity fluctuations by S^{ij}, so that $T^{ij} = P^{ij} + S^{ij}$ with

$$P^{ij} = \left[g^{il}\left(\overline{\frac{p'}{\rho}u^j}\right)_{,l} + g^{jl}\left(\overline{\frac{p'}{\rho}u^i}\right)_{,l} \right]$$

and $$S^{ij} = \overline{(u^i u^j u^l)}_{,l} = \overline{u^l (u^i u^j)_{,l}}$$

since $u^l_{,l} = 0$ by continuity.

$$\therefore \; S^{ij} = \overline{u^l \tau^{ij}_{,l}}$$

where $\tau^{ij} = +u^i u^j$ here.

We note the similarity of the expression for P^{ij} with that for the pressure re-distribution term R^{ij}; if we write

$p^i = \frac{p'}{\rho} u^i$ then $P^{ij} = -\left[g^{il} p^j_{,l} + g^{jl} p^i_{,l} \right]$ which is exactly similar to the expression for r^{ij}. Therefore we can directly deduce P^{ij} from R^{ij}.

As for S^{ij}, we note that this is exactly similar to the expression for the mean transport term M^{ij} except that U^l is replaced by the fluctuating velocity component u^l, so that we can deduce the expressions for S^{ij} directly from the expressions for M^{ij}.

(a) The Term P^{ij}:

(i) For $i = j = 1$:

$$P^{11} = \frac{2}{h_1^3}\left(\frac{\partial p^1}{\partial s} + \frac{p^2}{R} \right)$$

from the expression for r^{11} in III-(i) above.

$$\therefore \quad P^{11} = \frac{2}{h_1^3}\left[\frac{\partial}{\partial s}\left(\overline{\frac{p'u}{\rho}}\right) + \overline{\frac{p'}{\rho}\cdot\frac{v}{R}}\right] \quad (A2.30)$$

(ii) For i = j = 2:

From the expression for r^{22} from III-(ii) we obtain:

$$P^{22} = 2\frac{\partial}{\partial n}(p^2) = 2\frac{\partial}{\partial n}\left(\overline{\frac{p'v}{\rho}}\right) \quad (A2.31)$$

(iii) For i = j = 3:

By comparison with r^{33} from III-(iii) we obtain:

$$P^{33} = 2\frac{\partial p^3}{\partial z} = 2\frac{\partial}{\partial z}\left(\overline{\frac{p'w}{\rho}}\right) \quad (A2.32)$$

(iv) For i = 1, j = 2:

By comparison with r^{12} in III-(iv) we get:

$$P^{12} = \frac{1}{h_1^2}\left[\frac{\partial p^2}{\partial s} + h_1\frac{\partial p^1}{\partial n} - \frac{p^1}{R}\right]$$

$$= \frac{1}{h_1^2}\left[\frac{\partial}{\partial s}\left(\overline{\frac{p'v}{\rho}}\right) + h_1\frac{\partial}{\partial n}\left(\overline{\frac{p'}{\rho}u}\right) - \left(\overline{\frac{p'}{\rho}\cdot\frac{u}{R}}\right)\right] \quad (A2.33)$$

(v) For i = 1, j = 3:

Comparing with r^{13} from III-(v) we find:

$$P^{13} = \frac{1}{h_1^2}\left[h_1\frac{\partial p^1}{\partial z} + \frac{\partial p^3}{\partial s}\right] = \frac{1}{h_1^2}\left[h_1\frac{\partial}{\partial z}\left(\overline{\frac{p'u}{\rho}}\right) + \frac{\partial}{\partial s}\left(\overline{\frac{p'w}{\rho}}\right)\right] \quad (A2.34)$$

(vi) For i = 2, j = 3:

In comparison with r^{23} in III-(vi) we find:

$$P^{23} = \frac{\partial p^3}{\partial n} + \frac{\partial p^2}{\partial z} = \frac{\partial}{\partial n}\left(\overline{\frac{p'w}{\rho}}\right) + \frac{\partial}{\partial z}\left(\overline{\frac{p'v}{\rho}}\right) \quad (A2.35)$$

(b) The Term S^{ij}:

(i) For i = j = 1:

If we put u for U, v for V and w for W in (A2.9) we obtain the expression for S^{11}:

Thus $$S^{11} = \frac{1}{h_1^3}\left[\overline{u\frac{\partial u^2}{\partial s}} + h_1 \overline{v\frac{\partial u^2}{\partial n}} + 2\frac{\overline{u^2 v}}{R} + h_1 \overline{w\frac{\partial u^2}{\partial z}} \right]$$

Now, the continuity equation for the fluctuating velocities is

$$\frac{\partial u}{\partial s} + h_1 \frac{\partial v}{\partial n} + \frac{v}{R} + h_1 \frac{\partial w}{\partial z} = 0$$

The above expression for S^{11} can be written:

$$S^{11} = \frac{1}{h_1^3}\left[\frac{\partial \overline{u^3}}{\partial s} - \overline{u^2 \frac{\partial u}{\partial s}} + h_1 \frac{\partial \overline{u^2 v}}{\partial n} - \overline{u^2 h_1 \frac{\partial v}{\partial n}} + 2\frac{\overline{u^2 v}}{R} + h_1 \frac{\partial}{\partial z}(\overline{u^2 w}) - \overline{u^2 h_1 \frac{\partial w}{\partial z}} \right]$$

If we multiply the above continuity equation by u^2 and take the mean we obtain

$$\overline{u^2 \frac{\partial u}{\partial s}} + \overline{u^2 h_1 \frac{\partial v}{\partial n}} + \overline{u^2 h_1 \frac{\partial w}{\partial z}} = -\frac{\overline{u^2 v}}{R}$$

so that

$$S^{11} = \frac{1}{h_1^3}\left[\frac{\partial \overline{u^3}}{\partial s} + h_1 \frac{\partial \overline{u^2 v}}{\partial n} + h_1 \frac{\partial \overline{u^2 w}}{\partial z} + 3\frac{\overline{u^2 v}}{R} \right] \qquad (A2.36)$$

(ii) For i = j = 2:

Using (A2.10) and through the use of continuity, as in (i) above, we obtain

$$S^{22} = \frac{1}{h_1}\left[\overline{u\frac{\partial v^2}{\partial s}} + h_1 \overline{v\frac{\partial v^2}{\partial n}} - 2\frac{\overline{u^2 v}}{R} + h_1 \overline{w\frac{\partial v^2}{\partial z}} \right]$$

$$= \frac{1}{h_1}\left[\frac{\partial \overline{uv^2}}{\partial s} + h_1 \frac{\partial \overline{v^3}}{\partial n} + h_1 \frac{\partial \overline{v^2 w}}{\partial z} + \left(\frac{\overline{v^3} - 2\overline{u^2 v}}{R} \right) \right] \qquad (A2.37)$$

(iii) <u>For i = j = 3</u>:

Using (A2.12) and continuity, we obtain:

$$S^{33} = \frac{1}{h_1}\left[\overline{u\frac{\partial w^2}{\partial s}} + h_1\,\overline{v\frac{\partial w^2}{\partial n}} + h_1\,\overline{w\frac{\partial w^2}{\partial z}}\right]$$

$$= \frac{1}{h_1}\left[\frac{\partial \overline{uw^2}}{\partial s} + h_1\frac{\partial \overline{vw^2}}{\partial n} + h_1\frac{\partial \overline{w^3}}{\partial z} + \frac{\overline{w^2 v}}{R}\right]$$

(A2.38)

(iv) <u>For i = 1, j = 2</u>:

From (A2.11) and using continuity, we find:

$$S^{12} = \frac{1}{h_1^2}\left[\overline{u\frac{\partial uv}{\partial s}} + h_1\,\overline{v\frac{\partial uv}{\partial n}} + h_1\,\overline{w\frac{\partial uv}{\partial z}} + \left(\frac{\overline{u^3} - \overline{uv^2}}{R}\right)\right]$$

$$= \frac{1}{h_1^2}\left[\frac{\partial \overline{u^2 v}}{\partial s} + h_1\frac{\partial \overline{uv^2}}{\partial n} + h_1\frac{\partial \overline{uvw}}{\partial z} + \left(\frac{2\overline{uv^2} - \overline{u^3}}{R}\right)\right]$$

(A2.39)

(v) <u>For i = 1, j = 3</u>:

From (A2.13) and using continuity, we find:

$$S^{13} = \frac{1}{h_1^2}\left[\overline{u\frac{\partial uw}{\partial s}} + h_1\,\overline{v\frac{\partial uw}{\partial n}} + h_1\,\overline{w\frac{\partial uw}{\partial z}} + \frac{\overline{uvw}}{R}\right]$$

(A2.40)

(vi) <u>For i = 2, j = 3</u>:

From (A2.14) and using continuity, we obtain:

$$S^{23} = \frac{1}{h_1}\left[\overline{u\frac{\partial vw}{\partial s}} + h_1\,\overline{v\frac{\partial vw}{\partial n}} + h_1\,\overline{w\frac{\partial vw}{\partial z}} - \frac{\overline{u^2 w}}{R}\right]$$

$$= \frac{1}{h_1}\left[\frac{\partial \overline{uvw}}{\partial s} + h_1\frac{\partial \overline{v^2 w}}{\partial n} + h_1\frac{\partial \overline{vw^2}}{\partial z} + \left(\frac{\overline{v^2 w} - \overline{u^2 w}}{R}\right)\right]$$

(A2.41)

We can now write the transport equations for the Reynolds stresses $-\rho\overline{u^2}$, $-\rho\overline{v^2}$, $-\rho\overline{w^2}$, $-\rho\overline{uv}$, $-\rho\overline{vw}$, $-\rho\overline{uw}$ in s-n-z coordinates for incompressible flow (and neglecting the viscous terms), as follows:

(1) $-\overline{u^2}$ Equation:

$$U\frac{\partial}{\partial s}(-\overline{u^2}) + h_1 V\frac{\partial}{\partial n}(-\overline{u^2}) + \underline{h_1 W\frac{\partial}{\partial z}(-\overline{u^2})} + \frac{2U}{R}(-\overline{uv}) =$$

$$\text{I}$$

$$2\overline{u^2}\left(\frac{\partial U}{\partial s}+\frac{V}{R}\right) + 2h_1(\overline{uv})\frac{\partial U}{\partial n} + \underline{2h_1\overline{uw}\frac{\partial U}{\partial z}}$$

$$\text{II}$$

$$-2\overline{\frac{p'}{\rho}\left(\frac{\partial u}{\partial s}+\frac{v}{R}\right)}$$

$$\text{III}$$

$$+2\left[\frac{\partial}{\partial s}\left(\frac{\overline{p'u}}{\rho}\right)+\frac{\overline{p'v}}{\rho R}\right] + \left[\frac{\partial\overline{u^3}}{\partial s} + h_1\frac{\partial\overline{u^2v}}{\partial n} + \underline{h_1\frac{\partial\overline{u^2w}}{\partial z}} + 3\frac{\overline{u^2v}}{R}\right]$$

$$\text{IVa} \qquad\qquad \text{IVb} \qquad\qquad (A2.42)$$

(2) $-\overline{v^2}$ Equation:

$$U\frac{\partial}{\partial s}(-\overline{v^2}) + h_1 V\frac{\partial}{\partial n}(-\overline{v^2}) + \underline{h_1 W\frac{\partial}{\partial z}(-\overline{v^2})} - \frac{2U}{R}(-\overline{uv}) =$$

$$\text{I}$$

$$2h_1\overline{v^2}\frac{\partial V}{\partial n} + 2\overline{uv}\left(\frac{\partial V}{\partial s}-\frac{U}{R}\right) + \underline{2h_1(\overline{vw})\frac{\partial V}{\partial z}}$$

$$\text{II}$$

$$-2h_1\overline{\frac{p'}{\rho}\frac{\partial v}{\partial n}} \qquad \text{III}$$

$$+2h_1\frac{\partial}{\partial n}\left(\frac{\overline{p'v}}{\rho}\right) + \left[\frac{\partial\overline{uv^2}}{\partial s} + h_1\frac{\partial\overline{v^3}}{\partial n} + \underline{h_1\frac{\partial\overline{v^2w}}{\partial z}} + \left(\frac{\overline{v^3}-2\overline{u^2v}}{R}\right)\right]$$

$$\text{IVa} \qquad\qquad \text{IVb} \qquad\qquad (A2.43)$$

(3) $\overline{-w^2}$ Equation:

$$U\frac{\partial}{\partial s}(-\overline{w^2}) + h_1 V\frac{\partial}{\partial n}(-\overline{w^2}) + \underline{h_1 W\frac{\partial}{\partial z}(-\overline{w^2})} =$$

I

$$+ 2\overline{uw}\frac{\partial W}{\partial s} + 2h_1\overline{vw}\frac{\partial W}{\partial n} + \underline{2h_1\overline{w^2}\frac{\partial W}{\partial z}}$$

II

$$- \underline{2h_1\overline{\frac{p'}{\rho}\frac{\partial w}{\partial z}}} \qquad \text{III}$$

$$+ \underline{2h_1\frac{\partial}{\partial z}\left(\overline{\frac{p'w}{\rho}}\right)} + \left[\frac{\partial\overline{uw^2}}{\partial s} + h_1\frac{\partial\overline{vw^2}}{\partial n} + \underline{h_1\frac{\partial\overline{w^3}}{\partial z}} + \frac{\overline{w^2 v}}{R}\right]$$

IVa IVb (A2.44)

(4) $\overline{-uv}$ Equation:

$$U\frac{\partial}{\partial s}(-\overline{uv}) + h_1 V\frac{\partial}{\partial n}(-\overline{uv}) + \underline{h_1 W\frac{\partial}{\partial z}(-\overline{uv})} + \frac{U}{R}(\overline{u^2}-\overline{v^2}) =$$

I

$$+ \overline{u^2}\left(\frac{\partial V}{\partial s} - \frac{U}{R}\right) + h_1\overline{v^2}\frac{\partial U}{\partial n} + \underline{h_1\overline{uw}\frac{\partial V}{\partial z}} + \underline{h_1\overline{vw}\frac{\partial U}{\partial z}}$$

II

$$- \overline{\frac{p'}{\rho}\left(\frac{\partial v}{\partial s} + h_1\frac{\partial u}{\partial n} - \frac{u}{R}\right)} \qquad \text{III}$$

$$+ \left[\frac{\partial}{\partial s}\left(\overline{\frac{p'v}{\rho}}\right) + h_1\frac{\partial}{\partial n}\left(\overline{\frac{p'u}{\rho}}\right) - \overline{\frac{p'}{\rho}\cdot\frac{u}{R}}\right] \qquad \text{IVa}$$

$$+\left[\frac{\partial \overline{u^2 v}}{\partial s} + h_1 \frac{\partial \overline{uv^2}}{\partial n} + h_1 \frac{\partial}{\partial z}(\overline{uvw}) + \left(\frac{2\overline{uv^2} - \overline{u^3}}{R}\right)\right]$$

IV b (A2.45)

(5) $-\overline{vw}$ Equation:

$$U\frac{\partial}{\partial s}(-\overline{vw}) + h_1 V \frac{\partial}{\partial n}(-\overline{vw}) + \underline{h_1 W \frac{\partial}{\partial z}(-\overline{vw})} - \frac{U}{R}(-\overline{uw}) =$$

I

$$\underline{\overline{uv}\frac{\partial W}{\partial s}} + \underline{h_1 \overline{v^2}\frac{\partial W}{\partial n}} + \underline{h_1 \overline{w^2}\frac{\partial V}{\partial z}} + h_1 \overline{vw}\left(\underline{\frac{\partial W}{\partial z}} + \frac{\partial V}{\partial n}\right) + \overline{uw}\left(\frac{\partial V}{\partial s} - \frac{U}{R}\right)$$

II

$$- h_1 \overline{\frac{p'}{\rho}\left(\frac{\partial w}{\partial n} + \underline{\frac{\partial v}{\partial z}}\right)} \qquad \text{III}$$

$$+ h_1 \left[\frac{\partial}{\partial n}\left(\overline{\frac{p'w}{\rho}}\right) + \underline{\frac{\partial}{\partial z}\left(\overline{\frac{p'v}{\rho}}\right)}\right]$$

IVa

$$+\left[\frac{\partial \overline{uvw}}{\partial s} + h_1 \frac{\partial \overline{v^2 w}}{\partial n} + \underline{h_1 \frac{\partial \overline{vw^2}}{\partial z}} + \left(\frac{\overline{v^2 w} - \overline{u^2 w}}{R}\right)\right] \quad (A2.46)$$

IV b

(6) <u>$-\overline{uw}$ Equation</u>:

$$U\frac{\partial}{\partial s}(-\overline{uw}) + h_1 V\frac{\partial}{\partial n}(-\overline{uw}) + \underline{h_1 W\frac{\partial}{\partial z}(-\overline{uw})} + \frac{U}{R}(-\overline{vw}) =$$

$$\text{I}$$

$$\overline{u^2}\frac{\partial W}{\partial s} + h_1\overline{uv}\frac{\partial W}{\partial n} + \underline{h_1\overline{w^2}\frac{\partial U}{\partial z}} - h_1\overline{uw}\frac{\partial V}{\partial n} + h_1\overline{vw}\frac{\partial U}{\partial n}$$

$$\text{II}$$

$$-\overline{\frac{p'}{\rho}\left(\underline{h_1\frac{\partial u}{\partial z}} + \frac{\partial w}{\partial s}\right)} \quad \text{III}$$

$$+\left[h_1\frac{\partial}{\partial z}\left(\overline{\frac{p'}{\rho}u}\right) + \frac{\partial}{\partial s}\left(\overline{\frac{p'}{\rho}w}\right)\right] + \left[\frac{\partial\overline{u^2w}}{\partial s} + h_1\frac{\partial\overline{uvw}}{\partial n} + h_1\frac{\partial\overline{uw^2}}{\partial z} + 2\frac{\overline{uvw}}{R}\right]$$

$$\text{IV a} \qquad\qquad \text{IV b} \qquad (A2.47)$$

The underlined terms only apply for three dimensional flow; for two dimensional flow these terms are zero, since W = 0 and there is no variation in the z-direction (i.e. all $\frac{\partial}{\partial z}$ terms are zero). The terms I, II, III, IV correspond to those of equation (A2.2); term IV(a) represents the turbulent transport of Reynolds stress by pressure fluctuations and term IV(b) represents the turbulent transport of Reynolds stress by the velocity fluctuations in the turbulence. Note also that the terms in I which do not contain Reynolds stress gradients but are directly proportional to some of the Reynolds stresses, can be interpreted as being part of the generation term II, since true transport terms must depend on gradients of the Reynolds stresses.

A2.2 DERIVATION OF THE TURBULENT KINETIC ENERGY EQUATION IN s-n-z COORDINATES

We could derive the turbulent kinetic energy equation in s-n coordinates from its generalised tensor form given by equation (A2.4) in a similar way to the derivation of the Reynolds stress equations. However, as we have already derived the normal Reynolds stress $(-\overline{u^2}, -\overline{v^2}, -\overline{w^2})$ equations we can deduce equation for the turbulent kinetic energy $\frac{1}{2}\overline{q^2} \equiv \frac{1}{2}(\overline{u^2} + \overline{v^2} + \overline{w^2})$ by adding the $(-\overline{u^2}, -\overline{v^2}, -\overline{w^2})$ equations; thus we will add equations (A2.42), (A2.43) and (A2.44) together, term by term:

(i) Mean Transport:

Adding the mean transport terms of the normal Reynolds stress transport equations yields

$$-2A = -U\frac{\partial}{\partial s}(\overline{q^2}) - h_1 V\frac{\partial}{\partial n}(\overline{q^2}) - h_1 W\frac{\partial}{\partial z}(\overline{q^2})\ .$$

where A is the advection term in the kinetic energy equation.

(ii) Generation

If we add the generation terms and include the terms which form part of the mean transport term but which are proportional to the Reynolds stresses, we obtain

$$-2P = 2\overline{u^2}\left(\frac{\partial U}{\partial s} + \frac{V}{R}\right) + 2h_1\overline{v^2}\frac{\partial V}{\partial n} + 2h_1\overline{w^2}\frac{\partial W}{\partial z}$$

$$+ 2\overline{uv}\left(h_1\frac{\partial U}{\partial n} + \frac{\partial V}{\partial s} - \frac{U}{R}\right) + 2\overline{vw}\left(\frac{\partial V}{\partial z} + \frac{\partial W}{\partial n}\right) + 2\overline{uw}\left(h_1\frac{\partial U}{\partial z} + \frac{\partial W}{\partial s}\right)$$

(iii) Re-distribution:

$$2R = 2\overline{\frac{p'}{\rho}\left(\frac{\partial u}{\partial s} + \frac{v}{R}\right)} + 2h_1\overline{\frac{p'}{\rho}\frac{\partial v}{\partial n}} + 2h_1\overline{\frac{p'}{\rho}\frac{\partial w}{\partial z}}$$

$$= 2\overline{\frac{p'}{\rho}\left(\frac{\partial u}{\partial s} + h_1\frac{\partial v}{\partial n} + \frac{v}{R} + h_1\frac{\partial w}{\partial z}\right)} = 0$$

by continuity.

Therefore, there is no re-distribution term in the turbulent kinetic energy equation.

(iv) Turbulent Transport:

We will consider the turbulent transport by pressure and velocity fluctuations separately. Let the former be T_p and the latter T_v, then $T = T_p + T_v$.

Now, adding the contributions to T_p from the equations for $-\overline{u^2}$, $-\overline{v^2}$ and $-\overline{w^2}$ yields:

$$-2T_p = 2\frac{\partial}{\partial s}\left(\frac{\overline{p'u}}{\rho}\right) + 2\frac{\overline{p'}}{\rho}\cdot\frac{v}{R} + 2h_1\frac{\partial}{\partial n}\left(\frac{\overline{p'v}}{\rho}\right) + 2h_1\frac{\partial}{\partial z}\left(\frac{\overline{p'w}}{\rho}\right)$$

$$= 2\left[\frac{\partial}{\partial s}\left(\frac{\overline{p'u}}{\rho}\right) + \frac{\partial}{\partial n}\left(h_1\frac{\overline{p'v}}{\rho}\right) + h_1\frac{\partial}{\partial z}\left(\frac{\overline{p'w}}{\rho}\right)\right]$$

and

$$-2T_v = \frac{\partial\overline{u^3}}{\partial s} + \frac{\partial\overline{uv^2}}{\partial s} + \frac{\partial\overline{uw^2}}{\partial s} + h_1\frac{\partial}{\partial n}(\overline{u^2v}) + \frac{\overline{u^2v}}{R}$$
$$+ h_1\frac{\partial\overline{v^3}}{\partial n} + \frac{\overline{v^3}}{R} + h_1\frac{\partial}{\partial n}(\overline{w^2v}) + \frac{\overline{w^2v}}{R} + h_1\frac{\partial}{\partial z}(\overline{u^2w})$$
$$+ h_1\frac{\partial}{\partial z}(\overline{v^2w}) + h_1\frac{\partial}{\partial z}(\overline{w^3})$$
$$= \frac{\partial}{\partial s}(\overline{q^2u}) + \frac{\partial}{\partial n}(h_1\overline{q^2v}) + h_1\frac{\partial}{\partial z}(\overline{q^2w}) .$$

Hence the complete turbulent kinetic energy equation is written as $A = P + T - \varepsilon$ where ε is the viscous dissipation of turbulent kinetic energy.

Thus, we obtain:

$$U\frac{\partial}{\partial s}\left(\tfrac{1}{2}\overline{q^2}\right) + h_1 V\frac{\partial}{\partial n}\left(\tfrac{1}{2}\overline{q^2}\right) + h_1 W\frac{\partial}{\partial z}\left(\tfrac{1}{2}\overline{q^2}\right) =$$

$$-\overline{u^2}\left(\frac{\partial U}{\partial s}+\frac{V}{R}\right)-h_1\overline{v^2}\frac{\partial V}{\partial n}-\underline{h_1\overline{w^2}\frac{\partial W}{\partial z}}-\overline{uv}\left(h_1\frac{\partial U}{\partial n}+\frac{\partial V}{\partial s}-\frac{U}{R}\right)$$

$$-\underline{\overline{vw}\left(\frac{\partial V}{\partial z}+\frac{\partial W}{\partial n}\right)}-\overline{uw}\underline{\left(h_1\frac{\partial U}{\partial z}+\frac{\partial W}{\partial s}\right)}$$

$$-\frac{\partial}{\partial s}\left(\frac{\overline{p'u}}{\rho}+\frac{1}{2}\overline{q^2u}\right)-\frac{\partial}{\partial n}\left[h_1\left(\frac{\overline{p'v}}{\rho}+\frac{1}{2}\overline{q^2v}\right)\right]-\underline{h_1\frac{\partial}{\partial z}\left(\frac{\overline{p'w}}{\rho}+\frac{1}{2}\overline{q^2w}\right)}$$

$$-\epsilon \qquad (A2.48)$$

where the underlined terms are zero for two dimensional flow. The above equations for $-\overline{uv}$ and $\frac{1}{2}\overline{q^2}$ agree, in the two dimensional case, with those given by Bradshaw (1973).

APPENDIX A3

DERIVATION OF EQUATIONS, AND DEFINITIONS, FOR THE SHEAR LAYER CALCULATION

In this appendix we shall derive certain equations, which are referenced in the main body of the thesis, regarding the shear layer calculation. Firstly we shall write down the set of partial differential equations solved; these are the continuity equation (equation (A1.34)), the s-component momentum equation (equation (A1.35)), the n-component momentum equation (equation (A1.36)) and the turbulent kinetic energy equation (equation (A2.48)), for the case of steady, two dimensional flow. We have also inserted the BFA turbulence model assumptions into the turbulent kinetic energy equation, as stated in §1.1 of the thesis.

Thus, we have the following set of equations:

$$\frac{\partial U}{\partial s} + h\frac{\partial V}{\partial n} + \frac{V}{R} = 0 \qquad (A3.1)$$

$$U\frac{\partial U}{\partial s} + hV\frac{\partial U}{\partial n} + \frac{UV}{R} = -\frac{1}{\rho}\frac{\partial p}{\partial s} + \frac{h}{\rho}\frac{\partial \tau}{\partial n} - \frac{c_1}{\rho}\frac{\partial \tau}{\partial s} + \frac{2\tau}{\rho R} \qquad (A3.2)$$

$$U\frac{\partial V}{\partial s} + hV\frac{\partial V}{\partial n} - \frac{U^2}{R} = -\frac{h}{\rho}\frac{\partial p}{\partial n} + \frac{1}{\rho}\frac{\partial \tau}{\partial s} - \frac{hc_2}{\rho}\frac{\partial \tau}{\partial n} + \left(\frac{c_1 - c_2}{R}\right)\frac{\tau}{\rho} \qquad (A3.3)$$

$$U\frac{\partial}{\partial s}\left(\frac{\tau}{2a_1\rho}\right)+hV\frac{\partial}{\partial n}\left(\frac{\tau}{2a_1\rho}\right)=\frac{\tau}{\rho}\left(h\frac{\partial U}{\partial n}+\frac{\partial V}{\partial s}+\hat{e}-\frac{U}{R}\right)$$
$$-c_1\frac{\tau}{\rho}\left(\frac{\partial U}{\partial s}+\frac{V}{R}\right)-hc_2\frac{\tau}{\rho}\cdot\frac{\partial V}{\partial n}-\frac{\partial}{\partial n}\left[hG\left(\frac{\tau_m}{\rho}\right)^{\frac{1}{2}}\cdot\frac{\tau}{\rho}\right]-\frac{(\tau/\rho)^{3/2}}{L} \quad \text{(A3.4)}$$

where $h = 1 + \frac{n}{R}, \frac{\tau}{\rho} = -\overline{uv}$, $\overline{u^2} = c_1\frac{\tau}{\rho}$, $\overline{v^2} = c_2\frac{\tau}{\rho}$, $a_1 = (\frac{\tau/\rho}{\overline{q^2}})$.

Also, the streamwise turbulent transport term $-\frac{\partial}{\partial s}\left[\frac{\overline{p'u}}{\rho} + \frac{1}{2}\overline{q^2u}\right]$ has been neglected in comparison with the n-component turbulent transport term $-\frac{\partial}{\partial n}\left[h(\frac{\overline{p'v}}{\rho} + \frac{1}{2}\overline{q^2v})\right]$. The latter has been modelled by assuming that $(\frac{\overline{p'v}}{\rho} + \frac{1}{2}\overline{q^2v}) = G(\frac{n}{\delta})\cdot(\frac{\tau_m}{\rho})^{\frac{1}{2}}\cdot\frac{\tau}{\rho}$, where G is an empirical function of $\frac{n}{\delta}$ containing a further empirical factor $(\tau_m/\rho U_e^2)^{0.5}$. The viscous dissipation term ε has been assumed equal to $\frac{(\tau/\rho)^{3/2}}{L(n/\delta)}$, where L is an empirical length scale, such that $\frac{L}{\delta}$ is a function of $\frac{n}{\delta}$ only. We have also included an extra strain rate correction $\hat{e}$ to the turbulence model (in the analysis below) exactly as in the original BFA method.

A3.1 DERIVATION OF THE EQUATIONS FOR THE CHARACTERISTIC ANGLES

If we expand the derivative terms in (A3.4) and rearrange equations (A3.1) to (A3.4) such that all the derivative terms are written in the order: $\frac{\partial U}{\partial s}, \frac{\partial U}{\partial n}, \frac{\partial V}{\partial s}, \frac{\partial V}{\partial n}, \frac{\partial \tau}{\partial s}, \frac{\partial \tau}{\partial n}$, we obtain:

$$\frac{\partial U}{\partial s} + h\frac{\partial V}{\partial n} + \left[\frac{V}{R}\right] = 0 \quad \text{(A3.5)}$$

$$U\frac{\partial U}{\partial s}+hV\frac{\partial U}{\partial n}-\frac{h}{\rho}\frac{\partial \tau}{\partial n}+\left[\frac{UV}{R}+\frac{1}{\rho}\frac{\partial p}{\partial s}+\frac{\partial \overline{u^2}}{\partial s}-\frac{2\tau}{\rho R}\right]=0 \quad (A3.6)$$

$$\overline{u^2}\frac{\partial U}{\partial s}-h\frac{\tau}{\rho}\frac{\partial U}{\partial n}+h\overline{v^2}\frac{\partial V}{\partial n}+\frac{U}{2a_1\rho}\frac{\partial \tau}{\partial s}+\left\{\frac{hV}{2a_1\rho}+h\frac{G}{\rho}\left(\frac{\tau_m}{\rho}\right)^{\frac{1}{2}}\right\}\frac{\partial \tau}{\partial n}$$

$$+\left[\overline{u^2}\frac{V}{R}-\frac{\tau}{\rho}\left(\frac{\partial V}{\partial s}+\hat{e}\right)+\frac{\tau U}{\rho R}+\frac{(\tau/\rho)^{3/2}}{L}+\frac{G}{R}\left(\frac{\tau_m}{\rho}\right)^{\frac{1}{2}}\cdot\tau/\rho + h\frac{\tau}{\rho}\left(\frac{\tau_m}{\rho}\right)^{\frac{1}{2}}\cdot\frac{dG}{dn}\right]=0$$

(A3.7)

The terms in square brackets are treated as "known"; thus we are trying to find the directions of the characteristics in solving for the three variables U, V and τ assuming the quantities in the square brackets as given. In particular, we assume that the pressure gradient $\frac{\partial p}{\partial s}$ is known (from the previous guess for the pressure array) and also that the normal Reynolds stresses $-\rho\overline{u^2}$, $-\rho\overline{v^2}$ are given. We also assume that the total extra strain rate $\frac{\partial V}{\partial s}+\hat{e}$ is known.

In order to find the characteristic directions we have to solve a determinant, for the quantity $\frac{dn}{ds}$ (see Ralston and Wilf (1967a)); the resulting solution for $\frac{dn}{ds}$ gives the directions of the characteristics. In this determinant, we write the "coefficients" of the derivatives $\frac{\partial U}{\partial s}$, $\frac{\partial U}{\partial n}$, $\frac{\partial V}{\partial s}$, $\frac{\partial V}{\partial n}$, $\frac{\partial \tau}{\partial s}$, $\frac{\partial \tau}{\partial n}$ in order, for each of equations (A3.5), to (A3.7) in turn, as follows:

Eq. A3.5

Eq. A3.6

Eq. A3.7

$$\begin{vmatrix} 1 & 0 & 0 & h & 0 & 0 \\ U & hV & 0 & 0 & 0 & -h/\rho \\ \overline{u^2} & -\frac{h\tau}{\rho} & 0 & h\overline{v^2} & \frac{U}{2a_1\rho} & \frac{h}{\rho}\left(\frac{V}{2a_1}+\hat{G}\right) \\ ds & dn & 0 & 0 & 0 & 0 \\ 0 & 0 & ds & dn & 0 & 0 \\ 0 & 0 & 0 & 0 & ds & dn \end{vmatrix} = 0$$

where we have written $G(\frac{\tau_m}{\rho})^{\frac{1}{2}}$ as $\hat{G}$.

If we modify the fourth column by subtracting h times the 1st. column from the fourth column we obtain

$$\begin{vmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ U & hV & 0 & -hU & 0 & -h/\rho \\ \overline{u^2} & -\frac{h\tau}{\rho} & 0 & h(\overline{v^2}-\overline{u^2}) & \frac{U}{2a_1\rho} & \frac{h}{\rho}\left(\frac{V}{2a_1}+\hat{G}\right) \\ ds & dn & 0 & -h\,ds & 0 & 0 \\ 0 & 0 & ds & dn & 0 & 0 \\ 0 & 0 & 0 & 0 & ds & dn \end{vmatrix} = 0$$

Expanding by the first row yields:

$$\begin{vmatrix} hV & 0 & -hU & 0 & -h/\rho \\ -\frac{h\tau}{\rho} & 0 & h(\overline{v^2}-\overline{u^2}) & \frac{U}{2a_1\rho} & \frac{h}{\rho}\left(\frac{V}{2a_1}+\hat{G}\right) \\ dn & 0 & -h\,ds & 0 & 0 \\ 0 & ds & dn & 0 & 0 \\ 0 & 0 & 0 & ds & dn \end{vmatrix} = 0$$

Expanding by the second column gives:

$$ds \cdot \begin{vmatrix} hV & -hU & 0 & -h/\rho \\ -\frac{h\tau}{\rho} & h(\overline{v^2}-\overline{u^2}) & \frac{U}{2a_1\rho} & \frac{h}{\rho}\left(\frac{V}{2a_1}+\hat{G}\right) \\ dn & -h\,ds & 0 & 0 \\ 0 & 0 & ds & dn \end{vmatrix} = 0$$

so that ds = 0 is a solution and gives the vertical characteristic. If we further expand the determinant by the fourth row, we obtain

$$-ds \cdot \begin{vmatrix} hV & -hU & -h/\rho \\ -\frac{h\tau}{\rho} & h(\overline{v^2}-\overline{u^2}) & \frac{h}{\rho}\left(\frac{V}{2a_1}+\hat{G}\right) \\ dn & -h\,ds & 0 \end{vmatrix} + dn \cdot \begin{vmatrix} hV & -hU & 0 \\ -\frac{h\tau}{\rho} & h(\overline{v^2}-\overline{u^2}) & \frac{U}{2a_1\rho} \\ dn & -h\,ds & 0 \end{vmatrix} = 0$$

Expanding the two determinants yields

$$-ds\,dn\left[-h^2\frac{U}{\rho}\left(\frac{V}{2a_1}+\hat{G}\right)+\frac{h}{\rho}^2(\overline{v^2}-\overline{u^2})\right]$$

$$-h\,ds^2\left[h^2\frac{V}{\rho}\left(\frac{V}{2a_1}+\hat{G}\right)-h^2\frac{\tau}{\rho}\right]-\frac{U}{2a_1\rho}dn\left(-h^2V\,ds+hU\,dn\right)$$
$$=0$$

which reduces to the following quadratic for $\frac{1}{h}\frac{dn}{ds}$:

$$\frac{U^2}{2a_1}\left(\frac{1}{h}\frac{dn}{ds}\right)^2-\left(\frac{1}{h}\frac{dn}{ds}\right)\cdot\left[U\left(\frac{V}{a_1}+\hat{G}\right)+(\overline{u^2}-\overline{v^2})\right]$$

$$+\left[V\left(\frac{V}{2a_1}+\hat{G}\right)-\frac{\tau}{\rho}\right]=0 \qquad (A3.8)$$

The solution to (A3.8) is

$$\frac{1}{h}\frac{dn}{ds}=\frac{V}{U}+a_1\frac{\hat{G}}{U}+a_1\frac{(\overline{u^2}-\overline{v^2})}{U^2}$$
$$\pm\sqrt{\left\{\frac{a_1^2}{U^2}(U\hat{G}+\overline{u^2}-\overline{v^2})^2+2a_1\frac{V}{U}(\overline{u^2}-\overline{v^2})+2a_1\frac{\tau}{\rho}\right\}}$$

$$\frac{1}{h}\frac{dn}{ds}=\frac{V+\alpha\pm\beta}{U} \qquad (A3.9)$$

where $\alpha = a_1\left[\hat{G}+\left(\frac{\overline{u^2}-\overline{v^2}}{U}\right)\right]$

and $\beta = \sqrt{\left\{\alpha^2+2a_1\left[\tau/\rho+\frac{V}{U}(\overline{u^2}-\overline{v^2})\right]\right\}}$

Putting $\overline{u^2} = c_1\cdot\frac{\tau}{\rho}$ and $\overline{v^2} = c_2\cdot\frac{\tau}{\rho}$ yields

$$\alpha = a_1 \left[\hat{G} + \frac{(c_1 - c_2)}{U} . \frac{\tau}{\rho} \right] \quad (A3.10)$$

and
$$\beta = \sqrt{\left\{ \alpha^2 + 2a_1 \frac{\tau}{\rho} \left[1 + (c_1 - c_2) . \frac{V}{U} \right] \right\}} \quad (A3.11)$$

Equation (A3.9) gives the inclinations of the two inclined characteristics (the "ingoing" and "outgoing" characteristics). Note that this expression reduces to that given by Bradshaw and Unsworth for the original BFA method, if we put $c_1 = c_2 = 0$ and $h = 1$ (i.e. zero curvature).

A3.2 DERIVATION OF THE EQUATIONS ALONG THE CHARACTERISTICS

Firstly, we shall consider the equation along the vertical characteristic; since the characteristic direction in that case is n, we can obtain this equation by substituting the continuity equation (A3.5) into the s-momentum equation (A3.6) to obtain

$$hV dU - hU dV = -\frac{1}{\rho} \frac{\partial p}{\partial s} . dn - \frac{c_1}{\rho} \frac{\partial \tau}{\partial s} dn + h \frac{d\tau}{\rho} + \frac{2\tau}{\rho R} . dn$$

or
$$hV \frac{dU}{dn} - hU \frac{dV}{dn} = -\frac{1}{\rho} \frac{\partial p}{\partial s} - \frac{c_1}{\rho} \frac{\partial \tau}{\partial s} + \frac{h}{\rho} \frac{d\tau}{dn} + \frac{2\tau}{\rho R} \quad (A3.12)$$

where the derivatives in the n-direction are now total derivatives. This equation is used to solve for V.

We shall now derive the equations along the two inclined characteristics to solve for U, τ; we shall follow exactly the same procedure outlined by Ralston and Wilf (1967a), p. 166: we assume that our two partial differential equations (A3.6) and (A3.7) are written in the form:

$$A_1 \frac{\partial U}{\partial s} + B_1 \frac{\partial U}{\partial n} + C_1 \frac{\partial \tau}{\partial s} + D_1 \frac{\partial \tau}{\partial n} + E_1 = 0 \quad (A3.13)$$

and $$A_2 \frac{\partial U}{\partial s} + B_2 \frac{\partial U}{\partial n} + C_2 \frac{\partial \tau}{\partial s} + D_2 \frac{\partial \tau}{\partial n} + E_2 = 0 \quad (A3.14)$$

If the tangents of the characteristic angles are given by $\zeta\pm$, where $\frac{1}{h} \cdot \zeta\pm = \frac{V + \alpha \pm \beta}{U}$ in this case, then the equations along the characteristics are:

$$F' dU + (A'\zeta_{\pm} - G') . d\tau + (K'\zeta_{\pm} - H') . ds = 0 \quad (A3.15)$$

where $F' = A_1 B_2 - A_2 B_1$; $A' = A_1 C_2 - A_2 C_1$; $G' = B_1 C_2 - B_2 C_1$

$K' = A_1 E_2 - A_2 E_1$; $H' = B_1 E_2 - B_2 E_1$

Now, the values of these coefficients for the two equations (A3.6) and (A3.7) are

$A_1 = U$
$B_1 = hV$
$C_1 = 0$
$D_1 = -h/\rho$
$E_1 = \frac{UV}{R} + \frac{1}{\rho}\frac{\partial p}{\partial s} + \frac{\partial \overline{u^2}}{\partial s} - \frac{2\tau}{\rho R}$

$A_2 = \overline{u^2} - \overline{v^2}$ (using the continuity equation to substitute for $h\frac{\partial V}{\partial n}$ in (A3.7))
$B_2 = -h\tau/\rho$
$C_2 = U/2a_1\rho$
$D_2 = \frac{h}{\rho}\left(\frac{V}{2a_1} + \hat{G}\right)$

and $$E_2 = (\overline{u^2}-\overline{v^2})\frac{V}{R} - \frac{\tau}{\rho}\left(\frac{\partial V}{\partial s}+\hat{e}\right) + \frac{\tau U}{\rho R}$$
$$+\frac{(\tau/\rho)^{3/2}}{L} + \frac{G}{R}\left(\frac{\tau_m}{\rho}\right)^{\frac{1}{2}}\frac{\tau}{\rho} + h\frac{\tau}{\rho}\left(\frac{\tau_m}{\rho}\right)^{\frac{1}{2}}\frac{dG}{dn}$$

Thus, $$F' = -hU\left[\frac{\tau}{\rho} + (\overline{u^2}-\overline{v^2})\frac{V}{U}\right]$$

$$A' = \frac{U^2}{2a_1\rho}$$

$$G' = hUV/2a_1\rho$$

$$K' = -\frac{U\tau}{\rho}\left(\frac{\partial V}{\partial s}+\hat{e}\right) + \frac{\tau U^2}{\rho R} + \frac{U(\tau/\rho)^{3/2}}{L} + \frac{UG}{R}\left(\frac{\tau_m}{\rho}\right)^{\frac{1}{2}}\frac{\tau}{\rho}$$

$$+ hU\frac{\tau}{\rho}\left(\frac{\tau_m}{\rho}\right)^{1/2}\frac{dG}{dn} - (\overline{u^2}-\overline{v^2})\cdot\left(\frac{1}{\rho}\frac{\partial p}{\partial s} + \frac{\partial \overline{u^2}}{\partial s} - \frac{2\tau}{\rho R}\right)$$

$$H' = hV\left[(\overline{u^2}-\overline{v^2})\cdot\frac{V}{R} + \frac{2\tau U}{\rho R} - \frac{\tau}{\rho}\left(\frac{\partial V}{\partial s}+\hat{e}\right)\right.$$

$$\left.+\frac{(\tau/\rho)^{3/2}}{L} + \frac{G}{R}\left(\frac{\tau_m}{\rho}\right)^{\frac{1}{2}}\frac{\tau}{\rho} + h\frac{\tau}{\rho}\cdot\left(\frac{\tau_m}{\rho}\right)^{\frac{1}{2}}\frac{dG}{dn}\right]$$

Therefore

$$A'\zeta_{\pm} - G' = \frac{hU}{2a_1\rho}(\alpha \pm \beta)$$

and after much algebra,

$$\frac{K'\zeta_{\pm} - H'}{h} = \left[\frac{\tau}{\rho} + \frac{V}{U}(\overline{u^2} - \overline{v^2})\right]\left[\frac{2\tau}{\rho R} - \frac{1}{\rho}\frac{\partial p}{\partial s} - \frac{UV}{R} - \frac{\partial \overline{u^2}}{\partial s}\right]$$

$$+(\alpha \pm \beta)\left[-\frac{\tau}{\rho}\left(\frac{\partial V}{\partial s} + \hat{e}\right) + \frac{\tau U}{\rho R} + \frac{(\tau/\rho)^{3/2}}{L} + \frac{G}{R}\left(\frac{\tau_m}{\rho}\right)^{1/2}\frac{\tau}{\rho}\right.$$

$$\left. + \frac{h\tau}{\rho}\left(\frac{\tau_m}{\rho}\right)^{1/2}\frac{dG}{dn} + (\overline{u^2} - \overline{v^2})\left(\frac{2\tau}{\rho R} - \frac{1}{\rho}\frac{\partial p}{\partial s} - \frac{\partial \overline{u^2}}{\partial s}\right)\right] \equiv \Psi \text{, say.}$$

Therefore, the equations along the characteristics become:

$$\left[\frac{\tau}{\rho} + (\overline{u^2} - \overline{v^2}).\frac{V}{U}\right].dU - \left(\frac{\alpha \pm \beta}{2a_1}\right).\frac{d\tau}{\rho} - \frac{\Psi}{U}.ds = 0 \qquad \text{(A3.16)}$$

where we put $\overline{u^2} = c_1 \frac{\tau}{\rho}$ and $v^2 = c_2 \frac{\tau}{\rho}$.

A3.3 FINITE DIFFERENCE FORMS OF THE EQUATIONS USED FOR THE V,p CALCULATION

We shall derive here the finite difference forms of the equations used for the V, p calculation, using the finite difference scheme described in §2.2(c). See also Fig. (6) for the definition of the indices i and j. The two equations solved are the equation along the vertical characteristic (A3.12) and the normal momentum equation (A3.3).

(a) Solution for V

If we take equation (A3.12)

$$hV\frac{dU}{dn} - hU\frac{dV}{dn} = -\frac{1}{\rho}\frac{\partial p}{\partial s} - \frac{c_1}{\rho}\frac{\partial \tau}{\partial s} + \frac{h}{\rho}\frac{d\tau}{dn} + \frac{2\tau}{\rho R}$$

According to our finite difference scheme, we shall centre all n-derivatives at the point B, so that

$$\frac{dU}{dn} = \frac{U_{ij} - U_{i,j-1}}{\Delta n} \; ; \; \frac{dV}{dn} = \frac{V_{ij} - V_{i,j-1}}{\Delta n} \; ;$$

$$\frac{d\tau}{dn} = \frac{\tau_{ij} - \tau_{i,j-1}}{\Delta n} \; .$$

The variables which do not appear in derivative form, will be centred at the point A. $c_1 \frac{\partial \tau}{\partial s}$ is actually $\frac{\partial \overline{u^2}}{\partial s}$ and τ is known from the U, τ calculation, so that we use a simple backward difference for it. $\frac{\partial p}{\partial s}$ is differenced according to the rules of §2.2(b) and is also known (from the previous sweep).

With these assumptions, the finite difference form of the equation along the vertical characteristic, which is used to obtain V at any station i, becomes:

$$h_{i,j-\frac{1}{2}} \cdot \tfrac{1}{2}(V_{ij} + V_{i,j-1})\left(\frac{U_{ij} - U_{i,j-1}}{\Delta n}\right)$$

$$- h_{i,j-\frac{1}{2}} \cdot \tfrac{1}{2}(U_{ij} + U_{i,j-1}) \cdot \left(\frac{V_{ij} - V_{i,j-1}}{\Delta n}\right)$$

$$= -\frac{1}{\rho}\left(\frac{\partial p}{\partial s}\right)_{ij} - \frac{c_1}{\rho}\left(\frac{\partial \tau}{\partial s}\right)_{ij} + h_{i,j-\frac{1}{2}}\left(\frac{\tau_{ij} - \tau_{i,j-1}}{\rho \Delta n}\right)$$

$$+ \frac{1}{R}\left(\frac{\tau_{ij} + \tau_{i,j-1}}{\rho}\right)$$

where $h_{i,j-\frac{1}{2}} = \frac{1}{2}\left(h_{ij} + h_{i,j-1}\right)$

and $h_{ij} = 1 + n_j K_{i-\frac{1}{2}} = 1 + j\,\Delta n \cdot K_{i-\frac{1}{2}}$

where $\kappa_{i-\frac{1}{2}}$ is the curvature evaluated at A.

This reduces to

$$h_{i,j-\frac{1}{2}} U_{i,j-1} \cdot \underline{V_{ij}} = h_{i,j-\frac{1}{2}} U_{ij} \underline{V_{i,j-1}} + \Delta n \left(\frac{1}{\rho}\frac{\partial p}{\partial s} + \frac{c_1}{\rho}\frac{\partial \tau}{\partial s} \right)_{ij}$$
$$- \tau_{ij}\left(h_{i,j-\frac{1}{2}} + \frac{\Delta n}{R}\right) + \tau_{i,j-1}\left(h_{i,j-\frac{1}{2}} - \frac{\Delta n}{R}\right)$$
$$(A3.17)$$

So that along the vertical characteristic (in the n-direction) V_{ij} can be found at the jth. mesh point, given $V_{i,j-1}$ at the previous ((j-1)th.) mesh point, both at the ith. station.

(b) Solution for p

We will now consider the differencing of the normal momentum equation (A3.3)

$$U\frac{\partial V}{\partial s} + hV\frac{\partial V}{\partial n} - \frac{U^2}{R} = -\frac{h}{\rho}\frac{\partial p}{\partial n} + \frac{1}{\rho}\frac{\partial \tau}{\partial s} - \frac{hc_2}{\rho}\frac{\partial \tau}{\partial n} + \left(\frac{c_1 - c_2}{R}\right)\cdot\frac{\tau}{\rho}$$

The term $\left(\frac{c_1 - c_2}{R}\right)\frac{\tau}{\rho}$ is just $\frac{\overline{u^2} - \overline{v^2}}{R}$ and is taken as known. So is the term $-h\,\frac{c_2}{\rho}\,\frac{\partial \tau}{\partial n}$ which is just $\frac{-h}{\rho}\,\frac{\partial \overline{v^2}}{\partial n}$. We centre $\frac{\partial \tau}{\partial s}$ at A as usual. We wish to solve for p across the shear layer, having calculated V from equation (A3.17). Using our finite difference scheme described in §2.2(c), the normal momentum equation becomes:

$$\frac{1}{2}(U_{ij}+U_{i,j-1})\cdot\left(\frac{\partial V}{\partial s}\right)_{ij-\frac{1}{2}}+h_{i,j-\frac{1}{2}}\frac{1}{2}(V_{i-1,j}+V_{i-1,j-1})\cdot\left(\frac{V_{ij}-V_{i,j-1}}{\Delta n}\right)$$

$$-\frac{1}{4}K_{i-\frac{1}{2}}(U_{ij}+U_{i,j-1})^2 =$$

$$-\frac{h_{i,j-\frac{1}{2}}}{\Delta n}\left(\frac{p_{ij}-p_{i,j-1}}{\rho}\right)+\frac{1}{2}\left[\left(\frac{\tau_{i+1,j}-\tau_{ij}}{\rho\Delta s}\right)+\left(\frac{\tau_{i+1,j-1}-\tau_{i,j-1}}{\rho\Delta s}\right)\right]$$

$$-\frac{hc_2}{\rho}\left(\frac{\tau_{ij}-\tau_{i,j-1}}{\Delta n}\right)+(c_1-c_2)\cdot K_{i-\frac{1}{2}}\cdot\frac{1}{2}\left(\frac{\tau_{ij}+\tau_{i,j-1}}{\rho}\right)$$

which reduces to:

$$\underline{p_{i,j-1}}=\underline{p_{ij}}+\frac{\Delta n}{h_{i,j-\frac{1}{2}}}\left[\frac{1}{2}(U_{ij}+U_{i,j-1})\left(\frac{\partial V}{\partial s}\right)_{ij-\frac{1}{2}}\right.$$

$$+\frac{1}{2}h_{i,j-\frac{1}{2}}(V_{i-1,j}+V_{i-1,j-1})\cdot\left(\frac{V_{ij}-V_{i,j-1}}{\Delta n}\right)$$

$$-\frac{1}{4}K_{i-\frac{1}{2}}(U_{ij}+U_{i,j-1})^2-\frac{\tau_{ij}}{\rho}\left\{-\frac{hc_2}{\Delta n}+\left(\frac{c_1-c_2}{2}\right)K_{i-\frac{1}{2}}\right\}$$

$$-\frac{\tau_{i,j-1}}{\rho}\left\{\frac{hc_2}{\Delta n}+\left(\frac{c_1-c_2}{2}\right)\cdot K_{i-\frac{1}{2}}\right\}-\frac{1}{2}\left(\frac{\tau_{i+1,j}+\tau_{i+1,j-1}}{\rho\Delta s}\right)$$

$$\left.+\frac{1}{2}\left(\frac{\tau_{i-1,j}+\tau_{i-1,j-1}}{\rho\Delta s}\right)\right] \qquad (A3.18)$$

where $h_{i,j-\frac{1}{2}} = \frac{1}{2}(h_{ij} + h_{i,j-1})$

and $h_{ij} = 1 + j\,\Delta n.\, K_{i-\frac{1}{2}}$

$(\frac{\partial V}{\partial s})_{ij}$ is the finite difference form of $\frac{\partial V}{\partial s}$ given in 2.2(c)-(ii) as:

$$\left(\frac{\partial V}{\partial s}\right)_{ij} = \left(\frac{V_{ij} - V_{i-1,j}}{\Delta s_i}\right) \cdot \frac{\Delta s_{i+1}}{\Delta s_i + \Delta s_{i+1}}$$

$$+ \left(\frac{V_{i+1,j} - V_{ij}}{\Delta s_{i+1}}\right) \cdot \frac{\Delta s_i}{\Delta s_i + \Delta s_{i+1}} \ .$$

(c) Solution for p_w from p_1

From (A3.18) we can solve for p at the (j-1)th. mesh point from the value of p at the jth. mesh point. If we know the value of p at the last mesh point,
say, j = J, then $p_{iJ} = p_{e_i}$, where p_{e_i} is the external pressure at the ith. station. We can then solve for p_{ij} across the shear layer down to the first mesh point where the value of p_{ij} is p_1, say. Dropping the suffix notation, we will now consider obtaining p_w from p_1 at any given station; we shall assume that U is given by a fifth power law profile between the wall and the first mesh point, so that $\frac{U}{U_1} = (\frac{n}{\Delta n})^{1/5}$, where $U = U_1$ at the first mesh point. If we insert this into the continuity equation

$$\frac{\partial U}{\partial s} + \frac{\partial}{\partial n}(hV) = 0$$

and integrate with respect to n from the wall to the point n, we obtain

$$hV(n) = V_w - \frac{5}{6} \cdot \frac{dU_1}{ds} \cdot \frac{n^{6/5}}{(\Delta n)^{1/5}} \cdot$$

for $0 < n < \Delta n$.

Since $\frac{\Delta n}{R} << 1$, $h \sim 1$

so that $$V(n) \simeq V_w - \frac{5}{6} \frac{dU_1}{ds} \cdot \frac{n^{6/5}}{(\Delta n)^{1/5}} \qquad (A3.19)$$

We can write the normal momentum equation in the form

$$\frac{\partial}{\partial s}(UV) + h\frac{\partial V^2}{\partial n} + \left(\frac{V^2 - U^2}{R}\right) = -\frac{h}{\rho}\frac{\partial p}{\partial n} + \frac{1}{\rho}\frac{\partial \tau}{\partial s} - h\frac{\partial \overline{v^2}}{\partial n} - \left(\frac{\overline{v^2} - \overline{u^2}}{R}\right) \qquad (A3.20)$$

We then insert $\frac{U}{U_1} = \left(\frac{n}{\Delta n}\right)^{1/5}$; $V = V_w - \frac{5}{6}\frac{dU_1}{ds} \cdot \frac{n^{6/5}}{(\Delta n)^{1/5}}$

into this form of the normal momentum equation and integrate with respect to n from the wall to the first mesh point. We shall do this for each term separately:

(i) $\int_0^{\Delta n} \frac{\partial}{\partial s}(UV)\, dn = \frac{d}{ds}\int_0^{\Delta n} UV\, dn$ since Δn is constant.

$$\therefore \int_0^{\Delta n} \frac{\partial}{\partial s}(UV)\, dn = \frac{d}{ds}\int_0^{\Delta n} U_1\left(\frac{n}{\Delta n}\right)^{1/5}\left[V_w - \frac{5}{6}\frac{dU_1}{ds} \cdot \frac{n^{6/5}}{(\Delta n)^{1/5}}\right] dn$$

$$= \frac{5}{6}\Delta n \frac{d}{ds}(U_1 V_w) - \frac{25}{144}(\Delta n)^2 \frac{d^2}{ds^2}(U_1^2) .$$

We will neglect the second term here, since it is proportional to Δn^2, so that

$$\int_0^{\Delta n} \frac{\partial}{\partial s}(UV)\,dn \simeq \tfrac{5}{6}\,\Delta n.\frac{d}{ds}(U_1 V_W) \qquad (A3.21)$$

(ii) $$\int_0^{\Delta n} h\frac{\partial V^2}{\partial n}\,dn = V_1^2 - V_W^2 + \frac{1}{R}\left\{ \left[nV^2\right]_0^{\Delta n} - \int_0^{\Delta n} V^2\,dn \right\}$$

$$= \left(1+\frac{\Delta n}{R}\right)V_1^2 - V_W^2 - \frac{1}{R}\int_0^{\Delta n} V^2\,dn \qquad (A3.22)$$

(iii) $$\int_0^{\Delta n} \frac{V^2 - U^2}{R}\,dn = \frac{1}{R}\int_0^{\Delta n} V^2\,dn - \frac{1}{R}\int_0^{\Delta n} \frac{U_1^2}{(\Delta n)^{2/5}}.\,n^{2/5}\,dn$$

$$= \frac{1}{R}\int_0^{\Delta n} V^2\,dn - \tfrac{5}{7}\,U_1^2.\,\frac{\Delta n}{R} \qquad (A3.23)$$

(iv) $$\frac{c_2}{\rho}\int_0^{\Delta n} h\frac{\partial \tau}{\partial n}\,dn = \frac{c_2}{\rho}\left\{ \tau_1 - \tau_w + \frac{1}{R}\left(\left[\frac{n\tau}{\rho}\right]_0^{\Delta n} - \int_0^{\Delta n} \tau/\rho\,dn \right)\right\}$$

If we approximate $\int_0^{\Delta n} \frac{\tau}{\rho}\,dn$ by $\frac{1}{2}\Delta n.\left(\frac{\tau_1}{\rho} + \frac{\tau_w}{\rho}\right)$, we obtain

$$\frac{c_2}{\rho}\int_0^{\Delta n} h\frac{\partial \tau}{\partial n}\,dn = c_2\left(1+\frac{1}{2}.\frac{\Delta n}{R}\right)\left(\frac{\tau_1 - \tau_w}{\rho}\right) \qquad (A3.24)$$

(v) $$\int_0^{\Delta n} \frac{1}{\rho}\frac{\partial \tau}{\partial s}\,dn = \frac{d}{ds}\int_0^{\Delta n} \frac{\tau}{\rho}\,dn \simeq \frac{d}{ds}\left[\frac{1}{2}\left(\frac{\tau_1 + \tau_w}{\rho}\right)\right] \qquad (A3.25)$$

(vi) $$\frac{(c_1 - c_2)}{R}\int_0^{\Delta n} \frac{\tau}{\rho}\,dn \simeq \frac{(c_1 - c_2)}{R}.\,\frac{1}{2}\Delta n\left(\frac{\tau_1 + \tau_w}{\rho}\right) \qquad (A3.26)$$

(vii) $$\int_0^{\Delta n} \frac{h}{\rho}\frac{\partial p}{\partial n}\,dn = \left(1+\frac{1}{2}\frac{\Delta n}{R}\right)\left(\frac{p_1 - p_w}{\rho}\right) \qquad (A3.27)$$

in the same way as for (iv) above.

Therefore, if we insert these terms (A3.21) to (A3.26) into equation (A3.20) we obtain the following equation for $\frac{p_w - p_1}{\rho}$

$$\left(1+\frac{1}{2}\frac{\Delta n}{R}\right)\left(\frac{p_w-p_1}{\rho}\right) = \frac{5}{6}\Delta n \frac{d}{ds}(U_1 V_w) + \left(1+\frac{\Delta n}{R}\right)V_1^2 - V_w^2$$

$$-\frac{5}{7}U_1^2 \cdot \frac{\Delta n}{R} - \frac{1}{2}\Delta n \cdot \frac{d}{ds}\left(\frac{\tau_1+\tau_w}{\rho}\right) - \frac{\tau_1}{\rho}\left[-c_2+\left(\frac{1}{2}c_1-c_2\right)\cdot\frac{\Delta n}{R}\right]$$

$$-\frac{\tau_w}{\rho}\left[c_2+\frac{1}{2}c_1 \cdot \frac{\Delta n}{R}\right] \qquad \text{(A3.27)}$$

We can thus solve for the complete pressure profile starting at the MS down to the wall.

A3.4 METHOD OF SOLUTION FOR THE WALL BOUNDARY CONDITION

In this section we describe the method of application of the wall boundary conditions for the cases of solid wall and transpiration. As stated in §2.2(d) we seek to solve for U, $\frac{\tau_1}{\rho}$, $\frac{\tau_w}{p}$ and V_1 for the first mesh point, given the wall boundary conditions U = 0 and V = V_W (where, for the solid wall case V_W = 0). We obtain the values of U_1, $\frac{\tau_1}{\rho}$ and $\frac{\tau_w}{\rho}$ by solving the following three non-linear equations iteratively by Newton's method:

(i) The logarithmic law for the inner layer, written as an equation $F_1 = 0$.

(ii) The equation along the ingoing characteristic which passes through the first mesh point (see Fig. (7)); this is denoted by the equation $F_2 = 0$.

(iii) The s-momentum equation, with a fifth power law U-velocity profile between the wall and the first mesh point, integrated from the wall to the first mesh point; this is denoted by the equation $F_3 = 0$.

Although the method of solution is the same for both solid wall and transpiration cases, yet the details are different; we shall therefore consider each case separately. We shall then consider the calculation of V_1.

(a) <u>The Solid Wall Case</u>

We will consider the derivation of each of the functions F_1, F_2 and F_3 separately and then we will show the method of solution of the equations for F_1, F_2, F_3 by Newton's method. For the solid wall case, we do not solve for τ_1 directly, but instead we solve for $\alpha_o = \frac{\tau_1 - \tau_w}{\Delta n}$. Therefore, we solve for U_1, α_o and τ_w and we accordingly write F_1, F_2 and F_3 in terms of these variables.

(i) <u>The Function F_1</u>

This is the logarithmic law for the inner layer written at the first mesh point and is unchanged from that in the original BFA program. Thus

$$F_1(U_1, \alpha_o, \tau_w) \equiv U_1 - u_\tau \left[\frac{1}{K} \left\{ \log_e \frac{u_\tau \Delta n}{\nu} + \Phi'\left(\frac{n}{\delta}\right) \right\} + C \right] = 0 \tag{A3.28}$$

where Φ' is a function of $\frac{n}{\delta}$ only, C is the additive constant for the inner layer logarithmic law and $u_\tau^2 = \frac{\tau_w}{\rho}$. This is also divided by a factor $(1 + \frac{5}{6}\hat{e})$ to account for the extra strain rate $\hat{e}$.

(ii) <u>The Function F_2</u>

This is the equation along the "ingoing" characteristic which passes through the first mesh point. This is equation (A3.16) with the α-β coefficient for $\frac{d\tau}{\rho}$; thus corresponding to the characteristic angle Φ_{in} where $\tan \Phi_{in} = h(\frac{V + \alpha - \beta}{U})$. Thus,

$$\left[\frac{\tau}{\rho}+(\overline{u^2}-\overline{v^2}).\frac{V}{U}\right].dU-\left(\frac{\alpha-\beta}{2a_1}\right).\frac{d\tau}{\rho}-\frac{\Psi}{U}.ds=0$$

Also G and $\frac{dG}{dn}$ are equated to zero near the wall, so that

$$\alpha = a_1\left(\frac{\overline{u^2}-\overline{v^2}}{U}\right) = a_1(c_1-c_2).\frac{\tau}{\rho U}\ .$$

and $\beta = \sqrt{\left\{\alpha^2+2a_1\frac{\tau}{\rho}\left[1+(c_1-c_2)\frac{V}{U}\right]\right\}}$ before.

If we write $B' = \alpha - \beta$ and $\tau_1 = \tau_w + \alpha_o\ \Delta n$ then the above equation along the characteristic can be written as

$$F_2(U_1,\alpha_o,\tau_w) \equiv (\tau_w+\alpha_o\Delta n-\tau_{int})$$

$$-\frac{2a_1}{B'}\left[1+(c_1-c_2)\frac{V}{U}\right].\frac{\tau}{\rho}.(U_1-U_{int})+\frac{2a_1}{B'}.\frac{\Psi}{U}\Delta s=0 \qquad (A3.29)$$

where U_{int}, τ_{int} are the values of U, τ interpolated at the point where the ingoing characteristic meets the previous station. The values of the various variables are written in exactly the same way as for the U, τ calculation (see §2.2(b)).

(iii) The Function F_3

This function is defined by inserting one-fifth-power law variation for U with n, into the s-momentum equation and then integrating it from the wall to the first mesh point. Insertion of $\frac{U}{U_1} = (\frac{n}{\Delta n})^{1/5}$ into the continuity equation and integration from the wall to the first mesh point yields

$$\left(1+\frac{n}{R}\right)V(n) = V_w - \frac{5}{6}\frac{dU_1}{ds}.\frac{n^{6/5}}{\Delta n^{1/5}} \qquad (A3.30)$$

So that at the first mesh point

$$\left(1+\frac{\Delta n}{R}\right)V_1 = V_W - \frac{5}{6}\frac{dU_1}{ds}.\,\Delta n \qquad (A3.31)$$

We can also write the s-momentum equation in the form

$$\frac{\partial U^2}{\partial s} + h\frac{\partial}{\partial n}(UV) + 2\frac{UV}{R} = -\frac{1}{\rho}\frac{\partial p}{\partial s} - \frac{\partial \overline{u^2}}{\partial s} + \frac{h}{\rho}\frac{\partial \tau}{\partial n} + \frac{2\tau}{\rho R}$$

$$(A3.31)$$

Integrating this with respect to n from the wall (n = 0) to the first mesh point (n = Δn) gives:

$$\frac{d}{ds}\int_0^{\Delta n} U^2 dn + \left(1+\frac{\Delta n}{R}\right).U_1V_1 + \frac{1}{R}\int_0^{\Delta n} UV\,dn =$$

$$-\int_0^{\Delta n}\frac{1}{\rho}\frac{\partial p}{\partial s}dn - \int_0^{\Delta n}\frac{\partial \overline{u^2}}{\partial s}dn + \left(1+\frac{\Delta n}{R}\right).\frac{\tau_1}{\rho} - \frac{\tau_w}{\rho}$$

$$+\frac{1}{R}\int_0^{\Delta n}\frac{\tau}{\rho}dn \qquad (A3.32)$$

Now, $\displaystyle\int_0^{\Delta n} U^2 dn = \int_0^{\Delta n}\frac{U_1^2}{(\Delta n)^{2/5}}.\,n^{2/5}dn = \frac{5}{7}U_1^2\Delta n.$

and

$$\int_0^{\Delta n} UV dn = \int_0^{\Delta n} U_1\left(\frac{n}{\Delta n}\right)^{1/5}\left[V_w - \frac{5}{6}\frac{dU_1}{ds}.\frac{n^{6/5}}{(\Delta n)^{1/5}}\right]dn$$

using equation (A3.30) for V(n) between n = 0 and n = Δn.

This reduces to

$$\int_0^{\Delta n} UV dn = U_1V_w.\frac{\Delta n}{R}.I_1 - \frac{5}{6}U_1\frac{dU_1}{ds}.\frac{(\Delta n)^2}{R}.I_2$$

where

$$I_1 = \int_0^1\frac{\eta^{1/5}}{\left(1+\frac{\Delta n}{R}.\eta\right)}.d\eta \;\; ; \;\; I_2 = \int_0^1\frac{\eta^{7/5}}{\left(1+\frac{\Delta n}{R}.\eta\right)}.d\eta$$

We can approximate the integrals I_1 and I_2 by assuming that $\frac{\Delta n}{R} \ll 1$. This yields

$$I_1 \simeq 5\left(\frac{1}{6} - \frac{1}{11}\cdot\frac{\Delta n}{R}\right) ; \; I_2 \simeq 5\left(\frac{1}{12} - \frac{1}{17}\cdot\frac{\Delta n}{R}\right)$$

Therefore substituting for $\int_0^{\Delta n} U^2 \, dn$ and $\int_0^{\Delta n} UV \, dn$, (A3.32) can be written as:

$$\left(1+\frac{\Delta n}{R}\right)\frac{\tau_1}{\rho} = \frac{\tau_w}{\rho} + \frac{25}{42}\Delta n . U_1\frac{dU_1}{ds} + U_1 V_w\left(1+\frac{\Delta n}{R}I_1\right)$$

$$-\frac{5}{6}\frac{(\Delta n)^2}{R} I_2 . U_1\frac{dU_1}{ds} + \int_0^{\Delta n}\left(\frac{1}{\rho}\frac{\partial p}{\partial s} + \frac{\partial \overline{u^2}}{\partial s}\right)dn - \int_0^{\Delta n}\frac{1}{R}\cdot\frac{\tau}{\rho}dn \qquad \text{(A3.33)}$$

The last two integrals are evaluated by the trapezium rule. Equation (A3.33) is the general form of the integrated s-momentum equation with a fifth power law U profile. For the present case of the solid wall ($V_W = 0$), we write the function F_3 (which defines the above equation) in terms of $\alpha_o = \left(\frac{\tau_1 - \tau_w}{\rho\Delta n}\right)$ instead of τ_1, so that

$$F_3(U_1,\alpha_o,\tau_w) \equiv \frac{5}{12}\Delta n\frac{dU_1^2}{ds}\left(\frac{5}{7} - \frac{\Delta n}{R}\cdot I_2\right) - \left(1+\frac{\Delta n}{R}\right)\alpha_o$$

$$-\frac{1}{R}\frac{\tau_w}{\rho} - \frac{1}{\Delta n . R}\int_0^{\Delta n}\tau/\rho \, dn + \frac{1}{\Delta n}\int_0^{\Delta n}\left(\frac{1}{\rho}\frac{\partial p}{\partial s} + \frac{\partial \overline{u^2}}{\partial s}\right)dn = 0 \qquad \text{(A3.34)}$$

(iv) Newton's Method Solution for U_1, α_o, τ_w

We have three simultaneous non-linear equations of the form

$$F_1\,(U_1, \alpha_o, \tau_w) = 0$$
$$F_2\,(U_1, \alpha_o, \tau_w) = 0$$
and $$F_3\,(U_1, \alpha_o, \tau_w) = 0$$

Firstly, we guess the values of U_1, α_o, τ_w (we can use the values at the previous stations). We then make increments dU_1, $d\alpha_o$ and $d\tau_w$ for each of U_1, α_o, τ_w. These produce corresponding increments dF_1, dF_2, dF_3 in F_1, F_2 and F_3; these increments are given by the chain rule for partial differentiation as:

$$dF_1 = \frac{\partial F_1}{\partial U_1} dU_1 + \frac{\partial F_1}{\partial \alpha_o} d\alpha_o + \frac{\partial F_1}{\partial \tau_w} . d\tau_w$$

$$dF_2 = \frac{\partial F_2}{\partial U_1} dU_1 + \frac{\partial F_2}{\partial \alpha_o} d\alpha_o + \frac{\partial F_2}{\partial \tau_w} . d\tau_w$$

and

$$dF_3 = \frac{\partial F_3}{\partial U_1} . dU_1 + \frac{\partial F_3}{\partial \alpha_o} d\alpha_o + \frac{\partial F_3}{\partial \tau_w} . d\tau_w$$

Now, for a solution $F_1 + dF_1 = 0$, $F_2 + dF_2 = 0$ and $F_3 + dF_3 = 0$ so that these three equations form a set of three linear algebraic equations for the increments dU_1, $d\alpha_o$ and $d\tau_w$, which we solve. This allows us to improve our original guess for U_1, α_o, τ_w and we insert these improved values into the three equations and again obtain better estimates for dU_1, $d\alpha_o$, $d\tau_w$. This procedure is iterated until the values of U_1, α_o and τ_w converge to within prescribed tolerances.

(b) The Transpiration Case

In this case we have a prescribed transpiration velocity $V = V_W$ at the wall; V_W is positive for injection and negative for suction. Here, we solve for $\frac{\tau_1}{\rho}$ directly, so that we seek the functions F_1, F_2 and F_3 in terms of U_1, τ_1 and τ_w.

(i) The Function F_1

This is the bi-logarithmic law for transpiration and is written at the first mesh point as

$$F_1 \equiv \left(U_1 V_w + \frac{\tau_w}{\rho}\right)^{\frac{1}{2}} - \left(\frac{\tau_w}{\rho}\right)^{\frac{1}{2}} - \frac{V_w}{2K}\left(\log \frac{u_\tau \Delta n}{\nu} + KC\right)$$

$$- K\left(\frac{25}{84}\Delta n . \frac{dU_1^2}{ds} + \int_0^{\Delta n} \frac{1}{\rho}\frac{\partial p}{\partial s} dn\right) . F$$

where F is a function of $\log_e \frac{u_\tau \Delta n}{\nu} + C + 2K u_\tau / V_w$

Using equation (A3.33) for $V_W \neq 0$, we substitute for $(U_1 V_W + \frac{\tau_W}{\rho})^{\frac{1}{2}}$ into the above expression for F_1 to yield:

$$F_1(U_1,\tau_1,\tau_w) \equiv \left[\left(1 + \frac{\Delta n}{R}\right) . \frac{\tau_1}{\rho} - \frac{5}{12}\frac{dU_1^2}{ds}\left(\frac{5}{7} - \frac{\Delta n}{R} . I_2\right)\Delta n\right.$$

$$\left. - \frac{\Delta n}{R} I_1(U_1 V_w) - \int_0^{\Delta n}\left(\frac{1}{\rho}\frac{\partial p}{\partial s} + \frac{\partial \overline{u^2}}{\partial s}\right) dn + \frac{1}{R}\int_0^{\Delta n} \frac{\tau}{\rho} dn\right]^{\frac{1}{2}}$$

$$- \left(\frac{\tau_w}{\rho}\right)^{\frac{1}{2}} - \frac{V_w}{2K}\left(\log \frac{u_\tau \Delta n}{\nu} + K.C\right) - K\left(\frac{25}{84}\Delta n \frac{dU_1^2}{ds}\right.$$

$$\left. + \int_0^{\Delta n} \frac{1}{\rho}\frac{\partial p}{\partial s} dn\right) . F = 0 \qquad (A3.35)$$

where curvature terms are neglected in the factor multiplying the function F.

(ii) <u>The Function F_2</u>

This again uses equation (A3.16) along the ingoing characteristic but in this case it is written in terms of $\frac{\tau_1}{\rho}$; thus we obtain

$$F_2(U_1,\tau_1,\tau_w) \equiv (\tau_1 - \tau_{int}) - \frac{2a_1}{B'}\left[\frac{\tau}{\rho} + (\overline{u^2} - \overline{v^2})\frac{V}{U}\right](U_1 - U_{int})$$

$$+ \frac{2a_1}{B'} . \frac{\Psi}{U} . \Delta s = 0 \qquad (A3.36)$$

(iii) The Function F_3

This is exactly as defined by equation (A3.33), so that

$$F_3(U_1, \tau_1, \tau_w) \equiv \left(1+\frac{\Delta n}{R}\right)\frac{\tau_1}{\rho} - \frac{\tau_w}{\rho} + \frac{5}{12}\Delta n\left(\frac{5}{7} - \frac{\Delta n}{R} I_2\right)\frac{dU_1^2}{ds}$$
$$- U_1 V_w\left(1 + \frac{\Delta n}{R} I_1\right) - \int_0^{\Delta n}\left(\frac{1}{\rho}\frac{\partial p}{\partial s} + \frac{\partial \overline{u^2}}{\partial s}\right) + \frac{1}{R}\int_0^{\Delta n} \tau/\rho \, dn \qquad (A3.37)$$

(iv) Newton's Method Solution

The procedure for the solution of the equations

$$F_1 + \frac{\partial F_1}{\partial U_1} dU_1 + \frac{\partial F_1}{\partial \tau_1} d\tau_1 + \frac{\partial F_1}{\partial \tau_w} d\tau_w = 0$$

$$F_2 + \frac{\partial F_2}{\partial U_1} dU_1 + \frac{\partial F_2}{\partial \tau_1} d\tau_1 + \frac{\partial F_2}{\partial \tau_w} d\tau_w = 0$$

and

$$F_3 + \frac{\partial F_3}{\partial U_1} dU_1 + \frac{\partial F_3}{\partial \tau_1} d\tau_1 + \frac{\partial F_3}{\partial \tau_w} d\tau_w = 0$$

is exactly the same as in the solid wall case, except that now we solve for dU_1, $d\tau_1$ and $d\tau_w$ in each iteration, to obtain the values of U_1, τ_1 and τ_w.

(c) The Re-Calculation of V_1 and the Ingoing Characteristic Angle

As described in §1.2(d), we re-calculate the value of V_1 and also the angle of the ingoing characteristic, to improve on the values of U_1, $\frac{\tau_1}{\rho}$ and $\frac{\tau_w}{\rho}$ calculated by Newton's method. V_1 is obtained by integrating the continuity equation

$$\frac{\partial U}{\partial s} + \frac{\partial}{\partial n}(hV) = 0$$ from the wall to the

first mesh point assuming $\frac{U}{U_1} = f(\frac{u_\tau n}{\nu})$. This yields:

$$\left(1+\frac{\Delta n}{R}\right) V_1 = V_w - U_1 \cdot \frac{\Delta n}{u_\tau}\frac{du_\tau}{ds} \qquad (A3.38)$$

where $u_\tau^2 = \frac{\tau_w}{\rho}$.

Now, the ingoing characteristic angle at the first mesh point is given by equation (A3.9) with the $-\beta$ root, so that

$$\frac{1}{h_1}\frac{dn}{ds} = \frac{V_1 + \alpha_1 - \beta_1}{U_1} \qquad (A3.39)$$

and $\tan\phi_{new} = h_1\left(\frac{V_1+\alpha_1-\beta_1}{U_1}\right)$

where $\alpha_1 \doteq a_1(c_1-c_2)\frac{\tau_1}{\rho U_1}$

and $\beta_1 = \sqrt{\left\{\alpha_1^2 + 2a_1\frac{\tau_1}{\rho}\left[1+\frac{V_1}{U_1}(c_1-c_2)\right]\right\}}$; $h = 1 + \frac{\Delta n}{R} \simeq 1$

$\hat{G} = 0$ near the wall has been inserted.

In the program, an extra allowance for lateral divergence $(\partial W/\partial z)$ has also been inserted in the solution for V_1.

A3.5 DERIVATION OF THE s-COMPONENT MOMENTUM INTEGRAL EQUATION

Here we shall derive the s-component momentum integral equation which is the integral in the n-direction, of the s-component momentum equation. This is used to perform the momentum integral check described in §1.2(e).

Now, we can write the s-component momentum equation in the following form:

$$\underbrace{\frac{\partial U^2}{\partial s}}_{1} + \underbrace{\frac{\partial}{\partial n}(hUV) + \frac{UV}{R}}_{2} = \underbrace{-\frac{1}{\rho}\frac{\partial p}{\partial s}}_{3} \underbrace{- \frac{\partial \overline{u^2}}{\partial s}}_{4} + \underbrace{\frac{\partial}{\partial n}\left(h\frac{\tau}{\rho}\right) + \frac{\tau}{\rho R}}_{5} \qquad (A3.40)$$

We will define integral quantities

$$\delta^* = \int_0^\delta \left(1 - \frac{U}{U_e}\right) dn \qquad (A3.41)$$

and $$\theta = \int_0^\delta \frac{U}{U_e}\left(1 - \frac{U}{U_e}\right) dn \qquad (A3.42)$$

where n = δ is the MS edge and U_e is the value of U on the MS (i.e. at n = δ). The definition (but not the physical significance) of δ* and θ is the same as in the ∂p/∂n = 0 case. From (A3.41) and (A3.42) we find that

$$\int_0^\delta U dn = U_e(\delta - \delta^*) \qquad (A3.43)$$

and $$\int_0^\delta U^2 dn = U_e(\delta - \delta^* - \theta) \qquad (A3.44)$$

The continuity equation states that

$$\frac{\partial U}{\partial s} + \frac{\partial}{\partial n}(hV) = 0$$

If we integrate this equation with respect to n, from n = 0 to n = δ, we obtain:

$$\frac{d}{ds}\int_0^\delta U dn - U_e \frac{d\delta}{ds} + \left(1 + \frac{\delta}{R}\right) V_e - V_w = 0$$

or $$\frac{d}{ds}\left[U_e(\delta - \delta^*)\right] - U_e \frac{d\delta}{ds} + \left(1 + \frac{\delta}{R}\right) V_e - V_w = 0 \qquad (A3.45)$$

where we assume that, in general $\delta = \delta(s)$.

Now, we shall integrate the s-momentum equation (A3.40) from $n = 0$ to δ; consider each term separately:

$$(1) \quad \int_0^\delta \frac{\partial U^2}{\partial s} dn = \frac{d}{ds}\int_0^\delta U^2 dn - U_e^2 \frac{d\delta}{ds}$$

$$= \frac{d}{ds}\left[U_e^2(\delta - \delta^* - \theta)\right] - U_e^2 \frac{d\delta}{ds}$$

$$(2) \quad \int_0^\delta \frac{\partial}{\partial n}(UVh)\, dn + \frac{1}{R}\int_0^\delta UV\, dn$$

$$= U_e V_e (1 + \delta/R) + \frac{1}{R}\int_0^\delta UV\, dn$$

$$(3) \quad \int_0^\delta -\frac{1}{\rho}\frac{\partial p}{\partial s} dn = -\int_0^\delta \frac{\partial}{\partial s}\left(\frac{p - p_{ref}}{\rho}\right) dn$$

$$(4) \quad \int_0^\delta -\frac{\partial \overline{u^2}}{\partial s} dn = -\frac{c_1}{\rho}\int_0^\delta \frac{\partial \tau}{\partial s} dn$$

$$(5) \quad \int_0^\delta \frac{\partial}{\partial n}\left(h\frac{\tau}{\rho}\right) dn + \frac{1}{R}\int_0^\delta \frac{\tau}{\rho} dn = -\frac{\tau_w}{\rho} + \frac{1}{R}\int_0^\delta \frac{\tau}{\rho} dn$$

since $\tau \to 0$ as $n \to \delta$.

Thus, the integrated form of (A3.40) becomes:

$$\frac{d}{ds}\left[U_e^2(\delta - \delta^* - \theta)\right] - U_e^2\frac{d\delta}{ds} + U_e V_e\left(1 + \frac{\delta}{R}\right) + \frac{1}{R}\int_0^\delta UV\, dn$$

$$= -\int_0^\delta \frac{1}{\rho}\frac{\partial p}{\partial s} dn - \frac{c_1}{\rho}\int_0^\delta \frac{\partial \tau}{\partial s} dn - \frac{\tau_w}{\rho} + \frac{1}{R}\int_0^\delta \frac{\tau}{\rho} dn \quad (A3.46)$$

Multiplying (A3.45) by U_e and substituting for $U_e V_e (1 + \frac{\delta}{R})$ into (A3.46) we obtain, after some algebra:

$$\frac{d}{ds}(U_e^2\theta) = \frac{\tau_w}{\rho} + U_e\frac{dU_e}{ds}(\delta-\delta^*) + \frac{1}{R}\int_0^\delta UV\,dn$$

$$-\frac{1}{R}\int_0^\delta \tau/\rho\,dn + U_eV_w + \int_0^\delta \frac{1}{\rho}\frac{\partial p}{\partial s}dn + \int_0^\delta \frac{\partial \overline{u^2}}{\partial s}dn \qquad \text{(A3.47)}$$

which we can write as:

$$\frac{d}{ds}(U_e^2\theta) = \frac{\tau_w}{\rho} + U_e\frac{dU_e}{ds}(\delta-\delta^*) + \left(\frac{C_{uv}-C_\tau}{R}\right)$$

$$+U_eV_w + C_p' + \frac{dC_{\overline{u^2}}}{ds} \qquad \text{(A3.48)}$$

where

$$C_{UV} = \int_0^\delta UV\,dn$$

$$C_\tau = \int_0^\delta \tau/\rho\,dn$$

$$C_p' = \int_0^\delta \frac{1}{\rho}\frac{\partial p}{\partial s}ds$$

$$C_{\overline{u^2}} = \int_0^\delta \overline{u^2}\,dn$$

and making use of the fact that

$$\int_0^\delta \frac{\partial\overline{u^2}}{\partial s}dn = \frac{d}{ds}\int_0^\delta \overline{u^2}dn + \overline{u^2}\Big|_{n=\delta}\cdot\frac{d\delta}{ds} = \frac{d}{ds}\int_0^\delta \overline{u^2}dn$$

Since $\overline{u^2} \to 0$ as $n \to \delta$ (i.e. as the turbulence decays). The program also includes a term $-\frac{1}{U}\frac{\partial W}{\partial z}(U_e^2\,\theta)$ to account for the effect of lateral divergence on the continuity equation. If $R \to \infty$ and $p = p_e - \rho\overline{v^2}$ then, noting that $\frac{\partial p_e}{\partial s} = -\rho U_e\frac{dU_e}{ds}$, we get the usual momentum integral equation

$$\frac{d}{ds}(U_e^2\theta) = \frac{\tau_w}{\rho} + \frac{\delta^*}{\rho}\frac{\partial p_e}{\partial s} + U_eV_w + \frac{\partial}{\partial s}\int_0^\delta(\overline{u^2}-\overline{v^2})dn$$

A3.6 NUMERICAL IMPLEMENTATION OF THE CENTRIFUGAL APPROXIMATION

Subroutine PRINIT (see §2.4(d)) fills up a pressure list using the centrifugal approximation

$$\frac{h}{\rho}\frac{\partial p}{\partial n} = \kappa U^2 \qquad (A3.49)$$

where $\kappa = \frac{1}{R}$.

The finite difference scheme used is the same as that for the V, p calculation (see §A3.3); the differenced form of (A3.49) is thus written

$$\frac{h_{i,j-\frac{1}{2}}}{\rho}\left(\frac{p_{ij} - p_{i,j-1}}{\Delta n}\right) = \frac{1}{4}\kappa_{i-\frac{1}{2}}\left(U_{ij} + U_{i,j-1}\right)^2$$

or $$p_{i,j-1} = p_{ij} - \frac{1}{4}\,\frac{\kappa_{i-\frac{1}{2}}.\Delta n}{h_{i,j-\frac{1}{2}}}\left(U_{ij} + U_{i,j-1}\right)^2 \qquad (A3.50)$$

where $h_{i,j-\frac{1}{2}} = \frac{1}{2}(h_{ij} + h_{i,j-1})$; $h_{ij} = 1 + j\Delta n.\kappa_{i-\frac{1}{2}}$

Again, as in the p calculation, we start with $p_{iJ} = p_e$ and calculate the pressure profile down to the value p_1 at the first mesh point. To obtain p_w from p_1, we insert a 1/5th. power law U profile into (A3.49) and integrate with respect to n from the wall to the first mesh point. Thus, putting $U = U_1 \left(\frac{n}{\Delta n}\right)^{1/5}$ into (A3.49) and integrating with respect to n gives

$$\int_0^{\Delta n} \frac{1}{\rho}\frac{\partial p}{\partial n}\,dn = \frac{\kappa U_1^2}{(\Delta n)^{2/5}} \int_0^{\Delta n} \frac{n^{2/5}}{\left(1+\frac{n}{R}\right)}\,dn$$

$$\simeq \frac{\kappa U_1^2}{(\Delta n)^{2/5}} \int_0^{\Delta n} n^{2/5}\left(1 - \frac{n}{R}\right) dn \qquad \text{for } \frac{n}{R} \ll 1.$$

This reduces to

$$\left(\frac{p_w - p_1}{\rho}\right) = -\frac{5}{7} U_1^2 K \Delta n \left(1 - \frac{7}{12} K \Delta n\right) \quad (A3.51)$$

A3.7 THWAITES' LAMINAR BOUNDARY LAYER CALCULATION

This is an integral method based on the laminar streamwise momentum equation. It relies on the definition of a universal parameter equal to $\frac{\theta^2}{\nu}\frac{dU_e}{ds}$, where θ is the laminar BL momentum thickness and U_e (s) the external (free stream) velocity. For a detailed description of the method see Duncan, Thom and Young (1970). The method produces a formula for the variation of θ with s; thus

$$\theta^2(s) = \frac{0.45\nu}{U_e^6(s)} \int_0^s U_e^5(\xi)\, d\xi \quad (A3.52)$$

Now, we can also deduce a formula for $V_e(x)$, the edge V velocity distribution; the continuity equation for (plane) laminar flow is $\frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} = 0$. If we integrate this equation with respect to y from y = 0 to y = δ (the laminar boundary layer edge), we obtain

$$V_e = V_w - \frac{d}{dx}\left[U_e(\delta - \delta^*)\right] + U_e\frac{d\delta}{dx} \quad (A3.53)$$

where

$\delta^* = \int_0^\delta \left(1 - \frac{U}{U_e}\right) dy$, which is the displacement thickness of the BL. If $d\delta/dx << 1$, this reduces to $V_e = V_w - \frac{d}{dx}\left[U_e(\delta - \delta^*)\right]$ which is the same as the entrainment velocity normal to the edge of the BL.

A3.8 THE SPALDING-CHI SKIN FRICTION FORMULA

This empirical formula may be used to give the starting value of the skin friction coefficient c_f at the start of the turbulent shear layer calculation. It uses the "overlap law" for skin friction in the form

$$\sqrt{\frac{2}{c_f}} = \frac{U_e}{u_\tau} = \frac{1}{K}\log_e \frac{U_e\delta^*}{\nu} + D(Re_\theta) \qquad (A3.54)$$

where $D(R_\theta)$ is an empirical function of R_θ where

$$D(Re_\theta) = 4.84 - 4.88/(1+7.14\times10^{-4}Re_\theta)^3 \qquad (A3.55)$$

The second term allows empirically for low R_θ effects.

$\delta^*/\theta = 1/(1-6.8\frac{u_\tau}{U_e})$ is an empirical formula used to obtain the shape factor $\frac{\delta^*}{\theta}$ for a turbulent boundary layer: it is equivalent to the statement that Clauser's parameter G is 6.8.

The procedure for finding c_f is: given θ and R_θ, firstly to guess a value (for example the value given by the simple formula $\frac{u_\tau}{U_e} = \frac{c_f}{2} = .113\ R_\theta^{-1/8}$). We then insert this guess into (A3.56) to obtain δ^* and insert this in turn into (A3.54) to give a better value of $\frac{U_e}{u_\tau}$ (and hence c_f). This value of $\frac{u_\tau}{U_e}$ is then used in (A3.56) and so on; in principle the procedure is repeated until c_f has converged. However, in the present case we have found it sufficient to obtain just one improvement on the initial guess for c_f.

APPENDIX A4

MISCELLANEOUS DERIVATIONS AND DEFINITIONS

A4.1 LAGRANGIAN INTERPOLATION FORMULA

Subroutine VALUE, which is used for linear and parabolic interpolation in some of the programs, uses Lagrange's formula for parabolic interpolation; this is the equation of a parabola passing through the three points (x_1,y_1), (x_2,y_2) and (x_3,y_3), written in the following form:

$$y = y_1\frac{(x-x_2)(x-x_3)}{(x_1-x_2)(x_1-x_3)} + y_2\frac{(x-x_1)(x-x_3)}{(x_2-x_1)(x_2-x_3)} + y_3\frac{(x-x_1)(x-x_2)}{(x_3-x_1)(x_3-x_2)}$$

A4.2 THE EXPRESSION FOR A CENTRAL DIFFERENCE DERIVATIVE

We will derive here an expression for the derivative at $y = y_2$, given by a parabolic fit to points (x_1,y_1), (x_2,y_2) and (x_3,y_3). For this purpose, we use the Lagrangian form of the equation of the parabola, given in §A4.1 above:

Putting

$$x_2-x_1 = \Delta x_1 \;;\; x_3-x_2 = \Delta x_2 \;;\; \Delta = x_3-x_1 = \Delta x_1+\Delta x_2$$

$$\therefore\; y = \frac{y_1}{\Delta x_1 . \Delta}(x-x_2)(x-x_3) - \frac{y_2}{\Delta x_1 . \Delta x_2}(x-x_1)(x-x_3)$$

$$+ \frac{y_3}{\Delta x_2 . \Delta}(x-x_1)(x-x_2)$$

$$\therefore\; \frac{dy}{dx} = \frac{y_1}{\Delta x_1 . \Delta}\left[(x-x_2)+(x-x_3)\right] - \frac{y_2}{\Delta x_1 . \Delta x_2}\left[(x-x_1)+(x-x_3)\right]$$

$$+ \frac{y_3}{\Delta x_2 . \Delta}\left[(x-x_1)+(x-x_2)\right]$$

At (x_2, y_2)

$$\left.\frac{dy}{dx}\right|_{x=x_2} = \frac{y_1}{\Delta x_1 . \Delta}(-\Delta x_2) - \frac{y_2}{\Delta x_1 . \Delta x_2}(\Delta x_1 - \Delta x_2)$$

$$+ \frac{y_3}{\Delta x_2 . \Delta} . \Delta x_1$$

which reduces to

$$\left.\frac{dy}{dx}\right|_{x=x_2} = \left(\frac{y_2 - y_1}{\Delta x_1}\right) . \frac{\Delta x_2}{\Delta} + \left(\frac{y_3 - y_2}{\Delta x_2}\right) . \frac{\Delta x_1}{\Delta}$$

A4.3 DERIVATION OF THE EXPRESSIONS FOR THE VELOCITIES INDUCED BY A STRAIGHT LINE SOURCE ELEMENT

We shall derive expressions for the velocities induced by a single straight line source element of source density m_n (i.e. source strength per unit length) at a point P (see Fig. (23)). $\bar{x}$ is the distance between P and the mid point of the element, in the direction parallel to the element AB, while $\bar{y}$ is the distance of P from the element mid point, in the direction normal to AB. If we consider a small segment of length $d\xi$ on AB, whose radial distance from P is r, and if we take this segment to be small enough so that it approximates a point source, then the radial velocity induced by that segment at P is $\frac{m_n d\xi}{2\pi r}$, where the equivalent source strength of the point source is $m_n d\xi$. Therefore the components of that velocity parallel and normal to AB are $\frac{m_n d\xi}{2\pi r} \cos\theta$ and $\frac{m_n d\xi}{2\pi r} \sin\theta$, respectively. Hence, the total velocities, parallel and normal to AB, induced by the whole source element AB are:

$$V_{1n} = \int_{-\frac{\Delta s_n}{2}}^{\frac{\Delta s_n}{2}} \frac{m_n d\xi}{2\pi r} \cos\theta \qquad (A4.1)$$

and $$V_{2n} = \int_{-\frac{\Delta s_n}{2}}^{\frac{\Delta s_n}{2}} \frac{m_n d\xi}{2\pi r} \sin\theta \qquad (A4.2)$$

respectively.

Now, $r^2 = (\bar{x}-\xi)^2 + \bar{y}^2$; $\cos\theta = \dfrac{\bar{x}-\xi}{r}$; $\sin\theta = \dfrac{\bar{y}}{r}$

$\therefore\; V_{1n} = \dfrac{m_n}{2\pi}\displaystyle\int_{-\frac{\Delta s_n}{2}}^{\frac{\Delta s_n}{2}} \frac{(\bar{x}-\xi)\,d\xi}{(\bar{x}-\xi)^2 + r^2}$, where m_n has been taken outside the integral, since it is assumed constant.

$$\therefore\quad V_{1n} = \frac{m_n}{4\pi}\log_e\left\{\frac{(\bar{x}+\frac{1}{2}\Delta s_n)^2 + \bar{y}^2}{(\bar{x}-\frac{1}{2}\Delta s_n)^2 + \bar{y}^2}\right\} \qquad (A4.3)$$

and $$V_{2n} = \frac{m_n}{2\pi}\int_{-\frac{\Delta s_n}{2}}^{\frac{\Delta s_n}{2}} \frac{\bar{y}\; d\xi}{(\bar{x}-\xi)^2 + \bar{y}^2} = \frac{m_n}{4\pi}\tan^{-1}\left\{\frac{\bar{y}\,\Delta s_n}{\bar{x}^2+\bar{y}^2-\frac{1}{4}(\Delta s_n)^2}\right\} \qquad (A4.4)$$

A4.4 THE COORDINATES AND CURVATURE DISTRIBUTION OF A NACA 0012 AEROFOIL

The equation of a NACA 0012 aerofoil in X, Y co-ordinates (see Abbott and Von Doenhoff (1959)) is given by:

$$Y = \frac{0.12}{0.20}\left(0.2969\sqrt{X} - 0.1260X - 0.3516X^2 + 0.2843X^3 - 0.1015X^4\right) \qquad (A4.5)$$

where X and Y are normalised with respect to the chord. The curvature distribution $\kappa(X)$ is given by the following expression:

$$K(X) = d^2Y/dX^2/[1+(dY/dX)^2]^{3/2}$$

so that from (A4.5) we find that

$$K(X) = f_2(X)/[X + f_1^2(X)]^{3/2}$$

where

$$f_1(X) = \frac{0.12}{0.20}\left[0.14845 + X^{1/2}\{-0.1260 - 0.7032X + 0.8529X^2 - 0.4060X^3\}\right]$$

and

$$f_2(X) = \frac{0.12}{0.20}\left[-0.074225 + X^{1/2}\{-0.7032X + 1.7058X^2 - 1.2180X^3\}\right]$$

APPENDIX A5

NAMELISTS

FOR VARIABLES USED

IN THE COMPUTER PROGRAMS

A5.1 Namelist for Variables in the Shear Layer Calculation Program TURB.

A5.2 Namelist for Variables in the Potential Flow Calculation Program AMOS.

A5.3 Namelist for Variables in the matching program MATCH (for internal and external flows).

A5.4 Namelist for Additional Variables in the Smoothing Program SMOOTH

A5.5 Namelist for Additional Variables in the Mass Flow Calculation Program TRAVERS.

A5.1

A	An input array containing scales and starting conditions for the SL calculation (see §3.3).
A2	s-spacing of boundary values(except for pressure and MS height boundary values); this is equal to A(2) (see §3.3).
A7	The under relaxation factor the pressure.
A1Ø	a_1 usually 0.15.
ACCEL	The acceleration term in the equation for $\frac{p_w - p_1}{\rho U_{ref}^2}$.
ALPHA	α.
ALPHAO	$\alpha_o = \frac{\tau_1 - \tau_w}{\rho \Delta n}$, the shear stress gradient at the wall (strictly , the average between n = O and n = Δn).
BDASH	$B' = \alpha - \beta$.
BETA	β.
C1, C2	The constants c_1, c_2 relating the normal Reynolds stress to the Reynolds shear stress.
CADD	The additive constant C in the inner layer logarithmic law for the U velocity profile.
CENTRF	The centrifugal acceleration term in the equation for $\frac{p_w - p_1}{\rho U_{ref}^2}$.
CFR	$c_f = \frac{\tau_w}{\frac{1}{2}\rho U_e^2}$.
CP	C_p'; the integral of $\frac{1}{\rho}\frac{\partial p}{\partial s}$ from n = O to the MS.
CPOLD	The value of CP at the previous station.
CTAU	C_τ; the integral of $\frac{\tau}{\rho}$ from n = O to the MS.
CU2	$C_{\overline{u^2}}$; the integral of $\overline{u^2}$ from n = O to the MS.

CU2OLD	The value of CU2 at the previous station.
CURV	The curvature κl_{ref} for the current station.
CURV1	The curvature at the first station (i.e. at the start of the turbulent shear layer calculation).
CURVA	Array containing curvature boundary values.
CURVFU	The value of the κl_{ref} at the station at which $s = s_o + \Delta n$, for the first sweep only.
CURVOL	The curvature for the previous station.
CUV	C_{uv}; the integral of UV from n = O to the MS.
DØ5	δ_{05}.
DA	$d\alpha_o$ in the application of the wall boundary condition.
DEL	The surface on which V_e is calculated in the laminar BL calculation, at a given station (or node).
DELO	The value of DEL at the previous station (or node) in the laminar BL calculation.
DELS, DELS1, DELS2, DELX	Various s-steps.
DELSTA	The integral δ^*.
DELTA	The MS height above the RS.
DGA	An array containing a table of value of $\delta_{05} \frac{\partial}{\partial n} \left[\frac{G}{(\tau_m/\rho U_e^2)^{\frac{1}{2}}}\right]$.
DIV	The lateral divergence $\frac{1}{U} \frac{\partial W}{\partial z}$.
DIVA	Array of lateral divergence boundary value.
DNSTR	The streamwise gradient of the normal stress $\rho\overline{u^2}$; i.e. $\frac{\partial \overline{u^2}}{\partial s} = c_1 \frac{\partial \tau}{\partial s}$.
DPDS,DPDX	The streamwise pressure gradient $\frac{\partial p}{\partial s}$.

DPINT	The integral of $\frac{1}{\rho}\frac{\partial p}{\partial s}$ from the wall to the first mesh point.
DT	$d\tau_1$ in the application of the wall boundary condition.
DTW	$d\tau_w$ in the application of the wall boundary condition.
DU	dU_1 in the application of the wall boundary condition.
DU2DS	The value of $\frac{\partial \overline{u^2}}{\partial s}$.
DU2INT	The integral of $\frac{\partial \overline{u^2}}{\partial s}$ from the wall to the first mesh point.
DVDS	The streamwise gradient of V; i.e. $\frac{\partial V}{\partial s}$.
F1,F2,F3	The functions F_1, F_2, F_3.
FACMS	A factor multiplying $\theta(x)$ to determine the surface on which V_e is to be evaluated, for the first sweep only of the laminar BL calculation. This factor is equal to $(2\Delta n + \delta_{Coles})/\theta$.
FUDUDX	The value of $U_e \frac{dU_e}{ds}$ at the future station $s + \Delta s$.
GA	An array containing a table of values of $\frac{G}{(\tau_m/\rho U_e^2)^{\frac{1}{2}}}$.
H1	The shape parameter $H_1 = \frac{\delta^*}{\theta}$.
HJAV	Equal to $h_{i,j-\frac{1}{2}}$ (for the current station).
HJAVOL	Equal to $h_{i-1,j-\frac{1}{2}}$ (for the previous station).
I	An input array containing control parameters, controlling options in the program (see §3.3).
I5	The number of boundary values (except for pressure and MS height boundary values).
I6	Equal to I(6), the number of mesh points for which the U, τ calculation is performed.

I61	Equal to I6 + 1.
I62	Equal to I6 + 2; this is the number of the mesh point that lies on the MS.
I6COLE	The value of I6 for the first turbulent SL calculation station, at which $n = \delta_{Coles}$.
I1Ø	Equal to the input parameter I(10) (see §3.3).
IDIV	Set to zero to suppress allowance for the extra strain rate effect of lateral divergence.
IORIG	A parameter giving the origin from which VPRESS is called; if IORIG=1, VPRESS is called from the main routine and if IORIG=2, VPRESS is called from subroutine NEWPRO.
JOPT	A parameter distinguishing between an unrealistic ($\sqrt{P' - p_w}$) and a realistic (U) velocity starting profile. (JOPT=1 is unrealistic and JOPT=2 is realistic).
NCOUNT	A count of the number of steps executed.
NEND	The RS node number for the end of the turbulent shear layer calculation.
NEXPTS	The maximum size of arrays UEXT, VEXT, and RNPNEW, $\leq$ 140.
NSTART	The RS node number for the start of the turbulent shear layer calculation.
NSTNS	The maximum number of calculation stations.
NSWEEP	A count of the number of sweeps of the SL calculation.
NXP	The number of stations in array XP (see §3.3).
OLTAUO	The value of τ_w at the previous station.
OMEGA	The under relaxation factor for the pressure.

P	A scratch pressure array.
PØ	The wall pressure corresponding to array P.
PA	Array of pressure boundary value.
PE	The external pressure on the MS $\frac{p_e - p_{ref}}{\rho U_{ref}^2}$ at the turbulent SL calculation stations, and at the nodes for the laminar BL calculation.
PEFUT	The value of $\frac{p_e - p_{ref}}{\rho U_{ref}^2}$ at the station where $s = s_o + \Delta n$, for the first sweep only.
PEND	An input array containing the pressure profile at the last station (see §3.3).
POLD	An array containing the pressure profile at the previous station.
POLDØ	The wall pressure at the previous station.
PRESS	Two dimensional pressure array.
PRESSW	An array containing the wall pressure distribution.
PW	The wall pressure $\frac{p_w - p_{ref}}{\rho U_{ref}^2}$ at the current station.
PWEND	The input wall pressure at the last station, corresponding to PEND.
RETRAN	The value of $Re_{\theta_{tran}}$: i.e. R_θ at which the transition criterion is applied.
RI6	A real variable equal to I6.
RINT1	The integral I_1.
RINT3, RINT2	The integral I_2.
RLA	An array containing a table of values of L/δ_{05}.
RLAMB	The parameter $\frac{\theta^2}{\nu}\frac{dU_e}{dx}$ for the laminar BL calculation.
RLEND	The s-distance between the input initial and final pressure profiles (see §3.3).

RM	The maximum value of the shear stress/U_e; i.e. τ_{max}/U_e, used in scaling G.
RMØ5	.05 τ_{max}.
RNORM	The sum of terms depending on the normal Reynolds stresses in the equation for $\frac{p_w - p_1}{\rho U_{ref}^2}$.
RNP	The initial guess height for the MS in the turbulent SL region.
RNPMAX	The maximum shear layer thickness.
RNPNEW	Array containing new MS height (in the n-direction); at nodes if in laminar BL region and at SL calculation stations if in turbulent SL region.
ROUGH	Dimensionless surface roughness.
ROUGHA	Array of roughness boundary value.
RTAU	$\frac{\delta_{05}\sqrt{\tau_{max}/\rho}}{\nu}$.
RTHETA	The Reynolds number based on θ; $\frac{U_e\theta}{\nu}$.
SCHMET	The value of momentum thickness obtained from the momentum integral equation.
SHEAR	The sum of terms depending on the Reynolds shear stress in the equation for $\frac{p_w - p_1}{\rho U_{ref}^2}$.
SSURF	An array containing the values of s for the RS nodes.
STRAIN	The extra strain rate correction ê in the turbulence model; it is not used, but merely set to zero in the program.
T	The value of θ/δ_{Coles} from the synthetic U velocity profile for the start of the turbulent SL calculation.
TANA	An array containing the tangents of the "outgoing" characteristic angles at station S.

TANAFU	An array containing the tangents of the "outgoing" characteristic angles at the future station s + Δs.
TANB	An array containing the tangents of the "ingoing" characteristic angles at station s.
TANBFU	An array containing the tangents of the "ingoing" characteristic angles at the future station s + Δs.
TANNEW	tan ϕ_{new}.
TAU	An array containing the τ profile at the current station s.
TAUO	The wall shear stress τ_w.
TFUT	An array containing the τ profile at the future station s + Δs.
THETA	The value of momentum thickness obtained by integrating the U velocity profile.
TINT	Equal to τ_{int}, which is the value of τ interpolated at the beginning of a characteristic segment.
TOLD	An array containing the τ profile at the previous station s - Δs.
TOR	The value of τ at the mid point of a characteristic segment.
TRAN	This is equal to $R_{e_\theta}/R_{e_{\theta,tran}}$.
TRANO	The value of TRAN at the previous station (or node) in the laminar BL calculation.
TSTART	An array containing the shear stress (τ) profile at the first station of the turbulent SL calculation (starting profile).

U	An array containing the U profile at the current station s.
UE2Ø6	$U_e^2 \times 10^{-6}$, used in clipping the τ profile.
U2CURV	Equal to U^2/R in the normal momentum equation.
UDUDX	The value of $U_e \frac{dU_e}{ds}$ at the current station s.
UDUDXO	The value of $U_e \frac{dU_e}{ds}$ at the previous station s - Δs.
UDVDS	Equal to $U \frac{\partial V}{\partial s}$ in the normal momentum equation.
UE	U_e at the current station s.
UE2	U_e^2 at the current station s.
UE2OLD	U_e^2 at the previous station s - Δs.
UEDDS	The value of $U_e(\delta-\delta^*)$ in the laminar BL calculation.
UEDDSO	The value of $U_e(\delta-\delta^*)$ in the <u>laminar</u> BL calculation at the previous calculation station (or node).
UEDS	The value of $U_e\delta^*$ in the laminar BL calculation.
UEDSO	The value of $U_e\delta^*$ at the start of the laminar BL calculation.
UEF	The value of U_e at the next (or future) station (or node) in the <u>laminar</u> BL calculation.
UEFUT	The value of U_e at the station where $s = s_o + \Delta n$, for the first sweep only.
UEOLD	U_e at the previous station s - Δs.
UEXT	Array containing values of U_e; at nodes if in laminar BL region and at SL calculation stations if in turbulent SL region.
UFUT	An array containing the U profile at the future station s + Δs.
UINT	The value of U_{int}, which is the interpolated value of U at the beginning of a characteristic segment.

UL	The value of U at the mid point of a characteristic segment.
UOLD	An array containing the U profile at the previous station s - Δs.
US	A scratch array used in intermediate operations.
USTART	An array containing the U profile at the first station of the turbulent SL calculation (starting profile).
UTAU	u_τ.
V	An array containing the V profile at the current station s.
V1	The value of V at the first mesh point.
VDVDN	Equal to $hV\frac{\partial V}{\partial n}$ in the normal momentum equation.
VEXT	Array containing values of V_e; at nodes if in laminar BL region and at SL calculation stations if in turbulent SL region.
VINT	The value V_{int}, which is the value of V interpolated at the beginning of a characteristic segment.
VL	The value of V at the mid point of a characteristic segment.
VOLD	An array containing the V profile at the previous station s - Δs.
VOLDER	An array containing the V profile at the station before the previous one.
VW	V_w, the wall transpiration velocity, at the current station.
VWA	Array containing the transpiration velocity boundary value.
VWOLD	V_w at the previous station s - Δs.

X	The value of s for the current calculation station.
XCAL	Array containing s-positions of SL calculation stations.
XCURV	Array containing s-positions for the curvature boundary value.
XF	The value of s at the next (or future) station (or node) for the laminar BL calculation.
XMAX	The maximum value of s for all boundary values except the pressure and MS height.
XMAX1	The maximum value of s for the pressure and MS height boundary values.
XP	An input integer array containing numbers of stations at which information is printed (see §3.3).
XSTEP	The s-step Δs.
XXSTEP	The value of s for the future station.
YSD	$\Delta n/\delta_{05}$.
YSTP	The vertical spacing Δn of the grid (or mesh) points.
ZØ1	Shift of L (length scale) profile in empirical allowance for low Reynolds number effect.

A5.2

A	The two dimensional array (or matrix) of influence coefficients A_{pn}.
ALP	The angle of incidence (in degrees) of the aerofoil, for external flow.
AX	$\overline{x}$.
AY	$\overline{y}$.
B	The two dimensional array (matrix) of coefficients B_{pn}.
CC	The aerofoil chord length for external flows. For internal flows it is set to the reference length l_{ref}.
CHD	The required length by which the coordinates of the MS are scaled when printed out; for external flow it is the required output chord of the aerofoil.
CL	The lift coefficient of the aerofoil, for external flow.
CP	An array containing values of the pressure coefficient $c_p = \frac{p - p_{ref}}{\frac{1}{2}\rho U_{ref}^2}$ at the mid points of the MS elements.
CPOFF	The pressure coefficient at an off-body point.
DET	The determinant of the influence coefficient matrix A_{pn}.
DG	An array containing the element source densities m'_n.
DS	An array containing the length of the MS elements.
GAP	The value of the circulation $\frac{\Gamma}{S}$ required to impose the Kutta-Zhukovskii condition, for a lifting aerofoil.

MV1, MV2	Working arrays used in the inversion of the influence coefficient matrix.
N	The number of source elements of the MS.
NEND	The number of the node denoting the end of the turbulent SL calculation.
NEXT	An integer describing the type of flow; if NEXT=1, it is an external flow and if NEXT=Ø, it is an internal flow.
NOFBDY	The number of off-body points.
NORUN	The number of runs of the potential flow calculation.
NSTART	The number of the node denoting the start of the turbulent SL calculation.
NTBE	The number of the "trailing edge" node for <u>external</u> flow. It is also the number of the element on the lower surface nearest to the TE. For <u>internal</u> flow it marks the number of the last node on the surface on which the turbulent SL is calculated.
NTE	This is equal to the number of elements up to the "trailing edge" node; it is also equal to the number of the element on the upper surface nearest to the TE, for <u>external</u> flow.
R	An array containing the X-coordinates of the mid points of the MS elements.
S	An array containing the Y-coordinates of the mid points of the MS elements.
SM	The arc length of the MS node at which the total velocity <u>magnitude</u> is a minimum.
SP	The total arc length around the MS.

SS	An array containing the arc lengths at the mid points of the MS elements.
STAG	The arc length at the stagnation point on the MS.
SV	An array containing the total (finally calculated) value of the tangential velocity at the MS element mid points.
TH	An array containing the angles which the MS elements make with the X-axis.
TSA	The total tangential velocity at the mid point of the upper surface element nearest to the TE, for flow case (2) of unit vorticity distribution.
TSB	The total tangential velocity at the mid point of the lower surface element nearest to the TE, for flow case (2) of unit vorticity distribution.
TT	The angle of incidence (in radians) of the aerofoil, for external flow.
TVBN	The total tangential velocity at the mid point of the lower surface element nearest to the TE, for flow case (1) of unit stream velocity.
TVTN	The total tangential velocity at the mid point of the upper surface element nearest to the TE, for flow case (1) of unit stream velocity.
TY	An array containing the inverse of the influence coefficient matrix A_{pn}.
VC	An array containing the total induced velocities normal to the MS elements at their mid points. Later in the program it is also used as an array containing the calculated element source densities m_n.

VMS	An array containing the specified velocities normal to the MS elements at their mid points.
VX	The velocity in the X-direction, at an off-body point.
VY	The velocity in the Y-direction, at an off-body point.
X	An array containing X-coordinates of the MS nodes.
XX	An array containing the X-coordinates of the off-body points.
Y	An array containing the Y-coordinates of the MS nodes. Also used to store the total velocities normal to the MS elements at their mid points, as a check on the calculation.
YY	An array containing the Y-coordinates of the off-body points.

A5.3

BOT	The total mass flow rate from the lower surface (MS) of the duct (for internal flow only).
DS	An array containing the lengths of the MS elements (as in AMOS).
GRAD	An array containing the gradients of the RS at the nodes (relative to the X,Y axes).
GRADM	An array containing the gradients of the MS at the nodes (relative to the X,Y axes).
I2	The value of the control parameter I(2) in the turbulent SL calculation program; I2=1 if a laminar BL calculation is performed for external flow.
IEL	An array containing the numbers of the corner elements to which normal correction velocities are applied (for internal flow only).
N	The number of elements for the RS.
NEND	The node number indicating the end of the turbulent SL calculation region. In external flow it applies to the upper surface (same as in AMOS).
NENLOW	The node number at the end of the turbulent SL calculation region for the lower surface (external flow only).
NORUN	The number of runs of the matching program.
NS1, NEND1	Dummy variables.
NSIDE	The number of elements on the sides of the duct (for internal flow only).
NSLOW	The node number at the start of the turbulent SL calculation region for the lower surface (external

flow only).

NSTART	The node number indicating the <u>start</u> of the turbulent SL calculation region. In external flow it applies to the upper surface.
NSTPS1	The number of turbulent SL calculation stations -1 for the upper surface in the case of external flow; for internal flow it applies only to the surface on which the turbulent SL is calculated.
NSTPS2	The same as NSTPS1 only for the <u>lower</u> surface in external flow.
NTE	The number of the "trailing edge" node.
NTEL	The number of elements up to the "trailing edge" node for external flows. For internal flows it is the number of elements for the surface on which the turbulent SL is calculated.
NTOP	The number of elements on the top surface of the duct (for internal flow only).
OMEGA	The under relaxation factor for the velocities normal to the MS, at the MS element mid points.
R	A working array used in intermediate computations.
RNP	An array containing the current MS height at the nodes.
RNPNEW	An array containing the new MS height values at the turbulent shear layer calculation stations; for the laminar BL region they are assumed to be at the nodes.
RNPNST	The constant MS height for the turbulent SL calculation region.
S	A working array used in intermediate computations.
SS	An array containing the arc lengths of the MS at the nodes.

SSM	An array containing the arc lengths of the MS at the element mid points.
SSURF	An array containing the arc lengths of the RS nodes.
TOP	The total mass flow rate from the top surface of the duct (for internal flow only).
UE	An array containing the velocities parallel to the RS at the turbulent SL calculation stations.
UEXIT	The duct exit velocity/U_{ref} (for internal flow only).
UINF	The duct entry velocity/U_{ref} (for internal flow only).
UMS	An array containing the velocities normal to the MS at the element mid points. It is also used in an intermediate calculation as a scratch array containing the interpolated velocities parallel to the RS at the nodes.
VCORR	An array containing the normal correction velocities applied at the mid points of the corner elements (for internal flow only).
VE	An array containing the velocities normal to the RS at the turbulent SL calculation stations.
VMS	An array containing the velocities normal to the MS at the nodes. It is also used in an intermediate calculation as a scratch array containing the velocities normal to the RS at the nodes.
VMSOLD	An array containing the velocities normal to the MS at the MS element mid points, from the previous viscous/inviscid iteration.

X	An array initially containing the X-coordinates of the RS nodes; later overwritten with the X-coordinates of the MS nodes.
XCAL1	An array containing the values of s for the turbulent shear layer calculation stations. These values are for the upper surface in external flow and for the surface on which the turbulent SL is calculated, in internal flow.
XCAL2	The same as XCAL1 except that it applies only to the lower surface in external flow.
Y	An array initially containing the Y-coordinates of the RS nodes; later overwritten with the Y-coordinates of the MS nodes.

A5.4

CPE	An array containing the current sweep values of the external pressure at the MS nodes.
DUM	A scratch array containing the values of the shifted pressure distribution $p'(s)\|_{n=const.}$, at the turbulent SL calculation stations.
M	The total number of RS or MS nodes for the turtulent SL calculation region.
ND	The number of internal cubic spline nodes (the number of points at which values are picked off the p'(s) distribution, excluding the first and last values).
NODES	The total number of points picked off from the p'(s) distribution.
PA	An array containing the interpolated values of the external pressure at the MS element mid points.
PE	The external pressure on the MS interpolated at the turbulent SL calculation stations, for the current sweep.
PEOLD	The value of PE from the previous sweep.
UEXT	A scratch array containing the pressure profile shift $p_e - p_{e,old}$ at the turbulent SL calculation stations.
XCAL	An array containing s-positions of the turbulent SL calculation stations.
XNODE	An input array containing the s-positions at which values are picked off the p'(s) distribution; these points are used as "smoothing points" through which a cubic spline will be fitted.

YNODE — An array containing the values of p'(s) interpolated at the "smoothing points" given by array XNODE.

A5.5

DEL	An array containing the vertical positions (normal to the MS), at which the duct velocity profile is measured, including the points on the body (MS) as well as the off-body points.
IBOT	The number of the element on the bottom surface (the MS) of the duct, through which a "traverse" station passes.
ITOP	The number of the element on the top surface of the duct, through which a "traverse" station passes.
NOFBDY	The total number of off-body points at which the duct velocity profile is calculated.
NPTS	The number of off-body points at each "traverse" station where the mass flow rate is calculated.
NTRAVS	The total number of "traverse" stations at which the velocity profile and mass flow rate are calculated.
RMASS	The mass flow rate calculated at a "traverse" station by integrating the velocity profile across the duct.
THETA	The angle (in degrees) relative to the X-axis, made by the MS elements through which a "traverse" station passes.
US	An array containing the tangential velocities at the mid points of the MS elements.
UTRAV	An array containing the velocity profile across the duct, at the traverse stations.
UX	An array containing the velocities parallel to the X-axis, at the off-body points.

VN	An array containing the normal velocities at the mid points of the MS elements.
VY	An array containing the velocities parallel to the Y-axis, at the off-body points.
WIDTH	H_D/l_{ref}.

APPENDIX A6

Listings of the Computer Programs

A6.1

Listing of Program TURB

```
      OVERLAY(OVTURB,0,0)
      PROGRAM TURB(OUTPUT=132B,TAPE5=132B,TAPE14=132B,TAPE6=132B)
C**** TURBULENT SHEAR LAYER CALCULATION PROGRAM IN INVISCID/VISCOUS
C**** INTERACTION CALCULATION. THIS IS FOR 2D INCOMPRESSIBLE
C**** ISOTHERMAL FLOW WITH ALGEBRAIC LENGTH SCALE IN THE TURBULENCE
C**** MODEL. IT INCLUDES THE SOLUTION OF THE NORMAL MOMENTUM EQUATION
C**** AND ALL EQUATIONS ARE WRITTEN IN S-N COORDINATES.
C**** THE CALCULATION METHOD IS BASED ON THE ORIGINAL BRADSHAW-FERRISS-
C**** ATWELL METHOD.
      COMMON/PRIM/PRESS(51,120),PRESSW(120),XCAL(120),
     1UEXT(140),VEXT(140),RNPNEW(140),NSTNS,NEXPTS
      COMMON/BVAL/DIVA(51),ROUGHA(51),VWA(51),XCURV(51),CURVA(51)
     1,A2,I5,I10,PA(51)
      COMMON/INTG/A(6),ALPHAO,CFR,DO5,DIV,DELSTA,FUDUDX,H1,SCHMET,TAUO,  CF170030
     1THETA,UDUDX,UE,UE2,UTAU,VW,X,XSTEP,YSTP,PW,PWALL,PE,PEXT
      COMMON/DDDS/I(14),XP(52),CADD,CURV,IDIV,NXP,STRAIN,ROUGH,YSD,Z01
     1,C1,C2
      COMMON/PROF/TANA(51),TANAFU(51),TANB(51),TANBFU(51),TAU(51),TFUT   CF170060
     1(51),U(51),UFUT(51),US(51),V(51),I6,I61,I62,RI6,RM,V1             CF170070
      COMMON/OLDPRO/UOLD(51),TOLD(51),VOLD(51),POLD(51),POLDO,VOLDER(51)
      COMMON/OLDINT/VWOLD,OLTAUO,CURVOL,PWOLD,PEOLD
      COMMON/FIRST/CURV1,USTART(51),TSTART(51)
      COMMON/RELAX/A7
      COMMON/EXT/SSURF(51),RNP
      COMMON/PRESSR/P(51),PO
      COMMON/COUNTS/NSWEEP,NCOUNT
      COMMON/END/RLEND,PEND(51),PWEND,JOPT
      COMMON/TURBOL/NSTART,NEND
      INTEGER XP
C
      READ(5,20) NSTNS,NEXPTS
   20 FORMAT(16I5)
C.....CALL STARTING ROUTINES
      CALL OVERLAY(6HOVTURB,2,0)
C
      IF(I(14).EQ.0) GO TO 115
      NCOUNT=1
      WRITE(6,50) NCOUNT,X,I62
   50 FORMAT(/1X,'STN.',I4,6X,'X=',E11.4,6X,'I62=',I3,6X,'(P-PREF)/UREF*
     1*2(FROM PREVIOUS SWEEP)=')
      WRITE(6,55) PRESSW(1),(PRESS(J,1),J=1,I62)
   55 FORMAT(1X,10E12.4)
      IF(NSWEEP.GT.0) GO TO 115
      XYSTP=X+YSTP
      WRITE(6,50) NCOUNT,XYSTP,I62
      WRITE(6,55) PRESSW(2),(PRESS(J,2),J=1,I62)
  115 NCOUNT=1
      XMAX=A2*(I5-1)                                                     CF170130
      XMAX1=SSURF(NEND)
C
C
C     MOVES RECENTLY CALCULATED PROFILES INTO OLD PROFILE STORE          CF170140
C     START OF FORWARD STEP LOOP                                         CF170150
C
  120 DO 133 J=I61,I62
      UC=SQRT(1.-2.*PRESS(J,NCOUNT))
      UFUT(J)=UC
  133 TFUT(J)=UE2*1.0E-8
      DO 140 J=1,I62
      IF(NCOUNT.GT.1) GO TO 135
      UOLD(J)=U(J)=UFUT(J)
      TOLD(J)=TAU(J)=TFUT(J)
      GO TO 140
  135 UOLD(J)=U(J)
```

```
      TOLD(J)=TAU(J)
      U(J)=UFUT(J)
      TAU(J)=TFUT(J)
  140 CONTINUE
      IF(NCOUNT.EQ.1) GO TO 145
      UEXT(NSTART-1+NCOUNT)=U(I62)
  145 CONTINUE
C     TAU MAX FOR G
      IENT=.25/YSD
      RM=0.
      DO 160 J=IENT,I6
  160 IF(RM.LT.TAU(J))RM=TAU(J)
      RM05=RM*.05
      RM=RM/UE
C     DELTA  05 FOR SCALING OF L AND G
      DO 170 J=1,I6
      L=I61-J
      IF(TAU(L).GT.RM05)GO TO 180
      L=J
  170 CONTINUE
  180 D05=YSTP*((RM05-TAU(L))/(TAU(L+1)-TAU(L))+L)
      YSD=YSTP/D05
C
C     PRESSURE, V AND CHC. ANGLES AT CURRENT X
      CALL VPRESS(I62,1,NSTNS,NEXPTS,PRESS,PRESSW,XCAL,VEXT)
      IF(NCOUNT.EQ.1) GO TO 175
      VEXT(NSTART-1+NCOUNT)=V(I62)
  175 CONTINUE
C
C     MOMENTUM INTEGRAL CHECK
      CALL INTGEQ(NSTNS,PRESS,PRESSW,XCAL)
C
C     COURANT FRIEDRICHS LEWY XSTEP CRITERION
      IF(NSWEEP.GT.0) GO TO 185
      CALL CFL
C
      XSTEP=XSTEP*A(6)
      XXSTEP=X+XSTEP
      XCAL(NCOUNT+1)=XXSTEP
      GO TO 187
  185 XXSTEP=XCAL(NCOUNT+1)
      X=XCAL(NCOUNT)
      XSTEP=XXSTEP-X
  187 CONTINUE
C
C*****AN EXTRA STRAIN RATE CORRECTION FOR THE TURBULENCE MODEL WOULD
      BE INSERTED HERE IF REQUIRED*****
      STRAIN=0.
C
      IF(I(3).GT.0) GO TO 195
      NXP=-I(3)
      DO 190 J=1,NXP
  190 IF((NCOUNT-XP(J)).EQ.0) CALL PRINT
      GO TO 197
  195 IF(NCOUNT.EQ.(NCOUNT/I(3))*I(3).OR.
     1   X.LE.A(3).OR.
     2NCOUNT.EQ.2.OR.NCOUNT.EQ.I(4)) CALL PRINT
  197 XLIM=XMAX
      IF(XMAX1.LE.XMAX)  XLIM=XMAX1
      IF(NCOUNT.GE.I(4).OR.ABS(X-XLIM).LT.1.0E-8.OR.
     1XXSTEP.GT.XLIM+1.0E-8) GO TO 270
C
C     BOUNDARY CONDITIONS
C
```

```
      CADD=5.2                                                           CF170560
C     OPTIONAL ROUGHNESS                                                 CF170570
      IF(I(8).EQ.0) GO TO 200                                            CF170580
      ROUGH=ORDIN(ROUGHA,A2,XXSTEP)                                      CF170590
      IF(UTAU*ROUGH*A(4).LT.6..AND.ROUGH.GE.0.) GO TO 200                CF170600
      CALL ROUGHC
C
C     TRANSPIRATION
  200 IF(I(12).EQ.0)  GO TO 210                                          CF170620
      VWOLD=VW
      VW=ORDIN(VWA,A2,XXSTEP)                                            CF170630
      IF(ABS(VW).LT..0001 *UE)VW=0.                                      CF170640
C
C     DIVERGENCE
  210 IF(I10.EQ.1)DIV=1./(XXSTEP-ORDIN(DIVA,A2,XXSTEP))                  CF170650
      IF(I10.GT.1)DIV=ORDIN(DIVA,A2,XXSTEP)                              CF170660
C
C     LOW REYNOLDS NUMBER FACTOR FOR LENGTH SCALE(BAKER AND LAUNDER)     CF170680
      RTAU=SQRT(RM*UE)*A(4)*D05                                          CF170690
      IF(RTAU.LT.200.) WRITE(6,220)                                      CF170700
      Z01=0.2375*EXP(-.0025*RTAU)                                        CF170710
      Z01=Z01+.006                                                       CF170720
  220 FORMAT(1H *REYNOLDS NUMBER TOO SMALL*)                             CF170730
      UEOLD=UE
      UE2OLD=UE*UE
      UDUDXO=FUDUDX
      OLTAUO=TAUO
C
C.....NEW CURVATURE AT MID-POINT OF X-STEP.....
      CURV=VALUE(XCURV,CURVA,I5,X+.5*XSTEP,1)
C
C.....NEW PRESSURE BOUNDARY VALUE.....
C.....EXTERNAL PRESSURE GIVEN.....
      PEOLD=PE
      IF(NSWEEP.GT.0) PE=PRESS(I62,NCOUNT+1)
      IF(NSWEEP.GT.0) GO TO 235
      PE=SPLINE(SSURF(NSTART),PA(NSTART),NEND-NSTART+1,XXSTEP)
C.....INITIAL FILLING UP OF PRESSURE ARRAY FOR FIRST SWEEP.....
      I62N=I62
      GO TO (206,208),JOPT
  206 CURVAT=0.
      IF(A(1).NE.0.) CURVAT=CURV
      CALL PRINIT(PRESS(1,NCOUNT+1),I62N,PRW,PE,CURVAT,YSTP,USTART,1)
      PRESSW(NCOUNT+1)=PRW
      GO TO 235
  208 PEX1=PRESS(I62N,1)
      PEXEND=PEND(I62N)
      DO 209 J=1,I62N
  209 PRESS(J,NCOUNT+1)=PE+(1.-X/RLEND)*(PRESS(J,1)-PEX1)+X/RLEND*
     1(PEND(J)-PEXEND)
      PRESSW(NCOUNT+1)=PE+(1.-X/RLEND)*(PRESSW(1)-PEX1)+X/RLEND*
     1(PWEND-PEXEND)
  235 CONTINUE
C
C     WALL BOUNDARY CONDITION                                            CF170860
      CALL WALLBC(NSTNS,PRESS,PRESSW,XCAL)
C
      IF(TAUO.GT.0.) GO TO 260                                           CF170880
      CALL PRINT
      WRITE(6,250)                                                       CF170900
  250 FORMAT(1HO*SEPARATION,OR TAU.LT.0 AT FIRST MESH POINT*)            CF170910
      GO TO 270
  260 UE2=UE*UE                                                          CF170930
      I6=I62-2
```

```
      I61=I62-1
      DØ 266 J=1,I62
  266 VØLDER(J)=VØLD(J)
C
C     NEW PRØFILES ØF U, TAU  AND  V                                    CF170940
      CALL NEWPRØ(NSTNS,NEXPTS,PRESS,PRESSW,XCAL,VEXT,RNPNEW)
C
      IF(I(14).EQ.0) GØ TØ 261
      NCP1=NCØUNT+1
      IF(I(3).GT.0) GØ TØ 253
      NXP=-I(3)
      DØ 255 J=1,NXP
  255 IF((NCP1-XP(J)).EQ.0) GØ.TØ 265
      GØ TØ 261
  253 IF(NCP1.EQ.(NCP1/I(3))*I(3).ØR.NCP1.EQ.2.ØR.NCP1.EQ.I(4)+1)
     1GØ TØ 265
      GØ TØ 261
  265 WRITE(6,50) NCP1,XXSTEP,I62
      WRITE(6,55) PRESSW(NCØUNT+1),(PRESS(J,NCØUNT+1),J=1,I62)
  261 FUDUDX=UE*(UE-UEØLD)/XSTEP
      DØ 267 J=1,I62
  267 VØLD(J)=V(J)
      X=XXSTEP                                                          CF170990
      NCØUNT=NCØUNT+1                                                   CF171000
      GØ TØ 120                                                         CF171010
C.....END ØF X-STEP LØØP.....
C
C
C.....PRESSURE PRØFILES AT LAST X-STN. AND AT STN. BEFØRE LAST.....
  270 CALL ØVERLAY(6HØVTURB,1,0)
C
C.....END ØF SWEEP.....
      WRITE(6,340) NSWEEP
  340 FØRMAT(//1X,'SWEEP NØ.',I3,2X,'ØF INVISCID/VISCØUS CALCULATIØN CØM
     1PLETED'/)
      STØP                                                              CF171060
      END                                                               CF171070



      SUBRØUTINE NEWPRØ(NSTNS,NEXPTS,PRESS,PRESSW,XCAL,VEXT,RNPNEW)
      DIMENSIØN PRESS(51,NSTNS),PRESSW(NSTNS),XCAL(NSTNS)
      DIMENSIØN VEXT(NEXPTS),RNPNEW(NEXPTS)
      CØMMØN/FUNC/DGA(30),GA(30),RLA(30)                                NEWP0010
      CØMMØN/INTG/A(6),ALPHA0,CFR,D05,DIV,DELSTA,FUDUDX,H1,SCHMET,TAU0, NEWP0020
     1THETA,UDUDX,UE,UE2,UTAU,VW,X,XSTEP,YSTP,PW,PWALL,PE,PEXT
      CØMMØN/PRØF/TANA(51),TANAFU(51),TANB(51),TANBFU(51),TAU(51),TFUT  NEWP0040
     1(51),U(51),UFUT(51),US(51),V(51),I6,I61,I62,RI6,RM,V1             NEWP0050
      CØMMØN/ØLDPRØ/UØLD(51),TØLD(51),VØLD(51),PØLD(51),PØLD0,VØLDER(51)
      CØMMØN/ØDDS/I(14),XP(52),CADD,CURV,IDIV,NXP,STRAIN,RØUGH,YSD,Z01
     1,C1,C2
      CØMMØN/PRESSR/P(51),P0
      CØMMØN/CØUNTS/NSWEEP,NCØUNT
      CØMMØN/EXT/SSURF(51),RNP
      CØMMØN/TURBBL/NSTART,NEND
      DIMENSIØN AL(2,3)                                                 NEWP0070
C
C.....CALCULATIØN ØF U AND TAU PRØFILES.....
C
      I6STØP=0
      UE206=1.0E-06*UE2                                                 NEWP0090
      FACMUL=-XSTEP/YSTP*.5
```

```
      A10=.15                                                           NEWP0110
      KOUT=1./YSD                                                       AUG 74
      IN=0                                                              NEWP0130
  100 K=2                                                               NEWP0140
      ISGN=1                                                            NEWP0150
C
  110 DO 130 I1=1,2                                                     NEWP0160
      ISGN=-ISGN                                                        NEWP0170
      ZK=K
      H=1.+ZK*YSTP*CURV
      CHMUL=H*FACMUL
      IF(I1.EQ.1)R=CHMUL*    (TANBFU(K)+TANB(K+1))                      NEWP0180
      IF(I1.EQ.2)R=CHMUL*    (TANAFU(K)+TANA(K-1))                      NEWP0190
      R2=R*R                                                            NEWP0200
      UINT=(1.-R2)*   U(K)+.5*((R2-R)*   U(K-1)+(R2+R)*   U(K+1))       NEWP0210
      TINT=(1.-R2)*TAU(K)+.5*((R2-R)*TAU(K-1)+(R2+R)*TAU(K+1))          NEWP0220
      VINT=(1.-R2)*V(K)+.5*((R2-R)*V(K-1)+(R2+R)*V(K+1))
      IF(IN.EQ.1) VINT=(1.-R2)*VOLD(K)+.5*((R2-R)*VOLD(K-1)+(R2+R)*
     1VOLD(K+1))
      IF(K.LT.KOUT) GO TO 120                                           NEWP0230
      IF(UINT.GT.U(I6+1)) UINT=.9999*U(I6+1)
      IF(TINT.LT.0.) TINT=UE206                                         NEWP0250
  120 IF(NSWEEP.GT.0) GO TO 125
      DPDS=(PRESS(K,NCOUNT+1)-PRESS(K,NCOUNT))/XSTEP
      GO TO 128
  125 DELS1=XCAL(NCOUNT+1)-XCAL(NCOUNT)
      DELS2=XCAL(NCOUNT+2)-XCAL(NCOUNT+1)
      DELS=DELS1+DELS2
      DPDS=DELS2/DELS*(PRESS(K,NCOUNT+1)-PRESS(K,NCOUNT))/DELS1+
     1DELS1/DELS*(PRESS(K,NCOUNT+2)-PRESS(K,NCOUNT+1))/DELS2
  128 CONTINUE
      IF(NCOUNT.EQ.1.OR.IN.EQ.1) GO TO 112
      XSTEPO=XCAL(NCOUNT)-XCAL(NCOUNT-1)
      DVDS=(V(K)-VOLD(K))/XSTEPO
      DNSTR=C1*(TAU(K)-TOLD(K))/XSTEPO
      GO TO 115
  112 DVDS=(V(K)-VOLD(K))/XSTEP
      DNSTR=C1*(TFUT(K)-TAU(K))/XSTEP
  115 CONTINUE
      UL=.5*(UINT+UFUT(K))                                              NEWP0270
      TOR=.5*(TINT+TFUT(K))                                             NEWP0280
      VL=.5*(VINT+V(K))
      RR=(ZK+.5*R)*YSD                                                  NEWP0290
      IF(RR.GT.1.44)RR=1.44                                             AUG 74
      D=RM*ORDIN(GA,.05,RR)                                             NEWP0300
      DG=RM*ORDIN(DGA,.05,RR)                                           NEWP0310
      DD=.41*RR                                                         NEWP0330
      RZ=RR-Z01                                                         NEWP0340
      IF(RZ.GT.0.)DD=ORDIN(RLA,.05,RZ)+.41*Z01                          NEWP0350
      TORFAC=(1.+(C1-C2)*VL/UL)*TOR
      STNOR=(C1-C2)*TOR/UL
      T=D+STNOR
      SIGMA=T+SQRT(T*T+2.*TORFAC/A10)*ISGN
      TERM1=TORFAC*(2.*CURV*TOR-UL*VL*CURV-DPDS-DNSTR)
      TERM2=-DVDS-UL*STRAIN+CURV*UL+SQRT(TOR)/(DD*D05)+H*DG/D05+CURV*D
     1+(C1-C2)*(2.*CURV*TOR-DPDS-DNSTR)
      TERM=TERM1+A10*SIGMA*TOR*TERM2
      AL(I1,1)=TORFAC
      AL(I1,2)=-.5*SIGMA
  130 AL(I1,3)=-TORFAC*UINT-AL(I1,2)*TINT-TERM*XSTEP/UL
C
      DET=AL(1,1)*AL(2,2) -AL(2,1)*AL(1,2)                              NEWP0400
      IF(DET.EQ.0.)GO TO 160                                            NEWP0410
      UFUT(K)=(AL(1,2)*AL(2,3)-AL(2,2)*AL(1,3))/DET                     NEWP0420
```

```
      TFUT(K)=(AL(1,3)*AL(2,1)-AL(2,3)*AL(1,1))/DET                     NEWP0430
      IF(IN.EQ.0) GO TO 140                                             NEWP0440
      IF(K.GE.I605) GO TO 205
      K=K+1                                                             NEWP0460
      GO TO 110                                                         NEWP0470
C
  140 IF(K.LT.KOUT) GO TO 150                                           NEWP0480
      UE=SQRT(1.-2.*PRESS(K,NCOUNT+1))
      UEL=.999*UE
      IF((UFUT(K).GT.UE).OR.(UFUT(K).LT.UFUT(K-1)))UFUT(K)=UE          NEWP0490
      IF((TFUT(K).LT.0.).OR.TFUT(K).GT.TFUT(K-1)) TFUT(K)=1.0E-8*UE2    NEWP0500
      IF(NSWEEP.GT.0) GO TO 145
      IF(I6STOP.EQ.0.AND.UFUT(K).GT.UEL.AND.TFUT(K).LT.UE206) I6STOP=K
  145 IF(K.EQ.I6) GO TO 170
  150 K=K+1                                                             NEWP0530
      GO TO 110                                                         NEWP0540
  160 I6=K-1                                                            NEWP0550
      GO TO 180                                                         NEWP0560
  170 I6=K                                                              NEWP0570
  180 RI6=I6                                                            NEWP0580
      IF(NSWEEP.GT.0) GO TO 185
      IF(I6STOP.EQ.0) I6STOP=K
      RNPNEW(NSTART+NCOUNT)=(I6STOP+2)*YSTP*1.1
  185 I61=I6+1
      I62=I6+2                                                          NEWP0600
      UE=SQRT(1.-2.*PE)
C
C
C     NEW V  AND CHC ANGLES NEAR SURFACE                                NEWP0610
      I605=I6/5
      DO 190 J=1,I605
      UOLD(J)=U(J)
      TOLD(J)=TAU(J)
      U(J)=UFUT(J)
      TAU(J)=TFUT(J)
      IF(NCOUNT.EQ.1) GO TO 190
      VOLD(J)=V(J)
  190 CONTINUE
      NCOUNT=NCOUNT+1
      CALL VPRESS(I605,2,NSTNS,NEXPTS,PRESS,PRESSW,XCAL,VEXT)
      NCOUNT=NCOUNT-1
      DO 200 J=1,I605
      UFUT(J)=U(J)
      TFUT(J)=TAU(J)
      U(J)=UOLD(J)
  200 TAU(J)=TOLD(J)
      CALL TANCAL(I605)
C     RECALCULATION FOR K.LT..2*I6 USING INTERPOLATION IN X             NEWP0680
      IN=1                                                              NEWP0690
      GO TO 100                                                         NEWP0700
  205 DO 210 J=1,I605
  210 V(J)=VOLD(J)
      RETURN
      END                                                               NEWP0710


      SUBROUTINE VPRESS(NN,IORIG,NSTNS,NEXPTS,PRESS,PRESSW,XCAL,VEXT)
      DIMENSION PRESS(51,NSTNS),PRESSW(NSTNS),XCAL(NSTNS)
      DIMENSION VEXT(NEXPTS)
C
C.....CALCULATION OF V AND PRESSURE PROFILES.....
```

```
C
      COMMON/INTG/A(6),ALPHA0,CFR,D05,DIV,DELSTA,FUDUDX,H1,SCHMET,TAU0,
     1THETA,UDUDX,UE,UE2,UTAU,VW,X,XSTEP,YSTP,PW,PWALL,PE,PEXT
      COMMON/PROF/TANA(51),TANAFU(51),TANB(51),TANBFU(51),TAU(51),TFUT
     1(51),U(51),UFUT(51),US(51),V(51),I6,I61,I62,RI6,RM,V1
      COMMON/ODDS/I(14),XP(52),CADD,CURV,IDIV,NXP,STRAIN,ROUGH,YSD,Z01
     1,C1,C2
      COMMON/PRESSR/P(51),P0
      COMMON/OLDPRO/UOLD(51),TOLD(51),VOLD(51),POLD(51),POLD0,VOLDER(51)
      COMMON/OLDINT/VWOLD,OLTAU0,CURVOL,PWOLD,PEOLD
      COMMON/COUNTS/NSWEEP,NCOUNT
      COMMON/BVAL/DIVA(51),ROUGHA(51),VWA(51),XCURV(51),CURVA(51)
     1,A2,I5,I10,PA(51)
      COMMON/FIRST/CURV1,USTART(51),TSTART(51)
      COMMON/RELAX/A7
      COMMON/EXT/SSURF(51),RNP
      COMMON/TURBBL/NSTART,NEND
C......N.B. TANA AND US ARE USED AS DUMMY ARRAYS IN THIS SUBROUTINE
C     DOWN TO THE CALL OF TANCAL ONLY--US CONTAINS THE CALCULATED
C     PRESSURE FOR THE CURRENT X-STATION.....
      N=NN
      C1=C2=0.
      OMEGA=A7
      IF(OMEGA.GT.1.) OMEGA=1.
      IF(IORIG.EQ.2) GO TO 105
      NPASS=1
      IF(NCOUNT.GT.1) GO TO 105
      DO 30 J=1,I62
   30 POLD(J)=PRESS(J,1)
      POLD0=PRESSW(1)
C.....CALCULATE FIRST V PROFILE.....
      VOLDER(1)=VOLD(1)=V(1)
      DO 100 J=2,I62
      RJ=J
      HJAV=1.+(RJ-.5)*CURV*YSTP
      IF(NSWEEP.EQ.0) GO TO 50
      DELX=XCAL(2)-XCAL(1)
      DPDX=(PRESS(J,2)-PRESS(J,1))/DELX
      GO TO 60
   50 DPDX=(PRESS(J,2)-PRESS(J,1))/YSTP
   60 CONTINUE
      VOLD(J)=(HJAV*UOLD(J)*VOLD(J-1)-(HJAV+CURV*YSTP)*TOLD(J)
     1+(HJAV-CURV*YSTP)*TOLD(J-1)+DPDX*YSTP)/(HJAV*UOLD(J-1))
  100 V(J)=VOLDER(J)=VOLD(J)
      VEXT(NSTART)=V(I62)
      GO TO 210
C
C.....V CALCULATION FROM EQN. ALONG VERTICAL CHARACTERISTIC.....
  105 V(1)=V1
      YR=CURV*YSTP
      IF(NSWEEP.EQ.0) GO TO 106
      DELS1=XCAL(NCOUNT)-XCAL(NCOUNT-1)
      DELS2=XCAL(NCOUNT+1)-XCAL(NCOUNT)
      DELS=DELS1+DELS2
  106 DO 110 J=2,N
      RJ=J
      HJAV=1.+(RJ-.5)*YR
      TM1=HJAV+YR
      TM2=HJAV-YR
      IF(NSWEEP.GT.0) GO TO 107
      DPDS=(PRESS(J,NCOUNT)-PRESS(J,NCOUNT-1))/XSTEP
      GO TO 108
  107 DPDS=DELS2/DELS*(PRESS(J,NCOUNT)-PRESS(J,NCOUNT-1))/DELS1+
     1DELS1/DELS*(PRESS(J,NCOUNT+1)-PRESS(J,NCOUNT))/DELS2
```

```
  108 DU2DS=C1*(TAU(J)-TOLD(J))
  110 V(J)=(HJAV*U(J)*V(J-1)+YSTP*(DPDS+DU2DS)+TM2*TAU(J-1)-TM1*TAU(J))
     1/(HJAV*U(J-1))
      IF(NCOUNT.LT.3) GO TO 114
      DO 112 J=1,N
  112 V(J)=.25*(VOLDER(J)+VOLD(J))+.5*V(J)
  114 IF(IORIG.EQ.2) RETURN
      IF(NCOUNT.LT.3) GO TO 210
C
C...PRESSURE CALCULATION FROM NORMAL MOMENTUM EQN. (AT PREVIOUS STEP)...
      DELS1=XCAL(NCOUNT-1)-XCAL(NCOUNT-2)
      DELS2=XCAL(NCOUNT)-XCAL(NCOUNT-1)
      DELS=DELS1+DELS2
      LIM=I62
      US(LIM)=PEOLD
  115 DO 117 J=2,LIM
      HJAVOL=1.+(RJ-.5)*CURVOL*YSTP
      DVDS1=DELS2/DELS*(VOLD(J-1)-VOLDER(J-1))/DELS1+
     1DELS1/DELS*(V(J-1)-VOLD(J-1))/DELS2
      DVDS2=DELS2/DELS*(VOLD(J)-VOLDER(J))/DELS1+
     1DELS1/DELS*(V(J)-VOLD(J))/DELS2
      UDVDS=.25*(UOLD(J)+UOLD(J-1))*(DVDS1+DVDS2)
      VDVDN=.5*HJAVOL*(VOLD(J)+VOLD(J-1))*(VOLD(J)-VOLD(J-1))/YSTP
      U2CURV=.25*CURVOL*(UOLD(J)+UOLD(J-1))*(UOLD(J)+UOLD(J-1))
      TAU1=.5*TAU(J)/XSTEP+TOLD(J)*(-C2*HJAVOL/YSTP+.5*CURVOL*(C1-C2))
      TAU2=.5*TAU(J-1)/XSTEP+TOLD(J-1)*(C2*HJAVOL/YSTP+.5*CURVOL*(C1-C2)
     1)
      TAU3=-.5*(TOLD(J)+TOLD(J-1))/XSTEP
  117 TANA(J)=(-UDVDS-VDVDN+U2CURV+TAU1+TAU2+TAU3)/HJAVOL*YSTP
C
C.....CALCULATE DELPW--THE DIFFERENCE BETWEEN THE WALL PRESSURE AND THE
C     PRESSURE AT THE FIRST MESH POINT.....
      IF(I(12).EQ.0) VWOLD=VW=0.
      ACCEL=5./6.*YSTP*(U(1)*VW-UOLD(1)*VWOLD)/XSTEP
     1+(1.+CURVOL*YSTP)*VOLD(1)*VOLD(1)-VWOLD*VWOLD
      CENTRF=-5./7.*YSTP*CURVOL*UOLD(1)*UOLD(1)
      SHEAR=-.5*YSTP*(TAU(1)+TAUO-TOLD(1)-OLTAUO)/XSTEP
      RNORM=-TOLD(1)*(-C2+(.5*C1-C2)*CURVOL*YSTP)-OLTAUO*(C2+.5*C1*
     1CURVOL*YSTP)
      DELPW=(ACCEL+CENTRF+SHEAR+RNORM)/(1.+.5*CURVOL*YSTP)
C
C.....EXTERNAL PRESSURE GIVEN AS BOUNDARY VALUE.....
      DO 120 JJ=2,LIM
      J=LIM-JJ+2
  120 US(J-1)=US(J)-TANA(J)
      IF(NPASS.NE.1) GO TO 150
      POLDO=PRESSW(NCOUNT-1)
      PWCALC=US(1)+DELPW
      PRESSW(NCOUNT-1)=OMEGA*PWCALC+(1.-OMEGA)*PRESSW(NCOUNT-1)
      DO 130 J=1,LIM-1
      POLD(J)=PRESS(J,NCOUNT-1)
  130 PRESS(J,NCOUNT-1)=OMEGA*US(J)+(1.-OMEGA)*PRESS(J,NCOUNT-1)
      IF(NCOUNT.LT.I(4)) GO TO 210
C
C.....CALCULATE PRESSURE AT CURRENT STN., ONLY IF IT IS THE STATION
C     BEFORE LAST.....
      DO 140 J=1,I62
      VOLDER(J)=VOLD(J)
      VOLD(J)=V(J)
  140 UOLD(J)=U(J)
      CURVOL=CURV
      VWOLD=VW
      NPASS=2
      LIM=I62
```

```
      US(LIM)=PE
      GO TO 115
  150 PWCALC=US(1)+DELPW
      PO=OMEGA*PWCALC+(1.-OMEGA)*PRESSW(NCOUNT)
      DO 160 J=1,LIM-1
  160 P(J)=OMEGA*US(J)+(1.-OMEGA)*PRESS(J,NCOUNT)
      P(LIM)=PE
C
C.....CALCULATE CHARACTERISTIC ANGLES.....
  210 CALL TANCAL(I62)
      DO 220 J=1,I62
      TANA(J)=TANAFU(J)
  220 TANB(J)=TANBFU(J)
      RETURN
      END
```

```
      SUBROUTINE PRINIT(PR,NPROF,PRW,PRE,CURV,YSTP,VEL,IOPT)
C.....THIS SUBROUTINE FILLS UP A PRESSURE LIST USING DPDY=RHO*U**2/R
C.....WHERE U MAY BE A CONSTANT VELOCITY.....
      DIMENSION PR(51),VEL(51)
      NP=NPROF
C.....EXTERNAL PRESSURE GIVEN AS BOUNDARY VALUE.....
      IF(IOPT.EQ.1) GO TO 50
      DO 30 J=1,NP
   30 VEL(J)=SQRT(1.-2.*PRE)
   50 PR(NP)=PRE
      DO 200 J=1,NP-1
      JJ=NP+1-J
      RJJ=JJ
      HJAV=1.+(RJJ-.5)*CURV*YSTP
  200 PR(JJ-1)=PR(JJ)-.25*YSTP*CURV*(VEL(JJ)+VEL(JJ-1))**2/HJAV
      PRW=PR(1)-5./7.*VEL(1)*VEL(1)*CURV*YSTP*(1.-7./12.*CURV*YSTP)
      RETURN
      END
```

```
      SUBROUTINE CFL                                                    CFL 0000
      COMMON/INTG/A(6),ALPHAO,CFR,DO5,DIV,DELSTA,FUOUDX,H1,SCHMET,TAUO, CFL 0010
     1THETA,UOUDX,UE,UE2,UTAU,VW,X,XSTEP,YSTP,PW,PWALL,PE,PEXT
      COMMON/ODDS/I(14),XP(52),CADD,CURV,IDIV,NXP,STRAIN,ROUGH,YSD,Z01
     1,C1,C2
      COMMON/PROF/TANA(51),TANAFU(51),TANB(51),TANBFU(51),TAU(51),TFUT  CFL 0040
     1(51),U(51),UFUT(51),US(51),V(51),I6,I61,I62,RI6,RM,V1             CFL 0050
C
C.....C-F-L CRITERION MODIFIED BY CURVATURE FACTOR.....
C
      RMAX=0.                                                           CFL 0060
      DO 100 J=1,I6                                                     CFL 0070
      IF(RMAX.LT.TANA(J))RMAX=TANA(J)                                   CFL 0080
  100 IF(RMAX.LT.-TANB(J))RMAX=-TANB(J)                                 CFL 0090
C     1.0 IS MAX PERMISSIBLE FACTOR                                     CFL 0100
      FAC=1.+DO5*CURV
      XSTEP=.9*YSTP/(RMAX*FAC)
      RETURN                                                            CFL 0150
      END                                                               CFL 0160
```

```
      FUNCTION F(ZZ)
      Z=ZZ
      F=1./Z/Z
      IF(Z.GT.0.) GO TO 100
      F=F-.64*F/(ABS(Z)**(.59))
      RETURN
  100 RLIM=10.
      IF(ABS(Z).GT.RLIM) RETURN
      IF(Z.LT.3.2) 120,110
  110 F=F*(1.+1.5*EXP(-Z/6.))
      RETURN
  120 IF(Z.GT.1.)130,140
  130 F=F*(Z-1.35)
      RETURN
  140 F=(.577216+ALOG(Z)+Z+(Z*Z )/4.)*EXP(-Z)-1./Z
      RETURN
      END
```

```
      FUNCTION GRAD(FR,H,IA,IB,N)
      DIMENSION FR(51)
C
C.....THE GRADIENT OF A FUNCTION DEFINED AT EQUAL INTERVALS.....
C
      IF(N-IA)110,100,110
  100 G=(    -FR(IA+2)+4.*FR(IA+1)-3.*FR(IA))/(2.*H)
      GO TO 140
  110 IF(N-IB)130,120,130
  120 G=(3.*FR(IB)-4.*FR(IB-1)+FR(IB-2))/(2.*H)
      GO TO 140
  130 G=(FR(N+1)-FR(N-1))/(2.*H)
  140 GRAD=G
      RETURN
      END
```

```
      SUBROUTINE INTGEQ(NSTNS,PRESS,PRESSW,XCAL)
      DIMENSION PRESS(51,NSTNS),PRESSW(NSTNS),XCAL(NSTNS)
      COMMON/INTG/A(6),ALPHA0,CFR,DD5,DIV,DELSTA,FUDUDX,H1,SCHMET,TAU0,
     1THETA,UDUDX,UE,UE2,UTAU,VW,X,XSTEP,YSTP,PW,PWALL,PE,PEXT
      COMMON/PROF/TANA(51),TANAFU(51),TANB(51),TANBFU(51),TAU(51),TFUT
     1(51),U(51),UFUT(51),US(51),V(51),I6,I61,I62,RI6,RM,V1
      COMMON/PRESSR/P(51),P0
      COMMON/ODDS/I(14),XP(52),CADD,CURV,IDIV,NXP,STRAIN,ROUGH,YS0,Z01
     1,C1,C2
      COMMON/COUNTS/NSWEEP,NCOUNT
      COMMON/OLDPRO/UOLD(51),TOLD(51),VOLD(51),POLD(51),POLDD,VOLDER(51)
C
C.....SOLUTION OF S-COMPONENT MOMENTUM INTEGRAL EQUATION.....
C
      I6OLD=I6
      I6=I62
      DO 100 J=1,I6
  100 US(J)=U(J)* U(J)
      DELTA=I6*YSTP
```

```
      DELSTA=FLOAT(I6)-(-46./A(4)/YSTP+U(1)-UTAU/.41+SIMPSN(U,1,I6,1.))
     1/UE
      THETA=FLOAT(I6)-DELSTA-(-687.*UTAU/A(4)/YSTP+US(1)
     1-2.*U(1)*UTAU/.41+2.*TAUO/.168+SIMPSN(US,1,I6,1.))/UE2
      DELSTA=DELSTA*YSTP
      THETA=THETA*YSTP
      H1=DELSTA/THETA
      RINT1=5.*(1./6.-CURV*YSTP/11.)
      RINT3=5.*(1./12.-CURV*YSTP/17.)
      DO 105 J=1,I6
  105 US(J)=U(J)*V(J)
C
C.....FIRST X-STATION.....
      IF(X.GT.A(3)) GO TO 110
      CUV=U(1)*VW*YSTP*RINT1-5./6.*DIV*U(1)*U(1)*YSTP*YSTP*RINT3
     1+SIMPSN(US,1,I6,1.)*YSTP
      DELS=YSTP
      IF(NSWEEP.GT.0) DELS=XCAL(2)-XCAL(1)
      DO 107 J=1,I6
  107 US(J)=(PRESS(J,2)-PRESS(J,1))/DELS
      PRW=(PRESSW(2)-PRESSW(1))/DELS
      CPOLD=.5*YSTP*(PRW+US(1))+YSTP*SIMPSN(US,1,I6,1.)
      CTAU=.5*(TAUO+TAU(1))*YSTP+SIMPSN(TAU,1,I6,1.)*YSTP
      TERM1=TAUO+(DELTA-DELSTA)*FUDUDX+CURV*(CUV-CTAU)-DIV*UE2*THETA
     1+VW*UE+CPOLD
      THUS=THETA*UE2
      SCHMET=THETA
      CU2OLD=C1*CTAU
      I6=I6OLD
      RETURN
C
C.....AFTER FIRST X-STATION.....
C
  110 CUV=U(1)*VW*YSTP*RINT1-5./6.*(.5*(U(1)*U(1)-UOLD(1)*UOLD(1))/XSTEP
     1+U(1)*U(1)*DIV)*YSTP*YSTP*RINT3+SIMPSN(US,1,I6,1.)*YSTP
      IF(NSWEEP.GT.0) GO TO 115
      DELS=XCAL(NCOUNT)-XCAL(NCOUNT-1)
      DO 113 K=1,I6
  113 US(K)=(PRESS(K,NCOUNT)-POLD(K))/DELS
      PRW=(PRESSW(NCOUNT)-POLDO)/DELS
      GO TO 118
  115 DELS1=XCAL(NCOUNT)-XCAL(NCOUNT-1)
      DELS2=XCAL(NCOUNT+1)-XCAL(NCOUNT)
      DELS=DELS1+DELS2
      DO 117 J=1,I6
  117 US(J)=DELS2/DELS*(PRESS(J,NCOUNT)-POLD(J))/DELS1+
     1DELS1/DELS*(PRESS(J,NCOUNT+1)-PRESS(J,NCOUNT))/DELS2
      PRW=DELS2/DELS*(PRESSW(NCOUNT)-POLDO)/DELS1+
     1DELS1/DELS*(PRESSW(NCOUNT+1)-PRESSW(NCOUNT))/DELS2
  118 CP=.5*YSTP*(PRW+US(1))+YSTP*SIMPSN(US,1,I6,1.)
      PINT=.5*YSTP*(PRESSW(NCOUNT)+PRESS(1,NCOUNT))
     1+YSTP*SIMPSN(PRESS(1,NCOUNT),1,I6,1.)
      CTAU=.5*(TAUO+TAU(1))*YSTP+SIMPSN(TAU,1,I6,1.)*YSTP
      CU2=C1*CTAU
      TERM2=TAUO+(DELTA-DELSTA)*FUDUDX+CURV*(CUV-CTAU)-DIV*UE2*THETA
     1+VW*UE+CP
      THUS=THUS+.5*XSTEP*(TERM1+TERM2)+CU2-CU2OLD
      SCHMET=THUS/UE2
      TERM1=TERM2
      CU2OLD=CU2
      I6=I6OLD
      RETURN
      END
```

```
      FUNCTION ORDIN(FA,DX,X)
C.....INTERPOLATION OF A FUNCTION DEFINED AT EQUAL INTERVALS--
C     LINEAR IF DX.GT.0 , PARABOLIC IF DX.LT.0 .....
      DIMENSION FA(51)
      XDX=ABS(X/DX)
      J=XDX-.0001
      IF(DX.LT.0.) GO TO 100
      R=XDX-J
      ORDIN=(1.-R)*FA(J+1)+R*FA(J+2)
      RETURN
 100  IF(J.GT.0) GO TO 110
      R=1.-XDX
      ORDIN=(1.-R*R)*FA(2)+.5*R*((R-1.)*FA(3)+(R+1.)*FA(1))
      RETURN
  110 R=XDX-J
      ORDIN=(1.-R*R)*FA(J+1)+.5*R*((R-1.)*FA(J)+(R+1.)*FA(J+2))
      RETURN
      END
```

```
      FUNCTION PHI(ZZ)
      Z=ZZ
      IF(ABS(Z).GT..1) GO TO 100
      PHI=Z*(.5-.0625*Z)
      RETURN
  100 R=SQRT(1.+Z)
      PHI=ALOG(4.*(R-1.)/(Z*(R+1.)))+2.*(R-1.)
      RETURN
      END
```

```
      SUBROUTINE PRINT
      COMMON/INTG/A(6),ALPHAO,CFR,D05,DIV,DELSTA,FUDUDX,H1,SCHMET,TAUO,
     1THETA,UDUDX,UE,UE2,UTAU,VW,X,XSTEP,YSTP,PW,PWALL,PE,PEXT
      COMMON/ODDS/I(14),XP(52),CADD,CURV,IDIV,NXP,STRAIN,ROUGH,YSD,Z01
     1,C1,C2
      COMMON/PROF/TANA(51),TANAFU(51),TANB(51),TANBFU(51),TAU(51),TFUT
     1(51),U(51),UFUT(51),US(51),V(51),I6,I61,I62,RI6,RM,V1
      COMMON/PRESSR/P(51),PO
      COMMON/COUNTS/NSWEEP,NCOUNT
C
C.....THIS SUBROUTINE PRINTS OUT THE INTEGRAL PARAMETERS AND PROFILES...
C
C.....PRINT OUT INTEGRAL PARAMETERS.....
      WRITE(6,100)
  100 FORMAT(1H0,'STN.',10X,'X',6X,'YSTEP',8X,'CF',7X,'  UE',4X,'DEL05',
     16X,'THETA',4X,'SCHMETA',10X,'H',5X,'RTHETA',5X,'I6')
      RTHETA=THETA*UE*A(4)
      CFR=2.*TAUO/UE2
      WRITE(6,110) NCOUNT,X,YSTP,CFR,UE,D05,THETA,SCHMET,H1,RTHETA,I6
  110 FORMAT(1H ,I4,2E11.4,F11.6,4E11.4,F11.5,E11.4,I7)
      IF(I(8)+I(9)+IDIV+I(12).EQ.0) GO TO 140
      RD05=ROUGH/D05
      CUD05=CURV*D05
```

```
      DIDO5=DIV*DO5                                                     PRIN0150
      STDO5=STRAIN*DO5                                                  PRIN0160
      VWUE=VW/UE                                                        PRIN0170
      WRITE(6,120)
  120 FORMAT(1HO,1X,'ROUGH/DO5',4X,'DO5/RAD',' DO5/(X-XO)',' STRAIN.DO5'
     1,6X,'VW/UE')
      WRITE(6,130) RDO5,CUDO5,DIDO5,STDO5,VWUE
  130 FORMAT(1H 5E11.4)
C
C.....PRINT OUT U,TAU,V AND CHC. ANGLE PROFILES.....
  140 IF(X.GE.A(3).AND.I(1).LT.0) RETURN
      WRITE(6,150)                                                      PRIN0240
  150 FORMAT(1HO57HY/YSTEP U/UE     TAU/UE**2    V/UE         TANA      PRIN0250
     1TANB)                                                             PRIN0260
      IALF=(I62+1)/2
      I62ODD=I62-(I62/2)*2
C.....VALUES UP TO I62 ARE PRINTED.....
      DO 160 J=1,IALF                                                   PRIN0290
      UK=U(J)/UE                                                        PRIN0300
      TAUK2=TAU(J)/UE2                                                  PRIN0310
      VK=V(J)/UE                                                        PRIN0320
      K=J
      IF(J.EQ.IALF.AND.I62ODD.EQ.1) GO TO 175
      JJ=J+IALF                                                         PRIN0330
      UK1=U(JJ)/UE                                                      PRIN0340
      TK1=TAU(JJ)/UE2                                                   PRIN0350
      VK1=V(JJ)/UE                                                      PRIN0360
  160 WRITE(6,170)J,UK    ,TAUK2    ,VK           ,TANA(J),TANB(J)      PRIN0370
     1,JJ,UK1,TK1,VK1,TANA(JJ),TANB(JJ)                                 PRIN0380
  170 FORMAT(1H 3H    I3,F8.4,3E12.4,E13.4,3X,I3,F8.4,3E12.4,E13.4)     PRIN0390
      GO TO 178
  175 WRITE(6,170) K,UK,TAUK2,VK,TANA(K),TANB(K)
  178 WRITE(6,180)
  180 FORMAT(1HO)                                                       PRIN0410
      RETURN                                                            PRIN0420
      END                                                               PRIN0430


      SUBROUTINE ROUGHC                                                 ROUG0000
      COMMON/INTG/A(6),ALPHAO,CFR,DO5,DIV,DELSTA,FUDUDX,H1,SCHMET,TAUO, ROUG0010
     1THETA,UDUDX,UE,UE2,UTAU,VW,X,XSTEP,YSTP,PW,PWALL,PE,PEXT
      COMMON/ODDS/I(14),XP(52),CADD,CURV,IDIV,NXP,STRAIN,ROUGH,YSD,ZO1
     1,C1,C2
      C=ALOG(UTAU*A(4)*ROUGH)                                           ROUG0060
C     SAND ROUGHNESS IF ROUGH POSITIVE, ZO IF NEGATIVE                  ROUG0040
      IF(ROUGH.LT.0.) GO TO 130                                         ROUG0050
      B=8.5                                                             ROUG0070
      IF(C-4.22)100,120,120                                             ROUG0080
  100 B=11.7-.76*C                                                      ROUG0090
      IF(C-2.77)110,120,120                                             ROUG0100
  110 B=9.6                                                             ROUG0110
  120 CADD=B-C/.41                                                      ROUG0120
      RETURN                                                            ROUG0130
  130 CADD=-ALOG(UTAU*A(4)*(-ROUGH))/.41                                ROUG0140
      IF(CADD.GT.5.2)CADD=5.2                                           ROUG0150
C     ADDITIVE CONSTANT CADD IS OVERWRITTEN IN WALLBC IF VW.NE.0.       ROUG0160
      RETURN                                                            ROUG0170
      END                                                               ROUG0180
```

```
      FUNCTION SIMPSN (FR,IB,M,H)
      DIMENSION FR(51)
C.....SIMPSONS RULE INTEGRATION WITH EQUAL INTERVALS.....
      N=M
      IA=IB
      N1=N-1
      IF((N-IA).NE.2*((N-IA)/2)) GO TO 110
      S=0.
      DO 100 I=IA,N1,2
  100 S=S+FR(I)+4.*FR(I+1)+FR(I+2)
      GO TO 130
  110 S=  (5.*FR(IA)+8.*FR(IA+1)-FR(IA+2))/4.
      IA1=IA+1
      DO 120 I=IA1,N1,2
  120 S=S+FR(I)+4.*FR(I+1)+FR(I+2)
  130 SIMPSN=S*H/3.
      RETURN
      END
```

```
      FUNCTION SPLINE(X,Y,M,XINT)
      DIMENSION X(M),Y(M),W(51),D(51)
C.....CUBIC SPLINE INTERPOLATION.....
      N=M-1
      CALL E01ADF(N,XINT,X,Y,W,D,M,VAL)
      SPLINE=VAL
      RETURN
      END
```

```
      SUBROUTINE TANCAL(JJ)
      COMMON/FUNC/DGA(30),GA(30),RLA(30)
      COMMON/ODDS/I(14),XP(52),CADD,CURV,IDIV,NXP,STRAIN,ROUGH,YSD,ZO1
     1,C1,C2
      COMMON/PROF/TANA(51),TANAFU(51),TANB(51),TANBFU(51),TAU(51),TFUT
     1(51),U(51),UFUT(51),US(51),V(51),I6,I61,I62,RI6,RM,V1
      COMMON/INTG/A(6),ALPHAO,CFR,DO5,DIV,DELSTA,FUDUDX,H1,SCHMET,TAUO,
     1THETA,UDUDX,UE,UE2,UTAU,VW,X,XSTEP,YSTP,PW,PWALL,PE,PEXT
C
C.....CALCULATION OF CHARACTERISTIC ANGLES.....
C
      JMAX=JJ
      DO 100 J=1,JMAX
      Z=J*YSD
      IF(Z.GT.1.44)Z=1.44                                               AUG 74
      D=RM*.15*ORDIN(GA,.05,Z)
      RJ=J
      H=1.+RJ*YSTP*CURV
      T1=D+.15*(C1-C2)*TFUT(J)/UFUT(J)
      P1=H*(V(J)+T1)/UFUT(J)
      T2=.3*(C1-C2)*V(J)*TFUT(J)/UFUT(J)
      P2=H*SQRT(T1*T1+T2+.3*TFUT(J))/UFUT(J)
      TANAFU(J)=P1+P2
  100 TANBFU(J)=P1-P2
      RETURN
      END
```

```
      FUNCTION VALUE(X,Y,N,XINT,IOPT)
      DIMENSION X(N),Y(N)
      DO 2 J=1,N
      K=J
      IF((XINT-X(J)).LE.0.) GO TO 5
    2 CONTINUE
    5 IF(K.EQ.1) K=2
      IF(K.EQ.N.AND.IOPT.EQ.2) K=N-1
      XX1=XINT-X(K-1)
      XX2=XINT-X(K)
      DX1=X(K)-X(K-1)
      GO TO (10,20),IOPT
C.....LINEAR INTERPOLATION.....
   10 VALUE=(-Y(K-1)*XX2+Y(K)*XX1)/DX1
      RETURN
C.....LAGRANGIAN QUADRATIC INTERPOLATION.....
   20 XX3=XINT-X(K+1)
      DX2=X(K+1)-X(K)
      DX=DX1+DX2
      VALUE=Y(K-1)*XX2*XX3/(DX*DX1)-Y(K)*XX1*XX3/(DX1*DX2)
     1+Y(K+1)*XX1*XX2/(DX*DX2)
      RETURN
      END
```

```
      SUBROUTINE WALLBC(NSTNS,PRESS,PRESSW,XCAL)
      DIMENSION PRESS(51,NSTNS),PRESSW(NSTNS),XCAL(NSTNS)
      COMMON/ODDS/I(14),XP(52),CADD,CURV,IDIV,NXP,STRAIN,ROUGH,YSD,ZO1
     1,C1,C2
      COMMON/INTG/A(6),ALPHAO,CFR,DO5,DIV,DELSTA,FUDUDX,H1,SCHMET,TAUO, WALL0020
     1THETA,UDUDX,UE,UE2,UTAU,VW,X,XSTEP,YSTP,PW,PWALL,PE,PEXT
      COMMON/PROF/TANA(51),TANAFU(51),TANB(51),TANBFU(51),TAU(51),TFUT  WALL0040
     1(51),U(51),UFUT(51),US(51),V(51),I6,I61,I62,RI6,RM,V1             WALL0050
      COMMON/OLDINT/VWOLD,OLTAUO,CURVOL,PWOLD,PEOLD
      COMMON/COUNTS/NSWEEP,NCOUNT
      COMMON/OLDPRO/UOLD(51),TOLD(51),VOLD(51),POLD(51),POLDO,VOLDER(51)
      COMMON/PRESSR/P(51),PO
C
C.....THIS SUBROUTINE CALCULATES UFUT(1),TFUT(1),TAUO AND V(1) (I.E. AT
C     FIRST MESH POINT) FROM GIVEN WALL BOUNDARY CONDITIONS.....
C
      UFAC=(U(2)-U(1))*1.443                                            WALL0060
      V1=V(1)
      A10=0.15
      H=-(1.+YSTP*CURVOL)*XSTEP*TANB(1)/YSTP
      TORO=.5*TAU(1)                                                    WALL0090
      TOR=TAU(2)*H+TAU(1)*(1.-H)                                        WALL0100
      UINT=U(1)+UFAC*ALOG(1.+H)                                         WALL0110
      VINT=H*V(2)+(1.-H)*V(1)
      TINT=TOR                                                          WALL0120
      UL=U(1)+UFAC*ALOG(1.+.5*H)                                        WALL0130
      VL=.5*(VINT+V(1))
      DTW=TAUO                                                          WALL0140
      C=UTAU                                                            WALL0160
      NIT=0                                                             WALL0170
      RINT1=5.*(1./6.-CURV*YSTP/11.)
```

```
      RINT2=5.*(1./12.-CURV*YSTP/17.)
      IF(NSWEEP.GT.0) GO TO 10
      DPDS=(PRESS(1,NCOUNT+1)-PRESS(1,NCOUNT))/XSTEP
      DPINT=.5*(PRESS(1,NCOUNT+1)+PRESSW(NCOUNT+1)-PRESS(1,NCOUNT)
     1-PRESSW(NCOUNT))/XSTEP
      GO TO 20
   10 DELS1=XCAL(NCOUNT+1)-XCAL(NCOUNT)
      DELS2=XCAL(NCOUNT+2)-XCAL(NCOUNT+1)
      DELS=DELS1+DELS2
      DPDS=DELS2/DELS*(PRESS(1,NCOUNT+1)-PRESS(1,NCOUNT))/DELS1+
     1DELS1/DELS*(PRESS(1,NCOUNT+2)-PRESS(1,NCOUNT+1))/DELS2
      DPWDS=DELS2/DELS*(PRESSW(NCOUNT+1)-PRESSW(NCOUNT))/DELS1+
     1DELS1/DELS*(PRESSW(NCOUNT+2)-PRESSW(NCOUNT+1))/DELS2
      DPINT=.5*(DPDS+DPWDS)
C
C.....THIS BLOCK IS EXECUTED FOR BOTH VW=0 AND VW NOT EQUAL TO 0.....
   20 IF(NCOUNT.EQ.1.OR.NIT.GT.1) GO TO 30
      XSTEPO=XCAL(NCOUNT)-XCAL(NCOUNT-1)
      DU2DS=C1*(TAU(1)-TOLD(1))/XSTEPO
      DVDS=(V(1)-VOLD(1))/XSTEPO
      DU2INT=.5*C1*(TAUO+TAU(1)-OLTAUO-TOLD(1))/XSTEPO
      GO TO 40
   30 DU2DS=C1*(TFUT(1)-TAU(1))/XSTEP
      DVDS=(V1-V(1))/XSTEP
      DU2INT=.5*C1*(TAUO+TFUT(1)-OLTAUO-TAU(1))/XSTEP
   40 FACTOR=TOR*(1.+(C1-C2)*VL/UL)
      ALPHA=A10*(C1-C2)*TOR/UL
      BETA=SQRT(ALPHA*ALPHA+2.*A10*FACTOR)
      BDASH=ALPHA-BETA
      B=-2.*A10*FACTOR/BDASH
      TERM1=FACTOR*(2.*CURV*TOR-CURV*UL*VL-DPDS-DU2DS)
      TERM2=TOR*(-DVDS-STRAIN*UINT+CURV*UL+SQRT(TOR)/(.41*(1.+.5*H)*YSTP
     1)+(C1-C2)*(2.*CURV*TOR-DPDS-DU2DS))
      IF(VW.NE.0.) GO TO 120
C
C     BOUNDARY CONDITION FOR SOLID SURFACE                              WALL0190
  100 TTW=ALPHAO*YSTP/TAUO                                              WALL0200
      NIT=NIT+1                                                         WALL0210
      F1=UFUT(1)-C*((ALOG(YSTP*A(4)*C)+PHI(TTW))/.41+CADD)              WALL0220
     1/(1.+5./6.*YSTP*STRAIN)                                           WALL0230
      F2=TAUO+ALPHAO*YSTP-TINT+B*(UFUT(1)-UINT)+2.*A10*(TERM1/BDASH
     1+TERM2)*XSTEP/UL
      F3=5./12.*(UFUT(1)*UFUT(1)-U(1)*U(1))*(5./7.-CURV*YSTP*RINT2)/
     1XSTEP+DPINT+DU2INT-(1.+CURV*YSTP)*ALPHAO-2.*CURV*TAUO
      IF(ABS(DTW/TAUO).LT..05) GO TO 110                                WALL0280
      TFAC=TAUO*(1.+SQRT(1.+TTW))                                       WALL0290
      DF1DTW=-.5*UFUT(1)/TAUO-2.5*(.5/C-ALPHAO*YSTP/(C*TFAC))           WALL0300
      DF1DA=-C*2.5*YSTP/TFAC                                            WALL0310
      DF3DU=5./6.*UFUT(1)*(5./7.-CURV*YSTP*RINT2)/XSTEP
      DF3DA=-(1.+CURV*YSTP)
      DF3DTW=-2.*CURV
  110 DET=DF1DTW*(B*DF3DA-YSTP*DF3DU)-DF1DA*(B*DF3DTW-DF3DU)
     1+DF3DTW*YSTP-DF3DA
      DETDU=-F1*(YSTP*DF3DTW-DF3DA)+F2*(DF1DA*DF3DTW-DF3DA*DF1DTW)
     1-F3*(DF1DA-YSTP*DF1DTW)
      DU=DETDU/DET
      DA=(F3-F2*DF3DTW+(DF3DU-B*DF3DTW)*DU)/(YSTP*DF3DTW-DF3DA)
      DTW=-YSTP*DA-F2-DU*B                                              WALL0360
      UFUT(1)=UFUT(1)+DU                                                WALL0370
      TAUO=TAUO+DTW                                                     WALL0380
      IF(TAUO.LT.0.) GO TO 160                                          WALL0390
      C=SQRT(TAUO)                                                      WALL0400
      ALPHAO=ALPHAO+DA                                                  WALL0410
      IF(ABS(DA/ALPHAO).GT..01) GO TO 100                               WALL0420
```

```
      IF (ABS (DTW/TAUO) .GT..01)  GO TO 100
      IF (ABS (DU/UFUT (1)) .GT..01)  GO TO 100
      TFUT (1) =TAUO+ALPHAO*YSTP
      GO TO 140
C
C     BOUNDARY CONDITION FOR POROUS SURFACE
C     DATA FIT FOR  MODERATE SUCTION/INJECTION (SIMPSON/COLES)
  120 CADD=5.2+ (2.*C/VW) * (SQRT (1.+10.8*VW/C) -1.) -10.8
      NIT=NIT+1
      AN=25./84.* (UFUT (1) *UFUT (1) -U (1) *U (1)) /XSTEP+DPINT
      D=ALOG (A (4) *YSTP*C)  +CADD*.41
      ZF=D+.82*C/VW
      E=F (ZF)
      TFAC= (1.+1.5*CURV*YSTP) *TFUT (1) -5./12.*YSTP* (UFUT (1) **2-U (1) **2)
     1* (5./7.-CURV*YSTP*RINT2) /XSTEP-YSTP* (DPINT+DU2INT) +.5*CURV*YSTP
     1*TAUO-CURV*YSTP*RINT1*VW*UFUT (1)
     1-CURV*YSTP*RINT1*VW*UFUT (1)
      IF (TFAC.LT.0.)  GO TO 160
      RTFAC=SQRT (TFAC)
      F1=RTFAC-VW/.82*D-C-.41*AN*YSTP/VW*E
      F2=TFUT (1) -TINT+B* (UFUT (1) -UINT) +2.*A10* (TERM1/BDASH+TERM2) *XSTEP
     1/UL
      F3=TFAC-TAUO-UFUT (1) *VW
      IF (ABS (DTW/TAUO) .LT..05)  GO TO 130
      DF1DU=-.5*YSTP* (CURV*RINT1*VW+5./6.*UFUT (1) * (5./7.-CURV*YSTP
     1*RINT2) /XSTEP) /RTFAC-25./42.*UFUT (1) *YSTP*.41*E/ (XSTEP*VW)
      DF1DT= (1.+1.5*CURV*YSTP) /RTFAC
      DF1DTW=-VW/ (1.6*TAUO) -.5/C-.4*AN*YSTP/VW* (1./ZF**2-E) * (.5/TAUO+
     1.4/VW/C) +.25*CURV*YSTP/RTFAC
      DF3DU=- (1.+CURV*YSTP*RINT1) *VW-5./6.*UFUT (1)
     1* (5./7.-CURV*YSTP*RINT2) /XSTEP*YSTP
      DF3DT= (1.+1.5*CURV*YSTP)
      DF3DTW=- (1.-.5*CURV*YSTP)
  130 DET=B* (DF1DTW*DF3DT-DF3DTW*DF1DT) +DF3DTW*DF1DU-DF3DU*DF1DTW
     1-0.05*VW/ABS (VW) /NIT
      DETDT=F2* (DF3DU*DF1DTW-DF3DTW*DF1DU) +B* (F1*DF3DTW-F3*DF1DTW)
      DT=DETDT/DET
      DU=- (F2+DT) /B
      DTW=- (F3+DF3DU*DU+DF3DT*DT) /DF3DTW
      UFUT (1) =UFUT (1) +DU
      TAUO=TAUO+DTW
      IF (TAUO.LT.0.)  GO TO 160
      C=SQRT (TAUO)
      TFUT (1) =TFUT (1) +DT
      IF (ABS (DT/TFUT (1)) .GT..01)  GO TO 120
      IF (ABS (DTW/TAUO) .GT..01)  GO TO 120
      IF (ABS (DU/UFUT (1)) .GT..01)  GO TO 120
C     END OF BOUNDARY CONDITION FOR POROUS SURFACE.  REPLACE BLOCK BY
C***  '120 CONTINUE' IF NOT REQUIRED, AND REMOVE FUNCTION F (Z)
  140 IF (ABS ((TFUT (1) -TORO) /TORO) .GT..01) GO TO 150
      UTAU=C
      RETURN
C
C.....CALCULATION OF V AT FIRST MESH POINT (V1).....
  150 V1=VW-.5*UFUT (1) *YSTP* (TAUO/OLTAUO-1.) /XSTEP
     1-DIV*YSTP* (UFUT (1) -C/.41)
      V1=V1/ (1.+CURV*YSTP)
      FACT1=A10* (C1-C2) *TFUT (1) /UFUT (1)
      FACT2=2.*A10* (1.+ (C1-C2) *V1/UFUT (1)) *TFUT (1)
      TANNEW= (V1+FACT1-SQRT (FACT1*FACT1+FACT2)) /UFUT (1)
      H=- (1.+CURV*YSTP) *XSTEP*TANNEW/YSTP
      UINT=U (1) +UFAC*ALOG (1.+H)
      TINT=TAU (2) *H+TAU (1) * (1.-H)
      VINT=H*V (2) + (1.-H) *V (1)
```

```
      UL=UFUT(1)+(U(2)-UFUT(1))*ALOG(1.+.5*H)*1.443                     WALL0900
      TOR=.5*(TINT+TFUT(1))                                             WALL0910
      VL=.5*(VINT+V1)
      TORO=TFUT(1)                                                      WALL0920
      IF(TORO.LT.0.) GO TO 160                                          WALL0930
      GO TO 20
  160 TAUO=0.                                                           WALL0960
      RETURN                                                            WALL0970
      END                                                               WALL0980


      BLOCK DATA
      COMMON/FUNC/DGA(30),GA(30),RLA(30)
      DATA DGA/
     1 0.29, 2.37, 4.28, 6.04, 7.67, 9.24,10.78,12.38,14.19;16.50,
     119.90,25.77,37.30,59.89,89.05,99.84,96.95,73.63,47.22,32.84,
     126.20,23.05,21.47,20.65,20.21,19.97,19.85,19.80,19.79,19.80/,
     1GA/
     1 0.00, 0.07, 0.24, 0.51, 0.88, 1.33, 1.86, 2.48, 3.18, 3.96,
     1 4.82, 5.76, 6.77, 9.33,13.88,18.42,22.97,27.51,31.68,32.62,
     133.55,34.48,35.42,36.36,37.29,38.22,39.16,40.09,41.03,41.96/,
     1RLA/
     10.0000,0.0200,0.0400,0.0600,0.0752,0.0812,0.0862,0.0901,0.0928,
     10.0945,0.0950,0.0945,0.0928,0.0901,0.0862,0.0812,0.0752,0.0681,
     10.0598,0.0505,0.0400,0.0285,0.0158,0.0097,0.0059,0.0036,0.0022,
     10.0013,0.0008,0.0005/
      END                                                                   0100


      OVERLAY(OVTURB,1,0)
      PROGRAM PRLAST
      COMMON/PRIM/PRESS(51,120),PRESSW(120),XCAL(120),
     1UEXT(140),VEXT(140),RNPNEW(140),NSTNS,NEXPTS
      COMMON/BVAL/DIVA(51),ROUGHA(51),VWA(51),XCURV(51),CURVA(51)
     1,A2,I5,I10,PA(51)
      COMMON/INTG/A(6),ALPHAO,CFR,DO5,DIV,DELSTA,FUDUDX,H1,SCHMET,TAUO,
     1THETA,UDUDX,UE,UE2,UTAU,VW,X,XSTEP,YSTP,PW,PWALL,PE,PEXT
      COMMON/ODDS/I(14),XP(52),CADO,CURV,IDIV,NXP,STRAIN,ROUGH,YSO,ZO1
     1,C1,C2
      COMMON/PROF/TANA(51),TANAFU(51),TANB(51),TANBFU(51),TAU(51),TFUT
     1(51),U(51),UFUT(51),US(51),V(51),I6,I61,I62,RI6,RM,V1
      COMMON/PRESSR/P(51),PO
      COMMON/COUNTS/NSWEEP,NCOUNT
      COMMON/FIRST/CURV1,USTART(51),TSTART(51)
      COMMON/RELAX/A7
      COMMON/END/RLEND,PEND(51),PWEND,JOPT
      COMMON/EXT/SSURF(51),RNP
      COMMON/TURBBL/NSTART,NEND
      INTEGER XP
C
C.....THIS SUBROUTINE -
C     1-FINDS PRESSURE PROFILE AT X-STATION BEFORE LAST
C     2-SETS PRESSURE PROFILE AT LAST X-STATION (DOWNSTREAM BOUNDARY
```

```
C          CONDITION)
C        3-FINDS NEW MATCHING SURFACE AND ACCORDINGLY ADJUSTS PRESSURE
C          PROFILES(FOR FIRST SWEEP ONLY).
C
      XMAX=A2*(I5-1)
      XMAX1=SSURF(NEND)
      XXSTEP=X+XSTEP
   50 FORMAT(/1X,'STN.',I4,6X,'X=',E11.4,6X,'I62=',I3,6X,'(P-PREF)/UREF*
     1*2(FROM PREVIOUS SWEEP)=')
   55 FORMAT(1X,10E12.4)
C
C.....PRESSURE PROFILE AT STATION BEFORE LAST.....
      DO 310 J=1,I62
  310 PRESS(J,NCOUNT)=P(J)
      PRESSW(NCOUNT)=PO
C
C.....PRESSURE PROFILE AT LAST STATION (DOWNSTREAM BOUNDARY CONDN.) ...
C.....EXTERNAL PRESSURE GIVEN AS BOUNDARY VALUE.....
      IF(XXSTEP.LE.XMAX1+1.0E-8) PE=SPLINE(SSURF(NSTART),PA(NSTART),
     1NEND-NSTART+1,XXSTEP)
      UE=SQRT(1.-2.*PE)
      UEXT(NSTART+NCOUNT)=UE
      UE2=UE*UE
      GO TO (326,328),JOPT
  326 DPE=PE-PRESS(I62,NCOUNT)
      DO 304 J=1,I62
  304 PRESS(J,NCOUNT+1)=PRESS(J,NCOUNT)+DPE
      PRESSW(NCOUNT+1)=PRESSW(NCOUNT)+DPE
      GO TO 275
  328 DO 329 J=1,I62
  329 PRESS(J,NCOUNT+1)=PEND(J)
      PRESSW(NCOUNT+1)=PWEND
  275 NSWEEP=NSWEEP+1
C
C
      IF(I(14).EQ.0) GO TO 340
      NCP1=NCOUNT+1
      WRITE(6,50) NCP1,XXSTEP,I62
      WRITE(6,55) PRESSW(NCOUNT+1),(PRESS(J,NCOUNT+1),J=1,I62)
C
C.....PRINT OUT PRESSURE ARRAY.....
      IF(I(14).EQ.0) GO TO 340
C.....VALUES OF (P-PREF)/UREF**2 PRINTED.....
      WRITE(6,400)
      DO 450 NC=1,NCOUNT+1
      XSTN=XCAL(NC)
      IF(I(3).GT.0) GO TO 336
      NXP=-I(3)
      DO 330 J=1,NXP
  330 IF((NC-XP(J)).EQ.0) GO TO 410
      GO TO 450
  336 IF(NC.EQ.(NC/I(3))*I(3).OR.NC.EQ.1.OR.NC.EQ.2.OR.
     1(NC.EQ.NCOUNT+1)) GO TO 410
      GO TO 450
  410 WRITE(6,420) NC,XSTN
      WRITE(6,55) PRESSW(NC),(PRESS(J,NC),J=1,I62)
  450 CONTINUE
C
  340 IF(NSWEEP.GT.1) GO TO 360
C.....DEFINITION OF NEW MATCHING SURFACE AND ADJUSTMENT OF THE
C     CORRESPONDING PRESSURE PROFILES.....
      RNPNEW(NSTART+NCOUNT)=RNPNEW(NSTART+NCOUNT-1)
      RNPMAX=RNPNEW(NSTART)
      DO 342 J=2,NCOUNT+1
```

```
      R=RNPNEW(NSTART-1+J)
  342 IF(R.GT.RNPMAX) RNPMAX=R
      NPI62=RNPMAX/YSTP
      RNPMAX=YSTP*FLOAT(NPI62)
C.....FILL IN EXTRA POINTS ON PRESSURE PROFILES UP TO NEW
C     MATCHING SURFACE.....
      DO 352 NC=1,NCOUNT+1
      US(1)=YSTP*FLOAT(I62-1)
      US(2)=US(1)+YSTP
      DO 350 J=I62,NPI62-1
      YEXTRP=YSTP*FLOAT(J+1)
  350 PRESS(J+1,NC)=VALUE(US,PRESS(I62-1,NC),2,YEXTRP,1)
  352 CONTINUE
      IF(I(2).NE.0) GO TO 356
C.....SYNTHETIC STARTING PROFILES USED.....
      FACTOR=RNPMAX/RNPNEW(NSTART)
      DO 354 J=1,NSTART
  354 RNPNEW(J)=FACTOR*RNPNEW(J)
C
  356 DO 358 J=1,NCOUNT+1
  358 RNPNEW(NSTART-1+J)=RNPMAX
C
  360 N1=NSTART
      IF(I(2).EQ.0) N1=1
      REWIND 14
      WRITE(14) NSWEEP+1
      WRITE(14) I(2),NSTART,YSTP
      WRITE(14) NCOUNT,NCOUNT,(XCAL(J),J=1,NCOUNT+1),(XCAL(J),J=1,NCOUNT
     1+1)
      WRITE(14) (RNPNEW(J),J=N1,NSTART+NCOUNT)
      WRITE(14) (UEXT(K),VEXT(K),K=N1,NSTART+NCOUNT)
      WRITE(14) (UEXT(K),VEXT(K),K=N1,NSTART+NCOUNT)
      WRITE(14) (PRESSW(J),(PRESS(II,J),II=1,51),J=1,NCOUNT+1)
C
      WRITE(6,99)
      WRITE(6,55) (XCAL(J),J=1,NCOUNT+1)
      WRITE(6,111)
      DO 500 J=NSTART,NSTART+NCOUNT-1
  500 RNPNEW(J)=VEXT(J)/UEXT(J)
      WRITE(6,55) (RNPNEW(J),J=NSTART,NSTART+NCOUNT-1)
      WRITE(6,222)
      WRITE(6,55) (PRESSW(J),J=1,NCOUNT+1)
      WRITE(6,333)
      LIM=I62
      DO 550 NC=1,NCOUNT+1
  550 PRESSW(NC)=PRESSW(NC)-PRESS(LIM,NC)
      WRITE(6,55) (PRESSW(NC),NC=1,NCOUNT+1)
   99 FORMAT(/1X,'X=')
  333 FORMAT(/1X,'(PW-PE)/UREF**2=')
  111 FORMAT(/1X,'VE/UE=')
  222 FORMAT(/1X,'(PW-PREF)/UREF**2=')
  400 FORMAT(//1X,'VALUES OF (P-PREF)/UREF**2 AT X-STATIONS'/)
  420 FORMAT(/1X,'STN. NO.',I4,6X,'X=',E11.4)
      RETURN
      END


      FUNCTION VALUE(X,Y,N,XINT,IOPT)
      DIMENSION X(N),Y(N)
      DO 2 J=1,N
      K=J
```

```
      IF((XINT-X(J)).LE.0.) GO TO 5
    2 CONTINUE
    5 IF(K.EQ.1) K=2
      IF(K.EQ.N.AND.IOPT.EQ.2) K=N-1
      XX1=XINT-X(K-1)
      XX2=XINT-X(K)
      DX1=X(K)-X(K-1)
      GO TO (10,20),IOPT
C.....LINEAR INTERPOLATION.....
   10 VALUE=(-Y(K-1)*XX2+Y(K)*XX1)/DX1
      RETURN
C.....LAGRANGIAN QUADRATIC INTERPOLATION.....
   20 XX3=XINT-X(K+1)
      DX2=X(K+1)-X(K)
      DX=DX1+DX2
      VALUE=Y(K-1)*XX2*XX3/(DX*DX1)-Y(K)*XX1*XX3/(DX1*DX2)
     1+Y(K+1)*XX1*XX2/(DX*DX2)
      RETURN
      END
```

```
      FUNCTION SPLINE(X,Y,M,XINT)
      DIMENSION X(M),Y(M),W(51),D(51)
      N=M-1
      CALL E01ADF(N,XINT,X,Y,W,D,M,VAL)
      SPLINE=VAL
      RETURN
      END
```

```
      OVERLAY(OVTURB,2,0)
      PROGRAM START1
      COMMON/PRIM/PRESS(51,120),PRESSW(120),XCAL(120),
     1UEXT(140),VEXT(140),RNPNEW(140),NSTNS,NEXPTS
      CALL STARTO(NSTNS,NEXPTS,PRESS,PRESSW,XCAL,UEXT,VEXT,RNPNEW)
      RETURN
      END
      SUBROUTINE STARTO(NSTNS,NEXPTS,PRESS,PRESSW,XCAL,UEXT,VEXT,RNPNEW)
      DIMENSION PRESS(51,NSTNS),PRESSW(NSTNS),XCAL(NSTNS)
      DIMENSION UEXT(NEXPTS),VEXT(NEXPTS),RNPNEW(NEXPTS)
      COMMON/BVAL/DIVA(51),ROUGHA(51),VWA(51),XCURV(51),CURVA(51)
     1,A2,I5,I10,PA(51)
      COMMON/INTG/A(6),ALPHAO,CFR,D05,DIV,DELSTA,FUDUDX,H1,SCHMET,TAU0,
     1THETA,UDUDX,UE,UE2,UTAU,VW,X,XSTEP,YSTP,PW,PWALL,PE,PEXT
      COMMON/ODDS/I(14),XP(52),CADD,CURV,IDIV,NXP,STRAIN,ROUGH,YSD,Z01
     1,C1,C2
      COMMON/PROF/TANA(51),TANAFU(51),TANB(51),TANBFU(51),TAU(51),TFUT
     1(51),U(51),UFUT(51),US(51),V(51),I6,I61,I62,RI6,RM,V1
      COMMON/PRESSR/P(51),PO
      COMMON/COUNTS/NSWEEP,NCOUNT
      COMMON/FIRST/CURV1,USTART(51),TSTART(51)
      COMMON/RELAX/A7
      COMMON/EXT/SSURF(51),RNP
```

```
      COMMON/TURBBL/NSTART,NEND
      COMMON/END/RLEND,PEND(51),PWEND,JOPT
      COMMON/STEPS/NSTEPS
C
C.....THIS SUBROUTINE READS IN RELEVANT DATA.....
C
C     US ARRAY USED FOR SCRATCH. READS AND PRINTS TITLE CARD OR BLANK   STAR0080
C.....N.B. TANA,TANB AND US ARE USED INITIALLY AS SCRATCH ARRAYS--
C     US IS THE EXTERNAL PRESSURE AT THE MID POINTS OF THE MS ELEMENTS
C     TANA IS THE ARC LENGTH AT THE MS ELEMENT MID POINTS
C     TANB IS THE ARC LENGTH AT THE MS NODES .....
      READ(14) NSW12
      READ(14) N,NTE,NSTART,NEND,(DUM,DUM,J=1,N),(DUM,J=1,N-1),
     1(SSURF(J),J=1,NEND),(RNP,J=1,NEND),(TANA(J),J=1,NEND),
     2(TANB(J),J=1,NEND)
      READ(14) NORUN
      READ(14) (US(J),J=1,NEND)
      DO 25 K=2,NEND
   25 PA(K)=.5*SPLINE(TANA,US,NEND,TANB(K))
      PA(1)=0.5
C
      NSWEEP=NORUN-1
      IF(NSWEEP.EQ.0) GO TO 75
      READ(14) NSW14
      READ(14) II2,NS,YSTP
      N1=NSTART
      IF(II2.EQ.0) N1=1
      READ(14) NSTEPS,NSTEPS,(XCAL(J),J=1,NSTEPS+1),(XCAL(J),J=1,NSTEPS+
     11)
      READ(14) (RNPNEW(J),J=N1,NSTART+NSTEPS)
      READ(14) (US(J),US(J),J=N1,NSTART+NSTEPS)
      READ(14) (US(J),US(J),J=N1,NSTART+NSTEPS)
      READ(14) (PRESSW(J),(PRESS(II,J),II=1,51),J=1,NSTEPS+1)
C
   75 CONTINUE
      WRITE(6,77) NORUN
   77 FORMAT(//1X,'RUN NO.',I3,2X,'OF BOUNDARY LAYER CALCULATION'/)
      READ(5,100) (US(J),J=1,8)                                         STAR0090
  100 FORMAT(8A10)                                                      STAR0100
      WRITE(6,110) (US(J),J=1,8)                                        STAR0110
  110 FORMAT(1H 8A10)                                                   STAR0120
      READ(5,120) (I(J),J=1,14)
  120 FORMAT(14I5)
      WRITE(6,120) (I(J),J=1,14)
      READ(5,130) (A(J),J=1,6),A7
  130 FORMAT(7F10.0)
      WRITE(6,140) (A(J),J=1,6),A7
  140 FORMAT(1H 7HA       ,8(1PE11.3))
      IF(I(4).EQ.0) I(4)=1000                                           STAR0200
      IF(I(6).GT.48.AND.I(2).EQ.0) I(6)=48                              STAR0210
      IF(I(5).LT.52.AND.I(6).LT.49) GO TO 160                           STAR0220
      WRITE(6,150)                                                      STAR0230
  150 FORMAT(1H *I(5).GT.51 OR I(6).GT.48*)                             STAR0240
      STOP                                                              STAR0250
  160 I5=I(5)                                                           STAR0260
      JOPT=2
      IF(I(13).LT.0) JOPT=1
      I6=I(6)
      I61=I6+1                                                          STAR0280
      I62=I6+2                                                          STAR0290
      IF(NSWEEP.EQ.0.AND.I(2).EQ.0) RNPNEW(1)=0.
      IF(NSWEEP.EQ.0.AND.I(2).NE.0) RNPNEW(1)=RNP
      IF(I(2).NE.0) RNPNEW(NSTART)=RNP
      IF(NSWEEP.EQ.0.AND.I(2).NE.0) YSTP=RNP/FLOAT(I62)
```

```
      RI6=I6                                                            STAR0300
      I10=I(10)                                                         STAR0310
      IDIV=1                                                            STAR0320
      IF(I10.GT.0)GO TO 170                                             STAR0330
      IDIV=0                                                            STAR0340
      I10=-I10                                                          STAR0350
  170 IF(I(11).EQ.0)  I(11)=1.5*I6                                      STAR0360
      IF(I(11).GT. 48)I(11)=48                                          STAR0370
      A2=A(2)                                                           STAR0390
      C1=C2=0.
      IF(I(2).NE.0)  A(3)=SSURF(NSTART)
      XCAL(1)=X=A(3)
      RLEND=A(1)
      ROUGH=0.                                                          STAR0410
      CURV=0.                                                           STAR0420
      DIV=0.                                                            STAR0430
      STRAIN=0.                                                         STAR0440
      VW=0.                                                             STAR0450
      CALL START(NSTNS,NEXPTS,PRESS,PRESSW,XCAL,UEXT,VEXT,RNPNEW)
      RETURN
      END


      SUBROUTINE START(NSTNS,NEXPTS,PRESS,PRESSW,XCAL,UEXT,VEXT,RNPNEW)
      DIMENSION PRESS(51,NSTNS),PRESSW(NSTNS),XCAL(NSTNS)
      DIMENSION UEXT(NEXPTS),VEXT(NEXPTS),RNPNEW(NEXPTS)
      COMMON/BVAL/DIVA(51),ROUGHA(51),VWA(51),XCURV(51),CURVA(51)
     1,A2,I5,I10,PA(51)
      COMMON/INTG/A(6),ALPHA0,CFR,D05,DIV,DELSTA,FUDUDX,H1,SCHMET,TAU0,  STAR0030
     1THETA,UDUDX,UE,UE2,UTAU,VW,X,XSTEP,YSTP,PW,PWALL,PE,PEXT
      COMMON/ODDS/I(14),XP(52),CADD,CURV,IDIV,NXP,STRAIN,ROUGH,YSD,Z01
     1,C1,C2
      COMMON/PROF/TANA(51),TANAFU(51),TANB(51),TANBFU(51),TAU(51),TFUT  STAR0060
     1(51),U(51),UFUT(51),US(51),V(51),I6,I61,I62,RI6,RM,V1             STAR0070
      COMMON/PRESSR/P(51),P0
      COMMON/COUNTS/NSWEEP,NCOUNT
      COMMON/FIRST/CURV1,USTART(51),TSTART(51)
      COMMON/RELAX/A7
      COMMON/EXT/SSURF(51),RNP
      COMMON/TURBBL/NSTART,NEND
      COMMON/END/RLEND,PEND(51),PWEND,JOPT
      COMMON/STEPS/NSTEPS
      INTEGER XP
  130 FORMAT(7F10.0)
C
C.....OPTIONAL SYNTHETIC PROFILES.....
      IF(I(2).EQ.1) GO TO 100
      CALL SYNTH(NEXPTS,UEXT,VEXT,RNPNEW)
      JOPT=1
      XCAL(1)=X=A(3)
  100 CONTINUE
C
C.....READ IN BOUNDARY AND STARTING VALUES.....
C
      IF(I(8).EQ.0) GO TO 270
      READ(5,130) (ROUGHA(J),J=1,I5)                                    STAR0640
      WRITE(6,240) (ROUGHA(J),J=1,I5)                                   STAR0650
  240 FORMAT(1H 7HROUGH   ,7(1PE11.3))                                  STAR0660
  270 IF(I(2).EQ.1) GO TO 150
      DO 140 J=1,I5
  140 XCURV(J)=SSURF(J)
```

```
      GO TO 255
  150 READ(5,130)  (XCURV(J),J=1,I5)
  255 WRITE(6,245)  (XCURV(J),J=1,I5)
  245 FORMAT(1H 'X FOR CURV. B. VALUE    ',7(1PE11.3))
      READ(5,130)  (CURVA(J),J=1,I5)
      WRITE(6,250)  (CURVA(J),J=1,I5)
  250 FORMAT(1H 7HCURV    ,7(1PE11.3))
  275 IF(I10.EQ.0) GO TO 320
      WRITE(6,280)  (DIVA(J),J=1,I5)                                    STAR0730
  280 FORMAT(1H 7HDIV     ,7(1PE11.3))                                  STAR0740
      IF(I10.NE.2) GO TO 310                                            STAR0750
      DO 290 J=1,I5                                                     STAR0760
C     US ARRAY USED FOR SCRATCH                                         STAR0770
  290 US(J)=GRAD(DIVA,A2,1,I5,J)/DIVA(J)                                STAR0780
      DO 300 J=1,I5                                                     STAR0790
  300 DIVA(J)=US(J)                                                     STAR0800
  310 IF(I10.EQ.1) DIV=1./(X-BROIN(DIVA,A2,X))                          STAR0810
      IF(I10.GT.1)DIV=BROIN(DIVA,A2,X)                                  STAR0820
  320 IF(I(12).EQ.0) GO TO 340
      READ(5,130)  (VWA(J),J=1,I5)                                      STAR0840
      WRITE(6,330) (VWA(J),J=1,I5)                                      STAR0850
  330 FORMAT(1H 7HVW      ,7(1PE11.3))                                  STAR0860
      VW=BROIN(VWA,A2,X)
  340 WRITE(6,341)  (SSURF(J),J=1,NEND)
  341 FORMAT(1H 'X FOR PRESS. AND NP B. VALUES    ',7(1PE13.4))
      WRITE(6,346)  (PA(J),J=1,NEND)
  346 FORMAT(1H 10HPE-PREF    ,7(1PE13.4))
      IF(I(2).NE.0) GO TO 365
      WRITE(6,344)  (RNPNEW(J),J=1,NSTART)
      WRITE(6,344)  (RNP,J=NSTART,NEND)
      GO TO 367
  365 WRITE(6,344)  (RNP,J=1,NEND)
  367 CONTINUE
  344 FORMAT(1H 2HNP        ,7(1PE13.4))
      CURV1=CURV=VALUE(XCURV,CURVA,I5,X,1)
C
C.....PRINT AT EVERY I(3) STEPS IF I(3).GT.0, READ (-I(3)) PRINT
C     STATIONS IF I(3).LT.0 -- N.B. XP ARE X-STATION NUMBERS .....
      IF(I(3).GT.0) GO TO 410
      NXP=-I(3)
      READ(5,350)  (XP(J),J=1,NXP)
  350 FORMAT(16I5)
C
C
  410 IF(I(2).EQ.0) GO TO 430
C     PROFILES ARE INPUT                                                STAR1100
      READ(5,130)  (U(J),J=1,I62)
      READ(5,130)  (TAU(J),J=1,I62)
      IF(NSWEEP.EQ.0) GO TO 430
      I62OLD=I62
      I62=RNPNEW(NSTART)/YSTP+.5
      I61=I62-1
      I6=I61-1
      DO 440 J=I62OLD+1,I62
      U(J)=U(I62OLD)
  440 TAU(J)=1.0E-8
C
      GO TO (430,562),JOPT
C.....UNREALISTIC INITIAL VEL. PROFILE GIVEN--ASSUME DPDY=RHO*U**2/R
C     AND OBTAIN REALISTIC VEL. PROFILE.....
C.....ITERATION TO OBTAIN PRESSURE AND VEL. PROFILES AT X=A(3).....
C.....EXTERNAL PRESSURE GIVEN.....
  430 PE=SPLINE(SSURF(NSTART),PA(NSTART),NEND-NSTART+1,X)
      IF(A(1).EQ.0.) CURV1=0.
```

```
      CALL PRINIT(PRESS(1,1),I62,PRW,PE,CURV1,YSTP,US,0)
      UE=SQRT(1.-2.*PE)
      UW=SQRT(1.-2.*PRW)
  545 DØ 550 J=1,I62
  550 UFUT(J)=SQRT(U(J)*U(J)*UW*UW+2.*(PRW-PRESS(J,1)))
      CALL PRINIT(PRESS(1,1),I62,PRW,PE,CURV1,YSTP,UFUT,1)
      UFUTØ=SQRT(1.-2.*PRW)
      IF(ABS(UFUTØ-UW).GE.UW*1.0E-4) GØ TØ 555
      GØ TØ 560
  555 UW=UFUTØ
      GØ TØ 545
  560 UW=UFUTØ
      PRESSW(1)=PRW
      DØ 532 J=1,I62
      USTART(J)=UFUT(J)
  532 TSTART(J)=TAU(J)*UE*UE
      GØ TØ 567
C
C...REALISTIC INITIAL VEL. PRØFILE AND INITIAL PRESSURE PRØFILE GIVEN...
  562 READ(5,130) PW,(PRESS(J,1),J=1,I62)
      PRESSW(1)=PW
      PE=PRESS(I62,1)
      UE=SQRT(1.-2.*PE)
      DØ 564 J=1,I62
      USTART(J)=U(J)*UE
  564 TSTART(J)=TAU(J)*UE*UE
C
C.....PRESSURE PRØFILE AT LAST STATIØN.....
      READ(5,130) PWEND,(PEND(J),J=1,I62)
C
  567 PEFUT=SPLINE(SSURF(NSTART),PA(NSTART),NEND-NSTART+1,X+YSTP)
      UEFUT=SQRT(1.-2.*PEFUT)
      IF(NSWEEP.GT.0) GØ TØ 535
C.....PRESSURE PRØFILE AT X=A(3)+YSTP FØR FIRST SWEEP ØNLY.....
C.....EXTERNAL PRESSURE GIVEN.....
      CURVFU=VALUE(XCURV,CURVA,I5,X+YSTP,1)
      IF(A(1).EQ.0.) CURVFU=0.
      I62FUT=I62
      GØ TØ (576,578),JØPT
  576 CALL PRINIT(PRESS(1,2),I62,PRW,PEFUT,CURVFU,YSTP,USTART,1)
      PRESSW(2)=PRW
      GØ TØ 535
  578 PEX1=PRESS(I62FUT,1)
      PEXEND=PEND(I62FUT)
      DØ 579 J=1,I62FUT
  579 PRESS(J,2)=PEFUT+(1.-(X+YSTP)/RLEND)*(PRESS(J,1)-PEX1)+
     1(X+YSTP)/RLEND*(PEND(J)-PEXEND)
      PRESSW(2)=PEFUT+(1.-(X+YSTP)/RLEND)*(PRESSW(1)-PEX1)+
     1(X+YSTP)/RLEND*(PWEND-PEXEND)
C
C
  535 FUDUDX=UE*(UEFUT-UE)/YSTP
      DØ 537 J=1,I62
      UFUT(J)=USTART(J)
  537 TFUT(J)=TSTART(J)
      UEXT(NSTART)=UFUT(I62)
      UE2=UE*UE
      TAUØ=UE2*A(5)
      UTAU=SQRT(TAUØ)                                                   STAR1170
      IF(ABS(VW).LT..0001*UE) VW=0.                                     STAR0880
      ALPHAØ=(TFUT(1)-TAUØ)/YSTP                                        STAR1180
      V(1)=VW                                                           STAR1190
     1-YSTP*(UFUT(1)-UTAU/.41)*DIV                                      STAR1200
      D05=YSTP*RI6*(1.-.002*UE/UTAU)                                    STAR1210
```

```
      V(1)=V(1)/(1.+YSTP*RI6*CURV1)
      YSD=YSTP/D05
      RETURN
      END



      SUBROUTINE SYNTH(NEXPTS,UEXT,VEXT,RNPNEW)
      DIMENSION UEXT(NEXPTS),VEXT(NEXPTS),RNPNEW(NEXPTS)
      COMMON/ODDS/I(14),XP(52),CADD,CURV,IDIV,NXP,STRAIN,ROUGH ,YSD,Z01
     1,C1,C2
      COMMON/PROF/TANA(51),TANAFU(51),TANB(51),TANBFU(51),TAU(51),TFUT
     1(51),U(51),UFUT(51),US(51),V(51),I6,I61,I62,RI6,RM,V1
      COMMON/INTG/A(6),ALPHA0,CFR,D05,DIV,DELSTA,FUDUDX,H1,SCHMET,TAU0,
     1THETA,UDUDX,UE,UE2,UTAU,VW,X,XSTEP,YSTP,PW,PWALL,PE,PEXT
      COMMON/BVAL/DIVA(51),ROUGHA(51),VWA(51),XCURV(51),CURVA(51)
     1,A2,I5,I10,PA(51)
      COMMON/EXT/SSURF(51),RNP
      COMMON/COUNTS/NSWEEP,NCOUNT
      COMMON/TURBBL/NSTART,NEND
C
C.....THWAITES LAMINAR B.L. CALCULATION.....
C.....INITIALISATION OF X-INTEGRATION LOOP.....
      RETRAN=600.
      A3=A(3)
      LOOP=1
      IF(NSWEEP.GT.0) LOOP=2
   25 THETA=0.
      PE=PA(1)
      UE=SQRT(1.-2.*PE)
      PEFU=VALUE(SSURF,PA,NEND,X+.01*A2,2)
      UEFU=SQRT(1.-2.*PEFU)
      DUDX=(UEFU-UE)/(.01*A2)
      IF(ABS(UE).LT.1.0E-9) THETA=SQRT(.075/(A(4)*DUDX))
      RTHETA=A(4)*THETA*UE
      THETO=THETA
      TRANO=RTHETA/RETRAN
      IF(NSWEEP.GT.0.AND.X.GE.SSURF(NSTART-1)) GO TO 115
      IF(NSWEEP.EQ.0.AND.TRANO.GT.1.) GO TO 115
      UEDSO=UE*THETA*2.05
      UEDDSO=-UEDSO
      DELO=0.
      UEXT(1)=UE
      VEXT(1)=0.
      IX=1
      IF(LOOP.EQ.2) WRITE(6,50)
   50 FORMAT(/1X,'THWAITES LAMINAR B.L. CALC.'/8X,'X',8X,'THETA',6X,'RTH
     1ETA',9X,'UE',10X,'VE')
C
C.....X-INTEGRATION LOOP*****SOLVES FOR THETA(X).....
      IX=IX+1
   90 IF(LOOP.EQ.2) WRITE(6,95) X,THETA,RTHETA,UEXT(IX-1),VEXT(IX-1)
   95 FORMAT(1X,5E12.4)
      DX=SSURF(IX)-SSURF(IX-1)
      XF=X+DX
      PEF=PA(IX)
      UEF=SQRT(1.-2.*PEF)
      UDUDX=-(VALUE(SSURF,PA,NEND,XF+.01*A2,2)-PEF)/(.01*A2)
      UR6=(UE/UEF)**6
      RINT=(1.-UR6)/(UEF-UE+1.E-8)
      IF(UEF.EQ.UE)RINT=6.*(UE**5)
      THETA=SQRT(.075*RINT*(XF-X)/A(4)+UR6*THETO*THETO)
```

```
      IF(LOOP.EQ.1) GO TO 103
      RLAMB=THETA*THETA*UDUDX*A(4)/UEF
      IF(RLAMB.GE.0.) H1=2.61-3.75*RLAMB*(1.-1.397*RLAMB)
      IF(RLAMB.LT.0.) H1=.0731/(0.14+RLAMB) +2.088
      IF(NSWEEP.EQ.0) DEL=FACMS*THETA
      IF(NSWEEP.GT.0) DEL=RNPNEW(IX)
      UEDS=UEF*THETA*H1
      UEDDS=UEF*DEL-UEDS
      RNPNEW(IX)=DEL
      VW=0.
      IF(I(12).NE.0) VW=ORDIN(VWA,-A2,XF)
      UEXT(IX)=UEF
      VEXT(IX)=VW+(UEF*(DEL-DELO)/DX-(UEDDS-UEDDSO)/DX)
  103 CONTINUE
      TRAN=UEF*THETA*A(4)/RETRAN
      IF(NSWEEP.GT.0.AND.XF.GT.SSURF(NSTART-1)) GO TO 105
      IF(NSWEEP.EQ.0.AND.TRAN.GT.1.) GO TO 105
      UE=UEF
      DELO=DEL
      UEDDSO=UEDDS
      THETO=THETA
      TRANO=TRAN
      IX=IX+1
      X=XF
      RTHETA=A(4)*UEF*THETA
C.....END OF X-INTEGRATION LOOP AND LAMINAR B.L. CALC. .....
      GO TO 90
  105 X=SSURF(IX)
      IF(NSWEEP.EQ.0) NSTART=IX
      A(3)=X
      PE=VALUE(SSURF,PA,NEND,X,2)
      UDUDX=-(VALUE(SSURF,PA,NEND,X+THETA,2)-PE)/THETA
      UE2=UE*UE
C
C.....CALCULATION OF INITIAL PROFILES FOR TURB. B.L. .....
  115 RTHETA=A(4)*THETA*UE
      RCF2=.113/(RTHETA**.125)
      TT1=ALOG(RTHETA/(1.-6.8*RCF2))/.41
      TT2=4.84-4.88/(1.+7.14E-4*RTHETA)**3
      RCF2=1./(TT1+TT2)
      IF(A(5).EQ.0.) A(5)=RCF2*RCF2
      IF(LOOP.EQ.2) WRITE(6,95) X,THETA,RTHETA,UEXT(NSTART),VEXT(NSTART)
      G=SQRT(A(5))/.41
      NIT=0
      T1=0.1
  110 B=1.-G*(2.12+ALOG(.41*G*RTHETA/T1))
      T=(G+.5*B-2.*G*G -.375*B*B -1.59*B*G)/(1.+(49.-297.*G)/RTHETA)
      NIT=NIT+1
      IF(ABS(1.-T/T1) .LT..005.OR.NIT.GT.5) GO TO 120
      T1=T
      IF(B.LT.-.01)G=1./(2.12+ALOG(.41*G*RTHETA/T1))
C     IF RE TOO LOW, CF IS ADJUSTED TO GIVE ACCEPTABLE PROFILE.
C     DIFFERENCE BETWEEN A(5) AND CF/2 AT X=A(3) IS DANGER SIGNAL
      GO TO 110
C
C.....DEFINITION OF MATCHING SURFACE FOR FIRST SWEEP ONLY.....
  120 IF(LOOP.EQ.2) GO TO 125
      YSTP=THETA/(T*RI6)
      FACMS=(RI6+2.)*YSTP/THETA
      X=A(3)=A3
      LOOP=2
      GO TO 25
C
  125 DO 140 J=1,I6
```

```
      Y=FLOAT(J)/RI6
      U(J)=G*ALOG(Y)+1.-.5*B*(1.+COS(3.1416*Y))
      TAUFAC=(G/Y+1.5708*B*SIN(3.1416*Y))*(.41*Y)
      TAU(J)=TAUFAC*TAUFAC
      IF(Y.GT..2) GO TO 130
      TAU(J)=TAU(J)*(1.-3.7*Y**1.6)
      GO TO 140
  130 TAU(J)=TAU(J)*1.58*EXP(-3.9*Y)
  140 CONTINUE
      WRITE(6,150)T
  150 FORMAT(1H042HSYNTHETIC STARTING PROFILES    THETA/DELTA=F6.4)
      I605=I6/5
      RI605=I605
      DO 160 J=1,I605
      RJ=J
  160 TAU(J)=TAU(I605)*RJ/RI605+A(5)*(1.-RJ/RI605)
      I6COLE=I6
      IF(NSWEEP.EQ.0) I62=RNP/YSTP+.5
      IF(NSWEEP.GT.0) I62=RNPNEW(NSTART)/YSTP+.5
      I6=I62-2
      I61=I62-1
      RI6=I6
      IF(I62.GT.51) WRITE(6,999) I62
  999 FORMAT(/1X,'VALUE OF I62 FROM SYNTH=',I5,5X,'GREATER THAN 51'/)
      IF(I62.GT.51) STOP
      DO 170 J=I6COLE,I62-1
      U(J+1)=U(J)
  170 TAU(J+1)=1.0E-8
      RETURN
      END
```



```
      FUNCTION GRAD(FR,H,IA,IB,N)
      DIMENSION FR(51)
      IF(N-IA)110,100,110
  100 G=(    -FR(IA+2)+4.*FR(IA+1)-3.*FR(IA))/(2.*H)
      GO TO 140
  110 IF(N-IB)130,120,130
  120 G=(3.*FR(IB)-4.*FR(IB-1)+FR(IB-2))/(2.*H)
      GO TO 140
  130 G=(FR(N+1)-FR(N-1))/(2.*H)
  140 GRAD=G
      RETURN
      END
```

```
      FUNCTION ORDIN(FA,DX,X)
C     NEW VERSION, AUG 1974. LINEAR IF DX.GT.0,PARABOLIC IF DX.LT.0.
      DIMENSION FA(51)
      XDX=ABS(X/DX)
      J=XDX-.0001
      IF(DX.LT.0.) GO TO 100
      R=XDX-J
      ORDIN=(1.-R)*FA(J+1)+R*FA(J+2)
      RETURN
  100 IF(J.GT.0) GO TO 110
      R=1.-XDX
      ORDIN=(1.-R*R)*FA(2)+.5*R*((R-1.)*FA(3)+(R+1.)*FA(1))
```

```
      RETURN
  110 R=XDX-J
      ORDIN=(1.-R*R)*FA(J+1)+.5*R*((R-1.)*FA(J)+(R+1.)*FA(J+2))
      RETURN
      END
```

```
      FUNCTION SPLINE(X,Y,M,XINT)
      DIMENSION X(M),Y(M),W(51),D(51)
      N=M-1
      CALL E01ADF(N,XINT,X,Y,W,D,M,VAL)
      SPLINE=VAL
      RETURN
      END
```

```
      FUNCTION VALUE(X,Y,N,XINT,IOPT)
      DIMENSION X(N),Y(N)
      DO 2 J=1,N
      K=J
      IF((XINT-X(J)).LE.0.) GO TO 5
    2 CONTINUE
    5 IF(K.EQ.1) K=2
      IF(K.EQ.N.AND.IOPT.EQ.2) K=N-1
      XX1=XINT-X(K-1)
      XX2=XINT-X(K)
      DX1=X(K)-X(K-1)
      GO TO (10,20),IOPT
C.....LINEAR INTERPOLATION.....
   10 VALUE=(-Y(K-1)*XX2+Y(K)*XX1)/DX1
      RETURN
C.....LAGRANGIAN QUADRATIC INTERPOLATION.....
   20 XX3=XINT-X(K+1)
      DX2=X(K+1)-X(K)
      DX=DX1+DX2
      VALUE=Y(K-1)*XX2*XX3/(DX*DX1)-Y(K)*XX1*XX3/(DX1*DX2)
     1+Y(K+1)*XX1*XX2/(DX*DX2)
      RETURN
      END
```

A6.2 Listing of Program AMOS

```
      PROGRAM AMOS(OUTPUT=132B,TAPE12=132B,TAPE13=132B,TAPE2=132B,
     1TAPE6=132B)
      DIMENSION A(51,51),B(51,51),TY(2601),VC(51),CP(51),SV(53),DG(51),
     1POG(51),POS(51),MV1(51),MV2(51),SS(53)
     2,XX(50),YY(50)
      COMMON/SURF/X(51),Y(51),TH(51),DS(51),R(51),S(51),N,NTE
      COMMON/MS/VMS(51),NSTART,NEND,NORUN
C
C.....INVISCID CALCULATION USING A.M.O. SMITH SURFACE SOURCE
```

```
C      DISTRIBUTION METHOD.....
C
       PI=3.1415927
 6206  FORMAT(2F10.0)
       READ(2,10) NEXT
   10  FORMAT(I5)
C
C.....READ IN BODY COORDINATES.....
       CALL COORD
C
       NTBE=NTE
       NTE=NTE-1
       N2=N*N
       CC=SQRT((X(NTBE)-X(1))**2+(Y(NTBE)-Y(1))**2)
       IF(NEXT.EQ.0) CC=1.0
       SS(1)=0.5*DS(1)/CC
       DO 80 J=2,N
   80  SS(J)=SS(J-1)+0.5*(DS(J)+DS(J-1))/CC
       SP=SS(N)+0.5*DS(N)/CC
       SS(N+1)=SS(1)+SP
       SS(N+2)=SS(2)+SP
C
C.....EVALUATION OF INFLUENCE COEFFICIENT MATRICES.....
       DO 11 K=1,N
       POS(K)=COS(TH(K))
   11  POG(K)=SIN(TH(K))
       DO 3 J=1,N
       DO 3 K=1,N
       AP=S(J)-S(K)
       AQ=R(J)-R(K)
       SIG=TH(J)-TH(K)
       AX=AP*POS(K)+AQ*POG(K)
       AY=AQ*POS(K)-AP*POG(K)
       AT=(AX+DS(K)/2.0)*(AX+DS(K)/2.0)+AY*AY
       AB=(AX-DS(K)/2.0)*(AX-DS(K)/2.0)+AY*AY
       AA=AT/AB
       PA=ALOG(AA)
       BT=AY*DS(K)
       BB=AX*AX+AY*AY-DS(K)*DS(K)/4.0
       PB=2.0*ATAN2(BT,BB)
       A(J,K)=PB*COS(SIG)-PA*SIN(SIG)
    3  B(J,K)=PA*COS(SIG)+PB*SIN(SIG)
C
C.....INVERSION OF INFLUENCE COEFFICIENT MATRIX.....
       IF(NORUN.GT.2) GO TO 30
       DO 27 K=1,N
       DO 27 J=1,N
 27    TY(J+N*(K-1))=A(J,K)
       CALL MINV(TY,N,DET,MV1,MV2)
       IF(DET)6216,35,6216
   35  WRITE(6,235)
 235   FORMAT(* DET ZERO NO SOLN*)
       GO TO 815
   30  READ(13) IDUM
       READ(13) (MV1(J),J=1,NEND)
       READ(13) (TY(J),J=1,N2)
C
C.....READ IN COORDINATES OF OFF-BODY POINTS AND INCIDENCE/CHORD DATA...
 6216  READ(2,6206) ALP,CHD
       READ(2,10) NOFBDY
       IF(NOFBDY.EQ.0) GO TO 32
       READ(2,6206) (XX(I),YY(I),I=1,NOFBDY)
   32  IF(NEXT.EQ.0) GO TO 40
       WRITE(6,5) ALP,CHD
```

```
 5    FORMAT(//* INCIDENCE =*F7.3,*      CHORD =*F7.3//)
      GO TO 45
   40 WRITE(6,20) CHD
   20 FORMAT(1X,'REFERENCE LENGTH=',F15.4)
   45 TT=ALP*PI/180.
C
C.....TOTAL VELOCITY NORMAL TO ELEMENT MID-PTS. .....
      DO 4 K=1,N
    4 VC(K)=SIN(TH(K)-TT)*NEXT+VMS(K)
C
C
C     1-EVALUATION OF VELOCITIES TANGENTIAL AND NORMAL TO ELEMENTS
C       AT THEIR MID-PTS.
C     2-EVALUATION OF CIRCULATION (FOR LIFTING BODY).
C     3-EVALUATION OF PRESSURE COEFFICIENT AT ELEMENT MID-PTS.
C
      DO 89 I=1,N
      SUM=0.0
      DO 88 J=1,N
 88   SUM=B(I,J)+SUM
 89   DG(I)=SUM
      DO 38 J=1,N
      SUM=0.0
      SVM=0.0
      DO 57 K=1,N
      SUM=SUM+DG(K)*TY(J+N*(K-1))
 57   SVM=SVM+VC(K)*TY(J+N*(K-1))
      POG(J)=SUM
 38   POS(J)=SVM
      DO 58 J=1,N
      DG(J)=POG(J)
  58  VC(J)=POS(J)
      TSUM=0.0
      TSVM=0.0
      DO 62 J=1,N
      TSVM=B(NTBE,J)*VC(J)+TSVM
 62   TSUM=B(NTE,J)*VC(J)+TSUM
      TVBN=TSVM+COS(TH(NTBE)-TT)*NEXT
      TVTN=TSUM+COS(TH(NTE)-TT)*NEXT
      TSB=0.0
      TSA=0.0
      DO 63 J=1,N
      TSA=A(NTE,J)+DG(J)*B(NTE,J)+TSA
 63   TSB=A(NTBE,J)+TSB+DG(J)*B(NTBE,J)
      GAP=-(TVTN+TVBN)/(TSA+TSB)
      IF(NEXT.EQ.0) GAP=0.
      DO 26 I=1,N
      SVM=0.0
      SUM=0.0
      DO 16 J=1,N
      SUM=SUM+A(I,J)*VC(J)-B(I,J)*GAP+A(I,J)*DG(J)*GAP
      XZ=B(I,J)*VC(J)+A(I,J)*GAP+B(I,J)*DG(J)*GAP
 16   SVM=SVM+XZ
      Y(I)=SUM-SIN(TH(I)-TT)*NEXT
      SV(I)=SVM+COS(TH(I)-TT)*NEXT
      ISGN=1
      IF(SV(I).LT.0.) ISGN=-1
   26 SV(I)=ISGN*SQRT(SV(I)*SV(I)+Y(I)*Y(I))
      WRITE(6,621)
  621 FORMAT(//6X,'X',9X,'Y',7X,'SSM',8X,'CP',5X,'U(TANG)',3X,'V(NORM)'/
     1)
      JM=N+1
      SM=ABS(SV(1))-1.0E-20
      SV(N+1)=SV(1)
```

```
      SV(N+2)=SV(2)
      CX=CHD/CC
  631 FORMAT(6F10.5)
      DO 133 J=1,N
      CP(J)=1.-SV(J)*SV(J)
      R(J)=R(J)*CX
  133 S(J)=S(J)*CX
      IF(NEXT.EQ.D) GO TO 65
      DO 134 J=1,NTE
      JLOW=2*NTE-J+1
  134 CP(JLOW)=CP(J)
   65 CONTINUE
C
C
C.....EVALUATION OF LIFT COEFF. (FOR LIFTING BODIES) AND OF STAGNATION
C     POINT POSITION.....
      DO 135 J=1,N
      WRITE(6,631) S(J),R(J),SS(J),CP(J),SV(J),Y(J)
      R(J)=R(J)/CX
      IF(ABS(SV(J))-SM) 70,135,135
   70 SM=ABS(SV(J))
      JM=J
  135 S(J)=S(J)/CX
      REWIND 13
      WRITE(13) NORUN
      WRITE(13) (CP(J),J=1,NEND)
      IF(NORUN.GE.2) GO TO 110
      GO TO 120
  110 WRITE(13) (TY(J),J=1,N2)
  120 IF(NEXT.EQ.0) GO TO 505
      CL=8.0*GAP*SP*PI
      WRITE(6,632) CL
  632 FORMAT (1H ,'LIFT COEFFICIENT ='F6.3)
      STAG1=(SV(JM+1)*SS(JM)-SV(JM)*SS(JM+1))/(SV(JM+1)-SV(JM))
      STAG2=(SV(JM)*SS(JM-1)-SV(JM-1)*SS(JM))/(SV(JM)-SV(JM-1))
      STAG=.5*(STAG1+STAG2)
      IF((ABS(SV(JM))-ABS(SV(JM-1))).LE.1.0E-8) STAG=STAG2
      IF((ABS(SV(JM+1))-ABS(SV(JM))).LE.1.0E-8) STAG=STAG1
      WRITE(6,633) STAG
  633 FORMAT(/1X,'ARC LENGTH FOR STAGN. PT. ON M.S.=',F10.5)
      GO TO 505
      WRITE(6,501)
      IF(STAG-SP) 76,76,77
   77 STAG=STAG-SP
   76 JX=0
      DO 90 J=2,N
      IF(JX) 79,79,90
   79 JU=JM+J-1
      IF(JU-N) 81,81,92
   92 JU=JU-N
   81 ST=SS(JU)-STAG
      IF(ST) 75,91,91
   75 ST=ST+SP
   91 IF(JU-NTBE+1) 93,94,93
   94 JX=1
   93 VV=ABS(SV(JU))
      WRITE(6,500) ST,VV
   90 CONTINUE
      WRITE(6,502)
      DO 95 J=2,N
      IF(JX-1) 96,96,95
   96 JL=JM-J+1
      IF(JL) 97,97,87
   97 JL=JL+N
```

```
   87 ST=STAG-SS(JL)
      IF(ST)74,98,98
   74 ST=ST+SP
   98 IF(JL-NTBE  )99,78,99
   78 JX=2
   99 VV=ABS(SV(JL))
      WRITE(6,500) ST,VV
   95 CONTINUE
  500 FORMAT (1H ,2F10.4)
  501 FORMAT (1H0,'UPPER SURFACE  ARC LENGTH, VELOCITY')
  502 FORMAT (1H0,'LOWER SURFACE  ARC LENGTH, VELOCITY')
C
  505 IF(NOFBDY.EQ.0) GO TO 815
C.....CALCULATION OF VELS. AND PRESSURE COEFFT. AT OFF-BODY POINTS.....
      WRITE(6,1590)
 1590 FORMAT(//1X,'OFF-BODY POINTS'/5X,' X',9X,' Y        U          V
     1       CP'/)
      DO 1600 IPT=1,NOFBDY
      XOFBDY=XX(IPT)
      YOFBDY=YY(IPT)
      VX=0.
      VY=0.
      DO 1500 K=1,N
      XDIF=XOFBDY-S(K)
      YDIF=YOFBDY-R(K)
      CS=COS(TH(K))
      SN=SIN(TH(K))
      AX=XDIF*CS+YDIF*SN
      AY=YDIF*CS-XDIF*SN
      AT=(AX+DS(K)/2.)*(AX+DS(K)/2.)+AY*AY
      AB=(AX-DS(K)/2.)*(AX-DS(K)/2.)+AY*AY
      AA=AT/AB
      PA=ALOG(AA)
      BT=AY*DS(K)
      BB=AX*AX+AY*AY-DS(K)*DS(K)/4.
      PB=2.*ATAN2(BT,BB)
      C=PA*CS-PB*SN
      D=PA*SN+PB*CS
      VX=VX+C*VC(K)+GAP*(C*DG(K)+D)
 1500 VY=VY+D*VC(K)+GAP*(D*DG(K)-C)
      VX=VX+NEXT*COS(TT)
      VY=VY+NEXT*SIN(TT)
      CPOFF=1.-VX*VX-VY*VY
      XOFF=XOFBDY/CX
      YOFF=YOFBDY/CX
      XX(IPT)=VX
      YY(IPT)=VY
 1600 WRITE(6,631) XOFF,YOFF,VX,VY,CPOFF
      WRITE(13) (SV(I),Y(I),I=1,N),(XX(I),YY(I),I=1,NOFBDY)
  815 STOP
      END


      SUBROUTINE COORD
      COMMON/SURF/X(51),Y(51),TH(51),DS(51),R(51),S(51),N,NTE
      COMMON/MS/VMS(51),NSTART,NEND,NORUN
C
C.....READ IN RELEVANT DATA.....
      READ(12) NORUN
      READ(12) N,NTE,NSTART,NEND,(X(J),Y(J),J=1,N),(VMS(J),J=1,N-1)
      WRITE(6,111) NORUN
```

```
  111 FORMAT(//1X,'RUN NO.',I3,2X,'OF PROGRAM AMOS'/)
      N=N-1
      DO 2 K=1,N
      R(K)=Y(K+1)-Y(K)
      S(K)=X(K+1)-X(K)
      TH(K)=ATAN2(R(K),S(K))
      DS(K)=SQRT(R(K)**2+S(K)**2)
      S(K)=S(K)/2.0+X(K)
    2 R(K)=R(K)/2.0+Y(K)
      RETURN
      END



      SUBROUTINE MINV(A,N,D,L,M)
      DIMENSION A(2601),L(51),M(51)
C
C.....MATRIX INVERSION SUBROUTINE.....
C
      D=1.0
      NK=-N
      DO 80 K=1,N
      NK=NK+N
      L(K)=K
      M(K)=K
      KK=NK+K
      BIGA=A(KK)
      DO 20 J=K,N
      IZ=N*(J-1)
      DO 20 I=K,N
      IJ=IZ+I
   10 IF( ABS(BIGA)- ABS(A(IJ))) 15,20,20
   15 BIGA=A(IJ)
      L(K)=I
      M(K)=J
   20 CONTINUE
      J=L(K)
      IF(J-K) 35,35,25
   25 KI=K-N
      DO 30 I=1,N
      KI=KI+N
      HOLD=-A(KI)
      JI=KI-K+J
      A(KI)=A(JI)
   30 A(JI) =HOLD
   35 I=M(K)
      IF(I-K) 45,45,38
   38 JP=N*(I-1)
      DO 40 J=1,N
      JK=NK+J
      JI=JP+J
      HOLD=-A(JK)
      A(JK)=A(JI)
   40 A(JI) =HOLD
   45 IF(BIGA) 48,46,48
   46 D=0.0
      RETURN
   48 DO 55 I=1,N
      IF(I-K) 50,55,50
   50 IK=NK+I
      A(IK)=A(IK)/(-BIGA)
   55 CONTINUE
```

```
      DO 65 I=1,N
      IK=NK+I
      HOLD=A(IK)
      IJ=I-N
      DO 65 J=1,N
      IJ=IJ+N
      IF(I-K) 60,65,60
   60 IF(J-K) 62,65,62
   62 KJ=IJ-I+K
      A(IJ)=HOLD*A(KJ)+A(IJ)
   65 CONTINUE
      KJ=K-N
      DO 75 J=1,N
      KJ=KJ+N
      IF(J-K) 70,75,70
   70 A(KJ)=A(KJ)/BIGA
   75 CONTINUE
      D=D*BIGA
      A(KK)=1.0/BIGA
   80 CONTINUE
      K=N
  100 K=(K-1)
      IF(K) 150,150,105
  105 I=L(K)
      IF(I-K) 120,120,108
  108 JQ=N*(K-1)
      JR=N*(I-1)
      DO 110 J=1,N
      JK=JQ+J
      HOLD=A(JK)
      JI=JR+J
      A(JK)=-A(JI)
  110 A(JI) =HOLD
  120 J=M(K)
      IF(J-K) 100,100,125
  125 KI=K-N
      DO 130 I=1,N
      KI=KI+N
      HOLD=A(KI)
      JI=KI-K+J
      A(KI)=-A(JI)
  130 A(JI) =HOLD
      GO TO 100
  150 RETURN
      END
```

A6.3 Listing of Program MATCH for External Flows

```
      PROGRAM MATCH(OUTPUT=132B,TAPE12=132B,TAPE14=132B,TAPE5=132B,
     1TAPE6=132B)
      DIMENSION X(61),Y(61),R(61),S(61),SSM(61)
     1,SS(61),DS(61)
      COMMON/RUN/NORUN
      COMMON/SSTNS/XCAL1(120),XCAL2(120),NSTPS1,NSTPS2
      COMMON/BLCALC/NSTART,NEND,NSLOW,NENLOW
      COMMON/RS/SSURF(61),GRAD(62)
      COMMON/EXT/RNP(62),RNPNEW(140)
```

```
      COMMON/BLINV/UE(140),VE(140)
      COMMON/MS/GRADM(62),UMS(61),VMS(61),VMSOLD(61)
      COMMON/LAM/I2
C.....THIS PROGRAM GENERATES THE FOLLOWING--
C     1- THE COORDS. OF THE MATCHING SURFACE, GIVEN THE REAL SURFACE
C     COORDS.
C     2- THE DISTANCES NORMAL TO THE REAL SURFACE AT THE NODES,
C     WHICH DEFINE THE MATCHING SURFACE NODES
C     3- THE VELOCITY DISTRIBUTION NORMAL TO THE MATCHING SURFACE AT
C     THE MID POINTS OF THE ELEMENTS.....
C
C.....READ REAL SURFACE COORDS. AND R.S. CURVATURE.....
      READ(5,21) N,NTEL
      NTE=NTEL+1
      READ(5,10) (X(J),Y(J),J=1,N)
   10 FORMAT(2F10.0)
   21 FORMAT(16I5)
  101 FORMAT(//1X,'RUN NO.',I3,2X,'OF PROGRAM MATCH'/)
C
  111 FORMAT(///1X,'REAL SURFACE COORDS. AT NODES'/)
  222 FORMAT(1X,2E15.4)
  555 FORMAT(1X,10E12.4)
      READ(14) NORUN
      WRITE(6,101) NORUN
      IF(NORUN.EQ.1) READ(5,21) NSTART,NEND
      IF(NORUN.GT.1) READ(5,21) NS1,NEND1
      READ(5,10) RNPNST,OMEGA
      IF(NORUN.EQ.1) GO TO 25
      READ(14) I2,NSTART
      READ(14) NSTPS1,NSTPS2,(XCAL1(J),J=1,NSTPS1+1),(XCAL2(J),J=1,
     1 NSTPS2+1)
      N1=NSTART
      IF(I2.EQ.0) N1=1
      READ(14) (RNPNEW(J),J=N1,NSTART+NSTPS1)
      DO 22 J=N1,NSTART+NSTPS1
      JLOW=2*NTE-J
   22 RNPNEW(JLOW+1)=RNPNEW(J)
      READ(12) NSW12
      READ(12) N,NTE,NS1,NEND1,(DUM,DUM,J=1,N),(VMSOLD(J),J=1,N-1)
C
C.....COMPUTE ARC LENGTH ALONG REAL SURFACE.....
   25 N=N-1
      NLOW=N-NTE+2
      SSURF(1)=0.
      DO 30 J=1,N
      R(J)=X(J+1)-X(J)
      S(J)=Y(J+1)-Y(J)
      DSSURF=SQRT(R(J)*R(J)+S(J)*S(J))
   30 SSURF(J+1)=SSURF(J)+DSSURF
      IF(NORUN.GT.1) GO TO 35
      WRITE(6,111)
      WRITE(6,222) (X(J),Y(J),J=1,N+1)
C
C.....COMPUTE GRADIENTS OF REAL SURFACE AT NODES.....
C.....UPPER SURFACE.....
   35 GRAD(1)=S(1)/R(1)
      DO 50 J=2,NTE-1
   50 GRAD(J)=.5*(S(J-1)/R(J-1)+S(J)/R(J))
      GRAD(NTE)=S(NTE-1)/R(NTE-1)
C.....LOWER SURFACE.....
      GRAD(NTE+1)=S(NTE)/R(NTE)
      DO 55 J=NTE+1,N
   55 GRAD(J+1)=.5*(S(J-1)/R(J-1)+S(J)/R(J))
      GRAD(N+2)=S(N)/R(N)
```

```
C
C.....DEFINITION OF MATCHING SURFACE UPSTREAM OF TURB. B.L. CALC.
C     REGION.....
      IF(NORUN.GT.1) GO TO 80
C
C.....FOR FIRST SWEEP.....
C.....UPPER SURFACE.....
      CALL PARAB(SSURF(1),RNP(1),61,0.,RNPNST,NSTART,2)
C.....LOWER SURFACE.....
      NSLOW=2*NTE-NSTART
      NENLOW=2*NTE-NEND
      CALL PARAB(SSURF(NSLOW),RNP(NSLOW+1),61,RNPNST,0.,N-NSLOW+2,1)
      GO TO 130
C
C.....AFTER FIRST SWEEP.....
C.....UPPER SURFACE.....
   80 SSURFO=XCAL1(1)
      SSURFE=XCAL1(NSTPS1+1)
      DO 85 K=NSTART+1,NTE
      NEND=K
      IF((SSURF(K)-SSURFE).GE.0.) GO TO 90
   85 CONTINUE
   90 IF(I2.EQ.0) GO TO 95
      CALL PARAB(SSURF(1),RNP(1),61,0.,RNPNEW(NSTART),NSTART,2)
      GO TO 105
   95 DO 100 J=1,NSTART
  100 RNP(J)=RNPNEW(J)
C.....LOWER SURFACE.....
  105 NSLOW=2*NTE-NSTART
      SSURFO=SSURF(NSLOW)
      SSURFE=SSURFO-(XCAL2(NSTPS2+1)-XCAL2(1))
      DO 110 KK=1,NSLOW-NTE
      K=NSLOW-KK
      NENLOW=K
      IF((SSURFE-SSURF(K)).GE.0.) GO TO 115
  110 CONTINUE
  115 IF(I2.EQ.0) GO TO 120
      CALL PARAB(SSURF(NSLOW),RNP(NSLOW+1),61,RNPNEW(NSTART),0.,
     1N-NSLOW+2,1)
      GO TO 130
  120 DO 125 J=1,NSTART
      JLOW=2*NTE-J
  125 RNP(JLOW+1)=RNPNEW(J)
C
C.....DEFINITION OF MATCHING SURFACE FOR TURB. B.L. CALC. REGION.....
  130 IF(NORUN.GT.1) GO TO 62
C
C.....FOR FIRST SWEEP .....
C.....UPPER SURFACE.....
      DO 60 J=NSTART+1,NEND
   60 RNP(J)=RNPNST
C.....LOWER SURFACE.....
      DO 65 J=NENLOW,NSLOW-1
   65 RNP(J+1)=RNPNST
      GO TO 68
C
C.....AFTER FIRST SWEEP.....
C.....UPPER SURFACE.....
   62 DO 64 J=NSTART,NEND
   64 RNP(J)=RNPNEW(NSTART)
C.....LOWER SURFACE.....
      SSURFO=SSURF(N+1)
      DO 66 JJ=1,NSLOW-NENLOW
      J=NSLOW-JJ+1
```

```
   66 RNP(J+1)=RNPNEW(NSTART)
      RNP(NENLØW+1)=RNP(NENLØW+2)
C
C.....DEFINITIØN ØF MATCHING SURFACE DØWNSTREAM ØF TURB.B.L. CALC.
C     REGIØN.....
C.....UPPER SURFACE.....
   68 NPTS=NTE-NEND+1
      CALL PARAB(SSURF(NEND),RNP(NEND),61,RNP(NEND),0.,NPTS,1)
C.....LØWER SURFACE.....
      NPTLØW=NENLØW-NTE+1
      CALL PARAB(SSURF(NTE),RNP(NTE+1),61,0.,RNP(NENLØW+1),NPTLØW,2)
C
C.....CØMPUTATIØN ØF X-Y CØØRDS. FØR MATCHING SURFACE.....
C.....UPPER SURFACE.....
      DØ 70 J=1,NTE
      FACTØR=RNP(J)/SQRT(1.+GRAD(J)*GRAD(J))
      Y(J)=Y(J)+FACTØR
   70 X(J)=X(J)-FACTØR*GRAD(J)
C.....LØWER SURFACE.....
      DØ 75 J=NTE+1,N+1
      FACTØR=RNP(J+1)/SQRT(1.+GRAD(J+1)*GRAD(J+1))
      Y(J)=Y(J)-FACTØR
   75 X(J)=X(J)+FACTØR*GRAD(J+1)
      IF(NØRUN.GT.2) GØ TØ 445
      WRITE(6,444)
  444 FØRMAT(///1X,'MATCHING SURFACE CØØRDS. AT NØDES'/)
      WRITE(6,222)  (X(J),Y(J),J=1,N+1)
C
C.....CØMPUTE ARC LENGTHS ØF MATCHING SURFACE AT NØDES AND AT MID PTS.
C     ØF ELEMENTS.....
  445 SS(1)=0.
      DØ 140 K=1,N
      S(K)=X(K+1)-X(K)
      R(K)=Y(K+1)-Y(K)
      DS(K)=SQRT(R(K)*R(K)+S(K)*S(K))
  140 SS(K+1)=SS(K)+DS(K)
      SSM(1)=.5*DS(1)
      DØ 150 J=2,N
  150 SSM(J)=SSM(J-1)+.5*(DS(J)+DS(J-1))
C
C.....CØMPUTE GRADIENTS ØF MATCHING SURFACE AT NØDES.....
C.....UPPER SURFACE.....
      GRADM(1)=R(1)/S(1)
      DØ 160 J=2,NTE-1
  160 GRADM(J)=.5*(R(J-1)/S(J-1)+R(J)/S(J))
      GRADM(NTE)=R(NTE-1)/S(NTE-1)
      GRADM(NTE+1)=R(NTE)/S(NTE)
C.....LØWER SURFACE.....
      DØ 170 J=NTE+1,N
  170 GRADM(J+1)=.5*(R(J-1)/S(J-1)+R(J)/S(J))
      GRADM(N+2)=R(N)/S(N)
C
C.....CØMPUTE VELØCITIES NØRMAL TØ MATCHING SURFACE, AT NØDES.....
      CALL VMATCH(N,NTE)
      WRITE(6,777)
  777 FØRMAT(//1X,'VELS. NØRMAL TØ MATCHING SURFACE AT NØDES'/)
      WRITE(6,555)  (VMS(J),J=1,N+1)
C
C.....CØMPUTE VELS. NØRMAL TØ MATCHING SURFACE AT MID PTS. ØF ELMTS. ...
C.....UPPER SURFACE.....
      DØ 180 J=1,NTE-1
  180 UMS(J)=VALUE(SS(1),VMS(1),NTE,SSM(J),2)
C.....LØWER SURFACE.....
      DØ 185 JJ=1,N-NTE+2
```

```
      J=N-JJ+2
      S(JJ)=SS(N+1)-SS(J)
  185 R(JJ)=VMS(J)
      SSME=SS(N+1)
      DO 190 JJ=NTE,N
      J=N+NTE-JJ
      ARC=SSME-SSM(J)
  190 UMS(J)=VALUE(S(1),R(1),N-NTE+2,SSME-SSM(J),2)
      IF(NORUN.EQ.1) GO TO 210
      DO 200 J=1,N
  200 UMS(J)=OMEGA*UMS(J)+(1.-OMEGA)*VMSOLD(J)
  210 WRITE(6,888)
  888 FORMAT(//1X,'VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.'
     1/)
      WRITE(6,555)  (UMS(J),J=1,N)
C
C.....ARC LENGTH ALONG REAL SURFACE AT NODES,ALONG MATCHING SURFACE
C      AT NODES, ALONG M.S. AT ELEMENT MID PTS. AND DIST. NORMAL TO
C      REAL SURFACE AT NODES,ALL MEASURED FROM THE L.E. .....
C.....N.B. THIS IS FOR UPPER SURFACE ONLY HERE.....
      N=N+1
      REWIND 12
      WRITE(12) NORUN
      WRITE(12) N,NTE,NSTART,NEND,(X(J),Y(J),J=1,N),(UMS(J),J=1,N-1),
     1(SSURF(J),J=1,NEND),(RNP(J),J=1,NEND),(SSM(J),J=1,NEND),
     2(SS(J),J=1,NEND)
C
      STOP
      END



      SUBROUTINE VMATCH(N,NTBE)
      COMMON/MS/GRADM(62),UMS(61),VMS(61),VMSOLD(61)
      COMMON/RUN/NORUN
      COMMON/SSTNS/XCAL1(120),XCAL2(120),NSTPS1,NSTPS2
      COMMON/BLCALC/NSTART,NEND,NSLOW,NENLOW
      COMMON/BLINV/UE(140),VE(140)
      COMMON/RS/SSURF(61),GRAD(62)
      COMMON/LAM/I2
C.....THIS SUBROUTINE MATCHES THE NORMAL VELOCITY OBTAINED FROM THE
C      BOUNDARY LAYER CALCULATION--N.B. THIS VELOCITY IS NORMAL TO THE
C      MATCHING SURFACE.....
C
C
C.....DEFINITION OF THE NORMAL VELOCITY FOR THE B.L. CALC. REGION.....
      IF(NORUN.GT.1) GO TO 9
C
C.....FIRST RUN OF INVISCID CALCULATION.....
      DO 2 J=NSTART,NEND
    2 VMS(J)=-.017
      DO 4 J=NENLOW,NSLOW
    4 VMS(J)=-.017
      GO TO 100
C
C.....AFTER FIRST RUN OF INVISCID+B.L. CALC. .....
C.....UPPER SURFACE.....
    9 N1=NSTART
      IF(I2.EQ.0) N1=1
      READ(14)  (UE(K),VE(K),K=N1,NSTART+NSTPS1)
      UE(NSTART+NSTPS1)=UE(NSTART+NSTPS1-1)
      VE(NSTART+NSTPS1)=VE(NSTART+NSTPS1-1)
```

```
C.....VELS. NORMAL AND PARALLEL TO REAL SURFACE AT NODES.....
      IF(I2.NE.0) GO TO 40
      DO 30 J=1,NSTART-1
      VMS(J)=VE(J)
   30 UMS(J)=UE(J)
   40 DO 50 J=NSTART,NEND-1
      VMS(J)=VALUE(XCAL1(1),VE(NSTART),NSTPS1+1,SSURF(J),2)
   50 UMS(J)=VALUE(XCAL1(1),UE(NSTART),NSTPS1+1,SSURF(J),2)
      UMS(NEND)=UMS(NEND-1)
      VMS(NEND)=VMS(NEND-1)
C.....COMPUTE VELS. NORMAL TO MATCHING SURFACE AT NODES.....
      DO 60 J=NSTART,NEND
      T=(GRADM(J)-GRAD(J))/(1.+GRADM(J)*GRAD(J))
   60 VMS(J)=(VMS(J)-T*UMS(J))/SQRT(1.+T*T)
C
C.....LOWER SURFACE.....
      N1=NST=N+2-NSLOW
      IF(I2.EQ.0) N1=1
      READ(14) (UE(K),VE(K),K=N1,NST+NSTPS2)
      UE(NST+NSTPS2)=UE(NST+NSTPS2-1)
      VE(NST+NSTPS2)=VE(NST+NSTPS2-1)
C.....VELS. NORMAL AND PARALLEL TO REAL SURFACE AT NODES.....
      SSURFO=SSURF(N+1)
      IF(I2.NE.0) GO TO 75
      DO 70 J=NSLOW+1,N+1
      JL=N+2-J
      VMS(J)=VE(JL)
   70 UMS(J)=UE(JL)
   75 DO 80 JJ=NENLOW+1,NSLOW
      J=NSLOW+NENLOW+1-JJ
      SINT=SSURFO-SSURF(J)
      VMS(J)=VALUE(XCAL2(1),VE(NST),NSTPS2+1,SINT,2)
   80 UMS(J)=-VALUE(XCAL2(1),UE(NST),NSTPS2+1,SINT,2)
      UMS(NENLOW)=UMS(NENLOW+1)
      VMS(NENLOW)=VMS(NENLOW+1)
C.....COMPUTE VELS. NORMAL TO MATCHING SURFACE.....
      DO 90 J=NENLOW,NSLOW
      T=(GRADM(J+1)-GRAD(J+1))/(1.+GRADM(J+1)*GRAD(J+1))
   90 VMS(J)=(VMS(J)-T*UMS(J))/SQRT(1.+T*T)
C
C
C.....DEFINITION OF NORMAL VELOCITY UPSTREAM OF TURB. B.L. CALC.
C     REGION, AT MATCHING SURFACE NODES.....
  100 IF(NORUN.EQ.1) GO TO 105
      IF(I2.EQ.0) GO TO 110
C.....UPPER SURFACE.....
  105 CALL PARAB(SSURF(1),VMS(1),61,0.,VMS(NSTART),NSTART,2)
C.....LOWER SURFACE.....
      CALL PARAB(SSURF(NSLOW),VMS(NSLOW),61,VMS(NSLOW),0.,N-NSLOW+2,1)
C
C.....DEFINITION OF NORMAL VEL. DOWNSTREAM OF B.L. CALC. REGION.....
C.....UPPER SURFACE.....
  110 CALL PARAB(SSURF(NEND),VMS(NEND),61,VMS(NEND),0.,NTBE-NEND+1,1)
C.....LOWER SURFACE.....
      CALL PARAB(SSURF(NTBE),VMS(NTBE),61,0.,VMS(NENLOW),NENLOW-NTBE+1,
     12)
      RETURN
      END


      SUBROUTINE PARAB(X,Y,N,Y1,YNP,NP,IOPT)
```

```
      DIMENSION X(N),Y(N)
C.....THIS SUBROUTINE PASSES A PARABOLA THROUGH TWO POINTS WITH ZERO
C     SLOPE AT ONE OF THE POINTS.....
      IS=1
      XM=X(1)
      YM=Y1
      IF(IOPT.EQ.2) IS=-1
      IF(IOPT.EQ.2) XM=X(NP)
      IF(IOPT.EQ.2) YM=YNP
      H=(X(NP)-X(1))/FLOAT(NP-1)
      FAC=IS*(YNP-Y1)/(X(NP)-X(1))**2
      DO 10 J=1,NP
   10 Y(J)=YM+FAC*(X(J)-XM)*(X(J)-XM)
      RETURN
      END
```

```
      FUNCTION VALUE(X,Y,N,XINT,IOPT)
      DIMENSION X(N),Y(N)
      IF(XINT.LT.X(1)-1.0E-8) PRINT 111
      IF(XINT.GT.X(N)+1.0E-8) PRINT 222
  111 FORMAT(1X,'WARNING-XINT LESS THAN X(1)-VALUE EXTRAPOLATED')
  222 FORMAT(1X,'WARNING-XINT GREATER THAN X(N)-VALUE EXTRAPOLATED')
      DO 2 J=1,N
      K=J
      IF((XINT-X(J)).LE.0.) GO TO 5
    2 CONTINUE
    5 IF(K.EQ.1) K=2
      IF(K.EQ.N.AND.IOPT.EQ.2) K=N-1
      XX1=XINT-X(K-1)
      XX2=XINT-X(K)
      DX1=X(K)-X(K-1)
      GO TO (10,20),IOPT
C.....LINEAR INTERPOLATION.....
   10 VALUE=(-Y(K-1)*XX2+Y(K)*XX1)/DX1
      RETURN
C.....LAGRANGIAN QUADRATIC INTERPOLATION.....
   20 XX3=XINT-X(K+1)
      DX2=X(K+1)-X(K)
      DX=DX1+DX2
      VALUE=Y(K-1)*XX2*XX3/(DX*DX1)-Y(K)*XX1*XX3/(DX1*DX2)
     1+Y(K+1)*XX1*XX2/(DX*DX2)
      RETURN
      END
```

A6.4 Listing of Program MATCH for Internal Flows

```
      PROGRAM MATCH(OUTPUT=132B,TAPE12=132B,TAPE14=132B,TAPE5=132B,
     1TAPE6=132B)
      DIMENSION X(61),Y(61),R(61),S(61),SSM(61)
     1,SS(61),DS(61)
     2,IEL(8),VCORR(8)
      COMMON/RUN/NORUN
      COMMON/SSTNS/XCAL1(120),NSTPS1
```

```
      COMMON/BLCALC/NSTART,NEND,NSLOW,NENLOW
      COMMON/RS/SSURF(61),GRAD(62)
      COMMON/EXT/RNP(62),RNPNEW(140)
      COMMON/BLINV/UE(140),VE(140)
      COMMON/MS/GRADM(62),UMS(61),VMS(61),VMSOLD(61)
      COMMON/LAM/I2
C.....THIS PROGRAM GENERATES THE FOLLOWING--
C     1- THE COORDS. OF THE MATCHING SURFACE, GIVEN THE REAL SURFACE
C     COORDS.
C     2- THE DISTANCES NORMAL TO THE REAL SURFACE AT THE NODES,
C     WHICH DEFINE THE MATCHING SURFACE NODES
C     3- THE VELOCITY DISTRIBUTION NORMAL TO THE MATCHING SURFACE AT
C     THE MID POINTS OF THE ELEMENTS.....
C
C.....READ REAL SURFACE COORDS. AND R.S. CURVATURE.....
      READ(5,21) N,NTEL,NSIDE,NTOP
      NTE=NTEL+1
      READ(5,20) (X(J),Y(J),J=1,N)
   20 FORMAT(2F10.0)
   10 FORMAT(8F10.0)
   21 FORMAT(16I5)
  101 FORMAT(//1X,'RUN NO.',I3,2X,'OF PROGRAM MATCH'/)
C
  111 FORMAT(///1X,'REAL SURFACE COORDS. AT NODES'/)
  222 FORMAT(1X,2E15.4)
  555 FORMAT(1X,10E12.4)
      READ(14) NORUN
      WRITE(6,101) NORUN
      IF(NORUN.EQ.1) READ(5,21) NSTART,NEND
      IF(NORUN.GT.1) READ(5,21) NS1,NEND1
      READ(5,10) RNPNST,UINF,OMEGA
      IF(NORUN.EQ.1) GO TO 25
      READ(14) I2,NSTART
      READ(14) NSTPS1,NSTPS2,(XCAL1(J),J=1,NSTPS1+1),(DUM,J=1,NSTPS2+1)
      READ(14) (RNPNEW(J),J=NSTART,NSTART+NSTPS1)
      READ(12) NSW12
      READ(12) N,NTE,NS1,NEND1,(DUM,DUM,J=1,N),(VMSOLD(J),J=1,N-1)
C
C.....COMPUTE ARC LENGTH ALONG REAL SURFACE.....
   25 N=N-1
      SSURF(1)=0.
      DO 30 J=1,NTE-1
      R(J)=X(J+1)-X(J)
      S(J)=Y(J+1)-Y(J)
      DSSURF=SQRT(R(J)*R(J)+S(J)*S(J))
   30 SSURF(J+1)=SSURF(J)+DSSURF
      IF(NORUN.GT.1) GO TO 35
      WRITE(6,111)
      WRITE(6,222) (X(J),Y(J),J=1,N+1)
C
C.....COMPUTE GRADIENTS OF REAL SURFACE AT NODES.....
   35 GRAD(1)=S(1)/R(1)
      DO 50 J=2,NTE-1
   50 GRAD(J)=.5*(S(J-1)/R(J-1)+S(J)/R(J))
      GRAD(NTE)=S(NTE-1)/R(NTE-1)
C
C.....DEFINITION OF MATCHING SURFACE UPSTREAM OF TURB. B.L. CALC.
C     REGION.....
      IF(NORUN.GT.1) GO TO 80
C
C.....FOR FIRST SWEEP.....
      DO 55 J=1,NSTART
   55 RNP(J)=RNPNST
      GO TO 130
```

```
C
C.....AFTER FIRST SWEEP.....
   80 SSURFO=XCAL1(1)
      SSURFE=XCAL1(NSTPS1+1)
      DO 85 K=NSTART+1,NTE
      NEND=K
      IF((SSURF(K)-SSURFE).GE.0.) GO TO 90
   85 CONTINUE
   90 DO 95 J=1,NSTART
   95 RNP(J)=RNPNEW(NSTART)
C
C.....DEFINITION OF MATCHING SURFACE FOR TURB. B.L. CALC. REGION.....
  130 IF(NORUN.GT.1) GO TO 62
C
C.....FOR FIRST SWEEP .....
      DO 60 J=NSTART+1,NEND
   60 RNP(J)=RNPNST
      GO TO 68
C
C.....AFTER FIRST SWEEP.....
   62 DO 64 J=NSTART,NEND
   64 RNP(J)=RNPNEW(NSTART)
C
C.....DEFINITION OF MATCHING SURFACE DOWNSTREAM OF TURB.B.L. CALC.
C     REGION.....
   68 RNPEND=RNP(NEND)
      DO 66 J=NEND,NTE-1
   66 RNP(J+1)=RNPEND
C
C.....COMPUTATION OF X-Y COORDS. FOR MATCHING SURFACE.....
      DO 70 J=1,NTE
      FACTOR=RNP(J)/SQRT(1.+GRAD(J)*GRAD(J))
      Y(J)=Y(J)+FACTOR
   70 X(J)=X(J)-FACTOR*GRAD(J)
      IF(NORUN.GT.2) GO TO 445
      WRITE(6,444)
  444 FORMAT(///1X,'MATCHING SURFACE COORDS. AT NODES'/)
      WRITE(6,222)  (X(J),Y(J),J=1,N+1)
C
C.....COMPUTE ARC LENGTHS OF MATCHING SURFACE AT NODES AND AT MID PTS.
C     OF ELEMENTS.....
  445 SS(1)=0.
      DO 140 K=1,NTE-1
      S(K)=X(K+1)-X(K)
      R(K)=Y(K+1)-Y(K)
      DS(K)=SQRT(R(K)*R(K)+S(K)*S(K))
  140 SS(K+1)=SS(K)+DS(K)
      SSM(1)=.5*DS(1)
      DO 150 J=2,NTE-1
  150 SSM(J)=SSM(J-1)+.5*(DS(J)+DS(J-1))
C.....COMPUTE ELEMENT LENGTHS FOR TOP SURFACE OF DUCT.....
      DO 155 J=NTE+NSIDE,NTE+NSIDE+NTOP-1
      XX=X(J+1)-X(J)
      YY=Y(J+1)-Y(J)
  155 DS(J)=SQRT(XX*XX+YY*YY)
C
C.....COMPUTE GRADIENTS OF MATCHING SURFACE AT NODES.....
      GRADM(1)=R(1)/S(1)
      DO 160 J=2,NTE-1
  160 GRADM(J)=.5*(R(J-1)/S(J-1)+R(J)/S(J))
      GRADM(NTE)=R(NTE-1)/S(NTE-1)
C
C.....COMPUTE VELOCITIES NORMAL TO MATCHING SURFACE, AT NODES.....
      CALL VMATCH(NTE)
```

```
      WRITE(6,777)
  777 FORMAT(//1X,'VELS. NORMAL TO MATCHING SURFACE AT NODES'/)
      WRITE(6,555)  (VMS(J),J=1,NTE)
C
C.....COMPUTE VELS. NORMAL TO MATCHING SURFACE AT MID PTS. OF ELMTS. ...
      DO 180 J=1,NTE-1
  180 UMS(J)=VALUE(SS(1),VMS(1),NTE,SSM(J),2)
      IF(NORUN.EQ.1) GO TO 187
      DO 185 J=NSTART,NEND
  185 UMS(J)=OMEGA*UMS(J)+(1.-OMEGA)*VMSOLD(J)
C.....REST OF DUCT.....
  187 DO 190 J=NTE+NSIDE,NTE+NSIDE+NTOP-1
  190 UMS(J)=.002
      DO 195 J=NTE+NSIDE+NTOP,NTE+2*NSIDE+NTOP-1
  195 UMS(J)=UINF
      BOT=0.
      TOP=0.
      DO 210 J=1,NTE-1
  210 BOT=BOT+UMS(J)*DS(J)
      DO 220 J=NTE+NSIDE,NTE+NSIDE+NTOP-1
  220 TOP=TOP+UMS(J)*DS(J)
      UEXIT=(UINF*(5.-RNP(1))+BOT+TOP)/(5.-RNP(NTE))
      DO 230 J=NTE,NTE+NSIDE-1
  230 UMS(J)=-UEXIT
C.....CORRECT FOR MASS FLOW, AT CORNERS.....
      READ(5,21)  (IEL(K),K=1,8)
      READ(5,10)  (VCORR(K),K=1,8)
      DO 200 K=1,8
      JEL=IEL(K)
  200 UMS(JEL)=UMS(JEL)+VCORR(K)
      WRITE(6,888)
  888 FORMAT(//1X,'VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.'
     1/)
      WRITE(6,555)  (UMS(J),J=1,N)
C
      N=N+1
      REWIND 12
      WRITE(12)  NORUN
      WRITE(12)  N,NTE,NSTART,NEND,(X(J),Y(J),J=1,N),(UMS(J),J=1,N-1),
     1(SSURF(J),J=1,NEND),(RNP(J),J=1,NEND),(SSM(J),J=1,NEND),
     2(SS(J),J=1,NEND)
      WRITE(12)  (SSURF(J),RNP(J),J=NEND+1,NTE)
C
      STOP
      END


      SUBROUTINE VMATCH(NTE)
      COMMON/MS/GRADM(62),UMS(61),VMS(61),VMSOLD(61)
      COMMON/RUN/NORUN
      COMMON/SSTNS/XCAL1(120),NSTPS1
      COMMON/BLCALC/NSTART,NEND,NSLOW,NENLOW
      COMMON/BLINV/UE(140),VE(140)
      COMMON/RS/SSURF(61),GRAD(62)
      COMMON/LAM/I2
C.....THIS SUBROUTINE MATCHES THE NORMAL VELOCITY OBTAINED FROM THE
C     BOUNDARY LAYER CALCULATION--N.B. THIS VELOCITY IS NORMAL TO THE
C     MATCHING SURFACE.....
C
C
C.....DEFINITION OF THE NORMAL VELOCITY FOR THE B.L. CALC. REGION.....
```

```
      IF(NORUN.GT.1) GO TO 9
C
C.....FIRST RUN OF INVISCID CALCULATION.....
      DO 2 J=NSTART,NEND
    2 VMS(J)=-.018
      GO TO 100
C
C.....AFTER FIRST RUN OF INVISCID+B.L. CALC. .....
    9 READ(14)  (UE(K),VE(K),K=NSTART,NSTART+NSTPS1)
      UE(NSTART+NSTPS1)=UE(NSTART+NSTPS1-1)
      VE(NSTART+NSTPS1)=VE(NSTART+NSTPS1-1)
C.....VELS. NORMAL AND PARALLEL TO REAL SURFACE AT NODES.....
      DO 50 J=NSTART,NEND-1
      VMS(J)=VALUE(XCAL1(1),VE(NSTART),NSTPS1+1,SSURF(J),1)
   50 UMS(J)=VALUE(XCAL1(1),UE(NSTART),NSTPS1+1,SSURF(J),1)
      UMS(NEND)=UMS(NEND-1)
      VMS(NEND)=VMS(NEND-1)
C.....COMPUTE VELS. NORMAL TO MATCHING SURFACE AT NODES.....
      DO 60 J=NSTART,NEND
      T=(GRADM(J)-GRAD(J))/(1.+GRADM(J)*GRAD(J))
   60 VMS(J)=(VMS(J)-T*UMS(J))/SQRT(1.+T*T)
C
C
C.....DEFINITION OF NORMAL VELOCITY UPSTREAM OF TURB. B.L. CALC.
C     REGION, AT MATCHING SURFACE NODES.....
  100 DO 110 J=1,NSTART-1
  110 VMS(J)=.002
C
C.....DEFINITION OF NORMAL VEL. DOWNSTREAM OF B.L. CALC. REGION.....
      DO 120 J=NEND+1,NTE
  120 VMS(J)=.002
      RETURN
      END
```

```
      FUNCTION VALUE(X,Y,N,XINT,IOPT)
      DIMENSION X(N),Y(N)
      IF(XINT.LT.X(1)-1.0E-8) PRINT 111
      IF(XINT.GT.X(N)+1.0E-8) PRINT 222
  111 FORMAT(1X,'WARNING-XINT LESS THAN X(1)-VALUE EXTRAPOLATED')
  222 FORMAT(1X,'WARNING-XINT GREATER THAN X(N)-VALUE EXTRAPOLATED')
      DO 2 J=1,N
      K=J
      IF((XINT-X(J)).LE.0.) GO TO 5
    2 CONTINUE
    5 IF(K.EQ.1) K=2
      IF(K.EQ.N.AND.IOPT.EQ.2) K=N-1
      XX1=XINT-X(K-1)
      XX2=XINT-X(K)
      DX1=X(K)-X(K-1)
      GO TO  (10,20),IOPT
C.....LINEAR INTERPOLATION.....
   10 VALUE=(-Y(K-1)*XX2+Y(K)*XX1)/DX1
      RETURN
C.....LAGRANGIAN QUADRATIC INTERPOLATION.....
   20 XX3=XINT-X(K+1)
      DX2=X(K+1)-X(K)
      DX=DX1+DX2
      VALUE=Y(K-1)*XX2*XX3/(DX*DX1)-Y(K)*XX1*XX3/(DX1*DX2)
     1+Y(K+1)*XX1*XX2/(DX*DX2)
      RETURN
```

```
      END
```

A6.5 Listing of Program SMOOTH

```
      PROGRAM SMOOTH(INPUT=132B,TAPE1=132B)
      DIMENSION PRESS(52,120),XCAL(120),DUM(120)
      DIMENSION UEXT(140),VEXT(140),RNPNEW(140)
      DIMENSION SSURF(51),SSMID(51),SSNODE(51),CPE(51),PA(51)
      DIMENSION XNODE(51),YNODE(51),XNEW(51)
C.....READ IN RELEVANT DATA.....
      READ(1) NSW12
      READ(1) N,NTE,NSTART,NEND,(DM,DM,J=1,N),(DM,J=1,N-1),
     1(SSURF(J),J=1,NEND),(DM,J=1,NEND),(SSMID(J),J=1,NEND),
     2(SSNODE(J),J=1,NEND)
      READ(1) NSW13
      READ(1) (CPE(J),J=1,NEND)
      READ(1) NSWP
      READ(1) I2,NSTART,YSTP
      N1=NSTART
      IF(I2.EQ.0) N1=1
      READ(1) NCOUNT,NCOUNT,(XCAL(I),I=1,NCOUNT+1),(XCAL(I),I=1,NCOUNT+1
     1)
      READ(1) (RNPNEW(I),I=N1,NSTART+NCOUNT)
      READ(1) (UEXT(I),VEXT(I),I=N1,NSTART+NCOUNT)
      READ(1) (UEXT(I),VEXT(I),I=N1,NSTART+NCOUNT)
      READ(1) (PRESS(1,NC),(PRESS(J,NC),J=2,52),NC=1,NCOUNT+1)
      M=NEND-NSTART+1
C
      READ ,ND,(XNODE(I),I=2,ND+1)
      NODES=ND+2
      XNODE(1)=XCAL(1)
      XNODE(NODES)=XCAL(NCOUNT+1)
C
      I62=RNPNEW(NSTART)/YSTP+.5
C
C.....SHIFT PRESSURE PROFILES ACCORDING TO NEW EXTERNAL PRESSURE.....
      DO 50 K=NSTART,NEND
   50 PA(K)=.5*SPLINE(SSMID,CPE,NEND,SSNODE(K))
      DO 80 NC=1,NCOUNT+1
      PE=SPLINE(SSURF(NSTART),PA(NSTART),M,XCAL(NC))
      PEOLD=PRESS(I62+1,NC)
   80 UEXT(NC)=PE-PEOLD
C
C
C..... S M O O T H I N G .....
      DO 140 MPT=1,I62+1
      DO 100 NC=1,NCOUNT+1
  100 DUM(NC)=PRESS(MPT,NC)+UEXT(NC)
      DO 110 I=1,NODES
  110 YNODE(I)=VALUE(XCAL,DUM,NCOUNT+1,XNODE(I),2)
      DO 120 NC=1,NCOUNT+1
  120 PRESS(MPT,NC)=SPLINE(XNODE,YNODE,NODES,XCAL(NC))
  140 CONTINUE
C
C
C.....OVER-WRITE DATA WITH SMOOTHED ARRAYS.....
      REWIND 1
```

```
      WRITE(1)  NSWP
      WRITE(1)  I2,NSTART,YSTP
      WRITE(1)  NCOUNT,NCOUNT,(XCAL(J),J=1,NCOUNT+1),(XCAL(J),J=1,NCOUNT
     1+1)
      WRITE(1)  (RNPNEW(J),J=N1,NSTART+NCOUNT)
      WRITE(1)  (UEXT(J),VEXT(J),J=N1,NSTART+NCOUNT)
      WRITE(1)  (UEXT(J),VEXT(J),J=N1,NSTART+NCOUNT)
      WRITE(1)  (PRESS(1,NC),(PRESS(J,NC),J=2,52),NC=1,NCOUNT+1)
C
      STOP
      END


      FUNCTION SPLINE(X,Y,M,XINT)
      DIMENSION X(M),Y(M),W(50),D(50)
      N=M-1
      CALL E01ADF(N,XINT,X,Y,W,D,M,VAL)
      SPLINE=VAL
      RETURN
      END


      FUNCTION VALUE(X,Y,N,XINT,IOPT)
      DIMENSION X(N),Y(N)
      IF(XINT.LT.X(1)-1.0E-8)  PRINT 111
      IF(XINT.GT.X(N)+1.0E-8)  PRINT 222
  111 FORMAT(1X,'WARNING-XINT LESS THAN X(1)-VALUE EXTRAPOLATED')
  222 FORMAT(1X,'WARNING-XINT GREATER THAN X(N)-VALUE EXTRAPOLATED')
      DO 2 J=1,N
      K=J
      IF((XINT-X(J)).LE.0.)  GO TO 5
    2 CONTINUE
    5 IF(K.EQ.1)  K=2
      IF(K.EQ.N.AND.IOPT.EQ.2)  K=N-1
      XX1=XINT-X(K-1)
      XX2=XINT-X(K)
      DX1=X(K)-X(K-1)
      GO TO  (10,20),IOPT
C.....LINEAR INTERPOLATION.....
   10 VALUE=(-Y(K-1)*XX2+Y(K)*XX1)/DX1
      RETURN
C.....LAGRANGIAN QUADRATIC INTERPOLATION.....
   20 XX3=XINT-X(K+1)
      DX2=X(K+1)-X(K)
      DX=DX1+DX2
      VALUE=Y(K-1)*XX2*XX3/(DX*DX1)-Y(K)*XX1*XX3/(DX1*DX2)
     1+Y(K+1)*XX1*XX2/(DX*DX2)
      RETURN
      END
```

A6.6

Listing of Program TRAVERS

```
      PROGRAM TRAVERS(OUTPUT=132B,TAPE12=132B,TAPE13=132B,TAPE14=132B,
     1TAPE5=132B,TAPE6=132B)
      DIMENSION SSURF(61),RNP(61),US(61),VN(61),UX(50),VY(50),DEL(10),
     1SSURFM(60),UTRAV(10),U(10)
C
C.....PROGRAM TO COMPUTE VELOCITY PROFILE AND MASS FLOW RATE AT
C     TRAVERSE STATIONS ACROSS THE DUCT.....
C
      PI=3.1415927
      READ(5,20) WIDTH
      READ(5,10) NTRAVS,NOFBOY
C
      READ (12) NORUN
      READ(12) N,NTE,NSTART,NEND,(DUM,DUM,J=1,N),(DUM,J=1,N-1),
     1(SSURF(J),J=1,NEND),(RNP(J),J=1,NEND),(DUM,J=1,NEND),
     2(DUM,J=1,NEND)
      READ(12) (SSURF(J),RNP(J),J=NEND+1,NTE)
C
      N2=(N-1)*(N-1)
      READ(13) NORUN
      READ(13) (DUM,J=1,NEND)
      IF(NORUN.GE.2) READ(13) (DUM,J=1,N2)
      READ(13) (US(I),VN(I),I=1,N-1),(UX(I),VY(I),I=1,NOFBOY)
      WRITE(6,111) NORUN
  111 FORMAT(//1X,'RUN NO.',I3,2X,'OF PROGRAM TRAVERS'/)
C
      SSURFM(1)=.5*SSURF(2)
      DO 50 J=2,NTE-1
   50 SSURFM(J)=.5*(SSURF(J)+SSURF(J+1))
C
      NTOT=0
      DO 200 ITRAV=1,NTRAVS
      READ(5,10) NPTS,IBOT,ITOP
      READ(5,20) THETA,(DEL(I),I=2,NPTS+1)
      IF(ITRAV.GT.1) NTOT=NTOT+NPTS
      DEL(1)=VALUE(SSURF,RNP,NTE,SSURFM(IBOT),1)
      DEL(NPTS+2)=WIDTH
      H=(WIDTH-DEL(1))/FLOAT(NPTS+1)
      UTRAV(1)=ABS(US(IBOT))
      UTRAV(NPTS+2)=ABS(US(ITOP))
      THETA=THETA*PI/180.
      C=COS(THETA)
      S=SIN(THETA)
      DO 100 I=2,NPTS+1
  100 UTRAV(I)=UX(NTOT+I-1)*S-VY(NTOT+I-1)*C
      WRITE(6,30) ITRAV
      WRITE(6,40) (DEL(I),UTRAV(I),I=1,NPTS+2)
      DO 150 I=1,NPTS+2
      DELINT=DEL(1)+H*FLOAT(I-1)
  150 U(I)=VALUE(DEL,UTRAV,NPTS+2,DELINT,2)
      RMASS=SIMPSN(U,1,NPTS+2,H)
      WRITE(6,45) RMASS
  200 CONTINUE
C
   10 FORMAT(3I5)
   20 FORMAT(8F10.0)
   30 FORMAT(//1X,'VELOCITY PROFILE ACROSS DUCT AT STATION NO.',I3/
     17X,'YNORM',12X,'U')
   40 FORMAT(1X,2E15.5)
   45 FORMAT(/1X,'MASS FLOW RATE=',E15.5)
      STOP
      END
```

```
      FUNCTION SIMPSN (FR,IB,M,H)
      DIMENSION FR(61)
C.....SIMPSONS RULE INTEGRATION WITH EQUAL INTERVALS.....
      N=M
      IA=IB
      N1=N-1
      IF((N-IA).NE.2*((N-IA)/2)) GO TO 110
      S=0.
      DO 100 I=IA,N1,2
  100 S=S+FR(I)+4.*FR(I+1)+FR(I+2)
      GO TO 130
  110 S=  (5.*FR(IA)+8.*FR(IA+1)-FR(IA+2))/4.
      IA1=IA+1
      DO 120 I=IA1,N1,2
  120 S=S+FR(I)+4.*FR(I+1)+FR(I+2)
  130 SIMPSN=S*H/3.
      RETURN
      END
```

```
      FUNCTION VALUE(X,Y,N,XINT,IOPT)
      DIMENSION X(N),Y(N)
      IF(XINT.LT.X(1)-1.0E-8) PRINT 111
      IF(XINT.GT.X(N)+1.0E-8) PRINT 222
  111 FORMAT(1X,'WARNING-XINT LESS THAN X(1)-VALUE EXTRAPOLATED')
  222 FORMAT(1X,'WARNING-XINT GREATER THAN X(N)-VALUE EXTRAPOLATED')
      DO 2 J=1,N
      K=J
      IF((XINT-X(J)).LE.0.) GO TO 5
    2 CONTINUE
    5 IF(K.EQ.1) K=2
      IF(K.EQ.N.AND.IOPT.EQ.2) K=N-1
      XX1=XINT-X(K-1)
      XX2=XINT-X(K)
      DX1=X(K)-X(K-1)
      GO TO (10,20),IOPT
C.....LINEAR INTERPOLATION.....
   10 VALUE=(-Y(K-1)*XX2+Y(K)*XX1)/DX1
      RETURN
C.....LAGRANGIAN QUADRATIC INTERPOLATION.....
   20 XX3=XINT-X(K+1)
      DX2=X(K+1)-X(K)
      DX=DX1+DX2
      VALUE=Y(K-1)*XX2*XX3/(DX*DX1)-Y(K)*XX1*XX3/(DX1*DX2)
     1+Y(K+1)*XX1*XX2/(DX*DX2)
      RETURN
      END
```

APPENDIX A7

Computer Printouts for Test Cases

A7.1 Printout of Ten Iterations for the Curved Duct Calculation.

A7.2 Printout of Ten Iterations for the Aerofoil Calculation.

A7.1 Printout of Ten Iterations for the Curved Duct Calculation

RUN NO. 1 OF PROGRAM MATCH

REAL SURFACE COORDS. AT NODES

0	0
.2000E+01	0
.4000E+01	0
.6000E+01	0
.8000E+01	0
.1000E+02	0
.1100E+02	0
.1200E+02	0
.1300E+02	0
.1344E+02	-.1900E-01
.1387E+02	-.7600E-01
.1429E+02	-.1700E+00
.1471E+02	-.3020E+00
.1511E+02	-.4690E+00
.1550E+02	-.6700E+00
.1637E+02	-.1170E+01
.1722E+02	-.1670E+01
.1810E+02	-.2170E+01
.1983E+02	-.3170E+01
.2156E+02	-.4170E+01
.2329E+02	-.5170E+01
.2503E+02	-.6170E+01
.2676E+02	-.7170E+01
.2849E+02	-.8170E+01
.2964E+02	-.6176E+01
.3009E+02	-.5393E+01
.3054E+02	-.4619E+01
.3099E+02	-.3840E+01
.2926E+02	-.2940E+01
.2753E+02	-.1840E+01
.2579E+02	-.8400E+00
.2406E+02	.1600E+00
.2233E+02	.1160E+01
.2060E+02	.2160E+01
.1800E+02	.3660E+01
.1723E+02	.4063E+01
.1642E+02	.4397E+01
.1559E+02	.4659E+01
.1474E+02	.4843E+01
.1387E+02	.4962E+01
.1300E+02	.5000E+01
.1000E+02	.5000E+01
.8000E+01	.5000E+01
.6000E+01	.5000E+01
.4000E+01	.5000E+01
.2000E+01	.5000E+01
0	.5000E+01
0	.4050E+01
0	.3100E+01
0	.2150E+01
0	0

MATCHING SURFACE COORDS. AT NODES

0	.1200E+01
.2000E+01	.1200E+01
.4000E+01	.1200E+01
.6000E+01	.1200E+01
.8000E+01	.1200E+01
.1000E+02	.1200E+01
.1100E+02	.1200E+01
.1200E+02	.1200E+01
.1303E+02	.1200E+01
.1354E+02	.1176E+01
.1408E+02	.1106E+01
.1461E+02	.9888E+00
.1512E+02	.8249E+00
.1562E+02	.6183E+00
.1608E+02	.3822E+00
.1697E+02	-.1308E+00
.1783E+02	-.6308E+00
.1870E+02	-.1131E+01
.2043E+02	-.2131E+01
.2216E+02	-.3131E+01
.2389E+02	-.4131E+01
.2563E+02	-.5131E+01
.2736E+02	-.6131E+01
.2909E+02	-.7131E+01
.2964E+02	-.6178E+01
.3009E+02	-.5399E+01
.3054E+02	-.4619E+01
.3099E+02	-.3840E+01
.2926E+02	-.2840E+01
.2753E+02	-.1840E+01
.2579E+02	-.8400E+00
.2406E+02	.1600E+00
.2233E+02	.1160E+01
.2060E+02	.2160E+01
.1800E+02	.3650E+01
.1723E+02	.4063E+01
.1642E+02	.4397E+01
.1559E+02	.4659E+01
.1474E+02	.4848E+01
.1387E+02	.4962E+01
.1300E+02	.5000E+01
.1000E+02	.5000E+01
.8000E+01	.5000E+01
.6000E+01	.5000E+01
.4000E+01	.5000E+01
.2000E+01	.5000E+01
0	.5000E+01
0	.4050E+01
0	.3100E+01
0	.2150E+01
0	0

VELS. NØRMAL TØ MATCHING SURFACE AT NØDES

.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01
-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01
.2000E-02	.2000E-02	.2000E-02	.2000E-02						

VELS. NØRMAL TØ MATCHING SURFACE AT ELEMENT MID PTS.

.5200E-01	.2000E-02	.2000E-02	.4500E-02	-.1133E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01

-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.1800E-01	-.2050E-01	-.5500E-02
.2000E-02	.2000E-02	-.4800E-01	-.1213E+01	-.1053E+01	-.1053E+01	-.1213E+01	-.4800E-01	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.5200E-01	.1260E+01	.1100E+01	.1100E+01	.1260E+01

RUN NO. 1 OF PROGRAM AMOS

REFERENCE LENGTH= 1.0000

X	Y	SSM	CP	U (TANG)	V (NORM)
1.00000	1.20000	1.00000	-.48354	1.21801	.05200
3.00000	1.20000	3.00000	-.18371	1.08798	.00200
5.00000	1.20000	5.00000	-.15231	1.07346	.00200
7.00000	1.20000	7.00000	-.17537	1.08415	.00450
9.00000	1.20000	9.00000	-.19332	1.09239	-.01133
10.50000	1.20000	10.50000	-.24207	1.11448	-.01800
11.50000	1.20000	11.50000	-.26302	1.12384	-.01800
12.51307	1.19986	12.51307	-.35699	1.16490	-.01800
13.28353	1.18806	13.28379	-.58574	1.25966	-.01800
13.80863	1.14109	13.81148	-.71149	1.30824	-.01800
14.34102	1.04729	14.35257	-.75852	1.32609	-.01800
14.86400	.90688	14.89461	-.75137	1.32339	-.01800
15.37149	.72164	15.43534	-.68956	1.29983	-.01800
15.94832	.50025	15.96200	-.56269	1.25007	-.01800
16.52150	.12570	16.73210	-.34223	1.15855	-.01800
17.39901	-.38078	17.74529	-.20207	1.09539	-.01800
18.26501	-.68078	18.74527	-.14698	1.07097	-.01600
19.56401	-1.63078	20.24524	-.10423	1.05082	-.01800
21.29601	-2.63078	22.24519	-.06621	1.03258	-.02050
23.02801	-3.63078	24.24515	-.04160	1.02059	-.00550
24.76001	-4.63078	26.24510	-.03344	1.01658	.00200
26.49201	-5.63078	28.24506	-.01467	1.00731	.00200
28.22401	-6.63078	30.24502	.34200	.81117	-.04800
29.36501	-6.65439	31.79505	-.59198	1.26174	-1.21326
29.86500	-5.79350	32.79493	-.10942	1.05329	-1.05326
30.31500	-5.00900	33.69500	-.11002	-1.05358	-1.05326
30.76500	-4.22950	34.59507	-.59284	-1.26208	-1.21326
30.12400	-3.34000	36.04486	.31173	-.82962	-.04800
28.39200	-2.34000	38.04482	-.01239	-1.00618	.00200
26.65000	-1.34000	40.04477	-.03118	-1.01547	.00200
24.92800	-.34000	42.04473	-.04238	-1.02097	.00200
23.19600	.66000	44.04469	-.05365	-1.02647	.00200
21.46400	1.66000	46.04464	-.06433	-1.03166	.00200
19.29900	2.91000	48.54459	.04858	-.97541	.00200
17.61300	3.66150	50.48087	.10149	-.94790	.00200
16.82300	4.23000	51.35342	.17014	-.91097	.00200
16.00400	4.52800	52.22579	.18635	-.90203	.00200
15.16250	4.75350	53.09779	.17793	-.90668	.00200
14.30450	4.90500	53.96990	.14193	-.92632	.00200
13.43600	4.98100	54.84255	.04210	-.97872	.00200
11.50000	5.00000	56.77897	-.06031	-1.02971	.00200
9.00000	5.00000	59.27897	-.16144	-1.07770	.00200
7.00000	5.00000	61.27897	-.14410	-1.06952	.00200
5.00000	5.00000	63.27897	-.08950	-1.04379	.00200
3.00000	5.00000	65.27897	.08274	-.95774	.00200
1.00000	5.00000	67.27897	.93602	-.25295	.05200
0	4.52500	68.75397	-2.61037	-1.90010	1.26000
0	3.57500	69.70397	-.40260	-1.18431	1.10000
0	2.62500	70.65397	-.35733	-1.16505	1.10000
0	1.07500	72.20397	-5.77917	2.60368	1.26000

ØFF-BØDY PØINTS

X	Y	U	V	CP
5.00000	2.15000	1.10386	.00782	-.21856
5.00000	3.10000	1.09943	.00794	-.20880
5.00000	4.05000	1.09073	.00317	-.18971
9.00000	2.15000	1.10781	-.00802	-.22731
9.00000	3.10000	1.10511	-.00634	-.22130
9.00000	4.05000	1.10138	-.00380	-.21306
21.84600	-1.67800	.89534	-.53157	-.08420
22.29600	-.89900	.69877	-.52863	-.08724
22.74600	-.11900	.89999	-.52547	-.08609
25.31000	-3.67800	.89459	-.51788	-.06849
25.76000	-2.89900	.89577	-.51886	-.07162
26.21000	-2.11900	.89537	-.51849	-.07052

RUN NØ. 1 ØF PRØGRAM TRAVERS

VELØCITY PRØFILE ACRØSS DUCT AT STATIØN NØ. 1

YNØRM	U
.12000E+01	.10735E+01
.21500E+01	.11039E+01
.31000E+01	.10994E+01
.40500E+01	.10907E+01
.50000E+01	.10438E+01

MASS FLØW RATE= .41466E+01

VELØCITY PRØFILE ACRØSS DUCT AT STATIØN NØ. 2

YNØRM	U
.12000E+01	.10924E+01
.21500E+01	.11078E+01
.31000E+01	.11051E+01
.40500E+01	.11014E+01
.50000E+01	.10777E+01

MASS FLØW RATE= .41854E+01

VELØCITY PRØFILE ACRØSS DUCT AT STATIØN NØ. 3

YNØRM	U
.12000E+01	.10326E+01
.23000E+01	.10412E+01
.32000E+01	.10427E+01
.41000E+01	.10421E+01
.50000E+01	.10265E+01

MASS FLØW RATE= .39508E+01

VELØCITY PRØFILE ACRØSS DUCT AT STATIØN NØ. 4

YNØRM	U
.12000E+01	.10166E+01
.23000E+01	.10337E+01
.32000E+01	.10352E+01
.41000E+01	.10347E+01
.50000E+01	.10155E+01

MASS FLØW RATE= .39179E+01

```
RUN NO.  1  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS CYCLE--S.YOUNG TEST CASE

1977    1   10   99   46   34    0     0     1     0    51     0    -2     0
A                  0  6.000E-01              0  6.256E+04  1.375E-03  3.000E-01  3.000E-01
X FOR CURV. B. VALUE               0  4.000E+00  8.000E+00  1.000E+01  1.200E+01  1.220E+01  1.240E+01
 1.260E+01  1.280E+01  1.290E+01  1.300E+01  1.310E+01  1.320E+01  1.340E+01
 1.360E+01  1.380E+01  1.400E+01  1.420E+01  1.440E+01  1.460E+01  1.480E+01
 1.500E+01  1.520E+01  1.540E+01  1.550E+01  1.560E+01  1.570E+01  1.580E+01
 1.600E+01  1.620E+01  1.640E+01  1.660E+01  1.700E+01  1.900E+01  2.100E+01
 2.200E+01  2.250E+01  2.300E+01  2.350E+01  2.400E+01  2.450E+01  2.500E+01
 2.550E+01  2.600E+01  2.650E+01  2.700E+01
CURV               0          0          0          0          0  2.000E-02  4.000E-02
 6.000E-02  8.000E-02  9.000E-02  1.000E-01  1.100E-01  1.200E-01  1.400E-01
 1.600E-01  1.800E-01  2.000E-01  2.000E-01  2.000E-01  2.000E-01  1.800E-01
 1.600E-01  1.400E-01  1.200E-01  1.100E-01  1.000E-01  9.000E-02  8.000E-02
 6.000E-02  4.000E-02  2.000E-02          0          0          0          0
         0          0          0          0          0          0          0
         0          0          0          0
X FOR PRESS. AND NP B. VALUES             0   2.0000E+00   4.0000E+00   6.0000E+00   8.0000E+00   1.0000E+01   1.1000E+01
  1.2000E+01   1.3000E+01   1.3436E+01   1.3872E+01   1.4308E+01   1.4745E+01   1.5181E+01
  1.5517E+01   1.6617E+01   1.7617E+01   1.8617E+01   2.0617E+01   2.2617E+01
PE-PREF        5.0000E-01  -1.5414E-01  -7.1691E-02  -8.3305E-02  -8.9694E-02  -1.1314E-01  -1.2653E-01
 -1.4197E-01  -2.5281E-01  -3.2836E-01  -3.7192E-01  -3.8043E-01  -3.6434E-01  -3.1580E-01
 -2.4304E-01  -1.2557E-01  -8.4955E-02  -6.4802E-02  -4.1749E-02  -2.6402E-02
NP   1.2000E+00   1.2000E+00   1.2000E+00   1.2000E+00   1.2000E+00   1.2000E+00.  1.2000E+00
  1.2000E+00   1.2000E+00   1.2000E+00   1.2000E+00   1.2000E+00   1.2000E+00   1.2000E+00
  1.2000E+00   1.2000E+00   1.2000E+00   1.2000E+00   1.2000E+00   1.2000E+00

STN.          X       YSTEP        CF         UE    DEL05       THETA    SCHMETA         H    RTHETA      I6
   1  .1000E+02  .3333E-01    .002750  .1107E+01  .8208E+00  .9627E-01  .9627E-01    1.37720  .6670E+04     34

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0          0          0          0          0

STN.          X       YSTEP        CF         UE    DEL05       THETA    SCHMETA         H    RTHETA      I6
   2  .1025E+02  .3333E-01    .002594  .1111E+01  .8111E+00  .8867E-01  .9614E-01    1.47813  .6165E+04     34

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0          0          0          0          0

STN.          X       YSTEP        CF         UE    DEL05       THETA    SCHMETA         H    RTHETA      I6
  10  .1232E+02  .3333E-01    .003245  .1153E+01  .8013E+00  .6100E-01  .8936E-01    1.94508  .4399E+04     34

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .2580E-01          0          0          0

STN.          X       YSTEP        CF         UE    DEL05       THETA    SCHMETA         H    RTHETA      I6
  20  .1312E+02  .3333E-01    .004085  .1244E+01  .7442E+00  .5790E-01  .5924E-01    1.54323  .4505E+04     34

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .8315E-01          0          0          0

STN.          X       YSTEP        CF         UE    DEL05       THETA    SCHMETA         H    RTHETA      I6
  30  .1368E+02  .3333E-01    .004290  .1310E+01  .6882E+00  .4862E-01  .3135E-01    1.48300  .3983E+04     34

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1155E+00          0          0          0

STN.          X       YSTEP        CF         UE    DEL05       THETA    SCHMETA         H    RTHETA      I6
```

```
 40  .1524E+02  .3333E-01    .002864  .1270E+01  .6779E+00  .7854E-01  .1827E-01    1.03223  .6239E+04      34

 RGUGH/D05     D05/RAD D05/(X-XD) STRAIN.D05        VW/UE
         0  .9191E-01          0          0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA          H     RTHETA      I6
 50  .1574E+02  .3333E-01    .002140  .1203E+01  .7461E+00  .8880E-01  .2073E-01    1.20929  .6681E+04      34

 RGUGH/D05     D05/RAD D05/(X-XD) STRAIN.D05        VW/UE
         0  .6399E-01          0          0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA          H     RTHETA      I6
 60  .1623E+02  .3333E-01    .001707  .1149E+01  .8107E+00  .1007E+00  .2530E-01    1.30888  .7241E+04      34

 RGUGH/D05     D05/RAD D05/(X-XD) STRAIN.D05        VW/UE
         0  .3011E-01          0          0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA          H     RTHETA      I6
 70  .1690E+02  .3333E-01    .001492  .1103E+01  .8712E+00  .1153E+00  .3296E-01    1.41188  .7960E+04      34

 RGUGH/D05     D05/RAD D05/(X-XD) STRAIN.D05        VW/UE
         0          0          0          0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA          H     RTHETA      I6
 80  .1815E+02  .3333E-01    .001582  .1071E+01  .8936E+00  .1287E+00  .4363E-01    1.47109  .8621E+04      34

 RGUGH/D05     D05/RAD D05/(X-XD) STRAIN.D05        VW/UE
         0          0          0          0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA          H     RTHETA      I6
 90  .1969E+02  .3333E-01    .001744  .1049E+01  .9258E+00  .1384E+00  .5614E-01    1.49900  .9084E+04      34

 RGUGH/D05     D05/RAD D05/(X-XD) STRAIN.D05        VW/UE
         0          0          0          0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA          H     RTHETA      I6
 99  .2131E+02  .3333E-01    .001846  .1036E+01  .9849E+00  .1462E+00  .6846E-01    1.50229  .9474E+04      34

 RGUGH/D05     D05/RAD D05/(X-XD) STRAIN.D05        VW/UE
         0          0          0          0            0

X=
   .1000E+02  .1025E+02  .1049E+02  .1075E+02  .1102E+02  .1128E+02  .1155E+02  .1181E+02  .1207E+02  .1232E+02
   .1249E+02  .1260E+02  .1269E+02  .1277E+02  .1283E+02  .1290E+02  .1295E+02  .1301E+02  .1307E+02  .1312E+02
   .1317E+02  .1322E+02  .1327E+02  .1332E+02  .1337E+02  .1342E+02  .1348E+02  .1354E+02  .1361E+02  .1368E+02
   .1376E+02  .1385E+02  .1396E+02  .1410E+02  .1429E+02  .1457E+02  .1483E+02  .1504E+02  .1516E+02  .1524E+02
   .1531E+02  .1537E+02  .1542E+02  .1547E+02  .1552E+02  .1556E+02  .1561E+02  .1565E+02  .1570E+02  .1574E+02
   .1579E+02  .1583E+02  .1588E+02  .1593E+02  .1597E+02  .1602E+02  .1607E+02  .1612E+02  .1618E+02  .1623E+02
   .1628E+02  .1634E+02  .1640E+02  .1646E+02  .1653E+02  .1659E+02  .1666E+02  .1674E+02  .1682E+02  .1690E+02
   .1699E+02  .1709E+02  .1720E+02  .1731E+02  .1743E+02  .1756E+02  .1770E+02  .1765E+02  .1800E+02  .1815E+02
   .1830E+02  .1845E+02  .1860E+02  .1875E+02  .1890E+02  .1905E+02  .1921E+02  .1936E+02  .1952E+02  .1969E+02
   .1965E+02  .2003E+02  .2020E+02  .2038E+02  .2056E+02  .2075E+02  .2093E+02  .2112E+02  .2131E+02  .2149E+02

VE/UE=
  -.2030E-01 -.1621E-01 -.1898E-01 -.1632E-01 -.1279E-01 -.8094E-02 -.8537E-02 -.1641E-01 -.3304E-01 -.5532E-01
  -.7676E-01 -.9456E-01 -.1088E+00 -.1200E+00 -.1290E+00 -.1362E+00 -.1420E+00 -.1468E+00 -.1506E+00 -.1527E+00
  -.1531E+00 -.1519E+00 -.1490E+00 -.1446E+00 -.1386E+00 -.1310E+00 -.1217E+00 -.1114E+00 -.1003E+00 -.8865E-01
  -.7646E-01 -.6363E-01 -.5002E-01 -.3569E-01 -.2060E-01 -.3646E-02  .1968E-01  .4786E-01  .7470E-01  .9739E-01
   .1159E+00  .1305E+00  .1418E+00  .1503E+00  .1565E+00  .1610E+00  .1637E+00  .1650E+00  .1652E+00  .1647E+00
   .1636E+00  .1623E+00  .1606E+00  .1587E+00  .1565E+00  .1543E+00  .1517E+00  .1489E+00  .1460E+00  .1427E+00
   .1392E+00  .1353E+00  .1311E+00  .1264E+00  .1213E+00  .1156E+00  .1093E+00  .1023E+00  .9493E-01  .8731E-01
   .7977E-01  .7211E-01  .6454E-01  .5754E-01  .5114E-01  .4580E-01  .4194E-01  .3916E-01  .3693E-01  .3504E-01
   .3331E-01  .3165E-01  .3000E-01  .2836E-01  .2669E-01  .2513E-01  .2364E-01  .2224E-01  .2094E-01  .1974E-01
   .1864E-01  .1765E-01  .1678E-01  .1604E-01  .1544E-01  .1499E-01  .1465E-01  .1437E-01  .1415E-01
```

(PW-PREF) /UREF**2=

-.1131E+00	-.1173E+00	-.1227E+00	-.1220E+00	-.1231E+00	-.1254E+00	-.1330E+00	-.1458E+00	-.1650E+00	-.2009E+00
-.2331E+00	-.2546E+00	-.2689E+00	-.2795E+00	-.2888E+00	-.2976E+00	-.3066E+00	-.3152E+00	-.3214E+00	-.3253E+00
-.3284E+00	-.3313E+00	-.3343E+00	-.3376E+00	-.3414E+00	-.3459E+00	-.3527E+00	-.3628E+00	-.3750E+00	-.3884E+00
-.4024E+00	-.4168E+00	-.4316E+00	-.4456E+00	-.4528E+00	-.4441E+00	-.4127E+00	-.3566E+00	-.3160E+00	-.2926E+00
-.2805E+00	-.2759E+00	-.2748E+00	-.2744E+00	-.2743E+00	-.2740E+00	-.2735E+00	-.2714E+00	-.2671E+00	-.2612E+00
-.2546E+00	-.2476E+00	-.2403E+00	-.2329E+00	-.2255E+00	-.2181E+00	-.2108E+00	-.2036E+00	-.1965E+00	-.1894E+00
-.1825E+00	-.1757E+00	-.1691E+00	-.1625E+00	-.1561E+00	-.1498E+00	-.1443E+00	-.1397E+00	-.1346E+00	-.1289E+00
-.1232E+00	-.1178E+00	-.1120E+00	-.1061E+00	-.1001E+00	-.9386E-01	-.8806E-01	-.8333E-01	-.7940E-01	-.7595E-01
-.7286E-01	-.7004E-01	-.6742E-01	-.6500E-01	-.6263E-01	-.6028E-01	-.5806E-01	-.5591E-01	-.5385E-01	-.5186E-01
-.4993E-01	-.4805E-01	-.4625E-01	-.4449E-01	-.4276E-01	-.4107E-01	-.3945E-01	-.3789E-01	-.3629E-01	-.3484E-01

(PW-PE) /UREF**2=

0	.2507E-03	-.1347E-02	.2642E-02	.3543E-02	.1839E-02	-.3990E-02	-.1156E-01	-.1920E-01	-.3648E-01
-.5250E-01	-.6083E-01	-.6362E-01	-.6370E-01	-.6283E-01	-.6192E-01	-.6132E-01	-.6033E-01	-.5709E-01	-.5172E-01
-.4562E-01	-.3938E-01	-.3345E-01	-.2802E-01	-.2320E-01	-.1923E-01	-.1791E-01	-.2017E-01	-.2477E-01	-.3083E-01
-.3794E-01	-.4601E-01	-.5551E-01	-.6579E-01	-.7221E-01	-.7009E-01	-.5484E-01	-.2169E-01	.2889E-02	.1343E-01
.1458E-01	.9356E-02	.1424E-02	-.6729E-02	-.1471E-01	-.2220E-01	-.2916E-01	-.3434E-01	-.3707E-01	-.3800E-01
-.3816E-01	-.3785E-01	-.3709E-01	-.3514E-01	-.3506E-01	-.3396E-01	-.3278E-01	-.3162E-01	-.3048E-01	-.2929E-01
-.2812E-01	-.2700E-01	-.2588E-01	-.2475E-01	-.2359E-01	-.2244E-01	-.2197E-01	-.2219E-01	-.2175E-01	-.2043E-01
-.1894E-01	-.1749E-01	-.1548E-01	-.1319E-01	-.1054E-01	-.7645E-02	-.5144E-02	-.3693E-02	-.2969E-02	-.2594E-02
-.2428E-02	-.2365E-02	-.2348E-02	-.2370E-02	-.2288E-02	-.2110E-02	-.1946E-02	-.1763E-02	-.1583E-02	-.1401E-02
-.1221E-02	-.1052E-02	-.8896E-03	-.7167E-03	-.5424E-03	-.3968E-03	-.3015E-03	-.2375E-03	-.9225E-04	-.9225E-04

SWEEP NO. 1 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NØ. 2 ØF PRØGRAM MATCH

MATCHING SURFACE CØØRDS. AT NØDES

0	.1300E+01
.2000E+01	.1300E+01
.4000E+01	.1300E+01
.6000E+01	.1300E+01
.8000E+01	.1300E+01
.1000E+02	.1300E+01
.1100E+02	.1300E+01
.1200E+02	.1300E+01
.1303E+02	.1300E+01
.1355E+02	.1276E+01
.1409E+02	.1204E+01
.1463E+02	.1085E+01
.1516E+02	.9189E+00
.1566E+02	.7069E+00
.1613E+02	.4699E+00
.1702E+02	-.4418E-01
.1788E+02	-.5442E+00
.1875E+02	-.1044E+01
.2046E+02	-.2044E+01
.2221E+02	-.3044E+01
.2394E+02	-.4044E+01
.2568E+02	-.5044E+01
.2741E+02	-.6044E+01
.2914E+02	-.7044E+01
.2964E+02	-.6178E+01
.3009E+02	-.5399E+01
.3054E+02	-.4619E+01
.3099E+02	-.3840E+01
.2926E+02	-.2840E+01
.2753E+02	-.1840E+01
.2579E+02	-.8400E+00
.2406E+02	.1600E+00
.2233E+02	.1160E+01
.2060E+02	.2160E+01
.1800E+02	.3660E+01
.1723E+02	.4063E+01
.1642E+02	.4397E+01
.1559E+02	.4659E+01
.1474E+02	.4848E+01
.1387E+02	.4962E+01
.1300E+02	.5000E+01
.1000E+02	.5000E+01
.8000E+01	.5000E+01
.6000E+01	.5000E+01
.4000E+01	.5000E+01
.2000E+01	.5000E+01
0	.5000E+01
0	.4050E+01
0	.3100E+01
0	.2150E+01
0	0

VELS. NØRMAL TØ MATCHING SURFACE AT NØDES

.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	-.2248E-01	-.1456E-01	-.3228E-01	-.1776E+00	-.1650E+00
-.8048E-01	-.2577E-01	.1599E-01	.1016E+00	.1987E+00	.1268E+00	.4796E-01	.3170E-01	.1593E-01	.1593E-01
.2000E-02	.2000E-02	.2000E-02	.2000E-02						

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.8200E-01	.2000E-02	.2000E-02	.5060E-02	-.1696E-01	-.1719E-01	-.1505E-01	-.5256E-01	-.6647E-01	-.4830E-01
-.2805E-01	-.1573E-01	.4401E-02	.3582E-01	.3657E-01	.1126E-01	-.8597E-03	-.6046E-02	-.9047E-02	-.1682E-02
.2000E-02	.2000E-02	-.7800E-01	-.1321E+01	-.1081E+01	-.1081E+01	-.1321E+01	-.7800E-01	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.8200E-01	.1340E+01	.1100E+01	.1100E+01	.1340E+01

RUN NO. 2 OF PROGRAM AMOS

REFERENCE LENGTH= 1.0000

X	Y	SSM	CP	U (TANG)	V (NORM)
1.00000	1.30000	1.00000	-.33503	1.15543	.08200
3.00000	1.30000	3.00000	-.16869	1.08106	.00200
5.00000	1.30000	5.00000	-.15476	1.07460	.00200
7.00000	1.30000	7.00000	-.18380	1.08802	.00506
9.00000	1.30000	9.00000	-.19811	1.09458	-.01696
10.50000	1.30000	10.50000	-.23830	1.11279	-.01719
11.50000	1.30000	11.50000	-.28053	1.13160	-.01505
12.51416	1.29985	12.51416	-.36499	1.16933	-.05256
13.28699	1.28786	13.28325	-.52674	1.23561	-.06647
13.82168	1.24014	13.82458	-.59114	1.26140	-.04830
14.35269	1.14482	14.37443	-.61493	1.27080	-.02805
14.89416	1.00212	14.92528	-.60029	1.26503	-.01573
15.40981	.81390	15.47471	-.54094	1.24135	.00440
15.89402	.58940	16.00890	-.45817	1.20755	.03582
16.57054	.21284	16.78335	-.32240	1.14996	.03557
17.44901	-.29418	17.79764	-.23534	1.11146	.01126
18.31501	-.79418	18.79762	-.19115	1.09140	-.00086
19.61401	-1.54418	20.29758	-.14612	1.07057	-.00605
21.34601	-2.54418	22.29754	-.11979	1.05820	-.00905
23.07801	-3.54418	24.29749	-.10203	1.04978	-.00168
24.81001	-4.54418	26.29745	-.08920	1.04355	.00200
26.54201	-5.54418	28.29741	-.06109	1.03009	.00200
28.27401	-6.54418	30.29736	.42682	.75709	-.07800
29.39001	-6.61109	31.79740	-1.01080	1.41803	-1.32124
29.86500	-5.76650	32.74726	-.16951	1.08144	-1.08124
30.31500	-5.00900	33.64735	-.17005	-1.08169	-1.08124
30.76500	-4.22950	34.54741	-1.00465	-1.41586	-1.32124
30.12400	-3.34000	35.99721	.40276	-.77281	-.07800
28.39200	-2.34000	37.99716	-.05645	-1.02861	.00200
26.66000	-1.34000	39.99712	-.08421	-1.04125	.00200
24.92800	-.34000	41.99708	-.09635	-1.04707	.00200
23.19600	.66000	43.99703	-.10262	-1.05006	.00200
21.46400	1.66000	45.99699	-.10300	-1.05024	.00200
19.29900	2.91000	48.49693	.02667	-.98657	.00200
17.61300	3.85150	50.43322	.10216	-.94754	.00200
16.82300	4.23000	51.30576	.17705	-.90717	.00200
16.00400	4.52800	52.17813	.19699	-.89511	.00200
15.16250	4.75350	53.05014	.19041	-.69977	.00200
14.30450	4.90500	53.92225	.15539	-.91903	.00200
13.43500	4.98100	54.79450	.05735	-.97090	.00200
11.50000	5.00000	56.73131	-.04882	-1.02412	.00200
9.00000	5.00000	59.23131	-.16282	-1.07834	.00200
7.00000	5.00000	61.23131	-.15176	-1.07320	.00200

5.00000	5.00000	63.23131	-.10822	-1.05272	.00200
3.00000	5.00000	65.23131	.02547	-.98718	.00200
1.00000	5.00000	67.23131	.86444	-.36818	.08200
0	4.52500	68.70631	-2.33246	-1.82550	1.34000
0	3.57500	69.65631	-.30825	-1.14379	1.10000
0	2.62500	70.60631	-.26816	-1.12613	1.10000
0	1.07500	72.15631	-4.98821	2.44708	1.34000

OFF-BODY POINTS

X	Y	U	V	CP
5.00000	2.15000	1.10271	.00509	-.21599
5.00000	3.10000	1.10136	.00459	-.21301
5.00000	4.05000	1.09521	.00097	-.19948
9.00000	2.15000	1.10800	-.01137	-.22780
9.00000	3.10000	1.10540	-.00809	-.22198
9.00000	4.05000	1.10154	-.00457	-.21341
21.84600	-1.67800	.92219	-.53901	-.14096
22.29600	-.89900	.92370	-.53778	-.14243
22.74600	-.11900	.92311	-.53616	-.13961
25.31000	-3.67800	.92154	-.53271	-.13302
25.76000	-2.89900	.92262	-.53351	-.13585
26.21000	-2.11900	.92168	-.53295	-.13352

RUN NO. 2 OF PROGRAM TRAVERS

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 1

YNORM	U
.13000E+01	.10746E+01
.21500E+01	.11027E+01
.31000E+01	.11014E+01
.40500E+01	.10952E+01
.50000E+01	.10527E+01

MASS FLOW RATE= .40455E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 2

YNORM	U
.13000E+01	.10945E+01
.21500E+01	.11080E+01
.31000E+01	.11054E+01
.40500E+01	.11015E+01
.50000E+01	.10783E+01

MASS FLOW RATE= .40763E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 3

YNORM	U
.13000E+01	.10582E+01
.23000E+01	.10681E+01
.32000E+01	.10688E+01
.41000E+01	.10675E+01
.50000E+01	.10501E+01

MASS FLOW RATE= .39430E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 4

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      YNORM               U
     .13000E+01      .10436E+01
     .23000E+01      .10644E+01
     .32000E+01      .10658E+01
     .41000E+01      .10647E+01
     .50000E+01      .10413E+01

MASS FLOW RATE=      .39253E+01


RUN NO.  2  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCIO/VISCOUS CYCLE--S.YOUNG TEST CASE


1977    1   10   99   46   34    0    0    1    0   51    0   -2    0
A                0  6.000E-01          0  6.256E+04  1.375E-03  3.000E-01  3.000E-01
X FOR CURV. B. VALUE           0  4.000E+00  8.000E+00  1.000E+01  1.200E+01  1.220E+01  1.240E+01
 1.260E+01  1.280E+01  1.290E+01  1.300E+01  1.310E+01  1.320E+01  1.340E+01
 1.360E+01  1.380E+01  1.400E+01  1.420E+01  1.440E+01  1.460E+01  1.480E+01
 1.500E+01  1.520E+01  1.540E+01  1.550E+01  1.560E+01  1.570E+01  1.580E+01
 1.600E+01  1.620E+01  1.640E+01  1.660E+01  1.700E+01  1.900E+01  2.100E+01
 2.200E+01  2.250E+01  2.300E+01  2.350E+01  2.400E+01  2.450E+01  2.500E+01
 2.550E+01  2.600E+01  2.650E+01  2.700E+01
CURV             0          0          0          0          0  2.000E-02  4.000E-02
 6.000E-02  8.000E-02  9.000E-02  1.000E-01  1.100E-01  1.200E-01  1.400E-01
 1.600E-01  1.800E-01  2.000E-01  2.000E-01  2.000E-01  2.000E-01  1.800E-01
 1.600E-01  1.400E-01  1.200E-01  1.100E-01  1.000E-01  9.000E-02  8.000E-02
 6.000E-02  4.000E-02  2.000E-02          0          0          0          0
         0          0          0          0          0          0          0
         0          0          0          0
X FOR PRESS. AND NP B. VALUES             0  2.0000E+00  4.0000E+00  6.0000E+00  8.0000E+00  1.0000E+01  1.1000E+01
  1.2000E+01  1.3000E+01  1.3436E+01  1.3872E+01  1.4308E+01  1.4745E+01  1.5181E+01
  1.5617E+01  1.6617E+01  1.7617E+01  1.8617E+01  2.0617E+01  2.2617E+01
PE-PREF      5.0000E-01  -1.1894E-01  -7.3265E-02  -8.5392E-02  -9.4762E-02  -1.1044E-01  -1.2955E-01
 -1.5282E-01  -2.3691E-01  -2.6245E-01  -3.0374E-01  -3.0658E-01  -2.8755E-01  -2.5055E-01
 -2.0538E-01  -1.3333E-01  -1.0574E-01  -8.6722E-02  -6.4919E-02  -5.5440E-02
NP   1.3000E+00  1.3000E+00  1.3000E+00  1.3000E+00  1.3000E+00  1.3000E+00  1.3000E+00
  1.3000E+00  1.3000E+00  1.3000E+00  1.3000E+00  1.3000E+00  1.3000E+00  1.3000E+00
  1.3000E+00  1.3000E+00  1.3000E+00  1.3000E+00  1.3000E+00  1.3000E+00

STN.           X       YSTEP        CF         UE      OEL05       THETA     SCHMETA          H      RTHETA      I6
  1   .1000E+02   .3333E-01   .002750   .1105E+01   .8208E+00   .9611E-01   .9611E-01   1.37743   .6644E+04     37

 ROUGH/D05     005/RAO 005/(X-XO)  STRAIN.005       VW/UE
         0          0          0          0          0

STN.           X       YSTEP        CF         UE      OEL05       THETA     SCHMETA          H      RTHETA      I6
  2   .1025E+02   .3333E-01   .002563   .1110E+01   .8128E+00   .8754E-01   .9794E-01   1.52381   .6079E+04     37

 ROUGH/D05     005/RAO 005/(X-XO)  STRAIN.005       VW/UE
         0          0          0          0          0

STN.           X       YSTEP        CF         UE      OEL05       THETA     SCHMETA          H      RTHETA      I6
 10   .1232E+02   .3333E-01   .003774   .1162E+01   .7769E+00   .3711E-01   .6599E-01   2.40440   .2697E+04     37

 ROUGH/D05     005/RAO 005/(X-XO)  STRAIN.005       VW/UE
         0   .2501E-01         0          0          0

STN.           X       YSTEP        CF         UE      OEL05       THETA     SCHMETA          H      RTHETA      I6
 20   .1312E+02   .3333E-01   .004143   .1224E+01   .7370E+00   .5011E-01   .4840E-01   1.45729   .3839E+04     37

 ROUGH/D05     005/RAO 005/(X-XO)  STRAIN.005       VW/UE
         0   .8234E-01         0          0          0
```

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
30	.1368E+02	.3333E-01	.004336	.1260E+01	.7078E+00	.4034E-01	.3052E-01	1.46371	.3180E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.005	VW/UE
0	.1188E+00	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
40	.1524E+02	.3333E-01	.002796	.1223E+01	.7072E+00	.6987E-01	.3919E-01	1.11077	.5344E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.005	VW/UE
0	.9590E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
50	.1574E+02	.3333E-01	.002386	.1184E+01	.7524E+00	.7681E-01	.4807E-01	1.24731	.5688E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.005	VW/UE
0	.6453E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
60	.1623E+02	.3333E-01	.002105	.1147E+01	.7910E+00	.8609E-01	.5312E-01	1.29607	.6179E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.2938E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
70	.1690E+02	.3333E-01	.001866	.1113E+01	.8394E+00	.9779E-01	.6191E-01	1.37942	.6811E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.005	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
80	.1815E+02	.3333E-01	.001767	.1092E+01	.8685E+00	.1206E+00	.8200E-01	1.43730	.8236E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.005	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
90	.1969E+02	.3333E-01	.001882	.1070E+01	.8917E+00	.1300E+00	.9171E-01	1.46297	.8699E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.005	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
99	.2131E+02	.3333E-01	.001995	.1059E+01	.9430E+00	.1366E+00	.1001E+00	1.47203	.9056E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	0	0	0	0

X=

.1000E+02	.1025E+02	.1049E+02	.1075E+02	.1102E+02	.1128E+02	.1155E+02	.1181E+02	.1207E+02	.1232E+02
.1249E+02	.1260E+02	.1269E+02	.1277E+02	.1283E+02	.1290E+02	.1296E+02	.1301E+02	.1307E+02	.1312E+02
.1317E+02	.1322E+02	.1327E+02	.1332E+02	.1337E+02	.1342E+02	.1348E+02	.1354E+02	.1361E+02	.1368E+02
.1376E+02	.1385E+02	.1396E+02	.1410E+02	.1429E+02	.1457E+02	.1483E+02	.1504E+02	.1516E+02	.1524E+02
.1531E+02	.1537E+02	.1542E+02	.1547E+02	.1552E+02	.1556E+02	.1561E+02	.1565E+02	.1570E+02	.1574E+02
.1579E+02	.1583E+02	.1588E+02	.1593E+02	.1597E+02	.1602E+02	.1607E+02	.1612E+02	.1618E+02	.1623E+02
.1628E+02	.1634E+02	.1640E+02	.1646E+02	.1653E+02	.1659E+02	.1666E+02	.1674E+02	.1682E+02	.1690E+02
.1699E+02	.1709E+02	.1720E+02	.1731E+02	.1743E+02	.1756E+02	.1770E+02	.1785E+02	.1800E+02	.1815E+02
.1830E+02	.1845E+02	.1860E+02	.1875E+02	.1890E+02	.1905E+02	.1921E+02	.1936E+02	.1952E+02	.1969E+02
.1985E+02	.2003E+02	.2020E+02	.2038E+02	.2056E+02	.2075E+02	.2093E+02	.2112E+02	.2131E+02	.2149E+02

VE/UE=

-.1580E-01	-.1212E-01	-.1715E-01	-.1962E-01	-.2447E-01	-.3061E-01	-.3938E-01	-.5058E-01	-.6337E-01	-.7456E-01
-.8212E-01	-.8727E-01	-.9059E-01	-.9236E-01	-.9335E-01	-.9347E-01	-.9325E-01	-.9249E-01	-.9155E-01	-.9039E-01

-.8907E-01	-.8761E-01	-.8600E-01	-.8427E-01	-.8238E-01	-.8033E-01	-.7808E-01	-.7559E-01	-.7280E-01	-.6962E-01
-.6594E-01	-.6159E-01	-.5604E-01	-.4565E-01	-.2317E-01	.1438E-01	.4449E-01	.6521E-01	.7913E-01	.8844E-01
.9458E-01	.9869E-01	.1014E+00	.1033E+00	.1045E+00	.1053E+00	.1059E+00	.1062E+00	.1064E+00	.1065E+00
.1065E+00	.1063E+00	.1060E+00	.1057E+00	.1052E+00	.1046E+00	.1039E+00	.1030E+00	.1020E+00	.1008E+00
.9937E-01	.9773E-01	.9582E-01	.9362E-01	.9110E-01	.8831E-01	.8524E-01	.8187E-01	.7829E-01	.7453E-01
.7060E-01	.6653E-01	.6235E-01	.5808E-01	.5381E-01	.4973E-01	.4579E-01	.4224E-01	.3919E-01	.3659E-01
.3431E-01	.3220E-01	.3033E-01	.2863E-01	.2709E-01	.2568E-01	.2435E-01	.2305E-01	.2175E-01	.2042E-01
.1906E-01	.1767E-01	.1630E-01	.1500E-01	.1382E-01	.1279E-01	.1192E-01	.1124E-01	.1075E-01	

(PW-PREF)/UREF**2=

-.1104E+00	-.1154E+00	-.1233E+00	-.1268E+00	-.1341E+00	-.1422E+00	-.1530E+00	-.1665E+00	-.1830E+00	-.2117E+00
-.2359E+00	-.2515E+00	-.2624E+00	-.2713E+00	-.2790E+00	-.2665E+00	-.2937E+00	-.3010E+00	-.3079E+00	-.3149E+00
-.3218E+00	-.3287E+00	-.3357E+00	-.3427E+00	-.3500E+00	-.3574E+00	-.3652E+00	-.3734E+00	-.3822E+00	-.3915E+00
-.4017E+00	-.4126E+00	-.4209E+00	-.4229E+00	-.4179E+00	-.4040E+00	-.3781E+00	-.3425E+00	-.3209E+00	-.3113E+00
-.3064E+00	-.3028E+00	-.2991E+00	-.2948E+00	-.2902E+00	-.2851E+00	-.2795E+00	-.2739E+00	-.2681E+00	-.2622E+00
-.2562E+00	-.2502E+00	-.2441E+00	-.2380E+00	-.2319E+00	-.2258E+00	-.2197E+00	-.2136E+00	-.2076E+00	-.2015E+00
-.1954E+00	-.1893E+00	-.1833E+00	-.1771E+00	-.1708E+00	-.1642E+00	-.1585E+00	-.1544E+00	-.1501E+00	-.1457E+00
-.1413E+00	-.1368E+00	-.1323E+00	-.1278E+00	-.1232E+00	-.1187E+00	-.1144E+00	-.1103E+00	-.1063E+00	-.1025E+00
-.9911E-01	-.9579E-01	-.9254E-01	-.8948E-01	-.8656E-01	-.8388E-01	-.8148E-01	-.7932E-01	-.7733E-01	-.7548E-01
-.7374E-01	-.7207E-01	-.7045E-01	-.6886E-01	-.6731E-01	-.6583E-01	-.6440E-01	-.6303E-01	-.6151E-01	-.6048E-01

(PW-PE)/UREF**2=

0	.6306E-03	-.2395E-02	-.9218E-03	-.4352E-02	-.9387E-02	-.1611E-01	-.2235E-01	-.2613E-01	-.3674E-01
-.4692E-01	-.5209E-01	-.5439E-01	-.5586E-01	-.5690E-01	-.5824E-01	-.5962E-01	-.6149E-01	-.6331E-01	-.6534E-01
-.6752E-01	-.6985E-01	-.7237E-01	-.7504E-01	-.7793E-01	-.8107E-01	-.8453E-01	-.8839E-01	-.9275E-01	-.9776E-01
-.1037E+00	-.1105E+00	-.1153E+00	-.1151E+00	-.1111E+00	-.1065E+00	-.9628E-01	-.7743E-01	-.6593E-01	-.6379E-01
-.6503E-01	-.6678E-01	-.6604E-01	-.6850E-01	-.6826E-01	-.6746E-01	-.6627E-01	-.6481E-01	-.6319E-01	-.6147E-01
-.5969E-01	-.5788E-01	-.5606E-01	-.5425E-01	-.5244E-01	-.5065E-01	-.4886E-01	-.4707E-01	-.4528E-01	-.4347E-01
-.4163E-01	-.3976E-01	-.3783E-01	-.3575E-01	-.3336E-01	-.3058E-01	-.2866E-01	-.2808E-01	-.2717E-01	-.2600E-01
-.2459E-01	-.2297E-01	-.2112E-01	-.1907E-01	-.1675E-01	-.1437E-01	-.1212E-01	-.9935E-02	-.8089E-02	-.6738E-02
-.5903E-02	-.5306E-02	-.4827E-02	-.4481E-02	-.4167E-02	-.3908E-02	-.3700E-02	-.3518E-02	-.3333E-02	-.3141E-02
-.2936E-02	-.2713E-02	-.2446E-02	-.2136E-02	-.1812E-02	-.1491E-02	-.1182E-02	-.8811E-03	-.4049E-03	-.4049E-03

SWEEP NO. 2 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 3 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	-.1745E-01	-.2712E-01	-.6839E-01	-.1113E+00	-.9847E-01
-.7655E-01	-.2626E-01	.4363E-01	.9904E-01	.1254E+00	.9798E-01	.5300E-01	.3268E-01	.1437E-01	.1437E-01
.2000E-02	.2000E-02	.2000E-02	.2000E-02						

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.8200E-01	.2000E-02	.2000E-02	.4432E-02	-.7748E-02	-.1754E-01	-.2485E-01	-.6713E-01	-.7828E-01	-.6111E-01
-.3579E-01	-.7874E-02	.2554E-01	.5975E-01	.5982E-01	.2961E-01	.1197E-01	.2138E-02	-.1559E-02	.8137E-03
.2000E-02	.2000E-02	-.7800E-01	-.1347E+01	-.1107E+01	-.1107E+01	-.1347E+01	-.7800E-01	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.8200E-01	.1340E+01	.1100E+01	.1100E+01	.1340E+01

RUN NO. 3 OF PROGRAM AMOS

REFERENCE LENGTH= 1.0000

X	Y	SSM	CP	U (TANG)	V (NORM)
1.00000	1.30000	1.00000	-.33254	1.15436	.08200
3.00000	1.30000	3.00000	-.16493	1.07932	.00200
5.00000	1.30000	5.00000	-.15080	1.07275	.00200
7.00000	1.30000	7.00000	-.17683	1.08482	.00443
9.00000	1.30000	9.00000	-.19996	1.09543	-.00775
10.50000	1.30000	10.50000	-.25843	1.12180	-.01754
11.50000	1.30000	11.50000	-.29464	1.13782	-.02485
12.51416	1.29985	12.51416	-.36186	1.16699	-.06713
13.28839	1.26786	13.28925	-.50617	1.22726	-.07828
13.82168	1.24014	13.82458	-.55670	1.24768	-.06111
14.36269	1.14482	14.37443	-.56007	1.24903	-.03579
14.89416	1.00212	14.92528	-.53866	1.24043	-.00787
15.40981	.81390	15.47471	-.49733	1.22365	.02554
15.89402	.56940	16.00690	-.43992	1.19997	.05975
16.57054	.21264	16.78335	-.32883	1.15275	.05982
17.44901	-.29418	17.79764	-.26014	1.12256	.02961
18.31501	-.79418	18.79762	-.22557	1.10705	.01197
19.61401	-1.54418	20.29758	-.18332	1.08780	.00214
21.34601	-2.54418	22.29754	-.16496	1.07933	-.00156
23.07801	-3.54418	24.29749	-.15277	1.07367	.00081
24.81001	-4.54418	26.29745	-.13917	1.06732	.00200
26.54201	-5.54418	28.29741	-.10888	1.05303	.00200
28.27401	-6.54418	30.29736	.39575	.77734	-.07800
29.39001	-6.61109	31.79740	-1.08441	1.44375	-1.34674
29.86500	-5.78650	32.74728	-.22536	1.10696	-1.10674
30.31500	-5.00900	33.64735	-.22592	-1.10721	-1.10674
30.76500	-4.22950	34.54741	-1.07605	-1.44154	-1.34574
30.12400	-3.34000	35.99721	.37079	-.79322	-.07800
28.39200	-2.34000	37.99716	-.10569	-1.05152	.00200
26.66000	-1.34000	39.99712	- 13160	-1.06376	.00200
24.92800	-.34000	41.99708	-.14152	-1.06842	.00200
23.19600	.66000	43.99703	-.14232	-1.06930	.00200
21.46400	1.66000	45.99699	-.13366	-1.05473	.00200
19.29900	2.91000	48.49693	.01394	-.99300	.00200
17.61300	3.66150	50.43322	.10181	-.94773	.00200

16.82300	4.23000	51.30576	.17962	-.90575	.00200
16.00400	4.52800	52.17813	.20142	-.89363	.00200
15.16250	4.75350	53.05014	.19569	-.89684	.00200
14.30450	4.90500	53.92225	.16058	-.91620	.00200
13.43600	4.98100	54.79490	.06179	-.96861	.00200
11.50000	5.00000	56.73131	-.04840	-1.02391	.00200
9.00000	5.00000	59.23131	-.16269	-1.07828	.00200
7.00000	5.00000	61.23131	-.14941	-1.07210	.00200
5.00000	5.00000	63.23131	-.10459	-1.05099	.00200
3.00000	5.00000	65.23131	.03022	-.98477	.00200
1.00000	5.00000	67.23131	.86967	-.36102	.08200
0	4.52500	68.70631	-2.36022	-1.83309	1.34000
0	3.57500	69.65631	-.31028	-1.14467	1.10000
0	2.62500	70.60631	-.26875	-1.12639	1.10000
0	1.07500	72.15631	-5.06378	2.46247	1.34000

OFF-BODY POINTS

X	Y	U	V	CP
5.00000	2.15000	1.10101	.00517	-.21224
5.00000	3.10000	1.09970	.00473	-.20937
5.00000	4.05000	1.09360	.00106	-.19596
9.00000	2.15000	1.10890	-.00711	-.22972
9.00000	3.10000	1.10590	-.00641	-.22307
9.00000	4.05000	1.10170	-.00398	-.21375
21.84600	-1.67800	.94265	-.54509	-.18572
22.29500	-.89900	.94262	-.54500	-.18555
22.74600	-.11900	.94075	-.54451	-.18150
25.31000	-3.67800	.94236	-.54423	-.18424
25.76000	-2.89900	.94314	-.54485	-.18638
26.21000	-2.11900	.94187	-.54430	-.18339

RUN NO. 3 OF PROGRAM TRAVERS

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 1

YNORM	U
.13000E+01	.10728E+01
.21500E+01	.11010E+01
.31000E+01	.10997E+01
.40500E+01	.10936E+01
.50000E+01	.10510E+01

MASS FLOW RATE= .40393E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 2

YNORM	U
.13000E+01	.10954E+01
.21500E+01	.11089E+01
.31000E+01	.11059E+01
.40500E+01	.11017E+01
.50000E+01	.10783E+01

MASS FLOW RATE= .40781E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 3

YNORM	U
.13000E+01	.10793E+01
.23000E+01	.10889E+01

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     .32000E+01      .10888E+01
     .41000E+01      .10870E+01
     .50000E+01      .10688E+01

MASS FLOW RATE=      .40173E+01


VELOCITY PROFILE ACROSS DUCT AT STATION NO.  4
       YNORM              U
     .13000E+01      .10673E+01
     .23000E+01      .10882E+01
     .32000E+01      .10892E+01
     .41000E+01      .10878E+01
     .50000E+01      .10638E+01

MASS FLOW RATE=      .40120E+01


RUN NO.  3  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS CYCLE--S.YOUNG TEST CASE


1977     1    10    99    46    34     0     0     1     0    51     0    -2     0
A                  0  6.000E-01            0  6.256E+04  1.375E-03  3.000E-01  3.000E-01
X FOR CURV. B. VALUE              0  4.000E+00  8.000E+00  1.000E+01  1.200E+01  1.220E+01  1.240E+01
 1.260E+01  1.280E+01  1.290E+01  1.300E+01  1.310E+01  1.320E+01  1.340E+01
 1.360E+01  1.380E+01  1.400E+01  1.420E+01  1.440E+01  1.460E+01  1.480E+01
 1.500E+01  1.520E+01  1.540E+01  1.550E+01  1.560E+01  1.570E+01  1.580E+01
 1.600E+01  1.620E+01  1.640E+01  1.660E+01  1.700E+01  1.900E+01  2.100E+01
 2.200E+01  2.250E+01  2.300E+01  2.350E+01  2.400E+01  2.450E+01  2.500E+01
 2.550E+01  2.600E+01  2.650E+01  2.700E+01
CURV                0          0          0          0          0  2.000E-02  4.000E-02
 6.000E-02  8.000E-02  9.000E-02  1.000E-01  1.100E-01  1.200E-01  1.400E-01
 1.600E-01  1.800E-01  2.000E-01  2.000E-01  2.000E-01  2.000E-01  1.800E-01
 1.600E-01  1.400E-01  1.200E-01  1.100E-01  1.000E-01  9.000E-02  8.000E-02
 6.000E-02  4.000E-02  2.000E-02          0          0          0          0
         0          0          0          0          0          0          0
         0          0          0          0
X FOR PRESS. AND NP B. VALUES             0   2.0000E+00   4.0000E+00   6.0000E+00   8.0000E+00   1.0000E+01   1.1000E+01
  1.2000E+01   1.3000E+01   1.3436E+01   1.3872E+01   1.4308E+01   1.4745E+01   1.5181E+01
  1.5617E+01   1.6617E+01   1.7617E+01   1.8617E+01   2.0617E+01   2.2617E+01
PE-PREF       5.0000E-01  -1.1727E-01  -7.1452E-02  -8.2621E-02  -9.1835E-02  -1.1848E-01  -1.3911E-01
 -1.5615E-01  -2.2960E-01  -2.6916E-01  -2.8135E-01  -2.7597E-01  -2.6005E-01  -2.3537E-01
 -2.0127E-01  -1.4165E-01  -1.2105E-01  -1.0479E-01  -8.5211E-02  -7.9667E-02
NP   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00

STN.          X       YSTEP         CF        UE     DELO5       THETA    SCHMETA          H    RTHETA      I6
  1   .1000E+02  .3333E-01    .002750  .1112E+01  .8208E+00  .9611E-01  .9611E-01    1.37736  .6687E+04      37

 ROUGH/DO5     DO5/RAD  DO5/(X-XO)  STRAIN.DO5       VW/UE
         0          0          0          0          0

STN.          X       YSTEP         CF        UE     DELO5       THETA    SCHMETA          H    RTHETA      I6
  2   .1025E+02  .3333E-01    .002629  .1118E+01  .8094E+00  .8431E-01  .9601E-01    1.54617  .5896E+04      37

 ROUGH/DO5     DO5/RAD  DO5/(X-XO)  STRAIN.DO5       VW/UE
         0          0          0          0          0

STN.          X       YSTEP         CF        UE     DELO5       THETA    SCHMETA          H    RTHETA      I6
 10   .1232E+02  .3333E-01    .003793  .1162E+01  .7692E+00  .3757E-01  .6334E-01    2.23963  .2731E+04      37
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 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0  .2476E-01          0          0              0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA            H     RTHETA      I6
 20   .1312E+02  .3333E-01    .004531  .1216E+01  .7254E+00  .3414E-01  .3440E-01    1.54723  .2597E+04      37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0  .8105E-01          0          0              0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA            H     RTHETA      I6
 30   .1368E+02  .3333E-01    .004819  .1245E+01  .6900E+00  .1674E-01  .8658E-02    1.81017  .1303E+04      37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0  .1158E+00          0          0              0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA            H     RTHETA      I6
 40   .1524E+02  .3333E-01    .003073  .1207E+01  .7192E+00  .5330E-01  .2959E-01    1.11293  .4025E+04      37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0  .9752E-01          0          0              0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA            H     RTHETA      I6
 50   .1574E+02  .3333E-01    .002545  .1176E+01  .7607E+00  .6391E-01  .4211E-01    1.26620  .4701E+04      37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0  .6524E-01          0          0              0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA            H     RTHETA      I6
 60   .1623E+02  .3333E-01    .002180  .1150E+01  .7982E+00  .7799E-01  .5369E-01    1.32756  .5609E+04      37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0  .2965E-01          0          0              0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA            H     RTHETA      I6
 70   .1690E+02  .3333E-01    .001947  .1127E+01  .8436E+00  .9401E-01  .6713E-01    1.38551  .6628E+04      37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0          0          0          0              0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA            H     RTHETA      I6
 80   .1815E+02  .3333E-01    .001878  .1107E+01  .8661E+00  .1151E+00  .8452E-01    1.41579  .7968E+04      37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0          0          0          0              0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA            H     RTHETA      I6
 90   .1969E+02  .3333E-01    .001979  .1088E+01  .8836E+00  .1250E+00  .9503E-01    1.44343  .8509E+04      37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0          0          0          0              0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA            H     RTHETA      I6
 99   .2131E+02  .3333E-01    .002094  .1079E+01  .9293E+00  .1307E+00  .1025E+00    1.45512  .8827E+04      37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0          0          0          0              0

X=
   .1000E+02  .1025E+02  .1049E+02  .1075E+02  .1102E+02  .1128E+02  .1155E+02  .1181E+02  .1207E+02  .1232E+02
   .1249E+02  .1260E+02  .1269E+02  .1277E+02  .1283E+02  .1290E+02  .1296E+02  .1301E+02  .1307E+02  .1312E+02
   .1317E+02  .1322E+02  .1327E+02  .1332E+02  .1337E+02  .1342E+02  .1348E+02  .1354E+02  .1361E+02  .1368E+02
   .1376E+02  .1385E+02  .1396E+02  .1410E+02  .1429E+02  .1457E+02  .1483E+02  .1504E+02  .1516E+02  .1524E+02
   .1531E+02  .1537E+02  .1542E+02  .1547E+02  .1552E+02  .1556E+02  .1561E+02  .1565E+02  .1570E+02  .1574E+02
   .1579E+02  .1583E+02  .1598E+02  .1593E+02  .1597E+02  .1602E+02  .1607E+02  .1612E+02  .1618E+02  .1623E+02
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.1628E+02	.1634E+02	.1640E+02	.1646E+02	.1653E+02	.1659E+02	.1666E+02	.1674E+02	.1682E+02	.1690E+02
.1639E+02	.1709E+02	.1720E+02	.1731E+02	.1743E+02	.1756E+02	.1770E+02	.1785E+02	.1800E+02	.1815E+02
.1830E+02	.1845E+02	.1860E+02	.1875E+02	.1890E+02	.1905E+02	.1921E+02	.1936E+02	.1952E+02	.1969E+02
.1985E+02	.2003E+02	.2020E+02	.2038E+02	.2056E+02	.2075E+02	.2093E+02	.2112E+02	.2131E+02	.2149E+02

VE/UE=

-.3025E-01	-.2684E-01	-.2986E-01	-.2856E-01	-.2794E-01	-.2852E-01	-.3323E-01	-.4270E-01	-.5625E-01	-.7001E-01
-.8025E-01	-.8796E-01	-.9348E-01	-.9743E-01	-.1002E+00	-.1021E+00	-.1034E+00	-.1041E+00	-.1043E+00	-.1038E+00
-.1027E+00	-.1009E+00	-.9858E-01	-.9561E-01	-.9200E-01	-.8770E-01	-.8262E-01	-.7663E-01	-.6953E-01	-.6102E-01
-.5068E-01	-.3778E-01	-.2143E-01	-.4194E-02	.1012E-01	.2511E-01	.4135E-01	.5643E-01	.6778E-01	.7653E-01
.8299E-01	.8787E-01	.9155E-01	.9437E-01	.9654E-01	.9820E-01	.9946E-01	.1004E+00	.1010E+00	.1013E+00
.1014E+00	.1012E+00	.1007E+00	.9986E-01	.9871E-01	.9723E-01	.9550E-01	.9360E-01	.9157E-01	.8944E-01
.8720E-01	.8489E-01	.8249E-01	.8000E-01	.7743E-01	.7477E-01	.7196E-01	.6896E-01	.6585E-01	.6262E-01
.5930E-01	.5591E-01	.5247E-01	.4304E-01	.4567E-01	.4247E-01	.3959E-01	.3713E-01	.3521E-01	.3370E-01
.3234E-01	.3102E-01	.2365E-01	.2816E-01	.2653E-01	.2476E-01	.2294E-01	.2113E-01	.1939E-01	.1775E-01
.1623E-01	.1486E-01	.1363E-01	.1253E-01	.1157E-01	.1074E-01	.1006E-01	.9529E-02	.9153E-02	

(PW-PREF)/UREF**2=

-.1185E+00	-.1254E+00	-.1332E+00	-.1365E+00	-.1431E+00	-.1507E+00	-.1615E+00	-.1756E+00	-.1930C+C0	-.2238E+00
-.2506E+00	-.2686E+00	-.2811E+00	-.2910E+00	-.2998E+00	-.3081E+00	-.3161E+00	-.3233E+00	-.3295E+00	-.3349E+00
-.3400E+00	-.3449E+00	-.3499E+00	-.3550E+00	-.3604E+00	-.3559E+00	-.3716E+00	-.3777E+00	-.3838E+00	-.3898E+00
-.3954E+00	-.4005E+00	-.4093E+00	-.4224E+00	-.4275E+00	-.4157E+00	-.3904E+00	-.3553E+00	-.3320E+00	-.3192E+00
-.3117E+00	-.3063E+00	-.3020E+00	-.2978E+00	-.2935E+00	-.2891E+00	-.2846E+00	-.2799E+00	-.2752E+00	-.2705E+00
-.2657E+00	-.2610E+00	-.2564E+00	-.2519E+00	-.2473E+00	-.2425E+00	-.2371E+00	-.2314E+00	-.2254E+00	-.2193E+00
-.2131E+00	-.2068E+00	-.2005E+00	-.1940E+00	-.1874E+00	-.1807E+00	-.1752E+00	-.1712E+00	-.1672E+00	-.1631E+00
-.1588E+00	-.1546E+00	-.1503E+00	-.1459E+00	-.1415E+00	-.1370E+00	-.1326E+00	-.1282E+00	-.1241E+00	-.1205E+00
-.1172E+00	-.1143E+00	-.1116E+00	-.1091E+00	-.1068E+00	-.1045E+00	-.1024E+00	-.1002E+00	-.9820E-01	-.9625E-01
-.9440E-01	-.9266E-01	-.9108E-01	-.6962E-01	-.8824E-01	-.8694E-Ci	-.8571E-01	-.8454E-01	-.8328E-01	-.8258E-01

(PW-PE)/UREF**2=

0	-.5632E-03	-.2864E-02	-.9166E-03	-.3804E-02	-.9278E-02	-.1754E-01	-.2630E-01	-.3354E-01	-.4893E-01
-.6371E-01	-.7259E-01	-.7766E-01	-.8118E-01	-.8416E-01	-.8716E-01	-.9018E-01	-.9276E-01	-.9454E-01	--.9577E-01
-.9682E-01	-.9791E-01	-.9916E-01	-.1007E+00	-.1024E+00	-.1045E+00	-.1068E+00	-.1094E+00	-.1123E+00	-.1151E+00
-.1179E+00	-.1208E+00	-.1283E+00	-.1422E+00	-.1512E+00	-.1483E+00	-.1347E+00	-.1127E+00	-.9763E-01	-.9082E-01
-.8829E-01	-.8733E-01	-.8693E-01	-.8647E-01	-.8578E-01	-.8482E-01	-.8364E-01	-.8231E-01	-.8087E-01	-.7937E-01
-.7785E-01	-.7635E-01	-.7499E-01	-.7349E-01	-.7204E-01	-.7020E-01	-.6781E-01	-.6500E-01	-.6191E-01	-.5862E-01
-.5516E-01	-.5158E-01	-.4786E-01	-.4400E-01	-.3999E-01	-.3586E-01	-.3283E-01	-.3136E-01	-.2973E-01	-.2797E-01
-.2610E-01	-.2414E-01	-.2208E-01	-.1993E-01	-.1770E-01	-.1546E-01	-.1320E-01	-.1103E-01	-.9168E-02	-.7848E-02
-.7019E-02	-.6512E-02	-.6224E-02	-.6082E-02	-.6006E-02	-.5884E-02	-.5651E-02	-.5333E-02	-.4962E-02	-.4553E-02
-.4122E-02	-.3700E-02	-.3304E-02	-.2908E-02	-.2507E-02	-.2101E-02	-.1690E-02	-.1274E-02	-.7264E-03	-.7264E-03

SWEEP NO. 3 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 4 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	-.3365E-01	-.3163E-01	-.6016E-01	-.1243E+00	-.1059E+00
-.4320E-01	.1392E-01	.4455E-01	.8379E-01	.1166E+00	.8361E-01	.4611E-01	.3244E-01	.1225E-01	.1225E-01
.2000E-02	.2000E-02	.2000E-02	.2000E-02						

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.8200E-01	.2000E-02	.2000E-02	.6456E-02	-.2244E-01	-.2092E-01	-.2991E-01	-.7965E-01	-.9083E-01	-.6492E-01
-.2846E-01	.2926E-02	.3730E-01	.7317E-01	.7214E-01	.3929E-01	.2007E-01	.7443E-02	.2968E-02	.2323E-02
.2000E-02	.2000E-02	-.7800E-01	-.1352E+01	-.1112E+01	-.1112E+01	-.1352E+01	-.7800E-01	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.8200E-01	.1340E+01	.1100E+01	.1100E+01	.1340E+01

RUN NO. 4 OF PROGRAM AMOS

REFERENCE LENGTH= 1.0000

X	Y	SSM	CP	U (TANG)	V (NORM)
1.00000	1.30000	1.00000	-.33231	1.15426	.08200
3.00000	1.30000	3.00000	-.16468	1.07920	.00200
5.00000	1.30000	5.00000	-.15055	1.07264	.00200
7.00000	1.30000	7.00000	-.18286	1.08760	.00546
9.00000	1.30000	9.00000	-.19629	1.09375	-.02244
10.50000	1.30000	10.50000	-.23694	1.11218	-.02092
11.50000	1.30000	11.50000	-.27758	1.13030	-.02991
12.51416	1.29935	12.51416	-.33518	1.15550	-.07955
13.28899	1.28736	13.28325	-.45476	1.20613	-.09083
13.82168	1.24014	13.82458	-.48938	1.22040	-.06492
14.36269	1.14482	14.37443	-.49487	1.22265	-.02846
14.69416	1.00212	14.92528	-.48655	1.21924	.00293
15.40981	.81390	15.47471	-.45669	1.20693	.03730
15.89402	.58940	16.00690	-.41089	1.18781	.07317
16.57054	.21284	16.78335	-.31344	1.14605	.07214
17.44301	-.29418	17.79764	-.25433	1.11997	.03929
18.31501	-.79418	18.79762	-.22576	1.10714	.02007
19.61401	-1.54418	20.29758	-.18708	1.08953	.00744
21.34601	-2.54418	22.29754	-.17428	1.08364	.00297
23.07801	-3.54418	24.29749	-.16558	1.07962	.00232
24.81001	-4.54418	26.29745	-.15170	1.07317	.00200
26.54201	-5.54418	28.29741	-.12059	1.05858	.00200
28.27401	-6.54418	30.29736	.38743	.78267	-.07800
29.39001	-6.61109	31.79740	-1.10006	1.44916	-1.35249
29.86500	-5.78850	32.74728	-.23811	1.11270	-1.11249
30.31500	-5.00900	33.64735	-.23868	-1.11296	-1.11249
30.76500	-4.22950	34.54741	-1.09373	-1.44697	-1.35249
30.12400	-3.34000	35.99721	.36236	-.79052	-.07800
28.39200	-2.34000	37.99716	-.11709	-1.05593	.00200
26.66000	-1.34000	39.99712	-.14265	-1.06895	.00200
24.92800	-.34000	41.99708	-.15104	-1.07286	.00200
23.19600	.66000	43.99703	-.14841	-1.07164	.00200
21.46400	1.66000	45.99699	-.13422	-1.06500	.00200
19.29900	2.91000	48.49593	.02184	-.98902	.00200
17.61300	3.86150	50.43322	.11599	-.94022	.00200

16.82300	4.23000	51.30576	.19453	-.89748	.00200
16.00400	4.52800	52.17813	.21739	-.88465	.00200
15.16250	4.75350	53.05014	.21257	-.88737	.00200
14.30450	4.90500	53.92225	.17822	-.90652	.00200
13.43600	4.98100	54.79490	.08074	-.95878	.00200
11.50000	5.00000	56.73131	-.03342	-1.01657	.00200
9.00000	5.00000	59.23131	-.15472	-1.07458	.00200
7.00000	5.00000	61.23131	-.14689	-1.07093	.00200
5.00000	5.00000	63.23131	-.10388	-1.05066	.00200
3.00000	5.00000	65.23131	.03059	-.98459	.00200
1.00000	5.00000	67.23131	.86991	-.36069	.08200
0	4.52500	68.70631	-2.36124	-1.83337	1.34000
0	3.57500	69.65631	-.31036	-1.14471	1.10000
0	2.62500	70.60631	-.26878	-1.12640	1.10000
0	1.07500	72.15631	-5.06371	2.46246	1.34000

OFF-BODY POINTS

X	Y	U	V	CP
5.00000	2.15000	1.10100	.00517	-.21223
5.00000	3.10000	1.09966	.00463	-.20928
5.00000	4.05000	1.09344	.00097	-.19560
9.00000	2.15000	1.10657	-.01506	-.22473
9.00000	3.10000	1.10285	-.01052	-.21638
9.00000	4.05000	1.09818	-.00583	-.20603
21.84600	-1.67800	.94761	-.54444	-.19437
22.29600	-.89900	.94650	-.54503	-.19311
22.74600	-.11900	.94395	-.54523	-.18832
25.31000	-3.67800	.94751	-.54690	-.19688
25.76000	-2.89900	.94811	-.54741	-.19856
26.21000	-2.11900	.94664	-.54687	-.19520

RUN NO. 4 OF PROGRAM TRAVERS

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 1

YNORM	U
.13000E+01	.10726E+01
.21500E+01	.11010E+01
.31000E+01	.10997E+01
.40500E+01	.10934E+01
.50000E+01	.10507E+01

MASS FLOW RATE= .40389E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 2

YNORM	U
.13000E+01	.10937E+01
.21500E+01	.11066E+01
.31000E+01	.11028E+01
.40500E+01	.10982E+01
.50000E+01	.10746E+01

MASS FLOW RATE= .40672E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 3

YNORM	U
.13000E+01	.10836E+01
.23000E+01	.10929E+01

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     .32000E+01      .10923E+01
     .41000E+01      .10901E+01
     .50000E+01      .10716E+01

MASS FLOW RATE=      .40304E+01


VELOCITY PROFILE ACROSS DUCT AT STATION NO.  4
      YNORM              U
     .13000E+01      .10732E+01
     .23000E+01      .10940E+01
     .32000E+01      .10948E+01
     .41000E+01      .10933E+01
     .50000E+01      .10689E+01

MASS FLOW RATE=      .40327E+01


RUN NO.   4  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS CYCLE--S.YOUNG TEST CASE


1977    1   10   99   46   34    0    0    1    0   51    0   -2    0
A                0  6.000E-01            0  6.256E+04  1.375E-03  3.000E-01  3.000E-01
X FOR CURV. B. VALUE                0  4.000E+00  8.000E+00  1.000E+01  1.200E+01  1.220E+01  1.240E+01
 1.260E+01  1.280E+01  1.290E+01  1.300E+01  1.310E+01  1.320E+01  1.340E+01
 1.360E+01  1.380E+01  1.400E+01  1.420E+01  1.440E+01  1.460E+01  1.480E+01
 1.500E+01  1.520E+01  1.540E+01  1.550E+01  1.560E+01  1.570E+01  1.580E+01
 1.600E+01  1.620E+01  1.640E+01  1.660E+01  1.700E+01  1.900E+01  2.100E+01
 2.200E+01  2.250E+01  2.300E+01  2.350E+01  2.400E+01  2.450E+01  2.500E+01
 2.550E+01  2.600E+01  2.650E+01  2.700E+01
CURV             0          0          0          0          0  2.000E-02  4.000E-02
 6.000E-02  8.000E-02  9.000E-02  1.000E-01  1.100E-01  1.200E-01  1.400E-01
 1.600E-01  1.800E-01  2.000E-01  2.000E-01  2.000E-01  2.000E-01  1.800E-01
 1.600E-01  1.400E-01  1.200E-01  1.100E-01  1.000E-01  9.000E-02  8.000E-02
 6.000E-02  4.000E-02  2.000E-02          0          0          0          0
         0          0          0          0          0          0          0
         0          0          0          0
X FOR PRESS. AND NP B. VALUES             0   2.0000E+00   4.0000E+00   6.0000E+00   8.0000E+00   1.0000E+01   1.1000E+01
  1.2000E+01   1.3000E+01   1.3436E+01   1.3872E+01   1.4308E+01   1.4745E+01   1.5181E+01
  1.5617E+01   1.6617E+01   1.7617E+01   1.8617E+01   2.0617E+01   2.2617E+01
PE-PREF       5.0000E-01  -1.1725E-01  -7.0984E-02  -8.4148E-02  -9.4271E-02  -1.0944E-01  -1.2925E-01
 -1.4688E-01  -2.0859E-01  -2.3866E-01  -2.4707E-01  -2.4647E-01  -2.3697E-01  -2.1801E-01
 -1.8936E-01  -1.3699E-01  -1.1982E-01  -1.0571E-01  -8.8421E-02  -8.5347E-02
NP    1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00

STN.          X        YSTEP        CF         UE       DEL05        THETA     SCHMETA          H      RTHETA      I6
  1  .1000E+02  .3333E-01     .002750  .1104E+01  .8208E+00  .9611E-01  .9611E-01   1.37744  .6638E+04     37

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0          0          0          0          0

STN.          X        YSTEP        CF         UE       DEL05        THETA     SCHMETA          H      RTHETA      I6
  2  .1025E+02  .3333E-01     .002517  .1109E+01  .8105E+00  .8561E-01  .9649E-01   1.53115  .5941E+04     37

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0          0          0          0          0

STN.          X        YSTEP        CF         UE       DEL05        THETA     SCHMETA          H      RTHETA      I6
 10  .1232E+02  .3333E-01     .003855  .1151E+01  .7671E+00  .3822E-01  .5983E-01   2.06833  .2751E+04     37
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 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .2469E-01          0           0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA           H     RTHETA     I6
 20  .1312E+02  .3333E-01      .004406  .1194E+01  .7338E+00  .3807E-01  .3826E-01      1.47007  .2843E+04       37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .8199E-01          0           0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA           H     RTHETA     I6
 30  .1368E+02  .3333E-01      .004717  .1217E+01  .7094E+00  .2297E-01  .1672E-01      1.59178  .1749E+04       37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .1191E+00          0           0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA           H     RTHETA     I6
 40  .1524E+02  .3333E-01      .003294  .1194E+01  .7010E+00  .3755E-01  .1221E-01      1.13128  .2805E+04       37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .9505E-01          0           0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA           H     RTHETA     I6
 50  .1574E+02  .3333E-01      .002698  .1167E+01  .7394E+00  .5056E-01  .2568E-01      1.28459  .3691E+04       37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .6341E-01          0           0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA           H     RTHETA     I6
 60  .1623E+02  .3333E-01      .002246  .1143E+01  .7783E+00  .6782E-01  .3983E-01      1.33811  .4851E+04       37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .2891E-01          0           0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA           H     RTHETA     I6
 70  .1690E+02  .3333E-01      .001888  .1122E+01  .8277E+00  .8990E-01  .5898E-01      1.40279  .6312E+04       37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0          0          0           0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA           H     RTHETA     I6
 80  .1815E+02  .3333E-01      .001897  .1107E+01  .8516E+00  .1113E+00  .7699E-01      1.43075  .7708E+04       37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0          0          0           0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA           H     RTHETA     I6
 90  .1969E+02  .3333E-01      .001998  .1090E+01  .8586E+00  .1207E+00  .8606E-01      1.44901  .8230E+04       37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0          0          0           0            0

STN.          X        YSTEP          CF          UE    DEL05       THETA     SCHMETA           H     RTHETA     I6
 99  .2131E+02  .3333E-01      .002124  .1083E+01  .9009E+00  .1263E+00  .9298E-01      1.45997  .8560E+04       37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0          0          0           0            0

X=
   .1000E+02   .1025E+02   .1049E+02   .1075E+02   .1102E+02   .1128E+02   .1155E+02   .1181E+02   .1207E+02   .1232E+02
   .1249E+02   .1260E+02   .1269E+02   .1277E+02   .1283E+02   .1290E+02   .1296E+02   .1301E+02   .1307E+02   .1312E+02
   .1317E+02   .1322E+02   .1327E+02   .1332E+02   .1337E+02   .1342E+02   .1348E+02   .1354E+02   .1361E+02   .1368E+02
   .1376E+02   .1385E+02   .1396E+02   .1410E+02   .1429E+02   .1457E+02   .1483E+02   .1504E+02   .1516E+02   .1524E+02
   .1531E+02   .1537E+02   .1542E+02   .1547E+02   .1552E+02   .1556E+02   .1561E+02   .1565E+02   .1570E+02   .1574E+02
   .1579E+02   .1583E+02   .1588E+02   .1593E+02   .1597E+02   .1602E+02   .1607E+02   .1612E+02   .1618E+02   .1623E+02
```

.1628E+02	.1634E+02	.1640E+02	.1646E+02	.1653E+02	.1659E+02	.1666E+02	.1674E+02	.1682E+02	.1690E+02
.1699E+02	.1709E+02	.1720E+02	.1731E+02	.1743E+02	.1756E+02	.1770E+02	.1785E+02	.1800E+02	.1815E+02
.1830E+02	.1845E+02	.1860E+02	.1875E+02	.1890E+02	.1905E+02	.1921E+02	.1936E+02	.1952E+02	.1969E+02
.1985E+02	.2003E+02	.2020E+02	.2038E+02	.2056E+02	.2075E+02	.2093E+02	.2112E+02	.2131E+02	.2149E+02

VE/UE=

-.2538E-01	-.2250E-01	-.2654E-01	-.2772E-01	-.3043E-01	-.3393E-01	-.3953E-01	-.4717E-01	-.5627E-01	-.6444E-01
-.7002E-01	-.7386E-01	-.7629E-01	-.7774E-01	-.7848E-01	-.7872E-01	-.7859E-01	-.7819E-01	-.7759E-01	-.7684E-01
-.7596E-01	-.7496E-01	-.7386E-01	-.7266E-01	-.7135E-01	-.6991E-01	-.6833E-01	-.6657E-01	-.6459E-01	-.6233E-01
-.5970E-01	-.5656E-01	-.5253E-01	-.4387E-01	-.2546E-01	.1559E-02	.2425E-01	.4333E-01	.5701E-01	.6726E-01
.7463E-01	.8013E-01	.8426E-01	.8744E-01	.8993E-01	.9193E-01	.9355E-01	.9488E-01	.9597E-01	.9685E-01
.9755E-01	.9805E-01	.9836E-01	.9847E-01	.9837E-01	.9806E-01	.9757E-01	.9692E-01	.9612E-01	.9518E-01
.9408E-01	.9280E-01	.9134E-01	.8964E-01	.8769E-01	.8544E-01	.8278E-01	.7960E-01	.7591E-01	.7162E-01
.6666E-01	.6116E-01	.5550E-01	.4967E-01	.4402E-01	.3878E-01	.3428E-01	.3083E-01	.2857E-01	.2733E-01
.2654E-01	.2593E-01	.2530E-01	.2453E-01	.2356E-01	.2237E-01	.2104E-01	.1963E-01	.1820E-01	.1676E-01
.1535E-01	.1398E-01	.1268E-01	.1149E-01	.1041E-01	.9480E-02	.8699E-02	.8086E-02	.7648E-02	

(PW-PREF)/UREF**2=

-.1094E+00	-.1162E+00	-.1245E+00	-.1288E+00	-.1363E+00	-.1443E+00	-.1545E+00	-.1671E+00	-.1823E+00	-.2094E+00
-.2323E+00	-.2474E+00	-.2582E+00	-.2659E+00	-.2747E+00	-.2820E+00	-.2891E+00	-.2960E+00	-.3028E+00	-.3095E+00
-.3151E+00	-.3227E+00	-.3294E+00	-.3361E+00	-.3430E+00	-.3501E+00	-.3576E+00	-.3654E+00	-.3738E+00	-.3828E+00
-.3927E+00	-.4032E+00	-.4112E+00	-.4144E+00	-.4140E+00	-.4073E+00	-.3871E+00	-.3536E+00	-.3310E+00	-.3196E+00
-.3136E+00	-.3094E+00	-.3058E+00	-.3019E+00	-.2978E+00	-.2933E+00	-.2885E+00	-.2835E+00	-.2783E+00	-.2730E+00
-.2677E+00	-.2522E+00	-.2568E+00	-.2514E+00	-.2459E+00	-.2404E+00	-.2346E+00	-.2286E+00	-.2226E+00	-.2166E+00
-.2105E+00	-.2044E+00	-.1983E+00	-.1922E+00	-.1860E+00	-.1799E+00	-.1751E+00	-.1721E+00	-.1690E+00	-.1661E+00
-.1629E+00	-.1588E+00	-.1543E+00	-.1497E+00	-.1447E+00	-.1397E+00	-.1346E+00	-.1296E+00	-.1249E+00	-.1210E+00
-.1178E+00	-.1150E+00	-.1126E+00	-.1104E+00	-.1084E+00	-.1065E+00	-.1045E+00	-.1027E+00	-.1009E+00	-.9919E-01
-.9758E-01	-.9606E-01	-.9465E-01	-.9332E-01	-.9207E-01	-.9090E-01	-.8980E-01	-.8876E-01	-.8760E-01	-.8710E-01

(PW-PE)/UREF**2=

0	-.1036E-02	-.4116E-02	-.3392E-02	-.6897E-02	-.1191E-01	-.1885E-01	-.2618E-01	-.3267E-01	-.4736E-01
-.6075E-01	-.6876E-01	-.7372E-01	-.7747E-01	-.8075E-01	-.8394E-01	-.8716E-01	-.9045E-01	-.9381E-01	-.9723E-01
-.1007E+00	-.1044E+00	-.1081E+00	-.1120E+00	-.1161E+00	-.1204E+00	-.1251E+00	-.1302E+00	-.1359E+00	-.1422E+00
-.1495E+00	-.1578E+00	-.1641E+00	-.1666E+00	-.1674E+00	-.1654E+00	-.1529E+00	-.1293E+00	-.1133E+00	-.1068E+00
-.1050E+00	-.1044E+00	-.1042E+00	-.1035E+00	-.1025E+00	-.1009E+00	-.9908E-01	-.9696E-01	-.9465E-01	-.9221E-01
-.8967E-01	-.8708E-01	-.8447E-01	-.8186E-01	-.7920E-01	-.7636E-01	-.7328E-01	-.7001E-01	-.6662E-01	-.6314E-01
-.5959E-01	-.5598E-01	-.5233E-01	-.4863E-01	-.4487E-01	-.4114E-01	-.3865E-01	-.3785E-01	-.3702E-01	-.3619E-01
-.3502E-01	-.3287E-01	-.3013E-01	-.2719E-01	-.2381E-01	-.2029E-01	-.1658E-01	-.1323E-01	-.1023E-01	-.8143E-02
-.6998E-02	-.6403E-02	-.6174E-02	-.6161E-02	-.6241E-02	-.6266E-02	-.6151E-02	-.5923E-02	-.5621E-02	-.5269E-02
-.4882E-02	-.4474E-02	-.4048E-02	-.3591E-02	-.3116E-02	-.2634E-02	-.2152E-02	-.1669E-02	-.1028E-02	-.1028E-02

SWEEP NO. 4 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 5 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	-.2802E-01	-.3396E-01	-.6109E-01	-.9167E-01	-.8302E-01
-.6801E-01	-.2888E-01	.2059E-01	.7040E-01	.1090E+00	.9533E-01	.4125E-01	.2776E-01	.1100E-01	.1100E-01
.2000E-02	.2000E-02	.2000E-02	.2000E-02						

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.8200E-01	.2000E-02	.2000E-02	.5752E-02	-.1603E-01	-.2315E-01	-.3510E-01	-.8104E-01	-.8999E-01	-.6900E-01
-.3484E-01	.7835E-03	.4011E-01	.7927E-01	.8274E-01	.4647E-01	.2427E-01	.1039E-01	.5714E-02	.3238E-02
.2000E-02	.2000E-02	-.7800E-01	-.1362E+01	-.1122E+01	-.1122E+01	-.1362E+01	-.7800E-01	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.8200E-01	.1340E+01	.1100E+01	.1100E+01	.1340E+01

RUN NO. 5 OF PROGRAM AMOS

REFERENCE LENGTH= 1.0000

X	Y	SSM	CP	U (TANG)	V (NORM)
1.00000	1.30000	1.00000	-.33133	1.15383	.08200
3.00000	1.30000	3.00000	-.16319	1.07851	.00200
5.00000	1.30000	5.00000	-.14902	1.07192	.00200
7.00000	1.30000	7.00000	-.17898	1.08581	.00575
9.00000	1.30000	9.00000	-.19825	1.09455	-.01603
10.50000	1.30000	10.50000	-.24989	1.11754	-.02315
11.50000	1.30000	11.50000	-.28134	1.13196	-.03510
12.51416	1.29985	12.51416	-.33366	1.15484	-.08104
13.28899	1.28786	13.28925	-.45616	1.20671	-.08999
13.82168	1.24014	13.82458	-.49223	1.22157	-.06900
14.36269	1.14482	14.37443	-.48816	1.21990	-.03484
14.89416	1.00212	14.92528	-.47079	1.21276	.00078
15.40981	.81390	15.47471	-.44025	1.20010	.04011
15.89402	.58940	16.00890	-.39815	1.18244	.07927
16.57054	.21284	16.78335	-.31466	1.14659	.08274
17.44901	-.29418	17.79764	-.26569	1.12503	.04647
18.31501	-.79418	18.79762	-.24006	1.11358	.02427
19.61401	-1.54418	20.29758	-.20176	1.09625	.01039
21.34601	-2.54418	22.29754	-.19200	1.09179	.00571
23.07801	-3.54418	24.29749	-.18541	1.08876	.00324
24.81001	-4.54418	26.29745	-.17123	1.08223	.00200
26.54201	-5.54418	28.29741	-.13926	1.06736	.00200
28.27401	-6.54418	30.29736	.37531	.79037	-.07800
29.39001	-6.61109	31.79740	-1.12897	1.45910	-1.36230
29.86500	-5.78850	32.74728	-.26005	1.12252	-1.12230
30.31500	-5.00900	33.64735	-.26063	-1.12278	-1.12230
30.76500	-4.22950	34.54741	-1.12254	-1.45690	-1.36230
30.12400	-3.34000	35.99721	.34989	-.80630	-.07800
28.39200	-2.34000	37.99716	-.13555	-1.06562	.00200
26.66000	-1.34000	39.99712	-.16117	-1.07758	.00200
24.92800	-.34000	41.99708	-.16872	-1.08107	.00200
23.19600	.66000	43.99703	-.16402	-1.07890	.00200
21.46400	1.66000	45.99699	-.14645	-1.07072	.00200
19.29900	2.91000	48.49693	.01627	-.99163	.00200
17.61300	3.86150	50.43322	.11476	-.94087	.00200

16.82300	4.23000	51.30576	.19419	-.89767	.00200
16.00400	4.52800	52.17813	.21748	-.88460	.00200
15.16250	4.75350	53.05014	.21275	-.88727	.00200
14.30450	4.90500	53.92225	.17821	-.90652	.00200
13.43600	4.98100	54.79490	.08032	-.95900	.00200
11.50000	5.00000	56.73131	-.03490	-1.01730	.00200
9.00000	5.00000	59.23131	-.15559	-1.07498	.00200
7.00000	5.00000	61.23131	-.14621	-1.07061	.00200
5.00000	5.00000	63.23131	-.10247	-1.04999	.00200
3.00000	5.00000	65.23131	.03247	-.98363	.00200
1.00000	5.00000	67.23131	.87196	-.35782	.08200
0	4.52500	68.70631	-2.37244	-1.83642	1.34000
0	3.57500	69.65631	-.31118	-1.14507	1.10000
0	2.62500	70.60631	-.26902	-1.12651	1.10000
0	1.07500	72.15631	-5.09448	2.46870	1.34000

OFF-BODY POINTS

X	Y	U	V	CP
5.00000	2.15000	1.10032	.00519	-.21073
5.00000	3.10000	1.09899	.00469	-.20781
5.00000	4.05000	1.09280	.00101	-.19420
9.00000	2.15000	1.10748	-.01214	-.22666
9.00000	3.10000	1.10350	-.00933	-.21780
9.00000	4.05000	1.09868	-.00538	-.20712
21.84600	-1.67800	.95544	-.54686	-.21192
22.29600	-.89900	.95387	-.54788	-.21004
22.74600	-.11900	.95075	-.54849	-.20477
25.31000	-3.67800	.95548	-.55132	-.21689
25.76000	-2.89900	.95597	-.55176	-.21831
26.21000	-2.11900	.95438	-.55123	-.21469

RUN NO. 5 OF PROGRAM TRAVERS

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 1

YNORM	U
.13000E+01	.10719E+01
.21500E+01	.11003E+01
.31000E+01	.10990E+01
.40500E+01	.10928E+01
.50000E+01	.10500E+01

MASS FLOW RATE= .40364E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 2

YNORM	U
.13000E+01	.10946E+01
.21500E+01	.11075E+01
.31000E+01	.11035E+01
.40500E+01	.10987E+01
.50000E+01	.10750E+01

MASS FLOW RATE= .40697E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 3

YNORM	U
.13000E+01	.10918E+01
.23000E+01	.11009E+01

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     .32000E+01      .11000E+01
     .41000E+01      .10976E+01
     .50000E+01      .10789E+01

MASS FLOW RATE=      .40591E+01


VELOCITY PROFILE ACROSS DUCT AT STATION NO.  4
      YNORM            U
     .13000E+01      .10822E+01
     .23000E+01      .11031E+01
     .32000E+01      .11038E+01
     .41000E+01      .11021E+01
     .50000E+01      .10776E+01

MASS FLOW RATE=      .40658E+01


RUN NO.  5  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS CYCLE--S.YOUNG TEST CASE


1977    1   10   99   46   34    0    0    1    0   51    0   -2    0
A                0  6.000E-01          0  6.256E+04  1.375E-03  3.000E-01  3.000E-01
X FOR CURV. B. VALUE             0  4.000E+00  8.000E+00  1.000E+01  1.200E+01  1.220E+01  1.240E+01
 1.260E+01  1.280E+01  1.290E+01  1.300E+01  1.310E+01  1.320E+01  1.340E+01
 1.360E+01  1.380E+01  1.400E+01  1.420E+01  1.440E+01  1.460E+01  1.480E+01
 1.500E+01  1.520E+01  1.540E+01  1.550E+01  1.560E+01  1.570E+01  1.580E+01
 1.600E+01  1.620E+01  1.640E+01  1.660E+01  1.700E+01  1.900E+01  2.100E+01
 2.200E+01  2.250E+01  2.300E+01  2.350E+01  2.400E+01  2.450E+01  2.500E+01
 2.550E+01  2.600E+01  2.650E+01  2.700E+01
CURV               0          0          0          0          0  2.000E-02  4.000E-02
 6.000E-02  8.000E-02  9.000E-02  1.000E-01  1.100E-01  1.200E-01  1.400E-01
 1.600E-01  1.800E-01  2.000E-01  2.000E-01  2.000E-01  2.000E-01  1.800E-01
 1.600E-01  1.400E-01  1.200E-01  1.100E-01  1.000E-01  9.000E-02  8.000E-02
 6.000E-02  4.000E-02  2.000E-02          0          0          0          0
         0          0          0          0          0          0          0
         0          0          0          0
X FOR PRESS. AND NP B. VALUES              0   2.0000E+00   4.0000E+00   6.0000E+00   8.0000E+00   1.0000E+01   1.1000E+01
  1.2000E+01   1.3000E+01   1.3436E+01   1.3872E+01   1.4308E+01   1.4745E+01   1.5181E+01
  1.5617E+01   1.6617E+01   1.7617E+01   1.8617E+01   2.0617E+01   2.2617E+01
PE-PREF       5.0000E-01  -1.1658E-01  -7.0337E-02  -8.2767E-02  -9.2677E-02  -1.1482E-01  -1.3363E-01
 -1.4686E-01  -2.0850E-01  -2.4038E-01  -2.4659E-01  -2.4041E-01  -2.2851E-01  -2.1043E-01
 -1.8507E-01  -1.4092E-01  -1.2649E-01  -1.1301E-01  -9.6387E-02  -9.4839E-02
NP   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00

STN.          X       YSTEP         CF          UE     DEL05       THETA     SCHMETA          H     RTHETA      I6
   1  .1000E+02  .3333E-01    .002750  .1109E+01  .8208E+00  .9611E-01  .9611E-01     1.37739  .6668E+04      37

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0          0          0          0          0

STN.          X       YSTEP         CF          UE     DEL05       THETA     SCHMETA          H     RTHETA      I6
   2  .1025E+02  .3333E-01    .002641  .1114E+01  .8090E+00  .8457E-01  .9550E-01     1.53411  .5895E+04      37

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0          0          0          0          0

STN.          X       YSTEP         CF          UE     DEL05       THETA     SCHMETA          H     RTHETA      I6
  10  .1232E+02  .3333E-01    .003924  .1151E+01  .7582E+00  .3537E-01  .5882E-01     2.18146  .2548E+04      37
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 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0  .2473E-01          0          0              0

STN.          X       YSTEP          CF          UE    DEL05        THETA    SCHMETA           H      RTHETA      I6
 20  .1312E+02  .3333E-01     .004812  .1197E+01  .7236E+00  .2312E-01  .2433E-01    1.67054  .1731E+04       37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.DC5        VW/UE
         0  .8085E-01          0          0              0

STN.          X       YSTEP          CF          UE    DEL05        THETA    SCHMETA           H      RTHETA      I6
 30  .1368E+02  .3333E-01     .005147  .1218E+01  .6910E+00  .2302E-02 -.3937E-02    5.64135  .1754E+03       37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.DD5        VW/UE
         0  .1160E+00          0          0              0

STN.          X       YSTEP          CF          UE    DEL05        THETA    SCHMETA           H      RTHETA      I6
 40  .1524E+02  .3333E-01     .003341  .1189E+01  .7114E+00  .3205E-01  .1030E-01    1.16163  .2383E+04       37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0  .9646E-01          0          0              0

STN.          X       YSTEP          CF          UE    DEL05        THETA    SCHMETA           H      RTHETA      I6
 50  .1574E+02  .3333E-01     .002705  .1165E+01  .7516E+00  .4818E-01  .2698E-01    1.30330  .3512E+04       37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0  .6446E-01          0          0              0

STN.          X       YSTEP          CF          UE    DEL05        THETA    SCHMETA           H      RTHETA      I6
 60  .1623E+02  .3333E-01     .002225  .1144E+01  .7900E+00  .6680E-01  .4272E-01    1.34800  .4780E+04       37

 ROUGH/D05      D05/RAD 005/(X-XO) STRAIN.D05        VW/UE
         0  .2934E-01          0          D              0

STN.          X       YSTEP          CF          UE    DEL05        THETA    SCHMETA           H      RTHETA      I6
 70  .1690E+02  .3333E-01     .001906  .1125E+01  .8358E+00  .8704E-01  .6031E-01    1.40889  .6124E+04       37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0          0          D          0              0

STN.          X       YSTEP          CF          UE    DEL05        THETA    SCHMETA           H      RTHETA      I6
 80  .1815E+02  .3333E-01     .001891  .1111E+01  .8565E+00  .1101E+00  .8068E-01    1.44600  .7654E+04       37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0          0          0          0              0

STN.          X       YSTEP          CF          UE    OEL05        THETA    SCHMETA           H      RTHETA      I6
 90  .1969E+02  .3333E-01     .002033  .1097E+01  .8602E+00  .1212E+00  .9005E-01    1.43275  .8325E+04       37

 ROUGH/D05      D05/RAD D05/(X-XO) STRAIN.D05        VW/UE
         0          0          0          D              0

STN.          X       YSTEP          CF          UE    DEL05        THETA    SCHMETA           H      RTHETA      I6
 99  .2131E+02  .3333E-01     .002160  .1091E+01  .9022E+00  .1253E+00  .9615E-01    1.45482  .8546E+04       37

 ROUGH/D05      D05/RAD DD5/(X-XO) STRAIN.D05        VW/UE
         0          0          0          0              0

X=
   .1000E+02   .1025E+02   .1049E+02   .1075E+02   .1102E+02   .1128E+02   .1155E+02   .1181E+02   .1207E+02   .1232E+02
   .1249E+02   .1260E+02   .1269E+02   .1277E+02   .1283E+02   .1290E+02   .1296E+02   .1301E+02   .1307E+02   .1312E+02
   .1317E+02   .1322E+02   .1327E+02   .1332E+02   .1337E+02   .1342E+02   .1348E+02   .1354E+02   .1361E+02   .1368E+02
   .1376E+02   .1385E+02   .1396E+02   .1410E+02   .1429E+02   .1457E+02   .1483E+02   .1504E+02   .1516E+02   .1524E+02
   .1531E+02   .1537E+02   .1542E+02   .1547E+02   .1552E+02   .1556E+02   .1561E+02   .1565E+02   .1570E+02   .1574E+02
   .1579E+02   .1583E+02   .1588E+02   .1593E+02   .1597E+02   .1602E+02   .1607E+02   .1612E+02   .1618E+02   .1623E+02
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.1628E+02	.1634E+02	.1640E+02	.1646E+02	.1653E+02	.1659E+02	.1666E+02	.1674E+02	.1682E+02	.1690E+02
.1699E+02	.1709E+02	.1720E+02	.1731E+02	.1743E+02	.1756E+02	.1770E+02	.1785E+02	.1800E+02	.1815E+02
.1830E+02	.1845E+02	.1860E+02	.1875E+02	.1890E+02	.1905E+02	.1921E+02	.1936E+02	.1952E+02	.1969E+02
.1985E+02	.2003E+02	.2020E+02	.2038E+02	.2056E+02	.2075E+02	.2093E+02	.2112E+02	.2131E+02	.2149E+02

VE/UE=

-.3125E-01	-.2790E-01	-.3054E-01	-.2859E-01	-.2709E-01	-.2691E-01	-.3156E-01	-.4181E-01	-.5664E-01	-.7123E-01
-.8153E-01	-.8887E-01	-.9373E-01	-.9684E-01	-.9867E-01	-.9959E-01	-.9983E-01	-.9955E-01	-.9876E-01	-.9750E-01
-.9576E-01	-.9358E-01	-.9096E-01	-.8790E-01	-.8436E-01	-.8032E-01	-.7568E-01	-.7034E-01	-.6415E-01	-.5685E-01
-.4812E-01	-.3739E-01	-.2400E-01	-.1023E-01	.1675E-02	.1742E-01	.3439E-01	.4916E-01	.6028E-01	.6879E-01
.7509E-01	.7988E-01	.8356E-01	.8645E-01	.8876E-01	.9064E-01	.9216E-01	.9345E-01	.9449E-01	.9534E-01
.9600E-01	.9646E-01	.9674E-01	.9680E-01	.9665E-01	.9625E-01	.9558E-01	.9462E-01	.9332E-01	.9169E-01
.8981E-01	.8773E-01	.8550E-01	.8311E-01	.8059E-01	.7792E-01	.7505E-01	.7195E-01	.6866E-01	.6519E-01
.6153E-01	.5770E-01	.5371E-01	.4957E-01	.4544E-01	.4121E-01	.3708E-01	.3316E-01	.2964E-01	.2660E-01
.2416E-01	.2231E-01	.2105E-01	.2010E-01	.1933E-01	.1861E-01	.1789E-01	.1713E-01	.1630E-01	.1538E-01
.1434E-01	.1319E-01	.1200E-01	.1085E-01	.9789E-02	.8844E-02	.8045E-02	.7412E-02	.6956E-02	

(PW-PREF)/UREF**2=

-.1148E+00	-.1217E+00	-.1292E+00	-.1322E+00	-.1383E+00	-.1458E+00	-.1570E+00	-.1717E+00	-.1897E+00	-.2208E+00
-.2475E+00	-.2648E+00	-.2764E+00	-.2856E+00	-.2937E+00	-.3015E+00	-.3090E+00	-.3162E+00	-.3228E+00	-.3288E+00
-.3347E+00	-.3405E+00	-.3464E+00	-.3524E+00	-.3585E+00	-.3648E+00	-.3713E+00	-.3781E+00	-.3849E+00	-.3919E+00
-.3986E+00	-.4052E+00	-.4150E+00	-.4277E+00	-.4318E+00	-.4210E+00	-.3973E+00	-.3635E+00	-.3408E+00	-.3284E+00
-.3210E+00	-.3158E+00	-.3113E+00	-.3069E+00	-.3024E+00	-.2976E+00	-.2927E+00	-.2877E+00	-.2825E+00	-.2772E+00
-.2719E+00	-.2666E+00	-.2612E+00	-.2559E+00	-.2506E+00	-.2455E+00	-.2404E+00	-.2354E+00	-.2304E+00	-.2251E+00
-.2192E+00	-.2131E+00	-.2067E+00	-.2001E+00	-.1933E+00	-.1865E+00	-.1808E+00	-.1767E+00	-.1725E+00	-.1683E+00
-.1640E+00	-.1597E+00	-.1554E+00	-.1510E+00	-.1468E+00	-.1428E+00	-.1390E+00	-.1355E+00	-.1321E+00	-.1289E+00
-.1258E+00	-.1229E+00	-.1202E+00	-.1179E+00	-.1159E+00	-.1138E+00	-.1120E+00	-.1103E+00	-.1086E+00	-.1070E+00
-.1055E+00	-.1040E+00	-.1027E+00	-.1014E+00	-.1002E+00	-.9915E-01	-.9815E-01	-.9723E-01	-.9621E-01	-.9600E-01

(PW-PE)/UREF**2=

0	-.1009E-02	-.3373E-02	-.1585E-02	-.4583E-02	-.1054E-01	-.1994E-01	-.3052E-01	-.4003E-01	-.5798E-01
-.7438E-01	-.8399E-01	-.8939E-01	-.9321E-01	-.9653E-01	-.9994E-01	-.1035E+00	-.1069E+00	-.1100E+00	-.1128E+00
-.1156E+00	-.1185E+00	-.1215E+00	-.1247E+00	-.1282E+00	-.1320E+00	-.1360E+00	-.1404E+00	-.1450E+00	-.1498E+00
-.1547E+00	-.1600E+00	-.1694E+00	-.1634E+00	-.1911E+00	-.1871E+00	-.1716E+00	-.1470E+00	-.1302E+00	-.1221E+00
-.1183E+00	-.1162E+00	-.1146E+00	-.1130E+00	-.1111E+00	-.1090E+00	-.1066E+00	-.1040E+00	-.1013E+00	-.9853E-01
-.9569E-01	-.9282E-01	-.8996E-01	-.8714E-01	-.8437E-01	-.8167E-01	-.7905E-01	-.7652E-01	-.7394E-01	-.7098E-01
-.6749E-01	-.6361E-01	-.5946E-01	-.5509E-01	-.5052E-01	-.4583E-01	-.4224E-01	-.4023E-01	-.3807E-01	-.3580E-01
-.3345E-01	-.3102E-01	-.2651E-01	-.2579E-01	-.2315E-01	-.2071E-01	-.1825E-01	-.1595E-01	-.1372E-01	-.1159E-01
-.9638E-02	-.7863E-02	-.6480E-02	-.5624E-02	-.5102E-02	-.4816E-02	-.4685E-02	-.4657E-02	-.4690E-02	-.4751E-02
-.4794E-02	-.4756E-02	-.4573E-02	-.4250E-02	-.3824E-02	-.3319E-02	-.2759E-02	-.2160E-02	-.1388E-02	-.1388E-02

SWEEP NO. 5 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NØ. 6 ØF PRØGRAM MATCH

VELS. NØRMAL TØ MATCHING SURFACE AT NØDES

.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	-.3465E-01	-.3057E-01	-.5979E-01	-.1173E+00	-.9503E-01
-.4242E-01	.3375E-02	.3494E-01	.7345E-01	.1071E+00	.8689E-01	.4421E-01	.2320E-01	.1038E-01	.1038E-01
.2000E-02	.2000E-02	.2000E-02	.2000E-02						

VELS. NØRMAL TØ MATCHING SURFACE AT ELEMENT MID PTS.

.8200E-01	.2000E-02	.2000E-02	.6582E-02	-.2380E-01	-.2474E-01	-.3713E-01	-.8834E-01	-.9586E-01	-.6866E-01
-.2971E-01	.6028E-02	.4445E-01	.8368E-01	.8792E-01	.5138E-01	.2674E-01	.1183E-01	.7429E-02	.3810E-02
.2000E-02	.2000E-02	-.7800E-01	-.1363E+01	-.1123E+01	-.1123E+01	-.1363E+01	-.7800E-01	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.8200E-01	.1340E+01	.1100E+01	.1100E+01	.1340E+01

RUN NØ. 6 ØF PRØGRAM AMØS

REFERENCE LENGTH= 1.0000

X	Y	SSM	CP	U (TANG)	V (NØRM)
1.00000	1.30000	1.00000	-.33143	1.15387	.08200
3.00000	1.30000	3.00000	-.16340	1.07861	.00200
5.00000	1.30000	5.00000	-.14930	1.07206	.00200
7.00000	1.30000	7.00000	-.18235	1.08736	.00658
9.00000	1.30000	9.00000	-.19626	1.09374	-.02380
10.50000	1.30000	10.50000	-.23734	1.11236	-.02474
11.50000	1.30000	11.50000	-.27303	1.12829	-.03713
12.51416	1.29985	12.51416	-.32011	1.14896	-.08834
13.28899	1.28786	13.28925	-.42761	1.19483	-.09586
13.82168	1.24014	13.82458	-.45800	1.20748	-.06866
14.36269	1.14482	14.37443	-.45887	1.20784	-.02971
14.89416	1.00212	14.92528	-.44930	1.20387	.00603
15.40981	.81390	15.47471	-.42312	1.19294	.04445
15.89402	.58940	16.00890	-.38366	1.17629	.08368
16.57054	.21284	16.78335	-.30545	1.14256	.08792
17.44901	-.29418	17.79764	-.26207	1.12342	.05138
18.31501	-.79418	18.79762	-.23919	1.11319	.02674
19.61401	-1.54418	20.29758	-.20067	1.09575	.01183
21.34601	-2.54418	22.29754	-.19258	1.09205	.00743
23.07801	-3.54418	24.29749	-.18750	1.08972	.00381
24.81001	-4.54418	26.29745	-.17326	1.08317	.00200
26.54201	-5.54418	28.29741	-.14106	1.06820	.00200
28.27401	-6.54418	30.29736	.37377	.79135	-.07800
29.39001	-6.61109	31.79740	-1.13051	1.45963	-1.36302
29.86500	-5.78850	32.74728	-.26166	1.12324	-1.12302
30.31500	-5.00900	33.64735	-.26224	-1.12349	-1.12302
30.76500	-4.22950	34.54741	-1.12411	-1.45743	-1.36302
30.12400	-3.34000	35.99721	.34837	-.80724	-.07800
28.39200	-2.34000	37.99716	-.13725	-1.06642	.00200
26.66000	-1.34000	39.99712	-.16267	-1.07827	.00200
24.92800	-.34000	41.99708	-.16964	-1.08150	.00200
23.19600	.66000	43.99703	-.16371	-1.07875	.00200
21.46400	1.66000	45.99699	-.14423	-1.06969	.00200
19.29900	2.91000	48.49693	.02134	-.98927	.00200
17.61300	3.86150	50.43322	.12218	-.93692	.00200

16.82300	4.23000	51.30576	.20180	-.89342	.00200
16.00400	4.52800	52.17813	.22552	-.88005	.00200
15.16250	4.75350	53.05014	.22121	-.88249	.00200
14.30450	4.90500	53.92225	.18708	-.90162	.00200
13.43600	4.98100	54.79490	.08990	-.95399	.00200
11.50000	5.00000	56.73131	-.02721	-1.01351	.00200
9.00000	5.00000	59.23131	-.15154	-1.07310	.00200
7.00000	5.00000	61.23131	-.14508	-1.07009	.00200
5.00000	5.00000	63.23131	-.10240	-1.04935	.00200
3.00000	5.00000	65.23131	.03226	-.98374	.00200
1.00000	5.00000	67.23131	.87153	-.35828	.00200
0	4.52500	68.70631	-2.37050	-1.83589	1.34000
0	3.57500	69.65631	-.31104	-1.14501	1.10000
0	2.62500	70.60631	-.26897	-1.12649	1.10000
0	1.07500	72.15631	-5.08771	2.46733	1.34000

OFF-BODY POINTS

X	Y	U	V	CP
5.00000	2.15000	1.10048	.00516	-.21108
5.00000	3.10000	1.09911	.00460	-.20607
5.00000	4.05000	1.09284	.00095	-.19430
9.00000	2.15000	1.10622	-.01634	-.22399
9.00000	3.10000	1.10191	-.01149	-.21433
9.00000	4.05000	1.09687	-.00635	-.20317
21.84600	-1.67800	.95612	-.54601	-.21230
22.29600	-.89900	.95424	-.54730	-.21011
22.74600	-.11900	.95086	-.54816	-.20462
25.31000	-3.67800	.95630	-.55168	-.21887
25.76000	-2.89900	.95672	-.55208	-.22011
26.21000	-2.11900	.95506	-.55156	-.21636

RUN NO. 6 OF PROGRAM TRAVERS

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 1

YNORM	U
.13000E+01	.10721E+01
.21500E+01	.11005E+01
.31000E+01	.10991E+01
.40500E+01	.10928E+01
.50000E+01	.10500E+01

MASS FLOW RATE= .40368E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 2

YNORM	U
.13000E+01	.10937E+01
.21500E+01	.11062E+01
.31000E+01	.11019E+01
.40500E+01	.10969E+01
.50000E+01	.10731E+01

MASS FLOW RATE= .40640E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 3

YNORM	U
.13000E+01	.10921E+01
.23000E+01	.11010E+01

```
      .32000E+01      .11000E+01
      .41000E+01      .10976E+01
      .50000E+01      .10788E+01

MASS FLOW RATE=      .40593E+01


VELOCITY PROFILE ACROSS DUCT AT STATION NO.  4
       YNORM               U
      .13000E+01      .10832E+01
      .23000E+01      .11040E+01
      .32000E+01      .11046E+01
      .41000E+01      .11029E+01
      .50000E+01      .10783E+01

MASS FLOW RATE=      .40689E+01


RUN NO.  6  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCIO/VISCOUS CYCLE--S.YOUNG TEST CASE


1977    1   10   99   46   34    0    0    1    0   51    0   -2    0
A                 0  6.000E-01            0  6.256E+04  1.375E-03  3.000E-01  3.000E-01
X FOR CURV. B. VALUE              0  4.000E+00  8.000E+00  1.000E+01  1.200E+01  1.220E+01  1.240E+01
 1.260E+01  1.280E+01  1.290E+01  1.300E+01  1.310E+01  1.320E+01  1.340E+01
 1.360E+01  1.380E+01  1.400E+01  1.420E+01  1.440E+01  1.460E+01  1.480E+01
 1.500E+01  1.520E+01  1.540E+01  1.550E+01  1.560E+01  1.570E+01  1.580E+01
 1.600E+01  1.620E+01  1.640E+01  1.660E+01  1.700E+01  1.900E+01  2.100E+01
 2.200E+01  2.250E+01  2.300E+01  2.350E+01  2.400E+01  2.450E+01  2.500E+01
 2.550E+01  2.600E+01  2.650E+01  2.700E+01
CURV              0          0          0          0          0  2.000E-02  4.000E-02
 6.000E-02  8.000E-02  9.000E-02  1.000E-01  1.100E-01  1.200E-01  1.400E-01
 1.600E-01  1.800E-01  2.000E-01  2.000E-01  2.000E-01  2.000E-01  1.800E-01
 1.600E-01  1.400E-01  1.200E-01  1.100E-01  1.000E-01  9.000E-02  8.000E-02
 6.000E-02  4.000E-02  2.000E-02          0          0          0          0
         0          0          0          0          0          0          0
         0          0          0          0
X FOR PRESS. AND NP B. VALUES              0   2.0000E+00   4.0000E+00   6.0000E+00   8.0000E+00   1.0000E+01   1.1000E+01
  1.2000E+01   1.3000E+01   1.3436E+01   1.3872E+01   1.4308E+01   1.4745E+01   1.5181E+01
  1.5617E+01   1.6617E+01   1.7617E+01   1.8617E+01   2.0617E+01   2.2617E+01
PE-PREF       5.0000E-01  -1.1671E-01  -7.0294E-02  -8.3727E-02  -9.4020E-02  -1.0990E-01  -1.2850E-01
 -1.4253E-01  -1.9680E-01  -2.2413E-01  -2.3019E-01  -2.2783E-01  -2.1907E-01  -2.0253E-01
 -1.7863E-01  -1.3791E-01  -1.2555E-01  -1.1268E-01  -9.6102E-02  -9.5567E-02
NP   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00

STN.          X        YSTEP          CF         UE     DELO5       THETA     SCHMETA          H     RTHETA      I6
   1   .1000E+02   .3333E-01     .002750   .1104E+01   .8208E+00   .9611E-01   .9611E-01     1.37743   .6641E+04     37

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05       VW/UE
         0          0          0          0          0

STN.          X        YSTEP          CF         UE     DELO5       THETA     SCHMETA          H     RTHETA      I6
   2   .1025E+02   .3333E-01     .002622   .1110E+01   .8102E+00   .8560E-01   .9619E-01     1.52751   .5942E+04     37

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05       VW/UE
         0          0          0          0          0

STN.          X        YSTEP          CF         UE     DELO5       THETA     SCHMETA          H     RTHETA      I6
  10   .1232E+02   .3333E-01     .004132   .1146E+01   .7657E+00   .2900E-01   .5150E-01     2.30178   .2080E+04     37
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 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5      VW/UE
         0   .2465E-01          0           0           0

STN.          X       YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
 20   .1312E+02  .3333E-01   .004856  .1186E+01  .7242E+00  .1760E-01  .1948E-01    1.80352  .1306E+04      37

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5      VW/UE
         0   .8091E-01          0           0           0

STN.          X       YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
 30   .1368E+02  .3333E-01   .005036  .1205E+01  .7049E+00  .4895E-02  .5686E-03    3.16960  .3689E+03      37

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5      VW/UE
         0   .1183E+00          0           0           0

STN.          X       YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
 40   .1524E+02  .3333E-01   .003436  .1183E+01  .7064E+00  .2448E-01  .2812E-02    1.19387  .1811E+04      37

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5      VW/UE
         0   .9579E-01          0           0           0

STN.          X       YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
 50   .1574E+02  .3333E-01   .002751  .1161E+01  .7462E+00  .4265E-01  .2102E-01    1.32082  .3096E+04      37

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5      VW/UE
         0   .6400E-01          0           0           0

STN.          X       YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
 60   .1623E+02  .3333E-01   .002239  .1140E+01  .7854E+00  .6274E-01  .3796E-01    1.35491  .4474E+04      37

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5      VW/UE
         0   .2917E-01          0           0           0

STN.          X       YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
 70   .1690E+02  .3333E-01   .001877  .1121E+01  .8325E+00  .8473E-01  .5691E-01    1.41456  .5941E+04      37

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5      VW/UE
         0           0          0           0           0

STN.          X       YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
 80   .1815E+02  .3333E-01   .001840  .1107E+01  .8539E+00  .1095E+00  .7894E-01    1.46105  .7581E+04      37

 ROUGH/DO5     005/RAD DO5/(X-XO) STRAIN.DO5      VW/UE
         0           0          0           0           0

STN.          X       YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
 90   .1969E+02  .3333E-01   .002039  .1097E+01  .8542E+00  .1209E+00  .8842E-01    1.43636  .8295E+04      37

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5      VW/UE
         0           0          0           0           0

STN.          X       YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
 99   .2131E+02  .3333E-01   .002169  .1091E+01  .8953E+00  .1245E+00  .9393E-01    1.45609  .8498E+04      37

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5      VW/UE
         0           0          0           0           0

X=
   .1000E+02   .1025E+02   .1049E+02   .1075E+02   .1102E+02   .1128E+02   .1155E+02   .1181E+02   .1207E+02   .1232E+02
   .1249E+02   .1260E+02   .1269E+02   .1277E+02   .1283E+02   .1290E+02   .1296E+02   .1301E+02   .1307E+02   .1312E+02
   .1317E+02   .1322E+02   .1327E+02   .1332E+02   .1337E+02   .1342E+02   .1348E+02   .1354E+02   .1361E+02   .1368E+02
   .1376E+02   .1385E+02   .1396E+02   .1410E+02   .1429E+02   .1457E+02   .1483E+02   .1504E+02   .1516E+02   .1524E+02
   .1531E+02   .1537E+02   .1542E+02   .1547E+02   .1552E+02   .1556E+02   .1561E+02   .1565E+02   .1570E+02   .1574E+02
   .1579E+02   .1583E+02   .1588E+02   .1593E+02   .1597E+02   .1602E+02   .1607E+02   .1612E+02   .1618E+02   .1623E+02
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.1628E+02	.1634E+02	.1640E+02	.1646E+02	.1653E+02	.1659E+02	.1666E+02	.1674E+02	.1682E+02	.1690E+02
.1699E+02	.1709E+02	.1720E+02	.1731E+02	.1743E+02	.1756E+02	.1770E+02	.1785E+02	.1800E+02	.1815E+02
.1830E+02	.1845E+02	.1660E+02	.1875E+02	.1890E+02	.1905E+02	.1921E+02	.1936E+02	.1952E+02	.1969E+02
.1995E+02	.2003E+02	.2020E+02	.2038E+02	.2056E+02	.2075E+02	.2093E+02	.2112E+02	.2131E+02	.2149E+02

VE/UE=

-.2639E-01	-.2323E-01	-.2672E-01	-.2660E-01	-.2768E-01	-.3046E-01	-.3762E-01	-.4953E-01	-.6453E-01	-.7720E-01
-.8468E-01	-.8885E-01	-.9046E-01	-.9037E-01	-.8908E-01	-.8698E-01	-.8429E-01	-.8121E-01	-.7798E-01	-.7476E-01
-.7163E-01	-.6862E-01	-.6575E-01	-.6300E-01	-.6036E-01	-.5780E-01	-.5532E-01	-.5288E-01	-.5047E-01	-.4807E-01
-.4567E-01	-.4326E-01	-.4057E-01	-.3400E-01	-.1820E-01	.5950E-02	.2660E-01	.4430E-01	.5709E-01	.6678E-01
.7360E-01	.7909E-01	.8308E-01	.8620E-01	.8866E-01	.9066E-01	.9230E-01	.9366E-01	.9479E-01	.9573E-01
.9648E-01	.9705E-01	.9743E-01	.9762E-01	.9760E-01	.9736E-01	.9685E-01	.9607E-01	.9497E-01	.9356E-01
.9191E-01	.9007E-01	.8807E-01	.8592E-01	.8363E-01	.8120E-01	.7854E-01	.7564E-01	.7252E-01	.6918E-01
.6563E-01	.6185E-01	.5784E-01	.5372E-01	.4932E-01	.4477E-01	.4014E-01	.3559E-01	.3127E-01	.2730E-01
.2378E-01	.2078E-01	.1829E-01	.1645E-01	.1523E-01	.1457E-01	.1423E-01	.1398E-01	.1369E-01	.1327E-01
.1265E-01	.1183E-01	.1087E-01	.9906E-02	.8984E-02	.8153E-02	.7446E-02	.6884E-02	.6483E-02	

(PW-PREF)/UREF**2=

-.1099E+00	-.1164E+00	-.1242E+00	-.1277E+00	-.1348E+00	-.1435E+00	-.1558E+00	-.1715E+00	-.1899E+00	-.2198E+00
-.2441E+00	-.2585E+00	-.2676E+00	-.2747E+00	-.2810E+00	-.2871E+00	-.2933E+00	-.2998E+00	-.3070E+00	-.3147E+00
-.3225E+00	-.3305E+00	-.3385E+00	-.3466E+00	-.3546E+00	-.3628E+00	-.3712E+00	-.3798E+00	-.3888E+00	-.3984E+00
-.4086E+00	-.4194E+00	-.4273E+00	-.4295E+00	-.4273E+00	-.4185E+00	-.3970E+00	-.3629E+00	-.3399E+00	-.3279E+00
-.3214E+00	-.3166E+00	-.3128E+00	-.3087E+00	-.3044E+00	-.2997E+00	-.2948E+00	-.2897E+00	-.2844E+00	-.2790E+00
-.2736E+00	-.2680E+00	-.2625E+00	-.2570E+00	-.2515E+00	-.2461E+00	-.2408E+00	-.2356E+00	-.2303E+00	-.2248E+00
-.2187E+00	-.2124E+00	-.2056E+00	-.1990E+00	-.1921E+00	-.1851E+00	-.1792E+00	-.1750E+00	-.1706E+00	-.1662E+00
-.1618E+00	-.1574E+00	-.1527E+00	-.1483E+00	-.1441E+00	-.1400E+00	-.1362E+00	-.1327E+00	-.1295E+00	-.1266E+00
-.1238E+00	-.1214E+00	-.1189E+00	-.1165E+00	-.1142E+00	-.1121E+00	-.1103E+00	-.1087E+00	-.1073E+00	-.1059E+00
-.1047E+00	-.1035E+00	-.1023E+00	-.1011E+00	-.1001E+00	-.9908E-01	-.9817E-01	-.9732E-01	-.9640E-01	-.9624E-01

(PW-PE)/UREF**2=

0	-.8838E-03	-.3644E-02	-.2450E-02	-.6159E-02	-.1275E-01	-.2288E-01	-.3437E-01	-.4472E-01	-.6293E-01
-.7807E-01	-.8573E-01	-.8939E-01	-.9179E-01	-.9394E-01	-.9629E-01	-.9899E-01	-.1024E+00	-.1066E+00	-.1114E+00
-.1167E+00	-.1221E+00	-.1277E+00	-.1334E+00	-.1393E+00	-.1452E+00	-.1515E+00	-.1580E+00	-.1650E+00	-.1726E+00
-.1811E+00	-.1905E+00	-.1974E+00	-.1998E+00	-.1993E+00	-.1951E+00	-.1804E+00	-.1544E+00	-.1367E+00	-.1287E+00
-.1255E+00	-.1238E+00	-.1225E+00	-.1210E+00	-.1191E+00	-.1169E+00	-.1143E+00	-.1116E+00	-.1086E+00	-.1056E+00
-.1025E+00	-.9932E-01	-.9616E-01	-.9303E-01	-.8995E-01	-.8693E-01	-.8399E-01	-.8114E-01	-.7825E-01	-.7500E-01
-.7125E-01	-.6714E-01	-.6279E-01	-.5822E-01	-.5348E-01	-.4863E-01	-.4490E-01	-.4277E-01	-.4049E-01	-.3813E-01
-.3568E-01	-.3316E-01	-.3042E-01	-.2773E-01	-.2526E-01	-.2271E-01	-.2029E-01	-.1800E-01	-.1586E-01	-.1382E-01
-.1191E-01	-.1019E-01	-.8518E-02	-.6686E-02	-.5488E-02	-.4479E-02	-.3980E-02	-.3846E-02	-.3928E-02	-.4135E-02
-.4371E-02	-.4515E-02	-.4461E-02	-.4226E-02	-.3863E-02	-.3405E-02	-.2882E-02	-.2315E-02	-.1598E-02	-.1598E-02

SWEEP NO. 6 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 7 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	-.2914E-01	-.3096E-01	-.6847E-01	-.9538E-01	-.6759E-01
-.5147E-01	-.1998E-01	.2395E-01	.6963E-01	.1068E+00	.9037E-01	.4778E-01	.1998E-01	.9538E-02	.9538E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02						

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.8200E-01	.2000E-02	.2000E-02	.5893E-02	-.1816E-01	-.2499E-01	-.4133E-01	-.9048E-01	-.9109E-01	--.6649E-01
-.3198E-01	.4741E-02	.4541E-01	.8619E-01	.9217E-01	.5614E-01	.2832E-01	.1232E-01	.8344E-02	.4115E-02
.2000E-02	.2000E-02	-.7800E-01	-.1369E+01	-.1129E+01	-.1129E+01	-.1369E+01	-.7800E-01	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.8200E-01	.1340E+01	.1100E+01	.1100E+01	.1340E+01

RUN NO. 7 OF PROGRAM AMOS

REFERENCE LENGTH= 1.0000

X	Y	SSM	CP	U (TANG)	V (NORM)
1.00000	1.30000	1.00000	-.33080	1.15361	.08200
3.00000	1.30000	3.00000	-.16244	1.07817	.00200
5.00000	1.30000	5.00000	-.14833	1.07160	.00200
7.00000	1.30000	7.00000	-.17918	1.08590	.00589
9.00000	1.30000	9.00000	-.19776	1.09442	- 01816
10.50000	1.30000	10.50000	-.24828	1.11726	-.02499
11.50000	1.30000	11.50000	-.27859	1.13075	-.04133
12.51416	1.29985	12.51416	-.31839	1.14621	-.09048
13.28899	1.28786	13.28925	-.42519	1.19381	-.09109
13.82168	1.24014	13.82458	-.46464	1.21022	-.06649
14.35269	1.14482	14.37443	-.45444	1.21014	-.03198
14.89416	1.00212	14.92528	-.44913	1.20380	.00474
15.40981	.81390	15.47471	-.42121	1.19214	.04541
15.89402	.58940	16.00890	-.38270	1.17588	.08619
16.57054	.21284	16.78335	-.30911	1.14416	.09217
17.44901	-.29418	17.79764	-.27132	1.12753	.05614
18.31501	-.79418	18.79762	-.25106	1.11851	.02832
19.61401	-1.54418	20.29758	-.21084	1.10038	.01232
21.34601	-2.54418	22.29754	-.20306	1.09684	.00834
23.07801	-3.54418	24.29749	-.19878	1.09489	.00411
24.81001	-4.54418	26.29745	-.18441	1.08830	.00200
26.54201	-5.54418	28.29741	-.15179	1.07321	.00200
28.27401	-6.54418	30.29736	.36688	.79569	-.07800
29.39001	-6.61109	31.79740	-1.14741	1.46540	-1.36867
29.86500	-5.78850	32.74728	-.27440	1.12890	-1.12867
30.31500	-5.00900	33.64735	-.27498	-1.12915	-1.12867
30.76500	-4.22950	34.54741	-1.14096	-1.46320	-1.36867
30.12400	-3.34000	35.99721	.34126	-.81163	-.07800
28.39200	-2.34000	37.99716	-.14790	-1.07140	.00200
26.66000	-1.34000	39.99712	-.17344	-1.08326	.00200
24.92800	-.34000	41.99708	-.18016	-1.08635	.00200
23.19600	.66000	43.99703	-.17356	-1.08331	.00200
21.46400	1.66000	45.99699	-.15289	-1.07373	.00200
19.29900	2.91000	48.49693	.01597	-.99199	.00200
17.61300	3.86150	50.43322	.11902	-.93861	.00200

16.82300	4.23000	51.30576	.19933	-.89480	.00200
16.00400	4.52800	52.17813	.22342	-.88124	.00200
15.16250	4.75350	53.05014	.21929	-.88358	.00200
14.30450	4.90500	53.92225	.16518	-.90268	.00200
13.43600	4.98100	54.79490	.08778	-.95510	.00200
11.50000	5.00000	56.73131	-.02958	-1.01468	.00200
9.00000	5.00000	59.23131	-.15287	-1.07372	.00200
7.00000	5.00000	61.23131	-.14498	-1.05999	.00200
5.00000	5.00000	63.23131	-.10154	-1.04954	.00200
3.00000	5.00000	65.23131	.03346	-.98313	.00200
1.00000	5.00000	67.23131	.87296	-.35643	.08200
0	4.52500	68.70631	-2.37781	-1.83788	1.34000
0	3.57500	69.65631	-.31157	-1.14524	1.10000
0	2.62500	70.60631	-.26913	-1.12656	1.10000
0	1.07500	72.15631	-5.10817	2.47147	1.34000

ØFF-BØDY PØINTS

X	Y	U	V	CP
5.00000	2.15000	1.10003	.00517	-.21010
5.00000	3.10000	1.09867	.00465	-.20711
5.00000	4.05000	1.09243	.00098	-.19341
9.00000	2.15000	1.10701	-.01363	-.22567
9.00000	3.10000	1.10263	-.01030	-.21591
9.00000	4.05000	1.09754	-.00588	-.20463
21.84600	-1.67600	.96056	-.54792	-.22289
22.29600	-.89900	.95852	-.54936	-.22056
22.74600	-.11900	.95501	-.55035	-.21492
25.31000	-3.67800	.96082	-.55423	-.23034
25.76000	-2.89900	.96120	-.55460	-.23150
26.21000	-2.11900	.95950	-.55408	-.22765

RUN NØ. 7 ØF PRØGRAM TRAVERS

VELØCITY PRØFILE ACRØSS DUCT AT STATIØN NØ. 1

YNØRM	U
.13000E+01	.10716E+01
.21500E+01	.11000E+01
.31000E+01	.10987E+01
.40500E+01	.10924E+01
.50000E+01	.10495E+01

MASS FLØW RATE= .40352E+01

VELØCITY PRØFILE ACRØSS DUCT AT STATIØN NØ. 2

YNØRM	U
.13000E+01	.10944E+01
.21500E+01	.11070E+01
.31000E+01	.11026E+01
.40500E+01	.10975E+01
.50000E+01	.10737E+01

MASS FLØW RATE= .40667E+01

VELØCITY PRØFILE ACRØSS DUCT AT STATIØN NØ. 3

YNØRM	U
.13000E+01	.10968E+01
.23000E+01	.11058E+01

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     .32000E+01      .11048E+01
     .41000E+01      .11022E+01
     .50000E+01      .10833E+01

MASS FLOW RATE=      .40768E+01


VELOCITY PROFILE ACROSS DUCT AT STATION NO.  4
      YNORM            U
     .13000E+01      .10883E+01
     .23000E+01      .11092E+01
     .32000E+01      .11097E+01
     .41000E+01      .11080E+01
     .50000E+01      .10833E+01

MASS FLOW RATE=      .40879E+01


RUN NO.  7  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS CYCLE--S.YOUNG TEST CASE


1977    1   10   99   46   34    0    0    1    0   51    0   -2    0
A                0  6.000E-01          0  6.256E+04  1.375E-03  3.000E-01  3.000E-01
X FOR CURV. B. VALUE               0  4.000E+00  8.000E+00  1.000E+01  1.200E+01  1.220E+01  1.240E+01
 1.260E+01  1.280E+01  1.290E+01  1.300E+01  1.310E+01  1.320E+01  1.340E+01
 1.360E+01  1.380E+01  1.400E+01  1.420E+01  1.440E+01  1.460E+01  1.480E+01
 1.500E+01  1.520E+01  1.540E+01  1.550E+01  1.560E+01  1.570E+01  1.580E+01
 1.600E+01  1.620E+01  1.640E+01  1.660E+01  1.700E+01  1.900E+01  2.100E+01
 2.200E+01  2.250E+01  2.300E+01  2.350E+01  2.400E+01  2.450E+01  2.500E+01
 2.550E+01  2.600E+01  2.650E+01  2.700E+01
CURV            0          0          0          0          0  2.000E-02  4.000E-02
 6.000E-02  8.000E-02  9.000E-02  1.000E-01  1.100E-01  1.200E-01  1.400E-01
 1.600E-01  1.800E-01  2.000E-01  2.000E-01  2.000E-01  2.000E-01  1.800E-01
 1.600E-01  1.400E-01  1.200E-01  1.100E-01  1.000E-01  9.000E-02  8.000E-02
 6.000E-02  4.000E-02  2.000E-02          0          0          0          0
         0          0          0          0          0          0          0
         0          0          0          0
X FOR PRESS. AND NP B. VALUES             0   2.0000E+00    4.0000E+00    6.0000E+00    8.0000E+00    1.0000E+01    1.1000E+01
  1.2000E+01   1.3000E+01   1.3436E+01   1.3872E+01   1.4308E+01   1.4745E+01   1.5181E+01
  1.5617E+01   1.6617E+01   1.7617E+01   1.8617E+01   2.0617E+01   2.2617E+01
PE-PREF        5.0000E-01  -1.1627E-01  -6.9913E-02  -8.2690E-02  -9.2631E-02  -1.1457E-01  -1.3308E-01
 -1.4351E-01  -1.9473E-01  -2.2519E-01  -2.3395E-01  -2.2909E-01  -2.1829E-01  -2.0169E-01
 -1.7879E-01  -1.4131E-01  -1.3106E-01  -1.1853E-01  -1.0104E-01  -1.0105E-01
NP   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00

STN.         X       YSTEP          CF         UE     DEL05       THETA     SCHMETA          H     RTHETA      I6
   1  .1000E+02  .3333E-01    .002750  .1109E+01  .8208E+00  .9611E-01  .9611E-01     1.37739  .6666E+04      37

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
        0          0          0          0           0

STN.         X       YSTEP          CF         UE     DEL05       THETA     SCHMETA          H     RTHETA      I6
   2  .1025E+02  .3333E-01    .002617  .1114E+01  .8103E+00  .8555E-01  .9636E-01     1.53037  .5962E+04      37

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
        0          0          0          0           0

STN.         X       YSTEP          CF         UE     DEL05       THETA     SCHMETA          H     RTHETA      I6
  10  .1232E+02  .3333E-01    .003934  .1145E+01  .7663E+00  .3583E-01  .5493E-01     2.01011  .2568E+04      37
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 ROUGH/D05     005/RAO 005/(X-XO) STRAIN.005       VW/UE
         0  .2467E-01          0           0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA    SCHMETA          H     RTHETA     I6
 20  .1312E+02  .3333E-01    .004899  .1185E+01  .7263E+00  .1869E-01  .2117E-01    1.79385  .1386E+04       37

 ROUGH/D05     005/RAO 005/(X-XO) STRAIN.005       VW/UE
         0  .8114E-01          0           0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA    SCHMETA          H     RTHETA     I6
 30  .1368E+02  .3333E-01    .005472  .1207E+01  .6847E+00 -.1093E-01 -.1471E-01     .03109 -.8254E+03       37

 ROUGH/D05     005/RAO 005/(X-XO) STRAIN.005       VW/UE
         0  .1149E+00          0           0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA    SCHMETA          H     RTHETA     I6
 40  .1524E+02  .3333E-01    .003457  .1182E+01  .7034E+00  .2111E-01  .1139E-02    1.22163  .1560E+04       37

 ROUGH/D05     005/RAO 005/(X-XO) STRAIN.005       VW/UE
         0  .9538E-01          0           0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA    SCHMETA          H     RTHETA     I6
 50  .1574E+02  .3333E-01    .002768  .1161E+01  .7432E+00  .3971E-01  .2000E-01    1.34345  .2884E+04       37

 ROUGH/D05     005/RAO 005/(X-XO) STRAIN.005       VW/UE
         0  .6374E-01          0           0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA    SCHMETA          H     RTHETA     I6
 60  .1623E+02  .3333E-01    .002247  .1142E+01  .7816E+00  .6032E-01  .3772E-01    1.36951  .4309E+04       37

 ROUGH/D05     005/RAO 005/(X-XO) STRAIN.005       VW/UE
         0  .2903E-01          0           0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA    SCHMETA          H     RTHETA     I6
 70  .1690E+02  .3333E-01    .001879  .1124E+01  .8284E+00  .8280E-01  .5737E-01    1.42506  .5824E+04       37

 ROUGH/D05     005/RAO 005/(X-XO) STRAIN.005       VW/UE
         0          0          0           0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA    SCHMETA          H     RTHETA     I6
 80  .1815E+02  .3333E-01    .001842  .1112E+01  .8473E+00  .1066E+00  .7996E-01    1.47225  .7413E+04       37

 ROUGH/D05     005/RAO 005/(X-XO) STRAIN.005       VW/UE
         0          0          0           0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA    SCHMETA          H     RTHETA     I6
 90  .1969E+02  .3333E-01    .002030  .1102E+01  .8481E+00  .1201E+00  .8994E-01    1.43782  .8278E+04       37

 ROUGH/D05     005/RAO 005/(X-XO) STRAIN.005       VW/UE.
         0          0          0           0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA    SCHMETA          H     RTHETA     I6
 99  .2131E+02  .3333E-01    .002169  .1095E+01  .8898E+00  .1234E+00  .9521E-01    1.45906  .8454E+04       37

 ROUGH/D05     005/RAO 005/(X-XO) STRAIN:005       VW/UE
         0          0          0           0            0

X=
   .1000E+02   .1025E+02   .1049E+02   .1075E+02   .1102E+02   .1128E+02   .1155E+02   .1181E+02   .1207E+02   .1232E+02
   .1249E+02   .1260E+02   .1269E+02   .1277E+02   .1283E+02   .1290E+02   .1296E+02   .1301E+02   .1307E+02   .1312E+02
   .1317E+02   .1322E+02   .1327E+02   .1332E+02   .1337E+02   .1342E+02   .1348E+02   .1354E+02   .1361E+02   .1368E+02
   .1376E+02   .1385E+02   .1396E+02   .1410E+02   .1429E+02   .1457E+02   .1483E+02   .1504E+02   .1516E+02   .1524E+02
   .1531E+02   .1537E+02   .1542E+02   .1547E+02   .1552E+02   .1556E+02   .1561E+02   .1565E+02   .1570E+02   .1574E+02
   .1579E+02   .1583E+02   .1588E+02   .1593E+02   .1597E+02   .1602E+02   .1607E+02   .1612E+02   .1618E+02   .1623E+02
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.1628E+02	.1634E+02	.1640E+02	.1646E+02	.1653E+02	.1659E+02	.1666E+02	.1674E+02	.1682E+02	.1690E+02
.1699E+02	.1709E+02	.1720E+02	.1731E+02	.1743E+02	.1756E+02	.1770E+02	.1785E+02	.1800E+02	.1815E+02
.1830E+02	.1845E+02	.1860E+02	.1875E+02	.1890E+02	.1905E+02	.1921E+02	.1936E+02	.1952E+02	.1969E+02
.1985E+02	.2003E+02	.2020E+02	.2038E+02	.2056E+02	.2075E+02	.2093E+02	.2112E+02	.2131E+02	.2149E+02

VE/UE=

-.2584E-01	-.2289E-01	-.2689E-01	-.2785E-01	-.3023E-01	-.3318E-01	-.3795E-01	-.4449E-01	-.5283E-01	-.6196E-01
-.6972E-01	-.7637E-01	-.8192E-01	-.8661E-01	-.9062E-01	-.9411E-01	-.9719E-01	-.9987E-01	-.1020E+00	-.1033E+00
-.1039E+00	-.1037E+00	-.1027E+00	-.1009E+00	-.9837E-01	-.9500E-01	-.9075E-01	-.8546E-01	-.7895E-01	-.7092E-01
-.6091E-01	-.4821E-01	-.3188E-01	-.1483E-01	-.5543E-03	.1626E-01	.3368E-01	.4845E-01	.5951E-01	.6789E-01
.7408E-01	.7877E-01	.8235E-01	.8517E-01	.8741E-01	.8924E-01	.9074E-01	.9199E-01	.9303E-01	.9389E-01
.9457E-01	.9507E-01	.9540E-01	.9555E-01	.9549E-01	.9521E-01	.9468E-01	.9388E-01	.9277E-01	.9137E-01
.8973E-01	.8790E-01	.8592E-01	.8380E-01	.8153E-01	.7913E-01	.7651E-01	.7365E-01	.7058E-01	.6731E-01
.6383E-01	.6012E-01	.5620E-01	.5219E-01	.4790E-01	.4349E-01	.3901E-01	.3463E-01	.3049E-01	.2670E-01
.2339E-01	.2059E-01	.1831E-01	.1667E-01	.1567E-01	.1521E-01	.1504E-01	.1492E-01	.1470E-01	.1428E-01
.1358E-01	.1259E-01	.1143E-01	.1023E-01	.9073E-02	.8028E-02	.7133E-02	.6418E-02	.5900E-02	

(PW-PREF) /UREF**2=

-.1146E+00	-.1216E+00	-.1299E+00	-.1343E+00	-.1416E+00	-.1491E+00	-.1586E+00	-.1706E+00	-.1863E+00	-.2159E+00
-.2426E+00	-.2618E+00	-.2763E+00	-.2884E+00	-.2991E+00	-.3091E+00	-.3184E+00	-.3266E+00	-.3331E+00	-.3385E+00
-.3432E+00	-.3479E+00	-.3526E+00	-.3575E+00	-.3627E+00	-.3684E+00	-.3744E+00	-.3808E+00	-.3875E+00	-.3944E+00
-.4011E+00	-.4076E+00	-.4183E+00	-.4336E+00	-.4404E+00	-.4306E+00	-.4066E+00	-.3723E+00	-.3494E+00	-.3369E+00
-.3295E+00	-.3242E+00	-.3196E+00	-.3150E+00	-.3104E+00	-.3055E+00	-.3004E+00	-.2952E+00	-.2898E+00	-.2844E+00
-.2788E+00	-.2733E+00	-.2677E+00	-.2622E+00	-.2567E+00	-.2513E+00	-.2460E+00	-.2408E+00	-.2355E+00	-.2299E+00
-.2239E+00	-.2175E+00	-.2110E+00	-.2042E+00	-.1973E+00	-.1903E+00	-.1844E+00	-.1802E+00	-.1759E+00	-.1716E+00
-.1672E+00	-.1628E+00	-.1582E+00	-.1537E+00	-.1496E+00	-.1455E+00	-.1417E+00	-.1382E+00	-.1351E+00	-.1321E+00
-.1294E+00	-.1269E+00	-.1244E+00	-.1219E+00	-.1195E+00	-.1174E+00	-.1155E+00	-.1140E+00	-.1125E+00	-.1112E+00
-.1100E+00	-.1088E+00	-.1076E+00	-.1064E+00	-.1053E+00	-.1043E+00	-.1034E+00	-.1025E+00	-.1016E+00	-.1014E+00

(PW-PE) /UREF**2=

0	-.1193E-02	-.4506E-02	-.4190E-02	-.8432E-02	-.1444E-01	-.2254E-01	-.3145E-01	-.4065E-01	-.5987E-01
-.7828E-01	-.9118E-01	-.1005E+00	-.1080E+00	-.1145E+00	-.1207E+00	-.1264E+00	-.1312E+00	-.1344E+00	-.1366E+00
-.1384E+00	-.1401E+00	-.1420E+00	-.1442E+00	-.1467E+00	-.1497E+00	-.1531E+00	-.1569E+00	-.1611E+00	-.1656E+00
-.1702E+00	-.1750E+00	-.1849E+00	-.2011E+00	-.2110E+00	-.2075E+00	-.1909E+00	-.1649E+00	-.1472E+00	-.1386E+00
-.1344E+00	-.1318E+00	-.1298E+00	-.1277E+00	-.1254E+00	-.1227E+00	-.1199E+00	-.1169E+00	-.1137E+00	-.1105E+00
-.1072E+00	-.1038E+00	-.1005E+00	-.9717E-01	-.9390E-01	-.9070E-01	-.8758E-01	-.8455E-01	-.8147E-01	-.7803E-01
-.7411E-01	-.6983E-01	-.6529E-[illegible]	-.6055E-01	-.5563E-01	-.5060E-01	-.4670E-01	-.4440E-01	-.4197E-01	-.3944E-01
-.3683E-01	-.3417E-01	-.3124E-01	-.2840E-01	-.2578E-01	-.2308E-01	-.2051E-01	-.1810E-01	-.1584E-01	-.1373E-01
-.1173E-01	-.9941E-02	-.8214E-02	-.6532E-02	-.5098E-02	-.4085E-02	-.3623E-02	-.3559E-02	-.3734E-02	-.4050E-02
-.4404E-02	-.4647E-02	-.4652E-02	-.4442E-02	-.4087E-02	-.3631E-02	-.3109E-02	-.2541E-02	-.1770E-02	-.1770E-02

SWEEP NO. 7 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 8 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	-.2864E-01	-.3385E-01	-.5726E-01	-.1158E+00	-.1118E+00
-.5450E-01	.7408E-03	.3367E-01	.7206E-01	.1050E+00	.8828E-01	.4662E-01	.2012E-01	.9604E-02	.9604E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02						

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.8200E-01	.2000E-02	.2000E-02	.5830E-02	-.1669E-01	-.2619E-01	-.4136E-01	-.9260E-01	-.9976E-01	-.7140E-01
-.2962E-01	.8267E-02	.4779E-01	.8794E-01	.9450E-01	.5896E-01	.2930E-01	.1269E-01	.9007E-02	.4336E-02
.2000E-02	.2000E-02	-.7800E-01	-.1370E+01	-.1130E+01	-.1130E+01	-.1370E+01	-.7800E-01	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.8200E-01	.1340E+01	.1100E+01	.1100E+01	.1340E+01

RUN NO. 8 OF PROGRAM AMOS

REFERENCE LENGTH= 1.0000

X	Y	SSM	CP	U (TANG)	V (NORM)
1.00000	1.30000	1.00000	-.33065	1.15354	.08200
3.00000	1.30000	3.00000	-.16221	1.07806	.00200
5.00000	1.30000	5.00000	-.14806	1.07148	.00200
7.00000	1.30000	7.00000	-.17848	1.08558	.00583
9.00000	1.30000	9.00000	-.19866	1.09483	-.01669
10.50000	1.30000	10.50000	-.25100	1.11648	-.02619
11.50000	1.30000	11.50000	-.28086	1.13175	-.04136
12.51416	1.29985	12.51416	-.32198	1.14977	-.09260
13.28899	1.28786	13.28925	-.42433	1.19348	-.09976
13.82168	1.24014	13.82458	-.45060	1.20441	-.07140
14.36269	1.14482	14.37443	-.44939	1.20391	-.02962
14.89416	1.00212	14.92528	-.44129	1.20054	.00827
15.40981	.81390	15.47471	-.41750	1.19059	.04779
15.89402	.58940	16.00690	-.37988	1.17468	.08794
16.57054	.21284	16.78335	-.30768	1.14363	.09450
17.44901	-.29418	17.79764	-.27314	1.12833	.05896
18.31501	-.79418	18.79762	-.25449	1.12004	.02930
19.61401	-1.54418	20.29758	-.21341	1.10155	.01269
21.34601	-2.54418	22.29754	-.20601	1.09819	.00901
23.07801	-3.54418	24.29749	-.20234	1.09651	.00434
24.81001	-4.54418	26.29745	-.18792	1.08992	.00200
26.54201	-5.54418	28.29741	-.15513	1.07477	.00200
28.27401	-6.54418	30.29736	.36467	.79708	-.07800
29.39001	-6.61109	31.79740	-1.15247	1.46713	-1.37039
29.86500	-5.78850	32.74728	-.27829	1.13062	-1.13039
30.31500	-5.00900	33.64735	-.27887	-1.13087	-1.13039
30.76500	-4.22950	34.54741	-1.14600	-1.46492	-1.37039
30.12400	-3.34000	35.99721	.33899	-.81302	-.07800
28.39200	-2.34000	37.99716	-.15119	-1.07294	.00200
26.66000	-1.34000	39.99712	-.17673	-1.08477	.00200
24.92600	-.34000	41.99708	-.18324	-1.08777	.00200
23.19600	.65000	43.99703	-.17617	-1.08451	.00200
21.46400	1.66000	45.99699	-.15474	-1.07459	.00200
19.29900	2.91000	48.49693	.01573	-.99210	.00200
17.61300	3.86150	50.43322	.12003	-.93807	.00200

16.82300	4.23000	51.30576	.20058	-.89410	.00200
16.00400	4.52800	52.17813	.22482	-.88044	.00200
15.16250	4.75350	53.05014	.22070	-.88278	.00200
14.30450	4.90500	53.92225	.18546	-.90197	.00200
13.43600	4.98100	54.79490	.08881	-.95456	.00200
11.50000	5.00000	56.73131	-.02944	-1.01461	.00200
9.00000	5.00000	59.23131	-.15311	-1.07383	.00200
7.00000	5.00000	61.23131	-.14485	-1.06998	.00200
5.00000	5.00000	63.23131	-.10135	-1.04945	.00200
3.00000	5.00000	65.23131	.03374	-.98299	.00200
1.00000	5.00000	67.23131	.87326	-.35600	.08200
0	4.52500	68.70631	-2.37947	-1.83833	1.34000
0	3.57500	69.65631	-.31169	-1.14529	1.10000
0	2.62500	70.60631	-.26917	-1.12657	1.10000
0	1.07500	72.15631	-5.11257	2.47236	1.34000

OFF-BODY POINTS

X	Y	U	V	CP
5.00000	2.15000	1.09992	.00518	-.20985
5.00000	3.10000	1.09857	.00467	-.20689
5.00000	4.05000	1.09235	.00100	-.19322
9.00000	2.15000	1.10739	-.01301	-.22646
9.00000	3.10000	1.10288	-.01008	-.21644
9.00000	4.05000	1.09770	-.00581	-.20498
21.84600	-1.67800	.96191	-.54824	-.22584
22.29600	-.89900	.95977	-.54978	-.22342
22.74600	-.11900	.95616	-.55087	-.21769
25.31000	-3.67800	.96224	-.55501	-.23393
25.76000	-2.89900	.96260	-.55536	-.23502
26.21000	-2.11900	.95086	-.55484	-.23111

RUN NO. 8 OF PROGRAM TRAVERS

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 1

YNORM	U
.13000E+01	.10715E+01
.21500E+01	.10999E+01
.31000E+01	.10986E+01
.40500E+01	.10923E+01
.50000E+01	.10495E+01

MASS FLOW RATE= .40348E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 2

YNORM	U
.13000E+01	.10948E+01
.21500E+01	.11074E+01
.31000E+01	.11029E+01
.40500E+01	.10977E+01
.50000E+01	.10738E+01

MASS FLOW RATE= .40676E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 3

YNORM	U
.13000E+01	.10982E+01
.23000E+01	.11072E+01

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      .32000E+01     .11061E+01
      .41000E+01     .11035E+01
      .50000E+01     .10845E+01

MASS FLOW RATE=      .40816E+01


VELOCITY PROFILE ACROSS DUCT AT STATION NO.  4
      YNORM            U
      .13000E+01     .10899E+01
      .23000E+01     .11108E+01
      .32000E+01     .11113E+01
      .41000E+01     .11096E+01
      .50000E+01     .10848E+01

MASS FLOW RATE=      .40938E+01


RUN NO.  8  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS CYCLE--S.YOUNG TEST CASE


1977    1   10   99   46   34    0    0    1    0   51    0   -2    0
A               0  6.000E-01           0  6.256E+04  1.375E-03  3.000E-01  3.000E-01
X FOR CURV. B. VALUE             0  4.000E+00  8.000E+00  1.000E+01  1.200E+01  1.220E+01  1.240E+01
 1.260E+01  1.280E+01  1.290E+01  1.300E+01  1.310E+01  1.320E+01  1.340E+01
 1.360E+01  1.380E+01  1.400E+01  1.420E+01  1.440E+01  1.460E+01  1.480E+01
 1.500E+01  1.520E+01  1.540E+01  1.550E+01  1.560E+01  1.570E+01  1.580E+01
 1.600E+01  1.620E+01  1.640E+01  1.660E+01  1.700E+01  1.900E+01  2.100E+01
 2.200E+01  2.250E+01  2.300E+01  2.350E+01  2.400E+01  2.450E+01  2.500E+01
 2.550E+01  2.600E+01  2.650E+01  2.700E+01
CURV               0          0          0          0          0  2.000E-02  4.000E-02
 6.000E-02  8.000E-02  9.000E-02  1.000E-01  1.100E-01  1.200E-01  1.400E-01
 1.600E-01  1.800E-01  2.000E-01  2.000E-01  2.000E-01  2.000E-01  1.800E-01
 1.600E-01  1.400E-01  1.200E-01  1.100E-01  1.000E-01  9.000E-02  8.000E-02
 6.000E-02  4.000E-02  2.000E-02          0          0          0          0
         0          0          0          0          0          0          0
         0          0          0          0
X FOR PRESS. AND NP B. VALUES              0   2.0000E+00   4.0000E+00   6.0000E+00   8.0000E+00   1.0000E+01   1.1000E+01
  1.2000E+01   1.3000E+01   1.3436E+01   1.3872E+01   1.4308E+01   1.4745E+01   1.5181E+01
  1.5617E+01   1.6617E+01   1.7617E+01   1.8617E+01   2.0617E+01   2.2617E+01
PE-PREF       5.0000E-01  -1.1616E-01  -6.9817E-02  -8.2410E-02  -9.2502E-02  -1.1578E-01  -1.3431E-01
 -1.4487E-01  -1.9614E-01  -2.2147E-01  -2.2575E-01  -2.2329E-01  -2.1570E-01  -2.0014E-01
 -1.7757E-01  -1.4149E-01  -1.3251E-01  -1.2022E-01  -1.0229E-01  -1.0271E-01
NP    1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00

STN.          X       YSTEP        CF          UE     DEL05       THETA     SCHMETA         H     RTHETA      I6
  1   .1000E+02  .3333E-01    .002750   .1110E+01  .8208E+00  .9611E-01  .9611E-01    1.37738  .6673E+04     37

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0          0          0          0          0

STN.          X       YSTEP        CF          UE     DEL05       THETA     SCHMETA         H     RTHETA      I6
  2   .1025E+02  .3333E-01    .002653   .1115E+01  .8084E+00  .8431E-01  .9507E-01    1.53109  .5881E+04     37

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0          0          0          0          0

STN.          X       YSTEP        CF          UE     DEL05       THETA     SCHMETA         H     RTHETA      I6
 10   .1232E+02  .3333E-01    .004184   .1146E+01  .7647E+00  .2936E-01  .5011E-01    2.16251  .2106E+04     37
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ROUGH/DD5	DD5/RAD	DD5/(X-XO)	STRAIN.DD5	VW/UE
0	.2462E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
20	.1312E+02	.3333E-01	.005170	.1178E+01	.7196E+00	.2625E-02	.6163E-02	5.54505	.1935E+03	37

ROUGH/DD5	DD5/RAD	DD5/(X-XO)	STRAIN.DD5	VW/UE
0	.8039E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
30	.1368E+02	.3333E-01	.005427	.1195E+01	.6953E+00	-.1820E-01	-.1913E-01	.43872	-.1360E+04	37

ROUGH/DD5	DD5/RAD	DD5/(X-XO)	STRAIN.DD5	VW/UE
0	.1167E+00	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
40	.1524E+02	.3333E-01	.003449	.1180E+01	.7084E+00	.1929E-01	.3321E-02	1.22188	.1424E+04	37

ROUGH/DD5	DD5/RAD	DD5/(X-XO)	STRAIN.DD5	VW/UE
0	.9605E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
50	.1574E+02	.3333E-01	.002703	.1159E+01	.7507E+00	.4005E-01	.2490E-01	1.35050	.2903E+04	37

ROUGH/DD5	DD5/RAD	DD5/(X-XO)	STRAIN.DD5	VW/UE
0	.6438E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
60	.1623E+02	.3333E-01	.002227	.1142E+01	.7886E+00	.6076E-01	.4368E-01	1.38662	.4341E+04	37

ROUGH/DD5	DD5/RAD	DD5/(X-XO)	STRAIN.DD5	VW/UE
0	.2929E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
70	.1690E+02	.3333E-01	.001942	.1129E+01	.8305E+00	.8202E-01	.6272E-01	1.43062	.5795E+04	37

ROUGH/DD5	DD5/RAD	DD5/(X-XO)	STRAIN.DD5	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
80	.1815E+02	.3333E-01	.001835	.1117E+01	.8481E+00	.1094E+00	.8583E-01	1.44543	.7640E+04	37

ROUGH/DD5	DD5/RAD	DD5/(X-XO)	STRAIN.DD5	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
90	.1969E+02	.3333E-01	.002013	.1103E+01	.8535E+00	.1214E+00	.9657E-01	1.43979	.8375E+04	37

ROUGH/DD5	DD5/RAD	DD5/(X-XO)	STRAIN.DD5	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
99	.2131E+02	.3333E-01	.002153	.1097E+01	.8953E+00	.1247E+00	.1017E+00	1.45765	.8555E+04	37

ROUGH/DD5	DD5/RAD	DD5/(X-XO)	STRAIN.DD5	VW/UE
0	0	0	0	0

X=

.1000E+02	.1025E+02	.1049E+02	.1075E+02	.1102E+02	.1128E+02	.1155E+02	.1181E+02	.1207E+02	.1232E+02
.1249E+02	.1260E+02	.1269E+02	.1277E+02	.1283E+02	.1290E+02	.1296E+02	.1301E+02	.1307E+02	.1312E+02
.1317E+02	.1322E+02	.1327E+02	.1332E+02	.1337E+02	.1342E+02	.1348E+02	.1354E+02	.1361E+02	.1368E+02
.1376E+02	.1385E+02	.1396E+02	.1410E+02	.1429E+02	.1457E+02	.1483E+02	.1504E+02	.1516E+02	.1524E+02
.1531E+02	.1537E+02	.1542E+02	.1547E+02	.1552E+02	.1556E+02	.1561E+02	.1565E+02	.1570E+02	.1574E+02
.1579E+02	.1583E+02	.1588E+02	.1593E+02	.1597E+02	.1602E+02	.1607E+02	.1612E+02	.1618E+02	.1623E+02

.1628E+02	.1634E+02	.1640E+02	.1646E+02	.1653E+02	.1659E+02	.1666E+02	.1674E+02	.1682E+02	.1690E+02
.1699E+02	.1709E+02	.1720E+02	.1731E+02	.1743E+02	.1756E+02	.1770E+02	.1785E+02	.1800E+02	.1815E+02
.1830E+02	.1845E+02	.1860E+02	.1875E+02	.1890E+02	.1905E+02	.1921E+02	.1936E+02	.1952E+02	.1969E+02
.1985E+02	.2003E+02	.2020E+02	.2038E+02	.2056E+02	.2075E+02	.2093E+02	.2112E+02	.2131E+02	.2149E+02

VE/UE=

-.3351E-01	-.3012E-01	-.3227E-01	-.2936E-01	-.2660E-01	-.2585E-01	-.3155E-01	-.4480E-01	-.6313E-01	-.7862E-01
-.8726E-01	-.9193E-01	-.9381E-01	-.9405E-01	-.9320E-01	-.9169E-01	-.8974E-01	-.8753E-01	-.8514E-01	-.8263E-01
-.8003E-01	-.7734E-01	-.7457E-01	-.7169E-01	-.6869E-01	-.6552E-01	-.6215E-01	-.5851E-01	-.5451E-01	-.5005E-01
-.4496E-01	-.3903E-01	-.3184E-01	-.2263E-01	-.9513E-02	.1035E-01	.3009E-01	.4795E-01	.6116E-01	.7127E-01
.7861E-01	.8410E-01	.8818E-01	.9126E-01	.9358E-01	.9533E-01	.9661E-01	.9751E-01	.9807E-01	.9830E-01
.9822E-01	.9782E-01	.9708E-01	.9596E-01	.9446E-01	.9258E-01	.9043E-01	.8812E-01	.8568E-01	.8317E-01
.8060E-01	.7799E-01	.7535E-01	.7270E-01	.7005E-01	.6741E-01	.6475E-01	.6208E-01	.5947E-01	.5697E-01
.5463E-01	.5239E-01	.5016E-01	.4787E-01	.4547E-01	.4304E-01	.4045E-01	.3779E-01	.3511E-01	.3250E-01
.2997E-01	.2758E-01	.2534E-01	.2324E-01	.2138E-01	.1971E-01	.1819E-01	.1677E-01	.1542E-01	.1413E-01
.1288E-01	.1168E-01	.1056E-01	.9530E-02	.8609E-02	.7810E-02	.7145E-02	.6625E-02	.6257E-02	

(PW-PREF)/UREF**2=

-.1158E+00	-.1228E+00	-.1301E+00	-.1327E+00	-.1389E+00	-.1474E+00	-.1607E+00	-.1779E+00	-.1973E+00	-.2278E+00
-.2524E+00	-.2670E+00	-.2766E+00	-.2845E+00	-.2920E+00	-.2994E+00	-.3069E+00	-.3144E+00	-.3218E+00	-.3292E+00
-.3365E+00	-.3438E+00	-.3511E+00	-.3584E+00	-.3657E+00	-.3732E+00	-.3808E+00	-.3887E+00	-.3969E+00	-.4054E+00
-.4142E+00	-.4234E+00	-.4329E+00	-.4410E+00	-.4427E+00	-.4328E+00	-.4085E+00	-.3716E+00	-.3470E+00	-.3339E+00
-.3269E+00	-.3221E+00	-.3183E+00	-.3145E+00	-.3105E+00	-.3062E+00	-.3016E+00	-.2972E+00	-.2925E+00	-.2878E+00
-.2831E+00	-.2785E+00	-.2740E+00	-.2696E+00	-.2653E+00	-.2605E+00	-.2550E+00	-.2491E+00	-.2429E+00	-.2365E+00
-.2299E+00	-.2233E+00	-.2165E+00	-.2096E+00	-.2025E+00	-.1953E+00	-.1892E+00	-.1847E+00	-.1800E+00	-.1752E+00
-.1704E+00	-.1659E+00	-.1616E+00	-.1575E+00	-.1533E+00	-.1493E+00	-.1456E+00	-.1421E+00	-.1388E+00	-.1357E+00
-.1329E+00	-.1302E+00	-.1278E+00	-.1254E+00	-.1231E+00	-.1209E+00	-.1189E+00	-.1170E+00	-.1152E+00	-.1134E+00
-.1118E+00	-.1103E+00	-.1090E+00	-.1077E+00	-.1066E+00	-.1056E+00	-.1047E+00	-.1039E+00	-.1030E+00	-.1028E+00

(PW-PE)/UREF**2=

0	-.1241E-02	-.3449E-02	-.1428E-02	-.4481E-02	-.1146E-01	-.2339E-01	-.3749E-01	-.5021E-01	-.7063E-01
-.8766E-01	-.9690E-01	-.1022E+00	-.1066E+00	-.1109E+00	-.1155E+00	-.1203E+00	-.1253E+00	-.1304E+00	-.1356E+00
-.1408E+00	-.1460E+00	-.1513E+00	-.1566E+00	-.1621E+00	-.1676E+00	-.1733E+00	-.1792E+00	-.1854E+00	-.1918E+00
-.1966E+00	-.2057E+00	-.2132E+00	-.2197E+00	-.2205E+00	-.2131E+00	-.1951E+00	-.1664E+00	-.1469E+00	-.1379E+00
-.1341E+00	-.1323E+00	-.1311E+00	-.1298E+00	-.1282E+00	-.1262E+00	-.1240E+00	-.1216E+00	-.1191E+00	-.1166E+00
-.1140E+00	-.1114E+00	-.1090E+00	-.1066E+00	-.1042E+00	-.1014E+00	-.9777E-01	-.9363E-01	-.8916E-01	-.8442E-01
-.7947E-01	-.7436E-01	-.6908E-01	-.6363E-01	-.5799E-01	-.5218E-01	-.4743E-01	-.4424E-01	-.4086E-01	-.3734E-01
-.3387E-01	-.3068E-01	-.2778E-01	-.2505E-01	-.2232E-01	-.1982E-01	-.1764E-01	-.1561E-01	-.1384E-01	-.1223E-01
-.1081E-01	-.9568E-02	-.8550E-02	-.7616E-02	-.6762E-02	-.6139E-02	-.5708E-02	-.5434E-02	-.5251E-02	-.5117E-02
-.4985E-02	-.4824E-02	-.4600E-02	-.4294E-02	-.3916E-02	-.3477E-02	-.2989E-02	-.2465E-02	-.1811E-02	-.1811E-02

SWEEP NO. 8 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 9 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	-.3719E-01	-.3015E-01	-.6599E-01	-.1020E+00	-.7598E-01
-.4499E-01	-.9792E-02	.2842E-01	.7441E-01	.1115E+00	.7524E-01	.4717E-01	.2795E-01	.9188E-02	.9188E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02						

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.8200E-01	.2000E-02	.2000E-02	.6899E-02	-.2648E-01	-.2682E-01	-.4340E-01	-.9436E-01	-.9665E-01	-.6828E-01
-.2906E-01	.8282E-02	.4914E-01	.9085E-01	.9389E-01	.5930E-01	.3153E-01	.1375E-01	.9331E-02	.4444E-02
.2000E-02	.2000E-02	-.7800E-01	-.1367E+01	-.1127E+01	-.1127E+01	-.1367E+01	-.7800E-01	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.8200E-01	.1340E+01	.1100E+01	.1100E+01	.1340E+01

RUN NO. 9 OF PROGRAM AMOS

REFERENCE LENGTH= 1.0000

X	Y	SSM	CP	U (TANG)	V (NORM)
1.00000	1.30000	1.00000	-.33111	1.15374	.08200
3.00000	1.30000	3.00000	-.16295	1.07840	.00200
5.00000	1.30000	5.00000	-.14888	1.07186	.00200
7.00000	1.30000	7.00000	-.18314	1.08772	.00690
9.00000	1.30000	9.00000	-.19606	1.09364	-.02648
10.50000	1.30000	10.50000	-.23580	1.11166	-.02682
11.50000	1.30000	11.50000	-.26821	1.12615	-.04340
12.51416	1.29985	12.51416	-.30579	1.14271	-.09436
13.28899	1.28786	13.28925	-.40446	1.18510	-.09665
13.82168	1.24014	13.82458	-.43640	1.19850	-.06828
14.36269	1.14482	14.37443	-.43743	1.19893	-.02906
14.89416	1.00212	14.92528	-.42750	1.19478	.00828
15.40981	.81390	15.47471	-.40352	1.18470	.04914
15.89402	.56940	16.00890	-.37049	1.17068	.09085
16.57054	.21284	16.78335	-.29861	1.13956	.09389
17.44901	-.29418	17.79764	-.26240	1.12357	.05930
18.31501	-.79418	18.79762	-.24571	1.11612	.03153
19.61401	-1.54418	20.29758	-.20705	1.09866	.01375
21.34601	-2.54418	22.29754	-.20041	1.09563	.00933
23.07801	-3.54418	24.29749	-.19679	1.09398	.00444
24.81001	-4.54418	26.29745	-.18240	1.08738	.00200
26.54201	-5.54418	28.29741	-.14974	1.07226	.00200
28.27401	-6.54418	30.29736	.36785	.79508	-.07600
29.39001	-6.61109	31.79740	-1.14303	1.46391	-1.36739
29.86500	-5.78650	32.74728	-.27151	1.12761	-1.12739
30.31500	-5.00900	33.64735	-.27209	-1.12787	-1.12739
30.76500	-4.22950	34.54741	-1.13663	-1.46172	-1.36739
30.12400	-3.34000	35.99721	.34232	-.81098	-.07800
28.39200	-2.34000	37.99716	-.14579	-1.07041	.00200
26.66000	-1.34000	39.99712	-.17113	-1.08219	.00200
24.92800	-.34000	41.99708	-.17745	-1.08511	.00200
23.19600	.66000	43.99703	-.17000	-1.08167	.00200
21.46400	1.66000	45.99699	-.14789	-1.07139	.00200
19.29900	2.91000	48.49693	.02266	-.98860	.00200
17.61300	3.86150	50.43322	.12707	-.93431	.00200

16.82300	4.23000	51.30576	.20720	-.89039	.00200
16.00400	4.52800	52.17813	.23144	-.87668	.00200
15.16250	4.75350	53.05014	.22752	-.87891	.00200
14.30450	4.90500	53.92225	.19368	-.89795	.00200
13.43600	4.98100	54.79490	.09693	-.95030	.00200
11.50000	5.00000	56.73131	-.02207	-1.01097	.00200
9.00000	5.00000	59.23131	-.14900	-1.07192	.00200
7.00000	5.00000	61.23131	-.14404	-1.06960	.00200
5.00000	5.00000	63.23131	-.10180	-1.04967	.00200
3.00000	5.00000	65.23131	.03285	-.98344	.00200
1.00000	5.00000	67.23131	.87221	-.35748	.08200
0	4.52500	68.70631	-2.37357	-1.83673	1.34000
0	3.57500	69.65631	-.31126	-1.14510	1.10000
0	2.62500	70.60631	-.26904	-1.12652	1.10000
0	1.07500	72.15631	-5.09510	2.46883	1.34000

OFF-BODY POINTS

X	Y	U	V	CP
5.00000	2.15000	1.10032	.00515	-.21073
5.00000	3.10000	1.09893	.00457	-.20767
5.00000	4.05000	1.09262	.00092	-.19382
9.00000	2.15000	1.10583	-.01809	-.22319
9.00000	3.10000	1.10111	-.01257	-.21260
9.00000	4.05000	1.09581	-.00689	-.20085
21.84600	-1.67800	.95976	-.54663	-.21993
22.29600	-.89900	.95747	-.54819	-.21726
22.74600	-.11900	.95375	-.54934	-.21141
25.31000	-3.67800	.96001	-.55369	-.22819
25.76000	-2.89900	.96035	-.55404	-.22923
26.21000	-2.11900	.95860	-.55353	-.22531

RUN NO. 9 OF PROGRAM TRAVERS

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 1

YNORM	U
.13000E+01	.10719E+01
.21500E+01	.11003E+01
.31000E+01	.10969E+01
.40500E+01	.10926E+01
.50000E+01	.10497E+01

MASS FLOW RATE= .40361E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 2

YNORM	U
.13000E+01	.10936E+01
.21500E+01	.11058E+01
.31000E+01	.11011E+01
.40500E+01	.10958E+01
.50000E+01	.10719E+01

MASS FLOW RATE= .40613E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 3

YNORM	U
.13000E+01	.10956E+01
.23000E+01	.11045E+01

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     .32000E+01      .11033E+01
     .41000E+01      .11006E+01
     .50000E+01      .10817E+01

MASS FLOW RATE=      .40714E+01


VELOCITY PROFILE ACROSS DUCT AT STATION NO.. 4
       YNORM              U
     .13000E+01      .10874E+01
     .23000E+01      .11082E+01
     .32000E+01      .11087E+01
     .41000E+01      .11059E+01
     .50000E+01      .10822E+01

MASS FLOW RATE=      .40842E+01


RUN NO.  9  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS CYCLE--S.YOUNG TEST CASE


1977    1   10   99   46   34    0    0    1    0   51    0   -2    0
A                0  6.000E-01           0  6.256E+04  1.375E-03  3.000E-01  3.000E-01
X FOR CURV. B. VALUE                0  4.000E+00  8.000E+00  1.000E+01  1.200E+01  1.220E+01  1.240E+01
 1.260E+01  1.280E+01  1.290E+01  1.300E+01  1.310E+01  1.320E+01  1.340E+01
 1.360E+01  1.380E+01  1.400E+01  1.420E+01  1.440E+01  1.460E+01  1.480E+01
 1.500E+01  1.520E+01  1.540E+01  1.550E+01  1.560E+01  1.570E+01  1.580E+01
 1.600E+01  1.620E+01  1.640E+01  1.660E+01  1.700E+01  1.900E+01  2.100E+01
 2.200E+01  2.250E+01  2.300E+01  2.350E+01  2.400E+01  2.450E+01  2.500E+01
 2.550E+01  2.600E+01  2.650E+01  2.700E+01
CURV              0          0          0          0          0  2.000E-02  4.000E-02
 6.000E-02  8.000E-02  9.000E-02  1.000E-01  1.100E-01  1.200E-01  1.400E-01
 1.600E-01  1.800E-01  2.000E-01  2.000E-01  2.000E-01  2.000E-01  1.800E-01
 1.600E-01  1.400E-01  1.200E-01  1.100E-01  1.000E-01  9.000E-02  8.000E-02
 6.000E-02  4.000E-02  2.000E-02          0          0          0          0
         0          0          0          0          0          0          0
         0          0          0          0
X FOR PRESS. AND NP B. VALUES           0  2.0000E+00  4.0000E+00  6.0000E+00  8.0000E+00  1.0000E+01  1.1000E+01
  1.2000E+01  1.3000E+01  1.3436E+01  1.3872E+01  1.4308E+01  1.4745E+01  1.5181E+01
  1.5617E+01  1.6617E+01  1.7617E+01  1.8617E+01  2.0617E+01  2.2617E+01
PE-PREF       5.0000E-01  -1.1654E-01  -7.0001E-02  -8.3864E-02  -9.4259E-02  -1.0946E-01  -1.2715E-01
 -1.3830E-01  -1.8613E-01  -2.1273E-01  -2.1959E-01  -2.1695E-01  -2.0843E-01  -1.9430E-01
 -1.7335E-01  -1.3626E-01  -1.2752E-01  -1.1636E-01  -9.9400E-02  -9.9933E-02
NP   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00

STN.          X     YSTEP        CF         UE     DELOS      THETA    SCHMETA        H     RTHETA     I6
  1  .1000E+02  .3333E-01    .002750  .1104E+01  .8208E+00  .9611E-01  .9611E-01    1.37744  .6638E+04    37

 ROUGH/DOS     DOS/RAD  DOS/(X-XO)  STRAIN.DOS      VW/UE
         0          0          0          0          0

STN.          X     YSTEP        CF         UE     DELOS      THETA    SCHMETA        H     RTHETA     I6
  2  .1025E+02  .3333E-01    .002603  .1109E+01  .8112E+00  .8650E-01  .9677E-01    1.52137  .6001E+04    37

 ROUGH/DOS     DOS/RAD  DOS/(X-XO)  STRAIN.DOS      VW/UE
         0          0          0          0          0

STN.          X     YSTEP        CF         UE     DELOS      THETA    SCHMETA        H     RTHETA     I6
 10  .1232E+02  .3333E-01    .004181  .1141E+01  .7648E+00  .2765E-01  .4747E-01    2.22671  .1973E+04    37
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ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.2462E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
20	.1312E+02	.3333E-01	.005126	.1177E+01	.7222E+00	.6164E-02	.9475E-02	3.10222	.4537E+03	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.8069E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
30	.1368E+02	.3333E-01	.005548	.1196E+01	.6897E+00	-.1900E-01	-.2126E-01	.47818	-.1422E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.1158E+00	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
40	.1524E+02	.3333E-01	.003633	.1174E+01	.7033E+00	.9151E-02	-.8876E-02	1.42994	.6720E+03	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.9536E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
50	.1574E+02	.3333E-01	.002877	.1155E+01	.7419E+00	.2957E-01	.1141E-01	1.41639	.2136E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.6363E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
60	.1623E+02	.3333E-01	.002228	.1138E+01	.7832E+00	.5585E-01	.3464E-01	1.38994	.3975E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.2909E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
70	.1690E+02	.3333E-01	.001825	.1124E+01	.8340E+00	.8309E-01	.5982E-01	1.44796	.5841E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
80	.1815E+02	.3333E-01	.001910	.1116E+01	.8428E+00	.1046E+00	.7847E-01	1.44682	.7299E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
90	.1969E+02	.3333E-01	.002012	.1100E+01	.8459E+00	.1187E+00	.9026E-01	1.44659	.8165E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
99	.2131E+02	.3333E-01	.002163	.1094E+01	.8883E+00	.1228E+00	.9561E-01	1.45850	.8406E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	0	0	0	0

X=

.1000E+02	.1025E+02	.1049E+02	.1075E+02	.1102E+02	.1128E+02	.1155E+02	.1181E+02	.1207E+02	.1232E+02
.1249E+02	.1260E+02	.1269E+02	.1277E+02	.1283E+02	.1290E+02	.1296E+02	.1301E+02	.1307E+02	.1312E+02
.1317E+02	.1322E+02	.1327E+02	.1332E+02	.1337E+02	.1342E+02	.1348E+02	.1354E+02	.1361E+02	.1368E+02
.1376E+02	.1385E+02	.1396E+02	.1410E+02	.1429E+02	.1457E+02	.1483E+02	.1504E+02	.1516E+02	.1524E+02
.1531E+02	.1537E+02	.1542E+02	.1547E+02	.1552E+02	.1556E+02	.1561E+02	.1565E+02	.1570E+02	.1574E+02
.1579E+02	.1583E+02	.1588E+02	.1593E+02	.1597E+02	.1602E+02	.1607E+02	.1612E+02	.1618E+02	.1623E+02

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  .1628E+02   .1634E+02   .1640E+02   .1646E+02   .1653E+02   .1659E+02   .1666E+02   .1674E+02   .1682E+02   .1690E+02
  .1699E+02   .1709E+02   .1720E+02   .1731E+02   .1743E+02   .1756E+02   .1770E+02   .1785E+02   .1800E+02   .1815E+02
  .1830E+02   .1845E+02   .1860E+02   .1875E+02   .1890E+02   .1905E+02   .1921E+02   .1936E+02   .1952E+02   .1969E+02
  .1985E+02   .2003E+02   .2020E+02   .2038E+02   .2056E+02   .2075E+02   .2093E+02   .2112E+02   .2131E+02   .2149E+02

VE/UE=
 -.2210E-01  -.1917E-01  -.2362E-01  -.2553E-01  -.2935E-01  -.3430E-01  -.4168E-01  -.5130E-01  -.6249E-01  -.7264E-01
 -.7975E-01  -.8484E-01  -.8826E-01  -.9053E-01  -.9195E-01  -.9278E-01  -.9317E-01  -.9320E-01  -.9287E-01  -.9213E-01
 -.9100E-01  -.8947E-01  -.8754E-01  -.8522E-01  -.8248E-01  -.7929E-01  -.7558E-01  -.7126E-01  -.6618E-01  -.6018E-01
 -.5294E-01  -.4403E-01  -.3275E-01  -.1923E-01  -.4131E-02   .1308E-01   .2903E-01   .4360E-01   .5458E-01   .6322E-01
  .6975E-01   .7468E-01   .7897E-01   .8233E-01   .8515E-01   .8759E-01   .8975E-01   .9170E-01   .9349E-01   .9514E-01
  .9668E-01   .9812E-01   .9945E-01   .1007E+00   .1018E+00   .1028E+00   .1036E+00   .1040E+00   .1041E+00   .1037E+00
  .1028E+00   .1013E+00   .9897E-01   .9579E-01   .9171E-01   .8690E-01   .8153E-01   .7570E-01   .6958E-01   .6326E-01
  .5704E-01   .5071E-01   .4456E-01   .3871E-01   .3342E-01   .2899E-01   .2574E-01   .2403E-01   .2392E-01   .2498E-01
  .2630E-01   .2744E-01   .2803E-01   .2786E-01   .2678E-01   .2486E-01   .2244E-01   .1988E-01   .1738E-01   .1510E-01
  .1314E-01   .1154E-01   .1027E-01   .9227E-02   .8368E-02   .7663E-02   .7101E-02   .6675E-02   .6381E-02

(PW-PREF)/UREF**2=
 -.1095E+00  -.1159E+00  -.1242E+00  -.1286E+00  -.1365E+00  -.1450E+00  -.1563E+00  -.1704E+00  -.1880E+00  -.2186E+00
 -.2448E+00  -.2623E+00  -.2748E+00  -.2852E+00  -.2944E+00  -.3031E+00  -.3116E+00  -.3194E+00  -.3266E+00  -.3331E+00
 -.3395E+00  -.3457E+00  -.3519E+00  -.3583E+00  -.3648E+00  -.3716E+00  -.3786E+00  -.3860E+00  -.3937E+00  -.4016E+00
 -.4097E+00  -.4179E+00  -.4271E+00  -.4371E+00  -.4415E+00  -.4335E+00  -.4112E+00  -.3771E+00  -.3538E+00  -.3405E+00
 -.3325E+00  -.3264E+00  -.3213E+00  -.3163E+00  -.3112E+00  -.3058E+00  -.3003E+00  -.2945E+00  -.2886E+00  -.2826E+00
 -.2764E+00  -.2702E+00  -.2638E+00  -.2574E+00  -.2511E+00  -.2451E+00  -.2395E+00  -.2342E+00  -.2292E+00  -.2246E+00
 -.2203E+00  -.2163E+00  -.2127E+00  -.2093E+00  -.2051E+00  -.1997E+00  -.1944E+00  -.1903E+00  -.1857E+00  -.1805E+00
 -.1752E+00  -.1703E+00  -.1651E+00  -.1599E+00  -.1545E+00  -.1492E+00  -.1437E+00  -.1383E+00  -.1334E+00  -.1295E+00
 -.1268E+00  -.1247E+00  -.1231E+00  -.1218E+00  -.1208E+00  -.1195E+00  -.1179E+00  -.1159E+00  -.1138E+00  -.1118E+00
 -.1097E+00  -.1079E+00  -.1064E+00  -.1051E+00  -.1039E+00  -.1029E+00  -.1020E+00  -.1011E+00  -.1002E+00  -.9993E-01

(PW-PE)/UREF**2=
          0  -.1023E-02  -.4526E-02  -.4458E-02  -.9189E-02  -.1607E-01  -.2565E-01  -.3652E-01  -.4754E-01  -.6812E-01
 -.6640E-01  -.9799E-01  -.1057E+00  -.1118E+00  -.1173E+00  -.1226E+00  -.1278E+00  -.1327E+00  -.1369E+00  -.1408E+00
 -.1446E+00  -.1484E+00  -.1522E+00  -.1563E+00  -.1605E+00  -.1651E+00  -.1699E+00  -.1751E+00  -.1806E+00  -.1866E+00
 -.1928E+00  -.1995E+00  -.2078E+00  -.2181E+00  -.2243E+00  -.2212E+00  -.2061E+00  -.1799E+00  -.1613E+00  -.1516E+00
 -.1464E+00  -.1430E+00  -.1402E+00  -.1374E+00  -.1344E+00  -.1311E+00  -.1275E+00  -.1238E+00  -.1199E+00  -.1158E+00
 -.1116E+00  -.1073E+00  -.1030E+00  -.9856E-01  -.9422E-01  -.9016E-01  -.8648E-01  -.8316E-01  -.8014E-01  -.7740E-01
 -.7496E-01  -.7283E-01  -.7106E-01  -.6934E-01  -.6680E-01  -.6295E-01  -.5922E-01  -.5646E-01  -.5315E-01  -.4905E-01
 -.4490E-01  -.4095E-01  -.3655E-01  -.3204E-01  -.2737E-01  -.2263E-01  -.1786E-01  -.1325E-01  -.9330E-02  -.6850E-02
 -.5794E-02  -.5587E-02  -.5967E-02  -.6768E-02  -.7731E-02  -.8402E-02  -.8512E-02  -.8198E-02  -.7646E-02  -.6939E-02
 -.6155E-02  -.5418E-02  -.4814E-02  -.4290E-02  -.3796E-02  -.3313E-02  -.2829E-02  -.2339E-02  -.1765E-02  -.1765E-02

SWEEP NO.  9  OF INVISCID/VISCOUS CALCULATION COMPLETED
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RUN NØ. 10 ØF PRØGRAM MATCH

VELS. NØRMAL TØ MATCHING SURFACE AT NØDES

.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	-.2440E-01	-.3261E-01	-.6709E-01	-.1079E+00	-.9232E-01
-.5009E-01	-.3516E-02	.2845E-01	.6584E-01	.1034E+00	.9581E-01	.3107E-01	.3111E-01	.8935E-02	.8935E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02						

VELS. NØRMAL TØ MATCHING SURFACE AT ELEMENT MID PTS.

.8200E-01	.2000E-02	.2000E-02	.5300E-02	-.1286E-01	-.2634E-01	-.4514E-01	-.9587E-01	-.9859E-01	-.6931E-01
-.2784E-01	.9327E-02	.4846E-01	.9002E-01	.9784E-01	.5811E-01	.3168E-01	.1480E-01	.9472E-02	.4491E-02
.2000E-02	.2000E-02	-.7800E-01	-.1374E+01	-.1134E+01	-.1134E+01	-.1374E+01	-.7800E-01	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02
.2000E-02	.2000E-02	.2000E-02	.2000E-02	.2000E-02	.8200E-01	.1340E+01	.1100E+01	.1100E+01	.1340E+01

RUN NØ. 10 ØF PRØGRAM AMØS

REFERENCE LENGTH= 1.0000

X	Y	SSM	CP	U (TANG)	V (NØRM)
1.00000	1.30000	1.00000	-.33024	1.15336	.08200
3.00000	1.30000	3.00000	-.16159	1.07777	.00200
5.00000	1.30000	5.00000	-.14744	1.07119	.00200
7.00000	1.30000	7.00000	-.17634	1.08459	.00530
9.00000	1.30000	9.00000	-.19978	1.09535	-.01286
10.50000	1.30000	10.50000	-.25914	1.12211	-.02634
11.50000	1.30000	11.50000	-.28538	1.13374	-.04514
12.51416	1.29985	12.51416	-.31964	1.14376	-.09587
13.28899	1.28786	13.28925	-.41735	1.19053	-.09859
13.82168	1.24014	13.82458	-.44736	1.20306	-.06931
14.36269	1.14492	14.37443	-.44916	1.20381	-.02784
14.89416	1.00212	14.92528	-.44211	1.20088	.00933
15.40981	.81390	15.47471	-.41742	1.19055	.04846
15.89402	.58940	16.00890	-.37975	1.17463	.09002
16.5[illegible]054	.21284	16.78335	-.31249	1.14564	.09784
17.44901	-.29418	17.79764	-.27705	1.13007	.05811
18.31501	-.79418	18.79762	-.25738	1.12133	.03168
19.61401	-1.54418	20.29758	-.21984	1.10446	.01480
21.34601	-2.54418	22.29754	-.21411	1.10187	.00947
23.07801	-3.54418	24.29749	-.21028	1.10013	.00449
24.81001	-4.54418	26.29745	-.19569	1.09348	.00200
26.54201	-5.54418	28.29741	-.16263	1.07825	.00200
28.27401	-6.54418	30.29736	.35981	.80012	-.07800
29.39001	-6.61109	31.79740	-1.16418	1.47112	-1.37431
29.86500	-5.78850	32.74728	-.28717	1.13453	-1.13431
30.31500	-5.00900	33.64735	-.28775	-1.13479	-1.13431
30.76500	-4.22950	34.54741	-1.15768	-1.46890	-1.37431
30.12400	-3.34000	35.99721	.33399	-.81610	-.07800
28.39200	-2.34000	37.99716	-.15864	-1.07640	.00200
26.66000	-1.34000	39.99712	-.18426	-1.08824	.00200
24.92800	-.34000	41.99708	-.19057	-1.09113	.00200
23.19600	.66000	43.99703	-.18283	-1.08758	.00200
21.46400	1.66000	45.99699	-.16009	-1.07708	.00200
19.29900	2.91000	48.49693	.01281	-.99357	.00200
17.61300	3.86150	50.43322	.11853	-.93887	.00200

16.82300	4.23000	51.30576	.19953	-.89469	.00200
16.00400	4.52800	52.17813	.22407	-.88087	.00200
15.16250	4.75350	53.05014	.22015	-.88309	.00200
14.30450	4.90500	53.92225	.18598	-.90223	.00200
13.43600	4.98100	54.79490	.08823	-.95487	.00200
11.50000	5.00000	56.73131	-.03052	-1.01515	.00200
9.00000	5.00003	59.23131	-.15385	-1.07417	.00200
7.00000	5.00000	61.23131	-.14467	-1.06989	.00200
5.00000	5.00000	63.23131	-.10077	-1.04918	.00200
3.00000	5.00000	65.23131	.03453	-.98258	.00200
1.00000	5.00000	67.23131	.87412	-.35479	.08200
0	4.52500	68.70631	-2.38424	-1.83963	1.34000
0	3.57500	69.65631	-.31204	-1.14544	1.10000
0	2.62500	70.60631	-.26927	-1.12662	1.10000
0	1.07500	72.15631	-5.12583	2.47504	1.34000

OFF-BODY POINTS

X	Y	U	V	CP
5.00000	2.15000	1.09963	.00518	-.20922
5.00000	3.10000	1.09829	.00469	-.20626
5.00000	4.05000	1.09208	.00102	-.19263
9.00000	2.15000	1.10793	-.01122	-.22764
9.00000	3.10000	1.10334	-.00934	-.21745
9.00000	4.05000	1.09809	-.00552	-.20584
21.84600	-1.67800	.96521	-.54956	-.23366
22.29600	-.89900	.96283	-.55112	-.23077
22.74600	-.11900	.95902	-.55229	-.22474
25.31000	-3.67800	.96537	-.55678	-.24195
25.76000	-2.89900	.96571	-.55712	-.24299
26.21000	-2.11900	.96395	-.55660	-.23901

RUN NO. 10 OF PROGRAM TRAVERS

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 1

YNORM	U
.13000E+01	.10712E+01
.21500E+01	.10996E+01
.31000E+01	.10983E+01
.40500E+01	.10921E+01
.50000E+01	.10492E+01

MASS FLOW RATE= .40338E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 2

YNORM	U
.13000E+01	.10953E+01
.21500E+01	.11079E+01
.31000E+01	.11033E+01
.40500E+01	.10981E+01
.50000E+01	.10742E+01

MASS FLOW RATE= .40693E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 3

YNORM	U
.13000E+01	.11019E+01
.23000E+01	.11107E+01

.32000E+01	.11094E+01
.41000E+01	.11067E+01
.50000E+01	.10876E+01

MASS FLOW RATE= .40940E+01

VELOCITY PROFILE ACROSS DUCT AT STATION NO. 4

YNORM	U
.13000E+01	.10935E+01
.23000E+01	.11144E+01
.32000E+01	.11149E+01
.41000E+01	.11131E+01
.50000E+01	.10882E+01

MASS FLOW RATE= .41070E+01

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RUN NO. 10  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS CYCLE--S.YOUNG TEST CASE

1977     1    10    99    46    34     0     0     1     0    51     0    -2     0
A                    0  6.000E-01             0  6.256E+04  1.375E-03  3.000E-01  3.000E-01
X FOR CURV. B. VALUE                0  4.000E+00  8.000E+00  1.000E+01  1.200E+01  1.220E+01  1.240E+01
 1.260E+01  1.280E+01  1.290E+01  1.300E+01  1.310E+01  1.320E+01  1.340E+01
 1.360E+01  1.380E+01  1.400E+01  1.420E+01  1.440E+01  1.460E+01  1.480E+01
 1.500E+01  1.520E+01  1.540E+01  1.550E+01  1.560E+01  1.570E+01  1.580E+01
 1.600E+01  1.620E+01  1.640E+01  1.660E+01  1.700E+01  1.900E+01  2.100E+01
 2.200E+01  2.250E+01  2.300E+01  2.350E+01  2.400E+01  2.450E+01  2.500E+01
 2.550E+01  2.600E+01  2.650E+01  2.700E+01
CURV                0          0          0          0          0  2.000E-02  4.000E-02
 6.000E-02  8.000E- 2  9.000E-02  1.000E-01  1.100E-01  1.200E-01  1.400E-01
 1.600E-01  1.800E-01  2.000E-01  2.000E-01  2.000E-01  2.000E-01  1.800E-01
 1.600E-01  1.400E-01  1.200E-01  1.100E-01  1.000E-01  9.000E-02  8.000E-02
 6.000E-02  4.000E-02  2.000E-02          0          0          0          0
         0          0          0          0          0          0          0
         0          0          0          0
X FOR PRESS. AND NP B. VALUES             0   2.0000E+00   4.0000E+00   6.0000E+00   8.0000E+00   1.0000E+01   1.1000E+01
  1.2000E+01   1.3000E+01   1.3436E+01   1.3872E+01   1.4308E+01   1.4745E+01   1.5181E+01
  1.5617E+01   1.6617E+01   1.7617E+01   1.8617E+01   2.0617E+01   2.2617E+01
PE-PREF       5.0000E-01  -1.1586E-01  -6.9576E-02  -8.1726E-02  -9.1544E-02  -1.1920E-01  -1.3784E-01
 -1.4564E-01  -1.9287E-01  -2.1867E-01  -2.2504E-01  -2.2356E-01  -2.1595E-01  -1.9990E-01
 -1.7820E-01  -1.4404E-01  -1.3400E-01  -1.2208E-01  -1.0621E-01  -1.0674E-01
NP   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00

STN.          X       YSTEP        CF         UE     DEL05       THETA     SCHMETA          H     RTHETA       I6
   1  .1000E+02  .3333E-01    .002750  .1113E+01  .8208E+00  .9611E-01  .9611E-01    1.37735  .6691E+04     37

 ROUGH/D05     D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0          0          0          0          0

STN.          X       YSTEP        CF         UE     DEL05       THETA     SCHMETA          H     RTHETA       I6
   2  .1025E+02  .3333E-01    .002649  .1118E+01  .8086E+00  .8415E-01  .9525E-01    1.53661  .5887E+04     37

 ROUGH/D05     D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0          0          0          0          0

STN.          X       YSTEP        CF         UE     DEL05       THETA     SCHMETA          H     RTHETA       I6
  10  .1232E+02  .3333E-01    .004192  .1147E+01  .7635E+00  .2776E-01  .4790E-01    2.19623  .1991E+04     37

 ROUGH/D05     D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0  .2458E-01          0          0          0

STN.          X       YSTEP        CF         UE     DEL05       THETA     SCHMETA          H     RTHETA       I6
  20  .1312E+02  .3333E-01    .005133  .1182E+01  .7197E+00  .4450E-02  .8365E-02    3.85115  .3291E+03     37

 ROUGH/D05     D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0  .8041E-01          0          0          0

STN.          X       YSTEP        CF         UE     DEL05       THETA     SCHMETA          H     RTHETA       I6
  30  .1368E+02  .3333E-01    .005376  .1200E+01  .6978E+00 -.1273E-01 -.1416E-01     .22460 -.9562E+03     37

 ROUGH/D05     D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0  .1171E+00          0          0          0

STN.          X       YSTEP        CF         UE     DEL05       THETA     SCHMETA          H     RTHETA       I6
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 40  .1524E+02  .3333E-01    .003458  .1179E+01  .7042E+00  .1460E-01 -.3457E-02   1.29591  .1077E+04     37

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .9549E-01         0          0            0

STN.          X       YSTEP        CF          UE    DEL05       THETA    SCHMETA          H    RTHETA     I6
 50  .1574E+02  .3333E-01    .002611  .1159E+01  .7495E+00  .3998E-01  .2278E-01   1.37258  .2900E+04     37

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .6428E-01         0          0            0

STN.          X       YSTEP        CF          UE    DEL05       THETA    SCHMETA          H    RTHETA     I6
 60  .1623E+02  .3333E-01    .002156  .1144E+01  .7884E+00  .6210E-01  .4298E-01   1.39796  .4444E+04     37

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .2929E-01         0          0            0

STN.          X       YSTEP        CF          UE    DEL05       THETA    SCHMETA          H    RTHETA     I6
 70  .1690E+02  .3333E-01    .002016  .1132E+01  .8261E+00  .7929E-01  .5787E-01   1.43061  .5613E+04     37

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0          0         0          0            0

STN.          X       YSTEP        CF          UE    DEL05       THETA    SCHMETA          H    RTHETA     I6
 80  .1815E+02  .3333E-01    .001875  .1118E+01  .8391E+00  .1034E+00  .7934E-01   1.44870  .7233E+04     37

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0          0         0          0            0

STN.          X       YSTEP        CF          UE    DEL05       THETA    SCHMETA          H    RTHETA     I6
 90  .1969E+02  .3333E-01    .001984  .1106E+01  .8485E+00  .1204E+00  .9401E-01   1.45090  .8328E+04     37

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0          0         0          0            0

STN.          X       YSTEP        CF          UE    DEL05       THETA    SCHMETA          H    RTHETA     I6
 99  .2131E+02  .3333E-01    .002124  .1100E+01  .8913E+00  .1247E+00  .9992E-01   1.46590  .8587E+04     37

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0          0         0          0            0

X=
   .1000E+02   .1025E+02   .1049E+02   .1075E+02   .1102E+02   .1128E+02   .1155E+02   .1181E+02   .1207E+02   .1232E+02
   .1249E+02   .1260E+02   .1269E+02   .1277E+02   .1283E+02   .1290E+02   .1296E+02   .1301E+02   .1307E+02   .1312E+02
   .1317E+02   .1322E+02   .1327E+02   .1332E+02   .1337E+02   .1342E+02   .1348E+02   .1354E+02   .1361E+02   .1368E+02
   .1376E+02   .1385E+02   .1396E+02   .1410E+02   .1429E+02   .1457E+02   .1483E+02   .1504E+02   .1516E+02   .1524E+02
   .1531E+02   .1537E+02   .1542E+02   .1547E+02   .1552E+02   .1556E+02   .1561E+02   .1565E+02   .1570E+02   .1574E+02
   .1579E+02   .1583E+02   .1568E+02   .1593E+02   .1597E+02   .1602E+02   .1607E+02   .1612E+02   .1618E+02   .1623E+02
   .1628E+02   .1634E+02   .1640E+02   .1646E+02   .1653E+02   .1659E+02   .1666E+02   .1674E+02   .1682E+02   .1690E+02
   .1699E+02   .1709E+02   .1720E+02   .1731E+02   .1743E+02   .1756E+02   .1770E+02   .1785E+02   .1800E+02   .1815E+02
   .1830E+02   .1845E+02   .1860E+02   .1875E+02   .1890E+02   .1905E+02   .1921E+02   .1936E+02   .1952E+02   .1969E+02
   .1985E+02   .2003E+02   .2020E+02   .2038E+02   .2056E+02   .2075E+02   .2093E+02   .2112E+02   .2131E+02   .2149E+02

VE/UE=
  -.3317E-01  -.2987E-01  -.3234E-01  -.3006E-01  -.2814E-01  -.2790E-01  -.3313E-01  -.4471E-01  -.6093E-01  -.7560E-01
  -.8477E-01  -.9038E-01  -.9315E-01  -.9402E-01  -.9353E-01  -.9209E-01  -.8997E-01  -.8740E-01  -.8457E-01  -.8162E-01
  -.7864E-01  -.7564E-01  -.7265E-01  -.6964E-01  -.6662E-01  -.6353E-01  -.6036E-01  -.5705E-01  -.5355E-01  -.4978E-01
  -.4565E-01  -.4102E-01  -.3557E-01  -.2778E-01  -.1454E-01   .5817E-02   .2850E-01   .4875E-01   .6378E-01   .7522E-01
   .8374E-01   .9000E-01   .9465E-01   .9811E-01   .1007E+00   .1025E+00   .1038E+00   .1045E+00   .1049E+00   .1048E+00
   .1043E+00   .1033E+00   .1018E+00   .9984E-01   .9730E-01   .9423E-01   .9080E-01   .8715E-01   .8337E-01   .7952E-01
   .7565E-01   .7179E-01   .6799E-01   .6427E-01   .6068E-01   .5725E-01   .5401E-01   .5099E-01   .4833E-01   .4612E-01
   .4449E-01   .4332E-01   .4240E-01   .4158E-01   .4077E-01   .3990E-01   .3692E-01   .3760E-01   .3654E-01   .3513E-01
   .3357E-01   .3188E-01   .3009E-01   .2815E-01   .2610E-01   .2394E-01   .2177E-01   .1965E-01   .1762E-01   .1573E-01
   .1399E-01   .1242E-01   .1103E-01   .9802E-02   .6724E-02   .7800E-02   .7036E-02   .6440E-02   .6016E-02
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(PW-PREF) /UREF**2=

-.1192E+00	-.1265E+00	-.1342E+00	-.1374E+00	-.1440E+00	-.1524E+00	-.1649E+00	-.1812E+00	-.2003E+00	-.2316E+00
-.2573E+00	-.2727E+00	-.2824E+00	-.2899E+00	-.2966E+00	-.3031E+00	-.3096E+00	-.3165E+00	-.3238E+00	-.3315E+00
-.3393E+00	-.3472E+00	-.3551E+00	-.3631E+00	-.3711E+00	-.3793E+00	-.3876E+00	-.3962E+00	-.4052E+00	-.4145E+00
-.4243E+00	-.4347E+00	-.4442E+00	-.4508E+00	-.4512E+00	-.4409E+00	-.4154E+00	-.3755E+00	-.3489E+00	-.3345E+00
-.3273E+00	-.3232E+00	-.3199E+00	-.3167E+00	-.3133E+00	-.3095E+00	-.3056E+00	-.3015E+00	-.2974E+00	-.2933E+00
-.2893E+00	-.2854E+00	-.2817E+00	-.2784E+00	-.2750E+00	-.2710E+00	-.2660E+00	-.2602E+00	-.2540E+00	-.2474E+00
-.2406E+00	-.2336E+00	-.2265E+00	-.2191E+00	-.2116E+00	-.2038E+00	-.1970E+00	-.1918E+00	-.1863E+00	-.1806E+00
-.1751E+00	-.1703E+00	-.1662E+00	-.1623E+00	-.1586E+00	-.1549E+00	-.1513E+00	-.1479E+00	-.1446E+00	-.1415E+00
-.1387E+00	-.1360E+00	-.1336E+00	-.1313E+00	-.1291E+00	-.1270E+00	-.1248E+00	-.1227E+00	-.1206E+00	-.1186E+00
-.1167E+00	-.1149E+00	-.1134E+00	-.1121E+00	-.1110E+00	-.1099E+00	-.1090E+00	-.1081E+00	-.1072E+00	-.1070E+00

(PW-PE) /UREF**2=

0	-.1313E-02	-.3802E-02	-.2339E-02	-.6061E-02	-.1349E-01	-.2544E-01	-.3942E-01	-.5262E-01	-.7417E-01
-.9205E-01	-.1016E+00	-.1064E+00	-.1097E+00	-.1126E+00	-.1157E+00	-.1191E+00	-.1230E+00	-.1276E+00	-.1326E+00
-.1379E+00	-.1435E+00	-.1491E+00	-.1549E+00	-.1607E+00	-.1668E+00	-.1730E+00	-.1796E+00	-.1865E+00	-.1939E+00
-.2020E+00	-.2108E+00	-.2193E+00	-.2259E+00	-.2275E+00	-.2212E+00	-.2029E+00	-.1713E+00	-.1499E+00	-.1393E+00
-.1352E+00	-.1338E+00	-.1330E+00	-.1321E+00	-.1309E+00	-.1293E+00	-.1275E+00	-.1254E+00	-.1233E+00	-.1212E+00
-.1191E+00	-.1172E+00	-.1154E+00	-.1139E+00	-.1124E+00	-.1102E+00	-.1069E+00	-.1028E+00	-.9818E-01	-.9320E-01
-.8793E-01	-.8245E-01	-.7677E-01	-.7085E-01	-.6469E-01	-.5829E-01	-.5286E-01	-.4893E-01	-.4476E-01	-.4041E-01
-.3626E-01	-.3283E-01	-.3007E-01	-.2766E-01	-.2544E-01	-.2332E-01	-.2130E-01	-.1940E-01	-.1765E-01	-.1606E-01
-.1463E-01	-.1339E-01	-.1229E-01	-.1135E-01	-.1056E-01	-.9840E-02	-.9134E-02	-.8450E-02	-.7806E-02	-.7190E-02
-.6590E-02	-.6025E-02	-.5496E-02	-.4964E-02	-.4414E-02	-.3843E-02	-.3253E-02	-.2647E-02	-.1889E-02	-.1889E-02

SWEEP NO. 10 OF INVISCID/VISCOUS CALCULATION COMPLETED

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RUN NO. 10  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS CYCLE--S.YOUNG TEST CASE

1977    1    1   99   46   34    0    0    1    0   51    0   -2    0
A              0  6.000E-01            0  6.256E+04  1.375E-03  3.000E-01  3.000E-01
X FOR CURV. B. VALUE           0  4.000E+00  8.000E+00  1.000E+01  1.200E+01  1.220E+01  1.240E+01
 1.260E+01  1.280E+01  1.290E+01  1.300E+01  1.310E+01  1.320E+01  1.340E+01
 1.360E+01  1.380E+01  1.400E+01  1.420E+01  1.440E+01  1.460E+01  1.480E+01
 1.500E+01  1.520E+01  1.540E+01  1.550E+01  1.560E+01  1.570E+01  1.580E+01
 1.600E+01  1.620E+01  1.640E+01  1.660E+01  1.700E+01  1.900E+01  2.100E+01
 2.200E+01  2.250E+01  2.300E+01  2.350E+01  2.400E+01  2.450E+01  2.500E+01
 2.550E+01  2.600E+01  2.650E+01  2.700E+01
CURV               0          0          0          0          0  2.000E-02  4.000E-02
 6.000E-02  8.000E-02  9.000E-02  1.000E-01  1.100E-01  1.200E-01  1.400E-01
 1.600E-01  1.800E-01  2.000E-01  2.000E-01  2.000E-01  2.000E-01  1.800E-01
 1.600E-01  1.400E-01  1.200E-01  1.100E-01  1.000E-01  9.000E-02  8.000E-02
 6.000E-02  4.000E-02  2.000E-02          0          0          0          0
         0          0          0          0          0          0          0
         0          0          0          0
X FOR PRESS. AND NP B. VALUES              0   2.0000E+00   4.0000E+00   6.0000E+00   8.0000E+00   1.0000E+01   1.1000E+01
  1.2000E+01   1.3000E+01   1.3436E+01   1.3872E+01   1.4308E+01   1.4745E+01   1.5181E+01
  1.5617E+01   1.6617E+01   1.7617E+01   1.6617E+01   2.0617E+01   2.2617E+01
PE-PREF       5.0000E-01  -1.1586E-01  -6.9576E-02  -8.1726E-02  -9.1544E-02  -1.1920E-01  -1.3784E-01
 -1.4564E-01  -1.9287E-01  -2.1867E-01  -2.2504E-01  -2.2356E-01  -2.1595E-01  -1.9990E-01
 -1.7820E-01  -1.4404E-01  -1.3400E-01  -1.2208E-01  -1.0621E-01  -1.0674E-01
NP   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00

STN.          X       YSTEP        CF          UE     DEL05        THETA     SCHMETA          H     RTHETA      I6
   1  .1000E+02  .3333E-01    .002750  .1113E+01  .8208E+00  .9611E-01  .9611E-01     1.37735  .6691E+04     37

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.          X       YSTEP        CF          UE     DEL05        THETA     SCHMETA          H     RTHETA      I6
   2  .1025E+02  .3333E-01    .002649  .1118E+01  .8086E+00  .8415E-01  .9525E-01     1.53661  .5887E+04     37

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.          X       YSTEP        CF          UE     DEL05        THETA     SCHMETA          H     RTHETA      I6
   3  .1049E+02  .3333E-01    .002741  .1123E+01  .8048E+00  .8419E-01  .9354E-01     1.50380  .5914E+04     37

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.          X       YSTEP        CF          UE     DEL05        THETA     SCHMETA          H     RTHETA      I6
   4  .1075E+02  .3333E-01    .002826  .1127E+01  .7995E+00  .8295E-01  .9163E-01     1.48378  .5848E+04     37

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.          X       YSTEP        CF          UE     DEL05        THETA     SCHMETA          H     RTHETA      I6
   5  .1102E+02  .3333E-01    .002890  .1130E+01  .7932E+00  .8316E-01  .8914E-01     1.42831  .5876E+04     37

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.          X       YSTEP        CF          UE     DEL05        THETA     SCHMETA          H     RTHETA      I6
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  6  .1128E+02  .3333E-01    .002973  .1130E+01  .7899E+00  .8211E-01  .8540E-01    1.37169  .5806E+04      37
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005      VW/UE
         0          0         0         0          0
STN.          X        YSTEP         CF         UE    DEL05      THETA    SCHMETA         H     RTHETA     I6
  7  .1155E+02  .3333E-01    .003128  .1131E+01  .7866E+00  .7625E-01  .7959E-01    1.36066  .5394E+04      37
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005      VW/UE
         0          0         0         0          0
STN.          X        YSTEP         CF         UE    DEL05      THETA    SCHMETA         H     RTHETA     I6
  8  .1181E+02  .3333E-01    .003392  .1133E+01  .7816E+00  .6437E-01  .7119E-01    1.42105  .4562E+04      37
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005      VW/UE
         0          0         0         0          0
STN.          X        YSTEP         CF         UE    DEL05      THETA    SCHMETA         H     RTHETA     I6
  9  .1207E+02  .3333E-01    .003772  .1138E+01  .7738E+00  .4680E-01  .6016E-01    1.63500  .3332E+04      37
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005      VW/UE
         0  .5440E-02         0         0          0
STN.          X        YSTEP         CF         UE    DEL05      THETA    SCHMETA         H     RTHETA     I6
 10  .1232E+02  .3333E-01    .004192  .1147E+01  .7635E+00  .2776E-01  .4790E-01    2.19623  .1991E+04      37
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005      VW/UE
         0  .2458E-01         0         0          0
STN.          X        YSTEP         CF         UE    DEL05      THETA    SCHMETA         H     RTHETA     I6
 11  .1249E+02  .3333E-01    .004431  .1153E+01  .7564E+00  .2309E-01  .3940E-01    2.19887  .1666E+04      37
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005      VW/UE
         0  .3673E-01         0         0          0
STN.          X        YSTEP         CF         UE    DEL05      THETA    SCHMETA         H     RTHETA     I6
 12  .1260E+02  .3333E-01    .004582  .1159E+01  .7506E+00  .2130E-01  .3356E-01    2.06831  .1544E+04      37
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005      VW/UE
         0  .4496E-01         0         0          0
STN.          X        YSTEP         CF         UE    DEL05      THETA    SCHMETA         H     RTHETA     I6
 13  .1269E+02  .3333E-01    .004698  .1163E+01  .7455E+00  .1901E-01  .2900E-01    2.04431  .1383E+04      37
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005      VW/UE
         0  .5134E-01         0         0          0
STN.          X        YSTEP         CF         UE    DEL05      THETA    SCHMETA         H     RTHETA     I6
 14  .1277E+02  .3333E-01    .004791  .1166E+01  .7407E+00  .1663E-01  .2515E-01    2.07906  .1214E+04      37
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005      VW/UE
         0  .5669E-01         0         0          0
STN.          X        YSTEP         CF         UE    DEL05      THETA    SCHMETA         H     RTHETA     I6
 15  .1283E+02  .3333E-01    .004870  .1170E+01  .7362E+00  .1431E-01  .2174E-01    2.15754  .1047E+04      37
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005      VW/UE
         0  .6139E-01         0         0          0
STN.          X        YSTEP         CF         UE    DEL05      THETA    SCHMETA         H     RTHETA     I6
 16  .1290E+02  .3333E-01    .004937  .1172E+01  .7321E+00  .1211E-01  .1866E-01    2.27990  .8879E+03      37
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005      VW/UE
         0  .6565E-01         0         0          0
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STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
17	.1296E+02	.3333E-01	.004996	.1175E+01	.7285E+00	.9908E-02	.1582E-01	2.47654	.7285E+03	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.6963E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
18	.1301E+02	.3333E-01	.005048	.1178E+01	.7253E+00	.7973E-02	.1318E-01	2.74213	.5874E+03	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.7339E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
19	.1307E+02	.3333E-01	.005093	.1180E+01	.7224E+00	.6164E-02	.1071E-01	3.14876	.4550E+03	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.7696E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
20	.1312E+02	.3333E-01	.005133	.1182E+01	.7197E+00	.4450E-02	.8365E-02	3.85115	.3291E+03	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.8041E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
21	.1317E+02	.3333E-01	.005163	.1184E+01	.7172E+00	.2790E-02	.6118E-02	5.37828	.2067E+03	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.8377E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
22	.1322E+02	.3333E-01	.005202	.1186E+01	.7149E+00	.1164E-02	.3937E-02	11.14903	.8637E+02	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.8709E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
23	.1327E+02	.3333E-01	.005232	.1188E+01	.7127E+00	-.4458E-03	.1797E-02	-24.71879	-.3314E+02	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.9039E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
24	.1332E+02	.3333E-01	.005259	.1190E+01	.7106E+00	-.2054E-02	-.3250E-03	-4.43532	-.1530E+03	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.9374E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
25	.1337E+02	.3333E-01	.005284	.1192E+01	.7086E+00	-.3678E-02	-.2452E-02	-1.96530	-.2743E+03	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.9715E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
26	.1342E+02	.3333E-01	.005307	.1194E+01	.7067E+00	-.5336E-02	-.4608E-02	-1.00153	-.3985E+03	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.1007E+00	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
27	.1348E+02	.3333E-01	.005328	.1195E+01	.7047E+00	-.7050E-02	-.6821E-02	-.48630	-.5272E+03	37

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 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .1044E+00           0            0           0

STN.             X       YSTEP        CF          UE    DEL05       THETA     SCHMETA           H     RTHETA      I6
 28  .1354E+02  .3333E-01    .005347  .1197E+01  .7028E+00 -.8849E-02 -.9125E-02      -.16362 -.6628E+03      37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .1083E+00           0            0           0

STN.             X       YSTEP        CF          UE    DEL05       THETA     SCHMETA           H     RTHETA      I6
 29  .1361E+02  .3333E-01    .005363  .1199E+01  .7009E+00 -.1074E-01 -.1156E-01       .05900 -.8055E+03      37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .1126E+00           0            0           0

STN.             X       YSTEP        CF          UE    DEL05       THETA     SCHMETA           H     RTHETA      I6
 30  .1368E+02  .3333E-01    .005376  .1200E+01  .6978E+00 -.1273E-01 -.1416E-01       .22460 -.9562E+03      37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .1171E+00           0            0           0

STN.             X       YSTEP        CF          UE    DEL05       THETA     SCHMETA           H     RTHETA      I6
 31  .1376E+02  .3333E-01    .005384  .1202E+01  .6934E+00 -.1491E-01 -.1699E-01       .35919 -.1121E+04      37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .1220E+00           0            0           0

STN.             X       YSTEP        CF          UE    DEL05       THETA     SCHMETA           H     RTHETA      I6
 32  .1385E+02  .3333E-01    .005386  .1203E+01  .6883E+00 -.1711E-01 -.2015E-01       .47195 -.1288E+04      37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .1274E+00           0            0           0

STN.             X       YSTEP        CF          UE    DEL05       THETA     SCHMETA           H     RTHETA      I6
 33  .1396E+02  .3333E-01    .005376  .1204E+01  .6825E+00 -.1937E-01 -.2379E-01       .58075 -.1459E+04      37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .1339E+00           0            0           0

STN.             X       YSTEP        CF          UE    DEL05       THETA     SCHMETA           H     RTHETA      I6
 34  .1410E+02  .3333E-01    .005331  .1204E+01  .6757E+00 -.2120E-01 -.2799E-01       .69851 -.1597E+04      37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .1351E+00           0            0           0

STN.             X       YSTEP        CF          UE    DEL05       THETA     SCHMETA           H     RTHETA      I6
 35  .1429E+02  .3333E-01    .005173  .1203E+01  .6686E+00 -.2116E-01 -.3166E-01       .79417 -.1593E+04      37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .1337E+00           0            0           0

STN.             X       YSTEP        CF          UE    DEL05       THETA     SCHMETA           H     RTHETA      I6
 36  .1457E+02  .3333E-01    .004735  .1200E+01  .6666E+00 -.1187E-01 -.3001E-01      1.00970 -.8909E+03      37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .1333E+00           0            0           0

STN.             X       YSTEP        CF          UE    DEL05       THETA     SCHMETA           H     RTHETA      I6
 37  .1483E+02  .3333E-01    .004254  .1194E+01  .6735E+00  .1654E-02 -.2253E-01     -2.01942  .1235E+03      37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .1195E+00           0            0           0

STN.             X       YSTEP        CF          UE    DEL05       THETA     SCHMETA           H     RTHETA      I6
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   38  .1504E+02  .3333E-01    .003828  .1187E+01  .6912E+00  .1269E-01 -.1341E-01     .55998  .9422E+03      37

  ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .1077E+00          0           0           0

 STN.          X        YSTEP         CF         UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
   39  .1516E+02  .3333E-01    .003614  .1182E+01  .6991E+00  .1267E-01 -.7702E-02    1.08700  .9369E+03      37

  ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .1006E+00          0           0           0

 STN.          X        YSTEP         CF         UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
   40  .1524E+02  .3333E-01    .003458  .1179E+01  .7042E+00  .1460E-01 -.3457E-02    1.29591  .1077E+04      37

  ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .9549E-01          0           0           0

 STN.          X        YSTEP         CF         UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
   41  .1531E+02  .3333E-01    .003334  .1177E+01  .7092E+00  .1706E-01  .5158E-04    1.36769  .1256E+04      37

  ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .9138E-01          0           0           0

 STN.          X        YSTEP         CF         UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
   42  .1537E+02  .3333E-01    .003226  .1174E+01  .7140E+00  .1966E-01  .3136E-02    1.39006  .1445E+04      37

  ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .8783E-01          0           0           0

 STN.          X        YSTEP         CF         UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
   43  .1542E+02  .3333E-01    .003131  .1172E+01  .7186E+00  .2227E-01  .5950E-02    1.39522  .1633E+04      37

  ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .8461E-01          0           0           0

 STN.          X        YSTEP         CF         UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
   44  .1547E+02  .3333E-01    .003044  .1170E+01  .7232E+00  .2486E-01  .8587E-02    1.39331  .1820E+04      37

  ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .8158E-01          0           0           0

 STN.          X        YSTEP         CF         UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
   45  .1552E+02  .3333E-01    .002962  .1168E+01  .7275E+00  .2742E-01  .1110E-01    1.38928  .2004E+04      37

  ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .7865E-01          0           0           0

 STN.          X        YSTEP         CF         UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
   46  .1556E+02  .3333E-01    .002885  .1166E+01  .7317E+00  .2996E-01  .1353E-01    1.38484  .2186E+04      37

  ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .7576E-01          0           0           0

 STN.          X        YSTEP         CF         UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
   47  .1561E+02  .3333E-01    .002812  .1165E+01  .7362E+00  .3248E-01  .1590E-01    1.38085  .2366E+04      37

  ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .7293E-01          0           0           0

 STN.          X        YSTEP         CF         UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
   48  .1565E+02  .3333E-01    .002742  .1163E+01  .7407E+00  .3499E-01  .1822E-01    1.37727  .2545E+04      37

  ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .7010E-01          0           0           0
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STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
49	.1570E+02	.3333E-01	.002675	.1161E+01	.7452E+00	.3749E-01	.2052E-01	1.37442	.2723E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.6723E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
50	.1574E+02	.3333E-01	.002611	.1159E+01	.7495E+00	.3998E-01	.2278E-01	1.37258	.2900E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.6428E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
51	.1579E+02	.3333E-01	.002549	.1158E+01	.7536E+00	.4246E-01	.2503E-01	1.37153	.3075E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.6125E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
52	.1583E+02	.3333E-01	.002490	.1156E+01	.7577E+00	.4489E-01	.2725E-01	1.37180	.3247E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.5812E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
53	.1588E+02	.3333E-01	.002434	.1154E+01	.7616E+00	.4728E-01	.2943E-01	1.37310	.3414E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.5491E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
54	.1593E+02	.3333E-01	.002382	.1153E+01	.7653E+00	.4960E-01	.3157E-01	1.37527	.3577E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.5158E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
55	.1597E+02	.3333E-01	.002334	.1151E+01	.7696E+00	.5186E-01	.3365E-01	1.37825	.3735E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.4820E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
56	.1602E+02	.3333E-01	.002290	.1150E+01	.7740E+00	.5405E-01	.3566E-01	1.38178	.3887E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.4471E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
57	.1607E+02	.3333E-01	.002251	.1148E+01	.7781E+00	.5617E-01	.3760E-01	1.38572	.4034E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.4107E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
58	.1612E+02	.3333E-01	.002215	.1147E+01	.7818E+00	.5821E-01	.3946E-01	1.38977	.4176E+04	37

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.3730E-01	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
59	.1618E+02	.3333E-01	.002184	.1145E+01	.7853E+00	.6019E-01	.4126E-01	1.39385	.4312E+04	37

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 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .3337E-01         0           0          0

STN.          X       YSTEP        CF         UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
  60  .1623E+02  .3333E-01    .002156  .1144E+01  .7884E+00  .6210E-01  .4298E-01   1.39796  .4444E+04     37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .2929E-01         0           0          0

STN.          X       YSTEP        CF         UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
  61  .1628E+02  .3333E-01    .002131  .1142E+01  .7913E+00  .6397E-01  .4465E-01   1.40179  .4572E+04     37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .2502E-01         0           0          0

STN.          X       YSTEP        CF         UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
  62  .1634E+02  .3333E-01    .002110  .1141E+01  .7940E+00  .6577E-01  .4625E-01   1.40579  .4695E+04     37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .2057E-01         0           0          0

STN.          X       YSTEP        CF         UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
  63  .1640E+02  .3333E-01    .002092  .1140E+01  .7964E+00  .6751E-01  .4780E-01   1.40967  .4815E+04     37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .1592E-01         0           0          0

STN.          X       YSTEP        CF         UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
  64  .1646E+02  .3333E-01    .002076  .1139E+01  .7985E+00  .6922E-01  .4929E-01   1.41340  .4931E+04     37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .1105E-01         0           0          0

STN.          X       YSTEP        CF         UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
  65  .1653E+02  .3333E-01    .002062  .1137E+01  .8006E+00  .7088E-01  .5074E-01   1.41694  .5044E+04     37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .5939E-02         0           0          0

STN.          X       YSTEP        CF         UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
  66  .1659E+02  .3333E-01    .002051  .1136E+01  .8153E+00  .7254E-01  .5216E-01   1.42019  .5156E+04     37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0  .5574E-03         0           0          0

STN.          X       YSTEP        CF         UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
  67  .1666E+02  .3333E-01    .002041  .1135E+01  .8183E+00  .7419E-01  .5356E-01   1.42313  .5268E+04     37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0          0         0           0          0

STN.          X       YSTEP        CF         UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
  68  .1674E+02  .3333E-01    .002033  .1134E+01  .8211E+00  .7585E-01  .5496E-01   1.42588  .5381E+04     37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0          0         0           0          0

STN.          X       YSTEP        CF         UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
  69  .1682E+02  .3333E-01    .002025  .1133E+01  .8237E+00  .7754E-01  .5639E-01   1.42848  .5494E+04     37

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
         0          0         0           0          0

STN.          X       YSTEP        CF         UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
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 70  .1690E+02  .3333E-01   .002016  .1132E+01  .8261E+00  .7929E-01  .5787E-01   1.43061  .5613E+04     37

 ROUGH/D05    D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.           X      YSTEP          CF         UE     DEL05      THETA    SCHMETA        H    RTHETA     I6
 71  .1699E+02  .3333E-01   .002006  .1130E+01  .8284E+00  .8117E-01  .5944E-01   1.43223  .5740E+04     37

 ROUGH/D05    D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.           X      YSTEP          CF         UE     DEL05      THETA    SCHMETA        H    RTHETA     I6
 72  .1709E+02  .3333E-01   .001994  .1129E+01  .8305E+00  .8319E-01  .6114E-01   1.43344  .5877E+04     37

 ROUGH/D05    D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.           X      YSTEP          CF         UE     DEL05      THETA    SCHMETA        H    RTHETA     I6
 73  .1720E+02  .3333E-01   .001979  .1128E+01  .8324E+00  .8538E-01  .6299E-01   1.43448  .6024E+04     37

 ROUGH/D05    D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.           X      YSTEP          CF         UE     DEL05      THETA    SCHMETA        H    RTHETA     I6
 74  .1731E+02  .3333E-01   .001962  .1127E+01  .8344E+00  .8772E-01  .6501E-01   1.43561  .6182E+04     37

 ROUGH/D05    D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.           X      YSTEP          CF         UE     DEL05      THETA    SCHMETA        H    RTHETA     I6
 75  .1743E+02  .3333E-01   .001944  .1125E+01  .8364E+00  .9023E-01  .6719E-01   1.43680  .6352E+04     37

 ROUGH/D05    D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.           X      YSTEP          CF         UE     DEL05      THETA    SCHMETA        H    RTHETA     I6
 76  .1756E+02  .3333E-01   .001925  .1124E+01  .8380E+00  .9288E-01  .6953E-01   1.43828  .6530E+04     37

 ROUGH/D05    D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.           X      YSTEP          CF         UE     DEL05      THETA    SCHMETA        H    RTHETA     I6
 77  .1770E+02  .3333E-01   .001908  .1123E+01  .8390E+00  .9559E-01  .7198E-01   1.44025  .6713E+04     37

 ROUGH/D05    D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.           X      YSTEP          CF         UE     DEL05      THETA    SCHMETA        H    RTHETA     I6
 78  .1785E+02  .3333E-01   .001894  .1121E+01  .8395E+00  .9828E-01  .7448E-01   1.44289  .6893E+04     37

 ROUGH/D05    D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.           X      YSTEP          CF         UE     DEL05      THETA    SCHMETA        H    RTHETA     I6
 79  .1800E+02  .3333E-01   .001882  .1120E+01  .8395E+00  .1009E+00  .7695E-01   1.44585  .7067E+04     37

 ROUGH/D05    D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0

STN.           X      YSTEP          CF         UE     DEL05      THETA    SCHMETA        H    RTHETA     I6
 80  .1815E+02  .3333E-01   .001875  .1118E+01  .8391E+00  .1034E+00  .7934E-01   1.44870  .7233E+04     37

 ROUGH/D05    D05/RAD  D05/(X-X0)  STRAIN.D05      VW/UE
        0          0          0          0          0
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STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
81	.1830E+02	.3333E-01	.001872	.1117E+01	.8385E+00	.1057E+00	.8161E-01	1.45124	.7389E+04	37

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
82	.1845E+02	.3333E-01	.001872	.1116E+01	.8379E+00	.1079E+00	.8373E-01	1.45332	.7535E+04	37

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
83	.1860E+02	.3333E-01	.001876	.1115E+01	.8375E+00	.1115E+00	.8569E-01	1.44884	.7772E+04	37

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
84	.1875E+02	.3333E-01	.001884	.1113E+01	.8374E+00	.1133E+00	.8747E-01	1.44999	.7893E+04	37

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
85	.1890E+02	.3333E-01	.001695	.1112E+01	.8378E+00	.1150E+00	.8905E-01	1.45053	.8001E+04	37

ROUGH/D05	005/RAD	005/(X-X0)	STRAIN.D05	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
86	.1905E+02	.3333E-01	.001909	.1111E+01	.8387E+00	.1165E+00	.9041E-01	1.45043	.8096E+04	37

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
87	.1921E+02	.3333E-01	.001926	.1110E+01	.8402E+00	.1178E+00	.9156E-01	1.45009	.8175E+04	37

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.005	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
88	.1936E+02	.3333E-01	.001944	.1108E+01	.8424E+00	.1188E+00	.9252E-01	1.44999	.8239E+04	37

ROUGH/D05	005/RAD	005/(X-X0)	STRAIN.D05	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
89	.1952E+02	.3333E-01	.001963	.1107E+01	.8451E+00	.1197E+00	.9333E-01	1.45022	.8289E+04	37

ROUGH/D05	005/RAD	005/(X-X0)	STRAIN.D05	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
90	.1969E+02	.3333E-01	.001984	.1106E+01	.8485E+00	.1204E+00	.9401E-01	1.45090	.8328E+04	37

ROUGH/D05	D05/RAD	005/(X-X0)	STRAIN.D05	VW/UE
0	0	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
91	.1985E+02	.3333E-01	.002004	.1105E+01	.8526E+00	.1209E+00	.9462E-01	1.45216	.8357E+04	37

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RØUGH/D05     005/RAO 005/(X-XO) STRAIN.005      VW/UE
        0           0           0          0          0

STN.        X      YSTEP       CF         UE     DELO5      THETA     SCHMETA        H      RTHETA     I6
 92  .2003E+02  .3333E-01   .002024  .1104E+01  .8573E+00  .1214E+00  .9520E-01   1.45422  .8380E+04    37

RØUGH/D05     005/RAO 005/(X-XO) STRAIN.005      VW/UE
        0           0           0          0          0

STN.        X      YSTEP       CF         UE     DELO5      THETA     SCHMETA        H      RTHETA     I6
 93  .2020E+02  .3333E-01   .002043  .1103E+01  .8625E+00  .1217E+00  .9579E-01   1.45738  .8398E+04    37

RØUGH/D05     005/RAO D05/(X-XO) STRAIN.D05      VW/UE
        0           0           0          0          0

STN.        X      YSTEP       CF         UE     DELO5      THETA     SCHMETA        H      RTHETA     I6
 94  .2038E+02  .3333E-01   .002060  .1102E+01  .8685E+00  .1221E+00  .9641E-01   1.46008  .8419E+04    37

RØUGH/D05     005/RAO 005/(X-XO) STRAIN.D05      VW/UE
        0           0           0          0          0

STN.        X      YSTEP       CF         UE     DELO5      THETA     SCHMETA        H      RTHETA     I6
 95  .2056E+02  .3333E-01   .002076  .1101E+01  .8741E+00  .1226E+00  .9706E-01   1.46223  .8444E+04    37

RØUGH/D05     005/RAO 005/(X-XO) STRAIN.D05      VW/UE
        0           0           0          0          0

STN.        X      YSTEP       CF         UE     DELO5      THETA     SCHMETA        H      RTHETA     I6
 96  .2075E+02  .3333E-01   .002091  .1101E+01  .8774E+00  .1230E+00  .9775E-01   1.46391  .8474E+04    37

RØUGH/D05     005/RAO 005/(X-XO) STRAIN.005      VW/UE
        0           0           0          0          0

STN.        X      YSTEP       CF         UE     DELO5      THETA     SCHMETA        H      RTHETA     I6
 97  .2093E+02  .3333E-01   .002104  .1101E+01  .8814E+00  .1236E+00  .9846E-01   1.46511  .8508E+04    37

RØUGH/D05     005/RAO 005/(X-XO) STRAIN.005      VW/UE
        0           0           0          0          0

STN.        X      YSTEP       CF         UE     DELO5      THETA     SCHMETA        H      RTHETA     I6
 98  .2112E+02  .3333E-01   .002115  .1100E+01  .8861E+00  .1241E+00  .9918E-01   1.46581  .8545E+04    37

RØUGH/D05     005/RAO 005/(X-XO) STRAIN.005      VW/UE
        0           0           0          0          0

STN.        X      YSTEP       CF         UE     DELO5      THETA     SCHMETA        H      RTHETA     I6
 99  .2131E+02  .3333E-01   .002124  .1100E+01  .8913E+00  .1247E+00  .9992E-01   1.46590  .8587E+04    37

RØUGH/D05     005/RAO 005/(X-XO) STRAIN.005      VW/UE
        0           0           0          0          0

X=
   .1000E+02  .1025E+02  .1049E+02  .1075E+02  .1102E+02  .1128E+02  .1155E+02  .1181E+02  .1207E+02  .1232E+02
   .1249E+02  .1260E+02  .1269E+02  .1277E+02  .1283E+02  .1290E+02  .1296E+02  .1301E+02  .1307E+02  .1312E+02
   .1317E+02  .1322E+02  .1327E+02  .1332E+02  .1337E+02  .1342E+02  .1348E+02  .1354E+02  .1361E+02  .1368E+02
   .1376E+02  .1395E+02  .1396E+02  .1410E+02  .1429E+02  .1457E+02  .1483E+02  .1504E+02  .1516E+02  .1524E+02
   .1531E+02  .1537E+02  .1542E+02  .1547E+02  .1552E+02  .1556E+02  .1561E+02  .1565E+02  .1570E+02  .1574E+02
   .1579E+02  .1583E+02  .1588E+02  .1593E+02  .1597E+02  .1602E+02  .1607E+02  .1612E+02  .1618E+02  .1623E+02
   .1628E+02  .1634E+02  .1640E+02  .1646E+02  .1653E+02  .1659E+02  .1666E+02  .1674E+02  .1682E+02  .1690E+02
   .1699E+02  .1709E+02  .1720E+02  .1731E+02  .1743E+02  .1756E+02  .1770E+02  .1785E+02  .1800E+02  .1815E+02
   .1830E+02  .1845E+02  .1860E+02  .1875E+02  .1690E+02  .1905E+02  .1921E+02  .1936E+02  .1952E+02  .1969E+02
   .1985E+02  .2003E+02  .2020E+02  .2038E+02  .2056E+02  .2075E+02  .2093E+02  .2112E+02  .2131E+02  .2149E+02

VE/UE=
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-.3317E-01	-.2987E-01	-.3234E-01	-.3006E-01	-.2814E-01	-.2790E-01	-.3313E-01	-.4471E-01	-.6093E-01	-.7560E-01
-.8477E-01	-.9038E-01	-.9315E-01	-.9402E-01	-.9353E-01	-.9209E-01	-.8997E-01	-.8740E-01	-.8457E-01	-.8162E-01
-.7864E-01	-.7564E-01	-.7265E-01	-.6964E-01	-.6662E-01	-.6353E-01	-.6036E-01	-.5705E-01	-.5355E-01	-.4978E-01
-.4565E-01	-.4102E-01	-.3557E-01	-.2778E-01	-.1454E-01	.6817E-02	.2850E-01	.4875E-01	.6378E-01	.7522E-01
.8374E-01	.9000E-01	.9465E-01	.9811E-01	.1007E+00	.1025E+00	.1038E+00	.1045E+00	.1049E+00	.1048E+00
.1043E+00	.1033E+00	.1018E+00	.9984E-01	.9730E-01	.9423E-01	.9080E-01	.8715E-01	.8337E-01	.7952E-01
.7565E-01	.7179E-01	.6799E-01	.6427E-01	.6068E-01	.5725E-01	.5401E-01	.5099E-01	.4833E-01	.4612E-01
.4449E-01	.4332E-01	.4240E-01	.4158E-01	.4077E-01	.3990E-01	.3892E-01	.3780E-01	.3654E-01	.3513E-01
.3357E-01	.3188E-01	.3009E-01	.2815E-01	.2610E-01	.2394E-01	.2177E-01	.1965E-01	.1762E-01	.1573E-01
.1399E-01	.1242E-01	.1103E-01	.9802E-02	.8724E-02	.7800E-02	.7036E-02	.6440E-02	.6016E-02	

(PW-PREF)/UREF**2=

-.1192E+00	-.1265E+00	-.1342E+00	-.1374E+00	-.1440E+00	-.1524E+00	-.1649E+00	-.1812E+00	-.2003E+00	-.2316E+00
-.2573E+00	-.2727E+00	-.2824E+00	-.2899E+00	-.2966E+00	-.3031E+00	-.3096E+00	-.3165E+00	-.3238E+00	-.3315E+00
-.3393E+00	-.3472E+00	-.3551E+00	-.3631E+00	-.3711E+00	-.3793E+00	-.3876E+00	-.3962E+00	-.4052E+00	-.4145E+00
-.4243E+00	-.4347E+00	-.4442E+00	-.4508E+00	-.4512E+00	-.4409E+00	-.4154E+00	-.3755E+00	-.3489E+00	-.3345E+00
-.3273E+00	-.3232E+00	-.3199E+00	-.3167E+00	-.3133E+00	-.3095E+00	-.3056E+00	-.3015E+00	-.2974E+00	-.2933E+00
-.2893E+00	-.2854E+00	-.2817E+00	-.2784E+00	-.2750E+00	-.2710E+00	-.2660E+00	-.2602E+00	-.2540E+00	-.2474E+00
-.2406E+00	-.2335E+00	-.2265E+00	-.2191E+00	-.2116E+00	-.2038E+00	-.1970E+00	-.1918E+00	-.1863E+00	-.1806E+00
-.1751E+00	-.1703E+00	-.1662E+00	-.1623E+00	-.1586E+00	-.1549E+00	-.1513E+00	-.1479E+00	-.1446E+00	-.1415E+00
-.1387E+00	-.1350E+00	-.1336E+00	-.1313E+00	-.1291E+00	-.1270E+00	-.1248E+00	-.1227E+00	-.1206E+00	-.1186E+00
-.1167E+00	-.1149E+00	-.1134E+00	-.1121E+00	-.1110E+00	-.1099E+00	-.1090E+00	-.1081E+00	-.1072E+00	-.1070E+00

(PW-PE)/UREF**2=

0	-.1313E-02	-.3802E-02	-.2339E-02	-.6061E-02	-.1349E-01	-.2544E-01	-.3942E-01	-.5262E-01	-.7417E-01
-.9205E-01	-.1016E+00	-.1064E+00	-.1097E+00	-.1126E+00	-.1157E+00	-.1191E+00	-.1230E+00	-.1276E+00	-.1326E+00
-.1379E+00	-.1435E+00	-.1491E+00	-.1549E+00	-.1607E+00	-.1668E+00	-.1730E+00	-.1796E+00	-.1865E+00	-.1939E+00
-.2020E+00	-.2108E+00	-.2193E+00	-.2259E+00	-.2275E+00	-.2212E+00	-.2029E+00	-.1713E+00	-.1499E+00	-.1393E+00
-.1352E+00	-.1338E+00	-.1330E+00	-.1321E+00	-.1309E+00	-.1293E+00	-.1275E+00	-.1254E+00	-.1233E+00	-.1212E+00
-.1191E+00	-.1172E+00	-.1154E+00	-.1139E+00	-.1124E+00	-.1102E+00	-.1069E+00	-.1028E+00	-.9818E-01	-.9320E-01
-.8793E-01	-.8246E-01	-.7677E-01	-.7085E-01	-.6468E-01	-.5829E-01	-.5286E-01	-.4893E-01	-.4476E-01	-.4041E-01
-.3626E-01	-.3283E-01	-.3007E-01	-.2766E-01	-.2544E-01	-.2332E-01	-.2130E-01	-.1940E-01	-.1765E-01	-.1606E-01
-.1463E-01	-.1339E-01	-.1229E-01	-.1135E-01	-.1056E-01	-.9840E-02	-.9134E-02	-.8450E-02	-.7806E-02	-.7190E-02
-.6590E-02	-.6025E-02	-.5496E-02	-.4964E-02	-.4414E-02	-.3843E-02	-.3253E-02	-.2647E-02	-.1889E-02	-.1889E-02

SWEEP NO. 10 OF INVISCID/VISCOUS CALCULATION COMPLETED

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RUN NO. 10  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS CYCLE--S.YOUNG TEST CASE
1977    1  -15   99   46   34    0    0    1    0   51    0   -2    1
A                0  6.000E-01             0  6.256E+04  1.375E-03  3.000E-01  3.000E-01
X FOR CURV. B. VALUE               0  4.000E+00  8.000E+00  1.000E+01  1.200E+01  1.220E+01  1.240E+01
 1.260E+01  1.280E+01  1.290E+01  1.300E+01  1.310E+01  1.320E+01  1.340E+01
 1.360E+01  1.380E+01  1.400E+01  1.420E+01  1.440E+01  1.460E+01  1.480E+01
 1.500E+01  1.520E+01  1.540E+01  1.550E+01  1.560E+01  1.570E+01  1.580E+01
 1.600E+01  1.620E+01  1.640E+01  1.660E+01  1.700E+01  1.900E+01  2.100E+01
 2.200E+01  2.250E+01  2.300E+01  2.350E+01  2.400E+01  2.450E+01  2.500E+01
 2.550E+01  2.600E+01  2.650E+01  2.700E+01
CURV              0          0          0          0          0  2.000E-02  4.000E-02
 6.000E-02  8.000E-02  9.000E-02  1.000E-01  1.100E-01  1.200E-01  1.400E-01
 1.600E-01  1.800E-01  2.000E-01  2.000E-01  2.000E-01  2.000E-01  1.800E-01
 1.600E-01  1.400E-01  1.200E-01  1.100E-01  1.000E-01  9.000E-02  8.000E-02
 6.000E-02  4.000E-02  2.000E-02          0          0          0          0
         0          0          0          0          0          0          0
         0          0          0          0
X FOR PRESS. AND NP B. VALUES              0   2.0000E+00   4.0000E+00   6.0000E+00   8.0000E+00   1.0000E+01   1.1000E+01
  1.2000E+01   1.3000E+01   1.3436E+01   1.3872E+01   1.4308E+01   1.4745E+01   1.5181E+01
  1.5617E+01   1.6617E+01   1.7617E+01   1.8617E+01   2.0617E+01   2.2617E+01
PE-PREF      5.0000E-01  -1.1586E-01  -6.9576E-02  -8.1726E-02  -9.1544E-02  -1.1920E-01  -1.3784E-01
 -1.4564E-01  -1.9287E-01  -2.1867E-01  -2.2504E-01  -2.2356E-01  -2.1595E-01  -1.9990E-01
 -1.7820E-01  -1.4404E-01  -1.3400E-01  -1.2208E-01  -1.0621E-01  -1.0674E-01
NP   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00
  1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00   1.3000E+00

STN.   1       X=  .1000E+02       I62= 39       (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=
  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00
  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00
  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00
  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00  -.1192E+00
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STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
1	.1000E+02	.3333E-01	.002750	.1113E+01	.8208E+00	.9611E-01	.9611E-01	1.37735	.6691E+04	37

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	0	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB
1	.5650	.1370E-02	0	.3590E-01	-.3586E-01
2	.6367	.1362E-02	-.1401E-02	.2960E-01	-.3390E-01
3	.6800	.1350E-02	-.2724E-02	.2568E-01	-.3351E-01
4	.7087	.1327E-02	-.3966E-02	.2271E-01	-.3360E-01
5	.7353	.1299E-02	-.5181E-02	.2002E-01	-.3368E-01
6	.7600	.1265E-02	-.6367E-02	.1755E-01	-.3372E-01
7	.7807	.1220E-02	-.7497E-02	.1528E-01	-.3373E-01
8	.8003	.1169E-02	-.8603E-02	.1313E-01	-.3368E-01
9	.8190	.1112E-02	-.9685E-02	.1106E-01	-.3356E-01
10	.8350	.1045E-02	-.1072E-01	.9071E-02	-.3336E-01
11	.8510	.9720E-03	-.1173E-01	.7101E-02	-.3306E-01
12	.8670	.8940E-03	-.1274E-01	.5152E-02	-.3267E-01
13	.8823	.8127E-03	-.1372E-01	.3240E-02	-.3222E-01
14	.8967	.7313E-03	-.1468E-01	.1386E-02	-.3174E-01
15	.9100	.6500E-03	-.1562E-01	-.3647E-03	-.3118E-01
16	.9220	.5693E-03	-.1653E-01	-.1876E-02	-.3045E-01
17	.9337	.4893E-03	-.1743E-01	-.3026E-02	-.2943E-01
18	.9450	.4100E-03	-.1832E-01	-.4152E-02	-.2843E-01
19	.9453	.3353E-03	-.1899E-01	-.5049E-02	-.2758E-01
20	.9630	.2663E-03	-.2002E-01	-.6137E-02	-.2667E-01
21	.9710	.2030E-03	-.2084E-01	-.6979E-02	-.2592E-01
22	.9777	.1530E-03	-.2164E-01	-.7650E-02	-.2545E-01
23	.9837	.1097E-03	-.2243E-01	-.8839E-02	-.2523E-01
24	.9890	.7300E-04	-.2320E-01	-.1006E-01	-.2513E-01
25	.9930	.4967E-04	-.2395E-01	-.1101E-01	-.2527E-01
26	.9963	.3133E-04	-.2468E-01	-.1186E-01	-.2551E-01
27	.9990	.1800E-04	-.2540E-01	-.1259E-01	-.2585E-01
28	.9997	.1133E-04	-.2607E-01	-.1315E-01	-.2634E-01
29	1.0000	.6333E-05	-.2673E-01	-.1365E-01	-.2688E-01
30	1.0000	.3000E-05	-.2738E-01	-.1411E-01	-.2745E-01
31	1.0000	.1333E-05	-.2803E-01	-.1453E-01	-.2805E-01
32	1.0000	.3367E-06	-.2867E-01	-.1493E-01	-.2868E-01
33	1.0000	.1000E-07	-.2931E-01	-.1532E-01	-.2931E-01
34	1.0000	.1000E-07	-.2996E-01	-.1569E-01	-.2996E-01
35	1.0000	.1000E-07	-.3060E-01	-.1607E-01	-.3060E-01
36	1.0000	.1000E-07	-.3124E-01	-.1659E-01	-.3124E-01
37	1.0000	.1000E-07	-.3188E-01	-.1723E-01	-.3188E-01
38	1.0000	.1000E-07	-.3253E-01	-.1788E-01	-.3253E-01
39	1.0000	.1000E-07	-.3317E-01	-.1852E-01	-.3317E-01

STN. 5 X= .1102E+02 I62= 39 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.1470E+00	-.1470E+00	-.1470E+00	-.1469E+00	-.1469E+00	-.1468E+00	-.1467E+00	-.1466E+00	-.1465E+00	-.1464E+00
-.1462E+00	-.1460E+00	-.1459E+00	-.1457E+00	-.1455E+00	-.1453E+00	-.1450E+00	-.1448E+00	-.1445E+00	-.1443E+00
-.1440E+00	-.1437E+00	-.1434E+00	-.1431E+00	-.1427E+00	-.1424E+00	-.1421E+00	-.1417E+00	-.1414E+00	-.1411E+00
-.1407E+00	-.1404E+00	-.1401E+00	-.1397E+00	-.1394E+00	-.1391E+00	-.1388E+00	-.1385E+00	-.1382E+00	-.1379E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
5	.1102E+02	.3333E-01	.002890	.1130E+01	.7932E+00	.8316E-01	.8914E-01	1.42831	.5876E+04	37

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.005	VW/UE
0	0	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB	Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB
1	.6073	.1276E-02	-.8661E-03	.3073E-01	-.3354E-01	21	.9784	.1750E-03	-.1916E-01	-.3694E-02	-.2302E-01
2	.6640	.1430E-02	-.2320E-02	.2769E-01	-.3457E-01	22	.9847	.1324E-03	-.1984E-01	-.4404E-02	-.2274E-01
3	.7021	.1400E-02	-.3438E-02	.2434E-01	-.3391E-01	23	.9900	.9338E-04	-.2050E-01	-.5439E-02	-.2257E-01
4	.7308	.1366E-02	-.4507E-02	.2165E-01	-.3363E-01	24	.9945	.6081E-04	-.2114E-01	-.6363E-02	-.2249E-01
5	.7561	.1350E-02	-.5579E-02	.1944E-01	-.3367E-01	25	.9978	.4056E-04	-.2175E-01	-.7044E-02	-.2263E-01
6	.7790	.1286E-02	-.6584E-02	.1705E-01	-.3326E-01	26	1.0003	.2442E-04	-.2234E-01	-.7624E-02	-.2283E-01
7	.7990	.1221E-02	-.7555E-02	.1490E-01	-.3291E-01	27	1.0013	.1340E-04	-.2290E-01	-.8078E-02	-.2314E-01
8	.8178	.1162E-02	-.8519E-02	.1294E-01	-.3263E-01	28	1.0027	.8352E-05	-.2343E-01	-.8384E-02	-.2353E-01
9	.8352	.1087E-02	-.9450E-02	.1096E-01	-.3220E-01	29	1.0024	.4388E-05	-.2393E-01	-.8650E-02	-.2396E-01
10	.8505	.1014E-02	-.1035E-01	.9132E-02	-.3181E-01	30	1.0022	.1959E-05	-.2441E-01	-.8867E-02	-.2440E-01
11	.8660	.9435E-03	-.1125E-01	.7390E-02	-.3143E-01	31	1.0019	.8123E-06	-.2488E-01	-.9046E-02	-.2485E-01
12	.8812	.8625E-03	-.1213E-01	.5604E-02	-.3089E-01	32	1.0017	.1236E-06	-.2534E-01	-.9202E-02	-.2530E-01
13	.8957	.7751E-03	-.1299E-01	.3815E-02	-.3026E-01	33	1.0014	.3604E-08	-.2578E-01	-.9332E-02	-.2575E-01
14	.9092	.6862E-03	-.1383E-01	.2052E-02	-.2957E-01	34	1.0012	.1000E-07	-.2621E-01	-.9447E-02	-.2618E-01
15	.9217	.5975E-03	-.1464E-01	.5415E-03	-.2867E-01	35	1.0009	.9573E-08	-.2663E-01	-.9780E-02	-.2660E-01
16	.9331	.5138E-03	-.1544E-01	-.5371E-03	-.2759E-01	36	1.0007	.1000E-07	-.2703E-01	-.1018E-01	-.2701E-01
17	.9439	.4307E-03	-.1622E-01	-.1492E-02	-.2638E-01	37	1.0004	.9618E-08	-.2741E-01	-.1057E-01	-.2740E-01
18	.9522	.3418E-03	-.1695E-01	-.2428E-02	-.2512E-01	38	1.0002	.1000E-07	-.2778E-01	-.1094E-01	-.2778E-01
19	.9560	.2989E-03	-.1759E-01	-.2596E-02	-.2458E-01	39	1.0000	.1000E-07	-.2814E-01	-.1130E-01	-.2814E-01
20	.9732	.2370E-03	-.1849E-01	-.3223E-02	-.2374E-01						

STN. 9 X= .1207E+02 I62= 39 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.1960E+00	-.1960E+00	-.1958E+00	-.1956E+00	-.1953E+00	-.1950E+00	-.1945E+00	-.1940E+00	-.1935E+00	-.1928E+00
-.1921E+00	-.1913E+00	-.1905E+00	-.1895E+00	-.1886E+00	-.1875E+00	-.1864E+00	-.1852E+00	-.1839E+00	-.1826E+00
-.1813E+00	-.1798E+00	-.1783E+00	-.1768E+00	-.1752E+00	-.1736E+00	-.1719E+00	-.1702E+00	-.1685E+00	-.1668E+00
-.1650E+00	-.1632E+00	-.1614E+00	-.1595E+00	-.1576E+00	-.1557E+00	-.1537E+00	-.1517E+00	-.1497E+00	-.1477E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
9	.1207E+02	.3333E-01	.003772	.1138E+01	.7738E+00	.4680E-01	.6016E-01	1.63500	.3332E+04	37

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.005	VW/UE
0	.5440E-02	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB	Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB
1	.6914	.1151E-02	-.3530E-02	.2167E-01	-.3185E-01	21	1.0075	.1459E-03	-.4578E-01	-.2990E-01	-.4819E-01
2	.7363	.1375E-02	-.6721E-02	.1838E-01	-.3653E-01	22	1.0127	.1107E-03	-.4719E-01	-.3144E-01	-.4872E-01
3	.7667	.1397E-02	-.9483E-02	.1432E-01	-.3884E-01	23	1.0222	.7405E-04	-.4869E-01	-.3295E-01	-.4906E-01
4	.7925	.1391E-02	-.1212E-01	.1054E-01	-.4079E-01	24	1.0210	.4690E-04	-.4982E-01	-.3429E-01	-.4971E-01
5	.8144	.1365E-02	-.1467E-01	.6977E-02	-.4249E-01	25	1.0198	.3025E-04	-.5085E-01	-.3535E-01	-.5045E-01
6	.8344	.1280E-02	-.1706E-01	.3261E-02	-.4351E-01	26	1.0186	.1695E-04	-.5185E-01	-.3632E-01	-.5124E-01
7	.8527	.1204E-02	-.1943E-01	-.1435E-03	-.4453E-01	27	1.0173	.9161E-05	-.5280E-01	-.3712E-01	-.5208E-01
8	.8691	.1138E-02	-.2172E-01	-.3255E-02	-.4559E-01	28	1.0160	.5731E-05	-.5370E-01	-.3781E-01	-.5296E-01
9	.8844	.1051E-02	-.2392E-01	-.6360E-02	-.4636E-01	29	1.0146	.2740E-05	-.5456E-01	-.3844E-01	-.5382E-01
10	.8985	.9777E-03	-.2607E-01	-.9196E-02	-.4718E-01	30	1.0133	.1139E-05	-.5538E-01	-.3901E-01	-.5467E-01
11	.9123	.9056E-03	-.2818E-01	-.1191E-01	-.4793E-01	31	1.0119	.4165E-06	-.5616E-01	-.3953E-01	-.5550E-01
12	.9257	.8179E-03	-.3023E-01	-.1465E-01	-.4842E-01	32	1.0105	.1000E-07	-.5690E-01	-.4000E-01	-.5631E-01

13	.9383	.7233E-03	-.3222E-01	-.1737E-01	-.4873E-01	33	1.0091	.2328E-08	-.5760E-01	-.4042E-01	-.5708E-01
14	.9500	.6269E-03	-.3414E-01	-.2001E-01	-.4890E-01	34	1.0076	.1000E-07	-.5826E-01	-.4100E-01	-.5782E-01
15	.9608	.5330E-03	-.3599E-01	-.2228E-01	-.4877E-01	35	1.0062	.9268E-08	-.5888E-01	-.4167E-01	-.5852E-01
16	.9706	.4462E-03	-.3777E-01	-.2405E-01	-.4839E-01	36	1.0047	.1000E-07	-.5945E-01	-.4231E-01	-.5918E-01
17	.9790	.3607E-03	-.3947E-01	-.2570E-01	-.4797E-01	37	1.0031	.9312E-08	-.5999E-01	-.4291E-01	-.5980E-01
18	.9856	.2872E-03	-.4106E-01	-.2710E-01	-.4770E-01	38	1.0016	.1000E-07	-.6048E-01	-.4346E-01	-.6039E-01
19	.9924	.2672E-03	-.4264E-01	-.2763E-01	-.4822E-01	39	1.0000	.1000E-07	-.6093E-01	-.4398E-01	-.6093E-01
20	1.0055	.2008E-03	-.4448E-01	-.2890E-01	-.4808E-01						

STN. 17 X= .1296E+02 I62= 39 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.3181E+00	-.3163E+00	-.3139E+00	-.3115E+00	-.3089E+00	-.3062E+00	-.3035E+00	-.3006E+00	-.2977E+00	-.2947E+00
-.2916E+00	-.2884E+00	-.2852E+00	-.2819E+00	-.2786E+00	-.2752E+00	-.2718E+00	-.2683E+00	-.2648E+00	-.2612E+00
-.2576E+00	-.2539E+00	-.2503E+00	-.2466E+00	-.2430E+00	-.2394E+00	-.2358E+00	-.2322E+00	-.2287E+00	-.2251E+00
-.2216E+00	-.2181E+00	-.2146E+00	-.2111E+00	-.2076E+00	-.2042E+00	-.2008E+00	-.1973E+00	-.1939E+00	-.1905E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
17	.1296E+02	.3333E-01	.004996	.1175E+01	.7285E+00	.9908E-02	.1582E-01	2.47654	.7285E+03	37

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.6963E-01	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.8029	.9700E-03	-.4116E-02	.1613E-01	-.2639E-01	21	1.0449	.8594E-04	-.6717E-01	-.5442E-01	-.7035E-01
2	.8414	.1178E-02	-.8879E-02	.1186E-01	-.3300E-01	22	1.0424	.5646E-04	-.6904E-01	-.5694E-01	-.7201E-01
3	.8616	.1243E-02	-.1316E-01	.7240E-02	-.3790E-01	23	1.0398	.3158E-04	-.7062E-01	-.5911E-01	-.7347E-01
4	.8810	.1258E-02	-.1728E-01	.2576E-02	-.4197E-01	24	1.0373	.1973E-04	-.7215E-01	-.6096E-01	-.7517E-01
5	.8970	.1214E-02	-.2116E-01	-.2163E-02	-.4528E-01	25	1.0348	.1096E-04	-.7363E-01	-.6271E-01	-.7690E-01
6	.9127	.1127E-02	-.2489E-01	-.6978E-02	-.4792E-01	26	1.0323	.5081E-05	-.7506E-01	-.6436E-01	-.7867E-01
7	.9273	.1050E-02	-.2850E-01	-.1146E-01	-.5049E-01	27	1.0297	.3133E-05	-.7645E-01	-.6588E-01	-.8050E-01
8	.9400	.9751E-03	-.3197E-01	-.1571E-01	-.5293E-01	28	1.0272	.1629E-05	-.7779E-01	-.6735E-01	-.8231E-01
9	.9520	.8922E-03	-.3532E-01	-.1983E-01	-.5510E-01	29	1.0247	.3132E-06	-.7909E-01	-.6879E-01	-.8409E-01
10	.9630	.8233E-03	-.3855E-01	-.2368E-01	-.5728E-01	30	1.0222	.1197E-06	-.8034E-01	-.7017E-01	-.8588E-01
11	.9736	.7426E-03	-.4168E-01	-.2749E-01	-.5917E-01	31	1.0198	.1000E-07	-.8156E-01	-.7151E-01	-.8763E-01
12	.9835	.6480E-03	-.4469E-01	-.3132E-01	-.6073E-01	32	1.0173	.1000E-07	-.8273E-01	-.7300E-01	-.8936E-01
13	.9929	.5522E-03	-.4759E-01	-.3508E-01	-.6210E-01	33	1.0148	.9848E-08	-.8387E-01	-.7462E-01	-.9107E-01
14	1.0014	.4591E-03	-.5038E-01	-.3850E-01	-.6312E-01	34	1.0123	.9200E-08	-.8497E-01	-.7621E-01	-.9275E-01
15	1.0089	.3734E-03	-.5304E-01	-.4143E-01	-.6384E-01	35	1.0098	.8749E-08	-.8603E-01	-.7778E-01	-.9440E-01
16	1.0153	.2986E-03	-.5559E-01	-.4406E-01	-.6457E-01	36	1.0074	.1000E-07	-.8707E-01	-.7933E-01	-.9604E-01
17	1.0210	.2409E-03	-.5804E-01	-.4633E-01	-.6549E-01	37	1.0049	.8709E-08	-.8807E-01	-.8085E-01	-.9765E-01
18	1.0272	.2097E-03	-.6046E-01	-.4807E-01	-.6683E-01	38	1.0025	.1000E-07	-.8903E-01	-.8235E-01	-.9924E-01
19	1.0337	.1779E-03	-.6285E-01	-.4974E-01	-.6818E-01	39	1.0000	.1000E-07	-.8997E-01	-.8384E-01	-.1008E+00
20	1.0383	.1113E-03	-.6507E-01	-.5225E-01	-.6897E-01						

STN. 26 X= .1342E+02 I62= 39 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.3812E+00	-.3780E+00	-.3742E+00	-.3701E+00	-.3659E+00	-.3617E+00	-.3574E+00	-.3530E+00	-.3486E+00	-.3441E+00
-.3395E+00	-.3350E+00	-.3304E+00	-.3257E+00	-.3211E+00	-.3164E+00	-.3117E+00	-.3070E+00	-.3023E+00	-.2976E+00
-.2929E+00	-.2882E+00	-.2835E+00	-.2789E+00	-.2744E+00	-.2699E+00	-.2655E+00	-.2611E+00	-.2568E+00	-.2525E+00
-.2483E+00	-.2442E+00	-.2401E+00	-.2360E+00	-.2320E+00	-.2280E+00	-.2241E+00	-.2202E+00	-.2163E+00	-.2125E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
26	.1342E+02	.3333E-01	.005307	.1194E+01	.7067E+00	-.5336E-02	-.4608E-02	-1.00153	-.3985E+03	37

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1007E+00	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.8352	.1071E-02	-.2170E-02	.1893E-01	-.2413E-01	21	1.0518	.6156E-04	-.4780E-01	-.3668E-01	-.5142E-01
2	.8830	.1087E-02	-.5694E-02	.1414E-01	-.2708E-01	22	1.0487	.3442E-04	-.4894E-01	-.3848E-01	-.5233E-01
3	.8995	.1143E-02	-.8939E-02	.1086E-01	-.3083E-01	23	1.0456	.1820E-04	-.5004E-01	-.4003E-01	-.5346E-01
4	.9162	.1170E-02	-.1205E-01	.7553E-02	-.3405E-01	24	1.0425	.1165E-04	-.5111E-01	-.4131E-01	-.5481E-01

5	.9296	.1123E−02	−.1494E−01	.3948E−02	−.3640E−01	25	1.0395	.5371E−05	−.5215E−01	−.4256E−01	−.5615E−01
6	.9438	.1041E−02	−.1771E−01	.2316E−03	−.3820E−01	26	1.0365	.2437E−05	−.5315E−01	−.4370E−01	−.5755E−01
7	.9568	.9654E−03	−.2036E−01	−.3251E−02	−.3994E−01	27	1.0336	.1753E−05	−.5411E−01	−.4475E−01	−.5899E−01
8	.9681	.8886E−03	−.2293E−01	−.6579E−02	−.4153E−01	28	1.0306	.5090E−06	−.5505E−01	−.4580E−01	−.6039E−01
9	.9787	.8096E−03	−.2538E−01	−.9800E−02	−.4296E−01	29	1.0277	.1000E−07	−.5595E−01	−.4680E−01	−.6179E−01
10	.9884	.7405E−03	−.2773E−01	−.1281E−01	−.4437E−01	30	1.0249	.6525E−08	−.5682E−01	−.4776E−01	−.6319E−01
11	.9974	.6552E−03	−.2997E−01	−.1589E−01	−.4546E−01	31	1.0220	.3519E−08	−.5766E−01	−.4886E−01	−.6457E−01
12	1.0060	.5598E−03	−.3212E−01	−.1902E−01	−.4627E−01	32	1.0192	.1000E−07	−.5848E−01	−.5012E−01	−.6593E−01
13	1.0140	.4663E−03	−.3418E−01	−.2202E−01	−.4686E−01	33	1.0164	.8789E−08	−.5927E−01	−.5135E−01	−.6728E−01
14	1.0211	.3779E−03	−.3615E−01	−.2467E−01	−.4714E−01	34	1.0136	.1000E−07	−.6003E−01	−.5258E−01	−.6861E−01
15	1.0273	.3008E−03	−.3802E−01	−.2685E−01	−.4725E−01	35	1.0108	.9963E−08	−.6078E−01	−.5379E−01	−.6993E−01
16	1.0327	.2400E−03	−.3982E−01	−.2873E−01	−.4755E−01	36	1.0081	.9219E−08	−.6150E−01	−.5498E−01	−.7124E−01
17	1.0381	.1995E−03	−.4158E−01	−.3020E−01	−.4817E−01	37	1.0054	.8542E−08	−.6220E−01	−.5617E−01	−.7253E−01
18	1.0437	.1743E−03	−.4330E−01	−.3129E−01	−.4908E−01	38	1.0027	.1000E−07	−.6287E−01	−.5734E−01	−.7381E−01
19	1.0483	.1329E−03	−.4493E−01	−.3265E−01	−.4971E−01	39	1.0000	.1000E−07	−.6353E−01	−.5850E−01	−.7508E−01
20	1.0516	.7746E−04	−.4643E−01	−.3503E−01	−.5016E−01						

STN. 32 X= .1385E+02 I62= 39 (P−PREF)/UREF**2(FROM PREVIOUS SWEEP)=

−.4250E+00	−.4207E+00	−.4158E+00	−.4105E+00	−.4051E+00	−.3997E+00	−.3943E+00	−.3887E+00	−.3832E+00	−.3776E+00
−.3719E+00	−.3663E+00	−.3606E+00	−.3550E+00	−.3493E+00	−.3437E+00	−.3380E+00	−.3323E+00	−.3267E+00	−.3211E+00
−.3155E+00	−.3100E+00	−.3046E+00	−.2992E+00	−.2940E+00	−.2888E+00	−.2837E+00	−.2787E+00	−.2738E+00	−.2689E+00
−.2641E+00	−.2594E+00	−.2548E+00	−.2502E+00	−.2456E+00	−.2412E+00	−.2368E+00	−.2324E+00	−.2281E+00	−.2239E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
32	.1385E+02	.3333E−01	.005386	.1203E+01	.6883E+00	−.1711E−01	−.2015E−01	.47195	−.1288E+04	37

RBUGH/D05	D05/RAD	D05/(X−X0)	STRAIN.D05	VW/UE
0	.1274E+00	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.8487	.1263E−02	−.7965E−03	.2211E−01	−.2398E−01	21	1.0578	.4871E−04	−.3209E−01	−.2150E−01	−.3547E−01
2	.9092	.1038E−02	−.3094E−02	.1621E−01	−.2302E−01	22	1.0543	.2354E−04	−.3283E−01	−.2284E−01	−.3592E−01
3	.9251	.1059E−02	−.5389E−02	.1375E−01	−.2545E−01	23	1.0508	.1267E−04	−.3354E−01	−.2381E−01	−.3670E−01
4	.9400	.1097E−02	−.7611E−02	.1159E−01	−.2789E−01	24	1.0473	.8121E−05	−.3423E−01	−.2458E−01	−.3763E−01
5	.9518	.1052E−02	−.9650E−02	.8981E−02	−.2944E−01	25	1.0439	.3112E−05	−.3488E−01	−.2534E−01	−.3853E−01
6	.9650	.9776E−03	−.1160E−01	.6215E−02	−.3053E−01	26	1.0405	.1596E−05	−.3550E−01	−.2597E−01	−.3950E−01
7	.9770	.9038E−03	−.1347E−01	.3578E−02	−.3152E−01	27	1.0372	.1173E−05	−.3609E−01	−.2655E−01	−.4049E−01
8	.9875	.8272E−03	−.1525E−01	.1028E−02	−.3239E−01	28	1.0339	.1035E−06	−.3665E−01	−.2711E−01	−.4143E−01
9	.9973	.7513E−03	−.1695E−01	−.1433E−02	−.3316E−01	29	1.0306	.1000E−07	−.3718E−01	−.2761E−01	−.4237E−01
10	1.0060	.6816E−03	−.1859E−01	−.3759E−02	−.3390E−01	30	1.0274	.1000E−07	−.3768E−01	−.2818E−01	−.4330E−01
11	1.0140	.5950E−03	−.2013E−01	−.6205E−02	−.3433E−01	31	1.0243	.4617E−08	−.3816E−01	−.2896E−01	−.4420E−01
12	1.0218	.5012E−03	−.2160E−01	−.8718E−02	−.3451E−01	32	1.0211	.1000E−07	−.3860E−01	−.2971E−01	−.4508E−01
13	1.0290	.4106E−03	−.2301E−01	−.1105E−01	−.3444E−01	33	1.0180	.8522E−08	−.3902E−01	−.3045E−01	−.4594E−01
14	1.0353	.3273E−03	−.2435E−01	−.1299E−01	−.3409E−01	34	1.0149	.1000E−07	−.3941E−01	−.3116E−01	−.4678E−01
15	1.0409	.2583E−03	−.2563E−01	−.1457E−01	−.3376E−01	35	1.0119	.9184E−08	−.3978E−01	−.3185E−01	−.4759E−01
16	1.0459	.2079E−03	−.2686E−01	−.1580E−01	−.3369E−01	36	1.0089	.8598E−08	−.4012E−01	−.3252E−01	−.4839E−01
17	1.0510	.1759E−03	−.2807E−01	−.1663E−01	−.3396E−01	37	1.0059	.1000E−07	−.4044E−01	−.3317E−01	−.4916E−01
18	1.0556	.1507E−03	−.2922E−01	−.1728E−01	−.3439E−01	38	1.0029	.1000E−07	−.4074E−01	−.3379E−01	−.4991E−01
19	1.0589	.1065E−03	−.3028E−01	−.1858E−01	−.3453E−01	39	1.0000	.1000E−07	−.4102E−01	−.3439E−01	−.5064E−01
20	1.0614	.5983E−04	−.3126E−01	−.2045E−01	−.3459E−01						

STN. 34 X= .1410E+02 I62= 39 (P−PREF)/UREF**2(FROM PREVIOUS SWEEP)=

−.4423E+00	−.4378E+00	−.4325E+00	−.4268E+00	−.4211E+00	−.4152E+00	−.4093E+00	−.4034E+00	−.3974E+00	−.3913E+00
−.3853E+00	−.3792E+00	−.3731E+00	−.3669E+00	−.3608E+00	−.3547E+00	−.3486E+00	−.3425E+00	−.3364E+00	−.3303E+00
−.3243E+00	−.3183E+00	−.3124E+00	−.3067E+00	−.3010E+00	−.2954E+00	−.2899E+00	−.2845E+00	−.2791E+00	−.2739E+00
−.2687E+00	−.2636E+00	−.2585E+00	−.2535E+00	−.2486E+00	−.2438E+00	−.2390E+00	−.2342E+00	−.2296E+00	−.2250E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
34	.1410E+02	.3333E−01	.005331	.1204E+01	.6757E+00	−.2120E−01	−.2799E−01	.69851	−.1597E+04	37

ROUGH/D05 D05/RAD D05/(X-X0) STRAIN.D05 VW/UE
0 .1351E+00 0 0 0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB
1	.8494	.1415E-02	.5230E-04	.2449E-01	-.2434E-01
2	.9188	.1030E-02	-.1431E-02	.1785E-01	-.2092E-01
3	.9359	.1017E-02	-.3114E-02	.1573E-01	-.2235E-01
4	.9504	.1059E-02	-.4775E-02	.1424E-01	-.2427E-01
5	.9615	.1018E-02	-.6282E-02	.1224E-01	-.2532E-01
6	.9744	.9482E-03	-.7717E-02	.1006E-01	-.2594E-01
7	.9861	.8755E-03	-.9093E-02	.7946E-02	-.2646E-01
8	.9966	.7986E-03	-.1040E-01	.5874E-02	-.2686E-01
9	1.0061	.7241E-03	-.1166E-01	.3881E-02	-.2720E-01
10	1.0145	.6542E-03	-.1286E-01	.1984E-02	-.2751E-01
11	1.0222	.5678E-03	-.1399E-01	-.5285E-04	-.2752E-01
12	1.0297	.4753E-03	-.1506E-01	-.2171E-02	-.2731E-01
13	1.0366	.3865E-03	-.1609E-01	-.4065E-02	-.2692E-01
14	1.0428	.3059E-03	-.1706E-01	-.5547E-02	-.2606E-01
15	1.0481	.2411E-03	-.1800E-01	-.6728E-02	-.2544E-01
16	1.0531	.1952E-03	-.1890E-01	-.7551E-02	-.2511E-01
17	1.0580	.1662E-03	-.1978E-01	-.7998E-02	-.2512E-01
18	1.0621	.1405E-03	-.2061E-01	-.8356E-02	-.2524E-01
19	1.0649	.9634E-04	-.2137E-01	-.9650E-02	-.2510E-01
20	1.0663	.5350E-04	-.2206E-01	-.1116E-01	-.2492E-01
21	1.0624	.4383E-04	-.2264E-01	-.1186E-01	-.2551E-01
22	1.0586	.1978E-04	-.2316E-01	-.1289E-01	-.2565E-01
23	1.0549	.1091E-04	-.2365E-01	-.1350E-01	-.2618E-01
24	1.0511	.6922E-05	-.2413E-01	-.1396E-01	-.2682E-01
25	1.0475	.2426E-05	-.2456E-01	-.1440E-01	-.2743E-01
26	1.0438	.1369E-05	-.2498E-01	-.1471E-01	-.2811E-01
27	1.0402	.9747E-06	-.2536E-01	-.1497E-01	-.2879E-01
28	1.0367	.1000E-07	-.2571E-01	-.1521E-01	-.2943E-01
29	1.0332	.3623E-08	-.2603E-01	-.1540E-01	-.3007E-01
30	1.0297	.1000E-07	-.2633E-01	-.1582E-01	-.3068E-01
31	1.0263	.4668E-08	-.2659E-01	-.1627E-01	-.3127E-01
32	1.0229	.1000E-07	-.2683E-01	-.1670E-01	-.3183E-01
33	1.0195	.8394E-08	-.2704E-01	-.1710E-01	-.3236E-01
34	1.0162	.1000E-07	-.2723E-01	-.1747E-01	-.3287E-01
35	1.0129	.8825E-08	-.2739E-01	-.1782E-01	-.3335E-01
36	1.0096	.8578E-08	-.2752E-01	-.1814E-01	-.3380E-01
37	1.0064	.1000E-07	-.2763E-01	-.1843E-01	-.3423E-01
38	1.0032	.1000E-07	-.2772E-01	-.1870E-01	-.3463E-01
39	1.0000	.1000E-07	-.2778E-01	-.1893E-01	-.3500E-01

STN. 37 X= .1483E+02 I62= 39 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.4193E+00	-.4157E+00	-.4112E+00	-.4061E+00	-.4008E+00	-.3955E+00	-.3901E+00	-.3846E+00	-.3790E+00	-.3734E+00
-.3677E+00	-.3620E+00	-.3563E+00	-.3506E+00	-.3448E+00	-.3390E+00	-.3332E+00	-.3274E+00	-.3216E+00	-.3157E+00
-.3099E+00	-.3041E+00	-.2985E+00	-.2928E+00	-.2873E+00	-.2819E+00	-.2765E+00	-.2712E+00	-.2660E+00	-.2608E+00
-.2557E+00	-.2507E+00	-.2457E+00	-.2408E+00	-.2359E+00	-.2311E+00	-.2264E+00	-.2217E+00	-.2171E+00	-.2125E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
37	.1483E+02	.3333E-01	.004254	.1194E+01	.6735E+00	.1654E-02	-.2253E-01	-2.01942	.1235E+03	37

ROUGH/D05 D05/RAD D05/(X-X0) STRAIN.D05 VW/UE
0 .1195E+00 0 0 0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB
1	.7773	.2104E-02	.3536E-02	.3729E-01	-.2811E-01
2	.8806	.1192E-02	.6060E-02	.2887E-01	-.1485E-01
3	.9140	.9439E-03	.7458E-02	.2725E-01	-.1046E-01
4	.9308	.9717E-03	.8494E-02	.2840E-01	-.9407E-02
5	.9419	.9479E-03	.9522E-02	.2921E-01	-.7925E-02
6	.9554	.8997E-03	.1058E-01	.2973E-01	-.6159E-02
7	.9680	.8349E-03	.1161E-01	.3008E-01	-.4250E-02
8	.9813	.7542E-03	.1264E-01	.3022E-01	-.2155E-02
9	.9919	.6810E-03	.1361E-01	.3044E-01	-.2060E-03
10	1.0011	.6122E-03	.1453E-01	.3066E-01	.1689E-02
11	1.0094	.5310E-03	.1543E-01	.3071E-01	.3768E-02
12	1.0177	.4435E-03	.1632E-01	.3060E-01	.5994E-02
13	1.0255	.3581E-03	.1719E-01	.3062E-01	.8452E-02
14	1.0327	.2816E-03	.1801E-01	.3099E-01	.1109E-01
15	1.0392	.2222E-03	.1879E-01	.3162E-01	.1347E-01
16	1.0453	.1810E-03	.1953E-01	.3255E-01	.1549E-01
17	1.0511	.1549E-03	.2023E-01	.3379E-01	.1714E-01
18	1.0553	.1314E-03	.2087E-01	.3505E-01	.1862E-01
19	1.0700	.9088E-04	.2174E-01	.3520E-01	.2034E-01
20	1.0662	.5071E-04	.2221E-01	.3530E-01	.2202E-01
21	1.0624	.4040E-04	.2263E-01	.3607E-01	.2297E-01
22	1.0586	.1890E-04	.2305E-01	.3654E-01	.2425E-01
23	1.0549	.1014E-04	.2345E-01	.3734E-01	.2517E-01
24	1.0512	.6373E-05	.2384E-01	.3827E-01	.2593E-01
25	1.0476	.2365E-05	.2421E-01	.3921E-01	.2670E-01
26	1.0439	.1283E-05	.2457E-01	.4023E-01	.2737E-01
27	1.0404	.9139E-06	.2492E-01	.4128E-01	.2802E-01
28	1.0368	.8847E-07	.2526E-01	.4232E-01	.2868E-01
29	1.0333	.9063E-08	.2559E-01	.4338E-01	.2932E-01
30	1.0299	.1000E-07	.2592E-01	.4416E-01	.2995E-01
31	1.0264	.4747E-08	.2623E-01	.4491E-01	.3058E-01
32	1.0230	.1000E-07	.2654E-01	.4566E-01	.3120E-01
33	1.0197	.8180E-08	.2684E-01	.4641E-01	.3183E-01
34	1.0163	.1000E-07	.2713E-01	.4716E-01	.3245E-01
35	1.0130	.8597E-08	.2742E-01	.4790E-01	.3307E-01
36	1.0097	.8243E-08	.2770E-01	.4865E-01	.3369E-01
37	1.0065	.1000E-07	.2797E-01	.4940E-01	.3431E-01
38	1.0032	.1000E-07	.2824E-01	.5014E-01	.3493E-01
39	1.0000	.1000E-07	.2850E-01	.5088E-01	.3554E-01

STN. 39 X= .1516E+02 I62= 39 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.3764E+00	-.3737E+00	-.3701E+00	-.3660E+00	-.3616E+00	-.3572E+00	-.3527E+00	-.3482E+00	-.3436E+00	-.3389E+00
-.3341E+00	-.3294E+00	-.3245E+00	-.3197E+00	-.3148E+00	-.3099E+00	-.3049E+00	-.3000E+00	-.2950E+00	-.2900E+00
-.2850E+00	-.2800E+00	-.2750E+00	-.2701E+00	-.2653E+00	-.2606E+00	-.2559E+00	-.2512E+00	-.2466E+00	-.2420E+00
-.2375E+00	-.2331E+00	-.2287E+00	-.2243E+00	-.2200E+00	-.2157E+00	-.2115E+00	-.2073E+00	-.2032E+00	-.1991E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
39	.1516E+02	.3333E-01	.003614	.1182E+01	.6991E+00	.1267E-01	-.7702E-02	1.08700	.9369E+03	37

R0UGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1006E+00	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.7229	.2405E-02	.5434E-02	.4505E-01	-.2991E-01	21	1.0563	.4668E-04	.5104E-01	.6475E-01	.5203E-01
2	.8336	.1450E-02	.1052E-01	.3815E-01	-.1258E-01	22	1.0529	.2644E-04	.5203E-01	.6600E-01	.5405E-01
3	.8826	.9858E-03	.1413E-01	.3617E-01	-.3526E-02	23	1.0496	.1363E-04	.5298E-01	.6740E-01	.5586E-01
4	.9044	.9615E-03	.1690E-01	.3841E-01	-.3863E-04	24	1.0463	.8262E-05	.5389E-01	.6899E-01	.5743E-01
5	.9165	.9428E-03	.1946E-01	.4084E-01	.3082E-02	25	1.0431	.3889E-05	.5476E-01	.7059E-01	.5894E-01
6	.9305	.9079E-03	.2203E-01	.4299E-01	.6315E-02	26	1.0398	.1788E-05	.5560E-01	.7224E-01	.6036E-01
7	.9439	.8519E-03	.2453E-01	.4485E-01	.9655E-02	27	1.0366	.1201E-05	.5640E-01	.7392E-01	.6171E-01
8	.9591	.7723E-03	.2703E-01	.4633E-01	.1319E-01	28	1.0334	.4119E-06	.5717E-01	.7558E-01	.6304E-01
9	.9712	.6960E-03	.2938E-01	.4778E-01	.1655E-01	29	1.0303	.6589E-07	.5790E-01	.7723E-01	.6434E-01
10	.9814	.6277E-03	.3160E-01	.4924E-01	.1974E-01	30	1.0272	.1350E-07	.5861E-01	.7888E-01	.6561E-01
11	.9905	.5504E-03	.3375E-01	.5051E-01	.2299E-01	31	1.0241	.5786E-08	.5929E-01	.8029E-01	.6686E-01
12	.9996	.4657E-03	.3585E-01	.5157E-01	.2634E-01	32	1.0210	.1000E-07	.5994E-01	.8162E-01	.6809E-01
13	1.0084	.3802E-03	.3789E-01	.5257E-01	.2980E-01	33	1.0179	.8593E-08	.6056E-01	.8293E-01	.6931E-01
14	1.0166	.3013E-03	.3984E-01	.5374E-01	.3339E-01	34	1.0149	.1000E-07	.6116E-01	.8422E-01	.7050E-01
15	1.0241	.2378E-03	.4170E-01	.5523E-01	.3686E-01	35	1.0119	.9337E-08	.6173E-01	.8550E-01	.7168E-01
16	1.0312	.1922E-03	.4347E-01	.5695E-01	.3995E-01	36	1.0089	.8160E-08	.6228E-01	.8676E-01	.7283E-01
17	1.0380	.1631E-03	.4517E-01	.5893E-01	.4261E-01	37	1.0059	.1000E-07	.6280E-01	.8800E-01	.7398E-01
18	1.0418	.1434E-03	.4669E-01	.6112E-01	.4498E-01	38	1.0029	.1000E-07	.6330E-01	.8922E-01	.7510E-01
19	1.0575	.1092E-03	.4870E-01	.6269E-01	.4754E-01	39	1.0000	.1000E-07	.6378E-01	.9043E-01	.7621E-01
20	1.0597	.6318E-04	.5001E-01	.6338E-01	.5012E-01						

STN. 47 X= .1561E+02 I62= 39 (P-PREF)/UREF**2(FR0M PREVI0US SWEEP)=

-.3077E+00	-.3062E+00	-.3040E+00	-.3014E+00	-.2986E+00	-.2957E+00	-.2928E+00	-.2897E+00	-.2866E+00	-.2834E+00
-.2802E+00	-.2769E+00	-.2735E+00	-.2701E+00	-.2666E+00	-.2631E+00	-.2596E+00	-.2560E+00	-.2524E+00	-.2488E+00
-.2451E+00	-.2414E+00	-.2377E+00	-.2340E+00	-.2303E+00	-.2267E+00	-.2231E+00	-.2195E+00	-.2159E+00	-.2124E+00
-.2089E+00	-.2054E+00	-.2019E+00	-.1985E+00	-.1950E+00	-.1916E+00	-.1882E+00	-.1849E+00	-.1815E+00	-.1781E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
47	.1561E+02	.3333E-01	.002812	.1165E+01	.7362E+00	.3248E-01	.1590E-01	1.38085	.2366E+04	37

R0UGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.7293E-01	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.6432	.2560E-02	.6942E-02	.5414E-01	-.3246E-01	21	1.0456	.7335E-04	.8352E-01	.9714E-01	.8354E-01
2	.7477	.1950E-02	.1453E-01	.5223E-01	-.1301E-01	22	1.0430	.4943E-04	.8512E-01	.9898E-01	.8628E-01
3	.8189	.1215E-02	.2130E-01	.4994E-01	.2774E-02	23	1.0404	.2954E-04	.8665E-01	.1008E+00	.8889E-01
4	.8557	.1005E-02	.2646E-01	.5207E-01	.1087E-01	24	1.0378	.1722E-04	.8811E-01	.1028E+00	.9128E-01
5	.8723	.9549E-03	.3079E-01	.5585E-01	.1632E-01	25	1.0352	.9791E-05	.8952E-01	.1049E+00	.9348E-01
6	.8875	.9322E-03	.3497E-01	.5972E-01	.2121E-01	26	1.0326	.5002E-05	.9086E-01	.1070E+00	.9557E-01
7	.9015	.8970E-03	.3902E-01	.6331E-01	.2599E-01	27	1.0301	.2695E-05	.9215E-01	.1092E+00	.9753E-01
8	.9182	.8334E-03	.4312E-01	.6638E-01	.3094E-01	28	1.0275	.1485E-05	.9338E-01	.1113E+00	.9943E-01
9	.9329	.7541E-03	.4703E-01	.6912E-01	.3582E-01	29	1.0250	.6698E-06	.9456E-01	.1134E+00	.1013E+00
10	.9453	.6839E-03	.5073E-01	.7180E-01	.4040E-01	30	1.0224	.2302E-06	.9568E-01	.1155E+00	.1031E+00
11	.9560	.6129E-03	.5424E-01	.7434E-01	.4484E-01	31	1.0199	.6100E-07	.9676E-01	.1176E+00	.1048E+00
12	.9662	.5357E-03	.5766E-01	.7666E-01	.4926E-01	32	1.0174	.1819E-07	.9779E-01	.1196E+00	.1065E+00
13	.9763	.4529E-03	.6098E-01	.7873E-01	.5368E-01	33	1.0149	.9982E-08	.9877E-01	.1213E+00	.1082E+00
14	.9860	.3695E-03	.6419E-01	.8076E-01	.5820E-01	34	1.0124	.9956E-08	.9971E-01	.1230E+00	.1098E+00
15	.9952	.2949E-03	.6726E-01	.8295E-01	.6274E-01	35	1.0099	.1000E-07	.1006E+00	.1247E+00	.1114E+00
16	1.0036	.2359E-03	.7022E-01	.8535E-01	.6700E-01	36	1.0074	.8737E-08	.1015E+00	.1263E+00	.1130E+00

17	1.0135	.1919E-03	.7315E-01	.8783E-01	.7086E-01	37	1.0049	.1000E-07	.1023E+00	.1279E+00	.1145E+00
18	1.0159	.1686E-03	.7548E-01	.9076E-01	.7419E-01	38	1.0025	.1000E-07	.1030E+00	.1295E+00	.1160E+00
19	1.0292	.1524E-03	.7859E-01	.9364E-01	.7730E-01	39	1.0000	.1000E-07	.1038E+00	.1310E+00	.1174E+00
20	1.0408	.1070E-03	.8138E-01	.9563E-01	.8068E-01						

STN. 71 X= .1699E+02 I62= 39 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.1837E+00	-.1839E+00	-.1839E+00	-.1839E+00	-.1837E+00	-.1834E+00	-.1830E+00	-.1826E+00	-.1822E+00	-.1816E+00
-.1810E+00	-.1803E+00	-.1796E+00	-.1787E+00	-.1778E+00	-.1769E+00	-.1758E+00	-.1748E+00	-.1736E+00	-.1724E+00
-.1711E+00	-.1697E+00	-.1683E+00	-.1668E+00	-.1653E+00	-.1637E+00	-.1621E+00	-.1604E+00	-.1588E+00	-.1571E+00
-.1554E+00	-.1536E+00	-.1519E+00	-.1501E+00	-.1482E+00	-.1464E+00	-.1446E+00	-.1427E+00	-.1408E+00	-.1389E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
71	.1699E+02	.3333E-01	.002006	.1130E+01	.8284E+00	.8117E-01	.5944E-01	1.43223	.5740E+04	37

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	0	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.5247	.1739E-02	.6875E-03	.4490E-01	-.4225E-01	21	.9944	.1793E-03	.3405E-01	.4728E-01	.3006E-01
2	.5801	.2433E-02	.1792E-02	.4976E-01	-.4348E-01	22	1.0088	.1466E-03	.3531E-01	.4813E-01	.3171E-01
3	.6365	.2607E-02	.3924E-02	.5024E-01	-.3773E-01	23	1.0190	.1077E-03	.3639E-01	.4844E-01	.3326E-01
4	.7022	.1983E-02	.7136E-02	.4507E-01	-.2448E-01	24	1.0205	.7479E-04	.3714E-01	.4866E-01	.3464E-01
5	.7541	.1364E-02	.1002E-01	.4033E-01	-.1338E-01	25	1.0192	.5053E-04	.3779E-01	.4906E-01	.3586E-01
6	.7881	.1083E-02	.1222E-01	.3866E-01	-.7136E-02	26	1.0180	.3281E-04	.3842E-01	.4955E-01	.3694E-01
7	.8089	.9881E-03	.1401E-01	.3897E-01	-.3654E-02	27	1.0167	.2026E-04	.3902E-01	.5014E-01	.3788E-01
8	.8266	.9640E-03	.1567E-01	.3998E-01	-.1223E-02	28	1.0154	.1198E-04	.3959E-01	.5081E-01	.3870E-01
9	.8440	.9204E-03	.1733E-01	.4076E-01	.1326E-02	29	1.0141	.6920E-05	.4014E-01	.5153E-01	.3942E-01
10	.8612	.8516E-03	.1998E-01	.4124E-01	.4060E-02	30	1.0128	.3956E-05	.4067E-01	.5228E-01	.4006E-01
11	.8770	.7740E-03	.2058E-01	.4159E-01	.6774E-02	31	1.0115	.2211E-05	.4118E-01	.5305E-01	.4066E-01
12	.8910	.7004E-03	.2211E-01	.4195E-01	.9334E-02	32	1.0101	.1167E-05	.4166E-01	.5382E-01	.4122E-01
13	.9039	.6293E-03	.2358E-01	.4228E-01	.1179E-01	33	1.0087	.5644E-06	.4213E-01	.5458E-01	.4175E-01
14	.9156	.5587E-03	.2501E-01	.4258E-01	.1419E-01	34	1.0073	.2459E-06	.4257E-01	.5533E-01	.4225E-01
15	.9290	.4768E-03	.2646E-01	.4264E-01	.1675E-01	35	1.0059	.9863E-07	.4299E-01	.5607E-01	.4274E-01
16	.9390	.3983E-03	.2776E-01	.4293E-01	.1939E-01	36	1.0044	.3902E-07	.4340E-01	.5675E-01	.4320E-01
17	.9529	.3336E-03	.2920E-01	.4349E-01	.2204E-01	37	1.0030	.1824E-07	.4378E-01	.5721E-01	.4365E-01
18	.9641	.2571E-03	.3049E-01	.4385E-01	.2482E-01	38	1.0015	.1000E-07	.4414E-01	.5766E-01	.4408E-01
19	.9716	.2129E-03	.3161E-01	.4472E-01	.2697E-01	39	1.0000	.1000E-07	.4449E-01	.5809E-01	.4449E-01
20	.9812	.1979E-03	.3278E-01	.4606E-01	.2852E-01						

STN. 79 X= .1800E+02 I62= 39 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.1480E+00	-.1482E+00	-.1483E+00	-.1484E+00	-.1485E+00	-.1485E+00	-.1484E+00	-.1483E+00	-.1482E+00	-.1481E+00
-.1479E+00	-.1477E+00	-.1474E+00	-.1471E+00	-.1467E+00	-.1463E+00	-.1459E+00	-.1454E+00	-.1448E+00	-.1443E+00
-.1437E+00	-.1430E+00	-.1423E+00	-.1416E+00	-.1408E+00	-.1400E+00	-.1392E+00	-.1383E+00	-.1375E+00	-.1366E+00
-.1357E+00	-.1348E+00	-.1338E+00	-.1329E+00	-.1319E+00	-.1309E+00	-.1300E+00	-.1290E+00	-.1280E+00	-.1269E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
79	.1800E+02	.3333E-01	.001882	.1120E+01	.8395E+00	.1009E+00	.7695E-01	1.44585	.7067E+04	37

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	0	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.5013	.1518E-02	.5256E-03	.4370E-01	-.4155E-01	21	.9691	.2066E-03	.2716E-01	.4457E-01	.2403E-01
2	.5630	.2061E-02	.1090E-02	.4622E-01	-.4221E-01	22	.9834	.1922E-03	.2825E-01	.4615E-01	.2529E-01
3	.5953	.2615E-02	.1710E-02	.5011E-01	-.4410E-01	23	.9965	.1607E-03	.2932E-01	.4704E-01	.2663E-01
4	.6298	.2770E-02	.3234E-02	.5117E-01	-.4048E-01	24	1.0079	.1185E-03	.3020E-01	.4715E-01	.2792E-01
5	.6778	.2226E-02	.5735E-02	.4694E-01	-.2941E-01	25	1.0104	.8242E-04	.3086E-01	.4742E-01	.2911E-01
6	.7294	.1553E-02	.8194E-02	.4125E-01	-.1800E-01	26	1.0097	.5672E-04	.3143E-01	.4791E-01	.3013E-01
7	.7659	.1173E-02	.1008E-01	.3818E-01	-.1087E-01	27	1.0090	.3780E-04	.3197E-01	.4849E-01	.3101E-01
8	.7901	.1049E-02	.1155E-01	.3771E-01	-.7256E-02	28	1.0084	.2399E-04	.3248E-01	.4913E-01	.3179E-01

9	.8086	.9977E-03	.1288E-01	.3811E-01	-.4757E-02	29	1.0077	.1466E-04	.3297E-01	.4983E-01	.3246E-01
10	.8260	.9415E-03	.1421E-01	.3849E-01	-.2295E-02	30	1.0069	.8728E-05	.3343E-01	.5056E-01	.3305E-01
11	.8428	.8643E-03	.1555E-01	.3865E-01	.3294E-03	31	1.0062	.5119E-05	.3387E-01	.5132E-01	.3357E-01
12	.8583	.7627E-03	.1685E-01	.3874E-01	.2913E-02	32	1.0055	.2954E-05	.3429E-01	.5208E-01	.3405E-01
13	.8729	.7029E-03	.1811E-01	.3883E-01	.5405E-02	33	1.0047	.1651E-05	.3468E-01	.5283E-01	.3449E-01
14	.8851	.6347E-03	.1931E-01	.3905E-01	.7679E-02	34	1.0040	.8719E-06	.3505E-01	.5357E-01	.3490E-01
15	.8995	.5560E-03	.2055E-01	.3908E-01	.1007E-01	35	1.0032	.4276E-06	.3539E-01	.5430E-01	.3527E-01
16	.9095	.4708E-03	.2168E-01	.3931E-01	.1277E-01	36	1.0024	.1930E-06	.3572E-01	.5500E-01	.3563E-01
17	.9234	.4116E-03	.2286E-01	.4011E-01	.1531E-01	37	1.0016	.8739E-07	.3601E-01	.5543E-01	.3595E-01
18	.9376	.3321E-03	.2407E-01	.4077E-01	.1815E-01	38	1.0008	.1000E-07	.3629E-01	.5575E-01	.3626E-01
19	.9483	.2573E-03	.2514E-01	.4151E-01	.2077E-01	39	1.0000	.1000E-07	.3654E-01	.5604E-01	.3654E-01
20	.9578	.2193E-03	.2614E-01	.4284E-01	.2267E-01						

STN. 86 X= .1905E+02 I62= 39 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.1250E+00	-.1250E+00	-.1250E+00	-.1250E+00	-.1250E+00	-.1249E+00	-.1249E+00	-.1247E+00	-.1246E+00	-.1245E+00
-.1244E+00	-.1243E+00	-.1242E+00	-.1240E+00	-.1239E+00	-.1237E+00	-.1235E+00	-.1233E+00	-.1231E+00	-.1229E+00
-.1227E+00	-.1224E+00	-.1222E+00	-.1219E+00	-.1217E+00	-.1214E+00	-.1211E+00	-.1208E+00	-.1205E+00	-.1202E+00
-.1199E+00	-.1196E+00	-.1193E+00	-.1190E+00	-.1187E+00	-.1184E+00	-.1181E+00	-.1177E+00	-.1174E+00	-.1171E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
86	.1905E+02	.3333E-01	.001909	.1111E+01	.8387E+00	.1165E+00	.9041E-01	1.45043	.8096E+04	37

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	0	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.4998	.1398E-02	-.1899E-03	.4068E-01	-.4136E-01	21	.9502	.2220E-03	.1660E-01	.4062E-01	.1427E-01
2	.5597	.1794E-02	-.7362E-04	.4148E-01	-.4153E-01	22	.9632	.2144E-03	.1729E-01	.4300E-01	.1518E-01
3	.5901	.2109E-02	.1571E-03	.4316E-01	-.4220E-01	23	.9789	.2053E-03	.1803E-01	.4458E-01	.1596E-01
4	.6081	.2543E-02	.3217E-03	.4635E-01	-.4460E-01	24	.9932	.1732E-03	.1873E-01	.4480E-01	.1682E-01
5	.6285	.2765E-02	.1031E-02	.4803E-01	-.4374E-01	25	.9964	.1268E-03	.1924E-01	.4516E-01	.1782E-01
6	.6665	.2416E-02	.2603E-02	.4502E-01	-.3587E-01	26	.9970	.8974E-04	.1967E-01	.4567E-01	.1869E-01
7	.7147	.1739E-02	.4446E-02	.3906E-01	-.2496E-01	27	.9974	.6258E-04	.2009E-01	.4629E-01	.1942E-01
8	.7546	.1294E-02	.5857E-02	.3492E-01	-.1739E-01	28	.9977	.4208E-04	.2049E-01	.4698E-01	.2006E-01
9	.7805	.1105E-02	.6889E-02	.3341E-01	-.1335E-01	29	.9980	.2738E-04	.2087E-01	.4772E-01	.2061E-01
10	.7995	.1021E-02	.7776E-02	.3311E-01	-.1060E-01	30	.9982	.1725E-04	.2124E-01	.4850E-01	.2108E-01
11	.8165	.9455E-03	.8646E-02	.3298E-01	-.8456E-02	31	.9985	.1056E-04	.2159E-01	.4930E-01	.2151E-01
12	.8325	.8634E-03	.9512E-02	.3280E-01	-.6095E-02	32	.9987	.6390E-05	.2193E-01	.5012E-01	.2189E-01
13	.8483	.7729E-03	.1038E-01	.3253E-01	-.3676E-02	33	.9990	.3812E-05	.2225E-01	.5095E-01	.2224E-01
14	.8613	.6970E-03	.1119E-01	.3246E-01	-.1519E-02	34	.9992	.2236E-05	.2257E-01	.5177E-01	.2256E-01
15	.8760	.6243E-03	.1202E-01	.3237E-01	.6068E-03	35	.9994	.1272E-05	.2287E-01	.5259E-01	.2287E-01
16	.8870	.5279E-03	.1281E-01	.3260E-01	.3331E-02	36	.9997	.6786E-06	.2316E-01	.5340E-01	.2316E-01
17	.9002	.4676E-03	.1360E-01	.3379E-01	.5822E-02	37	.9999	.3656E-06	.2343E-01	.5379E-01	.2343E-01
18	.9149	.4006E-03	.1441E-01	.3525E-01	.8368E-02	38	1.0003	.1000E-07	.2370E-01	.5403E-01	.2370E-01
19	.9278	.3187E-03	.1519E-01	.3664E-01	.1088E-01	39	1.0000	.1000E-07	.2394E-01	.5429E-01	.2394E-01
20	.9390	.2534E-03	.1591E-01	.3838E-01	.1291E-01						

STN. 91 X= .1985E+02 I62= 39 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.1158E+00	-.1158E+00	-.1158E+00	-.1158E+00	-.1158E+00	-.1158E+00	-.1158E+00	-.1157E+00	-.1156E+00	-.1155E+00
-.1154E+00	-.1154E+00	-.1153E+00	-.1152E+00	-.1151E+00	-.1150E+00	-.1148E+00	-.1147E+00	-.1146E+00	-.1144E+00
-.1143E+00	-.1141E+00	-.1139E+00	-.1138E+00	-.1136E+00	-.1134E+00	-.1132E+00	-.1130E+00	-.1127E+00	-.1125E+00
-.1123E+00	-.1121E+00	-.1118E+00	-.1116E+00	-.1114E+00	-.1111E+00	-.1109E+00	-.1106E+00	-.1103E+00	-.1101E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
91	.1985E+02	.3333E-01	.002004	.1105E+01	.8526E+00	.1209E+00	.9462E-01	1.45216	.8357E+04	37

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	0	0	0	0

Y/YSTEP U/UE TAU/UE**2 V/UE TANA TANB

1	.5077	.1305E-02	-.4077E-03	.3826E-01	-.3978E-01	21	.9441	.2364E-03	.8976E-02	.3426E-01	.6287E-02
2	.5640	.1639E-02	-.5945E-03	.3842E-01	-.4029E-01	22	.9570	.2203E-03	.9379E-02	.3670E-01	.7113E-02
3	.5952	.1841E-02	-.5412E-03	.3885E-01	-.4021E-01	23	.9722	.2207E-03	.9792E-02	.3907E-01	.7651E-02
4	.6145	.2169E-02	-.6835E-03	.4082E-01	-.4230E-01	24	.9880	.2046E-03	.1022E-01	.3932E-01	.8168E-02
5	.6261	.2558E-02	-.7989E-03	.4357E-01	-.4502E-01	25	.9938	.1609E-03	.1056E-01	.3956E-01	.8934E-02
6	.6452	.2718E-02	-.4083E-03	.4443E-01	-.4419E-01	26	.9955	.1177E-03	.1086E-01	.3994E-01	.9579E-02
7	.6824	.2325E-02	.7392E-03	.4079E-01	-.3673E-01	27	.9962	.8391E-04	.1114E-01	.4042E-01	.1031E-01
8	.7285	.1691E-02	.2028E-02	.3489E-01	-.2706E-01	28	.9967	.5782E-04	.1141E-01	.4100E-01	.1085E-01
9	.7548	.1277E-02	.2956E-02	.3086E-01	-.2045E-01	29	.9972	.3878E-04	.1167E-01	.4164E-01	.1131E-01
10	.7887	.1095E-02	.3589E-02	.2920E-01	-.1693E-01	30	.9977	.2530E-04	.1192E-01	.4233E-01	.1169E-01
11	.8069	.9960E-03	.4129E-02	.2849E-01	-.1456E-01	31	.9981	.1605E-04	.1216E-01	.4306E-01	.1203E-01
12	.8230	.9122E-03	.4647E-02	.2801E-01	-.1246E-01	32	.9984	.9998E-05	.1240E-01	.4382E-01	.1232E-01
13	.8391	.8166E-03	.5177E-02	.2742E-01	-.1024E-01	33	.9988	.6154E-05	.1264E-01	.4460E-01	.1259E-01
14	.8527	.7329E-03	.5675E-02	.2701E-01	-.8230E-02	34	.9991	.3754E-05	.1287E-01	.4539E-01	.1284E-01
15	.8675	.6577E-03	.6170E-02	.2667E-01	-.6323E-02	35	.9993	.2270E-05	.1310E-01	.4619E-01	.1308E-01
16	.8789	.5555E-03	.6669E-02	.2652E-01	-.3832E-02	36	.9996	.1305E-05	.1332E-01	.4700E-01	.1332E-01
17	.8922	.4901E-03	.7140E-02	.2734E-01	-.1569E-02	37	.9998	.8640E-06	.1355E-01	.4770E-01	.1354E-01
18	.9068	.4288E-03	.7618E-02	.2887E-01	.7430E-03	38	1.0002	.1000E-07	.1377E-01	.4790E-01	.1377E-01
19	.9202	.3538E-03	.8097E-02	.3040E-01	.2983E-02	39	1.0000	.1000E-07	.1399E-01	.4813E-01	.1399E-01
20	.9323	.2824E-03	.8553E-02	.3212E-01	.4918E-02						

STN. 99 X= .2131E+02 I62= 39 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

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 -.1076E+00 -.1077E+00 -.1077E+00 -.1077E+00 -.1077E+00 -.1077E+00 -.1078E+00 -.1078E+00 -.1077E+00 -.1077E+00
 -.1076E+00 -.1076E+00 -.1076E+00 -.1075E+00 -.1075E+00 -.1075E+00 -.1074E+00 -.1074E+00 -.1073E+00 -.1073E+00
 -.1072E+00 -.1072E+00 -.1071E+00 -.1070E+00 -.1069E+00 -.1068E+00 -.1068E+00 -.1067E+00 -.1066E+00 -.1065E+00
 -.1064E+00 -.1063E+00 -.1062E+00 -.1060E+00 -.1059E+00 -.1058E+00 -.1057E+00 -.1056E+00 -.1054E+00 -.1053E+00
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STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
99	.2131E+02	.3333E-01	.002124	.1100E+01	.8913E+00	.1247E+00	.9992E-01	1.46590	.8587E+04	37

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	0	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.5181	.1214E-02	-.2425E-03	.3641E-01	-.3727E-01	21	.9365	.2641E-03	.4057E-02	.2648E-01	.2525E-03
2	.5733	.1429E-02	-.4846E-03	.3539E-01	-.3687E-01	22	.9503	.2314E-03	.4258E-02	.2831E-01	.1254E-02
3	.6037	.1570E-02	-.5517E-03	.3523E-01	-.3667E-01	23	.9657	.2273E-03	.4435E-02	.3040E-01	.1758E-02
4	.6273	.1753E-02	-.7015E-03	.3576E-01	-.3736E-01	24	.9821	.2289E-03	.4612E-02	.3234E-01	.2120E-02
5	.6416	.1970E-02	-.9174E-03	.3694E-01	-.3885E-01	25	.9894	.2008E-03	.4774E-02	.3261E-01	.2609E-02
6	.6505	.2310E-02	-.1262E-02	.3921E-01	-.4176E-01	26	.9921	.1595E-03	.4922E-02	.3276E-01	.3212E-02
7	.6615	.2607E-02	-.1403E-02	.4103E-01	-.4355E-01	27	.9935	.1201E-03	.5057E-02	.3296E-01	.3780E-02
8	.6861	.2502E-02	-.9204E-03	.3966E-01	-.4024E-01	28	.9945	.8705E-04	.5181E-02	.3323E-01	.4257E-02
9	.7261	.1939E-02	.3084E-04	.3454E-01	-.3196E-01	29	.9954	.6035E-04	.5295E-02	.3357E-01	.4672E-02
10	.7648	.1411E-02	.8272E-03	.2946E-01	-.2442E-01	30	.9962	.4063E-04	.5397E-02	.3398E-01	.4988E-02
11	.7918	.1126E-02	.1322E-02	.2662E-01	-.1996E-01	31	.9970	.2678E-04	.5491E-02	.3445E-01	.5228E-02
12	.8105	.9910E-03	.1657E-02	.2531E-01	-.1742E-01	32	.9976	.1731E-04	.5577E-02	.3496E-01	.5412E-02
13	.8271	.8820E-03	.1968E-02	.2433E-01	-.1524E-01	33	.9981	.1104E-04	.5655E-02	.3550E-01	.5554E-02
14	.8417	.7858E-03	.2258E-02	.2354E-01	-.1328E-01	34	.9986	.6982E-05	.5728E-02	.3606E-01	.5666E-02
15	.8563	.7002E-03	.2535E-02	.2284E-01	-.1145E-01	35	.9991	.4441E-05	.5795E-02	.3663E-01	.5757E-02
16	.8682	.5932E-03	.2829E-02	.2196E-01	-.9372E-02	36	.9995	.2663E-05	.5858E-02	.3721E-01	.5835E-02
17	.8824	.5206E-03	.3087E-02	.2198E-01	-.7358E-02	37	.9999	.2090E-05	.5915E-02	.3779E-01	.5896E-02
18	.8971	.4553E-03	.3338E-02	.2266E-01	-.5245E-02	38	1.0001	.1000E-07	.5970E-02	.3837E-01	.5969E-02
19	.9108	.3869E-03	.3588E-02	.2375E-01	-.3126E-02	39	1.0000	.1000E-07	.6016E-02	.3869E-01	.6015E-02
20	.9236	.3193E-03	.3831E-02	.2499E-01	-.1244E-02						

STN. 100 X= .2149E+02 I62= 39 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

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 -.1070E+00 -.1070E+00 -.1070E+00 -.1071E+00 -.1071E+00 -.1071E+00 -.1071E+00 -.1071E+00 -.1071E+00 -.1071E+00
 -.1070E+00 -.1070E+00 -.1070E+00 -.1069E+00 -.1069E+00 -.1069E+00 -.1068E+00 -.1068E+00 -.1068E+00 -.1067E+00
 -.1067E+00 -.1066E+00 -.1066E+00 -.1065E+00 -.1064E+00 -.1064E+00 -.1063E+00 -.1062E+00 -.1062E+00 -.1061E+00
 -.1060E+00 -.1059E+00 -.1058E+00 -.1057E+00 -.1056E+00 -.1056E+00 -.1055E+00 -.1054E+00 -.1052E+00 -.1051E+00
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VALUES OF (P-PREF)/UREF**2 AT X-STATIONS

STN. NO. 1 X= .1000E+02

-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00
-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00
-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00
-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00	-.1192E+00

STN. NO. 5 X= .1102E+02

-.1440E+00	-.1440E+00	-.1440E+00	-.1439E+00	-.1439E+00	-.1438E+00	-.1438E+00	-.1437E+00	-.1436E+00	-.1435E+00
-.1434E+00	-.1433E+00	-.1431E+00	-.1430E+00	-.1429E+00	-.1427E+00	-.1425E+00	-.1424E+00	-.1422E+00	-.1420E+00
-.1418E+00	-.1416E+00	-.1414E+00	-.1412E+00	-.1409E+00	-.1407E+00	-.1405E+00	-.1403E+00	-.1400E+00	-.1398E+00
-.1396E+00	-.1394E+00	-.1392E+00	-.1390E+00	-.1388E+00	-.1386E+00	-.1384E+00	-.1382E+00	-.1381E+00	-.1379E+00

STN. NO. 9 X= .1207E+02

-.2003E+00	-.2003E+00	-.2001E+00	-.1999E+00	-.1996E+00	-.1992E+00	-.1988E+00	-.1982E+00	-.1976E+00	-.1969E+00
-.1961E+00	-.1953E+00	-.1944E+00	-.1933E+00	-.1923E+00	-.1911E+00	-.1899E+00	-.1886E+00	-.1872E+00	-.1858E+00
-.1843E+00	-.1827E+00	-.1811E+00	-.1794E+00	-.1777E+00	-.1759E+00	-.1741E+00	-.1722E+00	-.1704E+00	-.1685E+00
-.1665E+00	-.1645E+00	-.1625E+00	-.1605E+00	-.1584E+00	-.1563E+00	-.1542E+00	-.1521E+00	-.1499E+00	-.1477E+00

STN. NO. 17 X= .1296E+02

-.3096E+00	-.3078E+00	-.3054E+00	-.3030E+00	-.3004E+00	-.2977E+00	-.2950E+00	-.2922E+00	-.2894E+00	-.2864E+00
-.2835E+00	-.2804E+00	-.2773E+00	-.2742E+00	-.2710E+00	-.2678E+00	-.2646E+00	-.2613E+00	-.2580E+00	-.2547E+00
-.2513E+00	-.2479E+00	-.2446E+00	-.2412E+00	-.2379E+00	-.2346E+00	-.2313E+00	-.2280E+00	-.2248E+00	-.2216E+00
-.2184E+00	-.2152E+00	-.2121E+00	-.2089E+00	-.2058E+00	-.2027E+00	-.1997E+00	-.1966E+00	-.1936E+00	-.1905E+00

STN. NO. 26 X= .1342E+02

-.3793E+00	-.3760E+00	-.3721E+00	-.3680E+00	-.3638E+00	-.3596E+00	-.3553E+00	-.3509E+00	-.3464E+00	-.3420E+00
-.3374E+00	-.3329E+00	-.3283E+00	-.3237E+00	-.3190E+00	-.3144E+00	-.3097E+00	-.3051E+00	-.3004E+00	-.2957E+00
-.2911E+00	-.2865E+00	-.2819E+00	-.2773E+00	-.2729E+00	-.2685E+00	-.2641E+00	-.2598E+00	-.2556E+00	-.2514E+00
-.2473E+00	-.2433E+00	-.2392E+00	-.2353E+00	-.2314E+00	-.2275E+00	-.2237E+00	-.2199E+00	-.2162E+00	-.2125E+00

STN. NO. 32 X= .1385E+02

-.4347E+00	-.4304E+00	-.4253E+00	-.4199E+00	-.4144E+00	-.4089E+00	-.4032E+00	-.3975E+00	-.3918E+00	-.3860E+00
-.3802E+00	-.3743E+00	-.3685E+00	-.3626E+00	-.3567E+00	-.3507E+00	-.3448E+00	-.3389E+00	-.3330E+00	-.3271E+00
-.3212E+00	-.3154E+00	-.3097E+00	-.3040E+00	-.2985E+00	-.2930E+00	-.2876E+00	-.2823E+00	-.2770E+00	-.2719E+00
-.2668E+00	-.2617E+00	-.2568E+00	-.2519E+00	-.2471E+00	-.2423E+00	-.2376E+00	-.2330E+00	-.2284E+00	-.2239E+00

STN. NO. 34 X= .1410E+02

-.4508E+00	-.4462E+00	-.4408E+00	-.4349E+00	-.4289E+00	-.4229E+00	-.4168E+00	-.4107E+00	-.4045E+00	-.3983E+00
-.3920E+00	-.3857E+00	-.3794E+00	-.3730E+00	-.3667E+00	-.3603E+00	-.3540E+00	-.3477E+00	-.3413E+00	-.3350E+00
-.3287E+00	-.3225E+00	-.3164E+00	-.3104E+00	-.3045E+00	-.2986E+00	-.2929E+00	-.2872E+00	-.2817E+00	-.2761E+00
-.2707E+00	-.2654E+00	-.2601E+00	-.2549E+00	-.2497E+00	-.2447E+00	-.2396E+00	-.2347E+00	-.2298E+00	-.2250E+00

STN. NO. 37 X= .1483E+02

-.4154E+00	-.4117E+00	-.4071E+00	-.4019E+00	-.3966E+00	-.3912E+00	-.3857E+00	-.3802E+00	-.3747E+00	-.3690E+00
-.3634E+00	-.3577E+00	-.3521E+00	-.3464E+00	-.3407E+00	-.3350E+00	-.3292E+00	-.3235E+00	-.3178E+00	-.3121E+00
-.3064E+00	-.3008E+00	-.2952E+00	-.2898E+00	-.2844E+00	-.2791E+00	-.2739E+00	-.2688E+00	-.2637E+00	-.2588E+00
-.2538E+00	-.2490E+00	-.2442E+00	-.2395E+00	-.2349E+00	-.2303E+00	-.2258E+00	-.2213E+00	-.2169E+00	-.2125E+00

STN. NO. 39 X= .1516E+02

-.3489E+00	-.3462E+00	-.3428E+00	-.3388E+00	-.3347E+00	-.3305E+00	-.3264E+00	-.3222E+00	-.3179E+00	-.3137E+00
-.3094E+00	-.3051E+00	-.3008E+00	-.2966E+00	-.2923E+00	-.2881E+00	-.2838E+00	-.2796E+00	-.2754E+00	-.2712E+00
-.2670E+00	-.2628E+00	-.2588E+00	-.2547E+00	-.2508E+00	-.2470E+00	-.2432E+00	-.2394E+00	-.2358E+00	-.2322E+00
-.2286E+00	-.2251E+00	-.2217E+00	-.2183E+00	-.2150E+00	-.2117E+00	-.2085E+00	-.2053E+00	-.2022E+00	-.1991E+00

STN. NO. 47 X= .1561E+02

-.3056E+00	-.3042E+00	-.3021E+00	-.2995E+00	-.2968E+00	-.2939E+00	-.2910E+00	-.2880E+00	-.2850E+00	-.2819E+00
-.2787E+00	-.2754E+00	-.2721E+00	-.2688E+00	-.2654E+00	-.2620E+00	-.2585E+00	-.2550E+00	-.2514E+00	-.2478E+00
-.2442E+00	-.2406E+00	-.2369E+00	-.2333E+00	-.2296E+00	-.2261E+00	-.2225E+00	-.2190E+00	-.2154E+00	-.2119E+00
-.2085E+00	-.2050E+00	-.2016E+00	-.1982E+00	-.1948E+00	-.1914E+00	-.1881E+00	-.1848E+00	-.1814E+00	-.1781E+00

STN. NO. 71 X= .1699E+02

-.1751E+00	-.1752E+00	-.1753E+00	-.1752E+00	-.1750E+00	-.1748E+00	-.1745E+00	-.1741E+00	-.1738E+00	-.1733E+00
-.1728E+00	-.1722E+00	-.1716E+00	-.1709E+00	-.1702E+00	-.1694E+00	-.1686E+00	-.1677E+00	-.1668E+00	-.1658E+00
-.1647E+00	-.1636E+00	-.1625E+00	-.1613E+00	-.1600E+00	-.1588E+00	-.1575E+00	-.1562E+00	-.1548E+00	-.1535E+00
-.1521E+00	-.1507E+00	-.1493E+00	-.1478E+00	-.1464E+00	-.1449E+00	-.1434E+00	-.1419E+00	-.1404E+00	-.1389E+00

STN. NO. 79 X= .1800E+02

-.1446E+00	-.1447E+00	-.1448E+00	-.1449E+00	-.1449E+00	-.1449E+00	-.1448E+00	-.1447E+00	-.1445E+00	-.1444E+00
-.1442E+00	-.1440E+00	-.1438E+00	-.1435E+00	-.1432E+00	-.1428E+00	-.1424E+00	-.1420E+00	-.1416E+00	-.1411E+00
-.1406E+00	-.1401E+00	-.1395E+00	-.1389E+00	-.1382E+00	-.1376E+00	-.1369E+00	-.1362E+00	-.1355E+00	-.1348E+00
-.1340E+00	-.1333E+00	-.1325E+00	-.1318E+00	-.1310E+00	-.1302E+00	-.1294E+00	-.1286E+00	-.1278E+00	-.1269E+00

STN. NO. 86 X= .1905E+02

-.1270E+00	-.1270E+00	-.1269E+00	-.1269E+00	-.1269E+00	-.1269E+00	-.1268E+00	-.1267E+00	-.1265E+00	-.1264E+00
-.1262E+00	-.1261E+00	-.1259E+00	-.1257E+00	-.1256E+00	-.1253E+00	-.1251E+00	-.1249E+00	-.1246E+00	-.1244E+00
-.1241E+00	-.1238E+00	-.1235E+00	-.1232E+00	-.1228E+00	-.1225E+00	-.1221E+00	-.1218E+00	-.1214E+00	-.1210E+00
-.1206E+00	-.1202E+00	-.1199E+00	-.1195E+00	-.1191E+00	-.1187E+00	-.1183E+00	-.1179E+00	-.1175E+00	-.1171E+00

STN. NO. 91 X= .1985E+02

-.1167E+00	-.1167E+00	-.1167E+00	-.1167E+00	-.1167E+00	-.1167E+00	-.1167E+00	-.1166E+00	-.1165E+00	-.1164E+00
-.1163E+00	-.1162E+00	-.1161E+00	-.1160E+00	-.1159E+00	-.1157E+00	-.1156E+00	-.1154E+00	-.1153E+00	-.1151E+00
-.1149E+00	-.1147E+00	-.1146E+00	-.1143E+00	-.1141E+00	-.1139E+00	-.1136E+00	-.1134E+00	-.1132E+00	-.1129E+00
-.1126E+00	-.1124E+00	-.1121E+00	-.1118E+00	-.1115E+00	-.1113E+00	-.1110E+00	-.1107E+00	-.1104E+00	-.1101E+00

STN. NO. 99 X= .2131E+02

-.1072E+00	-.1072E+00	-.1072E+00	-.1072E+00	-.1072E+00	-.1073E+00	-.1073E+00	-.1073E+00	-.1073E+00	-.1072E+00
-.1072E+00	-.1072E+00	-.1071E+00	-.1071E+00	-.1071E+00	-.1070E+00	-.1070E+00	-.1070E+00	-.1069E+00	-.1069E+00
-.1068E+00	-.1068E+00	-.1067E+00	-.1067E+00	-.1066E+00	-.1065E+00	-.1065E+00	-.1064E+00	-.1063E+00	-.1062E+00
-.1062E+00	-.1061E+00	-.1060E+00	-.1059E+00	-.1058E+00	-.1057E+00	-.1056E+00	-.1055E+00	-.1054E+00	-.1053E+00

X=

.1000E+02	.1025E+02	.1049E+02	.1075E+02	.1102E+02	.1128E+02	.1155E+02	.1181E+02	.1207E+02	.1232E+02
.1249E+02	.1260E+02	.1269E+02	.1277E+02	.1283E+02	.1290E+02	.1296E+02	.1301E+02	.1307E+02	.1312E+02
.1317E+02	.1322E+02	.1327E+02	.1332E+02	.1337E+02	.1342E+02	.1348E+02	.1354E+02	.1361E+02	.1368E+02
.1376E+02	.1385E+02	.1396E+02	.1410E+02	.1429E+02	.1457E+02	.1483E+02	.1504E+02	.1516E+02	.1524E+02
.1531E+02	.1537E+02	.1542E+02	.1547E+02	.1552E+02	.1556E+02	.1561E+02	.1565E+02	.1570E+02	.1574E+02
.1579E+02	.1583E+02	.1588E+02	.1593E+02	.1597E+02	.1602E+02	.1607E+02	.1612E+02	.1618E+02	.1623E+02
.1628E+02	.1634E+02	.1640E+02	.1646E+02	.1653E+02	.1659E+02	.1666E+02	.1674E+02	.1682E+02	.1690E+02
.1699E+02	.1709E+02	.1720E+02	.1731E+02	.1743E+02	.1756E+02	.1770E+02	.1785E+02	.1800E+02	.1815E+02
.1830E+02	.1845E+02	.1860E+02	.1875E+02	.1890E+02	.1905E+02	.1921E+02	.1936E+02	.1952E+02	.1969E+02
.1985E+02	.2003E+02	.2020E+02	.2038E+02	.2056E+02	.2075E+02	.2093E+02	.2112E+02	.2131E+02	.2149E+02

VE/UE=

-.3317E-01	-.2987E-01	-.3234E-01	-.3006E-01	-.2814E-01	-.2790E-01	-.3313E-01	-.4471E-01	-.6093E-01	-.7560E-01
-.8477E-01	-.9038E-01	-.9315E-01	-.9402E-01	-.9353E-01	-.9209E-01	-.8997E-01	-.8740E-01	-.8457E-01	-.8162E-01
-.7864E-01	-.7564E-01	-.7265E-01	-.6964E-01	-.6662E-01	-.6353E-01	-.6036E-01	-.5705E-01	-.5355E-01	-.4978E-01
-.4565E-01	-.4102E-01	-.3557E-01	-.2778E-01	-.1454E-01	.6817E-02	.2850E-01	.4875E-01	.6378E-01	.7522E-01
.8374E-01	.9000E-01	.9465E-01	.9811E-01	.1007E+00	.1025E+00	.1038E+00	.1045E+00	.1049E+00	.1048E+00
.1043E+00	.1033E+00	.1018E+00	.9984E-01	.9730E-01	.9423E-01	.9080E-01	.8715E-01	.8337E-01	.7952E-01
.7565E-01	.7179E-01	.6799E-01	.6427E-01	.6068E-01	.5725E-01	.5401E-01	.5099E-01	.4833E-01	.4612E-01
.4449E-01	.4332E-01	.4240E-01	.4158E-01	.4077E-01	.3990E-01	.3892E-01	.3780E-01	.3654E-01	.3513E-01
.3357E-01	.3188E-01	.3009E-01	.2815E-01	.2610E-01	.2394E-01	.2177E-01	.1965E-01	.1762E-01	.1573E-01
.1399E-01	.1242E-01	.1103E-01	.9802E-02	.8724E-02	.7800E-02	.7036E-02	.6440E-02	.6016E-02	

(PW-PREF)/UREF**2=

-.1192E+00	-.1265E+00	-.1342E+00	-.1374E+00	-.1440E+00	-.1524E+00	-.1649E+00	-.1812E+00	-.2003E+00	-.2316E+00
-.2573E+00	-.2727E+00	-.2824E+00	-.2899E+00	-.2966E+00	-.3031E+00	-.3096E+00	-.3165E+00	-.3238E+00	-.3315E+00
-.3393E+00	-.3472E+00	-.3551E+00	-.3631E+00	-.3711E+00	-.3793E+00	-.3876E+00	-.3962E+00	-.4052E+00	-.4145E+00
-.4243E+00	-.4347E+00	-.4442E+00	-.4508E+00	-.4512E+00	-.4409E+00	-.4154E+00	-.3755E+00	-.3489E+00	-.3345E+00
-.3273E+00	-.3232E+00	-.3199E+00	-.3167E+00	-.3133E+00	-.3095E+00	-.3056E+00	-.3015E+00	-.2974E+00	-.2933E+00
-.2893E+00	-.2854E+00	-.2817E+00	-.2784E+00	-.2750E+00	-.2710E+00	-.2660E+00	-.2602E+00	-.2540E+00	-.2474E+00
-.2406E+00	-.2336E+00	-.2265E+00	-.2191E+00	-.2116E+00	-.2038E+00	-.1970E+00	-.1918E+00	-.1863E+00	-.1806E+00
-.1751E+00	-.1703E+00	-.1662E+00	-.1623E+00	-.1586E+00	-.1549E+00	-.1513E+00	-.1479E+00	-.1446E+00	-.1415E+00

-.1387E+00	-.1360E+00	-.1336E+00	-.1313E+00	-.1291E+00	-.1270E+00	-.1248E+00	-.1227E+00	-.1206E+00	-.1186E+00
-.1167E+00	-.1149E+00	-.1134E+00	-.1121E+00	-.1110E+00	-.1099E+00	-.1090E+00	-.1081E+00	-.1072E+00	-.1070E+00

(PW-PE) /UREF**2=

0	-.1313E-02	-.3802E-02	-.2339E-02	-.6061E-02	-.1349E-01	-.2544E-01	-.3942E-01	-.5262E-01	-.7417E-01
-.9205E-01	-.1016E+00	-.1064E+00	-.1097E+00	-.1126E+00	-.1157E+00	-.1191E+00	-.1230E+00	-.1276E+00	-.1326E+00
-.1379E+00	-.1435E+00	-.1491E+00	-.1549E+00	-.1607E+00	-.1668E+00	-.1730E+00	-.1796E+00	-.1865E+00	-.1939E+00
-.2020E+00	-.2108E+00	-.2193E+00	-.2259E+00	-.2275E+00	-.2212E+00	-.2029E+00	-.1713E+00	-.1499E+00	-.1393E+00
-.1352E+00	-.1338E+00	-.1330E+00	-.1321E+00	-.1309E+00	-.1293E+00	-.1275E+00	-.1254E+00	-.1233E+00	-.1212E+00
-.1191E+00	-.1172E+00	-.1154E+00	-.1139E+00	-.1124E+00	-.1102E+00	-.1069E+00	-.1028E+00	-.9818E-01	-.9320E-01
-.8793E-01	-.8246E-01	-.7677E-01	-.7085E-01	-.6468E-01	-.5829E-01	-.5286E-01	-.4893E-01	-.4476E-01	-.4041E-01
-.3626E-01	-.3283E-01	-.3007E-01	-.2766E-01	-.2544E-01	-.2332E-01	-.2130E-01	-.1940E-01	-.1765E-01	-.1606E-01
-.1463E-01	-.1339E-01	-.1229E-01	-.1135E-01	-.1056E-01	-.9840E-02	-.9134E-02	-.8450E-02	-.7806E-02	-.7190E-02
-.6590E-02	-.6025E-02	-.5496E-02	-.4964E-02	-.4414E-02	-.3843E-02	-.3253E-02	-.2647E-02	-.1889E-02	-.1899E-02

SWEEP NO. 10 OF INVISCID/VISCOUS CALCULATION COMPLETED

A7.2 Printout of Ten Iterations for the Aerofoil Calculation

RUN NO. 1 OF PROGRAM MATCH

REAL SURFACE COORDS. AT NODES

0	0
.5000E-02	.1221E-01
.1250E-01	.1894E-01
.2500E-01	.2615E-01
.5000E-01	.3555E-01
.7500E-01	.4200E-01
.1000E+00	.4683E-01
.1500E+00	.5345E-01
.2000E+00	.5738E-01
.2500E+00	.5941E-01
.3000E+00	.6002E-01
.4000E+00	.5803E-01
.5000E+00	.5294E-01
.6000E+00	.4563E-01
.7000E+00	.3664E-01
.8000E+00	.2623E-01
.9000E+00	.1448E-01
.9500E+00	.8066E-02
.9750E+00	.4714E-02
.1000E+01	0
.9750E+00	-.4714E-02
.9500E+00	-.8066E-02
.9000E+00	-.1448E-01
.8000E+00	-.2623E-01
.7000E+00	-.3664E-01
.6000E+00	-.4563E-01
.5000E+00	-.5294E-01
.4000E+00	-.5803E-01
.3000E+00	-.6002E-01
.2500E+00	-.5941E-01
.2000E+00	-.5738E-01
.1500E+00	-.5345E-01
.1000E+00	-.4683E-01
.7500E-01	-.4200E-01
.5000E-01	-.3555E-01
.2500E-01	-.2615E-01
.1250E-01	-.1894E-01
.5000E-02	-.1221E-01
0	0

MATCHING SURFACE COORDS. AT NODES

0	0
.4607E-02	.1245E-01
.1204E-01	.1957E-01
.2448E-01	.2724E-01
.4943E-01	.3734E-01
.7448E-01	.4432E-01
.9956E-01	.4952E-01
.1497E+00	.5643E-01
.1998E+00	.6037E-01
.2499E+00	.6241E-01
.3000E+00	.6302E-01

.4001E+00	.6103E-01
.5002E+00	.5593E-01
.6002E+00	.4862E-01
.7003E+00	.3963E-01
.8003E+00	.2921E-01
.9003E+00	.1672E-01
.9502E+00	.9372E-02
.9751E+00	.5414E-02
.1000E+01	0
.9751E+00	-.5414E-02
.9502E+00	-.9372E-02
.9003E+00	-.1672E-01
.8003E+00	-.2921E-01
.7003E+00	-.3963E-01
.6002E+00	-.4862E-01
.5002E+00	-.5593E-01
.4001E+00	-.6103E-01
.3000E+00	-.6302E-01
.2499E+00	-.6241E-01
.1998E+00	-.6037E-01
.1497E+00	-.5643E-01
.9956E-01	-.4952E-01
.7448E-01	-.4432E-01
.4943E-01	-.3734E-01
.2448E-01	-.2724E-01
.1204E-01	-.1957E-01
.4607E-02	-.1245E-01
.1284E-16	.5259E-17

VELS. NORMAL TO MATCHING SURFACE AT NODES

0	-.2593E-02	-.4429E-02	-.6840E-02	-.1063E-01	-.1345E-01	-.1543E-01	-.1700E-01	-.1700E-01	-.1700E-01
-.1700E-01	-.1700E-01	-.1700E-01	-.1700E-01	-.1700E-01	-.1700E-01	-.1277E-01	-.7466E-02	-.4017E-02	0
-.4017E-02	-.7466E-02	-.1277E-01	-.1700E-01	-.1700E-01	-.1700E-01	-.1700E-01	-.1700E-01	-.1700E-01	-.1700E-01
-.1700E-01	-.1700E-01	-.1543E-01	-.1345E-01	-.1063E-01	-.6840E-02	-.4429E-02	-.2593E-02	0	

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

-.1328E-02	-.3525E-02	-.5666E-02	-.8843E-02	-.1214E-01	-.1454E-01	-.1641E-01	-.1700E-01	-.1700E-01	-.1700E-01
-.1700E-01	-.1700E-01	-.1700E-01	-.1700E-01	-.1753E-01	-.1594E-01	-.1038E-01	-.5808E-02	-.2076E-02	-.2076E-02
-.5808E-02	-.1038E-01	-.1594E-01	-.1753E-01	-.1700E-01	-.1700E-01	-.1700E-01	-.1700E-01	-.1700E-01	-.1700E-01
-.1700E-01	-.1641E-01	-.1454E-01	-.1214E-01	-.8843E-02	-.5666E-02	-.3525E-02	-.1328E-02		

RUN NO. 1 OF PROGRAM AMOS

INCIDENCE = 0 CHORD = 1.000

X	Y	SSM	CP	U(TANG)	V(NORM)
.00230	.00622	.00664	.79955	.44771	-.00133
.00832	.01601	.01842	.10586	.94559	-.00353
.01826	.02340	.03087	-.16136	1.07766	-.00567
.03696	.03229	.05164	-.33437	1.15515	-.00884
.06196	.04083	.07810	-.44919	1.20382	-.01214
.08702	.04692	.10391	-.48404	1.21821	-.01454
.12462	.05298	.14202	-.46212	1.20918	-.01641

.17475	.05840	.19246	-.44429	1.20178	-.01700
.22487	.06139	.24268	-.41179	1.18819	-.01700
.27497	.06271	.29279	-.38075	1.17505	-.01700
.35006	.06202	.36790	-.32145	1.14954	-.01700
.45015	.05848	.46806	-.26102	1.12295	-.01700
.55021	.05228	.56833	-.20070	1.09576	-.01700
.65027	.04412	.66871	-.14192	1.06861	-.01700
.75031	.03442	.76923	-.08266	1.04051	-.01753
.85030	.02296	.86988	-.00708	1.00353	-.01594
.92522	.01304	.94546	.07806	.96018	-.01038
.96264	.00739	.98330	.14057	.92705	-.00581
.98756	.00271	1.00866	.26243	.85882	-.00208
.98756	-.00271	1.03413	.26243	-.85882	-.00208
.96264	-.00739	1.05950	.14057	-.92705	-.00581
.92522	-.01304	1.09734	.07806	-.96018	-.01038
.85030	-.02296	1.17292	-.00708	-1.00353	-.01594
.75031	-.03442	1.27357	-.08266	-1.04051	-.01753
.65027	-.04412	1.37408	-.14192	-1.06861	-.01700
.55021	-.05228	1.47447	-.20070	-1.09576	-.01700
.45015	-.05848	1.57474	-.26102	-1.12295	-.01700
.35006	-.06202	1.67490	-.32145	-1.14954	-.01700
.27497	-.06271	1.75001	-.38075	-1.17505	-.01700
.22487	-.06139	1.80012	-.41179	-1.18819	-.01700
.17475	-.05840	1.85034	-.44429	-1.20178	-.01700
.12462	-.05298	1.90078	-.46212	-1.20918	-.01641
.08702	-.04692	1.93889	-.48404	-1.21821	-.01454
.06196	-.04083	1.96470	-.44919	-1.20382	-.01214
.03696	-.03229	1.99116	-.33437	-1.15515	-.00884
.01826	-.02340	2.01193	-.16136	-1.07766	-.00567
.00832	-.01601	2.02438	.10586	-.94559	-.00353
.00230	-.00622	2.03616	.79955	-.44771	-.00133

LIFT COEFFICIENT = -.000

ARC LENGTH FOR STAGN. PT. ON M.S.= 2.04280

RUN NO. 1 OF BOUNDARY LAYER CALCULATION

B.L. CALC. IN INVISCID/VISCOUS INTERACTION CYCLE--AEROFOIL TEST CASE

1977 0 10 119 16 5 0 0 1 0 51 0 -2 0
A 0 1.000E-01 0 7.500E+06 0 1.000E+00 3.000E-01

THWAITES LAMINAR B.L. CALC.

X	THETA	RTHETA	UE	VE
0	.6651E-05	0	0	0
.1319E-01	.1288E-04	.7680E+02	.7948E+00	.1913E-02
.2327E-01	.1943E-04	.1495E+03	.1026E+01	-.1417E-02
.3770E-01	.2966E-04	.2471E+03	.1111E+01	.7333E-03
.6441E-01	.4186E-04	.3721E+03	.1185E+01	.4895E-03
.9023E-01	.5212E-04	.4746E+03	.1214E+01	.8629E-03
.1157E+00	.6266E-04	.5720E+03	.1217E+01	.1394E-02
.1661E+00	.8218E-04	.7502E+03	.1205E+01	.1384E-02

SYNTHETIC STARTING PROFILES THETA/DELTA= .1052
X FOR CURV. B. VALUE 0 1.319E-02 2.327E-02 3.770E-02 6.441E-02 9.023E-02 1.157E-01
1.661E-01 2.163E-01 2.663E-01 3.163E-01 4.163E-01 5.165E-01 6.167E-01
7.171E-01 8.177E-01
CURV 6.302E+01 3.406E+01 1.735E+01 8.571E+00 3.819E+00 2.344E+00 1.664E+00
1.035E+00 7.407E-01 5.675E-01 4.517E-01 3.049E-01 2.175E-01 1.651E-01
1.377E-01 1.307E-01
X FOR PRESS. AND NP B. VALUES 0 1.3194E-02 2.3271E-02 3.7701E-02 6.4410E-02 9.0229E-02 1.1569E-01
1.6613E-01 2.1628E-01 2.6632E-01 3.1633E-01 4.1635E-01 5.1648E-01 6.1674E-01

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 7.1715E-01   8.1769E-01
PE-PREF      5.0000E-01   1.8415E-01  -2.6198E-02  -1.1669E-01  -2.0235E-01  -2.3730E-01  -2.4072E-01
 -2.2570E-01  -2.1485E-01  -1.9813E-01  -1.8100E-01  -1.4446E-01  -1.1572E-01  -8.5374E-02
 -5.6809E-02  -2.3247E-02
NP.            0   1.7143E-04   2.5858E-04   3.9467E-04   5.5692E-04   6.9343E-04   8.3374E-04
 1.0934E-03
NP   3.0000E-03   3.0000E-03   3.0000E-03   3.0000E-03   3.0000E-03   3.0000E-03   3.0000E-03
 3.0000E-03   3.0000E-03

STN.          X        YSTEP        CF          UE      DEL05       THETA     SCHMETA         H       RTHETA      I6
  1   .1661E+00  .1562E-03    .004696  .1205E+01  .9055E-03  .8220E-04  .8220E-04     1.45593  .7428E+03       17

 ROUGH/D05    D05/RAO D05/(X-X0) STRAIN.005      VW/UE
         0  .9372E-03          0          0          0
REYNOLDS NUMBER TOO SMALL

STN.          X        YSTEP        CF          UE      DEL05       THETA     SCHMETA         H       RTHETA      I6
  2   .1705E+00  .1562E-03    .004725  .1204E+01  .7791E-03  .9574E-04  .9249E-04     1.39369  .8646E+03       17

 ROUGH/D05    D05/RAO D05/(X-X0) STRAIN.005      VW/UE
         0  .7866E-03          0          0          0

STN.          X        YSTEP        CF          UE      DEL05       THETA     SCHMETA         H       RTHETA      I6
 10   .2025E+00  .1562E-03    .003928  .1199E+01  .1461E-02  .1714E-03  .1643E-03     1.39553  .1541E+04       17

 ROUGH/D05    D05/RAO D05/(X-X0) STRAIN.005      VW/UE
         0  .1200E-02          0          0          0

STN.          X        YSTEP        CF          UE      DEL05       THETA     SCHMETA         H       RTHETA      I6
 20   .2414E+00  .1562E-03    .003571  .1189E+01  .2110E-02  .2564E-03  .2473E-03     1.37510  .2286E+04       17

 ROUGH/D05    D05/RAO D05/(X-X0) STRAIN.005      VW/UE
         0  .1379E-02          0          0          0

STN.          X        YSTEP        CF          UE      DEL05       THETA     SCHMETA         H       RTHETA      I6
 30   .2800E+00  .1562E-03    .003319  .1178E+01  .2697E-02  .3338E-03  .3320E-03     1.37765  .2948E+04       17

 ROUGH/D05    D05/RAO D05/(X-X0) STRAIN.005      VW/UE
         0  .1445E-02          0          0          0

STN.          X        YSTEP        CF          UE      DEL05       THETA     SCHMETA         H       RTHETA      I6
 40   .3182E+00  .1562E-03    .003128  .1166E+01  .2786E-02  .4007E-03  .4198E-03     1.39042  .3506E+04       17

 ROUGH/D05    D05/RAO D05/(X-X0) STRAIN.005      VW/UE
         0  .1251E-02          0          0          0

STN.          X        YSTEP        CF          UE      DEL05       THETA     SCHMETA         H       RTHETA      I6
 50   .3562E+00  .1562E-03    .002924  .1154E+01  .2789E-02  .4476E-03  .5128E-03     1.42814  .3876E+04       17

 ROUGH/D05    D05/RAO D05/(X-X0) STRAIN.005      VW/UE
         0  .1097E-02          0          0          0

STN.          X        YSTEP        CF          UE      DEL05       THETA     SCHMETA         H       RTHETA      I6
 60   .3938E+00  .1562E-03    .002695  .1142E+01  .2803E-02  .4720E-03  .6105E-03     1.48650  .4043E+04       17

 ROUGH/D05    D05/RAO D05/(X-X0) STRAIN.005      VW/UE
         0  .9474E-03          0          0          0

STN.          X        YSTEP        CF          UE      DEL05       THETA     SCHMETA         H       RTHETA      I6
 70   .4311E+00  .1562E-03    .002493  .1131E+01  .2801E-02  .4990E-03  .7106E-03     1.52718  .4233E+04       17

 ROUGH/D05    D05/RAO D05/(X-X0) STRAIN.005      VW/UE
         0  .8178E-03          0          0          0
```

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
80	.4682E+00	.1562E-03	.002326	.1122E+01	.2797E-02	.5026E-03	.8116E-03	1.56481	.4228E+04	17

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.7264E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
90	.5047E+00	.1562E-03	.002354	.1113E+01	.2800E-02	.5112E-03	.9162E-03	1.56875	.4266E+04	17

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.6377E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
100	.5415E+00	.1562E-03	.002218	.1103E+01	.2757E-02	.4960E-03	.1029E-02	1.60787	.4103E+04	17

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.5637E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
110	.5775E+00	.1562E-03	.002317	.1093E+01	.2801E-02	.5152E-03	.1149E-02	1.59193	.4223E+04	17

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.5199E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
119	.6104E+00	.1562E-03	.002180	.1084E+01	.2800E-02	.5236E-03	.1266E-02	1.60582	.4256E+04	17

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.4716E-03	0	0	0

X=

.1661E+00	.1705E+00	.1744E+00	.1785E+00	.1825E+00	.1866E+00	.1906E+00	.1946E+00	.1985E+00	.2025E+00
.2064E+00	.2103E+00	.2142E+00	.2181E+00	.2220E+00	.2259E+00	.2298E+00	.2337E+00	.2376E+00	.2414E+00
.2453E+00	.2492E+00	.2531E+00	.2569E+00	.2608E+00	.2646E+00	.2685E+00	.2723E+00	.2761E+00	.2800E+00
.2838E+00	.2877E+00	.2915E+00	.2953E+00	.2991E+00	.3030E+00	.3068E+00	.3106E+00	.3144E+00	.3182E+00
.3220E+00	.3258E+00	.3296E+00	.3334E+00	.3372E+00	.3410E+00	.3448E+00	.3486E+00	.3524E+00	.3562E+00
.3599E+00	.3637E+00	.3675E+00	.3713E+00	.3750E+00	.3788E+00	.3826E+00	.3863E+00	.3901E+00	.3938E+00
.3976E+00	.4013E+00	.4050E+00	.4088E+00	.4125E+00	.4162E+00	.4200E+00	.4237E+00	.4274E+00	.4311E+00
.4349E+00	.4386E+00	.4423E+00	.4460E+00	.4497E+00	.4534E+00	.4571E+00	.4608E+00	.4645E+00	.4682E+00
.4718E+00	.4755E+00	.4792E+00	.4828E+00	.4865E+00	.4901E+00	.4938E+00	.4974E+00	.5011E+00	.5047E+00
.5084E+00	.5121E+00	.5158E+00	.5195E+00	.5231E+00	.5268E+00	.5305E+00	.5342E+00	.5378E+00	.5415E+00
.5451E+00	.5489E+00	.5524E+00	.5559E+00	.5595E+00	.5631E+00	.5667E+00	.5703E+00	.5739E+00	.5775E+00
.5812E+00	.5848E+00	.5885E+00	.5922E+00	.5958E+00	.5995E+00	.6031E+00	.6068E+00	.6104E+00	.6140E+00

VE/UE=

.2983E-02	.3289E-02	.3371E-02	.3499E-02	.3561E-02	.3570E-02	.3532E-02	.3477E-02	.3417E-02	.3349E-02
.3306E-02	.3277E-02	.3268E-02	.3274E-02	.3291E-02	.3312E-02	.3334E-02	.3355E-02	.3369E-02	.3380E-02
.3387E-02	.3390E-02	.3390E-02	.3387E-02	.3382E-02	.3375E-02	.3365E-02	.3353E-02	.3339E-02	.3327E-02
.3317E-02	.3310E-02	.3306E-02	.3306E-02	.3310E-02	.3319E-02	.3330E-02	.3345E-02	.3364E-02	.3385E-02
.3409E-02	.3434E-02	.3459E-02	.3484E-02	.3508E-02	.3533E-02	.3556E-02	.3604E-02	.3596E-02	.3604E-02
.3638E-02	.3696E-02	.3735E-02	.3693E-02	.3667E-02	.3629E-02	.3602E-02	.3583E-02	.3521E-02	.3485E-02
.3448E-02	.3414E-02	.3380E-02	.3346E-02	.3312E-02	.3277E-02	.3239E-02	.3201E-02	.3161E-02	.3121E-02
.3144E-02	.3048E-02	.2982E-02	.2983E-02	.3027E-02	.3046E-02	.2915E-02	.2804E-02	.2681E-02	.2608E-02
.2493E-02	.2427E-02	.2367E-02	.2322E-02	.2289E-02	.2278E-02	.2285E-02	.2309E-02	.2348E-02	.2397E-02
.2450E-02	.2501E-02	.2549E-02	.2671E-02	.2635E-02	.2619E-02	.2687E-02	.2791E-02	.2852E-02	.2724E-02
.2600E-02	.2462E-02	.2398E-02	.2289E-02	.2253E-02	.2219E-02	.2237E-02	.2301E-02	.2377E-02	.2458E-02
.2531E-02	.2591E-02	.2634E-02	.2664E-02	.2679E-02	.2686E-02	.2772E-02	.2679E-02	.2609E-02	

(PW-PREF)/UREF**2=

-.2257E+00	-.2261E+00	-.2253E+00	-.2245E+00	-.2237E+00	-.2229E+00	-.2220E+00	-.2212E+00	-.2203E+00	-.2193E+00
-.2184E+00	-.2173E+00	-.2163E+00	-.2151E+00	-.2140E+00	-.2128E+00	-.2115E+00	-.2102E+00	-.2089E+00	-.2076E+00
-.2062E+00	-.2048E+00	-.2034E+00	-.2020E+00	-.2007E+00	-.1993E+00	-.1979E+00	-.1966E+00	-.1953E+00	-.1939E+00
-.1926E+00	-.1913E+00	-.1900E+00	-.1887E+00	-.1874E+00	-.1861E+00	-.1847E+00	-.1834E+00	-.1821E+00	-.1807E+00
-.1793E+00	-.1779E+00	-.1765E+00	-.1751E+00	-.1737E+00	-.1723E+00	-.1708E+00	-.1694E+00	-.1680E+00	-.1665E+00

-.1651E+00	-.1637E+00	-.1623E+00	-.1608E+00	-.1594E+00	-.1580E+00	-.1566E+00	-.1552E+00	-.1539E+00	-.1525E+00
-.1511E+00	-.1498E+00	-.1485E+00	-.1472E+00	-.1460E+00	-.1447E+00	-.1435E+00	-.1423E+00	-.1411E+00	-.1399E+00
-.1388E+00	-.1377E+00	-.1366E+00	-.1355E+00	-.1344E+00	-.1334E+00	-.1324E+00	-.1313E+00	-.1303E+00	-.1293E+00
-.1282E+00	-.1272E+00	-.1262E+00	-.1252E+00	-.1242E+00	-.1232E+00	-.1222E+00	-.1212E+00	-.1202E+00	-.1192E+00
-.1181E+00	-.1171E+00	-.1160E+00	-.1150E+00	-.1139E+00	-.1128E+00	-.1117E+00	-.1106E+00	-.1096E+00	-.1085E+00
-.1074E+00	-.1063E+00	-.1051E+00	-.1041E+00	-.1029E+00	-.1018E+00	-.1007E+00	-.9959E-01	-.9847E-01	-.9735E-01
-.9622E-01	-.9510E-01	-.9397E-01	-.9285E-01	-.9173E-01	-.9060E-01	-.8952E-01	-.8844E-01	-.8735E-01	-.8628E-01

(PW-PE)/UREF**2=

0	-.1175E-02	-.1153E-02	-.1124E-02	-.1105E-02	-.1083E-02	-.1056E-02	-.1024E-02	-.9911E-03	-.9535E-03
-.9133E-03	-.8744E-03	-.8363E-03	-.8001E-03	-.7758E-03	-.7535E-03	-.7322E-03	-.7127E-03	-.6929E-03	-.6734E-03
-.6540E-03	-.6348E-03	-.6156E-03	-.5966E-03	-.5781E-03	-.5598E-03	-.5422E-03	-.5291E-03	-.5154E-03	-.5013E-03
-.4871E-03	-.4729E-03	-.4589E-03	-.4450E-03	-.4313E-03	-.4180E-03	-.4049E-03	-.3921E-03	-.3796E-03	-.3674E-03
-.3584E-03	-.3497E-03	-.3413E-03	-.3333E-03	-.3255E-03	-.3180E-03	-.2985E-03	-.3016E-03	-.3056E-03	-.2844E-03
-.2658E-03	-.2729E-03	-.2695E-03	-.2824E-03	-.2826E-03	-.2775E-03	-.2682E-03	-.2570E-03	-.2601E-03	-.2513E-03
-.2430E-03	-.2371E-03	-.2312E-03	-.2253E-03	-.2198E-03	-.2149E-03	-.2104E-03	-.2068E-03	-.2035E-03	-.1792E-03
-.1941E-03	-.2075E-03	-.1786E-03	-.1575E-03	-.1747E-03	-.1782E-03	-.2020E-03	-.2086E-03	-.2008E-03	-.1842E-03
-.1881E-03	-.1776E-03	-.1709E-03	-.1660E-03	-.1590E-03	-.1520E-03	-.1455E-03	-.1391E-03	-.1343E-03	-.1304E-03
-.1278E-03	-.1259E-03	-.1022E-03	-.1213E-03	-.1399E-03	-.1094E-03	-.9190E-04	-.1146E-03	-.1233E-03	-.1518E-03
-.1620E-03	-.1521E-03	-.1321E-03	-.1366E-03	-.1246E-03	-.1154E-03	-.1052E-03	-.9786E-04	-.9506E-04	-.9382E-04
-.9448E-04	-.9611E-04	-.9722E-04	-.9855E-04	-.9870E-04	-.7640E-04	-.9699E-04	-.1162E-03	-.1123E-03	-.1123E-03

SWEEP NO. 1 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 2 OF PROGRAM MATCH

MATCHING SURFACE COORDS. AT NODES

0	0
.4580E-02	.1246E-01
.1206E-01	.1953E-01
.2452E-01	.2717E-01
.4952E-01	.3707E-01
.7456E-01	.4393E-01
.9962E-01	.4918E-01
.1497E+00	.5656E-01
.1998E+00	.6050E-01
.2499E+00	.6253E-01
.3000E+00	.6314E-01
.4001E+00	.6115E-01
.5002E+00	.5606E-01
.6003E+00	.4874E-01
.7003E+00	.3956E-01
.8003E+00	.2856E-01
.9002E+00	.1584E-01
.9501E+00	.8796E-02
.9751E+00	.5091E-02
.1000E+01	0
.9751E+00	-.5091E-02
.9501E+00	-.8796E-02
.9002E+00	-.1584E-01
.8003E+00	-.2856E-01
.7003E+00	-.3956E-01
.6003E+00	-.4874E-01
.5002E+00	-.5606E-01
.4001E+00	-.6115E-01
.3000E+00	-.6314E-01
.2499E+00	-.6253E-01

.1998E+00	-.6050E-01
.1497E+00	-.5656E-01
.9962E-01	-.4918E-01
.7456E-01	-.4393E-01
.4952E-01	-.3707E-01
.2452E-01	-.2717E-01
.1206E-01	-.1953E-01
.4580E-02	-.1246E-01
0	0

VELS. NORMAL TO MATCHING SURFACE AT NODES

0	.1913E-02	-.1417E-02	.7333E-03	.4895E-03	.8629E-03	.1394E-02	-.5312E-02	.3900E-02	.3981E-02
.3939E-02	.3718E-02	.2867E-02	.3942E-02	.3697E-02	.2960E-02	.1730E-02	.9294E-03	.4823E-03	0
.4823E-03	.9294E-03	.1730E-02	.2960E-02	.3697E-02	.3942E-02	.2867E-02	.3718E-02	.3939E-02	.3981E-02
.3900E-02	-.5312E-02	.1394E-02	.8629E-03	.4895E-03	.7333E-03	-.1417E-02	.1913E-02	0	

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

-.3808E-03	-.2544E-02	-.4008E-02	-.6031E-02	-.8303E-02	-.9742E-02	-.1268E-01	-.1177E-01	-.1071E-01	-.1071E-01
-.1073E-01	-.1098E-01	-.1083E-01	-.1074E-01	-.1125E-01	-.1044E-01	-.6863E-02	-.3853E-02	-.1380E-02	-.1380E-02
-.3853E-02	-.6863E-02	-.1044E-01	-.1125E-01	-.1074E-01	-.1083E-01	-.1098E-01	-.1073E-01	-.1071E-01	-.1071E-01
-.1177E-01	-.1268E-01	-.9742E-02	-.8303E-02	-.6031E-02	-.4008E-02	-.2544E-02	-.3808E-03		

RUN NO. 2 OF PROGRAM AMOS

INCIDENCE = 0 CHORD = 1.000

X	Y	SSM	CP	U (TANG)	V (NORM)
.00229	.00623	.00664	.80116	.44592	-.00038
.00832	.01600	.01842	.10417	.94648	-.00254
.01829	.02335	.03088	-.15345	1.07399	-.00401
.03702	.03212	.05163	-.32027	1.14903	-.00603
.06204	.04050	.07606	-.41992	1.19160	-.00830
.08709	.04656	.10384	-.45092	1.20454	-.00974
.12464	.05287	.14194	-.44697	1.20290	-.01268
.17474	.05853	.19238	-.44085	1.20035	-.01177
.22487	.06152	.24260	-.40601	1.18575	-.01071
.27496	.06284	.29272	-.37632	1.17317	-.01071
.35006	.06215	.36783	-.31910	1.14852	-.01073
.45015	.05861	.46800	-.26108	1.12298	-.01098
.55022	.05240	.56827	-.20401	1.09727	-.01083
.65027	.04415	.66866	-.14822	1.07155	-.01074
.75027	.03406	.76917	-.08524	1.04175	-.01125
.85021	.02220	.86982	-.00430	1.00215	-.01044
.92513	.01232	.94539	.07921	.95958	-.00686
.96258	.00694	.98322	.13403	.93058	-.00385
.98753	.00255	1.00856	.24791	.86723	-.00138
.98753	-.00255	1.03402	.24791	-.86723	-.00138
.96258	-.00694	1.05936	.13403	-.93058	-.00385
.92513	-.01232	1.09719	.07921	-.95958	-.00686
.85021	-.02220	1.17276	-.00430	-1.00215	-.01044
.75027	-.03406	1.27341	-.08524	-1.04175	-.01125
.65027	-.04415	1.37392	-.14822	-1.07155	-.01074
.55022	-.05240	1.47431	-.20401	-1.09727	-.01083

```
   .45015    -.05861    1.57458    -.26108  -1.12298    -.01098
   .35006    -.06215    1.67475    -.31910  -1.14852    -.01073
   .27496    -.06284    1.74986    -.37632  -1.17317    -.01071
   .22487    -.06152    1.79998    -.40601  -1.18575    -.01071
   .17474    -.05853    1.85020    -.44085  -1.20035    -.01177
   .12464    -.05287    1.90064    -.44697  -1.20290    -.01268
   .08709    -.04656    1.93874    -.45092  -1.20454    -.00974
   .06204    -.04050    1.96452    -.41992  -1.19160    -.00830
   .03702    -.03212    1.99095    -.32027  -1.14903    -.00603
   .01829    -.02335    2.01170    -.15345  -1.07399    -.00401
   .00832    -.01600    2.02415     .10417   -.94648    -.00254
   .00229    -.00623    2.03594     .80116   -.44592    -.00038
LIFT COEFFICIENT = -.000

ARC LENGTH FOR STAGN. PT. ON M.S.=   2.04258


RUN NO.  2  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS INTERACTION CYCLE--AEROFOIL TEST CASE


1977    0   10  119   16    5    0    0    1    0   51    0   -2    0
A                0  1.000E-01          0  7.500E+06           0  1.000E+00  3.000E-01

THWAITES LAMINAR B.L. CALC.
       X           THETA       RTHETA          UE          VE
           0    .6540E-05           0           0           0
   .1319E-01    .1288E-04   .7685E+02   .7958E+00   .1915E-02
   .2327E-01    .1946E-04   .1498E+03   .1025E+01  -.8619E-02
   .3770E-01    .2992E-04   .2481E+03   .1105E+01  -.1844E-02
   .6441E-01    .4231E-04   .3732E+03   .1176E+01  -.1370E-02
   .9023E-01    .5302E-04   .4774E+03   .1200E+01  -.1766E-04
   .1157E+00    .6323E-04   .5716E+03   .1205E+01   .9671E-03
   .1661E+00    .8123E-04   .7343E+03   .1202E+01   .1296E-02

SYNTHETIC STARTING PROFILES   THETA/DELTA= .1049
X FOR CURV. B. VALUE              0  1.319E-02  2.327E-02  3.770E-02  6.441E-02  9.023E-02  1.157E-01
 1.651E-01  2.163E-01  2.663E-01  3.163E-01  4.163E-01  5.165E-01  6.167E-01
       I          I
CURV     6.302E+01  3.406E+01  1.735E+01  8.571E+00  3.819E+00  2.344E+00  1.664E+0D
 1.035E+00  7.407E-01  5.675E-01  4.517E-01  3.049E-01  2.175E-01  1.651E-01
 1.377E-01  1.307E-01
X FOR PRESS. AND NP B. VALUES               0   1.3194E-02   2.3271E-02   3.7701E-02   6.4410E-02   9.0229E-02   1.1569E-01
  1.6613E-01   2.1628E-01   2.6632E-01   3.1633E-01   4.1635E-01   5.1648E-01   6.1674E-01
PE-PREF       5.0000E-01   1.8334E-01  -2.5443E-02  -1.1099E-01  -1.9176E-01  -2.2053E-01  -2.2641E-01
 -2.2252E-01  -2.1273E-01  -1.9533E-01  -1.7926E-01  -1.4383E-01  -1.1652E-01  -8.7901E-02
NP              0   4.8981E-04   7.3881E-04   1.1276E-03   1.5912E-03   1.9812E-03   2.3821E-03
  3.1240E-03
NP   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03

STN.           X       YSTEP         CF         UE     DEL05       THETA    SCHMETA          H    RTHETA     I6
   1  .1661E+00  .1562E-03    .004732  .1202E+01  .9061E-03  .8139E-04  .8139E-04    1.46065  .7338E+03     13

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05      VW/UE
         0  .9378E-03          0           0           0
REYNOLDS NUMBER TOO SMALL

STN.           X       YSTEP         CF         UE     DEL05       THETA    SCHMETA          H    RTHETA     I6
   2  .1705E+00  .1562E-03    .004733  .1201E+01  .7791E-03  .9573E-04  .9204E-04    1.38207  .8625E+03     18

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05      VW/UE
         0  .7866E-03          0           0           0
```

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
10	.2025E+00	.1562E-03	.003929	.1195E+01	.1461E-02	.1717E-03	.1635E-03	1.39394	.1539E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1200E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
20	.2414E+00	.1562E-03	.003581	.1186E+01	.2109E-02	.2555E-03	.2439E-03	1.37748	.2273E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1379E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
30	.2800E+00	.1562E-03	.003327	.1176E+01	.2732E-02	.3336E-03	.3233E-03	1.37565	.2943E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1464E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
40	.3182E+00	.1562E-03	.003141	.1165E+01	.2929E-02	.4042E-03	.4040E-03	1.38387	.3532E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1315E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
50	.3562E+00	.1562E-03	.002961	.1154E+01	.2792E-02	.4534E-03	.4861E-03	1.41529	.3924E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1098E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
60	.3938E+00	.1562E-03	.002759	.1143E+01	.2951E-02	.4879E-03	.5688E-03	1.46168	.4182E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.9974E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
70	.4311E+00	.1562E-03	.002555	.1132E+01	.1861E-02	.5357E-03	.6515E-03	1.50702	.4550E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.5433E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
80	.4682E+00	.1562E-03	.002243	.1122E+01	.2560E-02	.4215E-03	.7321E-03	1.63811	.3548E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.6647E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
90	.5047E+00	.1562E-03	.002259	.1113E+01	.2940E-02	.4723E-03	.8097E-03	1.50719	.3943E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.6695E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
100	.5415E+00	.1562E-03	.002713	.1104E+01	.2799E-02	.5072E-03	.9009E-03	1.46756	.4200E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.5722E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
110	.5775E+00	.1562E-03	.002588	.1095E+01	.2959E-02	.5126E-03	.9959E-03	1.50661	.4210E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE

0	.5492E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
119	.6104E+00	.1562E-03	.002441	.1086E+01	.1838E-02	.5629E-03	.1086E-02	1.54624	.4585E+04	18

RBUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.3095E-03	0	0	0

X=

.1661E+00	.1705E+00	.1744E+00	.1785E+00	.1825E+00	.1866E+00	.1906E+00	.1946E+00	.1985E+00	.2025E+00
.2064E+00	.2103E+00	.2142E+00	.2181E+00	.2220E+00	.2259E+00	.2298E+00	.2337E+00	.2376E+00	.2414E+00
.2453E+00	.2492E+00	.2531E+00	.2569E+00	.2608E+00	.2646E+00	.2685E+00	.2723E+00	.2761E+00	.2800E+00
.2838E+00	.2877E+00	.2915E+00	.2953E+00	.2991E+00	.3030E+00	.3068E+00	.3106E+00	.3144E+00	.3182E+00
.3220E+00	.3258E+00	.3296E+00	.3334E+00	.3372E+00	.3410E+00	.3448E+00	.3486E+00	.3524E+00	.3562E+00
.3599E+00	.3637E+00	.3675E+00	.3713E+00	.3750E+00	.3788E+00	.3826E+00	.3863E+00	.3901E+00	.3938E+00
.3976E+00	.4013E+00	.4050E+00	.4088E+00	.4125E+00	.4162E+00	.4200E+00	.4237E+00	.4274E+00	.4311E+00
.4349E+00	.4386E+00	.4423E+00	.4460E+00	.4497E+00	.4534E+00	.4571E+00	.4608E+00	.4645E+00	.4682E+00
.4718E+00	.4755E+00	.4792E+00	.4828E+00	.4865E+00	.4901E+00	.4938E+00	.4974E+00	.5011E+00	.5047E+00
.5084E+00	.5121E+00	.5158E+00	.5195E+00	.5231E+00	.5268E+00	.5305E+00	.5342E+00	.5378E+00	.5415E+00
.5451E+00	.5488E+00	.5524E+00	.5559E+00	.5595E+00	.5631E+00	.5667E+00	.5703E+00	.5739E+00	.5775E+00
.5812E+00	.5848E+00	.5885E+00	.5922E+00	.5958E+00	.5995E+00	.6031E+00	.6068E+00	.6104E+00	.6140E+00

VE/UE=

.3099E-02	.3506E-02	.3522E-02	.3653E-02	.3696E-02	.3696E-02	.3646E-02	.3578E-02	.3505E-02	.3422E-02
.3363E-02	.3315E-02	.3265E-02	.3267E-02	.3261E-02	.3260E-02	.3262E-02	.3265E-02	.3267E-02	.3269E-02
.3271E-02	.3274E-02	.3279E-02	.3285E-02	.3292E-02	.3300E-02	.3309E-02	.3318E-02	.3325E-02	.3333E-02
.3339E-02	.3344E-02	.3349E-02	.3354E-02	.3360E-02	.3356E-02	.3374E-02	.3381E-02	.3389E-02	.3397E-02
.3405E-02	.3413E-02	.3421E-02	.3430E-02	.3439E-02	.3448E-02	.3458E-02	.3468E-02	.3479E-02	.3486E-02
.3494E-02	.3497E-02	.3498E-02	.3538E-02	.3577E-02	.3613E-02	.3568E-02	.3545E-02	.3512E-02	.3491E-02
.3476E-02	.3425E-02	.3399E-02	.3408E-02	.3444E-02	.3513E-02	.3606E-02	.3714E-02	.3826E-02	.3941E-02
.4059E-02	.4163E-02	.3973E-02	.3780E-02	.3453E-02	.3275E-02	.3216E-02	.3093E-02	.2934E-02	.2763E-02
.2588E-02	.2398E-02	.2176E-02	.1927E-02	.1660E-02	.1380E-02	.1083E-02	.7612E-03	.4650E-03	.4122E-03
.3933E-03	.7409E-03	.1342E-02	.1712E-02	.2020E-02	.2247E-02	.2425E-02	.2564E-02	.2677E-02	.2821E-02
.2857E-02	.2908E-02	.3004E-02	.3128E-02	.3116E-02	.3125E-02	.3111E-02	.3117E-02	.3140E-02	.3104E-02
.3165E-02	.3257E-02	.3358E-02	.3503E-02	.3647E-02	.3796E-02	.3946E-02	.4096E-02	.4230E-02	

(PW-PREF)/UREF**2=

-.2225E+00	-.2228E+00	-.2219E+00	-.2209E+00	-.2200E+00	-.2190E+00	-.2181E+00	-.2171E+00	-.2162E+00	-.2152E+00
-.2142E+00	-.2133E+00	-.2123E+00	-.2113E+00	-.2102E+00	-.2092E+00	-.2082E+00	-.2071E+00	-.2060E+00	-.2049E+00
-.2038E+00	-.2026E+00	-.2015E+00	-.2003E+00	-.1990E+00	-.1978E+00	-.1966E+00	-.1953E+00	-.1940E+00	-.1927E+00
-.1914E+00	-.1901E+00	-.1888E+00	-.1874E+00	-.1861E+00	-.1847E+00	-.1834E+00	-.1820E+00	-.1807E+00	-.1793E+00
-.1780E+00	-.1767E+00	-.1753E+00	-.1740E+00	-.1727E+00	-.1714E+00	-.1700E+00	-.1687E+00	-.1674E+00	-.1661E+00
-.1649E+00	-.1636E+00	-.1623E+00	-.1610E+00	-.1597E+00	-.1585E+00	-.1572E+00	-.1560E+00	-.1547E+00	-.1535E+00
-.1523E+00	-.1510E+00	-.1498E+00	-.1486E+00	-.1474E+00	-.1461E+00	-.1449E+00	-.1438E+00	-.1426E+00	-.1414E+00
-.1403E+00	-.1391E+00	-.1380E+00	-.1369E+00	-.1358E+00	-.1347E+00	-.1336E+00	-.1325E+00	-.1314E+00	-.1303E+00
-.1292E+00	-.1281E+00	-.1271E+00	-.1260E+00	-.1250E+00	-.1239E+00	-.1229E+00	-.1219E+00	-.1208E+00	-.1198E+00
-.1187E+00	-.1176E+00	-.1166E+00	-.1157E+00	-.1147E+00	-.1137E+00	-.1128E+00	-.1118E+00	-.1108E+00	-.1098E+00
-.1088E+00	-.1078E+00	-.1068E+00	-.1058E+00	-.1049E+00	-.1039E+00	-.1029E+00	-.1018E+00	-.1008E+00	-.9970E-01
-.9862E-01	-.9755E-01	-.9646E-01	-.9537E-01	-.9429E-01	-.9319E-01	-.9210E-01	-.9103E-01	-.8995E-01	-.8887E-01

(PW-PE)/UREF**2=

0	-.1267E-02	-.1290E-02	-.1283E-02	-.1297E-02	-.1304E-02	-.1307E-02	-.1302E-02	-.1296E-02	-.1284E-02
-.1268E-02	-.1252E-02	-.1235E-02	-.1219E-02	-.1213E-02	-.1208E-02	-.1201E-02	-.1194E-02	-.1185E-02	-.1173E-02
-.1160E-02	-.1144E-02	-.1125E-02	-.1104E-02	-.1082E-02	-.1057E-02	-.1032E-02	-.1009E-02	-.9854E-03	-.9605E-03
-.9347E-03	-.9075E-03	-.8794E-03	-.8507E-03	-.8217E-03	-.7926E-03	-.7637E-03	-.7352E-03	-.7072E-03	-.6799E-03
-.6563E-03	-.6337E-03	-.6119E-03	-.5910E-03	-.5711E-03	-.5521E-03	-.5340E-03	-.5167E-03	-.4883E-03	-.4880E-03
-.4770E-03	-.4623E-03	-.4311E-03	-.4121E-03	-.4127E-03	-.4037E-03	-.4106E-03	-.4058E-03	-.3967E-03	-.3847E-03
-.3712E-03	-.3698E-03	-.3332E-03	-.3137E-03	-.2980E-03	-.2837E-03	-.2730E-03	-.2651E-03	-.2582E-03	-.2520E-03
-.2638E-03	-.2637E-03	-.3378E-03	-.3812E-03	-.3907E-03	-.3668E-03	-.3565E-03	-.3691E-03	-.3750E-03	-.3751E-03
-.3737E-03	-.3764E-03	-.3779E-03	-.3758E-03	-.3711E-03	-.3676E-03	-.3663E-03	-.3571E-03	-.3170E-03	-.2680E-03
-.2147E-03	-.1535E-03	-.1492E-03	-.1750E-03	-.1875E-03	-.1986E-03	-.2054E-03	-.2097E-03	-.1945E-03	-.2098E-03
-.2229E-03	-.2019E-03	-.1833E-03	-.2022E-03	-.2224E-03	-.2299E-03	-.2307E-03	-.2212E-03	-.2107E-03	-.1899E-03
-.1719E-03	-.1658E-03	-.1592E-03	-.1532E-03	-.1468E-03	-.1451E-03	-.1419E-03	-.1558E-03	-.1679E-03	-.1679E-03

SWEEP NO. 2 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 3 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

0	.1915E-02	-.8619E-02	-.1844E-02	-.1370E-02	-.1766E-04	.9671E-03	-.5161E-02	.3893E-02	.3897E-02
.3956E-02	.3994E-02	.1572E-02	.2648E-02	.2483E-02	.1988E-02	.1162E-02	.6243E-03	.3239E-03	0
.3239E-03	.6243E-03	.1162E-02	.1988E-02	.2483E-02	.2648E-02	.1572E-02	.3994E-02	.3956E-02	.3897E-02
.3893E-02	-.5161E-02	.9671E-03	-.1766E-04	-.1370E-02	-.1844E-02	-.8619E-02	.1915E-02	0	

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.6753E-03	-.3261E-02	-.4203E-02	-.4739E-02	-.6007E-02	-.6574E-02	-.1008E-01	-.8089E-02	-.6333E-02	-.6318E-02
-.6225E-02	-.6985E-02	-.6901E-02	-.6733E-02	-.7194E-02	-.6821E-02	-.4533E-02	-.2554E-02	-.9164E-03	-.9164E-03
-.2554E-02	-.4533E-02	-.6821E-02	-.7194E-02	-.6733E-02	-.6901E-02	-.6985E-02	-.6225E-02	-.6318E-02	-.6333E-02
-.8089E-02	-.1008E-01	-.6574E-02	-.6007E-02	-.4739E-02	-.4203E-02	-.3261E-02	.6753E-03		

RUN NO. 3 OF PROGRAM AMOS

INCIDENCE = 0 CHORD = 1.000

X	Y	SSM	CP	U(TANG)	V(NORM)
.00229	.00623	.00664	.80191	.44507	.00068
.00832	.01600	.01842	.10880	.94403	-.00326
.01829	.02335	.03088	-.14491	1.07001	-.00420
.03702	.03212	.05163	-.31013	1.14451	-.00474
.06204	.04050	.07806	-.40954	1.18724	-.00601
.08709	.04656	.10384	-.44188	1.20078	-.00657
.12464	.05287	.14194	-.43858	1.19941	-.01008
.17474	.05853	.19238	-.43278	1.19699	-.00809
.22487	.06152	.24260	-.39979	1.18313	-.00633
.27496	.06284	.29272	-.37187	1.17127	-.00632
.35006	.06215	.36783	-.31675	1.14750	-.00622
.45015	.05861	.46800	-.26058	1.12276	-.00699
.55022	.05240	.56827	-.20452	1.09750	-.00690
.65027	.04415	.66866	-.14992	1.07234	-.00673
.75027	.03406	.76917	-.08865	1.04338	-.00719
.85021	.02220	.86982	-.00984	1.00491	-.00682
.92513	.01232	.94539	.07180	.96343	-.00453
.96258	.00694	.98322	.12635	.93469	-.00255
.98753	.00255	1.00856	.24161	.87085	-.00092
.98753	-.00255	1.03402	.24161	-.87085	-.00092
.96258	-.00694	1.05936	.12635	-.93469	-.00255
.92513	-.01232	1.09719	.07180	-.96343	-.00453
.85021	-.02220	1.17276	-.00984	-1.00491	-.00682
.75027	-.03406	1.27341	-.08865	-1.04338	-.00719
.65027	-.04415	1.37392	-.14992	-1.07234	-.00673
.55022	-.05240	1.47431	-.20452	-1.09750	-.00690
.45015	-.05861	1.57458	-.26058	-1.12276	-.00699
.35006	-.06215	1.67475	-.31675	-1.14750	-.00622

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   .27496   -.06284   1.74986   -.37187  -1.17127   -.00632
   .22487   -.06152   1.79998   -.39979  -1.18313   -.00633
   .17474   -.05853   1.85020   -.43278  -1.19699   -.00809
   .12464   -.05287   1.90064   -.43858  -1.19941   -.01008
   .08709   -.04656   1.93874   -.44189  -1.20078   -.00657
   .06204   -.04050   1.96452   -.40954  -1.18724   -.00601
   .03702   -.03212   1.99095   -.31013  -1.14461   -.00474
   .01829   -.02335   2.01170   -.14491  -1.07001   -.00420
   .00832   -.01600   2.02415    .10880   -.94403   -.00326
   .00229   -.00623   2.03594    .80191   -.44507    .00068
LIFT COEFFICIENT = -.000

ARC LENGTH FOR STAGN. PT. ON M.S.=   2.04258


RUN NO.  3  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS INTERACTION CYCLE--AEROFOIL TEST CASE


1977    0   10  119   16    5    0    0    1    0   51    0   -2    0
A                 0  1.000E-01           0  7.500E+06             0  1.000E+00  3.000E-01

THWAITES LAMINAR B.L. CALC.
      X          THETA       RTHETA          UE           VE
          0   .6645E-05           0            0            0
   .1319E-01  .1289E-04   .7676E+02   .7940E+00   .1913E-02
   .2327E-01  .1953E-04   .1497E+03   .1022E+01  -.8555E-02
   .3770E-01  .3003E-04   .2480E+03   .1101E+01  -.1782E-02
   .6441E-01  .4240E-04   .3726E+03   .1172E+01  -.1376E-02
   .9023E-01  .5308E-04   .4763E+03   .1196E+01  -.4847E-04
   .1157E+00  .6324E-04   .5700E+03   .1202E+01   .9255E-03
   .1661E+00  .8127E-04   .7325E+03   .1199E+01   .1289E-02

SYNTHETIC STARTING PROFILES   THETA/DELTA= .1049
X FOR CURV. B. VALUE              0  1.319E-02  2.327E-02  3.770E-02  6.441E-02  9.023E-02  1.157E-01
 1.661E-01  2.163E-01  2.663E-01  3.163E-01  4.163E-01  5.165E-01  6.167E-01
         I          I
CURV     6.302E+01  3.406E+01  1.735E+01  8.571E+00  3.819E+00  2.344E+00  1.664E+00
 1.035E+00  7.407E-01  5.675E-01  4.517E-01  3.049E-01  2.175E-01  1.651E-01
 1.377E-01  1.307E-01
X FOR PRESS. AND NP B. VALUES             0   1.3194E-02   2.3271E-02   3.7701E-02   6.4410E-02   9.0229E-02   1.1569E-01
  1.6613E-01   2.1628E-01   2.6632E-01   3.1633E-01   4.1635E-01   5.1648E-01   6.1674E-01
PE-PREF        5.0000E-01   1.8479E-01  -2.2239E-02  -1.0616E-01  -1.8657E-01  -2.1563E-01  -2.2212E-01
 -2.1833E-01  -2.0910E-01  -1.9269E-01  -1.7741E-01  -1.4319E-01  -1.1654E-01  -8.8437E-02
NP             0   4.8981E-04   7.3881E-04   1.1276E-03   1.5912E-03   1.9812E-03   2.3821E-03
  3.1240E-03
NP   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03

STN.          X       YSTEP        CF          UE     DEL05       THETA    SCHMETA         H     RTHETA      I6
   1  .1661E+00  .1562E-03    .004736  .1199E+01  .9062E-03  .8136E-04  .8136E-04    1.46086  .7314E+03     18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
        0  .9379E-03         0           0            0
REYNOLDS NUMBER TOO SMALL

STN.          X       YSTEP        CF          UE     DEL05       THETA    SCHMETA         H     RTHETA      I6
   2  .1705E+00  .1562E-03    .004739  .1198E+01  .7791E-03  .9544E-04  .9195E-04    1.38548  .8574E+03     18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
        0  .7866E-03         0           0            0

STN.          X       YSTEP        CF          UE     DEL05       THETA    SCHMETA         H     RTHETA      I6
  10  .2025E+00  .1562E-03    .003936  .1192E+01  .1460E-02  .1712E-03  .1631E-03    1.39561  .1530E+04     18
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 ROUGH/DO5     DO5/RAD DD5/(X-XO) STRAIN.DO5        VW/UE
         0  .1200E-02          0           0          0

STN.           X        YSTEP        CF         UE    DEL05        THETA    SCHMETA          H     RTHETA      I6
. 20  .2414E+00  .1562E-03    .0D3589  .1184E+01  .2107E-02  .2546E-03  .2430E-03      1.37832  .2260E+04       18

 RGUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .1377E-02          0           0          0

STN.           X        YSTEP        CF         UE    DEL05        THETA    SCHMETA          H     RTHETA      I6
  30  .2800E+00  .1562E-03    .003334  .1174E+01  .2727E-02  .3324E-03  .3218E-03      1.37611  .2927E+04       18

 ROUGH/DO5     DO5/RAO 005/(X-XO) STRAIN.DO5        VW/UE
         0  .1461E-02          0           0          0

STN.           X        YSTEP        CF         UE    DEL05        THETA    SCHMETA          H     RTHETA      I6
  40  .3182E+00  .1562E-03    .003147  .1163E+01  .2929E-02  .4029E-03  .4019E-03      1.38394  .3516E+04       16

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .1315E-02          0           0          0

STN.           X        YSTEP        CF         UE    DEL05        THETA    SCHMETA          H     RTHETA      I6
  50  .3562E+00  .1562E-03    .002968  .1153E+01  .2792E-02  .4590E-03  .4831E-03      1.40975  .3968E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .1098E-02          0           0          0

STN.           X        YSTEP        CF         UE    DEL05        THETA    SCHMETA          H     RTHETA      I6
  60  .3938E+00  .1562E-03    .002766  .1142E+01  .2951E-02  .4865E-03  .5648E-03      1.46063  .4168E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .9974E-03          0           0          0

STN.           X        YSTEP        CF         UE    DEL05        THETA    SCHMETA          H     RTHETA      I6
  70  .4311E+00  .1562E-03    .002570  .1132E+01  .2958E-02  .5130E-03  .6463E-03      1.50440  .4355E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .8637E-03          0           0          0

STN.           X        YSTEP        CF         UE    DEL05        THETA    SCHMETA          H     RTHETA      I6
  80  .4682E+00  .1562E-03    .002394  .1122E+01  .2937E-02  .5212E-03  .7277E-03      1.54777  .4386E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .7626E-03          0           0          0

STN.           X        YSTEP        CF         UE    DEL05        THETA    SCHMETA          H     RTHETA      I6
  90  .5047E+00  .1562E-03    .002279  .1113E+01  .1863E-02  .5611E-03  .8089E-03      1.56391  .4684E+04       18

 RGUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .4243E-03          0           0          0

STN.           X        YSTEP        CF         UE    DEL05        THETA    SCHMETA          H     RTHETA      I6
 100  .5415E+00  .1562E-03    .002159  .1104E+01  .2852E-02  .4635E-03  .8914E-03      1.64051  .3839E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .5831E-03          0           0          0

STN.           X        YSTEP        CF         UE    DEL05        THETA    SCHMETA          H     RTHETA      I6
 110  .5775E+00  .1562E-03    .002169  .1095E+01  .2951E-02  .4982E-03  .9741E-03      1.53111  .4092E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .5478E-03          0           0          0
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STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
119	.6104E+00	.1562E-03	.002586	.1087E+01	.2957E-02	.5240E-03	.1062E-02	1.49820	.4270E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.4979E-03	0	0	0

X=

.1661E+00	.1705E+00	.1744E+00	.1785E+00	.1825E+00	.1866E+00	.1906E+00	.1946E+00	.1985E+00	.2025E+00
.2064E+00	.2103E+00	.2142E+00	.2181E+00	.2220E+00	.2259E+00	.2298E+00	.2337E+00	.2376E+00	.2414E+00
.2453E+00	.2492E+00	.2531E+00	.2569E+00	.2608E+00	.2646E+00	.2685E+00	.2723E+00	.2761E+00	.2800E+00
.2838E+0D	.2877E+00	.2915E+00	.2953E+00	.2991E+00	.3030E+00	.3068E+00	.3106E+00	.3144E+00	.3182E+00
.3220E+00	.3258E+00	.3296E+00	.3334E+00	.3372E+00	.3410E+00	.3448E+00	.3486E+00	.3524E+00	.3562E+00
.3599E+00	.3637E+00	.3675E+00	.3713E+00	.3750E+00	.3788E+00	.3826E+00	.3863E+00	.3901E+00	.3938E+00
.3976E+00	.4013E+00	.4050E+00	.4088E+00	.4125E+00	.4162E+00	.4200E+00	.4237E+00	.4274E+00	.4311E+00
.4349E+00	.4386E+00	.4423E+00	.4460E+00	.4497E+00	.4534E+00	.4571E+00	.4608E+00	.4645E+00	.4682E+00
.4718E+00	.4755E+00	.4792E+00	.4828E+00	.4865E+00	.4901E+00	.4938E+00	.4974E+00	.5011E+00	.5047E+00
.5084E+00	.5121E+00	.5158E+00	.5195E+00	.5231E+00	.5268E+00	.5305E+00	.5342E+00	.5378E+00	.5415E+00
.5451E+00	.5488E+00	.5524E+00	.5559E+00	.5595E+00	.5631E+00	.5667E+00	.5703E+00	.5739E+00	.5775E+00
.5812E+00	.5848E+00	.5885E+00	.5922E+00	.5958E+00	.5995E+00	.6031E+00	.6068E+00	.6104E+00	.6140E+00

VE/UE=

.3063E-02	.3465E-02	.3484E-02	.3614E-02	.3657E-02	.3656E-02	.3606E-02	.3538E-02	.3464E-02	.3381E-02
.3321E-02	.3273E-02	.3243E-02	.3225E-02	.3218E-02	.3217E-02	.3219E-02	.3223E-02	.3224E-02	.3226E-02
.3229E-02	.3232E-02	.3236E-02	.3242E-02	.3250E-02	.3258E-02	.3267E-02	.3276E-02	.3284E-02	.3291E-02
.3297E-02	.3302E-02	.3307E-02	.3313E-02	.3318E-02	.3325E-02	.3332E-02	.3339E-02	.3347E-02	.3355E-02
.3363E-02	.3371E-02	.3379E-02	.3387E-02	.3396E-02	.3406E-02	.3416E-02	.3426E-02	.3437E-02	.3469E-02
.3456E-02	.3458E-02	.3452E-02	.3489E-02	.3531E-02	.3566E-02	.3525E-02	.3503E-02	.3472E-02	.3452E-02
.3438E-02	.3387E-02	.3362E-02	.3336E-02	.3315E-02	.3294E-02	.3274E-02	.3257E-02	.3240E-02	.3223E-02
.3205E-02	.3186E-02	.3221E-02	.3152E-02	.3111E-02	.3124E-02	.3172E-02	.3089E-02	.3033E-02	.2957E-02
.2903E-02	.2864E-02	.2763E-02	.2757E-02	.2793E-02	.2859E-02	.2958E-02	.3077E-02	.3209E-02	.3352E-02
.3483E-02	.3291E-02	.3083E-02	.2775E-02	.2689E-02	.2686E-02	.2599E-02	.2493E-02	.2383E-02	.2270E-02
.2146E-02	.1998E-02	.1855E-02	.1687E-02	.1499E-02	.1285E-02	.1051E-02	.7900E-03	.5422E-03	.5065E-03
.5266E-03	.8380E-03	.1449E-02	.1828E-02	.2141E-02	.2367E-02	.2541E-02	.2672E-02	.2774E-02	

(PW-PREF)/UREF**2=

-.2183E+00	-.2187E+00	-.2178E+00	-.2170E+00	-.2161E+00	-.2153E+00	-.2144E+00	-.2135E+00	-.2126E+00	-.2117E+00
-.2108E+00	-.2099E+00	-.2090E+00	-.2080E+00	-.2071E+00	-.2061E+00	-.2052E+00	-.2042E+00	-.2032E+00	-.2021E+00
-.2011E+00	-.2000E+00	-.1989E+00	-.1977E+00	-.1966E+00	-.1954E+00	-.1942E+00	-.1930E+00	-.1918E+00	-.1905E+00
-.1893E+00	-.1880E+00	-.1868E+00	-.1855E+00	-.1842E+00	-.1829E+00	-.1816E+00	-.1803E+00	-.1790E+00	-.1777E+00
-.1764E+00	-.1751E+00	-.1739E+00	-.1726E+00	-.1713E+00	-.1700E+00	-.1688E+00	-.1675E+00	-.1662E+00	-.1650E+00
-.1637E+00	-.1625E+00	-.1612E+00	-.1600E+00	-.1588E+00	-.1576E+00	-.1564E+00	-.1552E+00	-.1540E+00	-.1528E+00
-.1516E+00	-.1504E+00	-.1492E+00	-.1480E+00	-.1468E+00	-.1457E+00	-.1445E+00	-.1434E+00	-.1422E+00	-.1411E+00
-.1399E+00	-.1388E+00	-.1377E+00	-.1366E+00	-.1355E+00	-.1343E+00	-.1333E+00	-.1322E+00	-.1312E+00	-.1301E+00
-.1290E+00	-.1280E+00	-.1269E+00	-.1258E+00	-.1248E+00	-.1238E+00	-.1228E+00	-.1218E+00	-.1208E+00	-.1198E+00
-.1188E+00	-.1179E+00	-.1169E+00	-.1160E+00	-.1150E+00	-.1140E+00	-.1130E+00	-.1121E+00	-.1111E+00	-.1101E+00
-.1091E+00	-.1081E+00	-.1072E+00	-.1062E+00	-.1052E+00	-.1042E+00	-.1032E+00	-.1022E+00	-.1012E+00	-.1001E+00
-.9902E-01	-.9791E-01	-.9684E-01	-.9580E-01	-.9475E-01	-.9369E-01	-.9263E-01	-.9156E-01	-.9050E-01	-.8943E-01

(PW-PE)/UREF**2=

0	-.1285E-02	-.1329E-02	-.1346E-02	-.1382E-02	-.1412E-02	-.1435E-02	-.1451E-02	-.1465E-02	-.1472E-02
-.1474E-02	-.1475E-02	-.1474E-02	-.1473E-02	-.1481E-02	-.1488E-02	-.1493E-02	-.1496E-02	-.1495E-02	-.1490E-02
-.1481E-02	-.1468E-02	-.1451E-02	-.1430E-02	-.1405E-02	-.1378E-02	-.1347E-02	-.1319E-02	-.1288E-02	-.1255E-02
-.1221E-02	-.1184E-02	-.1147E-02	-.1108E-02	-.1069E-02	-.1030E-02	-.9904E-03	-.9519E-03	-.9143E-03	-.8779E-03
-.8457E-03	-.8151E-03	-.7861E-03	-.7586E-03	-.7325E-03	-.7080E-03	-.6849E-03	-.6631E-03	-.6313E-03	-.6217E-03
-.6133E-03	-.5973E-03	-.5633E-03	-.5412E-03	-.5406E-03	-.5308E-03	-.5360E-03	-.5304E-03	-.5208E-03	-.5087E-03
-.4955E-03	-.4942E-03	-.4840E-03	-.4743E-03	-.4668E-03	-.4603E-03	-.4544E-03	-.4499E-03	-.4462E-03	-.4427E-03
-.4395E-03	-.4165E-03	-.4320E-03	-.4443E-03	-.4185E-03	-.3991E-03	-.4169E-03	-.4383E-03	-.4446E-03	-.4435E-03
-.4321E-03	-.4213E-03	-.4008E-03	-.3777E-03	-.3641E-03	-.3516E-03	-.3407E-03	-.3316E-03	-.3228E-03	-.3358E-03
-.3375E-03	-.3993E-03	-.4345E-03	-.4266E-03	-.3936E-03	-.3893E-03	-.3970E-03	-.3958E-03	-.3917E-03	-.3834E-03
-.3753E-03	-.3519E-03	-.3583E-03	-.3596E-03	-.3537E-03	-.3486E-03	-.3447E-03	-.3354E-03	-.3009E-03	-.2568E-03
-.2111E-03	-.1559E-03	-.1477E-03	-.1717E-03	-.1829E-03	-.1927E-03	-.1985E-03	-.2021E-03	-.2110E-03	-.2110E-03

SWEEP NO. 3 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 4 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

0	.1913E-02	-.8555E-02	-.1782E-02	-.1376E-02	-.4847E-04	.9255E-03	-.5188E-02	.3834E-02	.3840E-02
.3902E-02	.3740E-02	.3338E-02	.4413E-02	.4139E-02	.3314E-02	.1937E-02	.1041E-02	.5400E-03	0
.5400E-03	.1041E-02	.1937E-02	.3314E-02	.4139E-02	.4413E-02	.3338E-02	.3740E-02	.3902E-02	.3840E-02
.3834E-02	-.5188E-02	.9255E-03	-.4847E-04	-.1376E-02	-.1782E-02	-.8555E-02	.1913E-02	0	

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.1411E-02	-.3751E-02	-.4320E-02	-.3828E-02	-.4406E-02	-.4368E-02	-.8264E-02	-.5527E-02	-.3284E-02	-.3258E-02
-.3202E-02	-.3883E-02	-.3618E-02	-.3410E-02	-.3897E-02	-.3966E-02	-.2721E-02	-.1549E-02	-.5592E-03	-.5592E-03
-.1549E-02	-.2721E-02	-.3966E-02	-.3897E-02	-.3410E-02	-.3618E-02	-.3863E-02	-.3202E-02	-.3258E-02	-.3284E-02
-.5527E-02	-.8264E-02	-.4368E-02	-.4406E-02	-.3828E-02	-.4320E-02	-.3751E-02	.1411E-02		

RUN NO. 4 OF PROGRAM AMOS

INCIDENCE = 0 CHORD = 1.000

X	Y	SSM	CP	U (TANG)	V (NORM)
.00229	.00623	.00664	.80248	.44443	.00141
.00832	.01600	.01842	.11221	.94223	-.00375
.01829	.02335	.03088	-.13876	1.06713	-.00432
.03702	.03212	.05163	-.30285	1.14142	-.00383
.06204	.04050	.07806	-.40207	1.18409	-.00441
.08709	.04556	.10384	-.43532	1.19805	-.00437
.12464	.05287	.14194	-.43243	1.19684	-.00826
.17474	.05853	.19238	-.42683	1.19450	-.00553
.22487	.06152	.24260	-.39509	1.18114	-.00328
.27496	.06284	.29272	-.36838	1.16978	-.00326
.35006	.06215	.36783	-.31435	1.14645	-.00320
.45015	.05861	.46800	-.25927	1.12217	-.00388
.55022	.05240	.56827	-.20436	1.09743	-.00362
.65027	.04415	.66866	-.15109	1.07289	-.00341
.75027	.03406	.76917	-.09137	1.04469	-.00390
.85021	.02220	.86982	-.01429	1.00712	-.00397
.92513	.01232	.94539	.06594	.96647	-.00272
.96258	.00694	.98322	.12031	.93792	-.00155
.98753	.00255	1.00856	.23668	.87368	-.00056
.98753	-.00255	1.03402	.23668	-.87368	-.00056
.96258	-.00694	1.05936	.12031	-.93792	-.00155
.92513	-.01232	1.09719	.06594	-.96647	-.00272
.85021	-.02220	1.17276	-.01429	-1.00712	-.00397
.75027	-.03406	1.27341	-.09137	-1.04469	-.00390
.65027	-.04415	1.37392	-.15109	-1.07289	-.00341
.55022	-.05240	1.47431	-.20436	-1.09743	-.00362
.45015	-.05861	1.57458	-.25927	-1.12217	-.00388
.35006	-.06215	1.67475	-.31435	-1.14645	-.00320
.27496	-.06284	1.74986	-.36838	-1.16978	-.00326
.22487	-.06152	1.79998	-.39509	-1.18114	-.00328

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    .17474    -.05853    1.85020    -.42683  -1.19450    -.00553
    .12464    -.05287    1.90064    -.43243  -1.19684    -.00826
    .08709    -.04656    1.93874    -.43532  -1.19805    -.00437
    .06204    -.04050    1.96452    -.40207  -1.18409    -.00441
    .03702    -.03212    1.99095    -.30285  -1.14142    -.00383
    .01829    -.02335    2.01170    -.13876  -1.06713    -.00432
    .00832    -.01600    2.02415     .11221   -.94223    -.00375
    .00229    -.00623    2.03594     .80248   -.44443     .00141
LIFT COEFFICIENT = -.000

ARC LENGTH FOR STAGN. PT. ON M.S.=   2.04258

RUN NO.  4  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS INTERACTION CYCLE--AEROFOIL TEST CASE

1977    0   10  119   16    5    0    0    1    0   51    0   -2    0
A                  0  1.000E-01            0  7.500E+06            0  1.000E+00  3.000E-01

THWAITES LAMINAR B.L. CALC.
       X          THETA       RTHETA           UE           VE
           0   .6649E-05           0           0           0
   .1319E-01   .1290E-04   .7670E+02   .7926E+00   .1911E-02
   .2327E-01   .1956E-04   .1496E+03   .1020E+01  -.8509E-02
   .3770E-01   .3011E-04   .2479E+03   .1098E+01  -.1739E-02
   .6441E-01   .4246E-04   .3722E+03   .1169E+01  -.1380E-02
   .9023E-01   .5313E-04   .4755E+03   .1193E+01  -.6950E-04
   .1157E+00   .6325E-04   .5689E+03   .1199E+01   .8973E-03
   .1661E+00   .8130E-04   .7312E+03   .1196E+01   .1285E-02

SYNTHETIC STARTING PROFILES   THETA/DELTA= .1048
X FOR CURV. B. VALUE              0  1.319E-02  2.327E-02  3.770E-02  6.441E-02  9.023E-02  1.157E-01
 1.661E-01  2.163E-01  2.663E-01  3.163E-01  4.163E-01  5.165E-01  6.167E-01
         I          I
CURV      6.302E+01  3.406E+01  1.735E+01  8.571E+00  3.819E+00  2.344E+00  1.664E+00
 1.035E+00  7.407E-01  5.675E-01  4.517E-01  3.049E-01  2.175E-01  1.651E-01
 1.377E-01  1.307E-01
X FOR PRESS. AND NP B. VALUES              0  1.3194E-02  2.3271E-02  3.7701E-02  6.4410E-02  9.0229E-02  1.1569E-01
  1.6613E-01  2.1628E-01  2.6632E-01  3.1633E-01  4.1635E-01  5.1648E-01  6.1674E-01
PE-PREF      5.0000E-01  1.8587E-01  -1.9906E-02  -1.0269E-01  -1.8284E-01  -2.1209E-01  -2.1899E-01
 -2.1526E-01  -2.0640E-01  -1.9067E-01  -1.7589E-01  -1.4226E-01  -1.1616E-01  -8.8682E-02
NP             0   4.8981E-04   7.3881E-04   1.1276E-03   1.5912E-03   1.9812E-03   2.3821E-03
  3.1240E-03
NP   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03

STN.           X       YSTEP        CF          UE     DEL05       THETA    SCHMETA        H     RTHETA     I6
   1  .1661E+00  .1562E-03   .004739  .1196E+01  .9062E-03  .8133E-04  .8133E-04    1.46101  .7296E+03    18

 ROUGH/D05     D05/RAD D05/(X-XD) STRAIN.D05      VW/UE
         0  .9379E-03          0          0          0
REYNOLDS NUMBER TOO SMALL

STN.           X       YSTEP        CF          UE     DEL05       THETA    SCHMETA        H     RTHETA     I6
   2  .1705E+00  .1562E-03   .004743  .1195E+01  .7791E-03  .9524E-04  .9189E-04    1.38787  .8538E+03    18

 ROUGH/D05     D05/RAD D05/(X-XD) STRAIN.D05      VW/UE
         0  .7865E-03          0          0          0

STN.           X       YSTEP        CF          UE     DEL05       THETA    SCHMETA        H     RTHETA     I6
  10  .2025E+00  .1562E-03   .003940  .1190E+01  .1459E-02  .1708E-03  .1627E-03    1.39678  .1524E+04    18

 ROUGH/D05     D05/RAD D05/(X-XD) STRAIN.D05      VW/UE
```

0	.1199E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
20	.2414E+00	.1562E-03	.003594	.1182E+01	.2105E-02	.2539E-03	.2423E-03	1.37889	.2251E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.1376E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
30	.2800E+00	.1562E-03	.003339	.1172E+01	.2723E-02	.3316E-03	.3208E-03	1.37640	.2916E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.1459E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
40	.3182E+00	.1562E-03	.003152	.1162E+01	.2928E-02	.4020E-03	.4006E-03	1.38399	.3504E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.1315E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
50	.3562E+00	.1562E-03	.002972	.1152E+01	.2792E-02	.4582E-03	.4813E-03	1.40952	.3958E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.1098E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
60	.3938E+00	.1562E-03	.002770	.1141E+01	.2951E-02	.4859E-03	.5625E-03	1.46018	.4159E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.9974E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
70	.4311E+00	.1562E-03	.002574	.1131E+01	.2958E-02	.5125E-03	.6435E-03	1.50373	.4348E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.8637E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
80	.4682E+00	.1562E-03	.002398	.1122E+01	.2937E-02	.5206E-03	.7242E-03	1.54685	.4380E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.7626E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
90	.5047E+00	.1562E-03	.002285	.1113E+01	.1863E-02	.5604E-03	.8045E-03	1.56268	.4676E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.4243E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
100	.5415E+00	.1562E-03	.002166	.1104E+01	.2849E-02	.4628E-03	.8858E-03	1.63901	.3833E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.5824E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
110	.5775E+00	.1562E-03	.002171	.1095E+01	.2951E-02	.4973E-03	.9674E-03	1.53044	.4085E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.5478E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
119	.6104E+00	.1562E-03	.002590	.1087E+01	.2957E-02	.5232E-03	.1055E-02	1.49739	.4264E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.4979E-03	0	0	0

X=

.1661E+00	.1705E+00	.1744E+00	.1785E+00	.1825E+00	.1866E+00	.1906E+00	.1946E+00	.1985E+00	.2025E+00
.2064E+00	.2103E+00	.2142E+00	.2181E+00	.2220E+00	.2259E+00	.2298E+00	.2337E+00	.2376E+00	.2414E+00
.2453E+00	.2492E+00	.2531E+00	.2569E+00	.2608E+00	.2646E+00	.2685E+00	.2723E+00	.2761E+00	.2800E+00
.2838E+00	.2877E+00	.2915E+00	.2953E+00	.2991E+00	.3030E+00	.3068E+00	.3106E+00	.3144E+00	.3182E+00
.3220E+00	.3258E+00	.3296E+00	.3334E+00	.3372E+00	.3410E+00	.3448E+00	.3486E+00	.3524E+00	.3562E+00
.3599E+00	.3637E+00	.3675E+00	.3713E+00	.3750E+00	.3788E+00	.3826E+00	.3863E+00	.3901E+00	.3938E+00
.3976E+00	.4013E+00	.4050E+00	.4089E+00	.4125E+00	.4162E+00	.4200E+00	.4237E+00	.4274E+00	.4311E+00
.4349E+00	.4386E+00	.4423E+00	.4460E+00	.4497E+00	.4534E+00	.4571E+00	.4608E+00	.4645E+00	.4682E+00
.4718E+00	.4755E+00	.4792E+00	.4828E+00	.4865E+00	.4901E+00	.4938E+00	.4974E+00	.5011E+00	.5047E+00
.5084E+00	.5121E+00	.5158E+00	.5195E+00	.5231E+00	.5268E+00	.5305E+00	.5342E+00	.5378E+00	.5415E+00
.5451E+00	.5488E+00	.5524E+00	.5559E+00	.5595E+00	.5631E+00	.5667E+00	.5703E+00	.5739E+00	.5775E+00
.5812E+00	.5848E+00	.5885E+00	.5922E+00	.5958E+00	.5995E+00	.6031E+00	.6068E+00	.6104E+00	.6140E+00

VE/UE=

.3039E-02	.3436E-02	.3458E-02	.3587E-02	.3630E-02	.3629E-02	.3578E-02	.3510E-02	.3436E-02	.3353E-02
.3293E-02	.3244E-02	.3214E-02	.3196E-02	.3190E-02	.3188E-02	.3190E-02	.3194E-02	.3195E-02	.3198E-02
.3200E-02	.3203E-02	.3208E-02	.3214E-02	.3222E-02	.3230E-02	.3239E-02	.3248E-02	.3256E-02	.3264E-02
.3271E-02	.3276E-02	.3281E-02	.3287E-02	.3293E-02	.3300E-02	.3307E-02	.3315E-02	.3324E-02	.3332E-02
.3340E-02	.3349E-02	.3357E-02	.3366E-02	.3376E-02	.3386E-02	.3396E-02	.3407E-02	.3418E-02	.3451E-02
.3438E-02	.3441E-02	.3435E-02	.3472E-02	.3515E-02	.3550E-02	.3509E-02	.3488E-02	.3457E-02	.3438E-02
.3424E-02	.3373E-02	.3349E-02	.3322E-02	.3301E-02	.3280E-02	.3261E-02	.3243E-02	.3226E-02	.3208E-02
.3190E-02	.3171E-02	.3205E-02	.3136E-02	.3095E-02	.3108E-02	.3154E-02	.3071E-02	.3015E-02	.2938E-02
.2884E-02	.2844E-02	.2743E-02	.2736E-02	.2771E-02	.2835E-02	.2934E-02	.3050E-02	.3180E-02	.3321E-02
.3450E-02	.3259E-02	.3052E-02	.2746E-02	.2659E-02	.2656E-02	.2569E-02	.2465E-02	.2355E-02	.2244E-02
.2122E-02	.1975E-02	.1835E-02	.1668E-02	.1484E-02	.1274E-02	.1043E-02	.7859E-03	.5406E-03	.5012E-03
.5249E-03	.8214E-03	.1432E-02	.1810E-02	.2124E-02	.2350E-02	.2524E-02	.2654E-02	.2755E-02	

(PW-PREF)/UREF**2=

-.2153E+00	-.2157E+00	-.2149E+00	-.2141E+00	-.2133E+00	-.2124E+00	-.2116E+00	-.2108E+00	-.2100E+00	-.2091E+00
-.2083E+00	-.2074E+00	-.2065E+00	-.2056E+00	-.2048E+00	-.2038E+00	-.2029E+00	-.2020E+00	-.2010E+00	-.2000E+00
-.1990E+00	-.1979E+00	-.1969E+00	-.1958E+00	-.1947E+00	-.1935E+00	-.1924E+00	-.1912E+00	-.1900E+00	-.1888E+00
-.1876E+00	-.1864E+00	-.1852E+00	-.1839E+00	-.1827E+00	-.1814E+00	-.1801E+00	-.1789E+00	-.1776E+00	-.1763E+00
-.1751E+00	-.1738E+00	-.1726E+00	-.1713E+00	-.1701E+00	-.1668E+00	-.1676E+00	-.1663E+00	-.1651E+00	-.1638E+00
-.1626E+00	-.1614E+00	-.1602E+00	-.1589E+00	-.1577E+00	-.1565E+00	-.1553E+00	-.1542E+00	-.1530E+00	-.1518E+00
-.1506E+00	-.1494E+00	-.1483E+00	-.1471E+00	-.1459E+00	-.1448E+00	-.1436E+00	-.1425E+00	-.1414E+00	-.1402E+00
-.1391E+00	-.1380E+00	-.1369E+00	-.1358E+00	-.1347E+00	-.1336E+00	-.1326E+00	-.1315E+00	-.1305E+00	-.1294E+00
-.1284E+00	-.1273E+00	-.1263E+00	-.1253E+00	-.1242E+00	-.1232E+00	-.1222E+00	-.1213E+00	-.1203E+00	-.1193E+00
-.1184E+00	-.1175E+00	-.1166E+00	-.1156E+00	-.1147E+00	-.1137E+00	-.1128E+00	-.1119E+00	-.1109E+00	-.1100E+00
-.1090E+00	-.1080E+00	-.1071E+00	-.1062E+00	-.1052E+00	-.1042E+00	-.1033E+00	-.1023E+00	-.1012E+00	-.1002E+00
-.9912E-01	-.9803E-01	-.9698E-01	-.9596E-01	-.9492E-01	-.9388E-01	-.9283E-01	-.9179E-01	-.9074E-01	-.8970E-01

(PW-PE)/UREF**2=

0	-.1296E-02	-.1355E-02	-.1388E-02	-.1439E-02	-.1484E-02	-.1522E-02	-.1552E-02	-.1580E-02	-.1599E-02
-.1614E-02	-.1627E-02	-.1638E-02	-.1647E-02	-.1665E-02	-.1680E-02	-.1693E-02	-.1703E-02	-.1708E-02	-.1708E-02
-.1703E-02	-.1693E-02	-.1678E-02	-.1657E-02	-.1632E-02	-.1603E-02	-.1570E-02	-.1539E-02	-.1504E-02	-.1466E-02
-.1426E-02	-.1384E-02	-.1340E-02	-.1294E-02	-.1248E-02	-.1201E-02	-.1154E-02	-.1107E-02	-.1061E-02	-.1017E-02
-.9766E-03	-.9379E-03	-.9009E-03	-.8654E-03	-.8315E-03	-.7993E-03	-.7685E-03	-.7393E-03	-.7002E-03	-.6834E-03
-.6678E-03	-.6449E-03	-.6043E-03	-.5757E-03	-.5688E-03	-.5528E-03	-.5520E-03	-.5407E-03	-.5256E-03	-.5084E-03
-.4904E-03	-.4843E-03	-.4698E-03	-.4560E-03	-.4446E-03	-.4347E-03	-.4256E-03	-.4182E-03	-.4119E-03	-.4063E-03
-.4011E-03	-.3767E-03	-.3909E-03	-.4024E-03	-.3763E-03	-.3570E-03	-.3752E-03	-.3972E-03	-.4047E-03	-.4053E-03
-.3961E-03	-.3879E-03	-.3704E-03	-.3507E-03	-.3411E-03	-.3330E-03	-.3270E-03	-.3233E-03	-.3203E-03	-.3396E-03
-.3481E-03	-.4167E-03	-.4588E-03	-.4584E-03	-.4329E-03	-.4355E-03	-.4501E-03	-.4557E-03	-.4578E-03	-.4552E-03
-.4525E-03	-.4335E-03	-.4436E-03	-.4475E-03	-.4435E-03	-.4392E-03	-.4352E-03	-.4251E-03	-.3894E-03	-.3427E-03
-.2943E-03	-.2353E-03	-.2210E-03	-.2397E-03	-.2453E-03	-.2492E-03	-.2488E-03	-.2459E-03	-.2481E-03	-.2481E-03

SWEEP NO. 4 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 5 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

0	.1911E-02	-.8509E-02	-.1739E-02	-.1380E-02	-.6950E-04	.8973E-03	-.5207E-02	.3793E-02	.3801E-02
.3870E-02	.3722E-02	.3303E-02	.4378E-02	.4106E-02	.3288E-02	.1922E-02	.1032E-02	.5357E-03	0
.5357E-03	.1032E-02	.1922E-02	.3288E-02	.4106E-02	.4378E-02	.3303E-02	.3722E-02	.3870E-02	.3801E-02
.3793E-02	-.5207E-02	.8973E-03	-.6950E-04	-.1380E-02	-.1739E-02	-.8509E-02	.1911E-02	0	

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.1922E-02	-.4087E-02	-.4388E-02	-.3186E-02	-.3289E-02	-.2831E-02	-.7001E-02	-.3743E-02	-.1162E-02	-.1126E-02
-.1093E-02	-.1721E-02	-.1330E-02	-.1094E-02	-.1598E-02	-.1974E-02	-.1457E-02	-.8480E-03	-.3097E-03	-.3097E-03
-.8480E-03	-.1457E-02	-.1974E-02	-.1598E-02	-.1094E-02	-.1330E-02	-.1721E-02	-.1093E-02	-.1126E-02	-.1162E-02
-.3743E-02	-.7001E-02	-.2831E-02	-.3289E-02	-.3186E-02	-.4388E-02	-.4087E-02	.1922E-02		

RUN NO. 5 OF PROGRAM AMOS

INCIDENCE = 0 CHORD = 1.000

X	Y	SSM	CP	U (TANG)	V (NORM)
.00229	.00623	.00664	.80288	.44398	.00192
.00832	.01600	.01842	.11460	.94096	-.00409
.01829	.02335	.03088	-.13448	1.06512	-.00439
.03702	.03212	.05163	-.29780	1.13921	-.00319
.06204	.04050	.07806	-.39689	1.18190	-.00329
.08709	.04656	.10384	-.43076	1.19614	-.00283
.12464	.05287	.14194	-.42816	1.19506	-.00700
.17474	.05853	.19238	-.42271	1.19277	-.00374
.22487	.06152	.24260	-.39182	1.17976	-.00116
.27496	.06284	.29272	-.36596	1.16874	-.00113
.35006	.06215	.36783	-.31269	1.14573	-.00109
.45015	.05861	.46800	-.25836	1.12177	-.00172
.55022	.05240	.56827	-.20426	1.09739	-.00133
.65027	.04415	.66866	-.15192	1.07328	-.00109
.75027	.03406	.76917	-.09328	1.04560	-.00160
.85021	.02220	.85982	-.01740	1.00866	-.00197
.92513	.01232	.94539	.06183	.96859	-.00146
.96258	.00694	.98322	.11609	.94017	-.00085
.98753	.00255	1.00856	.23323	.87565	-.00031
.98753	-.00255	1.03402	.23323	-.87565	-.00031
.96258	-.00694	1.05936	.11609	-.94017	-.00085
.92513	-.01232	1.09719	.06183	-.96859	-.00146
.85021	-.02220	1.17276	-.01740	-1.00866	-.00197
.75027	-.03406	1.27341	-.09328	-1.04560	-.00160
.65027	-.04415	1.37392	-.15192	-1.07328	-.00109
.55022	-.05240	1.47431	-.20426	-1.09739	-.00133
.45015	-.05661	1.57458	-.25836	-1.12177	-.00172
.35006	-.06215	1.67475	-.31269	-1.14573	-.00109
.27496	-.06284	1.74986	-.36595	-1.16874	-.00113
.22487	-.06152	1.79398	-.39182	-1.17976	-.00116
.17474	-.05853	1.85020	-.42271	-1.19277	-.00374
.12464	-.05287	1.90064	-.42816	-1.19506	-.00700

.08709	-.04656	1.95874	-.43076	-1.19614	-.00283
.06204	-.04050	1.96452	-.39689	-1.18190	-.00329
.03702	-.03212	1.99095	-.29780	-1.13921	-.00319
.01829	-.02335	2.01170	-.13448	-1.06512	-.00439
.00832	-.01600	2.02415	.11450	-.94096	-.00409
.00229	-.00623	2.03594	.80288	-.44398	.00192

LIFT COEFFICIENT = -.000

ARC LENGTH FOR STAGN. PT. ON M.S.= 2.04258

RUN NO. 5 OF BOUNDARY LAYER CALCULATION

B.L. CALC. IN INVISCID/VISCOUS INTERACTION CYCLE—AEROFOIL TEST CASE

```
1977    0   10  119   16    5    0    0    1    0   51    0   -2    0
A              0  1.000E-01          0  7.500E+06          0  1.000E+00  3.000E-01
```

THWAITES LAMINAR B.L. CALC.

X	THETA	RTHETA	UE	VE
0	.6652E-05	0	0	0
.1319E-01	.1291E-04	.7665E+02	.7917E+00	.1910E-02
.2327E-01	.1958E-04	.1495E+03	.1018E+01	-.8478E-02
.3770E-01	.3016E-04	.2479E+03	.1096E+01	-.1709E-02
.6441E-01	.4251E-04	.3719E+03	.1166E+01	-.1383E-02
.9023E-01	.5316E-04	.4750E+03	.1191E+01	-.8414E-04
.1157E+00	.6326E-04	.5681E+03	.1197E+01	.8777E-03
.1661E+00	.8133E-04	.7303E+03	.1194E+01	.1282E-02

```
SYNTHETIC STARTING PROFILES   THETA/DELTA= .1048
X FOR CURV. B. VALUE             0  1.319E-02  2.327E-02  3.770E-02  6.441E-02  9.023E-02  1.157E-01
 1.661E-01  2.163E-01  2.663E-01  3.163E-01  4.163E-01  5.165E-01  6.167E-01
        I          I
CURV     6.302E+01  3.406E+01  1.735E+01  8.571E+00  3.819E+00  2.344E+00  1.664E+00
 1.035E+00  7.407E-01  5.675E-01  4.517E-01  3.049E-01  2.175E-01  1.651E-01
 1.377E-01  1.307E-01
X FOR PRESS. AND NP B. VALUES           0   1.3194E-02   2.3271E-02   3.7701E-02   6.4410E-02   9.0229E-02   1.1569E-01
  1.6613E-01   2.1628E-01   2.6632E-01   3.1633E-01   4.1635E-01   5.1648E-01   6.1674E-01
PE-PREF        5.0000E-01   1.8662E-01  -1.8278E-02  -1.0028E-01  -1.8025E-01  -2.0964E-01  -2.1681E-01
 -2.1313E-01  -2.0452E-01  -1.8927E-01  -1.7483E-01  -1.4163E-01  -1.1590E-01  -8.8860E-02
NP              0   4.8981E-04   7.3881E-04   1.1276E-03   1.5912E-03   1.9812E-03   2.3821E-03
  3.1240E-03
NP   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03
```

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
1	.1661E+00	.1562E-03	.004741	.1194E+01	.9063E-03	.8132E-04	.8132E-04	1.46112	.7284E+03	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.9360E-03	0	0	0

REYNOLDS NUMBER TOO SMALL

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
2	.1705E+00	.1562E-03	.004746	.1194E+01	.7790E-03	.9510E-04	.9185E-04	1.38955	.8513E+03	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.7865E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
10	.2025E+00	.1562E-03	.003943	.1188E+01	.1459E-02	.1705E-03	.1625E-03	1.39760	.1519E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1199E-02	0	0	0

```
STN.          X        YSTEP         CF          UE     DEL05       THETA     SCHMETA          H       RTHETA      I6
 20  .2414E+00  .1562E-03    .003598  .1180E+01  .2104E-02  .2535E-03  .2418E-03   1.37928  .2244E+04      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .1375E-02          0          0          0

STN.          X        YSTEP         CF          UE     DEL05       THETA     SCHMETA          H       RTHETA      I6
 30  .2800E+00  .1562E-03    .003343  .1171E+01  .2720E-02  .3310E-03  .3202E-03   1.37660  .2908E+04      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .1458E-02          0          0          0

STN.          X        YSTEP         CF          UE     DEL05       THETA     SCHMETA          H       RTHETA      I6
 40  .3182E+00  .1562E-03    .003155  .1161E+01  .2928E-02  .4014E-03  .3996E-03   1.38403  .3496E+04      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .1314E-02          0          0          0

STN.          X        YSTEP         CF          UE     DEL05       THETA     SCHMETA          H       RTHETA      I6
 50  .3562E+00  .1562E-03    .002975  .1151E+01  .2792E-02  .4577E-03  .4801E-03   1.40937  .3951E+04      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .1098E-02          0          0          0

STN.          X        YSTEP         CF          UE     DEL05       THETA     SCHMETA          H       RTHETA      I6
 60  .3938E+00  .1562E-03    .002772  .1141E+01  .2951E-02  .4854E-03  .5609E-03   1.45986  .4153E+04      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .9974E-03          0          0          0

STN.          X        YSTEP         CF          UE     DEL05       THETA     SCHMETA          H       RTHETA      I6
 70  .4311E+00  .1562E-03    .002577  .1131E+01  .2958E-02  .5121E-03  .6414E-03   1.50328  .4343E+04      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .8637E-03          0          0          0

STN.          X        YSTEP         CF          UE     DEL05       THETA     SCHMETA          H       RTHETA      I6
 80  .4682E+00  .1562E-03    .002402  .1121E+01  .2937E-02  .5203E-03  .7216E-03   1.54621  .4375E+04      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .7626E-03          0          0          0

STN.          X        YSTEP         CF          UE     DEL05       THETA     SCHMETA          H       RTHETA      I6
 90  .5047E+00  .1562E-03    .002290  .1112E+01  .1863E-02  .5599E-03  .8013E-03   1.56184  .4671E+04      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .4243E-03          0          0          0

STN.          X        YSTEP         CF          UE     DEL05       THETA     SCHMETA          H       RTHETA      I6
100  .5415E+00  .1562E-03    .002171  .1104E+01  .2847E-02  .4623E-03  .8819E-03   1.63797  .3828E+04      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .5819E-03          0          0          0

STN.          X        YSTEP         CF          UE     DEL05       THETA     SCHMETA          H       RTHETA      I6
110  .5775E+00  .1562E-03    .002173  .1095E+01  .2951E-02  .4968E-03  .9627E-03   1.52997  .4081E+04      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .5478E-03          0          0          0

STN.          X        YSTEP         CF          UE     DEL05       THETA     SCHMETA          H       RTHETA      I6
119  .6104E+00  .1562E-03    .002594  .1087E+01  .2957E-02  .5226E-03  .1049E-02   1.49681  .4260E+04      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
```

0	.4979E-03	0	0	0

X=

.1661E+00	.1705E+00	.1744E+00	.1785E+00	.1825E+00	.1866E+00	.1906E+00	.1946E+00	.1985E+00	.2025E+00
.2064E+00	.2103E+00	.2142E+00	.2181E+00	.2220E+00	.2259E+00	.2298E+00	.2337E+00	.2376E+00	.2414E+00
.2453E+00	.2492E+00	.2531E+00	.2569E+00	.2608E+00	.2646E+00	.2685E+00	.2723E+00	.2761E+00	.2800E+00
.2838E+00	.2877E+00	.2915E+00	.2953E+00	.2991E+00	.3030E+00	.3068E+00	.3106E+00	.3144E+00	.3182E+00
.3220E+00	.3258E+00	.3296E+00	.3334E+00	.3372E+00	.3410E+00	.3448E+00	.3486E+00	.3524E+00	.3562E+00
.3599E+00	.3637E+00	.3675E+00	.3713E+00	.3750E+00	.3788E+00	.3826E+00	.3863E+00	.3901E+00	.3938E+00
.3976E+00	.4013E+00	.4050E+00	.4088E+00	.4125E+00	.4162E+00	.4200E+00	.4237E+00	.4274E+00	.4311E+00
.4349E+00	.4386E+00	.4423E+00	.4460E+00	.4497E+00	.4534E+00	.4571E+00	.4608E+00	.4645E+00	.4682E+00
.4718E+00	.4755E+00	.4792E+00	.4828E+00	.4865E+00	.4901E+00	.4938E+00	.4974E+00	.5011E+00	.5047E+00
.5084E+00	.5121E+00	.5158E+00	.5195E+00	.5231E+00	.5268E+00	.5305E+00	.5342E+00	.5378E+00	.5415E+00
.5451E+00	.5488E+00	.5524E+00	.5559E+00	.5595E+00	.5631E+00	.5667E+00	.5703E+00	.5739E+00	.5775E+00
.5812E+00	.5848E+00	.5885E+00	.5922E+00	.5958E+00	.5995E+00	.6031E+00	.6068E+00	.6104E+00	.6140E+00

VE/UE=

.3022E-02	.3416E-02	.3440E-02	.3568E-02	.3611E-02	.3610E-02	.3559E-02	.3490E-02	.3416E-02	.3333E-02
.3273E-02	.3224E-02	.3194E-02	.3176E-02	.3169E-02	.3188E-02	.3170E-02	.3174E-02	.3175E-02	.3177E-02
.3180E-02	.3183E-02	.3188E-02	.3194E-02	.3202E-02	.3211E-02	.3220E-02	.3229E-02	.3238E-02	.3245E-02
.3252E-02	.3258E-02	.3264E-02	.3269E-02	.3276E-02	.3283E-02	.3290E-02	.3299E-02	.3307E-02	.3316E-02
.3325E-02	.3333E-02	.3342E-02	.3352E-02	.3362E-02	.3372E-02	.3383E-02	.3394E-02	.3405E-02	.3438E-02
.3426E-02	.3429E-02	.3424E-02	.3460E-02	.3503E-02	.3538E-02	.3498E-02	.3477E-02	.3446E-02	.3427E-02
.3414E-02	.3364E-02	.3339E-02	.3313E-02	.3292E-02	.3271E-02	.3251E-02	.3233E-02	.3216E-02	.3198E-02
.3180E-02	.3161E-02	.3194E-02	.3125E-02	.3084E-02	.3096E-02	.3142E-02	.3059E-02	.3002E-02	.2925E-02
.2870E-02	.2830E-02	.2729E-02	.2721E-02	.2756E-02	.2819E-02	.2916E-02	.3032E-02	.3160E-02	.3300E-02
.3427E-02	.3237E-02	.3031E-02	.2726E-02	.2638E-02	.2635E-02	.2549E-02	.2445E-02	.2336E-02	.2226E-02
.2105E-02	.1959E-02	.1820E-02	.1656E-02	.1473E-02	.1265E-02	.1037E-02	.7826E-03	.5391E-03	.4972E-03
.5232E-03	.8099E-03	.1419E-02	.1798E-02	.2112E-02	.2338E-02	.2512E-02	.2642E-02	.2742E-02	

(PW-PREF)/UREF**2=

-.2131E+00	-.2136E+00	-.2128E+00	-.2120E+00	-.2113E+00	-.2105E+00	-.2097E+00	-.2089E+00	-.2081E+00	-.2073E+00
-.2065E+00	-.2057E+00	-.2048E+00	-.2040E+00	-.2031E+00	-.2022E+00	-.2013E+00	-.2004E+00	-.1995E+00	-.1985E+00
-.1975E+00	-.1965E+00	-.1955E+00	-.1944E+00	-.1934E+00	-.1923E+00	-.1911E+00	-.1900E+00	-.1888E+00	-.1877E+00
-.1865E+00	-.1853E+00	-.1841E+00	-.1828E+00	-.1816E+00	-.1804E+00	-.1791E+00	-.1779E+00	-.1766E+00	-.1754E+00
-.1741E+00	-.1729E+00	-.1717E+00	-.1704E+00	-.1692E+00	-.1680E+00	-.1667E+00	-.1655E+00	-.1643E+00	-.1631E+00
-.1618E+00	-.1606E+00	-.1594E+00	-.1582E+00	-.1570E+00	-.1558E+00	-.1546E+00	-.1535E+00	-.1523E+00	-.1511E+00
-.1499E+00	-.1488E+00	-.1476E+00	-.1465E+00	-.1453E+00	-.1442E+00	-.1430E+00	-.1419E+00	-.1408E+00	-.1397E+00
-.1386E+00	-.1374E+00	-.1364E+00	-.1353E+00	-.1342E+00	-.1331E+00	-.1321E+00	-.1310E+00	-.1300E+00	-.1290E+00
-.1279E+00	-.1269E+00	-.1259E+00	-.1248E+00	-.1239E+00	-.1229E+00	-.1219E+00	-.1209E+00	-.1200E+00	-.1190E+00
-.1181E+00	-.1172E+00	-.1163E+00	-.1154E+00	-.1145E+00	-.1135E+00	-.1126E+00	-.1117E+00	-.1108E+00	-.1099E+00
-.1089E+00	-.1080E+00	-.1070E+00	-.1061E+00	-.1052E+00	-.1042E+00	-.1033E+00	-.1023E+00	-.1013E+00	-.1003E+00
-.9920E-01	-.9812E-01	-.9708E-01	-.9608E-01	-.9505E-01	-.9402E-01	-.9299E-01	-.9195E-01	-.9092E-01	-.8989E-01

(PW-PE)/UREF**2=

0	-.1304E-02	-.1374E-02	-.1417E-02	-.1479E-02	-.1535E-02	-.1583E-02	-.1622E-02	-.1659E-02	-.1688E-02
-.1711E-02	-.1732E-02	-.1751E-02	-.1767E-02	-.1792E-02	-.1814E-02	-.1832E-02	-.1847E-02	-.1856E-02	-.1860E-02
-.1858E-02	-.1850E-02	-.1835E-02	-.1815E-02	-.1790E-02	-.1759E-02	-.1725E-02	-.1691E-02	-.1653E-02	-.1612E-02
-.1569E-02	-.1523E-02	-.1474E-02	-.1423E-02	-.1372E-02	-.1320E-02	-.1267E-02	-.1215E-02	-.1164E-02	-.1114E-02
-.1068E-02	-.1024E-02	-.9810E-03	-.9401E-03	-.9008E-03	-.8632E-03	-.8272E-03	-.7928E-03	-.7487E-03	-.7268E-03
-.7063E-03	-.6787E-03	-.6335E-03	-.6004E-03	-.5891E-03	-.5689E-03	-.5639E-03	-.5487E-03	-.5299E-03	-.5091E-03
-.4877E-03	-.4783E-03	-.4607E-03	-.4441E-03	-.4301E-03	-.4178E-03	-.4065E-03	-.3972E-03	-.3890E-03	-.3818E-03
-.3754E-03	-.3499E-03	-.3633E-03	-.3742E-03	-.3479E-03	-.3286E-03	-.3470E-03	-.3695E-03	-.3778E-03	-.3795E-03
-.3718E-03	-.3653E-03	-.3498E-03	-.3326E-03	-.3256E-03	-.3205E-03	-.3178E-03	-.3177E-03	-.3188E-03	-.3424E-03
-.3555E-03	-.4288E-03	-.4756E-03	-.4803E-03	-.4600E-03	-.4674E-03	-.4866E-03	-.4970E-03	-.5034E-03	-.5049E-03
-.5058E-03	-.4901E-03	-.5027E-03	-.5086E-03	-.5060E-03	-.5025E-03	-.4986E-03	-.4882E-03	-.4519E-03	-.4038E-03
-.3537E-03	-.2923E-03	-.2743E-03	-.2897E-03	-.2917E-03	-.2918E-03	-.2875E-03	-.2806E-03	-.2786E-03	-.2786E-03

SWEEP NO. 5 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 6 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

0	.1910E-02	-.8478E-02	-.1709E-02	-.1383E-02	-.8414E-04	.8777E-03	-.5219E-02	.3764E-02	.3775E-02
.3848E-02	.3709E-02	.3279E-02	.4354E-02	.4083E-02	.3270E-02	.1911E-02	.1027E-02	.5327E-03	-.2776E-16
.5327E-C3	.1027E-02	.1911E-02	.3270E-02	.4083E-02	.4354E-02	.3279E-02	.3709E-02	.3848E-02	.3775E-02
.3764E-02	-.5219E-02	.8777E-03	-.8414E-04	-.1383E-02	-.1709E-02	-.8478E-02	.1910E-02	0	

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.2279E-02	-.4316E-02	-.4425E-02	-.2733E-02	-.2510E-02	-.1761E-02	-.6121E-02	-.2501E-02	.3150E-03	.3585E-03
.3797E-03	-.2126E-03	.2646E-03	.5203E-03	.4542E-05	-.5843E-03	-.5738E-03	-.3584E-03	-.1356E-03	-.1356E-03
-.3584E-03	-.5738E-03	-.5843E-03	.4542E-05	.5203E-03	.2646E-03	-.2126E-03	.3797E-03	.3585E-03	.3150E-03
-.2501E-02	-.6121E-02	-.1761E-02	-.2510E-02	-.2733E-02	-.4425E-02	-.4316E-02	.2279E-02		

RUN NO. 6 OF PROGRAM AMOS

INCIDENCE = 0 CHORD = 1.000

X	Y	SSM	CP	U(TANG)	V(NORM)
.00229	.00623	.00664	.80316	.44367	.00228
.00832	.01600	.01842	.11626	.94007	-.00432
.01829	.02335	.03088	-.13150	1.06372	-.00443
.03702	.03212	.05163	-.29429	1.13767	-.00273
.06204	.04050	.07806	-.39329	1.18038	-.00251
.08709	.04656	.10384	-.42760	1.19482	-.00176
.12464	.05287	.14194	-.42519	1.19381	-.00612
.17474	.05853	.19238	-.41984	1.19157	-.00250
.22487	.06152	.24260	-.38956	1.17879	.00031
.27496	.06284	.29272	-.36428	1.16802	.00036
.35006	.06215	.36783	-.31154	1.14522	.00038
.45015	.05861	.46800	-.25774	1.12149	-.00021
.55022	.05240	.56827	-.20420	1.09736	.00026
.65027	.04415	.66856	-.15251	1.07355	.00052
.75027	.03406	.76917	-.09462	1.04624	.00000
.85021	.02220	.86982	-.01957	1.00974	-.00058
.92513	.01232	.94539	.05897	.97007	-.00057
.96258	.00694	.98322	.11313	.94174	-.00036
.98753	.00255	1.00856	.23082	.87703	-.00014
.98753	-.00255	1.03402	.23082	-.87703	-.00014
.96258	-.00694	1.05936	.11313	-.94174	-.00036
.92513	-.01232	1.09719	.05897	-.97007	-.00057
.85021	-.02220	1.17276	-.01957	-1.00974	-.00058
.75027	-.03406	1.27341	-.09462	-1.04624	.00000
.65027	-.04415	1.37392	-.15251	-1.07355	.00052
.55022	-.05240	1.47431	-.20420	-1.09736	.00026
.45015	-.05861	1.57458	-.25774	-1.12149	-.00021
.35006	-.06215	1.67475	-.31154	-1.14522	.00038
.27496	-.06284	1.74986	-.36428	-1.16802	.00036
.22487	-.06152	1.79998	-.38956	-1.17879	.00031
.17474	-.05653	1.85020	-.41984	-1.19157	-.00250
.12464	-.05207	1.90064	-.42519	-1.19381	-.00612
.08709	-.04656	1.93874	-.42760	-1.19482	-.00176
.06204	-.04050	1.96452	-.39329	-1.18038	-.00251

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   .03702    -.03212   1.99095   -.29429  -1.13767   -.00273
   .01829    -.02335   2.01170   -.13150  -1.06372   -.00443
   .00832    -.01600   2.02415    .11626   -.94007   -.00432
   .00229    -.00623   2.03594    .80316   -.44367    .00228
LIFT COEFFICIENT = -.000

ARC LENGTH FOR STAGN. PT. ON M.S.=   2.04258


RUN NO.  6  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS INTERACTION CYCLE--AEROFOIL TEST CASE


1977    0   10  119   16    5    0    0    1    0   51    0   -2    0
A                  0  1.000E-01           0  7.500E+06          0  1.000E+00  3.000E-01


THWAITES LAMINAR B.L. CALC.
       X          THETA       RTHETA          UE           VE
           0   .6654E-05           0           0           0
   .1319E-01   .1292E-04   .7662E+02   .7910E+00   .1910E-02
   .2327E-01   .1960E-04   .1495E+03   .1017E+01  -.8456E-02
   .3770E-01   .3020E-04   .2478E+03   .1094E+01  -.1689E-02
   .6441E-01   .4254E-04   .3716E+03   .1165E+01  -.1385E-02
   .9023E-01   .5318E-04   .4746E+03   .1190E+01  -.9431E-04
   .1157E+00   .6326E-04   .5675E+03   .1196E+01   .8642E-03
   .1661E+00   .8135E-04   .7297E+03   .1193E+01   .1280E-02

SYNTHETIC STARTING PROFILES   THETA/DELTA= .1048
X FOR CURV. B. VALUE              0  1.319E-02  2.327E-02  3.770E-02  6.441E-02  9.023E-02  1.157E-01
 1.661E-01  2.163E-01  2.663E-01  3.163E-01  4.163E-01  5.165E-01  6.167E-01
        I          I
CURV      6.302E+01  3.406E+01  1.735E+01  8.571E+00  3.819E+00  2.344E+00  1.664E+00
 1.035E+00  7.407E-01  5.675E-01  4.517E-01  3.049E-01  2.175E-01  1.651E-01
 1.377E-01  1.307E-01
X FOR PRESS. AND NP B. VALUES            0   1.3194E-02   2.3271E-02   3.7701E-02   6.4410E-02   9.0229E-02   1.1569E-01
  1.6613E-01   2.1628E-01   2.6632E-01   3.1633E-01   4.1635E-01   5.1648E-01   6.1674E-01
PE-PREF       5.0000E-01   1.8715E-01  -1.7141E-02  -9.8604E-02  -1.7846E-01  -2.0794E-01  -2.1530E-01
 -2.1164E-01  -2.0322E-01  -1.8829E-01  -1.7410E-01  -1.4119E-01  -1.1572E-01  -8.8987E-02
NP              0   4.8981E-04   7.3881E-04   1.1276E-03   1.5912E-03   1.9812E-03   2.3821E-03
  3.1240E-03
NP    3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03

STN.          X        YSTEP        CF         UE      DEL05       THETA     SCHMETA          H     RTHETA      I6
  1   .1661E+00   .1562E-03   .004743   .1193E+01   .9063E-03   .8131E-04   .8131E-04     1.46119   .7275E+03     18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05        VW/UE
         0  .9380E-03          0           0            0
REYNOLDS NUMBER TOO SMALL

STN.          X        YSTEP        CF         UE      DEL05       THETA     SCHMETA          H     RTHETA      I6
  2   .1705E+00   .1562E-03   .004748   .1192E+01   .7790E-03   .9501E-04   .9182E-04     1.39072   .8496E+03     18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05        VW/UE
         0  .7865E-03          0           0            0

STN.          X        YSTEP        CF         UE      DEL05       THETA     SCHMETA          H     RTHETA      I6
 10   .2025E+00   .1562E-03   .003946   .1187E+01   .1459E-02   .1703E-03   .1624E-03     1.39818   .1516E+04     18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05        VW/UE
         0  .1198E-02          0           0            0

STN.          X        YSTEP        CF         UE      DEL05       THETA     SCHMETA          H     RTHETA      I6
 20   .2414E+00   .1562E-03   .003600   .1179E+01   .2103E-02   .2532E-03   .2415E-03     1.37956   .2239E+04     18
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ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.1375E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
30	.2800E+00	.1562E-03	.003345	.1171E+01	.2719E-02	.3306E-03	.3197E-03	1.37674	.2903E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.1457E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
40	.3182E+00	.1562E-03	.003157	.1161E+01	.2928E-02	.4010E-03	.3989E-03	1.38405	.3491E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.1314E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
50	.3562E+00	.1562E-03	.002977	.1150E+01	.2792E-02	.4573E-03	.4792E-03	1.40926	.3946E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.1098E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
60	.3938E+00	.1562E-03	.002774	.1140E+01	.2951E-02	.4851E-03	.5598E-03	1.45964	.4149E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.9974E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
70	.4311E+00	.1562E-03	.002578	.1130E+01	.2958E-02	.5119E-03	.6400E-03	1.50296	.4340E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.8637E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
80	.4682E+00	.1562E-03	.002404	.1121E+01	.2937E-02	.5200E-03	.7199E-03	1.54578	.4372E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.7626E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
90	.5047E+00	.1562E-03	.002292	.1112E+01	.1863E-02	.5596E-03	.7992E-03	1.56127	.4668E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.4243E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
100	.5415E+00	.1562E-03	.002175	.1104E+01	.2845E-02	.4620E-03	.8792E-03	1.63725	.3825E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.5816E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
110	.5775E+00	.1562E-03	.002175	.1095E+01	.2951E-02	.4963E-03	.9594E-03	1.52963	.4077E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.5478E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
119	.6104E+00	.1562E-03	.002596	.1087E+01	.2957E-02	.5222E-03	.1046E-02	1.49640	.4257E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.4979E-03	0	0	0

X=

.1661E+00	.1705E+00	.1744E+00	.1785E+00	.1825E+00	.1866E+00	.1906E+00	.1946E+00	.1985E+00	.2025E+00
.2064E+00	.2103E+00	.2142E+00	.2181E+00	.2220E+00	.2259E+00	.2298E+00	.2337E+00	.2376E+00	.2414E+00
.2453E+00	.2492E+00	.2531E+00	.2569E+00	.2608E+00	.2646E+00	.2685E+00	.2723E+00	.2761E+00	.2800E+00
.2838E+00	.2877E+00	.2915E+00	.2953E+00	.2991E+00	.3030E+00	.3068E+00	.3106E+00	.3144E+00	.3182E+00
.3220E+00	.3258E+00	.3296E+00	.3334E+00	.3372E+00	.3410E+00	.3448E+00	.3486E+00	.3524E+00	.3562E+00
.3599E+00	.3637E+00	.3675E+00	.3713E+00	.3750E+00	.3788E+00	.3826E+00	.3863E+00	.3901E+00	.3938E+00
.3976E+00	.4013E+00	.4050E+00	.4088E+00	.4125E+00	.4162E+00	.4200E+00	.4237E+00	.4274E+00	.4311E+00
.4349E+00	.4386E+00	.4423E+00	.4460E+00	.4497E+00	.4534E+00	.4571E+00	.4608E+00	.4645E+00	.4682E+00
.4718E+00	.4755E+00	.4792E+00	.4828E+00	.4865E+00	.4901E+00	.4938E+00	.4974E+00	.5011E+00	.5047E+00
.5084E+00	.5121E+00	.5158E+00	.5195E+00	.5231E+00	.5268E+00	.5305E+00	.5342E+00	.5378E+00	.5415E+00
.5451E+00	.5488E+00	.5524E+00	.5559E+00	.5595E+00	.5631E+00	.5667E+00	.5703E+00	.5739E+00	.5775E+00
.5812E+00	.5848E+00	.5885E+00	.5922E+00	.5958E+00	.5995E+00	.6031E+00	.6068E+00	.6104E+00	.6140E+00

VE/UE=

.3010E-02	.3402E-02	.3427E-02	.3555E-02	.3598E-02	.3596E-02	.3545E-02	.3476E-02	.3402E-02	.3319E-02
.3259E-02	.3210E-02	.3180E-02	.3162E-02	.3155E-02	.3154E-02	.3156E-02	.3159E-02	.3161E-02	.3164E-02
.3166E-02	.3169E-02	.3174E-02	.3181E-02	.3188E-02	.3197E-02	.3207E-02	.3216E-02	.3224E-02	.3232E-02
.3239E-02	.3245E-02	.3251E-02	.3257E-02	.3263E-02	.3271E-02	.3278E-02	.3287E-02	.3296E-02	.3305E-02
.3314E-02	.3323E-02	.3332E-02	.3342E-02	.3352E-02	.3362E-02	.3373E-02	.3384E-02	.3396E-02	.3429E-02
.3417E-02	.3420E-02	.3415E-02	.3452E-02	.3495E-02	.3530E-02	.3490E-02	.3469E-02	.3439E-02	.3420E-02
.3407E-02	.3357E-02	.3332E-02	.3306E-02	.3285E-02	.3264E-02	.3244E-02	.3226E-02	.3209E-02	.3191E-02
.3173E-02	.3153E-02	.3186E-02	.3117E-02	.3076E-02	.3087E-02	.3133E-02	.3050E-02	.2993E-02	.2916E-02
.2861E-02	.2821E-02	.2719E-02	.2711E-02	.2745E-02	.2808E-02	.2904E-02	.3019E-02	.3147E-02	.3285E-02
.3412E-02	.3222E-02	.3016E-02	.2712E-02	.2623E-02	.2620E-02	.2534E-02	.2431E-02	.2322E-02	.2213E-02
.2093E-02	.1948E-02	.1810E-02	.1646E-02	.1466E-02	.1259E-02	.1032E-02	.7800E-03	.5378E-03	.4942E-03
.5218E-03	.8019E-03	.1410E-02	.1789E-02	.2103E-02	.2329E-02	.2503E-02	.2632E-02	.2733E-02	

(PW-PREF)/UREF**2=

-.2116E+00	-.2121E+00	-.2114E+00	-.2106E+00	-.2099E+00	-.2091E+00	-.2084E+00	-.2076E+00	-.2068E+00	-.2061E+00
-.2053E+00	-.2045E+00	-.2036E+00	-.2028E+00	-.2020E+00	-.2011E+00	-.2003E+00	-.1994E+00	-.1984E+00	-.1975E+00
-.1965E+00	-.1956E+00	-.1945E+00	-.1935E+00	-.1924E+00	-.1914E+00	-.1903E+00	-.1891E+00	-.1880E+00	-.1868E+00
-.1857E+00	-.1845E+00	-.1833E+00	-.1821E+00	-.1809E+00	-.1797E+00	-.1784E+00	-.1772E+00	-.1760E+00	-.1747E+00
-.1735E+00	-.1723E+00	-.1710E+00	-.1698E+00	-.1686E+00	-.1674E+00	-.1661E+00	-.1649E+00	-.1637E+00	-.1625E+00
-.1613E+00	-.1601E+00	-.1589E+00	-.1577E+00	-.1565E+00	-.1553E+00	-.1542E+00	-.1530E+00	-.1518E+00	-.1506E+00
-.1495E+00	-.1483E+00	-.1472E+00	-.1460E+00	-.1449E+00	-.1437E+00	-.1426E+00	-.1415E+00	-.1404E+00	-.1393E+00
-.1382E+00	-.1371E+00	-.1360E+00	-.1349E+00	-.1338E+00	-.1328E+00	-.1317E+00	-.1307E+00	-.1297E+00	-.1286E+00
-.1276E+00	-.1266E+00	-.1256E+00	-.1246E+00	-.1236E+00	-.1226E+00	-.1216E+00	-.1207E+00	-.1197E+00	-.1188E+00
-.1179E+00	-.1171E+00	-.1162E+00	-.1153E+00	-.1143E+00	-.1134E+00	-.1125E+00	-.1116E+00	-.1107E+00	-.1098E+00
-.1089E+00	-.1079E+00	-.1070E+00	-.1061E+00	-.1052E+00	-.1042E+00	-.1033E+00	-.1023E+00	-.1013E+00	-.1003E+00
-.99[illegible]E-01	-.9819E-01	-.9716E-01	-.9616E-01	-.9515E-01	-.9413E-01	-.9310E-01	-.9208E-01	-.9105E-01	-.9004E-01

(PW-PE)/UREF**2=

0	-.1310E-02	-.1386E-02	-.1438E-02	-.1507E-02	-.1570E-02	-.1625E-02	-.1671E-02	-.1714E-02	-.1749E-02
-.1779E-02	-.1805E-02	-.1829E-02	-.1851E-02	-.1880E-02	-.1906E-02	-.1928E-02	-.1947E-02	-.1959E-02	-.1965E-02
-.1965E-02	-.1958E-02	-.1945E-02	-.1925E-02	-.1899E-02	-.1868E-02	-.1833E-02	-.1797E-02	-.1757E-02	-.1714E-02
-.1668E-02	-.1619E-02	-.1567E-02	-.1513E-02	-.1459E-02	-.1403E-02	-.1347E-02	-.1291E-02	-.1235E-02	-.1181E-02
-.1132E-02	-.1083E-02	-.1037E-02	-.9923E-03	-.9493E-03	-.9080E-03	-.8684E-03	-.8304E-03	-.7828E-03	-.7574E-03
-.7336E-03	-.7027E-03	-.6543E-03	-.6181E-03	-.6038E-03	-.5806E-03	-.5728E-03	-.5548E-03	-.5334E-03	-.5101E-03
-.4865E-03	-.4748E-03	-.4551E-03	-.4365E-03	-.4207E-03	-.4067E-03	-.3939E-03	-.3831E-03	-.3738E-03	-.3655E-03
-.3582E-03	-.3320E-03	-.3448E-03	-.3552E-03	-.3288E-03	-.3094E-03	-.3279E-03	-.3507E-03	-.3595E-03	-.3620E-03
-.3553E-03	-.3501E-03	-.3359E-03	-.3203E-03	-.3152E-03	-.3121E-03	-.3117E-03	-.3141E-03	-.3179E-03	-.3445E-03
-.3607E-03	-.4372E-03	-.4872E-03	-.4955E-03	-.4787E-03	-.4894E-03	-.5119E-03	-.5255E-03	-.5349E-03	-.5392E-03
-.5428E-03	-.5292E-03	-.5438E-03	-.5511E-03	-.5496E-03	-.5468E-03	-.5430E-03	-.5325E-03	-.4960E-03	-.4470E-03
-.3960E-03	-.3332E-03	-.3128E-03	-.3261E-03	-.3259E-03	-.3237E-03	-.3169E-03	-.3074E-03	-.3027E-03	-.3027E-03

SWEEP NO. 6 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 7 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

0	.1910E-02	-.8456E-02	-.1689E-02	-.1385E-02	-.9431E-04	.8642E-03	-.5228E-02	.3744E-02	.3756E-02
.3833E-02	.3701E-02	.3262E-02	.4337E-02	.4067E-02	.3257E-02	.1904E-02	.1023E-02	.5307E-03	.2776E-16
.5307E-03	.1023E-02	.1904E-02	.3257E-02	.4067E-02	.4337E-02	.3262E-02	.3701E-02	.3833E-02	.3756E-02
.3744E-02	-.5228E-02	.8642E-03	-.9431E-04	-.1385E-02	-.1689E-02	-.8456E-02	.1910E-02	0	

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.2527E-02	-.4472E-02	-.4445E-02	-.2413E-02	-.1967E-02	-.1015E-02	-.5508E-02	-.1637E-02	.1343E-02	.1393E-02
.1407E-02	.8390E-03	.1375E-02	.1645E-02	.1122E-02	.3854E-03	.4242E-04	-.1660E-04	-.1402E-04	-.1402E-04
-.1660E-04	.4242E-04	.3854E-03	.1122E-02	.1645E-02	.1375E-02	.8390E-03	.1407E-02	.1393E-02	.1343E-02
-.1637E-02	-.5508E-02	-.1015E-02	-.1967E-02	-.2413E-02	-.4445E-02	-.4472E-02	.2527E-02		

RUN NO. 7 OF PROGRAM AMOS

INCIDENCE = 0 CHORD = 1.000

X	Y	SSM	CP	U (TANG)	V (NORM)
.00229	.00623	.00664	.80335	.44345	.00253
.00832	.01600	.01842	.11743	.93945	-.00447
.01829	.02335	.03088	-.12943	1.06275	-.00445
.03702	.03212	.05163	-.29185	1.13660	-.00241
.06204	.04050	.07806	-.39080	1.17932	-.00197
.08709	.04656	.10384	-.42540	1.19390	-.00102
.12464	.05287	.14194	-.42313	1.19295	-.00551
.17474	.05853	.19238	-.41784	1.19073	-.00164
.22487	.06152	.24260	-.38798	1.17813	.00134
.27496	.06284	.29272	-.36310	1.16752	.00139
.35006	.06215	.36783	-.31074	1.14487	.00141
.45015	.05861	.46800	-.25731	1.12130	.00084
.55022	.05240	.56827	-.20416	1.09734	.00138
.65027	.04415	.66866	-.15292	1.07374	.00165
.75027	.03406	.76917	-.09555	1.04669	.00112
.85021	.02220	.86982	-.02109	1.01049	.00039
.92513	.01232	.94539	.05696	.97110	.00004
.96258	.00694	.98322	.11107	.94283	-.00002
.98753	.00255	1.00856	.22914	.87799	-.00001
.98753	-.00255	1.03402	.22914	-.87799	-.00001
.96258	-.00694	1.05936	.11107	-.94283	-.00002
.92513	-.01232	1.09719	.05696	-.97110	.00004
.85021	-.02220	1.17276	-.02109	-1.01049	.00039
.75027	-.03406	1.27341	-.09555	-1.04669	.00112
.65027	-.04415	1.37392	-.15292	-1.07374	.00165
.55022	-.05240	1.47431	-.20416	-1.09734	.00138
.45015	-.05861	1.57458	-.25731	-1.12130	.00084
.35006	-.06215	1.67475	-.31074	-1.14487	.00141
.27496	-.06284	1.74986	-.36310	-1.16752	.00139
.22487	-.06152	1.79998	-.38798	-1.17813	.00134
.17474	-.05853	1.85020	-.41784	-1.19073	-.00164
.12464	-.05287	1.90064	-.42313	-1.19295	-.00551
.08709	-.04656	1.93874	-.42540	-1.19390	-.00102
.06204	-.04050	1.96452	-.39080	-1.17932	-.00197
.03702	-.03212	1.99095	-.29185	-1.13660	-.00241
.01829	-.02335	2.01170	-.12943	-1.06275	-.00445

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   .00832   -.01600   2.02415    .11743   -.93945   -.00447
   .00229   -.00623   2.03594    .80335   -.44345    .00253
LIFT COEFFICIENT = -.000

ARC LENGTH FOR STAGN. PT. ON M.S.=   2.04258


RUN NO.   7  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS INTERACTION CYCLE--AEROFOIL TEST CASE


1977    0   10  119   16    5    0   0    1    0   51    0   -2    0
A                 0  1.000E-01            0  7.500E+06            0  1.000E+00  3.000E-01

THWAITES LAMINAR B.L. CALC.
       X          THETA       RTHETA          UE          VE
           0   .6655E-05           0           0           0
   .1319E-01   .1292E-04   .7660E+02   .7905E+00   .1909E-02
   .2327E-01   .1961E-04   .1495E+03   .1016E+01  -.8441E-02
   .3770E-01   .3022E-04   .2478E+03   .1093E+01  -.1675E-02
   .6441E-01   .4256E-04   .3715E+03   .1164E+01  -.1387E-02
   .9023E-01   .5319E-04   .4743E+03   .1169E+01  -.1014E-03
   .1157E+00   .6327E-04   .5671E+03   .1195E+01   .8548E-03
   .1661E+00   .8136E-04   .7293E+03   .1192E+01   .1278E-02

SYNTHETIC STARTING PROFILES   THETA/DELTA= .1048
X FOR CURV. B. VALUE               0  1.319E-02  2.327E-02  3.770E-02  6.441E-02  9.023E-02  1.157E-01
 1.661E-01  2.163E-01  2.663E-01  3.163E-01  4.163E-01  5.165E-01  6.167E-01
         I         I
CURV      6.302E+01  3.406E+01  1.735E+01  8.571E+00  3.819E+00  2.344E+00  1.664E+00
 1.035E+00  7.407E-01  5.675E-01  4.517E-01  3.049E-01  2.175E-01  1.651E-01
 1.377E-01  1.307E-01
X FOR PRESS. AND NP B. VALUES              0   1.3194E-02   2.3271E-02   3.7701E-02   6.4410E-02   9.0229E-02   1.1569E-01
  1.6613E-01   2.1628E-01   2.6632E-01   3.1633E-01   4.1635E-01   5.1648E-01   6.1674E-01
PE-PREF        5.0000E-01   1.8752E-01  -1.6347E-02  -9.7438E-02  -1.7721E-01  -2.0676E-01  -2.1426E-01
 -2.1061E-01  -2.0231E-01  -1.8761E-01  -1.7358E-01  -1.4088E-01  -1.1560E-01  -8.9077E-02
NP             0   4.8981E-04   7.3881E-04   1.1276E-03   1.5912E-03   1.9812E-03   2.3821E-03
  3.1240E-03
NP   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03

STN.            X       YSTEP         CF         UE     DEL05        THETA    SCHMETA          H    RTHETA      I6
   1  .1661E+00  .1562E-03    .004744  .1192E+01  .9063E-03  .8130E-04  .8130E-04    1.46124  .7269E+03      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
          0  .9380E-03          0          0          0
REYNOLDS NUMBER TOO SMALL

STN.            X       YSTEP         CF         UE     DEL05        THETA    SCHMETA          H    RTHETA      I6
   2  .1705E+00  .1562E-03    .004749  .1191E+01  .7790E-03  .9494E-04  .9179E-04    1.39154  .8484E+03      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
          0  .7865E-03          0          0          0

STN.            X       YSTEP         CF         UE     DEL05        THETA    SCHMETA          H    RTHETA      I6
  10  .2025E+00  .1562E-03    .003947  .1186E+01  .1458E-02  .1702E-03  .1623E-03    1.39857  .1514E+04      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
          0  .1198E-02          0          0          0

STN.            X       YSTEP         CF         UE     DEL05        THETA    SCHMETA          H    RTHETA      I6
  20  .2414E+00  .1562E-03    .003602  .1179E+01  .2103E-02  .2530E-03  .2413E-03    1.37975  .2236E+04      18

 ROUGH/D05    D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
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0	.1375E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
30	.2800E+00	.1562E-03	.003347	.1170E+01	.2717E-02	.3304E-03	.3193E-03	1.37684	.2899E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1456E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
40	.3182E+00	.1562E-03	.003158	.1160E+01	.2928E-02	.4007E-03	.3985E-03	1.38407	.3487E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1314E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
50	.3562E+00	.1562E-03	.002978	.1150E+01	.2792E-02	.4570E-03	.4786E-03	1.40918	.3942E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1098E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
60	.3938E+00	.1562E-03	.002775	.1140E+01	.2951E-02	.4849E-03	.5590E-03	1.45949	.4146E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.9973E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
70	.4311E+00	.1562E-03	.002580	.1130E+01	.2958E-02	.5117E-03	.6391E-03	1.50275	.4337E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.8637E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
80	.4682E+00	.1562E-03	.002406	.1121E+01	.2937E-02	.5198E-03	.7187E-03	1.54547	.4369E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.7626E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
90	.5047E+00	.1562E-03	.002294	.1112E+01	.1863E-02	.5593E-03	.7976E-03	1.56087	.4665E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.4243E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
100	.5415E+00	.1562E-03	.002177	.1104E+01	.2844E-02	.4618E-03	.8773E-03	1.63675	.3823E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.5813E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
110	.5775E+00	.1562E-03	.002176	.1095E+01	.2951E-02	.4961E-03	.9572E-03	1.52939	.4075E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.5478E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
119	.6104E+00	.1562E-03	.002597	.1087E+01	.2957E-02	.5220E-03	.1043E-02	1.49611	.4255E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.4979E-03	0	0	0

X=

.1661E+00	.1705E+00	.1744E+00	.1785E+00	.1825E+00	.1866E+00	.1906E+00	.1946E+00	.1985E+00	.2025E+00

.2064E+00	.2103E+00	.2142E+00	.2181E+00	.2220E+00	.2259E+00	.2298E+00	.2337E+00	.2376E+00	.2414E+00
.2453E+00	.2492E+00	.2531E+00	.2569E+00	.2608E+00	.2646E+00	.2685E+00	.2723E+00	.2761E+00	.2800E+00
.2838E+00	.2877E+00	.2915E+00	.2953E+00	.2991E+00	.3030E+00	.3068E+00	.3106E+00	.3144E+00	.3182E+00
.3220E+00	.3258E+00	.3296E+00	.3334E+00	.3372E+00	.3410E+00	.3448E+00	.3486E+00	.3524E+00	.3562E+00
.3599E+00	.3637E+00	.3675E+00	.3713E+00	.3750E+00	.3788E+00	.3826E+00	.3863E+00	.3901E+00	.3938E+00
.3976E+00	.4013E+00	.4050E+00	.4088E+00	.4125E+00	.4162E+00	.4200E+00	.4237E+00	.4274E+00	.4311E+00
.4349E+00	.4386E+00	.4423E+00	.4460E+00	.4497E+00	.4534E+00	.4571E+00	.4608E+00	.4645E+00	.4682E+00
.4716E+00	.4755E+00	.4792E+00	.4828E+00	.4865E+00	.4901E+00	.4938E+00	.4974E+00	.5011E+00	.5047E+00
.5084E+00	.5121E+00	.5158E+00	.5195E+00	.5231E+00	.5268E+00	.5305E+00	.5342E+00	.5378E+00	.5415E+00
.5451E+00	.5488E+00	.5524E+00	.5559E+00	.5595E+00	.5631E+00	.5667E+00	.5703E+00	.5739E+00	.5775E+00
.5812E+00	.5848E+00	.5885E+00	.5922E+00	.5958E+00	.5995E+00	.6031E+00	.6068E+00	.6104E+00	.6140E+00

VE/UE=

.3002E-02	.3392E-02	.3418E-02	.3546E-02	.3589E-02	.3587E-02	.3536E-02	.3467E-02	.3393E-02	.3309E-02
.3249E-02	.3201E-02	.3170E-02	.3152E-02	.3146E-02	.3144E-02	.3146E-02	.3150E-02	.3151E-02	.3154E-02
.3157E-02	.3160E-02	.3165E-02	.3171E-02	.3179E-02	.3188E-02	.3197E-02	.3207E-02	.3215E-02	.3223E-02
.3230E-02	.3237E-02	.3242E-02	.3248E-02	.3255E-02	.3262E-02	.3270E-02	.3279E-02	.3288E-02	.3297E-02
.3306E-02	.3315E-02	.3325E-02	.3335E-02	.3345E-02	.3356E-02	.3367E-02	.3378E-02	.3389E-02	.3423E-02
.3411E-02	.3414E-02	.3410E-02	.3446E-02	.3489E-02	.3524E-02	.3484E-02	.3464E-02	.3434E-02	.3415E-02
.3402E-02	.3352E-02	.3328E-02	.3301E-02	.3280E-02	.3260E-02	.3240E-02	.3222E-02	.3204E-02	.3186E-02
.3167E-02	.3148E-02	.3181E-02	.3111E-02	.3070E-02	.3082E-02	.3127E-02	.3044E-02	.2987E-02	.2910E-02
.2855E-02	.2814E-02	.2713E-02	.2704E-02	.2738E-02	.2800E-02	.2896E-02	.3010E-02	.3137E-02	.3275E-02
.3401E-02	.3211E-02	.3005E-02	.2702E-02	.2613E-02	.2609E-02	.2524E-02	.2421E-02	.2313E-02	.2203E-02
.2084E-02	.1940E-02	.1803E-02	.1640E-02	.1460E-02	.1255E-02	.1029E-02	.7781E-03	.5367E-03	.4921E-03
.5206E-03	.7964E-03	.1404E-02	.1783E-02	.2097E-02	.2323E-02	.2497E-02	.2626E-02	.2726E-02	

(PW-PREF) /UREF**2=

-.2106E+00	-.2111E+00	-.2104E+00	-.2097E+00	-.2089E+00	-.2082E+00	-.2075E+00	-.2067E+00	-.2060E+00	-.2052E+00
-.2044E+00	-.2036E+00	-.2028E+00	-.2020E+00	-.2012E+00	-.2004E+00	-.1995E+00	-.1986E+00	-.1977E+00	-.1968E+00
-.1958E+00	-.1949E+00	-.1939E+00	-.1928E+00	-.1918E+00	-.1907E+00	-.1896E+00	-.1885E+00	-.1874E+00	-.1863E+00
-.1851E+00	-.1839E+00	-.1828E+00	-.1816E+00	-.1804E+00	-.1791E+00	-.1779E+00	-.1767E+00	-.1755E+00	-.1743E+00
-.1730E+00	-.1718E+00	-.1706E+00	-.1694E+00	-.1682E+00	-.1670E+00	-.1657E+00	-.1645E+00	-.1633E+00	-.1621E+00
-.1609E+00	-.1597E+00	-.1585E+00	-.1573E+00	-.1562E+00	-.1550E+00	-.1538E+00	-.1526E+00	-.1515E+00	-.1503E+00
-.1491E+00	-.1480E+00	-.1469E+00	-.1457E+00	-.1446E+00	-.1434E+00	-.1423E+00	-.1412E+00	-.1401E+00	-.1390E+00
-.1379E+00	-.1368E+00	-.1357E+00	-.1347E+00	-.1336E+00	-.1325E+00	-.1315E+00	-.1305E+00	-.1294E+00	-.1284E+00
-.1274E+00	-.1264E+00	-.1254E+00	-.1244E+00	-.1234E+00	-.1224E+00	-.1215E+00	-.1205E+00	-.1196E+00	-.1187E+00
-.1178E+00	-.1169E+00	-.1161E+00	-.1152E+00	-.1142E+00	-.1133E+00	-.1124E+00	-.1115E+00	-.1106E+00	-.1097E+00
-.1088E+00	-.1079E+00	-.1070E+00	-.1061E+00	-.1052E+00	-.1043E+00	-.1033E+00	-.1024E+00	-.1014E+00	-.1003E+00
-.9930E-01	-.9824E-01	-.9722E-01	-.9623E-01	-.9522E-01	-.9421E-01	-.9319E-01	-.9217E-01	-.9115E-01	-.9014E-01

(PW-PE) /UREF**2=

0	-.1314E-02	-.1395E-02	-.1452E-02	-.1526E-02	-.1594E-02	-.1654E-02	-.1705E-02	-.1753E-02	-.1792E-02
-.1825E-02	-.1856E-02	-.1884E-02	-.1909E-02	-.1941E-02	-.1971E-02	-.1995E-02	-.2016E-02	-.2030E-02	-.2038E-02
-.2039E-02	-.2034E-02	-.2021E-02	-.2001E-02	-.1975E-02	-.1944E-02	-.1907E-02	-.1871E-02	-.1830E-02	-.1785E-02
-.1737E-02	-.1686E-02	-.1632E-02	-.1576E-02	-.1519E-02	-.1460E-02	-.1402E-02	-.1343E-02	-.1285E-02	-.1228E-02
-.1176E-02	-.1125E-02	-.1076E-02	-.1029E-02	-.9832E-03	-.9394E-03	-.8972E-03	-.8568E-03	-.8067E-03	-.7790E-03
-.7528E-03	-.7196E-03	-.6691E-03	-.6308E-03	-.6143E-03	-.5891E-03	-.5793E-03	-.5594E-03	-.5362E-03	-.5112E-03
-.4860E-03	-.4727E-03	-.4516E-03	-.4317E-03	-.4146E-03	-.3994E-03	-.3856E-03	-.3738E-03	-.3636E-03	-.3546E-03
-.3466E-03	-.3199E-03	-.3322E-03	-.3424E-03	-.3159E-03	-.2965E-03	-.3150E-03	-.3381E-03	-.3472E-03	-.3502E-03
-.3442E-03	-.3397E-03	-.3265E-03	-.3120E-03	-.3082E-03	-.3064E-03	-.3076E-03	-.3117E-03	-.3174E-03	-.3460E-03
-.3644E-03	-.4430E-03	-.4953E-03	-.5060E-03	-.4916E-03	-.5046E-03	-.5293E-03	-.5151E-03	-.5567E-03	-.5629E-03
-.5683E-03	-.5564E-03	-.5723E-03	-.5806E-03	-.5799E-03	-.5776E-03	-.5741E-03	-.5636E-03	-.5270E-03	-.4776E-03
-.4261E-03	-.3624E-03	-.3405E-03	-.3525E-03	-.3509E-03	-.3472E-03	-.3[illegible]89E-03	-.3277E-03	-.3214E-03	-.3214E-03

SWEEP NO. 7 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 8 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

0	.1909E-02	-.8441E-02	-.1675E-02	-.1387E-02	-.1014E-03	.8548E-03	-.5234E-02	.3730E-02	.3743E-02
.3822E-02	.3695E-02	.3250E-02	.4325E-02	.4056E-02	.3248E-02	.1899E-02	.1020E-02	.5292E-03	0
.5292E-03	.1020E-02	.1899E-02	.3248E-02	.4056E-02	.4325E-02	.3250E-02	.3695E-02	.3822E-02	.3743E-02
.3730E-02	-.5234E-02	.8548E-03	-.1014E-03	-.1387E-02	-.1675E-02	-.8441E-02	.1909E-02	0	

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.2700E-02	-.4579E-02	-.4454E-02	-.2188E-02	-.1588E-02	-.4960E-03	-.5081E-02	-.1035E-02	.2059E-02	.2113E-02
.2125E-02	.1572E-02	.2150E-02	.2429E-02	.1901E-02	.1062E-02	.4725E-03	.2220E-03	.7086E-04	.7086E-04
.2220E-03	.4725E-03	.1062E-02	.1901E-02	.2429E-02	.2150E-02	.1572E-02	.2125E-02	.2113E-02	.2059E-02
-.1035E-02	-.5081E-02	-.4960E-03	-.1588E-02	-.2188E-02	-.4454E-02	-.4579E-02	.2700E-02		

RUN NO. 8 OF PROGRAM AMOS

INCIDENCE = 0 CHORD = 1.000

X	Y	SSM	CP	U (TANG)	V (NORM)
.00229	.00623	.00664	.80349	.44329	.00270
.00832	.01600	.01842	.11825	.93901	-.00458
.01829	.02335	.03088	-.12798	1.06206	-.00445
.03702	.03212	.05163	-.29016	1.13585	-.00219
.06204	.04050	.07806	-.38906	1.17858	-.00159
.08709	.04656	.10384	-.42387	1.19326	-.00050
.12464	.05287	.14194	-.42170	1.19235	-.00508
.17474	.05853	.19238	-.41646	1.19015	-.00104
.22487	.06152	.24260	-.38688	1.17766	.00206
.27496	.06284	.29272	-.36228	1.16717	.00211
.35006	.06215	.36783	-.31018	1.14463	.00212
.45015	.05861	.46800	-.25702	1.12117	.00157
.55022	.05240	.56827	-.20413	1.09733	.00215
.65027	.04415	.66866	-.15321	1.07387	.00243
.75027	.03406	.76917	-.09620	1.04700	.00190
.85021	.02220	.86982	-.02215	1.01102	.00106
.92513	.01232	.94539	.05556	.97182	.00047
.96258	.00694	.98322	.10963	.94359	.00022
.98753	.00255	1.00856	.22796	.87866	.00007
.98753	-.00255	1.03402	.22796	-.87866	.00007
.96258	-.00694	1.05936	.10963	-.94359	.00022
.92513	-.01232	1.09719	.05556	-.97182	.00047
.85021	-.02220	1.17276	-.02215	-1.01102	.00106
.75027	-.03406	1.27341	-.09620	-1.04700	.00190
.65027	-.04415	1.37392	-.15321	-1.07387	.00243
.55022	-.05240	1.47431	-.20413	-1.09733	.00215
.45015	-.05861	1.57458	-.25702	-1.12117	.00157
.35006	-.06215	1.67475	-.31018	-1.14463	.00212
.27496	-.06284	1.74986	-.36228	-1.16717	.00211
.22487	-.06152	1.79998	-.38688	-1.17766	.00206
.17474	-.05853	1.85020	-.41646	-1.19015	-.00104
.12464	-.05287	1.90064	-.42170	-1.19235	-.00508
.08709	-.04656	1.93874	-.42387	-1.19326	-.00050
.06204	-.04050	1.96452	-.38906	-1.17858	-.00159
.03702	-.03212	1.99095	-.29016	-1.13585	-.00219
.01829	-.02335	2.01170	-.12798	-1.06206	-.00445
.00832	-.01600	2.02415	.11825	-.93901	-.00458
.00229	-.00623	2.03594	.80349	-.44329	.00270

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LIFT COEFFICIENT = -.000

ARC LENGTH FOR STAGN. PT. ON M.S.=   2.04258

RUN NO.  8  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS INTERACTION CYCLE--AEROFOIL TEST CASE

1977    0   10  119   16    5     0     0     1     D    51     0   -2     0
A                 0  1.000E-01               0  7.500E+06           0  1.000E+00  3.000E-01

THWAITES LAMINAR B.L. CALC.
       X           THETA        RTHETA           UE           VE
           0     .6656E-05            0            0            0
   .1319E-01    .1292E-04    .7658E+02    .7902E+00    .1909E-02
   .2327E-01    .1962E-04    .1494E+03    .1016E+01   -.8430E-02
   .3770E-01    .3024E-04    .2478E+03    .1092E+01   -.1665E-02
   .6441E-01    .4257E-04    .3714E+03    .1163E+01   -.1388E-02
   .9023E-01    .5320E-04    .4741E+03    .1188E+01   -.1063E-03
   .1157E+00    .6327E-04    .5669E+03    .1195E+01    .8483E-03
   .1661E+00    .8137E-04    .7290E+03    .1192E+01    .1277E-02

SYNTHETIC STARTING PROFILES    THETA/DELTA= .1048
X FOR CURV. B. VALUE                 0  1.319E-02  2.327E-02  3.770E-02  6.441E-02  9.023E-02  1.157E-01
 1.661E-01  2.163E-01  2.663E-01  3.163E-01  4.163E-01  5.165E-01  6.167E-01
        I          I
CURV     6.302E+01  3.406E+01  1.735E+01  8.571E+00  3.819E+00  2.344E+00  1.664E+00
 1.035E+00  7.407E-01  5.675E-01  4.517E-01  3.049E-01  2.175E-01  1.651E-01
 1.377E-01  1.307E-01
X FOR PRESS. AND NP B. VALUES              0   1.3194E-02   2.3271E-02   3.7701E-02   6.4410E-02   9.0229E-02   1.1569E-01
 1.6613E-01   2.1628E-01   2.6632E-01   3.1633E-01   4.1635E-01   5.1648E-01   6.1674E-01
PE-PREF      5.0000E-01   1.8779E-01  -1.5792E-02  -9.6626E-02  -1.7634E-01  -2.0593E-01  -2.1353E-01
 -2.0990E-01  -2.0168E-01  -1.8714E-01  -1.7323E-01  -1.4067E-01  -1.1552E-01  -8.9140E-02
NP             0   4.8981E-04   7.3881E-04   1.1276E-03   1.5912E-03   1.9812E-03   2.3821E-03
  3.1240E-03
NP   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03

STN.           X       YSTEP        CF         UE      DEL05       THETA     SCHMETA          H     RTHETA      I6
   1  .1661E+00  .1562E-03   .004744  .1192E+01  .9063E-03  .8130E-04  .8130E-04     1.46128  .7265E+03      18

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .9380E-03          0           0           0
REYNOLDS NUMBER TOO SMALL

STN.           X       YSTEP        CF         UE      DEL05       THETA     SCHMETA          H     RTHETA      I6
   2  .1705E+00  .1562E-03   .004750  .1191E+01  .7790E-03  .9489E-04  .9178E-04     1.39210  .8475E+03      18

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .7865E-03          0           0           0

STN.           X       YSTEP        CF         UE      DEL05       THETA     SCHMETA          H     RTHETA      I6
  10  .2025E+00  .1562E-03   .003948  .1186E+01  .1458E-02  .1701E-03  .1622E-03     1.39899  .1512E+04      18

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .1198E-02          0           0           0

STN.           X       YSTEP        CF         UE      DEL05       THETA     SCHMETA          H     RTHETA      I6
  20  .2414E+00  .1562E-03   .003603  .1178E+01  .2103E-02  .2528E-03  .2412E-03     1.37989  .2234E+04      18

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .1374E-02          0           0           0
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STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
30	.2800E+00	.1562E-03	.003348	.1170E+01	.2717E-02	.3302E-03	.3191E-03	1.37691	.2896E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1456E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
40	.3182E+00	.1562E-03	.003159	.1160E+01	.2927E-02	.4005E-03	.3982E-03	1.38408	.3484E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1314E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
50	.3562E+00	.1562E-03	.002979	.1150E+01	.2792E-02	.4569E-03	.4781E-03	1.40913	.3940E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1098E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
60	.3938E+00	.1562E-03	.002776	.1140E+01	.2951E-02	.4848E-03	.5585E-03	1.45939	.4144E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.9973E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
70	.4311E+00	.1562E-03	.002581	.1130E+01	.2958E-02	.5115E-03	.6384E-03	1.50260	.4335E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.8637E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
80	.4682E+00	.1562E-03	.002407	.1121E+01	.2937E-02	.5197E-03	.7178E-03	1.54526	.4368E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.7626E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
90	.5047E+00	.1562E-03	.002296	.1112E+01	.1863E-02	.5592E-03	.7966E-03	1.56059	.4663E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.4243E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
100	.5415E+00	.1562E-03	.002179	.1104E+01	.2843E-02	.4616E-03	.8760E-03	1.63641	.3821E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.5812E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
110	.5775E+00	.1562E-03	.002176	.1095E+01	.2951E-02	.4959E-03	.9556E-03	1.52922	.4074E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.5478E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
119	.6104E+00	.1562E-03	.002599	.1087E+01	.2957E-02	.5218E-03	.1041E-02	1.49590	.4254E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.4979E-03	0	0	0

X=

.1661E+00	.1705E+00	.1744E+00	.1785E+00	.1825E+00	.1866E+00	.1906E+00	.1946E+00	.1985E+00	.2025E+00
.2064E+00	.2103E+00	.2142E+00	.2181E+00	.2220E+00	.2259E+00	.2298E+00	.2337E+00	.2376E+00	.2414E+00
.2453E+00	.2492E+00	.2531E+00	.2569E+00	.2608E+00	.2646E+00	.2685E+00	.2723E+00	.2761E+00	.2800E+00

.2838E+00	.2877E+00	.2915E+00	.2953E+00	.2991E+00	.3030E+00	.3068E+00	.3106E+00	.3144E+00	.3182E+00
.3220E+00	.3258E+00	.3296E+00	.3334E+00	.3372E+00	.3410E+00	.3448E+00	.3486E+00	.3524E+00	.3562E+00
.3599E+00	.3637E+00	.3675E+00	.3713E+00	.3750E+00	.3788E+00	.3826E+00	.3863E+00	.3901E+00	.3938E+00
.3976E+00	.4013E+00	.4050E+00	.4088E+00	.4125E+00	.4162E+00	.4200E+00	.4237E+00	.4274E+00	.4311E+00
.4349E+00	.4386E+00	.4423E+00	.4460E+00	.4497E+00	.4534E+00	.4571E+00	.4608E+00	.4645E+00	.4682E+00
.4718E+00	.4755E+00	.4792E+00	.4828E+00	.4865E+00	.4901E+00	.4938E+00	.4974E+00	.5011E+00	.5047E+00
.5084E+00	.5121E+00	.5158E+00	.5195E+00	.5231E+00	.5268E+00	.5305E+00	.5342E+00	.5378E+00	.5415E+00
.5451E+00	.5488E+00	.5524E+00	.5559E+00	.5595E+00	.5631E+00	.5667E+00	.5703E+00	.5739E+00	.5775E+00
.5812E+00	.5848E+00	.5885E+00	.5922E+00	.5958E+00	.5995E+00	.6031E+00	.6068E+00	.6104E+00	.6140E+00

VE/UE=

.2996E-02	.3386E-02	.3412E-02	.3539E-02	.3582E-02	.3581E-02	.3529E-02	.3460E-02	.3386E-02	.3303E-02
.3243E-02	.3194E-02	.3163E-02	.3146E-02	.3139E-02	.3137E-02	.3140E-02	.3143E-02	.3145E-02	.3147E-02
.3150E-02	.3153E-02	.3158E-02	.3165E-02	.3172E-02	.3181E-02	.3191E-02	.3200E-02	.3209E-02	.3217E-02
.3224E-02	.3230E-02	.3236E-02	.3242E-02	.3249E-02	.3256E-02	.3264E-02	.3273E-02	.3282E-02	.3291E-02
.3301E-02	.3310E-02	.3320E-02	.3330E-02	.3340E-02	.3351E-02	.3362E-02	.3373E-02	.3385E-02	.3418E-02
.3407E-02	.3410E-02	.3406E-02	.3442E-02	.3485E-02	.3520E-02	.3480E-02	.3460E-02	.3430E-02	.3412E-02
.3398E-02	.3349E-02	.3324E-02	.3298E-02	.3277E-02	.3256E-02	.3236E-02	.3218E-02	.3201E-02	.3183E-02
.3164E-02	.3144E-02	.3177E-02	.3107E-02	.3066E-02	.3077E-02	.3123E-02	.3039E-02	.2983E-02	.2906E-02
.2850E-02	.2809E-02	.2708E-02	.2699E-02	.2732E-02	.2795E-02	.2890E-02	.3004E-02	.3130E-02	.3268E-02
.3393E-02	.3204E-02	.2998E-02	.2695E-02	.2606E-02	.2602E-02	.2517E-02	.2415E-02	.2306E-02	.2197E-02
.2078E-02	.1935E-02	.1798E-02	.1636E-02	.1456E-02	.1252E-02	.1027E-02	.7767E-03	.5359E-03	.4905E-03
.5197E-03	.7924E-03	.1399E-02	.1778E-02	.2092E-02	.2318E-02	.2492E-02	.2621E-02	.2722E-02	

(PW-PREF)/UREF**2=

-.2099E+00	-.2104E+00	-.2097E+00	-.2090E+00	-.2083E+00	-.2075E+00	-.2068E+00	-.2061E+00	-.2053E+00	-.2046E+00
-.2038E+00	-.2030E+00	-.2023E+00	-.2014E+00	-.2006E+00	-.1998E+00	-.1990E+00	-.1981E+00	-.1972E+00	-.1963E+00
-.1954E+00	-.1944E+00	-.1934E+00	-.1924E+00	-.1914E+00	-.1903E+00	-.1892E+00	-.1881E+00	-.1870E+00	-.1859E+00
-.1847E+00	-.1836E+00	-.1824E+00	-.1812E+00	-.1800E+00	-.1788E+00	-.1776E+00	-.1764E+00	-.1752E+00	-.1739E+00
-.1727E+00	-.1715E+00	-.1703E+00	-.1691E+00	-.1679E+00	-.1667E+00	-.1655E+00	-.1643E+00	-.1630E+00	-.1619E+00
-.1607E+00	-.1595E+00	-.1583E+00	-.1571E+00	-.1559E+00	-.1547E+00	-.1536E+00	-.1524E+00	-.1512E+00	-.1501E+00
-.1489E+00	-.1478E+00	-.1466E+00	-.1455E+00	-.1444E+00	-.1432E+00	-.1421E+00	-.1410E+00	-.1399E+00	-.1388E+00
-.1377E+00	-.1366E+00	-.1355E+00	-.1345E+00	-.1334E+00	-.1323E+00	-.1313E+00	-.1303E+00	-.1293E+00	-.1283E+00
-.1273E+00	-.1263E+00	-.1252E+00	-.1243E+00	-.1233E+00	-.1223E+00	-.1214E+00	-.1204E+00	-.1195E+00	-.1186E+00
-.1177E+00	-.1168E+00	-.1160E+00	-.1151E+00	-.1142E+00	-.1133E+00	-.1124E+00	-.1115E+00	-.1106E+00	-.1097E+00
-.1088E+00	-.1079E+00	-.1070E+00	-.1061E+00	-.1052E+00	-.1043E+00	-.1033E+00	-.1024E+00	-.1014E+00	-.1004E+00
-.9933E-01	-.9828E-01	-.9726E-01	-.9627E-01	-.9527E-01	-.9426E-01	-.9325E-01	-.9223E-01	-.9122E-01	-.9021E-01

(PW-PE)/UREF**2=

0	-.1316E-02	-.1401E-02	-.1462E-02	-.1539E-02	-.1611E-02	-.1674E-02	-.1728E-02	-.1779E-02	-.1822E-02
-.1858E-02	-.1891E-02	-.1922E-02	-.1949E-02	-.1984E-02	-.2015E-02	-.2042E-02	-.2064E-02	-.2079E-02	-.2089E-02
-.2091E-02	-.2086E-02	-.2073E-02	-.2054E-02	-.2028E-02	-.1996E-02	-.1959E-02	-.1922E-02	-.1880E-02	-.1834E-02
-.1785E-02	-.1733E-02	-.1677E-02	-.1620E-02	-.1561E-02	-.1501E-02	-.1440E-02	-.1380E-02	-.1320E-02	-.1261E-02
-.1207E-02	-.1154E-02	-.1103E-02	-.1054E-02	-.1007E-02	-.9613E-03	-.9175E-03	-.8753E-03	-.8236E-03	-.7942E-03
-.7664E-03	-.7316E-03	-.6796E-03	-.6398E-03	-.6219E-03	-.5953E-03	-.5841E-03	-.5629E-03	-.5385E-03	-.5123E-03
-.4859E-03	-.4716E-03	-.4494E-03	-.4286E-03	-.4106E-03	-.3946E-03	-.3800E-03	-.3677E-03	-.3568E-03	-.3473E-03
-.3388E-03	-.3118E-03	-.3238E-03	-.3337E-03	-.3071E-03	-.2877E-03	-.3063E-03	-.3295E-03	-.3388E-03	-.3422E-03
-.3367E-03	-.3328E-03	-.3202E-03	-.3064E-03	-.3035E-03	-.3026E-03	-.3048E-03	-.3102E-03	-.3171E-03	-.3471E-03
-.3670E-03	-.4471E-03	-.5009E-03	-.5132E-03	-.5006E-03	-.5151E-03	-.5414E-03	-.5588E-03	-.5718E-03	-.5793E-03
-.5860E-03	-.5752E-03	-.5921E-03	-.6011E-03	-.6010E-03	-.5992E-03	-.5959E-03	-.5855E-03	-.5489E-03	-.4992E-03
-.4474E-03	-.3833E-03	-.3604E-03	-.3715E-03	-.3691E-03	-.3645E-03	-.3552E-03	-.3430E-03	-.3357E-03	-.3357E-03

SWEEP NO. 8 OF INVISCIO/VISCOUS CALCULATION COMPLETED

RUN NO. 9 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

0	.1909E-02	-.8430E-02	-.1665E-02	-.1388E-02	-.1063E-03	.8483E-03	-.5238E-02	.3721E-02	.3734E-02

.3815E-02	.3690E-02	.3242E-02	.4317E-02	.4049E-02	.3242E-02	.1895E-02	.1018E-02	.5282E-03	0
.5282E-03	.1018E-02	.1895E-02	.3242E-02	.4049E-02	.4317E-02	.3242E-02	.3690E-02	.3815E-02	.3734E-02
.3721E-02	-.5238E-02	.8483E-03	-.1063E-03	-.1388E-02	-.1665E-02	-.8430E-02	.1909E-02	0	

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.2820E-02	-.4652E-02	-.4458E-02	-.2030E-02	-.1324E-02	-.1342E-03	-.4783E-02	-.6165E-03	.2557E-02	.2615E-02
.2625E-02	.2083E-02	.2689E-02	.2975E-02	.2445E-02	.1534E-02	.7728E-03	.3886E-03	.1301E-03	.1301E-03
.3886E-03	.7728E-03	.1534E-02	.2445E-02	.2975E-02	.2689E-02	.2083E-02	.2625E-02	.2615E-02	.2557E-02
-.6165E-03	-.4783E-02	-.1342E-03	-.1324E-02	-.2030E-02	-.4458E-02	-.4652E-02	.2820E-02		

RUN NO. 9 OF PROGRAM AMOS

INCIDENCE = 0 CHORD = 1.000

X	Y	SSM	CP	U(TANG)	V(NORM)
.00229	.00623	.00664	.80359	.44319	.00282
.00832	.01600	.01842	.11883	.93871	-.00465
.01829	.02335	.03088	-.12697	1.06159	-.00446
.03702	.03212	.05163	-.28898	1.13533	-.00203
.06204	.04050	.07806	-.38786	1.17807	-.00132
.08709	.04656	.10384	-.42281	1.19282	-.00013
.12464	.05287	.14194	-.42070	1.19193	-.00478
.17474	.05853	.19238	-.41549	1.18974	-.00062
.22487	.06152	.24260	-.38612	1.17733	.00256
.27496	.06284	.29272	-.36171	1.16692	.00262
.35006	.06215	.36783	-.30979	1.14446	.00263
.45015	.05861	.46800	-.25681	1.12108	.00208
.55022	.05240	.56827	-.20411	1.09732	.00269
.65027	.04415	.66866	-.15341	1.07397	.00298
.75027	.03406	.76917	-.09666	1.04721	.00244
.85021	.02220	.86982	-.02289	1.01138	.00153
.92513	.01232	.94539	.05459	.97232	.00077
.96258	.00694	.98322	.10862	.94413	.00039
.98753	.00255	1.00856	.22714	.87913	.00013
.98753	-.00255	1.03402	.22714	-.87913	.00013
.96258	-.00694	1.05936	.10862	-.94413	.00039
.92513	-.01232	1.09719	.05459	-.97232	.00077
.85021	-.02220	1.17276	-.02289	-1.01138	.00153
.75027	-.03406	1.27341	-.09666	-1.04721	.00244
.65027	-.04415	1.37392	-.15341	-1.07397	.00298
.55022	-.05240	1.47431	-.20411	-1.09732	.00269
.45015	-.05861	1.57458	-.25681	-1.12108	.00208
.35006	-.06215	1.67475	-.30979	-1.14446	.00263
.27496	-.06284	1.74986	-.36171	-1.16692	.00262
.22487	-.06152	1.79998	-.38612	-1.17733	.00256
.17474	-.05853	1.85020	-.41549	-1.18974	-.00062
.12464	-.05287	1.90064	-.42070	-1.19193	-.00478
.08709	-.04656	1.93874	-.42281	-1.19282	-.00013
.06204	-.04050	1.96452	-.38786	-1.17807	-.00132
.03702	-.03212	1.99095	-.28898	-1.13533	-.00203
.01829	-.02335	2.01170	-.12697	-1.06159	-.00446
.00832	-.01600	2.02415	.11883	-.93871	-.00465
.00229	-.00623	2.03594	.80359	-.44319	.00282

LIFT COEFFICIENT = -.000

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ARC LENGTH FOR STAGN. PT. ON M.S.=   2.04258

RUN NO.  9  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS INTERACTION CYCLE--AEROFOIL TEST CASE

1977     0    10  119    16     5     0     0     1     0    51     0    -2     0
A                   0  1.000E-01           0  7.500E+06           0  1.000E+00  3.000E-01

THWAITES LAMINAR B.L. CALC.
       X          THETA        RTHETA           UE            VE
           0    .6657E-05            0             0             0
   .1319E-01    .1292E-04    .7657E+02    .7900E+00    .1909E-02
   .2327E-01    .1962E-04    .1494E+03    .1015E+01   -.8423E-02
   .3770E-01    .3025E-04    .2477E+03    .1092E+01   -.1659E-02
   .6441E-01    .4258E-04    .3713E+03    .1163E+01   -.1389E-02
   .9023E-01    .5321E-04   ..4740E+03    .1188E+01   -.1097E-03
   .1157E+00    .6327E-04    .5667E+03    .1194E+01    .8438E-03
   .1661E+00    .8137E-04    .7288E+03    .1191E+01    .1277E-02

SYNTHETIC STARTING PROFILES   THETA/DELTA= .1048
X FOR CURV. B. VALUE                0  1.319E-02  2.327E-02  3.770E-02  6.441E-02  9.023E-02  1.157E-01
 1.661E-01  2.163E-01  2.663E-01  3.163E-01  4.163E-01  5.165E-01  6.167E-01
        I          I
CURV     6.302E+01  3.406E+01  1.735E+01  8.571E+00  3.819E+00  2.344E+00  1.664E+00
 1.035E+00  7.407E-01  5.675E-01  4.517E-01  3.049E-01  2.175E-01  1.651E-01
 1.377E-01  1.307E-01
X FOR PRESS. AND NP B. VALUES              0   1.3194E-02   2.3271E-02   3.7701E-02   6.4410E-02   9.0229E-02   1.1569E-01
  1.6613E-01   2.1628E-01   2.6632E-01   3.1633E-01   4.1635E-01   5.1648E-01   6.1674E-01
PE-PREF      5.0000E-01   1.8797E-01  -1.5403E-02  -9.6061E-02  -1.7574E-01  -2.0536E-01  -2.1302E-01
 -2.0940E-01  -2.0124E-01  -1.8681E-01  -1.7298E-01  -1.4052E-01  -1.1546E-01  -8.9184E-02
NP             0   4.8981E-04   7.3881E-04   1.1276E-03   1.5912E-03   1.9812E-03   2.3821E-03
  3.1240E-03
NP   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03

STN.          X        YSTEP         CF         UE     DEL05       THETA     SCHMETA         H     RTHETA      I6
   1  .1661E+00  .1562E-03    .004745  .1191E+01  .9063E-03  .8129E-04  .8129E-04    1.46131  .7262E+03      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .9380E-03          0          0          0
REYNOLDS NUMBER TOO SMALL

STN.          X        YSTEP         CF         UE     DEL05       THETA     SCHMETA         H     RTHETA      I6
   2  .1705E+00  .1562E-03    .004751  .1190E+01  .7790E-03  .9486E-04  .9177E-04    1.39250  .8469E+03      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .7865E-03          0          0          0

STN.          X        YSTEP         CF         UE     DEL05       THETA     SCHMETA         H     RTHETA      I6
  10  .2025E+00  .1562E-03    .003949  .1185E+01  .1458E-02  .1700E-03  .1621E-03    1.39918  .1511E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .1198E-02          0          0          0

STN.          X        YSTEP         CF         UE     DEL05       THETA     SCHMETA         H     RTHETA      I6
  20  .2414E+00  .1562E-03    .003604  .1178E+01  .2102E-02  .2527E-03  .2410E-03    1.37998  .2233E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05      VW/UE
         0  .1374E-02          0          0          0

STN.          X        YSTEP         CF         UE     DEL05       THETA     SCHMETA         H     RTHETA      I6
  30  .2800E+00  .1562E-03    .003349  .1169E+01  .2716E-02  .3300E-03  .3189E-03    1.37695  .2895E+04      18
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 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .1455E-02         0           0           0

STN.          X        YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
  40  .3182E+00  .1562E-03   .003160  .1160E+01  .2927E-02  .4004E-03  .3979E-03   1.38410  .3483E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .1314E-02         0           0           0

STN.          X        YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
  50  .3562E+00  .1562E-03   .002979  .1150E+01  .2792E-02  .4567E-03  .4779E-03   1.40910  .3938E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .1098E-02         0           0           0

STN.          X        YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
  60  .3938E+00  .1562E-03   .002777  .1140E+01  .2951E-02  .4847E-03  .5581E-03   1.45932  .4143E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .9973E-03         0           0           0

STN.          X        YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
  70  .4311E+00  .1562E-03   .002581  .1130E+01  .2958E-02  .5114E-03  .6379E-03   1.50249  .4334E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .8637E-03         0           0           0

STN.          X        YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
  80  .4682E+00  .1562E-03   .002407  .1121E+01  .2937E-02  .5196E-03  .7172E-03   1.54512  .4367E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .7626E-03         0           0           0

STN.          X        YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
  90  .5047E+00  .1562E-03   .002297  .1112E+01  .1863E-02  .5591E-03  .7958E-03   1.56039  .4662E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .4243E-03         0           0           0

STN.          X        YSTEP        CF          UE    DELO5.       THETA     SCHMETA          H     RTHETA      I6
 100  .5415E+00  .1562E-03   .002180  .1104E+01  .2842E-02  .4615E-03  .8751E-03   1.63617  .3820E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .5810E-03         0           0           0

STN.          X        YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
 110  .5775E+00  .1562E-03   .002177  .1095E+01  .2951E-02  .4957E-03  .9545E-03   1.52911  .4072E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .5478E-03         0           0           0

STN.          X        YSTEP        CF          UE    DELO5        THETA     SCHMETA          H     RTHETA      I6
 119  .6104E+00  .1562E-03   .002599  .1087E+01  .2956E-02  .5216E-03  .1040E-02   1.49576  .4253E+04       18

 ROUGH/DO5     DO5/RAD DO5/(X-XO) STRAIN.DO5        VW/UE
         0  .4979E-03         0           0           0

X=
   .1661E+00   .1705E+00   .1744E+00   .1785E+00   .1825E+00   .1866E+00   .1906E+00   .1946E+00   .1985E+00   .2025E+00
   .2064E+00   .2103E+00   .2142E+00   .2181E+00   .2220E+00   .2259E+00   .2298E+00   .2337E+00   .2376E+00   .2414E+00
   .2453E+00   .2492E+00   .2531E+00   .2569E+00   .2608E+00   .2646E+00   .2685E+00   .2723E+00   .2761E+00   .2800E+00
   .2838E+00   .2877E+00   .2915E+00   .2953E+00   .2991E+00   .3030E+00   .3068E+00   .3106E+00   .3144E+00   .3182E+00
   .3220E+00   .3258E+00   .3296E+00   .3334E+00   .3372E+00   .3410E+00   .3448E+00   .3486E+00   .3524E+00   .3562E+00
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.3599E+00	.3637E+00	.3675E+00	.3713E+00	.3750E+00	.3788E+00	.3826E+00	.3863E+00	.3901E+00	.3938E+00
.3976E+00	.4013E+00	.4050E+00	.4088E+00	.4125E+00	.4162E+00	.4200E+00	.4237E+00	.4274E+00	.4311E+00
.4349E+00	.4386E+00	.4423E+00	.4460E+00	.4497E+00	.4534E+00	.4571E+00	.4608E+00	.4645E+00	.4682E+00
.4718E+00	.4755E+00	.4792E+00	.4828E+00	.4865E+00	.4901E+00	.4938E+00	.4974E+00	.5011E+00	.5047E+00
.5084E+00	.5121E+00	.5158E+00	.5195E+00	.5231E+00	.5268E+00	.5305E+00	.5342E+00	.5378E+00	.5415E+00
.5451E+00	.5488E+00	.5524E+00	.5559E+00	.5595E+00	.5631E+00	.5667E+00	.5703E+00	.5739E+00	.5775E+00
.5812E+00	.5848E+00	.5885E+00	.5922E+00	.5958E+00	.5995E+00	.6031E+00	.6068E+00	.6104E+00	.6140E+00

VE/UE=

.2992E-02	.3381E-02	.3408E-02	.3535E-02	.3578E-02	.3576E-02	.3525E-02	.3456E-02	.3382E-02	.3298E-02
.3238E-02	.3189E-02	.3159E-02	.3141E-02	.3134E-02	.3133E-02	.3135E-02	.3138E-02	.3140E-02	.3142E-02
.3145E-02	.3149E-02	.3154E-02	.3160E-02	.3168E-02	.3177E-02	.3186E-02	.3196E-02	.3205E-02	.3213E-02
.3220E-02	.3226E-02	.3232E-02	.3238E-02	.3245E-02	.3252E-02	.3261E-02	.3269E-02	.3278E-02	.3288E-02
.3297E-02	.3306E-02	.3316E-02	.3326E-02	.3337E-02	.3347E-02	.3359E-02	.3370E-02	.3382E-02	.3415E-02
.3404E-02	.3407E-02	.3403E-02	.3439E-02	.3482E-02	.3517E-02	.3478E-02	.3458E-02	.3428E-02	.3409E-02
.3396E-02	.3346E-02	.3322E-02	.3296E-02	.3275E-02	.3254E-02	.3234E-02	.3216E-02	.3198E-02	.3180E-02
.3161E-02	.3142E-02	.3174E-02	.3105E-02	.3063E-02	.3075E-02	.3120E-02	.3036E-02	.2980E-02	.2902E-02
.2847E-02	.2806E-02	.2704E-02	.2696E-02	.2729E-02	.2791E-02	.2886E-02	.2999E-02	.3126E-02	.3263E-02
.3388E-02	.3199E-02	.2993E-02	.2691E-02	.2601E-02	.2597E-02	.2513E-02	.2410E-02	.2302E-02	.2193E-02
.2074E-02	.1931E-02	.1794E-02	.1632E-02	.1454E-02	.1249E-02	.1025E-02	.7757E-03	..5353E-03	.4902E-03
.5192E-03	.7899E-03	.1396E-02	.1775E-02	.2089E-02	.2315E-02	.2489E-02	.2618E-02	.2718E-02	

(PW-PREF)/UREF**2=

-.2094E+00	-.2099E+00	-.2092E+00	-.2085E+00	-.2078E+00	-.2071E+00	-.2064E+00	-.2056E+00	-.2049E+00	-.2042E+00
-.2034E+00	-.2026E+00	-.2019E+00	-.2011E+00	-.2003E+00	-.1994E+00	-.1986E+00	-.1977E+00	-.1969E+00	-.1960E+00
-.1950E+00	-.1941E+00	-.1931E+00	-.1921E+00	-.1910E+00	-.1900E+00	-.1889E+00	-.1878E+00	-.1867E+00	-.1856E+00
-.1844E+00	-.1833E+00	-.1821E+00	-.1809E+00	-.1798E+00	-.1786E+00	-.1773E+00	-.1761E+00	-.1749E+00	-.1737E+00
-.1725E+00	-.1713E+00	-.1701E+00	-.1689E+00	-.1677E+00	-.1665E+00	-.1653E+00	-.1641E+00	-.1629E+00	-.1617E+00
-.1605E+00	-.1593E+00	-.1581E+00	-.1569E+00	-.1557E+00	-.1546E+00	-.1534E+00	-.1522E+00	-.1511E+00	-.1499E+00
-.1488E+00	-.1476E+00	-.1465E+00	-.1453E+00	-.1442E+00	-.1431E+00	-.1420E+00	-.1409E+00	-.1398E+00	-.1387E+00
-.1376E+00	-.1365E+00	-.1354E+00	-.1344E+00	-.1333E+00	-.1322E+00	-.1312E+00	-.1302E+00	-.1292E+00	-.1282E+00
-.1272E+00	-.1262E+00	-.1252E+00	-.1242E+00	-.1232E+00	-.1222E+00	-.1213E+00	-.1203E+00	-.1194E+00	-.1185E+00
-.1176E+00	-.1168E+00	-.1159E+00	-.1150E+00	-.1141E+00	-.1132E+00	-.1123E+00	-.1115E+00	-.1106E+00	-.1097E+00
-.1088E+00	-.1079E+00	-.1070E+00	-.1061E+00	-.1052E+00	-.1043E+00	-.1033E+00	-.1024E+00	-.1014E+00	-.1004E+00
-.9935E-01	-.9830E-01	-.9729E-01	-.9631E-01	-.9530E-01	-.9430E-01	-.9329E-01	-.9227E-01	-.9126E-01	-.9026E-01

(PW-PE)/UREF**2=

0	-.1318E-02	-.1406E-02	-.1468E-02	-.1549E-02	-.1622E-02	-.1688E-02	-.1745E-02	-.1798E-02	-.1842E-02
-.1880E-02	-.1916E-02	-.1948E-02	-.1977E-02	-.2013E-02	-.2046E-02	-.2074E-02	-.2097E-02	-.2114E-02	-.2124E-02
-.2127E-02	-.2122E-02	-.2110E-02	-.2090E-02	-.2064E-02	-.2032E-02	-.1995E-02	-.1958E-02	-.1915E-02	-.1868E-02
-.1818E-02	-.1765E-02	-.1709E-02	-.1650E-02	-.1590E-02	-.1528E-02	-.1467E-02	-.1405E-02	-.1344E-02	-.1284E-02
-.1229E-02	-.1175E-02	-.1122E-02	-.1072E-02	-.1024E-02	-.9767E-03	-.9316E-03	-.8883E-03	-.8354E-03	-.8049E-03
-.7760E-03	-.7401E-03	-.6871E-03	-.6462E-03	-.6273E-03	-.5998E-03	-.5876E-03	-.5655E-03	-.5402E-03	-.5132E-03
-.4860E-03	-.4710E-03	-.4481E-03	-.4266E-03	-.4080E-03	-.3914E-03	-.3764E-03	-.3635E-03	-.3523E-03	-.3424E-03
-.3336E-03	-.3063E-03	-.3182E-03	-.3279E-03	-.3012E-03	-.2818E-03	-.3005E-03	-.3237E-03	-.3332E-03	-.3368E-03
-.3316E-03	-.3280E-03	-.3159E-03	-.3026E-03	-.3003E-03	-.3001E-03	-.3030E-03	-.3091E-03	-.3170E-03	-.3479E-03
-.3688E-03	-.4500E-03	-.5048E-03	-.5183E-03	-.5068E-03	-.5224E-03	-.5498E-03	-.5682E-03	-.5822E-03	-.5907E-03
-.5983E-03	-.5883E-03	-.6058E-03	-.6154E-03	-.6158E-03	-.6142E-03	-.6111E-03	-.6008E-03	-.5642E-03	-.5145E-03
-.4626E-03	-.3981E-03	-.3746E-03	-.3852E-03	-.3823E-03	-.3771E-03	-.3672E-03	-.3544E-03	-.3463E-03	-.3463E-03

SWEEP NO. 9 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 10 OF PROGRAM MATCH

VELS. NORMAL TO MATCHING SURFACE AT NODES

0	.1909E-02	-.8423E-02	-.1659E-02	-.1389E-02	-.1097E-03	.8438E-03	-.5241E-02	.3714E-02	.3728E-02
.3810E-02	.3687E-02	.3237E-02	.4311E-02	.4043E-02	.3238E-02	.1893E-02	.1017E-02	.5275E-03	0
.5275E-03	.1017E-02	.1893E-02	.3238E-02	.4043E-02	.4311E-02	.3237E-02	.3687E-02	.3810E-02	.3728E-02
.3714E-02	-.5241E-02	.8438E-03	-.1097E-03	-.1389E-02	-.1659E-02	-.8423E-02	.1909E-02	0	

VELS. NORMAL TO MATCHING SURFACE AT ELEMENT MID PTS.

.2904E-02	-.4702E-02	-.4458E-02	-.1918E-02	-.1140E-02	.1177E-03	-.4575E-02	-.3249E-03	.2904E-02	.2965E-02
.2974E-02	.2440E-02	.3065E-02	.3356E-02	.2824E-02	.1864E-02	.9824E-03	.5049E-03	.1715E-03	.1715E-03
.5049E-03	.9824E-03	.1864E-02	.2824E-02	.3356E-02	.3065E-02	.2440E-02	.2974E-02	.2965E-02	.2904E-02
-.3249E-03	-.4575E-02	.1177E-03	-.1140E-02	-.1918E-02	-.4458E-02	-.4702E-02	.2904E-02		

RUN NO. 10 OF PROGRAM AMOS

INCIDENCE = 0 CHORD = 1.000

X	Y	SSM	CP	U (TANG)	V (NORM)
.00229	.00623	.00664	.80365	.44311	.00290
.00832	.01600	.01842	.11923	.93849	-.00470
.01829	.02335	.03088	-.12627	1.06126	-.00446
.03702	.03212	.05163	-.28816	1.13497	-.00192
.06204	.04050	.07806	-.38702	1.17772	-.00114
.08709	.04656	.10384	-.42207	1.19251	.00012
.12464	.05287	.14194	-.42001	1.19164	-.00458
.17474	.05853	.19238	-.41482	1.18946	-.00032
.22487	.06152	.24260	-.38558	1.17711	.00290
.27496	.06284	.29272	-.36131	1.16675	.00297
.35006	.06215	.36783	-.30952	1.14434	.00297
.45015	.05861	.46800	-.25667	1.12101	.00244
.55022	.05240	.56827	-.20410	1.09732	.00306
.65027	.04415	.66866	-.15354	1.07403	.00336
.75027	.03406	.76917	-.09697	1.04737	.00282
.85021	.02220	.86982	-.02341	1.01164	.00186
.92513	.01232	.94539	.05390	.97267	.00098
.96258	.00694	.98322	.10792	.94450	.00050
.98753	.00255	1.00856	.22657	.87945	.00017
.98753	-.00255	1.03402	.22657	-.87945	.00017
.96258	-.00694	1.05936	.10792	-.94450	.00050
.92513	-.01232	1.09719	.05390	-.97267	.00098
.85021	-.02220	1.17276	-.02341	-1.01164	.00186
.75027	-.03406	1.27341	-.09697	-1.04737	.00282
.65027	-.04415	1.37392	-.15354	-1.07403	.00336
.55022	-.05240	1.47431	-.20410	-1.09732	.00306
.45015	-.05861	1.57458	-.25667	-1.12101	.00244
.35006	-.06215	1.67475	-.30952	-1.14434	.00297
.27496	-.06284	1.74986	-.36131	-1.16675	.00297
.22487	-.06152	1.79998	-.38558	-1.17711	.00290
.17474	-.05853	1.85020	-.41482	-1.18946	-.00032

.12464	-.05287	1.90064	-.42001	-1.19164	-.00458
.08709	-.04656	1.93874	-.42207	-1.19251	.00012
.06204	-.04050	1.96452	-.38702	-1.17772	-.00114
.03702	-.03212	1.99095	-.28816	-1.13497	-.00192
.01829	-.02335	2.01170	-.12627	-1.06126	-.00446
.00832	-.01600	2.02415	.11923	-.93849	-.00470
.00229	-.00623	2.03594	.80365	-.44311	.00290

LIFT COEFFICIENT = -.000

ARC LENGTH FOR STAGN. PT. ON M.S.= 2.04258

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RUN NO. 10  OF BOUNDARY LAYER CALCULATION

 B.L. CALC. IN INVISCID/VISCOUS INTERACTION CYCLE--AEROFOIL TEST CASE


1977    0   10  119   16    5    0    0    1    0  .51    0   -2    0
A                 0  1.000E-01             0  7.500E+06              0  1.000E+00  3.000E-01

THWAITES LAMINAR B.L. CALC.
       X         THETA       RTHETA          UE          VE
           0  .6657E-05           0           0           0
   .1319E-01  .1292E-04   .7656E+02   .7898E+00   .1908E-02
   .2327E-01  .1963E-04   .1494E+03   .1015E+01  -.8418E-02
   .3770E-01  .3026E-04   .2477E+03   .1091E+01  -.1654E-02
   .6441E-01  .4259E-04   .3712E+03   .1162E+01  -.1389E-02
   .9023E-01  .5322E-04   .4739E+03   .1187E+01  -.1120E-03
   .1157E+00  .6327E-04   .5666E+03   .1194E+01   .8407E-03
   .1661E+00  .8138E-04   .7287E+03   .1191E+01   .1276E-02

SYNTHETIC STARTING PROFILES   THETA/DELTA= .1048
X FOR CURV. B. VALUE              0  1.319E-02  2.327E-02  3.770E-02  6.441E-02  9.023E-02  1.157E-01
 1.661E-01  2.163E-01  2.663E-01  3.163E-01  4.163E-01  5.165E-01  6.167E-01
        I          I
CURV      6.302E+01  3.406E+01  1.735E+01  8.571E+00  3.819E+00  2.344E+00  1.664E+00
 1.035E+00  7.407E-01  5.675E-01  4.517E-01  3.049E-01  2.175E-01  1.651E-01
 1.377E-01  1.307E-01
X FOR PRESS. AND NP B. VALUES               0   1.3194E-02   2.3271E-02   3.7701E-02   6.4410E-02   9.0229E-02   1.1569E-01
  1.6613E-01   2.1628E-01   2.6632E-01   3.1633E-01   4.1635E-01   5.1648E-01   6.1674E-01
PE-PREF        5.0000E-01   1.8810E-01  -1.5132E-02  -9.5668E-02  -1.7532E-01  -2.0497E-01  -2.1267E-01
 -2.0905E-01  -2.0093E-01  -1.8658E-01  -1.7280E-01  -1.4042E-01  -1.1542E-01  -8.9215E-02
NP              0   4.8981E-04   7.3881E-04   1.1276E-03   1.5912E-03   1.9812E-03   2.3821E-03
  3.1240E-03
NP   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03

STN.          X       YSTEP          CF          UE      DEL05       THETA     SCHMETA          H    RTHETA      I6
   1  .1661E+00  .1562E-03     .004745  .1191E+01  .9063E-03  .8129E-04  .8129E-04    1.46132  .7260E+03     18

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
         0  .9380E-03          0          0          0
REYNOLDS NUMBER TOO SMALL

STN.          X       YSTEP          CF          UE      DEL05       THETA     SCHMETA          H    RTHETA      I6
   2  .1705E+00  .1562E-03     .004751  .1190E+01  .7790E-03  .9484E-04  .9176E-04    1.39277  .8465E+03     18

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
         0  .7865E-03          0          0          0

STN.          X       YSTEP          CF          UE      DEL05       THETA     SCHMETA          H    RTHETA      I6
  10  .2025E+00  .1562E-03     .003950  .1185E+01  .1458E-02  .1700E-03  .1621E-03    1.39931  .1510E+04     18

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
         0  .1198E-02          0          0          0

STN.          X       YSTEP          CF          UE      DEL05       THETA     SCHMETA          H    RTHETA      I6
  20  .2414E+00  .1562E-03     .003605  .1178E+01  .2102E-02  .2526E-03  .2410E-03    1.38004  .2232E+04     18

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
         0  .1374E-02          0          0          0

STN.          X       YSTEP          CF          UE      DEL05       THETA     SCHMETA          H    RTHETA      I6
  30  .2800E+00  .1562E-03     .003349  .1169E+01  .2716E-02  .3299E-03  .3188E-03    1.37699  .2893E+04     18
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 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1455E-02           0            0            0

STN.          X        YSTEP         CF          UE    DEL05        THETA     SCHMETA          H      RTHETA       I6
 40  .3182E+00  .1562E-03    .003160  .1160E+01  .2927E-02  .4003E-03  .3978E-03     1.38410  .3481E+04       18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1314E-02           0            0            0

STN.          X        YSTEP         CF          UE    DEL05        THETA     SCHMETA          H      RTHETA       I6
 50  .3562E+00  .1562E-03    .002980  .1150E+01  .2792E-02  .4567E-03  .4776E-03     1.40908  .3937E+04       18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1098E-02           0            0            0

STN.          X        YSTEP         CF          UE    DEL05        THETA     SCHMETA          H      RTHETA       I6
 60  .3938E+00  .1562E-03    .002777  .1140E+01  .2951E-02  .4846E-03  .5578E-03     1.45927  .4142E+04       18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .9973E-03           0            0            0

STN.          X        YSTEP         CF          UE    DEL05        THETA     SCHMETA          H      RTHETA       I6
 70  .4311E+00  .1562E-03    .002582  .1130E+01  .2958E-02  .5114E-03  .6376E-03     1.50242  .4333E+04       18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .8637E-03           0            0            0

STN.          X        YSTEP         CF          UE    DEL05        THETA     SCHMETA          H      RTHETA       I6
 80  .4682E+00  .1562E-03    .002408  .1121E+01  .2937E-02  .5195E-03  .7168E-03     1.54501  .4366E+04       18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .7626E-03           0            0            0

STN.          X        YSTEP         CF          UE    DEL05        THETA     SCHMETA          H      RTHETA       I6
 90  .5047E+00  .1562E-03    .002297  .1112E+01  .1863E-02  .5590E-03  .7953E-03     1.56026  .4661E+04       18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .4243E-03           0            0            0

STN.          X        YSTEP         CF          UE    DEL05        THETA     SCHMETA          H      RTHETA       I6
100  .5415E+00  .1562E-03    .002180  .1104E+01  .2842E-02  .4614E-03  .8745E-03     1.63600  .3819E+04       18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .5810E-03           0            0            0

STN.          X        YSTEP         CF          UE    DEL05        THETA     SCHMETA          H      RTHETA       I6
110  .5775E+00  .1562E-03    .002177  .1095E+01  .2951E-02  .4956E-03  .9537E-03     1.52902  .4072E+04       18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .5478E-03           0            0            0

STN.          X        YSTEP         CF          UE    DEL05        THETA     SCHMETA          H      RTHETA       I6
119  .6104E+00  .1562E-03    .002600  .1087E+01  .2956E-02  .5215E-03  .1039E-02     1.49566  .4252E+04       18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .4979E-03           0            0            0

X=
   .1661E+00   .1705E+00   .1744E+00   .1785E+00   .1825E+00   .1866E+00   .1906E+00   .1946E+00   .1985E+00   .2025E+00
   .2064E+00   .2103E+00   .2142E+00   .2181E+00   .2220E+00   .2259E+00   .2298E+00   .2337E+00   .2376E+00   .2414E+00
   .2453E+00   .2492E+00   .2531E+00   .2569E+00   .2608E+00   .2646E+00   .2685E+00   .2723E+00   .2761E+00   .2800E+00
   .2838E+00   .2877E+00   .2915E+00   .2953E+00   .2991E+00   .3030E+00   .3068E+00   .3106E+00   .3144E+00   .3182E+00
   .3220E+00   .3258E+00   .3296E+00   .3334E+00   .3372E+00   .3410E+00   .3448E+00   .3486E+00   .3524E+00   .3562E+00
   .3599E+00   .3637E+00   .3675E+00   .3713E+00   .3750E+00   .3788E+00   .3826E+00   .3863E+00   .3901E+00   .3938E+00
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.3976E+00	.4013E+00	.4050E+00	.4088E+00	.4125E+00	.4162E+00	.4200E+00	.4237E+00	.4274E+00	.4311E+00
.4349E+00	.4386E+00	.4423E+00	.4460E+00	.4497E+00	.4534E+00	.4571E+00	.4608E+00	.4645E+00	.4682E+00
.4718E+00	.4755E+00	.4792E+00	.4828E+00	.4865E+00	.4901E+00	.4938E+00	.4974E+00	.5011E+00	.5047E+00
.5084E+00	.5121E+00	.5158E+00	.5195E+00	.5231E+00	.5268E+00	.5305E+00	.5342E+00	.5378E+00	.5415E+00
.5451E+00	.5488E+00	.5524E+00	.5559E+00	.5595E+00	.5631E+00	.5667E+00	.5703E+00	.5739E+00	.5775E+00
.5812E+00	.5848E+00	.5885E+00	.5922E+00	.5958E+00	.5995E+00	.6031E+00	.6068E+00	.6104E+00	.6140E+00

VE/UF=

.2989E-02	.3378E-02	.3405E-02	.3532E-02	.3575E-02	.3573E-02	.3522E-02	.3453E-02	.3378E-02	.3295E-02
.3235E-02	.3186E-02	.3155E-02	.3138E-02	.3131E-02	.3130E-02	.3132E-02	.3135E-02	.3137E-02	.3139E-02
.3142E-02	.3145E-02	.3150E-02	.3157E-02	.3165E-02	.3174E-02	.3183E-02	.3193E-02	.3202E-02	.3210E-02
.3217E-02	.3223E-02	.3229E-02	.3235E-02	.3242E-02	.3250E-02	.3258E-02	.3267E-02	.3276E-02	.3285E-02
.3294E-02	.3304E-02	.3314E-02	.3324E-02	.3334E-02	.3345E-02	.3356E-02	.3368E-02	.3380E-02	.3413E-02
.3402E-02	.3405E-02	.3401E-02	.3437E-02	.3480E-02	.3515E-02	.3476E-02	.3456E-02	.3426E-02	.3407E-02
.3394E-02	.3344E-02	.3320E-02	.3294E-02	.3273E-02	.3252E-02	.3232E-02	.3214E-02	.3196E-02	.3178E-02
.3159E-02	.3140E-02	.3172E-02	.3103E-02	.3061E-02	.3072E-02	.3117E-02	.3034E-02	.2978E-02	.2900E-02
.2845E-02	.2804E-02	.2702E-02	.2693E-02	.2726E-02	.2788E-02	.2883E-02	.2996E-02	.3123E-02	.3259E-02
.3384E-02	.3195E-02	.2990E-02	.2687E-02	.2598E-02	.2594E-02	.2509E-02	.2407E-02	.2299E-02	.2190E-02
.2071E-02	.1928E-02	.1792E-02	.1630E-02	.1452E-02	.1248E-02	.1024E-02	.7750E-03	.5349E-03	.4894E-03
.5187E-03	.7879E-03	.1394E-02	.1773E-02	.2087E-02	.2313E-02	.2487E-02	.2616E-02	.2716E-02	

(PW-PREF)/UREF**2=

-.2091E+00	-.2095E+00	-.2089E+00	-.2082E+00	-.2075E+00	-.2068E+00	-.2061E+00	-.2053E+00	-.2046E+00	-.2039E+00
-.2031E+00	-.2024E+00	-.2016E+00	-.2008E+00	-.2000E+00	-.1992E+00	-.1983E+00	-.1975E+00	-.1966E+00	-.1957E+00
-.1948E+00	-.1938E+00	-.1929E+00	-.1919E+00	-.1908E+00	-.1898E+00	-.1887E+00	-.1876E+00	-.1865E+00	-.1854E+00
-.1843E+00	-.1831E+00	-.1819E+00	-.1808E+00	-.1796E+00	-.1784E+00	-.1772E+00	-.1760E+00	-.1748E+00	-.1736E+00
-.1724E+00	-.1711E+00	-.1699E+00	-.1687E+00	-.1675E+00	-.1663E+00	-.1651E+00	-.1639E+00	-.1627E+00	-.1615E+00
-.1604E+00	-.1592E+00	-.1580E+00	-.1568E+00	-.1556E+00	-.1544E+00	-.1533E+00	-.1521E+00	-.1510E+00	-.1498E+00
-.1487E+00	-.1475E+00	-.1464E+00	-.1452E+00	-.1441E+00	-.1430E+00	-.1419E+00	-.1408E+00	-.1397E+00	-.1386E+00
-.1375E+00	-.1364E+00	-.1353E+00	-.1343E+00	-.1332E+00	-.1321E+00	-.1311E+00	-.1301E+00	-.1291E+00	-.1281E+00
-.1271E+00	-.1261E+00	-.1251E+00	-.1241E+00	-.1231E+00	-.1222E+00	-.1212E+00	-.1203E+00	-.1194E+00	-.1185E+00
-.1176E+00	-.1167E+00	-.1159E+00	-.1150E+00	-.1141E+00	-.1132E+00	-.1123E+00	-.1114E+00	-.1106E+00	-.1097E+00
-.1088E+00	-.1079E+00	-.1070E+00	-.1061E+00	-.1052E+00	-.1043E+00	-.1033E+00	-.1024E+00	-.1014E+00	-.1004E+00
-.9937E-01	-.9832E-01	-.9731E-01	-.9633E-01	-.9533E-01	-.9433E-01	-.9332E-01	-.9231E-01	-.9130E-01	-.9030E-01

(PW-PE)/UREF**2=

0	-.1320E-02	-.1409E-02	-.1473E-02	-.1555E-02	-.1630E-02	-.1698E-02	-.1756E-02	-.1810E-02	-.1856E-02
-.1896E-02	-.1933E-02	-.1966E-02	-.1997E-02	-.2034E-02	-.2067E-02	-.2096E-02	-.2120E-02	-.2138E-02	-.2148E-02
-.2152E-02	-.2147E-02	-.2135E-02	-.2116E-02	-.2090E-02	-.2058E-02	-.2020E-02	-.1982E-02	-.1939E-02	-.1892E-02
-.1842E-02	-.1787E-02	-.1730E-02	-.1671E-02	-.1610E-02	-.1548E-02	-.1485E-02	-.1423E-02	-.1361E-02	-.1300E-02
-.1244E-02	-.1189E-02	-.1136E-02	-.1085E-02	-.1035E-02	-.9875E-03	-.9416E-03	-.8974E-03	-.8438E-03	-.8125E-03
-.7827E-03	-.7461E-03	-.6924E-03	-.6508E-03	-.6312E-03	-.6030E-03	-.5901E-03	-.5674E-03	-.5415E-03	-.5140E-03
-.4863E-03	-.4707E-03	-.4473E-03	-.4253E-03	-.4063E-03	-.3894E-03	-.3740E-03	-.3608E-03	-.3493E-03	-.3391E-03
-.3301E-03	-.3026E-03	-.3143E-03	-.3240E-03	-.2973E-03	-.2778E-03	-.2965E-03	-.3198E-03	-.3294E-03	-.3332E-03
-.3281E-03	-.3248E-03	-.3130E-03	-.3001E-03	-.2981E-03	-.2984E-03	-.3018E-03	-.3085E-03	-.3169E-03	-.3485E-03
-.3701E-03	-.4520E-03	-.5075E-03	-.5218E-03	-.5111E-03	-.5274E-03	-.5555E-03	-.5747E-03	-.5895E-03	-.5986E-03
-.6068E-03	-.5974E-03	-.6154E-03	-.6253E-03	-.6260E-03	-.6247E-03	-.6217E-03	-.6115E-03	-.5750E-03	-.5252E-03
-.4733E-03	-.4086E-03	-.3847E-03	-.3950E-03	-.3918E-03	-.3863E-03	-.3760E-03	-.3627E-03	-.3543E-03	-.3543E-03

SWEEP NO. 10 OF INVISCID/VISCOUS CALCULATION COMPLETED

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RUN NO. 10  OF BOUNDARY LAYER CALCULATION

 B.L. CALC: IN INVISCID/VISCOUS INTERACTION CYCLE--AEROFOIL TEST CASE

1977    0    1  119   16    5    0    0    1    0   51    0   -2    0
A                 0  1.000E-01            0  7.500E+06           0  1.000E+00  3.000E-01

THWAITES LAMINAR B.L. CALC.
       X           THETA        RTHETA          UE           VE
           0     .6657E-05           0           0            0
   .1319E-01   .1292E-04    .7656E+02   .7898E+00   .1908E-02
   .2327E-01   .1963E-04    .1494E+03   .1015E+01  -.8418E-02
   .3770E-01   .3026E-04    .2477E+03   .1091E+01  -.1654E-02
   .6441E-01   .4259E-04    .3712E+03   .1162E+01  -.1389E-02
   .9023E-01   .5322E-04    .4739E+03   .1187E+01  -.1120E-03
   .1157E+00   .6327E-04    .5666E+03   .1194E+01   .8407E-03
   .1661E+00   .8138E-04    .7287E+03   .1191E+01   .1276E-02

SYNTHETIC STARTING PROFILES    THETA/DELTA= .1048
X FOR CURV. B. VALUE              0  1.319E-02  2.327E-02  3.770E-02  6.441E-02  9.023E-02  1.157E-01
 1.661E-01  2.163E-01  2.663E-01  3.163E-01  4.163E-01  5.165E-01  6.167E-01
         I            I
CURV      6.302E+01  3.406E+01  1.735E+01  8.571E+00  3.819E+00  2.344E+00  1.664E+00
 1.035E+00  7.407E-01  5.675E-01  4.517E-01  3.049E-01  2.175E-01  1.651E-01
 1.377E-01  1.307E-01
X FOR PRESS. AND NP B. VALUES             0   1.3194E-02   2.3271E-02   3.7701E-02   6.4410E-02   9.0229E-02   1.1569E-01
  1.6613E-01   2.1628E-01   2.6632E-01   3.1633E-01   4.1635E-01   5.1648E-01   6.1674E-01
PE-PREF        5.0000E-01   1.8810E-01  -1.5132E-02  -9.5668E-02  -1.7532E-01  -2.0497E-01  -2.1267E-01
 -2.0905E-01  -2.0093E-01  -1.8658E-01  -1.7280E-01  -1.4042E-01  -1.1542E-01  -8.9215E-02
NP              0   4.8981E-04   7.3881E-04   1.1276E-03   1.5912E-03   1.9812E-03   2.3821E-03
  3.1240E-03
NP   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03   3.1240E-03

STN.          X       YSTEP        CF         UE      DEL05       THETA     SCHMETA          H     RTHETA      I6
   1  .1661E+00  .1562E-03   .004745  .1191E+01  .9063E-03  .8129E-04  .8129E-04    1.46132  .7260E+03      18

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .9380E-03        0            0           0
REYNOLDS NUMBER TOO SMALL

STN.          X       YSTEP        CF         UE      DEL05       THETA     SCHMETA          H     RTHETA      I6
   2  .1705E+00  .1562E-03   .004751  .1190E+01  .7790E-03  .9484E-04  .9176E-04    1.39277  .8465E+03      18

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .7865E-03        0            0           0

STN.          X       YSTEP        CF         UE      DEL05       THETA     SCHMETA          H     RTHETA      I6
   3  .1744E+00  .1562E-03   .004676  .1190E+01  .9036E-03  .1047E-03  .1012E-03    1.39550  .9340E+03      18

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .8912E-03        0            0           0

STN.          X       YSTEP        CF         UE      DEL05       THETA     SCHMETA          H     RTHETA      I6
   4  .1785E+00  .1562E-03   .004547  .1189E+01  .1012E-02  .1143E-03  .1106E-03    1.40091  .1019E+04      18

 ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05       VW/UE
         0  .9738E-03        0            0           0

STN.          X       YSTEP        CF         UE      DEL05       THETA     SCHMETA          H     RTHETA      I6
   5  .1825E+00  .1562E-03   .004397  .1188E+01  .1091E-02  .1240E-03  .1198E-03    1.40460  .1105E+04      18
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 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1024E-02          0           0           0

STN.           X       YSTEP         CF         UE    DEL05      THETA    SCHMETA          H    RTHETA     I6
   6  .1866E+00  .1562E-03    .004264  .1188E+01  .1174E-02  .1337E-03  .1287E-03    1.40562  .1191E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1074E-02          0           0           0

STN.           X       YSTEP         CF         UE    DEL05      THETA    SCHMETA          H    RTHETA     I6
   7  .1906E+00  .1562E-03    .004157  .1187E+01  .1242E-02  .1433E-03  .1374E-03    1.40536  .1276E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1107E-02          0           0           0

STN.           X       YSTEP         CF         UE    DEL05      THETA    SCHMETA          H    RTHETA     I6
   8  .1946E+00  .1562E-03    .004072  .1186E+01  .1313E-02  .1526E-03  .1458E-03    1.40418  .1357E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1140E-02          0           0           0

STN.           X       YSTEP         CF         UE    DEL05      THETA    SCHMETA          H    RTHETA     I6
   9  .1985E+00  .1562E-03    .004004  .1186E+01  .1398E-02  .1613E-03  .1540E-03    1.40240  .1434E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1181E-02          0           0           0

STN.           X       YSTEP         CF         UE    DEL05      THETA    SCHMETA          H    RTHETA     I6
  10  .2025E+00  .1562E-03    .003950  .1185E+01  .1458E-02  .1700E-03  .1621E-03    1.39931  .1510E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1198E-02          0           0           0

STN.           X       YSTEP         CF         UE    DEL05      THETA    SCHMETA          H    RTHETA     I6
  11  .2064E+00  .1562E-03    .003907  .1184E+01  .1517E-02  .1766E-03  .1701E-03    1.39546  .1587E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1212E-02          0           0           0

STN.           X       YSTEP         CF         UE    DEL05      THETA    SCHMETA          H    RTHETA     I6
  12  .2103E+00  .1562E-03    .003872  .1184E+01  .1571E-02  .1872E-03  .1781E-03    1.39190  .1662E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1219E-02          0           0           0

STN.           X       YSTEP         CF         UE    DEL05      THETA    SCHMETA          H    RTHETA     I6
  13  .2142E+00  .1562E-03    .003840  .1183E+01  .1643E-02  .1958E-03  .1860E-03    1.38893  .1737E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1237E-02          0           0           0

STN.           X       YSTEP         CF         UE    DEL05      THETA    SCHMETA          H    RTHETA     I6
  14  .2181E+00  .1562E-03    .003809  .1182E+01  .1702E-02  .2041E-03  .1939E-03    1.38667  .1810E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1250E-02          0           0           0

STN.           X       YSTEP         CF         UE    DEL05      THETA    SCHMETA          H    RTHETA     I6
  15  .2220E+00  .1562E-03    .003776  .1181E+01  .1772E-02  .2124E-03  .2018E-03    1.38495  .1882E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
         0  .1277E-02          0           0           0

STN.           X       YSTEP         CF         UE    DEL05      THETA    SCHMETA          H    RTHETA     I6
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  16  .2259E+00  .1562E-03   .003742  .1181E+01  .1838E-02  .2205E-03  .2097E-03   1.38352  .1953E+04    18
 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05     VW/UE
         0  .1300E-02          0           0           0
STN.         X       YSTEP        CF          UE     DEL05      THETA    SCHMETA         H     RTHETA    I6
  17  .2298E+00  .1562E-03   .003707  .1180E+01  .1899E-02  .2286E-03  .2175E-03   1.38237  .2023E+04    18
 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05     VW/UE
         0  .1318E-02          0           0           0
STN.         X       YSTEP        CF          UE     DEL05      THETA    SCHMETA         H     RTHETA    I6
  18  .2337E+00  .1562E-03   .003673  .1179E+01  .1962E-02  .2367E-03  .2254E-03   1.38147  .2093E+04    18
 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05     VW/UE
         0  .1349E-02          0           0           0
STN.         X       YSTEP        CF          UE     DEL05      THETA    SCHMETA         H     RTHETA    I6
  19  .2376E+00  .1562E-03   .003638  .1179E+01  .2033E-02  .2447E-03  .2332E-03   1.38073  .2163E+04    18
 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05     VW/UE
         0  .1356E-02          0           0           0
STN.         X       YSTEP        CF          UE     DEL05      THETA    SCHMETA         H     RTHETA    I6
  20  .2414E+00  .1562E-03   .003605  .1178E+01  .2102E-02  .2526E-03  .2410E-03   1.38004  .2232E+04    18
 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05     VW/UE
         0  .1374E-02          0           0           0
STN.         X       YSTEP        CF          UE     DEL05      THETA    SCHMETA         H     RTHETA    I6
  21  .2453E+00  .1562E-03   .003573  .1177E+01  .2159E-02  .2606E-03  .2487E-03   1.37937  .2300E+04    18
 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05     VW/UE
         0  .1382E-02          0           0           0
STN.         X       YSTEP        CF          UE     DEL05      THETA    SCHMETA         H     RTHETA    I6
  22  .2492E+00  .1562E-03   .003544  .1176E+01  .2218E-02  .2684E-03  .2565E-03   1.37870  .2368E+04    18
 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05     VW/UE
         0  .1390E-02          0           0           0
STN.         X       YSTEP        CF          UE     DEL05      THETA    SCHMETA         H     RTHETA    I6
  23  .2531E+00  .1562E-03   .003516  .1175E+01  .2282E-02  .2763E-03  .2643E-03   1.37808  .2435E+04    18
 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05     VW/UE
         0  .1400E-02          0           0           0
STN.         X       YSTEP        CF          UE     DEL05      THETA    SCHMETA         H     RTHETA    I6
  24  .2569E+00  .1562E-03   .003490  .1175E+01  .2336E-02  .2841E-03  .2720E-03   1.37757  .2502E+04    18
 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05     VW/UE
         0  .1402E-02          0           0           0
STN.         X       YSTEP        CF          UE     DEL05      THETA    SCHMETA         H     RTHETA    I6
  25  .2608E+00  .1562E-03   .003465  .1174E+01  .2403E-02  .2918E-03  .2798E-03   1.37719  .2569E+04    18
 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05     VW/UE
         0  .1410E-02          0           0           0
STN.         X       YSTEP        CF          UE     DEL05      THETA    SCHMETA         H     RTHETA    I6
  26  .2646E+00  .1562E-03   .003441  .1173E+01  .2462E-02  .2995E-03  .2876E-03   1.37696  .2635E+04    18
 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05     VW/UE
         0  .1412E-02          0           0           0
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STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
27	.2685E+00	.1562E-03	.003417	.1172E+01	.2520E-02	.3072E-03	.2954E-03	1.37683	.2700E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1417E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
28	.2723E+00	.1562E-03	.003394	.1171E+01	.2593E-02	.3149E-03	.3032E-03	1.37679	.2765E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1436E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
29	.2761E+00	.1562E-03	.003371	.1170E+01	.2644E-02	.3224E-03	.3110E-03	1.37685	.2830E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1440E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
30	.2800E+00	.1562E-03	.003349	.1169E+01	.2716E-02	.3299E-03	.3188E-03	1.37699	.2893E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1455E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
31	.2838E+00	.1562E-03	.003328	.1168E+01	.2788E-02	.3374E-03	.3267E-03	1.37719	.2956E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1469E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
32	.2877E+00	.1562E-03	.003307	.1167E+01	.2830E-02	.3448E-03	.3345E-03	1.37747	.3019E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1466E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
33	.2915E+00	.1562E-03	.003288	.1166E+01	.2853E-02	.3521E-03	.3424E-03	1.37783	.3080E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1453E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
34	.2953E+00	.1562E-03	.003268	.1165E+01	.2871E-02	.3593E-03	.3502E-03	1.37828	.3140E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1437E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
35	.2991E+00	.1562E-03	.003250	.1164E+01	.2885E-02	.3664E-03	.3581E-03	1.37885	.3200E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1418E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
36	.3030E+00	.1562E-03	.003232	.1163E+01	.2897E-02	.3734E-03	.3660E-03	1.37955	.3259E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.1398E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
37	.3068E+00	.1562E-03	.003214	.1162E+01	.2906E-02	.3803E-03	.3740E-03	1.38041	.3316E+04	18

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ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
        0  .1377E-02          0           0          0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA          H     RTHETA      I6
 38  .3106E+00  .1562E-03    .003196  .1162E+01  .2914E-02  .3871E-03  .3819E-03    1.38145  .3372E+04      18

ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
        0  .1355E-02          0           0          0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA          H     RTHETA      I6
 39  .3144E+00  .1562E-03    .003178  .1161E+01  .2921E-02  .3938E-03  .3898E-03    1.38267  .3428E+04      18

ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
        0  .1333E-02          0           0          0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA          H     RTHETA      I6
 40  .3182E+00  .1562E-03    .003160  .1160E+01  .2927E-02  .4003E-03  .3978E-03    1.38410  .3481E+04      18

ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
        0  .1314E-02          0           0          0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA          H     RTHETA      I6
 41  .3220E+00  .1562E-03    .003142  .1159E+01  .2932E-02  .4067E-03  .4057E-03    1.38574  .3533E+04      18

ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
        0  .1300E-02          0           0          0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA          H     RTHETA      I6
 42  .3258E+00  .1562E-03    .003124  .1158E+01  .2936E-02  .4128E-03  .4137E-03    1.38760  .3584E+04      18

ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
        0  .1285E-02          0           0          0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA          H     RTHETA      I6
 43  .3296E+00  .1562E-03    .003106  .1157E+01  .2939E-02  .4188E-03  .4217E-03    1.38966  .3633E+04      18

ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
        0  .1270E-02          0           0          0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA          H     RTHETA      I6
 44  .3334E+00  .1562E-03    .003089  .1156E+01  .2942E-02  .4246E-03  .4296E-03    1.39192  .3680E+04      18

ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
        0  .1255E-02          0           0          0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA          H     RTHETA      I6
 45  .3372E+00  .1562E-03    .003071  .1155E+01  .2943E-02  .4303E-03  .4376E-03    1.39438  .3726E+04      18

ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
        0  .1239E-02          0           0          0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA          H     RTHETA      I6
 46  .3410E+00  .1562E-03    .003053  .1154E+01  .2945E-02  .4358E-03  .4456E-03    1.39701  .3770E+04      18

ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
        0  .1223E-02          0           0          0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA          H     RTHETA      I6
 47  .3448E+00  .1562E-03    .003035  .1153E+01  .2946E-02  .4412E-03  .4536E-03    1.39981  .3813E+04      18

ROUGH/D05     D05/RAD D05/(X-XO) STRAIN.D05      VW/UE
        0  .1207E-02          0           0          0

STN.          X        YSTEP          CF          UE    DEL05       THETA    SCHMETA          H     RTHETA      I6
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 48  .3486E+00  .1562E-03   .003016  .1152E+01  .2947E-02  .4464E-03  .4616E-03    1.40275  .3856E+04     18
 ROUGH/D05     D05/RAD 005/(X-XO) STRAIN.D05       VW/UE
         0  .1191E-02          0          0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
 49  .3524E+00  .1562E-03   .002998  .1151E+01  .2947E-02  .4516E-03  .4696E-03    1.40585  .3897E+04     18
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005       VW/UE
         0  .1175E-02          0          0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
 50  .3562E+00  .1562E-03   .002980  .1150E+01  .2792E-02  .4567E-03  .4776E-03    1.40908  .3937E+04     18
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.D05       VW/UE
         0  .1098E-02          0          0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
 51  .3599E+00  .1562E-03   .002961  .1149E+01  .2913E-02  .4550E-03  .4857E-03    1.41737  .3919E+04     18
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005       VW/UE
         0  .1129E-02          0          0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
 52  .3637E+00  .1562E-03   .002942  .1148E+01  .2943E-02  .4614E-03  .4937E-03    1.41961  .3971E+04     18
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005       VW/UE
         0  .1125E-02          0          0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
 53  .3675E+00  .1562E-03   .002923  .1147E+01  .2952E-02  .4669E-03  .5017E-03    1.42255  .4015E+04     18
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005       VW/UE
         0  .1112E-02          0          0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
 54  .3713E+00  .1562E-03   .002903  .1146E+01  .2796E-02  .4716E-03  .5097E-03    1.42609  .4052E+04     18
 ROUGH/D05     D05/RAD 005/(X-XO) STRAIN.D05       VW/UE
         0  .1038E-02          0          0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
 55  .3750E+00  .1562E-03   .002883  .1145E+01  .2639E-02  .4781E-03  .5178E-03    1.42880  .4104E+04     18
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005       VW/UE
         0  .9647E-03          0          0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
 56  .3788E+00  .1562E-03   .002862  .1144E+01  .2767E-02  .4852E-03  .5258E-03    1.43190  .4161E+04     18
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.005       VW/UE
         0  .9962E-03          0          0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
 57  .3826E+00  .1562E-03   .002842  .1143E+01  .2852E-02  .4634E-03  .5338E-03    1.45464  .3971E+04     18
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.D05       VW/UE
         0  .1011E-02          0          0            0

STN.          X       YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA     I6
 58  .3863E+00  .1562E-03   .002821  .1142E+01  .2910E-02  .4713E-03  .5418E-03    1.45545  .4035E+04     18
 ROUGH/D05     005/RAD 005/(X-XO) STRAIN.D05       VW/UE
         0  .1016E-02          0          0            0
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STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
59	.3901E+00	.1562E-03	.002799	.1141E+01	.2939E-02	.4785E-03	.5498E-03	1.45688	.4093E+04	18

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.1010E-02	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
60	.3938E+00	.1562E-03	.002777	.1140E+01	.2951E-02	.4846E-03	.5578E-03	1.45927	.4142E+04	18

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.9973E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
61	.3976E+00	.1562E-03	.002756	.1139E+01	.2956E-02	.4894E-03	.5658E-03	1.46263	.4179E+04	18

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.9826E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
62	.4013E+00	.1562E-03	.002735	.1138E+01	.2957E-02	.4876E-03	.5738E-03	1.47137	.4160E+04	18

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.9669E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
63	.4050E+00	.1562E-03	.002715	.1137E+01	.2959E-02	.4914E-03	.5818E-03	1.47494	.4189E+04	18

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.9513E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
64	.4088E+00	.1562E-03	.002695	.1136E+01	.2960E-02	.4944E-03	.5898E-03	1.47919	.4211E+04	18

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.9353E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
65	.4125E+00	.1562E-03	.002676	.1135E+01	.2960E-02	.4970E-03	.5977E-03	1.48354	.4230E+04	18

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.9191E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
66	.4162E+00	.1562E-03	.002657	.1134E+01	.2959E-02	.4998E-03	.6057E-03	1.48771	.4249E+04	18

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.9028E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
67	.4200E+00	.1562E-03	.002638	.1133E+01	.2959E-02	.5026E-03	.6137E-03	1.49164	.4270E+04	18

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.8928E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
68	.4237E+00	.1562E-03	.002619	.1132E+01	.2958E-02	.5055E-03	.6216E-03	1.49536	.4291E+04	18

ROUGH/D05	D05/RAD	D05/(X-XD)	STRAIN.D05	VW/UE
0	.8830E-03	0	0	0

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
69	.4274E+00	.1562E-03	.002600	.1131E+01	.2958E-02	.5084E-03	.6296E-03	1.49895	.4312E+04	18

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 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .8733E-03          0          0          0

STN.          X       YSTEP         CF         UE    DEL05       THETA    SCHMETA         H     RTHETA      I6
 70  .4311E+00  .1562E-03    .002582  .1130E+01  .2958E-02  .5114E-03  .6376E-03    1.50242  .4333E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .8637E-03          0          0          0

STN.          X       YSTEP         CF         UE    DEL05       THETA    SCHMETA         H     RTHETA      I6
 71  .4349E+00  .1562E-03    .002563  .1129E+01  .2958E-02  .5143E-03  .6455E-03    1.50578  .4354E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .8540E-03          0          0          0

STN.          X       YSTEP         CF         UE    DEL05       THETA    SCHMETA         H     RTHETA      I6
 72  .4386E+00  .1562E-03    .002545  .1128E+01  .2958E-02  .5172E-03  .6535E-03    1.50901  .4375E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .8444E-03          0          0          0

STN.          X       YSTEP         CF         UE    DEL05       THETA    SCHMETA         H     RTHETA      I6
 73  .4423E+00  .1562E-03    .002526  .1127E+01  .2801E-02  .5201E-03  .6614E-03    1.51212  .4396E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .79D6E-03          0          0          0

STN.          X       YSTEP         CF         UE    DEL05       THETA    SCHMETA         H     RTHETA      I6
 74  .4460E+00  .1562E-03    .002508  .1126E+01  .2938E-02  .5150E-03  .6694E-03    1.52171  .4349E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .8197E-03          D          D          0

STN.          X       YSTEP         CF         UE    DEL05       THETA    SCHMETA         H     RTHETA      I6
 75  .4497E+00  .1562E-03    .002491  .1125E+01  .2955E-02  .5200E-03  .6773E-03    1.52251  .4388E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .8148E-03          0          0          0

STN.          X       YSTEP         CF         UE    DEL05       THETA    SCHMETA         H     RTHETA      I6
 76  .4534E+00  .1562E-03    .002474  .1124E+01  .2802E-02  .5235E-03  .6852E-03    1.52434  .4414E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .7638E-03          0          0          0

STN.          X       YSTEP         CF         UE    DELD5       THETA    SCHMETA         H     RTHETA      I6
 77  .4571E+00  .1562E-03    .002457  .1123E+01  .2645E-02  .5291E-03  .6931E-03    1.52506  .4458E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .7125E-03          0          0          0

STN.          X       YSTEP         CF         UE    DEL05       THETA    SCHMETA         H     RTHETA      I6
 78  .4608E+00  .1562E-03    .002440  .1122E+01  .2784E-02  .5D36E-03  .7011E-03    1.55090  .4239E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .7407E-03          0          0          0

STN.          X       YSTEP         CF         UE    DEL05       THETA    SCHMETA         H     RTHETA      I6
 79  .4645E+00  .1562E-03    .002424  .1121E+01  .2863E-02  .5122E-03  .7089E-03    1.54729  .4308E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0) STRAIN.D05       VW/UE
          0  .7528E-03          0          0          0

STN.          X       YSTEP         CF         UE    DEL05       THETA    SCHMETA         H     RTHETA      I6
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 80  .4682E+00  .1562E-03    .002408  .1121E+01  .2937E-02  .5195E-03  .7168E-03     1.54501  .4366E+04      18

 ROUGH/D05      D05/RAD DD5/(X-XO)  STRAIN.D05       VW/UE
         0  .7626E-03          0            0             0

STN.            X       YSTEP        CF          UE    DEL05       THETA    SCHMETA           H     RTHETA      I6
 81  .4718E+00  .1562E-03    .002392  .1120E+01  .2951E-02  .5249E-03  .7247E-03     1.54442  .4408E+04      18

 ROUGH/D05      D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0  .7568E-03          0            0             0

STN.            X       YSTEP        CF          UE    DEL05       THETA    SCHMETA           H     RTHETA      I6
 82  .4755E+00  .1562E-03    .002376  .1119E+01  .2957E-02  .5282E-03  .7326E-03     1.54549  .4432E+04      18

 ROUGH/D05      D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0  .7489E-03          0            0             0

STN.            X       YSTEP        CF          UE    DEL05       THETA    SCHMETA           H     RTHETA      I6
 83  .4792E+00  .1562E-03    .002361  .1118E+01  .2959E-02  .5227E-03  .7404E-03     1.55408  .4382E+04      18

 ROUGH/D05      D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0  .7399E-03          0            0             0

STN.            X       YSTEP        CF          UE    DEL05       THETA    SCHMETA           H     RTHETA      I6
 84  .4828E+00  .1562E-03    .002347  .1117E+01  .2804E-02  .5250E-03  .7483E-03     1.55488  .4398E+04      18

 ROUGH/D05      D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0  .6921E-03          0            0             0

STN.            X       YSTEP        CF          UE    DEL05       THETA    SCHMETA           H     RTHETA      I6
 85  .4865E+00  .1562E-03    .002335  .1116E+01  .2648E-02  .5303E-03  .7561E-03     1.55329  .4439E+04      18

 ROUGH/D05      D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0  .6451E-03          0            0             0

STN.            X       YSTEP        CF          UE    DEL05       THETA    SCHMETA           H     RTHETA      I6
 86  .4901E+00  .1562E-03    .002323  .1115E+01  .2491E-02  .5372E-03  .7639E-03     1.55186  .4493E+04      18

 ROUGH/D05      D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0  .5991E-03          0            0             0

STN.            X       YSTEP        CF          UE    DEL05       THETA    SCHMETA           H     RTHETA      I6
 87  .4938E+00  .1562E-03    .002314  .1114E+01  .2334E-02  .5422E-03  .7717E-03     1.55240  .4532E+04      18

 ROUGH/D05      D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0  .5539E-03          0            0             0

STN.            X       YSTEP        CF          UE    DEL05       THETA    SCHMETA           H     RTHETA      I6
 88  .4974E+00  .1562E-03    .002306  .1114E+01  .2177E-02  .5485E-03  .7796E-03     1.55373  .4581E+04      18

 ROUGH/D05      D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0  .5097E-03          0            0             0

STN.            X       YSTEP        CF          UE    DEL05       THETA    SCHMETA           H     RTHETA      I6
 89  .5011E+00  .1562E-03    .002301  .1113E+01  .2020E-02  .5533E-03  .7874E-03     1.55630  .4618E+04      18

 ROUGH/D05      D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0  .4665E-03          0            0             0

STN.            X       YSTEP        CF          UE    DEL05       THETA    SCHMETA           H     RTHETA      I6
 90  .5047E+00  .1562E-03    .002297  .1112E+01  .1863E-02  .5590E-03  .7953E-03     1.56026  .4661E+04      18

 ROUGH/D05      D05/RAD D05/(X-XO)  STRAIN.D05       VW/UE
         0  .4243E-03          0            0             0
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STN.         X        YSTEP         CF          UE      DEL05       THETA    SCHMETA            H     RTHETA     I6
  91  .5084E+00  .1562E-03    .002296  .1111E+01  .1999E-02  .5636E-03  .8033E-03    1.56479  .4696E+04      18

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05       VW/UE
          0  .4489E-03           0           0           0

STN.         X        YSTEP         CF          UE      DEL05       THETA    SCHMETA            H     RTHETA     I6
  92  .5121E+00  .1562E-03    .002295  .1110E+01  .2106E-02  .4134E-03  .8112E-03    1.68442  .3442E+04      18

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05       VW/UE
          0  .4662E-03           0           0           0

STN.         X        YSTEP         CF          UE      DEL05       THETA    SCHMETA            H     RTHETA     I6
  93  .5158E+00  .1562E-03    .002292  .1109E+01  .2157E-02  .4192E-03  .8190E-03    1.68139  .3488E+04      18

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05       VW/UE
          0  .4705E-03           0           0           0

STN.         X        YSTEP         CF          UE      DEL05       THETA    SCHMETA            H     RTHETA     I6
  94  .5195E+00  .1562E-03    .002288  .1109E+01  .2170E-02  .4256E-03  .8269E-03    1.67284  .3539E+04      18

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05       VW/UE
          0  .4685E-03           0           0           0

STN.         X        YSTEP         CF          UE      DEL05       THETA    SCHMETA            H     RTHETA     I6
  95  .5231E+00  .1562E-03    .002281  .1108E+01  .2273E-02  .4324E-03  .8348E-03    1.66322  .3593E+04      18

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05       VW/UE
          0  .4865E-03           0           0           0

STN.         X        YSTEP         CF          UE      DEL05       THETA    SCHMETA            H     RTHETA     I6
  96  .5268E+00  .1562E-03    .002271  .1107E+01  .2421E-02  .4374E-03  .8427E-03    1.65918  .3631E+04      18

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05       VW/UE
          0  .5136E-03           0           0           0

STN.         X        YSTEP         CF          UE      DEL05       THETA    SCHMETA            H     RTHETA     I6
  97  .5305E+00  .1562E-03    .002255  .1106E+01  .2506E-02  .4432E-03  .8507E-03    1.65506  .3676E+04      18

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05       VW/UE
          0  .5267E-03           0           0           0

STN.         X        YSTEP         CF          UE      DEL05       THETA    SCHMETA            H     RTHETA     I6
  98  .5342E+00  .1562E-03    .002233  .1105E+01  .2630E-02  .4499E-03  .8586E-03    1.64935  .3729E+04      18

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05       VW/UE
          0  .5478E-03           0           0           0

STN.         X        YSTEP         CF          UE      DEL05       THETA    SCHMETA            H     RTHETA     I6
  99  .5378E+00  .1562E-03    .002208  .1105E+01  .2753E-02  .4554E-03  .8666E-03    1.64331  .3772E+04      18

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05       VW/UE
          0  .5680E-03           0           0           0

STN.         X        YSTEP         CF          UE      DEL05       THETA    SCHMETA            H     RTHETA     I6
 100  .5415E+00  .1562E-03    .002180  .1104E+01  .2842E-02  .4614E-03  .8745E-03    1.63600  .3819E+04      18

 ROUGH/D05     D05/RAD  D05/(X-X0)  STRAIN.D05       VW/UE
          0  .5810E-03           0           0           0

STN.         X        YSTEP         CF          UE      DEL05       THETA    SCHMETA            H     RTHETA     I6
 101  .5451E+00  .1562E-03    .002152  .1103E+01  .2930E-02  .4664E-03  .8824E-03    1.63014  .3858E+04      18
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ROUGH/D05     005/RAO D05/(X-XD) STRAIN.D05       VW/UE
         0  .5933E-03           0            0           0

STN.           X       YSTEP        CF          UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
 102  .5488E+00  .1562E-03    .002124  .1102E+01  .2939E-02  .4704E-03  .8903E-03    1.62447  .3888E+04       18

ROUGH/D05     005/RAO 005/(X-X0) STRAIN.005       VW/UE
         0  .5897E-03           0            0           0

STN.           X       YSTEP        CF          UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
 103  .5524E+00  .1562E-03    .002097  .1101E+01  .2782E-02  .4737E-03  .8982E-03    1.61788  .3912E+04       18

ROUGH/D05     D05/RAO 005/(X-X0) STRAIN.005       VW/UE
         0  .5529E-03           0            0           0

STN.           X       YSTEP        CF          UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
 104  .5559E+00  .1562E-03    .002071  .1100E+01  .2917E-02  .4738E-03  .9059E-03    1.61547  .3910E+04       18

ROUGH/D05     005/RAO 005/(X-X0) STRAIN.005       VW/UE
         0  .5743E-03           0            0           0

STN.           X       YSTEP        CF          UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
 105  .5595E+00  .1562E-03    .002047  .1100E+01  .2937E-02  .4784E-03  .9138E-03    1.60573  .3946E+04       18

ROUGH/D05     005/RAO 005/(X-X0) STRAIN.005       VW/UE
         0  .5727E-03           0            0           0

STN.           X       YSTEP        CF          UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
 106  .5631E+00  .1562E-03    .002025  .1099E+01  .2943E-02  .4820E-03  .9216E-03    1.59514  .3972E+04       18

ROUGH/D05     005/RAO D05/(X-XD) STRAIN.D05       VW/UE
         0  .5683E-03           0            0           0

STN.           X       YSTEP        CF          UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
 107  .5667E+00  .1562E-03    .002007  .1098E+01  .2946E-02  .4854E-03  .9295E-03    1.58446  .3997E+04       18

ROUGH/D05     005/RAO 005/(X-X0) STRAIN.005       VW/UE
         0  .5634E-03           0            0           0

STN.           X       YSTEP        CF          UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
 108  .5703E+00  .1562E-03    .001999  .1097E+01  .2948E-02  .4886E-03  .9374E-03    1.57020  .4020E+04       18

ROUGH/D05     005/RAO 005/(X-XD) STRAIN.005       VW/UE
         0  .5583E-03           0            0           0

STN.           X       YSTEP        CF          UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
 109  .5739E+00  .1562E-03    .002028  .1096E+01  .2949E-02  .4918E-03  .9454E-03    1.55141  .4043E+04       18

ROUGH/D05     005/RAO 005/(X-X0) STRAIN.005       VW/UE
         0  .5530E-03           0            0           0

STN.           X       YSTEP        CF          UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
 110  .5775E+00  .1562E-03    .002177  .1095E+01  .2951E-02  .4956E-03  .9537E-03    1.52902  .4072E+04       18

ROUGH/D05     005/RAO 005/(X-XD) STRAIN.005       VW/UE
         0  .5478E-03           0            0           0

STN.           X       YSTEP        CF          UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
 111  .5812E+00  .1562E-03    .002424  .1094E+01  .2952E-02  .4992E-03  .9625E-03    1.51238  .4098E+04       18

ROUGH/D05     005/RAD 005/(X-X0) STRAIN.005       VW/UE
         0  .5423E-03           0            0           0

STN.           X       YSTEP        CF          UE    DEL05      THETA    SCHMETA         H     RTHETA      I6
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 112  .5848E+00  .1562E-03    .002571  .1094E+01  .2953E-02  .5018E-03  .9716E-03    1.50678  .4116E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
         0  .5368E-03          0           0            0

STN.          X        YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA    I6
 113  .5885E+00  .1562E-03    .002605  .1093E+01  .2953E-02  .5042E-03  .9810E-03    1.50236  .4132E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
         0  .5312E-03          0           0            0

STN.          X        YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA    I6
 114  .5922E+00  .1562E-03    .002615  .1092E+01  .2954E-02  .5069E-03  .9906E-03    1.49918  .4150E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
         0  .5256E-03          0           0            0

STN.          X        YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA    I6
 115  .5958E+00  .1562E-03    .002617  .1091E+01  .2954E-02  .5097E-03  .1000E-02    1.49713  .4170E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
         0  .5201E-03          0           0            0

STN.          X        YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA    I6
 116  .5995E+00  .1562E-03    .002615  .1090E+01  .2955E-02  .5126E-03  .1010E-02    1.49593  .4190E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
         0  .5145E-03          0           0            0

STN.          X        YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA    I6
 117  .6031E+00  .1562E-03    .002611  .1089E+01  .2956E-02  .5156E-03  .1019E-02    1.49535  .4211E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
         0  .5090E-03          0           0            0

STN.          X        YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA    I6
 118  .6068E+00  .1562E-03    .002606  .1088E+01  .2956E-02  .5186E-03  .1029E-02    1.49529  .4232E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
         0  .5035E-03          0           0            0

STN.          X        YSTEP         CF          UE    DEL05       THETA     SCHMETA          H     RTHETA    I6
 119  .6104E+00  .1562E-03    .002600  .1087E+01  .2956E-02  .5215E-03  .1039E-02    1.49566  .4252E+04      18

 ROUGH/D05     D05/RAD D05/(X-X0)  STRAIN.D05       VW/UE
         0  .4979E-03          0           0            0

X=
   .1661E+00   .1705E+00   .1744E+00   .1785E+00   .1825E+00   .1866E+00   .1906E+00   .1946E+00   .1985E+00   .2025E+00
   .2064E+00   .2103E+00   .2142E+0D   .2181E+0D   .222DE+00   .2259E+0D   .2298E+00   .2337E+0D   .2376E+00   .2414E+00
   .2453E+00   .2492E+00   .2531E+00   .2569E+00   .2608E+00   .2646E+00   .2685E+00   .2723E+00   .2761E+00   .2800E+00
   .2838E+00   .2877E+00   .2915E+00   .2953E+0D   .2991E+00   .3030E+00   .3068E+00   .3106E+00   .3144E+00   .3182E+00
   .3220E+00   .3258E+00   .3296E+00   .3334E+00   .3372E+00   .3410E+00   .3448E+00   .3486E+00   .3524E+00   .3562E+00
   .3599E+00   .3637E+00   .3675E+00   .3713E+00   .3750E+00   .3788E+00   .3826E+00   .3863E+00   .3901E+00   .3938E+00
   .3976E+00   .4013E+00   .4050E+00   .4088E+00   .4125E+00   .4162E+00   .4200E+00   .4237E+00   .4274E+00   .4311E+00
   .4349E+00   .4386E+00   .4423E+00   .4460E+00   .4497E+00   .4534E+00   .4571E+00   .4608E+00   .4645E+00   .4682E+00
   .4718E+00   .4755E+00   .4792E+00   .4828E+00   .4865E+00   .4901E+00   .4938E+00   .4974E+00   .5011E+00   .5047E+00
   .5084E+00   .5121E+00   .5158E+00   .5195E+00   .5231E+00   .5268E+00   .5305E+00   .5342E+00   .5378E+00   .5415E+00
   .5451E+00   .5488E+00   .5524E+00   .5559E+00   .5595E+00   .5631E+00   .5667E+00   .5703E+00   .5739E+00   .5775E+00
   .5812E+00   .5848E+00   .5885E+00   .5922E+00   .5958E+00   .5995E+0D   .6031E+00   .6068E+00   .6104E+00   .6140E+00

VE/UE=
   .2989E-02   .3378E-02   .3405E-02   .3532E-02   .3575E-02   .3573E-02   .3522E-02   .3453E-02   .3378E-02   .3295E-02
   .3235E-02   .3186E-02   .3155E-02   .3138E-02   .3131E-02   .3130E-02   .3132E-02   .3135E-02   .3137E-02   .3139E-02
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.3142E-02	.3145E-02	.3150E-02	.3157E-02	.3165E-02	.3174E-02	.3183E-02	.3193E-02	.3202E-02	.3210E-02
.3217E-02	.3223E-02	.3229E-02	.3235E-02	.3242E-02	.3250E-02	.3258E-02	.3267E-02	.3276E-02	.3285E-02
.3294E-02	.3304E-02	.3314E-02	.3324E-02	.3334E-02	.3345E-02	.3356E-02	.3368E-02	.3380E-02	.3413E-02
.3402E-02	.3405E-02	.3401E-02	.3437E-02	.3480E-02	.3515E-02	.3476E-02	.3456E-02	.3426E-02	.3407E-02
.3394E-02	.3344E-02	.3320E-02	.3294E-02	.3273E-02	.3252E-02	.3232E-02	.3214E-02	.3196E-02	.3178E-02
.3159E-02	.3140E-02	.3172E-02	.3103E-02	.3061E-02	.3072E-02	.3117E-02	.3034E-02	.2978E-02	.2900E-02
.2845E-02	.2804E-02	.2702E-02	.2693E-02	.2726E-02	.2788E-02	.2883E-02	.2996E-02	.3123E-02	.3259E-02
.3384E-02	.3195E-02	.2990E-02	.2687E-02	.2598E-02	.2594E-02	.2509E-02	.2407E-02	.2299E-02	.2190E-02
.2071E-02	.1928E-02	.1792E-02	.1630E-02	.1452E-02	.1248E-02	.1024E-02	.7750E-03	.5349E-03	.4894E-03
.5187E-03	.7879E-03	.1394E-02	.1773E-02	.2087E-02	.2313E-02	.2487E-02	.2616E-02	.2716E-02	

(PW-PREF) /UREF**2=

-.2091E+00	-.2095E+00	-.2089E+00	-.2082E+00	-.2075E+00	-.2068E+00	-.2061E+00	-.2053E+00	-.2046E+00	-.2039E+00
-.2031E+00	-.2024E+00	-.2016E+00	-.2008E+00	-.2000E+00	-.1992E+00	-.1983E+00	-.1975E+00	-.1966E+00	-.1957E+00
-.1948E+00	-.1938E+00	-.1929E+00	-.1919E+00	-.1908E+00	-.1898E+00	-.1887E+00	-.1876E+00	-.1865E+00	-.1854E+00
-.1843E+00	-.1831E+00	-.1819E+00	-.1808E+00	-.1796E+00	-.1784E+00	-.1772E+00	-.1760E+00	-.1748E+00	-.1736E+00
-.1724E+00	-.1711E+00	-.1699E+00	-.1687E+00	-.1675E+00	-.1663E+00	-.1651E+00	-.1639E+00	-.1627E+00	-.1615E+00
-.1604E+00	-.1592E+00	-.1580E+00	-.1568E+00	-.1556E+00	-.1544E+00	-.1533E+00	-.1521E+00	-.1510E+00	-.1498E+00
-.1487E+00	-.1475E+00	-.1464E+00	-.1452E+00	-.1441E+00	-.1430E+00	-.1419E+00	-.1408E+00	-.1397E+00	-.1386E+00
-.1375E+00	-.1364E+00	-.1353E+00	-.1343E+00	-.1332E+00	-.1321E+00	-.1311E+00	-.1301E+00	-.1291E+00	-.1281E+00
-.1271E+00	-.1261E+00	-.1251E+00	-.1241E+00	-.1231E+00	-.1222E+00	-.1212E+00	-.1203E+00	-.1194E+00	-.1185E+00
-.1176E+00	-.1167E+00	-.1159E+00	-.1150E+00	-.1141E+00	-.1132E+00	-.1123E+00	-.1114E+00	-.1106E+00	-.1097E+00
-.1088E+00	-.1079E+00	-.1070E+00	-.1061E+00	-.1052E+00	-.1043E+00	-.1033E+00	-.1024E+00	-.1014E+00	-.1004E+00
-.9937E-01	-.9832E-01	-.9731E-01	-.9633E-01	-.9533E-01	-.9433E-01	-.9332E-01	-.9231E-01	-.9130E-01	-.9030E-01

(PW-PE) /UREF**2=

0	-.1320E-02	-.1409E-02	-.1473E-02	-.1555E-02	-.1630E-02	-.1698E-02	-.1756E-02	-.1810E-02	-.1856E-02
-.1896E-02	-.1933E-02	-.1966E-02	-.1997E-02	-.2034E-02	-.2067E-02	-.2096E-02	-.2120E-02	-.2138E-02	-.2148E-02
-.2152E-02	-.2147E-02	-.2135E-02	-.2116E-02	-.2090E-02	-.2058E-02	-.2020E-02	-.1982E-02	-.1939E-02	-.1892E-02
-.1842E-02	-.1787E-02	-.1730E-02	-.1671E-02	-.1610E-02	-.1548E-02	-.1485E-02	-.1423E-02	-.1361E-02	-.1300E-02
-.1244E-02	-.1189E-02	-.1136E-02	-.1085E-02	-.1035E-02	-.9875E-03	-.9416E-03	-.8974E-03	-.8438E-03	-.8125E-03
-.7827E-03	-.7461E-03	-.6924E-03	-.6508E-03	-.6312E-03	-.6030E-03	-.5901E-03	-.5674E-03	-.5415E-03	-.5140E-03
-.4863E-03	-.4707E-03	-.4473E-03	-.4253E-03	-.4063E-03	-.3894E-03	-.3740E-03	-.3608E-03	-.3493E-03	-.3391E-03
-.3301E-03	-.3026E-03	-.3143E-03	-.3240E-03	-.2973E-03	-.2778E-03	-.2965E-03	-.3198E-03	-.3294E-03	-.3332E-03
-.3281E-03	-.3246E-03	-.3130E-03	-.3001E-03	-.2981E-03	-.2984E-03	-.3018E-03	-.3085E-03	-.3169E-03	-.3485E-03
-.3701E-03	-.4520E-03	-.5075E-03	-.5218E-03	-.5111E-03	-.5274E-03	-.5555E-03	-.5747E-03	-.5895E-03	-.5986E-03
-.6068E-03	-.5974E-03	-.6154E-03	-.6253E-03	-.6260E-03	-.6247E-03	-.6217E-03	-.6115E-03	-.5750E-03	-.5252E-03
-.4733E-03	-.4086E-03	-.3847E-03	-.3950E-03	-.3918E-03	-.3863E-03	-.3760E-03	-.3627E-03	-.3543E-03	-.3543E-03

SWEEP NO. 10 OF INVISCID/VISCOUS CALCULATION COMPLETED

RUN NO. 10 OF BOUNDARY LAYER CALCULATION

B.L. CALC. IN INVISCID/VISCOUS INTERACTION CYCLE—AEROFOIL TEST CASE
1977 0 10 119 16 5 0 0 1 0 51 0 -2 1
A 0 1.000E-01 0 7.500E+06 0 1.000E+00 3.000E-01

THWAITES LAMINAR B.L. CALC.

X	THETA	RTHETA	UE	VE
0	.6657E-05	0	0	0
.1319E-01	.1292E-04	.7656E+02	.7898E+00	.1908E-02
.2327E-01	.1963E-04	.1494E+03	.1015E+01	-.8418E-02
.3770E-01	.3026E-04	.2477E+03	.1091E+01	-.1654E-02
.6441E-01	.4259E-04	.3712E+03	.1162E+01	-.1389E-02
.9023E-01	.5322E-04	.4739E+03	.1187E+01	-.1120E-03
.1157E+00	.6327E-04	.5666E+03	.1194E+01	.8407E-03
.1661E+00	.8138E-04	.7287E+03	.1191E+01	.1276E-02

SYNTHETIC STARTING PROFILES THETA/DELTA= .1048
X FOR CURV. B. VALUE 0 1.319E-02 2.327E-02 3.770E-02 6.441E-02 9.023E-02 1.157E-01
1.661E-01 2.163E-01 2.663E-01 3.163E-01 4.163E-01 5.165E-01 6.167E-01
I I
CURV 6.302E+01 3.406E+01 1.735E+01 8.571E+00 3.819E+00 2.344E+00 1.664E+00
1.035E+00 7.407E-01 5.675E-01 4.517E-01 3.049E-01 2.175E-01 1.651E-01
1.377E-01 1.307E-01
X FOR PRESS. AND NP B. VALUES 0 1.3194E-02 2.3271E-02 3.7701E-02 6.4410E-02 9.0229E-02 1.1569E-01
1.6613E-01 2.1628E-01 2.6632E-01 3.1633E-01 4.1635E-01 5.1648E-01 6.1674E-01
PE-PREF 5.0000E-01 1.8810E-01 -1.5132E-02 -9.5668E-02 -1.7532E-01 -2.0497E-01 -2.1267E-01
-2.0905E-01 -2.0093E-01 -1.8658E-01 -1.7280E-01 -1.4042E-01 -1.1542E-01 -8.9215E-02
NP 0 4.8981E-04 7.3881E-04 1.1276E-03 1.5912E-03 1.9812E-03 2.3821E-03
3.1240E-03
NP 3.1240E-03 3.1240E-03 3.1240E-03 3.1240E-03 3.1240E-03 3.1240E-03 3.1240E-03

STN. 1 X= .1661E+00 I62= 20 (P-PREF)/UREF**2 (FROM PREVIOUS SWEEP) =
-.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00
-.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00 -.2091E+00
-.2091E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
1	.1661E+00	.1562E-03	.004745	.1191E+01	.9063E-03	.8129E-04	.8129E-04	1.46132	.7260E+03	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.9380E-03	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.7584	.2012E-02	0	.3244E-01	-.3236E-01	11	1.0000	.1000E-07	.2810E-02	.6583E-02	.2814E-02
2	.8547	.1291E-02	.9725E-03	.2430E-01	-.2177E-01	12	1.0000	.1000E-07	.2829E-02	.6603E-02	.2834E-02
3	.9201	.7285E-03	.1725E-02	.1820E-01	-.1395E-01	13	1.0000	.1000E-07	.2848E-02	.6623E-02	.2853E-02
4	.9682	.3001E-03	.2300E-02	.1280E-01	-.6847E-02	14	1.0000	.1000E-07	.2867E-02	.6644E-02	.2873E-02
5	1.0000	.7588E-04	.2625E-02	.8855E-02	-.1034E-02	15	1.0000	.1000E-07	.2887E-02	.6665E-02	.2893E-02
6	1.0000	.1000E-07	.2718E-02	.5802E-02	.2720E-02	16	1.0000	.1000E-07	.2907E-02	.6686E-02	.2914E-02
7	1.0000	.1000E-07	.2736E-02	.6112E-02	.2739E-02	17	1.0000	.1000E-07	.2927E-02	.6707E-02	.2935E-02
8	1.0000	.1000E-07	.2754E-02	.6421E-02	.2757E-02	18	1.0000	.1000E-07	.2948E-02	.6729E-02	.2955E-02
9	1.0000	.1000E-07	.2773E-02	.6543E-02	.2776E-02	19	1.0000	.1000E-07	.2968E-02	.6750E-02	.2977E-02
10	1.0000	.1000E-07	.2791E-02	.6563E-02	.2795E-02	20	1.0000	.1000E-07	.2989E-02	.6772E-02	.2998E-02

REYNOLDS NUMBER TOO SMALL

STN. 2 X= .1705E+00 I62= 20 (P-PREF)/UREF**2 (FROM PREVIOUS SWEEP) =
-.2084E+00 -.2084E+00 -.2084E+00 -.2084E+00 -.2084E+00 -.2084E+00 -.2084E+00 -.2083E+00 -.2083E+00 -.2083E+00
-.2083E+00 -.2083E+00 -.2083E+00 -.2083E+00 -.2083E+00 -.2083E+00 -.2083E+00 -.2083E+00 -.2082E+00 -.2082E+00
-.2082E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
2	.1705E+00	.1562E-03	.004751	.1190E+01	.7790E-03	.9484E-04	.9176E-04	1.39277	.8465E+03	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.7865E-03	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.7538	.2311E-02	-.1819E-04	.3534E-01	-.3457E-01	11	1.0001	.9882E-08	.3198E-02	.3224E-01	.3203E-02
2	.8257	.1799E-02	.6812E-03	.3036E-01	-.2602E-01	12	1.0001	.9882E-08	.3217E-02	.3227E-01	.3223E-02
3	.8965	.9351E-03	.1735E-02	.2406E-01	-.1489E-01	13	1.0000	.9882E-08	.3236E-02	.3229E-01	.3243E-02
4	.9523	.4103E-03	.2515E-02	.2548E-01	-.3314E-02	14	1.0000	.9882E-08	.3256E-02	.3232E-01	.3263E-02
5	.9932	.1117E-03	.2955E-02	.2784E-01	.1608E-02	15	1.0000	.9882E-08	.3276E-02	.3234E-01	.3283E-02
6	.9984	.8447E-05	.3093E-02	.2918E-01	.3003E-02	16	1.0000	.9882E-08	.3295E-02	.3237E-01	.3304E-02
7	1.0001	.9886E-08	.3124E-02	.3168E-01	.3128E-02	17	1.0000	.9882E-08	.3316E-02	.3239E-01	.3325E-02
8	1.0001	.9883E-08	.3143E-02	.3217E-01	.3146E-02	18	1.0000	.9882E-08	.3336E-02	.3242E-01	.3346E-02
9	1.0001	.9882E-08	.3161E-02	.3219E-01	.3165E-02	19	1.0000	.1000E-07	.3357E-02	.3244E-01	.3367E-02
10	1.0001	.9882E-08	.3179E-02	.3222E-01	.3184E-02	20	1.0000	.1000E-07	.3378E-02	.3247E-01	.3388E-02

STN. 10 X= .2025E+00 I62= 20 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.2032E+00 -.2032E+00 -.2032E+00 -.2032E+00 -.2031E+00 -.2031E+00 -.2030E+00 -.2030E+00 -.2029E+00 -.2028E+00
-.2028E+00 -.2027E+00 -.2026E+00 -.2025E+00 -.2025E+00 -.2024E+00 -.2023E+00 -.2022E+00 -.2022E+00 -.2021E+00
-.2020E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
10	.2025E+00	.1562E-03	.003950	.1185E+01	.1458E-02	.1700E-03	.1621E-03	1.39931	.1510E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.1198E-02	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.6765	.1909E-02	.2417E-03	.3586E-01	-.3493E-01	11	.9989	.2339E-04	.3089E-02	.2313E-01	.2744E-02
2	.7440	.1772E-02	.5759E-03	.3215E-01	-.2988E-01	12	.9997	.7202E-05	.3121E-02	.2397E-01	.3022E-02
3	.7907	.1662E-02	.8540E-03	.3007E-01	-.2648E-01	13	.9999	.1399E-05	.3145E-02	.2497E-01	.3131E-02
4	.8331	.1509E-02	.1158E-02	.2814E-01	-.2304E-01	14	1.0000	.1236E-06	.3166E-02	.2545E-01	.3171E-02
5	.8703	.1315E-02	.1563E-02	.2638E-01	-.1943E-01	15	1.0003	.7913E-08	.3188E-02	.2547E-01	.3193E-02
6	.9162	.9053E-03	.2153E-02	.2316E-01	-.1324E-01	16	1.0002	.1000E-07	.3209E-02	.2549E-01	.3215E-02
7	.9660	.4141E-03	.2653E-02	.2045E-01	-.4795E-02	17	1.0002	.8262E-08	.3230E-02	.2552E-01	.3237E-02
8	.9873	.1871E-03	.2876E-02	.2123E-01	-.2370E-03	18	1.0001	.1000E-07	.3252E-02	.2554E-01	.3259E-02
9	.9938	.1050E-03	.2976E-02	.2229E-01	.1338E-02	19	1.0001	.1000E-07	.3273E-02	.2557E-01	.3281E-02
10	.9971	.5582E-04	.3042E-02	.2257E-01	.2189E-02	20	1.0000	.1000E-07	.3295E-02	.2560E-01	.3303E-02

STN. 20 X= .2414E+00 I62= 20 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.1956E+00 -.1956E+00 -.1955E+00 -.1955E+00 -.1954E+00 -.1953E+00 -.1952E+00 -.1951E+00 -.1950E+00 -.1949E+00
-.1948E+00 -.1947E+00 -.1946E+00 -.1944E+00 -.1943E+00 -.1942E+00 -.1941E+00 -.1939E+00 -.1938E+00 -.1937E+00
-.1936E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
20	.2414E+00	.1562E-03	.003605	.1178E+01	.2102E-02	.2526E-03	.2410E-03	1.38004	.2232E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.1374E-02	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.6417	.1768E-02	.1236E-03	.3616E-01	-.3566E-01	11	.9746	.3098E-03	.2608E-02	.2038E-01	-.2870E-02
2	.7063	.1668E-02	.3380E-03	.3235E-01	-.3105E-01	12	.9867	.1747E-03	.2767E-02	.2094E-01	-.1733E-03
3	.7463	.1604E-02	.4954E-03	.3044E-01	-.2841E-01	13	.9928	.1001E-03	.2866E-02	.2061E-01	.1163E-02
4	.7783	.1520E-02	.6718E-03	.2891E-01	-.2605E-01	14	.9961	.5656E-04	.2933E-02	.2054E-01	.1973E-02
5	.8077	.1429E-02	.8619E-03	.2757E-01	-.2378E-01	15	.9979	.3089E-04	.2983E-02	.2078E-01	.2468E-02
6	.8352	.1317E-02	.1076E-02	.2627E-01	-.2145E-01	16	.9989	.1668E-04	.3022E-02	.2122E-01	.2753E-02

7	.8615	.1191E-02	.1311E-02	.2500E-01	-.1905E-01	17	.9994	.8938E-05	.3054E-02	.2178E-01	.2917E-02
8	.8870	.1057E-02	.1586E-02	.2378E-01	-.1658E-01	18	.9996	.4683E-05	.3084E-02	.2241E-01	.3017E-02
9	.9173	.8436E-03	.1950E-02	.2264E-01	-.1258E-01	19	1.0001	.1000E-07	.3114E-02	.2303E-01	.3119E-02
10	.9504	.5496E-03	.2333E-02	.2124E-01	-.7294E-02	20	1.0000	.1000E-07	.3139E-02	.2331E-01	.3146E-02

STN. 30 X= .2800E+00 I62= 20 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.1854E+00 -.1854E+00 -.1854E+00 -.1853E+00 -.1852E+00 -.1852E+00 -.1851E+00 -.1850E+00 -.1849E+00 -.1848E+00
-.1847E+00 -.1846E+00 -.1845E+00 -.1844E+00 -.1842E+00 -.1841E+00 -.1840E+00 -.1839E+00 -.1837E+00 -.1836E+00
-.1835E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
30	.2800E+00	.1562E-03	.003349	.1169E+01	.2716E-02	.3299E-03	.3188E-03	1.37699	.2893E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.1455E-02	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.6149	.1665E-02	.9476E-04	.3657E-01	-.3619E-01	11	.9008	.8737E-03	.1845E-02	.2232E-01	-.1394E-01
2	.6780	.1601E-02	.2679E-03	.3286E-01	-.3185E-01	12	.9248	.7075E-03	.2129E-02	.2162E-01	-.1059E-01
3	.7170	.1565E-02	.3886E-03	.3101E-01	-.2950E-01	13	.9487	.5158E-03	.2416E-02	.2079E-01	-.6913E-02
4	.7456	.1520E-02	.5176E-03	.2972E-01	-.2762E-01	14	.9683	.3421E-03	.2653E-02	.2013E-01	-.3578E-02
5	.7707	.1464E-02	.6593E-03	.2860E-01	-.2586E-01	15	.9808	.2217E-03	.2819E-02	.2020E-01	-.1129E-02
6	.7940	.1397E-02	.8166E-03	.2755E-01	-.2410E-01	16	.9881	.1428E-03	.2937E-02	.2035E-01	.4408E-03
7	.8161	.1316E-02	.9897E-03	.2651E-01	-.2228E-01	17	.9929	.8748E-04	.3028E-02	.1990E-01	.1467E-02
8	.8374	.1224E-02	.1178E-02	.2548E-01	-.2041E-01	18	.9952	.5769E-04	.3090E-02	.1987E-01	.2062E-02
9	.8583	.1120E-02	.1380E-02	.2441E-01	-.1845E-01	19	1.0001	.1000E-07	.3179E-02	.1932E-01	.3183E-02
10	.8791	.1005E-02	.1598E-02	.2329E-01	-.1640E-01	20	1.0000	.1000E-07	.3210E-02	.1985E-01	.3215E-02

STN. 40 X= .3182E+00 I62= 20 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.1735E+00 -.1735E+00 -.1735E+00 -.1734E+00 -.1734E+00 -.1734E+00 -.1733E+00 -.1732E+00 -.1732E+00 -.1731E+00
-.1731E+00 -.1730E+00 -.1729E+00 -.1729E+00 -.1728E+00 -.1727E+00 -.1726E+00 -.1725E+00 -.1724E+00 -.1724E+00
-.1723E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
40	.3182E+00	.1562E-03	.003160	.1160E+01	.2927E-02	.4003E-03	.3978E-03	1.38410	.3481E+04	18

ROUGH/D05	D05/RAD	D05/(X-XO)	STRAIN.D05	VW/UE
0	.1314E-02	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.5940	.1580E-02	.8226E-04	.3685E-01	-.3652E-01	11	.8554	.1021E-02	.1525E-02	.2402E-01	-.1710E-01
2	.6555	.1528E-02	.2405E-03	.3316E-01	-.3224E-01	12	.8730	.9241E-03	.1720E-02	.2343E-01	-.1504E-01
3	.6934	.1501E-02	.3520E-03	.3133E-01	-.2994E-01	13	.8923	.8207E-03	.1928E-02	.2336E-01	-.1248E-01
4	.7206	.1462E-02	.4751E-03	.3006E-01	-.2813E-01	14	.9127	.7170E-03	.2143E-02	.2340E-01	-.9959E-02
5	.7434	.1417E-02	.6041E-03	.2903E-01	-.2651E-01	15	.9329	.6048E-03	.2366E-02	.2341E-01	-.7488E-02
6	.7647	.1370E-02	.7347E-03	.2812E-01	-.2498E-01	16	.9513	.4864E-03	.2580E-02	.2340E-01	-.5110E-02
7	.7846	.1316E-02	.8735E-03	.2727E-01	-.2347E-01	17	.9667	.3548E-03	.2784E-02	.2303E-01	-.2792E-02
8	.8033	.1256E-02	.1020E-02	.2647E-01	-.2196E-01	18	.9728	.2822E-03	.2903E-02	.2244E-01	-.1630E-02
9	.8212	.1187E-02	.1176E-02	.2568E-01	-.2041E-01	19	1.0001	.1000E-07	.3251E-02	.1813E-01	.3254E-02
10	.8384	.1109E-02	.1344E-02	.2487E-01	-.1880E-01	20	1.0000	.1000E-07	.3285E-02	.1860E-01	.3289E-02

STN. 50 X= .3562E+00 I62= 20 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=

-.1614E+00 -.1614E+00 -.1614E+00 -.1614E+00 -.1614E+00 -.1613E+00 -.1613E+00 -.1613E+00 -.1612E+00 -.1612E+00
-.1612E+00 -.1611E+00 -.1611E+00 -.1611E+00 -.1611E+00 -.1610E+00 -.1610E+00 -.1609E+00 -.1608E+00 -.1608E+00
-.1607E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
50	.3562E+00	.1562E-03	.002980	.1150E+01	.2792E-02	.4567E-03	.4776E-03	1.40908	.3937E+04	18

ROUGH/DO5	DO5/RAD	DO5/(X-XO)	STRAIN.DO5	VW/UE
0	.1098E-02	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB
1	.5732	.1490E-02	.8547E-04	.3709E-01	-.3673E-01
2	.6327	.1439E-02	.2470E-03	.3336E-01	-.3238E-01
3	.6693	.1409E-02	.3659E-03	.3149E-01	-.3001E-01
4	.6953	.1366E-02	.4979E-03	.3019E-01	-.2811E-01
5	.7168	.1318E-02	.6355E-03	.2913E-01	-.2641E-01
6	.7368	.1268E-02	.7735E-03	.2820E-01	-.2482E-01
7	.7552	.1212E-02	.9182E-03	.2734E-01	-.2325E-01
8	.7726	.1152E-02	.1068E-02	.2655E-01	-.2169E-01
9	.7891	.1089E-02	.1221E-02	.2579E-01	-.2015E-01
10	.8050	.1022E-02	.1378E-02	.2507E-01	-.1861E-01
11	.8209	.9544E-03	.1538E-02	.2450E-01	-.1696E-01
12	.8373	.8868E-03	.1699E-02	.2451E-01	-.1491E-01
13	.8554	.8215E-03	.1862E-02	.2491E-01	-.1269E-01
14	.8752	.7612E-03	.2023E-02	.2537E-01	-.1066E-01
15	.8951	.6973E-03	.2189E-02	.2584E-01	-.8755E-02
16	.9137	.6366E-03	.2347E-02	.2632E-01	-.7100E-02
17	.9300	.5325E-03	.2542E-02	.2536E-01	-.5459E-02
18	.9302	.1000E-07	.2882E-02	.1799E-01	.3101E-02
19	1.0000	.1000E-07	.3377E-02	.1766E-01	.3381E-02
20	1.0000	.1000E-07	.3413E-02	.1813E-01	.3417E-02

STN. 60 X= .3938E+00 I62= 20 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=
-.1497E+00 -.1496E+00 -.1496E+00 -.1496E+00 -.1496E+00 -.1496E+00 -.1496E+00 -.1496E+00 -.1496E+00 -.1495E+00
-.1495E+00 -.1495E+00 -.1495E+00 -.1495E+00 -.1495E+00 -.1495E+00 -.1494E+00 -.1494E+00 -.1494E+00 -.1493E+00
-.1493E+00

STN.	X	YSTEP	CF	UE	DELO5	THETA	SCHMETA	H	RTHETA	I6
60	.3938E+00	.1562E-03	.002777	.1140E+01	.2951E-02	.4846E-03	.5578E-03	1.45927	.4142E+04	18

ROUGH/DO5	DO5/RAD	DO5/(X-XO)	STRAIN.DO5	VW/UE
0	.9973E-03	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB
1	.5493	.1383E-02	.9876E-04	.3733E-01	-.3692E-01
2	.6064	.1330E-02	.2742E-03	.3350E-01	-.3243E-01
3	.6416	.1297E-02	.4072E-03	.3158E-01	-.2997E-01
4	.6666	.1256E-02	.5480E-03	.3025E-01	-.2805E-01
5	.6873	.1208E-02	.6944E-03	.2915E-01	-.2632E-01
6	.7067	.1156E-02	.8432E-03	.2814E-01	-.2464E-01
7	.7247	.1098E-02	.9967E-03	.2718E-01	-.2299E-01
8	.7415	.1038E-02	.1151E-02	.2631E-01	-.2139E-01
9	.7574	.9785E-03	.1306E-02	.2550E-01	-.1985E-01
10	.7730	.9196E-03	.1462E-02	.2476E-01	-.1835E-01
11	.7889	.8660E-03	.1615E-02	.2410E-01	-.1694E-01
12	.8061	.8175E-03	.1764E-02	.2376E-01	-.1536E-01
13	.8256	.7672E-03	.1914E-02	.2388E-01	-.1339E-01
14	.8461	.7197E-03	.2059E-02	.2420E-01	-.1147E-01
15	.8687	.6655E-03	.2212E-02	.2443E-01	-.9582E-02
16	.8955	.8529E-03	.2175E-02	.2697E-01	-.1062E-01
17	.9546	.1199E-02	.2230E-02	.2947E-01	-.1226E-01
18	.9674	.5861E-03	.2857E-02	.2448E-01	-.5807E-02
19	1.0000	.1000E-07	.3371E-02	.1609E-01	.3374E-02
20	1.0000	.1000E-07	.3407E-02	.1650E-01	.3411E-02

STN. 70 X= .4311E+00 I62= 20 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=
-.1384E+00 -.1384E+00 -.1384E+00 -.1384E+00 -.1384E+00 -.1384E+00 -.1384E+00 -.1384E+00 -.1384E+00 -.1383E+00
-.1383E+00 -.1383E+00 -.1383E+00 -.1384E+00 -.1384E+00 -.1384E+00 -.1383E+00 -.1383E+00 -.1383E+00 -.1383E+00
-.1382E+00

STN.	X	YSTEP	CF	UE	DELO5	THETA	SCHMETA	H	RTHETA	I6
70	.4311E+00	.1562E-03	.002582	.1130E+01	.2958E-02	.5114E-03	.6376E-03	1.50242	.4333E+04	18

ROUGH/DO5	DO5/RAD	DO5/(X-XO)	STRAIN.DO5	VW/UE
0	.8637E-03	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB
1	.5258	.1291E-02	.9181E-04	.3766E-01	-.3725E-01
2	.5810	.1245E-02	.2561E-03	.3383E-01	-.3277E-01
3	.6150	.1218E-02	.3803E-03	.3191E-01	-.3032E-01
4	.6392	.1182E-02	.5134E-03	.3059E-01	-.2840E-01
5	.6592	.1143E-02	.6488E-03	.2954E-01	-.2671E-01
6	.6780	.1107E-02	.7806E-03	.2865E-01	-.2518E-01
7	.6957	.1070E-02	.9129E-03	.2786E-01	-.2372E-01
8	.7127	.1033E-02	.1044E-02	.2716E-01	-.2233E-01
9	.7293	.9957E-03	.1174E-02	.2652E-01	-.2099E-01
11	.7630	.9332E-03	.1426E-02	.2549E-01	-.1855E-01
12	.7833	.9369E-03	.1525E-02	.2556E-01	-.1751E-01
13	.8104	.1008E-02	.1568E-02	.2662E-01	-.1677E-01
14	.8453	.1154E-02	.1534E-02	.2816E-01	-.1662E-01
15	.8804	.1273E-02	.1482E-02	.2928E-01	-.1623E-01
16	.9067	.1252E-02	.1528E-02	.2955E-01	-.1476E-01
17	.9240	.1076E-02	.1741E-02	.2895E-01	-.1213E-01
18	.9284	.1010E-02	.1875E-02	.2870E-01	-.1120E-01
19	1.0000	.1000E-07	.3143E-02	.1602E-01	.3145E-02

10	.7457	.9602E-03	.1303E-02	.2595E-01	-.1971E-01	20	1.0000	.1000E-07	.3178E-02	.1643E-01	.3181E-02

STN. 80 X= .4682E+00 I62= 20 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=
-.1279E+00 -.1279E+00 -.1279E+00 -.1279E+00 -.1279E+00 -.1279E+00 -.1279E+00 -.1279E+00 -.1279E+00 -.1279E+00
-.1279E+00 -.1278E+00 -.1279E+00 -.1279E+00 -.1279E+00 -.1279E+00 -.1279E+00 -.1278E+00 -.1278E+00 -.1278E+00
-.1278E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
80	.4682E+00	.1562E-03	.002408	.1121E+01	.2937E-02	.5195E-03	.7168E-03	1.54501	.4366E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.7626E-03	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.5042	.1207E-02	.8369E-04	.3797E-01	-.3757E-01	11	.7642	.1260E-02	.8652E-03	.2838E-01	-.2268E-01
2	.5577	.1169E-02	.2356E-03	.3414E-01	-.3309E-01	12	.7858	.1236E-02	.9230E-03	.2806E-01	-.2121E-01
3	.5908	.1150E-02	.3467E-03	.3226E-01	-.3069E-01	13	.8071	.1163E-02	.1036E-02	.2798E-01	-.1883E-01
4	.6149	.1127E-02	.4637E-03	.3102E-01	-.2886E-01	14	.8274	.1074E-02	.1187E-02	.2799E-01	-.1633E-01
5	.6355	.1103E-02	.5800E-03	.3005E-01	-.2726E-01	15	.8480	.9840E-03	.1361E-02	.2806E-01	-.1396E-01
6	.6555	.1086E-02	.6848E-03	.2927E-01	-.2588E-01	16	.8707	.1223E-02	.1320E-02	.3089E-01	-.1500E-01
7	.6753	.1086E-02	.7722E-03	.2875E-01	-.2479E-01	17	.9448	.1348E-02	.1642E-02	.3093E-01	-.1383E-01
8	.6962	.1113E-02	.8302E-03	.2854E-01	-.2407E-01	18	.9767	.3376E-03	.2523E-02	.2174E-01	-.2975E-02
9	.7186	.1168E-02	.8531E-03	.2855E-01	-.2366E-01	19	1.0000	.1000E-07	.2866E-02	.1655E-01	.2868E-02
10	.7417	.1228E-02	.8536E-03	.2859E-01	-.2332E-01	20	1.0000	.1000E-07	.2900E-02	.1699E-01	.2902E-02

STN. 90 X= .5047E+00 I62= 20 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=
-.1185E+00 -.1185E+00 -.1184E+00 -.1184E+00 -.1184E+00 -.1184E+00 -.1184E+00 -.1184E+00 -.1183E+00 -.1183E+00
-.1183E+00 -.1183E+00 -.1183E+00 -.1183E+00 -.1183E+00 -.1183E+00 -.1183E+00 -.1182E+00 -.1182E+00 -.1182E+00
-.1181E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
90	.5047E+00	.1562E-03	.002297	.1112E+01	.1863E-02	.5590E-03	.7953E-03	1.56026	.4661E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.4243E-03	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.4905	.1170E-02	.4331E-04	.3839E-01	-.3807E-01	11	.7395	.8123E-03	.1035E-02	.3168E-01	-.1335E-01
2	.5444	.1167E-02	.1309E-03	.3485E-01	-.3395E-01	12	.7563	.1000E-07	.1675E-02	.1815E-01	.2215E-02
3	.5788	.1188E-02	.1668E-03	.3335E-01	-.3194E-01	13	.7586	.1000E-07	.1877E-02	.1910E-01	.2475E-02
4	.6055	.1191E-02	.2143E-03	.3229E-01	-.3022E-01	14	.7860	.1000E-07	.2158E-02	.1951E-01	.2746E-02
5	.6296	.1190E-02	.2595E-03	.3146E-01	-.2865E-01	15	.8158	.1000E-07	.2346E-02	.1971E-01	.2877E-02
6	.6511	.1164E-02	.3234E-03	.3060E-01	-.2692E-01	16	.8487	.1000E-07	.2541E-02	.1984E-01	.2996E-02
7	.6698	.1108E-02	.4206E-03	.2967E-01	-.2493E-01	17	.8768	.1000E-07	.2700E-02	.2003E-01	.3081E-02
8	.6860	.1018E-02	.5605E-03	.2941E-01	-.2192E-01	18	.9212	.1000E-07	.2929E-02	.1942E-01	.3181E-02
9	.7016	.9093E-03	.7363E-03	.2991E-01	-.1820E-01	19	1.0000	.1000E-07	.3227E-02	.1819E-01	.3229E-02
10	.7190	.8309E-03	.9068E-03	.3080E-01	-.1510E-01	20	1.0000	.1000E-07	.3259E-02	.1822E-01	.3262E-02

STN. 100 X= .5415E+00 I62= 20 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=
-.1096E+00 -.1096E+00 -.1096E+00 -.1096E+00 -.1096E+00 -.1095E+00 -.1095E+00 -.1095E+00 -.1094E+00 -.1094E+00
-.1094E+00 -.1094E+00 -.1094E+00 -.1093E+00 -.1093E+00 -.1093E+00 -.1093E+00 -.1092E+00 -.1092E+00 -.1091E+00
-.1091E+00

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
100	.5415E+00	.1562E-03	.002180	.1104E+01	.2842E-02	.4614E-03	.8745E-03	1.63600	.3819E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.5810E-03	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.4738	.1073E-02	.1072E-03	.3820E-01	-.3760E-01	11	.8296	.2386E-02	-.6333E-03	.3507E-01	-.2985E-01
2	.5234	.1003E-02	.3142E-03	.3399E-01	-.3234E-01	12	.8526	.1886E-02	-.2068E-03	.3287E-01	-.2381E-01
3	.5535	.9522E-03	.4781E-03	.3188E-01	-.2925E-01	13	.8857	.1463E-02	.3756E-03	.3192E-01	-.1738E-01
4	.5752	.9012E-03	.6474E-03	.3048E-01	-.2676E-01	14	.9206	.1173E-02	.6914E-03	.3171E-01	-.1269E-01
5	.5945	.8501E-03	.8189E-03	.2936E-01	-.2446E-01	15	.9370	.1006E-02	.9933E-03	.3324E-01	-.9652E-02
6	.6133	.8042E-03	.9868E-03	.2845E-01	-.2233E-01	16	.9505	.1034E-02	.1263E-02	.3634E-01	-.8507E-02
7	.6352	.8194E-03	.1099E-02	.2837E-01	-.2118E-01	17	.9703	.7331E-03	.1643E-02	.3527E-01	-.5281E-02
8	.6771	.1119E-02	.9710E-03	.3085E-01	-.2350E-01	18	.9933	.1647E-03	.2028E-02	.3061E-01	.2850E-03
9	.7521	.2014E-02	.2657E-03	.3568E-01	-.2995E-01	19	1.0000	.1000E-07	.2158E-02	.2961E-01	.2160E-02
10	.8045	.2656E-02	-.5068E-03	.3747E-01	-.3302E-01	20	1.0000	.1000E-07	.2190E-02	.3046E-01	.2191E-02

STN. 110 X= .5775E+00 I62= 20 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=
-.1005E+00 -.1004E+00 -.1004E+00 -.1004E+00 -.1004E+00 -.1004E+00 -.1003E+00 -.1003E+00 -.1003E+00 -.1002E+00
-.1002E+00 -.1002E+00 -.1002E+00 -.1002E+00 -.1001E+00 -.1001E+00 -.1000E+00 -.1000E+00 -.9996E-01 -.9991E-01
-.9987E-01

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
110	.5775E+00	.1562E-03	.002177	.1095E+01	.2951E-02	.4956E-03	.9537E-03	1.52902	.4072E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.5478E-03	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.4867	.1462E-02	-.3515E-03	.4239E-01	-.4374E-01	11	.7838	.1605E-02	-.1472E-02	.2876E-01	-.2751E-01
2	.5679	.2043E-02	-.1091E-02	.4186E-01	-.4541E-01	12	.8056	.1492E-02	-.1319E-02	.2811E-01	-.2488E-01
3	.6043	.2107E-02	-.1535E-02	.3939E-01	-.4388E-01	13	.8302	.1370E-02	-.1150E-02	.2823E-01	-.2157E-01
4	.6299	.2036E-02	-.1782E-02	.3692E-01	-.4162E-01	14	.8577	.1250E-02	-.9819E-03	.2859E-01	-.1833E-01
5	.6519	.1997E-02	-.1900E-02	.3537E-01	-.3980E-01	15	.8856	.1133E-02	-.8168E-03	.2906E-01	-.1541E-01
6	.6750	.1940E-02	-.1910E-02	.3390E-01	-.3767E-01	16	.9126	.1040E-02	-.6766E-03	.2980E-01	-.1303E-01
7	.6974	.1900E-02	-.1873E-02	.3281E-01	-.3576E-01	17	.9379	.9628E-03	-.5486E-03	.3062E-01	-.1113E-01
8	.7199	.1847E-02	-.1804E-02	.3177E-01	-.3377E-01	18	.9570	.9571E-03	-.4818E-03	.3052E-01	-.1064E-01
9	.7417	.1782E-02	-.1713E-02	.3077E-01	-.3175E-01	19	1.0000	.1000E-07	.4553E-03	.2105E-01	.4554E-03
10	.7629	.1703E-02	-.1604E-02	.2979E-01	-.2969E-01	20	1.0000	.1000E-07	.4894E-03	.2169E-01	.4896E-03

STN.	X	YSTEP	CF	UE	DEL05	THETA	SCHMETA	H	RTHETA	I6
119	.6104E+00	.1562E-03	.002600	.1087E+01	.2956E-02	.5215E-03	.1039E-02	1.49566	.4252E+04	18

ROUGH/D05	D05/RAD	D05/(X-X0)	STRAIN.D05	VW/UE
0	.4979E-03	0	0	0

Y/YSTEP	U/UE	TAU/UE**2	V/UE	TANA	TANB						
1	.5253	.1321E-02	.3352E-05	.3797E-01	-.3790E-01	11	.7639	.1401E-02	.4531E-03	.2928E-01	-.2457E-01
2	.5820	.1307E-02	.7746E-04	.3428E-01	-.3382E-01	12	.7839	.1383E-02	.5586E-03	.2912E-01	-.2311E-01
3	.6173	.1309E-02	.1194E-03	.3252E-01	-.3174E-01	13	.8070	.1352E-02	.6791E-03	.2936E-01	-.2105E-01
4	.6429	.1297E-02	.1718E-03	.3130E-01	-.3012E-01	14	.8328	.1308E-02	.8119E-03	.2962E-01	-.1882E-01
5	.6641	.1274E-02	.2195E-03	.3027E-01	-.2867E-01	15	.8591	.1239E-02	.9673E-03	.2973E-01	-.1653E-01
6	.6829	.1273E-02	.2420E-03	.2965E-01	-.2766E-01	16	.8833	.1145E-02	.1143E-02	.2974E-01	-.1422E-01
7	.6989	.1306E-02	.2471E-03	.2955E-01	-.2718E-01	17	.9040	.9816E-03	.1386E-02	.2927E-01	-.1149E-01
8	.7137	.1354E-02	.2596E-03	.2969E-01	-.2687E-01	18	.9113	.9703E-03	.1463E-02	.2938E-01	-.1105E-01
9	.7292	.1389E-02	.2983E-03	.2973E-01	-.2637E-01	19	1.0000	.1000E-07	.2680E-02	.1687E-01	.2681E-02
10	.7459	.1403E-02	.3647E-03	.2959E-01	-.2558E-01	20	1.0000	.1000E-07	.2716E-02	.1732E-01	.2717E-02

STN. 120 X= .6140E+00 I62= 20 (P-PREF)/UREF**2(FROM PREVIOUS SWEEP)=
-.9030E-01 -.9030E-01 -.9029E-01 -.9028E-01 -.9026E-01 -.9025E-01 -.9023E-01 -.9022E-01 -.9021E-01 -.9020E-01
-.9018E-01 -.9017E-01 -.9015E-01 -.9013E-01 -.9011E-01 -.9008E-01 -.9006E-01 -.9003E-01 -.9000E-01 -.8998E-01
-.8995E-01

VALUES OF (P-PREF)/UREF**2 AT X-STATIONS

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STN. NO.   1        X=  .1661E+00
  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00
  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00  -.2091E+00
  -.2091E+00

STN. NO.   2        X=  .1705E+00
  -.2095E+00  -.2095E+00  -.2095E+00  -.2094E+00  -.2094E+00  -.2093E+00  -.2092E+00  -.2092E+00  -.2091E+00  -.2090E+00
  -.2089E+00  -.2089E+00  -.2088E+00  -.2087E+00  -.2087E+00  -.2086E+00  -.2085E+00  -.2084E+00  -.2084E+00  -.2083E+00
  -.2082E+00

STN. NO.  10        X=  .2025E+00
  -.2039E+00  -.2038E+00  -.2038E+00  -.2037E+00  -.2037E+00  -.2036E+00  -.2035E+00  -.2034E+00  -.2033E+00  -.2032E+00
  -.2031E+00  -.2030E+00  -.2029E+00  -.2028E+00  -.2027E+00  -.2026E+00  -.2024E+00  -.2023E+00  -.2022E+00  -.2021E+00
  -.2020E+00

STN. NO.  20        X=  .2414E+00
  -.1957E+00  -.1957E+00  -.1956E+00  -.1955E+00  -.1955E+00  -.1954E+00  -.1953E+00  -.1952E+00  -.1951E+00  -.1950E+00
  -.1949E+00  -.1947E+00  -.1946E+00  -.1945E+00  -.1943E+00  -.1942E+00  -.1941E+00  -.1940E+00  -.1938E+00  -.1937E+00
  -.1936E+00

STN. NO.  30        X=  .2800E+00
  -.1854E+00  -.1854E+00  -.1853E+00  -.1852E+00  -.1852E+00  -.1851E+00  -.1850E+00  -.1849E+00  -.1849E+00  -.1848E+00
  -.1847E+00  -.1846E+00  -.1845E+00  -.1843E+00  -.1842E+00  -.1841E+00  -.1840E+00  -.1839E+00  -.1837E+00  -.1836E+00
  -.1835E+00

STN. NO.  40        X=  .3182E+00
  -.1736E+00  -.1735E+00  -.1735E+00  -.1735E+00  -.1734E+00  -.1734E+00  -.1733E+00  -.1733E+00  -.1732E+00  -.1731E+00
  -.1731E+00  -.1730E+00  -.1729E+00  -.1729E+00  -.1728E+00  -.1727E+00  -.1726E+00  -.1725E+00  -.1724E+00  -.1724E+00
  -.1723E+00

STN. NO.  50        X=  .3562E+00
  -.1615E+00  -.1615E+00  -.1615E+00  -.1615E+00  -.1614E+00  -.1614E+00  -.1614E+00  -.1613E+00  -.1613E+00  -.1613E+00
  -.1612E+00  -.1612E+00  -.1612E+00  -.1611E+00  -.1611E+00  -.1610E+00  -.1610E+00  -.1609E+00  -.1609E+00  -.1608E+00
  -.1607E+00

STN. NO.  60        X=  .3938E+00
  -.1498E+00  -.1498E+00  -.1498E+00  -.1498E+00  -.1497E+00  -.1497E+00  -.1497E+00  -.1497E+00  -.1497E+00  -.1497E+00
  -.1496E+00  -.1496E+00  -.1496E+00  -.1496E+00  -.1496E+00  -.1495E+00  -.1495E+00  -.1494E+00  -.1494E+00  -.1494E+00
  -.1493E+00

STN. NO.  70        X=  .4311E+00
  -.1386E+00  -.1386E+00  -.1386E+00  -.1385E+00  -.1385E+00  -.1385E+00  -.1385E+00  -.1385E+00  -.1385E+00  -.1385E+00
  -.1384E+00  -.1384E+00  -.1384E+00  -.1384E+00  -.1384E+00  -.1384E+00  -.1384E+00  -.1383E+00  -.1383E+00  -.1383E+00
  -.1382E+00

STN. NO.  80        X=  .4682E+00
  -.1281E+00  -.1281E+00  -.1281E+00  -.1281E+00  -.1280E+00  -.1280E+00  -.1280E+00  -.1280E+00  -.1280E+00  -.1280E+00
  -.1280E+00  -.1279E+00  -.1280E+00  -.1280E+00  -.1279E+00  -.1279E+00  -.1279E+00  -.1279E+00  -.1278E+00  -.1278E+00
  -.1278E+00

STN. NO.  90        X=  .5047E+00
  -.1185E+00  -.1185E+00  -.1185E+00  -.1184E+00  -.1184E+00  -.1184E+00  -.1184E+00  -.1184E+00  -.1184E+00  -.1183E+00
  -.1183E+00  -.1183E+00  -.1183E+00  -.1183E+00  -.1183E+00  -.1183E+00  -.1183E+00  -.1182E+00  -.1182E+00  -.1182E+00
  -.1181E+00

STN. NO. 100        X=  .5415E+00
  -.1097E+00  -.1097E+00  -.1097E+00  -.1096E+00  -.1096E+00  -.1096E+00  -.1095E+00  -.1095E+00  -.1095E+00  -.1095E+00
  -.1094E+00  -.1094E+00  -.1094E+00  -.1094E+00  -.1093E+00  -.1093E+00  -.1093E+00  -.1092E+00  -.1092E+00  -.1091E+00
  -.1091E+00
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STN. NO. 110 X= .5775E+00

-.1004E+00	-.1004E+00	-.1004E+00	-.1004E+00	-.1003E+00	-.1003E+00	-.1003E+00	-.1003E+00	-.1002E+00	-.1002E+00
-.1002E+00	-.1002E+00	-.1002E+00	-.1001E+00	-.1001E+00	-.1001E+00	-.1000E+00	-.1000E+00	-.9995E-01	-.9991E-01
-.9987E-01									

STN. NO. 120 X= .6140E+00

-.9030E-01	-.9030E-01	-.9029E-01	-.9028E-01	-.9026E-01	-.9025E-01	-.9023E-01	-.9022E-01	-.9021E-01	-.9020E-01
-.9018E-01	-.9017E-01	-.9015E-01	-.9013E-01	-.9011E-01	-.9008E-01	-.9006E-01	-.9003E-01	-.9000E-01	-.8998E-01
-.8995E-01									

X=

.1661E+00	.1705E+00	.1744E+00	.1785E+00	.1825E+00	.1866E+00	.1906E+00	.1946E+00	.1985E+00	.2025E+00
.2064E+00	.2103E+00	.2142E+00	.2181E+00	.2220E+00	.2259E+00	.2298E+00	.2337E+00	.2376E+00	.2414E+00
.2453E+00	.2492E+00	.2531E+00	.2569E+00	.2608E+00	.2646E+00	.2685E+00	.2723E+00	.2761E+00	.2800E+00
.2838E+00	.2877E+00	.2915E+00	.2953E+00	.2991E+00	.3030E+00	.3068E+00	.3106E+00	.3144E+00	.3182E+00
.3220E+00	.3258E+00	.3296E+00	.3334E+00	.3372E+00	.3410E+00	.3448E+00	.3486E+00	.3524E+00	.3562E+00
.3599E+00	.3637E+00	.3675E+00	.3713E+00	.3750E+00	.3788E+00	.3826E+00	.3863E+00	.3901E+00	.3938E+00
.3976E+00	.4013E+00	.4050E+00	.4088E+00	.4125E+00	.4162E+00	.4200E+00	.4237E+00	.4274E+00	.4311E+00
.4349E+00	.4386E+00	.4423E+00	.4460E+00	.4497E+00	.4534E+00	.4571E+00	.4608E+00	.4645E+00	.4682E+00
.4718E+00	.4755E+00	.4792E+00	.4828E+00	.4865E+00	.4901E+00	.4938E+00	.4974E+00	.5011E+00	.5047E+00
.5084E+00	.5121E+00	.5158E+00	.5195E+00	.5231E+00	.5268E+00	.5305E+00	.5342E+00	.5378E+00	.5415E+00
.5451E+00	.5488E+00	.5524E+00	.5559E+00	.5595E+00	.5631E+00	.5667E+00	.5703E+00	.5739E+00	.5775E+00
.5812E+00	.5848E+00	.5885E+00	.5922E+00	.5958E+00	.5995E+00	.6031E+00	.6068E+00	.6104E+00	.6140E+00

VE/UE=

.2989E-02	.3378E-02	.3405E-02	.3532E-02	.3575E-02	.3573E-02	.3522E-02	.3453E-02	.3378E-02	.3295E-02
.3235E-02	.3186E-02	.3155E-02	.3138E-02	.3131E-02	.3130E-02	.3132E-02	.3135E-02	.3137E-02	.3139E-02
.3142E-02	.3145E-02	.3150E-02	.3157E-02	.3165E-02	.3174E-02	.3183E-02	.3193E-02	.3202E-02	.3210E-02
.3217E-02	.3223E-02	.3229E-02	.3235E-02	.3242E-02	.3250E-02	.3258E-02	.3267E-02	.3276E-02	.3285E-02
.3294E-02	.3304E-02	.3314E-02	.3324E-02	.3334E-02	.3345E-02	.3356E-02	.3368E-02	.3380E-02	.3413E-02
.3402E-02	.3405E-02	.3401E-02	.3437E-02	.3480E-02	.3515E-02	.3476E-02	.3456E-02	.3426E-02	.3407E-02
.3394E-02	.3344E-02	.3320E-02	.3294E-02	.3273E-02	.3252E-02	.3232E-02	.3214E-02	.3196E-02	.3178E-02
.3159E-02	.3140E-02	.3172E-02	.3103E-02	.3061E-02	.3072E-02	.3117E-02	.3034E-02	.2978E-02	.2900E-02
.2845E-02	.2804E-02	.2702E-02	.2693E-02	.2726E-02	.2788E-02	.2883E-02	.2996E-02	.3123E-02	.3259E-02
.3384E-02	.3195E-02	.2990E-02	.2687E-02	.2598E-02	.2594E-02	.2509E-02	.2407E-02	.2299E-02	.2190E-02
.2071E-02	.1928E-02	.1792E-02	.1630E-02	.1452E-02	.1248E-02	.1024E-02	.7750E-03	.5349E-03	.4894E-03
.5187E-03	.7879E-03	.1394E-02	.1773E-02	.2087E-02	.2313E-02	.2487E-02	.2616E-02	.2716E-02	

(PW-PREF)/UREF**2=

-.2091E+00	-.2095E+00	-.2089E+00	-.2082E+00	-.2075E+00	-.2068E+00	-.2061E+00	-.2053E+00	-.2046E+00	-.2039E+00
-.2031E+00	-.2024E+00	-.2016E+00	-.2008E+00	-.2000E+00	-.1992E+00	-.1983E+00	-.1975E+00	-.1966E+00	-.1957E+00
-.1948E+00	-.1938E+00	-.1929E+00	-.1919E+00	-.1908E+00	-.1898E+00	-.1887E+00	-.1876E+00	-.1865E+00	-.1854E+00
-.1843E+00	-.1831E+00	-.1819E+00	-.1808E+00	-.1796E+00	-.1784E+00	-.1772E+00	-.1760E+00	-.1748E+00	-.1736E+00
-.1724E+00	-.1711E+00	-.1699E+00	-.1687E+00	-.1675E+00	-.1663E+00	-.1651E+00	-.1639E+00	-.1627E+00	-.1615E+00
-.1604E+00	-.1592E+00	-.1580E+00	-.1568E+00	-.1556E+00	-.1544E+00	-.1533E+00	-.1521E+00	-.1510E+00	-.1498E+00
-.1487E+00	-.1475E+00	-.1464E+00	-.1452E+00	-.1441E+00	-.1430E+00	-.1419E+00	-.1408E+00	-.1397E+00	-.1386E+00
-.1375E+00	-.1364E+00	-.1353E+00	-.1343E+00	-.1332E+00	-.1321E+00	-.1311E+00	-.1301E+00	-.1291E+00	-.1281E+00
-.1271E+00	-.1261E+00	-.1251E+00	-.1241E+00	-.1231E+00	-.1222E+00	-.1212E+00	-.1203E+00	-.1194E+00	-.1185E+00
-.1176E+00	-.1167E+00	-.1159E+00	-.1150E+00	-.1141E+00	-.1132E+00	-.1123E+00	-.1114E+00	-.1106E+00	-.1097E+00
-.1088E+00	-.1079E+00	-.1070E+00	-.1061E+00	-.1052E+00	-.1043E+00	-.1033E+00	-.1024E+00	-.1014E+00	-.1004E+00
-.9937E-01	-.9832E-01	-.9731E-01	-.9633E-01	-.9533E-01	-.9433E-01	-.9332E-01	-.9231E-01	-.9130E-01	-.9030E-01

(PW-PE)/UREF**2=

0	-.1320E-02	-.1409E-02	-.1473E-02	-.1555E-02	-.1630E-02	-.1698E-02	-.1756E-02	-.1810E-02	-.1856E-02
-.1896E-02	-.1933E-02	-.1966E-02	-.1997E-02	-.2034E-02	-.2067E-02	-.2096E-02	-.2120E-02	-.2138E-02	-.2148E-02
-.2152E-02	-.2147E-02	-.2135E-02	-.2116E-02	-.2090E-02	-.2058E-02	-.2020E-02	-.1982E-02	-.1939E-02	-.1892E-02
-.1842E-02	-.1787E-02	-.1730E-02	-.1671E-02	-.1610E-02	-.1548E-02	-.1485E-02	-.1423E-02	-.1361E-02	-.1300E-02
-.1244E-02	-.1189E-02	-.1136E-02	-.1085E-02	-.1035E-02	-.9875E-03	-.9416E-03	-.8974E-03	-.8438E-03	-.8125E-03
-.7827E-03	-.7461E-03	-.6924E-03	-.6508E-03	-.6312E-03	-.6030E-03	-.5901E-03	-.5674E-03	-.5415E-03	-.5140E-03
-.4863E-03	-.4707E-03	-.4473E-03	-.4253E-03	-.4063E-03	-.3894E-03	-.3740E-03	-.3608E-03	-.3493E-03	-.3391E-03
-.3301E-03	-.3026E-03	-.3143E-03	-.3240E-03	-.2973E-03	-.2778E-03	-.2965E-03	-.3198E-03	-.3294E-03	-.3332E-03
-.3281E-03	-.3248E-03	-.3130E-03	-.3001E-03	-.2981E-03	-.2984E-03	-.3018E-03	-.3085E-03	-.3169E-03	-.3485E-03
-.3701E-03	-.4520E-03	-.5075E-03	-.5218E-03	-.5111E-03	-.5274E-03	-.5555E-03	-.5747E-03	-.5895E-03	-.5986E-03

```
 -.6068E-03  -.5974E-03  -.6154E-03  -.6253E-03  -.6260E-03  -.6247E-03  -.6217E-03  -.6115E-03  -.5750E-03  -.5252E-03
 -.4733E-03  -.4086E-03  -.3847E-03  -.3950E-03  -.3918E-03  -.3863E-03  -.3760E-03  -.3627E-03  -.3543E-03  -.3543E-03

SWEEP NO. 10  OF INVISCID/VISCOUS CALCULATION COMPLETED
```

APPENDIX A8

VARIOUS COMPUTING OPERATIONS

In this Appendix, we shall describe the creation of the files which contain the programs in the viscous/inviscid iteration cycle and also the creation of the "fixed" data files, under the KRONOS Computer System for the CDC machines at Imperial College. We shall also list the procedure file executed when running the viscous/inviscid cycle.

A8.1 CREATION OF THE PROGRAM FILES

Each of the programs which are executed as part of the viscous/inviscid iteration cycle, resides as a binary file, so that it is already compiled and need only be executed when running the cycle. The control cards given below apply to the compilation and storage of a general binary file whose "permanent file" name is BINARY; this name should be replaced for each of the programs by their appropriate "permanent file" name TURB, AMOS, MATCH, SMOOTH or TRAVERS. The control cards necessary are as follows:

Col. 1
↓

JOB( )	Job card.
PASSWOR( )	Password card.
FORTRAN(B=BIN, other options)	Compilation card.
REPLACE(BIN=BINARY)	Saves BINARY as a permanent file.

EoR

The FORTRAN program

EoF

EoR is an End-of-Record card (having 7-8-9 punched in its first column) and EoF is an End-of-File card having 6-7-8-9 punched in the first column.

A8.2 CREATION OF THE FIXED DATA FILES

The permanent file name of the fixed data file (MATDAT1, AMOSDA1, BLDAT1 or TRAVDAT) should replace the file name FILE in the control card procedure given below, for each fixed data file created. The control cards necessary are as follows:

```
        Col. 1
        ↓
        JOB(          )            Job card.
        PASSWOR(          )        Password card.
        COPYCF(INPUT,FILE)
        REWIND(FILE)
        REPLACE(FILE)              Saves FILE as a
                                   permanent file.
    EoR
                Data
    EoF
```

The fixed data file created in this way is a coded file (as opposed to a binary file).

A8.3 INITIALISATION AND EXECUTION OF THE VISCOUS/ INVISCID ITERATION CYCLE

In order to initialise the iteration cycle, we need to write the number 1 (the run number of the cycle) in binary (unformatted) from on the "variable" data file MATDAT. This is done by running the following small program:

```
    Col. 1
    ↓
    JOB(     )
    PASSWOR(     )
    FORTRAN.
    REWIND(TAPE1)
    REPLACE(TAPE1=MATDAT)
EoR
          Col. 7
          ↓
          PROGRAM INITIAL(OUTPUT=132B,TAPE1=132B)
          NORUN=1
          WRITE(1) NORUN
          STOP
          END
EoF
```

We will now indicate the creation of the procedure file (called CYCLE) which is executed once for each viscous/ inviscid iteration cycle; to do this, the following job should be executed:

```
   Col. 1
   ↓
   JOB(     )
   PASSWOR(     )
   COPYCF(INPUT,CYCLE)
   REWIND(CYCLE)
   REPLACE(CYCLE)
EoR
   Col. 1
   ↓
   SET(R1=R1-1)
   SET(R2=R2+1)
   GET(MATCH,TAPE5=MATDAT1,TAPE12=AMOSDAT,TAPE14=MATDAT)
   MATCH.
   REWIND(TAPE12)
   REPLACE(TAPE12=AMOSDAT)

   RETURN(TAPE14)
   GET(AMOS,TAPE2=AMOSDA1,TAPE12=AMOSDAT,TAPE13=BLDAT)
   AMOS.
   REWIND(TAPE13)
   REPLACE(TAPE13=BLDAT)

   IF(R3.EQ.1)GO TO,4.
   GET(TRAVERS,TAPE5=TRAVDAT,TAPE12=AMOSDAT,TAPE13=BLDAT)
   TRAVERS.

   4,IF(R2.EQ.1)GO TO,5.
   GET(SMOOTH,AA=AMOSDAT,BB=BLDAT,CC=MATDAT)
   COPYBR(AA,TAPE1,2)
   COPYBR(BB,TAPE1,2)
   COPYBF(CC,TAPE1)
   LDSET(LIB=NAG5F)
   LOAD(SMOOTH)
   EXECUTE.
   REWIND(TAPE1)
   REPLACE(TAPE1=MATDAT)
```

Execution of matching program MATCH

Execution of potential flow program AMOS

Execution of smoothing program SMOOTH

```
5,GET(TURB,TAPE5=BLDAT1,A=AMOSDAT,B=BLDAT,C=MATDAT)   --- ↑
COPYBR(A,TAPE14,2)                                        |
COPYBR(B,TAPE14,2)                                    Execution of
COPYBF(C,TAPE14)                                      shear layer
REWIND(TAPE14)                                        program TURB
LDSET(LIB=NAG5F)                                          |
LOAD(TURB)                                                |
NOGO.                                                     |
OVTURB.                                                   |
REWIND(TAPE14)                                            |
REPLACE(TAPE14=MATDAT)                                --- ↓ ---
RETURN(TAPE1)
RETURN(TAPE12)
RETURN(TAPE13)
RETURN(TAPE14)
IF(B1.LE.Ø)GO TO,EOJ.
CALL(CYCLE,C)
6,EOJ.
```

In order to <u>execute</u> the cycle (procedure file), the following control cards should be run:

```
Col. 1
↓
JOB(     )
PASSWOR(     )
SET(R1=1Ø)
SET(R3= Ø) or SET(R3=1)
CALL(CYCLE,C)
EoR
          Data for Smoothing Program SMOOTH
EoF
```

This will execute the iteration cycle <u>R1</u> times. The value of the parameter <u>R3</u> specifies whether the flow is external or internal; R3=1 for external flow and R3=Ø for internal flow. The data for program SMOOTH should be supplied according to the format specified in §4.3(e).