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# MANEUVERING AEROTHERMAL TECHNOLOGY (MAT) PROGRAM

A METHOD FOR COUPLED THREE-DIMENSIONAL

INVISCID AND INTEGRAL BOUNDARY

LAYER CALCULATIONS

SCIENCE APPLICATIONS, INC. APPLIED MECHANICS OPERATION WAYNE, PENNSYLVANIA 19087

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AIR FORCE BALLISTIC MISSILE OFFICE NORTON AIR FORCE BASE, CALIFORNIA 92409



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JOHN E. KEESEE, Capt, USAF

Project Officer Advanced Systems

Advanced Strategic Missile Systems

KEVIN E. YELMGREN, Major, USAF Chief, Advanced Systems Division Advanced Strategic Missile Systems

FOR THE COMMANDER

RICHARD T. WILLIAMS, Lt COI, USAF

Director, Missile Systems

Advanced Strategic Missile Systems

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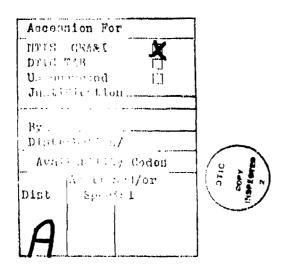
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This report describes the coupling of an inviscid flow field code (3IS) to an integral boundary layer procedure (3DMEIT) to provide a complete flow field prediction capability for maneuvering reentry vehicles. This effort was performed as part of Task 3 (Flow Field Effects) of the Maneuvering Aerothermal Technology (MAT) Program, Contract Number F04701-80-C-0033, for the Air Force Ballistic Missile Office. The project officer for this effort is Captain John Keesee, BMO/SYMST.

This study was conducted by personnel of Science Applications, Inc., Valley Forge, Pennsylvania, with work on the 3DMEIT integral boundary layer code being performed by personnel of the Aerotherm Division of the Acurex Corporation, Mountain View, California, on a subcontract from SAI.



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# NOMENCLATURE

В'	Blowing parameters
C <sub>m</sub>	Stanton number for mass transfer
h	Enthal py
$h_{\mathbf{C}}$	Solid (graphite or char layer) enthalpy
hg	Phenolic resin gas enthalpy
hβ	Streamline metric coefficient
m	Mass flux
$\dot{m}_{C}$	Thermochemical graphitic blowing rate
$\dot{m}_{\mathbf{g}}$	Phenolic resin gas blowing rate
М	Mach number
p	Pressure
Pr	Prandtl number
ģ	Heat flux
ġ <sub>c</sub>	Convective heat flux
$\dot{\mathfrak{q}}_{R}$	Re-radiative heat flux
r	Radial coordinate
Re	Reynolds number
$R_{N}$	Nose radius
S	Stream length measured from the stagnation point
T	Temperature
u	Streamwise velocity component (3DMEIT); radial velocity component (3IS)
U	Radial velocity component (2IT)
V	Body normal velocity component (3DMEIT); circumferential velocity component (3IS)
W	Axial velocity component (3IS)
У	Distance in surface normal direction 5.

- Υ Polar coordinate (2IT) Axial coordinate (315) Z Angle of attack α Boundary layer momentum thickness; circumferential coordinate (3IS) θ Body angle relative to the centerline θЬ 0 ' Circumferential coordinate (2IT) Viscosity μ Density Boundary layer energy thickness Subscripts
- e Boundary layer edge
- i Inviscid flow
- Laminar flow
- r Recovery state
- t Turbulent flow or stagnation conditions
- te Stagnation conditions at the boundary layer edge
- tiw Inviscid stagnation conditions at the wall
- tr Transition point
- w Wall

## SECTION 1

## INTRODUCTION

For most reentry vehicles and missions, the aerothermal environment of primary concern for vehicle design is the lower altitude flight regime (h  $\leq$  120 KFT), where peak aerodynamic loads and heating are experienced. Successful design and analysis of maneuvering reentry vehicles require the ability to accurately predict this aerothermal environment, where the Reynolds number is sufficiently large that the shock layer flow is primarily inviscid, with viscous effects confined to the thin boundary layer adjacent to the vehicle surface and to leeside regions of separated flow at high angles of attack.

Sophisticated flow field prediction techniques have been developed that directly compute the entire shock layer, both inviscid and viscous regions, eliminating the need for explicit coupling between the inviscid and viscous portions of the flow. These techniques, the parabolized Navier-Stokes (PNS) procedures, are thus capable of rigorously treating higher altitudes (where the boundary layer is not thin), as well as leeside separated flow regions. (A review of the current PNS methods was performed as part of the MAT program and is documented in Reference 1.)

These detailed PNS solutions, however, generally require a large amount of computer time and presently do not constitute a design technique. Consequently, more efficient inviscid flow field techniques are often used to predict the aerodynamic forces and moments (e.g., normal force, pitching moment, and inviscid contribution to the axial force). Boundary layer calculations are used to determine both the heat transfer

to the body and the viscous shear forces, with the required boundary layer edge conditions being obtained from the inviscid solution. This coupled inviscid-boundary layer solution procedure has been widely used to obtain accurate flow field predictions for both ballistic and maneuvering reentry vehicles.

For engineering calculations, the most appropriate approach for boundary layer predictions is the technique in which integral boundary layer equations are obtained by integrating the fundamental boundary layer equations across the layer. The solution of the resulting equations determines the viscous parameters of primary interest - shear stress, heat transfer, boundary layer thicknesses, etc. - but does not provide definition of specific details such as velocity and temperature profiles across the viscous layer. For three-dimensional problems, the integral boundary layer method is usually applied by integrating the axisymmetric integral equations along inviscid surface streamlines. Although this approach, termed the "small cross-flow approximation," neglects the cross-flow profiles in the boundary layer at angle of attack, it has been successfully applied to many RV configurations, providing reasonably accurate boundary layer solutions with great efficiency.

As part of the BMO Maneuvering Aerothermal Technology (MAT) program, an existing state-of-the-art three-dimensional inviscid flow field code has been coupled to an extension of an existing integral boundary layer solution procedure in order to provide the capability for efficient inviscid/viscous flow field solutions on maneuvering reentry vehicles, while taking maximum advantage of the inherent capabilities of the codes being coupled. The inviscid code used in this coupling procedure is the

BMO/3IS code, which is described in References 2-4. (The review of inviscid flow field codes for application to MaRV configurations conducted under the MAT program is documented in Reference 5.) The integral boundary layer code used is an extension of the Momentum-Energy Integral Technique (MEIT), described in References 6-10, which, unlike many integral boundary layer techniques, solves both the momentum and energy integral equations rather than invoking the Reynolds analogy to relate heat transfer and skin friction.

L

The approach taken in this coupling effort is described in Section 2 of this report, which also details the assumptions made. The inviscid flow field code used in this effort is briefly described in Section 3, as is the procedure developed in this effort to compute the inviscid surface streamlines. Details on the 3DMEIT integral boundary layer solution technique are provided in Section 4.

### SECTION 2

# APPROACH AND ASSUMPTIONS

The goal of this effort is the development of an efficient, robust, reliable procedure for computing complete flow fields on maneuvering reentry vehicles in the high Reynolds number flight regime, where the thin boundary layer assumption is valid. In this regime, the inviscid portion of the shock layer can be accurately computed without regard to the boundary layer, and the boundary layer solution can be determined using edge conditions obtained from the inviscid solution.

In this task, the BMO/3IS three-ormensional flow field code is used to define the inviscid shock layer, and an extension to the MEIT integral boundary layer procedure is used to determine the viscous flow. This extension, called 3DMEIT, solves the integral boundary layer equations along inviscid surface streamlines to efficiently model the three-dimensional boundary layer using the "small cross-flow" assumption. The coupling procedure developed in this effort provides definition of the inviscid surface streamlines and flow field properties obtained from the inviscid solution in a format compatible with the 3DMEIT boundary layer procedure.

A unique feature of this coupling procedure is the method used to define the inviscid surface streamlines. In previous 3-D integral boundary layer solutions, such as those described in References 11 and 12, the inviscid streamlines were determined in an approximate manner using the surface pressure distribution obtained from the inviscid flow field solution. In the current effort, the inviscid surface streamlines are

computed explicitly as part of the inviscid flow field procedure; this technique is described in Section 3.

Another unique feature of the coupled 3IS/3DMEIT flow field procedure is the method used for defining boundary layer edge properties. Rather than determining the edge entropy from a stream tube entrainment procedure (which works well for axisymmetric configurations at zero angle of attack, but is difficult to apply in three dimensional problems), the edge conditions are determined using a mass balance between the inviscid and boundary layer flows, using the detailed information available from the finite difference inviscid solution. This procedure is described in Section 4.2.6.

A buffer code has been developed to handle the coupling between the 3IS and 3DMEIT codes. This buffer code accepts as input the 3IS solution output file and defines the inviscid surface streamlines to be used by 3DMEIT in the boundary layer calculations. The format of the buffer code output is described in Section 3.4.

Several requirements were established for the 3DMEIT code in this effort. These requirements were:

- the ability to treat equilibrium air thermodynamics,
   in a manner consistent with the 3IS inviscid code
- the ability to automatically determine the wall temperature and mass addition rates for ablating heatshields using steady state ablation models (or, as an option, allow values of  $T_w$  and  $\dot{m}$  to be input by the user)
- the ability to treat laminar, transitional, or fully turbulent flows.

These capabilities of the 3DMEIT code, and others that have been implemented, are described in Section 4 of this report.

The coupled 3IS/3DMEIT procedure is applicable to any vehicle geometry which the inviscid (3IS) code is capable of treating. 3IS is formulated in a cylindrical coordinate system and allows the definition of generated afterbody cross-sections. Special geometry procedures are included to allow simple specification of multi-conics with slices, cuts and flaps. (Short-comings do exist in the current ability of 3IS to execute calculations over moderate to large flap deflection angles; however, activities are now underway to eliminate this limitation.) The ability of the 3IS/3DMEIT technique to treat control surfaces is partially demonstrated in the sample calculation in Section 4.4.3 which involves a fixed yaw stabilizer (FYS).

The intended emphasis of this effort was to develop and demonstrate a valid 3IS/3DMEIT coupling for afterbody applications. Therefore it was decided to initially restrict attention to spherical nosetip shapes. The axisymmetric 2IT nosetip code is currently used to determine the inviscid flow profiles associated with the streamlines on a sphere. This limitation can be removed by using the CM3DT blunt body code for the treatment of non-spherical, asymmetric nosetip shapes. It is necessary to simply calculate the streamlines paths from a converged CM3DT solution and transmit the corresponding inviscid flow field information to the buffer code.

In addition, the coupled 3IS/3DMEIT flow field procedure currently cannot treat non-zero sideslip angles because the 3DMEIT geometry routine is restricted to the description of bodies over a half-plane. The inviscid codes (blunt body and afterbody) which are used to provide the inviscid flow field information necessary to drive

the boundary layer solutions are fully capable of performing calculations for bodies at yaw. Thus, the current limitation to zero sideslip is not due to fundamental restrictions on the techniques themselves, but is simply a consequence of the 3DMEIT geometry description.

# SECTION 3

# INVISCID FLOW FIELD SOLUTION

The inviscid frustum flow field technique used in this effort is the BMO/3IS code. Since spherical nosetips are assumed in this initial effort, the required initial data for the 3IS afterbody calculations are obtained from the axisymmetric 2IT nosetip flow field code. Both the 2IT and 3IS codes are documented in References 2-4 and are briefly described in Sections 3.1 and 3.2 below.

Sections 3.3 and 3.4 describe the buffer code developed to handle the interface between the inviscid codes and the 3DMEIT boundary layer procedure and the user instructions for this buffer code.

#### 3.1 BLUNT BODY CODE DESCRIPTION

Inviscid flow field solutions on spherical nosetips are readily obtained with the time-dependent axisymmetric 2IT code. This code obtains the steady state solution as the asymptotic limit of an unsteady flow, starting from an assumed initial flow field. The time-dependent inviscid flow equations are solved using the MacCormack finite difference procedure.

Formulated in a spherical coordinate system, the 2IT code is ideally suited to the calculation of flows on spherical nosetips, since the grid is perfectly aligned with the body geometry. Calculations on spheres with 2IT are always performed in wind-fixed coordinates; appropriate initial data for the 3IS afterbody code at angle of attack are determined by interpolation and rotation of the 2IT solution. The 2IT code can treat either ideal gas or equilibrium air thermodynamics.

## 3.2 AFTERBODY CODE DESCRIPTION

Inviscid afterbody flow field solutions are obtained for this effort with the 3IS code. This code is a forward marching, steady, finite difference flow field solution procedure, and requires only that the axial component of the flow in the frustum shock layer be supersonic at all points.

3IS is formulated in a cylindrical coordinate system and allows the definition of generalized afterbody cross-sections. Alternatively, special geometry procedures have been implemented in the code to allow simple specification of multi-conics with slices, cuts, and flaps. Coordinate stretching can be used in the 3IS code to circumferentially concentrate mesh points in either the pitch or yaw planes. In addition, recent modifications to this code<sup>13</sup> also permit radial clustering of mesh points near the body to improve resolution of the flow gradients near the wall. Either ideal gas or equilibrium air thermodynamics can be used in the 3IS calculation procedure.

# 3.3 INVISCID SURFACE STREAMLINE CALCULATION

Inviscid surface streamlines are defined for the coupled 3IS/
3DMEIT procedure through explicit streamline calculations in the 3IS
inviscid afterbody code. The inviscid streamlines on the spherical nosetip are readily defined by noting that the streamlines remain in meridional
planes in wind-fixed coordinates on the sphere.

It is critical in this coupled inviscid-boundary layer approach to ensure that the selected inviscid streamlines along which boundary layer solutions are to be obtained provide complete coverage of the body. To accomplish this goal, the selected streamlines include those

streamlines that are equally spaced circumferentially at the initial afterbody plane (at the nosetip tangency point) as well as those that are equally spaced circumferentially at the end of the body. This choice allows complete coverage of the body, since at angle of attack the equally spaced streamlines at the initial plane will be swept around the body and will be concentrated near the lee plane at the end of the body, while those streamlines equally spaced at the end of the body will all originate near the winc place at the initial plane.

The details on the streamline calculation procedures used on the nosetip and the frustum are provided in Sections 3.3.1 and 3.3.2, respectively, below.

### 3.3.1 SPHERICAL NOSETIP STREAMLINE CALCULATION

The relationship between the 3IS  $(r,\theta,z)$  cylindrical coordinate system and the 2IT  $(R,\,\theta',\,Y)$  wind-fixed spherical coordinate system is depicted in Figure 3.1. The locations of the required inviscid surface streamlines at the 3IS initial data plane are assumed to be known, and are defined by specifying the appropriate value of  $\theta$  for each streamline. The track of each of these streamlines on the nosetip is readily defined by  $\theta'$  = constant on the sphere. The problem thus reduces to determining the relationship between  $\theta$  (3IS coordinates) and  $\theta'$  (2IT coordinates) at the initial data plane.

The relationship between  $\theta$  and  $\theta'$  may be written as

$$\tan \theta' = \frac{R_N \cos \theta_{b_1} \sin \theta}{\frac{R_N}{\sin \theta_{b_1}} - z_1 \sin \alpha + R_N \cos \theta_{b_1} \cos \theta \cos \alpha}$$
(3.1)

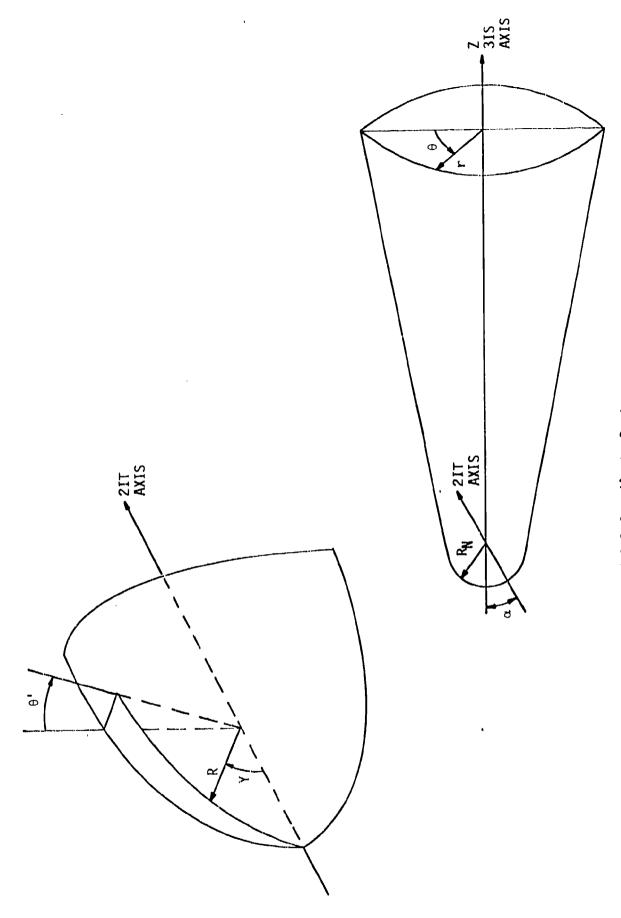


Figure 3.1. 2IT and 31S Coordinate Systems

where  $\theta_{b_1}$  is the body angle at the initial data plane,  $R_N$  is the nose radius, and  $z_1$  is the distance of the initial data plane from the virtual apex.

Knowing the appropriate value of 0' for each desired streamline, the inviscid nosetip flow field parameters may then be defined at the desired axial stations (in 3IS coordinates), requiring only transforming the 2IT velocity components to the appropriate 3IS velocity components. Given the U,V velocity components of the 2IT solution (defined in References 2 and 3), the 3IS velocity components (u,v,w) may be written at a given station (z) as

$$u = -V \left[ \sin\phi \cos\theta \sin\alpha + \cos\phi \left( \sin\theta \sin\theta' + \cos\theta \cos\theta' \sin\alpha \right) \right] + U\left[ -\cos\phi \cos\theta \sin\alpha + \sin\phi \left( \sin\theta \sin\theta' + \cos\theta \cos\theta' \cos\alpha \right) \right]$$
(3.2)

$$V = -V[-\sin\phi \sin\alpha + \cos\phi (\cos\theta \sin\theta' - \sin\theta \cos\theta' \cos\alpha)] + U[\cos\phi \sin\theta \sin\alpha + \sin\phi (\cos\theta \sin\theta' - \sin\theta \cos\theta' \cos\alpha)]$$
(3.3)

$$w = -V (\sin\phi \cos\alpha - \cos\phi \cos\theta' \sin\alpha)$$

$$-U (\sin\phi \cos\theta' \sin\alpha + \cos\phi \cos\alpha)$$
(3.5)

where

$$\cos v = 1 - \frac{z - z_0}{R_N}$$

$$\tan \theta = \frac{\sin \phi \sin \theta'}{\sin \phi \cos \theta' \cos \alpha - \cos \phi \sin \alpha}$$

with  $z_{\rm O}$  being the intersection of the 3IS axis with the spherical nose.

The nosetip flow field data obtained using this procedure is structured in the format described in Section 3.4.2 for use by the 3DMEIT code.

#### 3.3.2 AFTERBODY STREAMLINE CALCULATION

On the afterbody, as noted earlier, a procedure has been developed in this effort to allow the explicit calculation of inviscid surface streamlines within the 3IS code. This procedure takes advantage of the fact that functions which are conserved along streamlines can be readily computed in an inviscid flow field code using convective finite difference schemes. The calculation of entropy in the 3IS code is an example of such a procedure. (Since inviscid flows are isentropic, the value of entropy does not change along a streamline in inviscid flows.)

The attributes of such "convective" functions can readily be used to simplify the calculation of inviscid surface streamlines. In the 3IS code, each surface streamline is identified by a unique value of a function f, which is chosen to represent the value of  $\theta$  in the initial data plane through which that streamline passes. The "conservation of f" along streamlines can then be expressed mathematically as

$$\dot{\mathbf{V}} \cdot \nabla \mathbf{f} = \mathbf{0} \tag{3.5}$$

which can be expressed in terms of the 3IS variables at the body surface as

$$\frac{\partial f}{\partial 7} = -B \frac{\partial f}{\partial Y} \tag{3.6}$$

where Y is the transformed circumferential coordinate and

$$B = \frac{v}{rw} \frac{dY}{d0}$$

(For more detail on the 3IS equations and transformations, see References 2 and 3.)

Equation (3.6) is then solved using second-order accurate differences in a predictor-corrector scheme, simultaneously with the other flow equations being solved in 3IS, to define the appropriate value of f at all grid points located on the body.

Given the computed f distribution over the entire afterbody surface, the track of any given streamline (f = constant) can rapidly be determined by interpolation, along with the rest of the flow field information to be passed to 3DMEIT by the buffer code.

### 3.4 USER INSTRUCTIONS

#### 3.4.1 INPUT AND OUTPUT

As input, the buffer code between the 3IS and 3DMEIT procedures requires only two parameters to be input: the nose radius (RN) and the body angle at the nosetip tangency point (THB1), in degrees. These parameters are input in NAMELIST format. All other required inputs are provided either through the 2IT output file (which must be assigned to logical unit 23) and the 3IS output file (which must be assigned to logical unit 21). The formats of the 2IT and 3IS output files are described in Reference 3.

The output of the buffer code is written to a formatted file assigned to logical unit 22. The format of this file, which will be read as input to the 3DMEIT code, is described in the following section.

#### 3.4.2 INVISCID FLOW FIELD FILE DESCRIPTION

The first record on the output file of the buffer code contains:

 $M_{\infty}$  Mach number

α Angle of attack

MMAX Number of streamlines

NMAX Number of points through the shock layer.

The format of this record is 2E13.6,2I3,48X.

The second record contains the axial location on the body, Z, in the format E13.6,67X.

The third record contains values for

θ Circumferential angle

rb Body radius

rb, arb/az

rbe arb/ae

 $\omega$   $tan^{-1}(v/w)$  , where v and w are the circumferential and axial velocity components, respectively

SF Stream function, used to identify individual streamlines

for each of the MMAX streamlines at the axial station defined in the preceding record. These data are written in the format 6E13.6,2X.

The next NMAX records contain values for

p Pressure

T Temperature

u Radial velocity component

v Circumferential velocity component

- w Axial velocity component
- y Distance from the body surface, measured radially

for each streamline, written in the format 6E13.6,2X. Each of these records corresponds to a different value of N, where N=1 corresponds to the body surface and N=NMAX corresponds to the bow shock.

This sequence of records, starting with the second record, is repeated for each axial station at which the 3IS solution produced complete field output.

## SECTION 4

## **BOUNDARY LAYER SOLUTION**

#### 4.1 INTRODUCTION

The 3DMEIT code is a solution procedure for the boundary layer integral momentum and energy equations in a streamline-body normal coordinate system over a general three-dimensional body. The flow may be laminar, transitional or turbulent, and the procedure accounts for compressibility, real gas effects and surface ablation. The usual inputs to the code are the geometry of the body and the streamlines, a specification of inviscid flowfield data near the body surface and selection of a wall boundary condition.

Closure of the set of integral equations is accomplished by specifying the local shape factor, the recovery factor, the Stanton number and the friction coefficient as functions of the momentum and energy thickness Reynolds numbers. These basic "laws" are modified to account for the effects of surface roughness, transpiration, acceleration, and compressibility by influence coefficients, which are multiplicative factors on the local Stanton number and friction laws. The numerical solution procedure is an implicit finite difference scheme.

In Section 4.2.1 the basic equations are presented. This is followed by the formulation of local shape factor, recovery factor, Stanton number, friction coefficient and influence coefficients in Section 4.2.2. The transition criteria and surface roughness modeling are presented in

Sections 4.2.3 and 4.2.4, respectively. Section 4.2.5 describes the models used to approximate the ablation effects while Sections 4.2.6 and 4.2.7 detail the entropy swallowing and induced pressure models. The solution procedure is described in Section 4.2.8

#### 4.2 3DMEIT METHODOLOGY

#### 4.2.1 Basic Equations

The two equations that are basic to 3DMEIT are the integral momentum equation.

$$\frac{\partial \theta}{\partial s} = \theta \left\{ \frac{H}{\rho_e u_e^2} \frac{\partial p}{\partial s} - \frac{1}{h_B} \frac{\partial h_B}{\partial s} - \frac{1}{\rho_e u_e^2} \frac{\partial}{\partial s} (\rho_e u_e^2) \right\} + \frac{C_f}{2} + \frac{\rho_w v_w u_{iw}}{\rho_e u_e u_e}$$
(4.1)

and the integral energy equation,

$$\frac{\partial \phi}{\partial s} = C_h \frac{h_r - h_w}{h_{te} - h_w} + \frac{\rho_w V_w}{\rho_e u_e} \frac{(h_{tiw} - h_w)}{(h_{te} - h_w)}$$

$$- \phi \left\{ \frac{1}{h_\beta} \frac{\partial h_\beta}{\partial s} + \frac{1}{\rho_e u_e (h_{te} - h_w)} \frac{\partial}{\partial s} \left[ \rho_e u_e (h_{te} - h_w) \right] \right\}$$
(4.2)

where s is distance along a streamline and  $h_{\beta}$  is the body surface metric. These forms of the boundary layer equations result from neglecting the crossflow velocity; 3DMEIT is therefore most appropriate for regions where the crossflow is "small." However, a simplified form of the crossflow momentum equation can be added to 3DMEIT without changing the parabolic nature of the system of equations. This addition is a relatively simple change to the code and should be considered in predictions at the next level of detail in the flow are necessary.

The other variables in these equations are the momentum and energy thicknesses, which are respectively:

$$e = \int_{0}^{\infty} \frac{\rho u}{\rho_{e} u_{e}} \left( \frac{u_{e} - u}{u_{e}} \right) dy$$
 (4.3)

$$\phi = \int_{0}^{\infty} \left( \frac{\rho u}{\rho_{e} u_{e}} \frac{h_{te} - h_{t}}{h_{te} - h_{w}} \right) dy$$
 (4.4)

and the boundary layer shape factor, H, is defined as:

$$H = \frac{\delta^*}{\theta} \tag{4.5}$$

where 6\*, the displacement thickness, is given by:

$$\delta^* = \int_0^\infty \left( 1 - \frac{\sigma u}{\sigma_e u_e} \right) dy \tag{4.6}$$

The total enthalpy at the boundary layer edge is defined by:

$$h_{te} = h_e + \frac{u_e^2}{2}$$
 (4.7)

while the recovery enthalpy is given by:

$$h_r = h_e + F \frac{u_e^2}{2}$$
 (4.8)

where F is the recovery factor.

The heat transfer rate and skin friction are related to the Stanton number and friction coefficient, respectively, by:

$$\tau_{\mathbf{w}} = \rho_{\mathbf{e}} \mathbf{u}_{\mathbf{e}}^2 \frac{c_{\mathbf{f}}}{2} \tag{4.9}$$

$$\dot{q}_{w} = \rho_{e} u_{e} C_{h} \left( h_{r} - h_{w} \right) \tag{4.10}$$

Closure of this system of equations is described in the following subsection.

# 4.2.2 SHAPE FACTOR, RECOVERY FACTOR, STANTON NUMBER AND FRICTION COEFFICIENT

The shape and recovery factors are evaluated in 3DMEIT by the following relation for laminar flow:

$$H_{\chi} = 3.029 \frac{T_{w}}{T_{e}} - 0.614$$
 (4.11)

$$F_{\ell} = Pr^{1/2}$$
 (4.12)

and for turbulent flow:

$$H_{t} = H_{ref} [1 + D(6 - \log_{10} Re_{e})]$$
 (4.13)

where

$$H_{ref} = A e^{BM^C}$$
 (4.14)

$$A = \left\{ A_0 + A_1 \right\} \left\{ 0.0064 + 0.0231 \left( T_w / T_{te} \right) \right\} / A_0$$
 (4.15)

$$A_0 = -0.02 + 1.20 (T_w/T_{te})$$
 (4.16)

$$A_1 = (0.0372 + 0.0322 (T_w/T_{te}))f_4$$
 (4.17)

$$f_4 = \begin{cases} 0 & \text{for } k_s^+ < 3 \\ \log_{10}(k_s^+/3) & \text{for } k_s^+ \ge 3 \end{cases}$$
 (4.18)

$$B = \begin{cases} 0.35 \ (T_w/T_{te})^{-0.5} & \text{for M < 1.5} \\ 3.817 & \text{for M > 1.5} \end{cases}$$
 (4.19)

$$C = \begin{cases} 1.25 & \text{for M} < 1.5 \\ 0.29 & \text{for M} > 1.5 \end{cases}$$
 (4.20)

$$M = M_{e} \sqrt{\frac{\gamma_{e} - 1}{0.4}}$$
 (4.21)

$$D = \begin{cases} 0.05 & \text{for } k + 3 \\ 0.05 + 0.04 \log_{10}(k_s^{+/3}) & \text{for } k + 2 \end{cases}$$
 (4.22)

and

$$F_t = Pr^{1/3}$$
 (4.23)

where  $k_{\mathbf{S}}^{\dagger}$  is the local roughness Reynolds number.

The friction coefficient and the Stanton number are determined by the basic wall shear and heat flux laws respectively. The basic form of these laws comes from theory and data for incompressible flow along a smooth, isothermal, impervious, flat plate. The friction coefficient and Stanton number for laminar flow are:

$$\frac{C_{f, \ell, 0}}{2} = \frac{0.245}{Re_{\theta}} \tag{4.24}$$

$$C_{h,\ell,o} = \frac{0.22}{Pr^{4/3} Re_{b}}$$
 (4.25)

and for turbulent flow:

$$\frac{C_{f,t,0}}{2} = \frac{0.245}{Re_{e}} + \frac{0.010742 \text{ Re}_{e}}{100 + Re_{e}} (\log_{10} Re_{e})^{-1.5262}$$
 (4.26)

$$C_{h,t,o} = \frac{0.22}{Pr^{4/3}Re_{d}} + \frac{a Re_{d}}{(100 + Re_{d})} (\log_{10} Re_{d})^{-b}$$
 (4.27)

where

$$a = 0.0993 e^{(0.0648 Pr)}/(1 + 9.6 Pr)$$

$$b = 1.954 e^{(0.273 Pr)}/(1 + 0.71 Pr)$$

$$Pr \ge 0.6 \qquad (4.28)$$

or

$$a = 0.1256 e^{(0.2435 Pr)}/(1 + 14.2 Pr)$$

$$b = 2.217 e^{(0.6313 Pr)}/(1 + 1.677 Pr)$$
Pr < 0.6 (4.29)

The Stanton number and friction coefficient laws given above are modified by corresponding influence coefficients to account for various boundary layer effects:

$$C_{x,y} = C_{x,y,0} \prod_{i=1}^{z} I_{x,y,z} \qquad \text{for } x = h,f$$

$$y = \ell,t \qquad (4.30)$$

The influence coefficients are shown by  $I_{x,y,z}$  where the subscripts x and y indicate whether the influence coefficient pertains to heat or momentum transfer (x = h or f) and laminar or turbulent flow

(y = l or t), respectively. The subscript z indicates the type of phenomenon for which the basic laws are being modified.

Five phenomena are considered by 3DMEIT. These phenomena and their corresponding z-subscripts are given in Table 4.1. The influence coefficients corresponding to each of these effects are given below.

#### Acceleration

In laminar flow:

$$I_{f,\ell,\beta} = \begin{cases} (1+3\beta)^{1/3}, & \beta > 0\\ 1.0, & \beta < 0 \end{cases}$$
 (4.31)

$$I_{h,\ell,\beta} = \begin{cases} (1+4\beta) & , & \beta > 0 \\ 1.0, & \beta < 0 \end{cases}$$
 (4.32)

where

$$\beta \equiv \frac{2\xi}{u_e} \frac{du_e}{d\xi} \tag{4.33}$$

$$\xi = \int_0^s \rho_e^{\mu} e^{\mu} e^{\mu} e^{\mu} e^{\mu} ds \qquad (4.34)$$

Table 4.1. Notation for Influence Coefficients

Phenomena	z-Subscript of Influence Coefficient
Acceleration Transpiration Boundary layer properties Roughness Transition proximity	B' B' p r tr

In turbulent flow, only the first terms of the appropriate basic turbulent laws are modified by the above influence coefficients.

## Transpiration

Blowing effects on the wall shear are modeled by adaptations of film theory (Reference 14).

$$I_{f,y,B'} = \frac{\ln(1 + 2\lambda_{f,y}R'RB')}{2\lambda_{f,y}RR'B'}, y = \ell,t$$
 (4.35)

where:

$$B' \equiv \dot{m}/\rho_e u_e^C_m \tag{4.36}$$

and

 $R = C_h/C_f/2 = Reynolds Analogy Factor$ 

R' = Mass to heat transfer coefficient ratio =  $C_{m}/C_{h}$ 

 $\lambda_{f,V}$  = Blowing reduction parameter.

R is a dependent variable which is evaluated during the solution process. Both R' and  $\lambda_{f,y}$  are input; 3DMEIT, however, does provide built-in default values for  $\lambda_{f,y}$ . These default values are:

$$\lambda_{f,\ell} = 0.5$$
 (4.37)  $\lambda_{f,t} = 0.35$ 

The variables B' and R' are, in effect, definitions for the mass transfer coefficient, which, in 3DMEIT, are obtained from the analogy between heat and mass transfer. Therefore,  $C_{m}$  is the mass transfer analog of the Stanton number and  $\hat{m} = \rho_{e}u_{e}C_{m}$ .

Ordinarily, R'=1 and the default values of  $\lambda$  are used because these are the theoretical values for unity Prandtl and Lewis numbers in laminar flow. Also, the default values for turbulent flow have been chosen to fit available data. Other input values of R' and  $\lambda$  can be developed from finite difference calculations for chemically reacting boundary layers or by fits to mass transfer data. (A detailed description of these procedures is given in "An Evaluation of a Transfer Coefficient Approach for Unequal Diffusion Coefficients" by E. P. Bartlett and R. G. Grose, Aerotherm Report 69-50, June 30, 1969.)

There are two blowing correlation options for the heat transfer:

(1) Appotherm option and (2) GF option. The Appotherm option util:

(1) Aerotherm option and (2) GE option. The Aerotherm option utilizes the expression (Reference 15):

$$I_{h,y,B'} = \frac{C_h}{C_{h_0}} = \frac{\ln (1 + 1.4 B')}{1.4 B'}, \quad y = l,t$$
 (4.38)

The GE option employs the Costello correlation (Reference 16) for laminar flow:

$$I_{h,\ell,B'} = \frac{c_h}{c_{h_0}} = (1 + 0.69 B')^{-1}$$
 (4.39)

and another correlation (Reference 17) for turbulent flow

$$I_{h,t,B'} = \frac{C_h}{C_{h_0}} = \left[\frac{2}{B'}\left(\sqrt{1+B'}-1\right)\right]^{1.6} (1+B')^{0.2(\omega-1)}$$
 (4.40)

where

$$\omega = \left(\frac{T_{w}}{T_{e}}\right)^{-1/8} + 1/8 M_{e} \tag{4.41}$$

### Boundary Layer Properties

Boundary layer properties of density, viscosity, and Prandtl number are evaluated at a reference enthalpy h' as follows for laminar flow:

$$h' = 0.42 h_e + 0.19 h_r + 0.58 h_w$$
 (4.42)

and the property influence coefficients are:

$$I_{f,\ell,p} = 1 \tag{4.43}$$

$$I_{h,\ell,p} = \left(\frac{\rho'}{\rho_e}\right) \left(\frac{\mu'}{\mu_e}\right) \left(\frac{h_{te} - h_{w}}{h_r - h_{w}}\right) \tag{4.44}$$

For turbulent flows:

$$h' = 0.353 h_e + 0.19 h_r + 0.45 h_w + f_5 f(h_e, h_r, h_w)$$
 (4.45)

where

$$f(h_e, h_r, h_w)$$
 is the greater of zero or (-0.609  $h_e$  + 0.332  $h_r$  + 0.277  $h_w$ ) (4.45)

and

$$f_{5} = \begin{cases} 0 & \text{for } k_{s}^{+} \leq 3 \\ \frac{(k_{s}^{+} - 3)^{2}}{400 + (k_{s}^{+} - 3)^{2}} & \text{for } k_{s}^{+} > 3 \end{cases}$$
 (4.47)

where  $k_s^+$  is the local roughness Reynolds number.

The influence coefficients are:

$$I_{x,t,p} = \left(\frac{p'}{\rho_e}\right) \left(\frac{\mu'}{\mu_e}\right)^{0.25}, \quad x = f,h$$
 (4.48)

### Surface Roughness

In laminar flow:

$$I_{h,\ell,r} = I_{f,\ell,r} = 1$$
 (4.49)

The turbulent influence coefficient for the wall shear due to roughness is:

$$I_{f,t,r} = \frac{a(\log_{10} Re_{e})^{-e}}{0.010742 (\log_{10} Re_{e})^{-1.5262}}$$
(4.50)

where

$$a = b + c(k_s^+)^d$$
 (4.51)

$$e = f + g(k_s^+)^h$$
 (4.52)

The values of b, c, c, f, g and h are dependent on the local roughness Reynolds number  $(k_S^+ \underline{\Delta} \ u_T k_S / \nu_W)$  and are listed in Table 4.2. Re $_{\Theta}$  is the local momentum thickness Reynolds number for the rough wall,  $u_T$  is the local shear velocity  $(u_T \underline{\Delta} \ \sqrt{\tau_W / \rho_W})$ ,  $k_S$  is the equivalent sand-grain roughness height and  $\nu_W$  is the wall kinematic viscosity.

The turbulent heat transfer influence coefficient is:

$$I_{h,t,r} = 1 + R(I_{f,t,r} - 1)$$
 (4.53)

where

$$R = f_1 \left\{ [1 + g_2(g_3 - f_2)][1 - f_3] + f_3 \right\} - g_1 h \tag{4.54}$$

Table 4.2. Coefficients for the Turbulent Wall Shear Roughness Influence Coefficient

Range of ks	b х 10 <sup>3</sup>	c x 10 <sup>3</sup>	d	f	g	h
0 - 3	10.742	0		1.5262	0	-
3 - 7	10.650	0.00344	3.0340	1.5227	0.000155	2.8460
7 - 17	6.150	1.787	0.6011	1.3070	0.1204	0.3860
17 - 30	9.140	0.556	0.8850	1.3850	0.0710	0.4865
30 - 100	0.987	3.178	0.5324	-2.9459	4.1085	0.0397
100 - 1000	8.143	1.878	0.5997	-3.1856	4.3879	0.0357
1000 - 3000	-22.840	3.657	0.5370	4.7184	-4.6579	-0.1028
> 3000	0	1.301	0.6640	0	1.3560	0.0870

$$h = \begin{cases} \left[\log_{10}(10,000 \ k_s/e)^2\right] & \text{for } k_s/e > 10^{-4} \\ 0 & \text{for } k_s/e \le 10^{-4} \end{cases}$$
 (4.55)

$$g_1 = 0.005 \{1 + 0.35 \sin [\pi/2 (1 - Pr)]\}$$
 (4.56)

$$g_2 = 0.142 (Pr - 0.71)$$
 (4.57)

$$g_3 = (0.121 + 0.053 \text{ Pr})^{-1}$$
 (4.58)

The values  $\mathbf{f_2}$  and  $\mathbf{f_3}$  are functions of  $\mathbf{k_S^+}$  and are given in Table 4.3.

Table 4.3. Functions f<sub>2</sub> and f<sub>3</sub> for the Turbulent Heat Transfer Roughness Influence Coefficient

Range of ks	f <sub>2</sub>	f <sub>3</sub>
3 - 76	1.8808	$-0.32 \left[ \log_{10}(k_s^+ - 1.8808) \right]$
76 - 1500	log <sub>10</sub> (k <sub>s</sub> +)	0
1500 - 10 <sup>4</sup>	3.176	0.32 [log <sub>10</sub> (k <sub>s</sub> - 3.176)]

The function  $f_1$  is the relationship between heat transfer and roughness shear augmentation. The modified correlation is:

$$f_{1} = \begin{cases} 0.89 - 0.46(k_{s}^{+} - 3)/(k_{s}^{+} + 47) & \text{for } k_{s}^{+} > 3\\ 0.89 & \text{for } k_{s}^{+} \le 3 \end{cases}$$
 (4.59)

### Transition Proximity

The transition proximity influence coefficients apply only to the laminar region upstream of the transition point. The present influence coefficients are based on PANT and ART wind tunnel heat transfer data (References 18 and 19). It is assumed that the influence coefficient for momentum is the same as for heat transfer, i.e.,

$$I_{f,\ell,tr} = I_{h,\ell,tr} \tag{4.60}$$

and

$$I_{h,l,tr} =$$
 the greater of 1.0 or

$$7.6(s_{tk})^{-0.366} e^{0.0005 s_{tk}} s_{tk} < 1000$$
 (4.61)

where

$$s_{tk} = s_{tr}/e_{tr}(I_{h,\ell,tr})^{1.3}$$
 (4.62)

### Intermittency

The above formulations for H, F,  $C_h$ ,  $C_{f/2}$  are for entirely laminar or for entirely turbulent flows. To evaluate these four parameters for transitional flow the following relation is used:

$$P = (1 - f) P_{\ell} + fP_{t}$$

where P is one of the four parameters above and f is the transitional intermittency factor.

The transitional intermittency employed in 3DMEIT is based on the work of Persh (Reference 20), and an interpretation by Dahm (Reference 21):

$$f = 1 - \frac{\alpha}{Re_{\theta}^{2} \left(C_{f,t} - C_{f,\ell}\right)}$$
 (4.63)

where

$$\alpha = Re_{\theta, tr}^{2} (C_{f, t} - C_{f, \ell})_{tr}$$
(4.64)

and the subscript tr refers to conditions at the transition point.

f is set to zero in laminar flow, unity in turbulent flow, and varies between 0 and 1 in transitional flow.

This completes the formulation of the parameters required in the solutions of Equations (4.1) and (4.2).

#### 4.2.3 TRANSITION CRITERIA

The 3DMEIT code has several built-in options to specify the critical flow/material surface parameters that establish transition onset and location. In addition, all laminar or all turbulent (from stagnation point) calculations may be made.

The analytic transition criteria for rough wall calculations available are the Anderson criterion for nose transition and LORN criterion for cone transition (although use of the LORN criterion is not recommended). These are:

## Anderson Criterion

$$Re_{\Theta} \left( \frac{k_{\parallel}}{\Theta} \frac{1}{\Psi} \right)^{0.7} = \begin{cases} 255 \text{ onset} \\ 215 \text{ location} \end{cases}$$
 (4.65)

where

$$\psi = 0.1B' + (1 + 0.25 B') \rho_e/\rho_w$$
 (4.66)

## LORN Criterion

$$Re_{e} = 275 e$$
 (4.67)

where  $M_{e}$  is the boundary layer edge Mach number.

## 4.2.4 SURFACE ROUGHNESS MODELING

Two types of surface roughness are modeled

- Intrinsic roughness, k<sub>i</sub>
- Turbulent or scallop roughness, k<sub>t</sub>.

Intrinsic roughness  $(k_i)$  is that associated with the basic material granularity and is input as a constant for each material or as a function

of the axial length. The intrinsic roughness is used in the transition criteria and transition proximity influence coefficient.

The turbulent roughness  $(k_t)$  is the effective sand grain roughness that results from turbulent ablation and is used in the turbulent roughness influence coefficients. The roughness height,  $k_t$ , is specified in one of three ways. A uniform value of  $k_t$  for all turbulent regions may be input by the user; a distribution of  $k_t$  as a function of axial length may be input; or a value may be obtained by using the scallop dimension correlation. From the correlation, the effective turbulent region scallop depth is computed as follows:

$$k_t = K_1 p_e^{-0.77}$$
 (4.68)

where

 $k_t$  = the effective sand grain roughness height

K<sub>1</sub> = a material dependent property determined from experimental data and input by the user.

#### 4.2.5 SURFACE TEMPERATURE AND ABLATION MODELING

The technique used in 3DMEIT is an approximation because it assumes steady-state conditions; i.e., no transient conduction in the solid.

Under these special conditions of quasi-equilibrium, the energy balance is (excluding mechanical erosion):

$$\dot{q}_{NET} = \dot{q}_{c} - \dot{q}_{R} - \dot{m}_{T}h_{w} + \dot{m}_{c}h_{c} + \dot{m}_{q}h_{q}$$
 (4.69)

where

$$\dot{\mathbf{m}}_{\mathsf{T}} = \dot{\mathbf{m}}_{\mathsf{c}} + \dot{\mathbf{m}}_{\mathsf{q}} \tag{4.70}$$

Since the net heat conducted into the solid is approximately the energy lost due to mass removal, i.e.:

$$\dot{q}_{NET} \stackrel{\sim}{=} \dot{m}_{c}h_{c} + \dot{m}_{q}h_{q} \tag{4.71}$$

The surface energy balance can be further simplified to give:

$$\rho_{e} u_{e} C_{h} (h_{r} - h_{w}) - \dot{m}_{T} h_{w} - \dot{q}_{R} = 0$$
 (4.72)

This equation is solved iteratively for  $\dot{m}_T$  and  $h_w$  by varying the wall temperature until the recovery enthalpy matches, within a specified limit, the local value derived from mass balance considerations. The above equation is conveniently rewritten for this purpose as:

$$\Delta h_r = 1.0 - \left( \frac{\epsilon \sigma T_w^4 + \dot{m}_T h_w}{\rho_e u_e C_h} + h_w \right) / h_r$$
 (4.73)

## 4.2.5.1 Wall Gas Enthalpy

The wall gas enthalpy for graphitic materials is expressed in the functional form:

$$h_{w} = f(B') \tag{4.74}$$

where B' is the blowing parameter:

$$B' = \dot{m}_{T}/\rho_{e} u_{e}^{C} c_{h} \tag{4.75}$$

and  $C_h$  is the Stanton number,  $\dot{q}_{convective}/\rho_e u_e(h_r - h_w)$ , with blowing. f(B') is represented by the following polynomial relationships for the range of indicated pressures:

A = 
$$1.4216 + 0.0293$$
  $\log_{10} p_e$ 

C =  $0.55993 + 0.00348$   $\log_{10} p_e$ 

$$D = -8.1997 - 0.2173$$
  $\log_{10} p_e$ 

E =  $0.9024 - 0.062$   $\log_{10} p_e$ 

$$B' \leq 0.19: h_W^* = \frac{2500}{2C} \left[ -E + \sqrt{E^2 - 4C (0.0361A + 0.19D + 1)} \right] (4.77)$$

$$h_W^* = -172.46 + 76.63 \log_{10} p_e + 20.41 (\log_{10} p_e)^2 \qquad (4.78)$$

$$h_W^* = \left[ (h_W^* - h_W^*) B' + 0.19 h_W^* - 0.175 h_W^* \right] / 0.015 (4.79)$$

B' > 0.19: 
$$h_W = \frac{2500}{2C} \left[ -E + \sqrt{E^2 - 4C \left( AB'^2 + DB' + 1 \right)} \right]$$
 (4.80)

These relationships also satisfactorily approximate the wall gas enthalpies for carbon phenolic (Reference 15).

A discussion of the relevant expressions used in the three ablative material options is presented in the following subsections:

## 4.2.5.2 Graphite Ablation Option

For graphite (carbon/carbon, ATJ, etc.) ablation, the phenolic resin gas blowing rate is zero; i.e.,  $\dot{m}_g = 0$ . The ablation rate expression employed is of the form:

$$B' = B'_{c} = \exp \left[ \sum_{n=0}^{5} b_{n} T^{*n} \right]$$
 (4.81)

where

$$T^* = T_w - 6000 - \sum_{n=1}^4 a_n \log_{10} p_e$$
 (4.82)

and the numerical values for  $\boldsymbol{a}_n$  and  $\boldsymbol{b}_n$  are listed as follows:

Ablation Parameter Correlation Constants

n	<sup>a</sup> n	b <sub>n</sub>
0	**************************************	-1.3191
1	587.496	$6.5704 (10^{-4})$
2	32.826	3.6955 (10 <sup>-7</sup> )
3	9.643	$6.7268 (10^{-12})$
4	-2.965	$-2.7179 (10^{-14})$
5	•••	3.3450 (10 <sup>-17</sup> )

 $T^*$  is employed as a collapsing function which reduces the data to one curve. The relationship between  $T^*$  and  $B_{\bf c}^+$  is:

$$T^* < -4447$$
:  $B_C^* = 0.175$ 
 $-4447 < T^* < -939$ :  $B_C^* = 0.175 + 4.2759 (10^6) (T^* + 4447)$ 
 $T^* > -939$ :  $B_C^* = \exp\left[\sum_{n=0}^5 b_n T^{*n}\right]$ 

(4.83)

#### 4.2.5.3 Carbon Phenolic Ablation Option

In the carbon phenolic option, the total mass loss rate from Equation (4.70) becomes:

$$B' = B_c' \left( 1 + \frac{\dot{m}_g}{\dot{m}_c} \right) \tag{4.84}$$

where the char mass loss rate parameter  $B_{C}^{*}$  is obtained from Equations (4.81) and (4.82) and the ratio  $\dot{m}_{g}$  / $\dot{m}_{C}$  (correlated as a function of the zero-blowing film coefficient  $C_{h_{O}}$  from results reported in Reference 22) is

$$\frac{\dot{m}_{g}}{\dot{m}_{c}} = \begin{cases} 0.22 & C_{h_{o}} < 1.0 \\ 0.22 - 0.01 & C_{h_{o}} & C_{h_{o}} > 1.0 \end{cases}$$
 (4.85)

The wall gas enthalpy for carbon phenolic ablation is satisfactorily approximated (see Reference 23) using Equation (4.74) in the form

$$h_{W} = f(B_{C}^{*}) \tag{4.86}$$

This approximation is valid only for  $\dot{m}_g/\dot{m}_c < 10$  which encompasses most reentry applications.

The procedure to compute the blowing rate and wall temperature is identical to that described in the "Graphite Ablation Option" section.

4.2.5.4 <u>Teflon Ablation Option</u>

For Teflon ablation, the empirical "heat of ablation" concept is employed to obtain the mass loss rate. The expression employed in

subroutine ABLATE was obtained from Reference 24 and is utilized in the form:

$$\dot{m}_{T} = \frac{c_{h_{0}}}{0.4594 - 0.0027 p_{p}}$$
 (4.87)

with the ablation temperature of Teflon set at  $1,800^{\circ}R$ . Any of the three material options described above may be used at one time.

#### 4.2.6 EDGE ENTROPY MODELS

The 3DMEIT code has four different models for determining the entropy at the edge of the boundary layer. The first two options are very simple and do not account for entrainment into the boundary layer. Option 1 uses a constant entropy equal to that behind a normal shock and Option 2 uses the entropy calculated from the inviscid pressure and temperaure at the wall. Options 3 and 4 account for swallowing and use the inviscid flowfield data to calculate the edge entropy. Option 3 is the streamtube entrainment method used in ASCC and is shown schematically in Figure 4.1.

Balancing the mass entering the streamtube with the mass flux in the boundary layer gives:

$$\int_{0}^{\overline{y}} \rho_{\infty} u_{\infty} y dy = 2h_{\beta} \int_{0}^{\delta} \rho u dy - 2 \int_{0}^{s} h_{\beta} (\rho v)_{w} ds$$
 (4.88)

where  $h_{\beta}$  is the spreading metric. In axisymmetric flow,  $h_{\beta} = r(s)$ , which is the local body radius. Note that y is the body normal coordinate in the right hand side of this equation. Then, using MEIT's variables, this becomes:

$$\rho_{\infty} u_{\infty} \overline{y}^{2} = 2h_{\beta} F_{\mu} e^{Re} - 2 \int_{0}^{S} h_{\beta} (\rho v)_{w} ds \qquad (4.89)$$

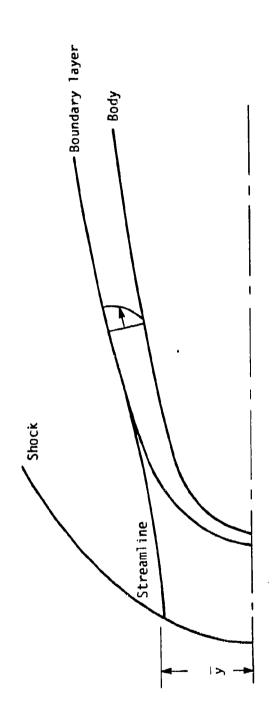


Figure 4.1. Schematic of Boundary Layer Entrainment

Equation (4.89) is solved for  $\overline{y}$  which is then used with the inviscid shock shape and entropy to determine the entropy of the streamline at the edge to the boundary layer. This model works well on axisymmetric configurations at zero angle of attack. However, in three-dimensional problems, the tracking of the streamline at the edge of the boundary layer is difficult because the streamlines curve around the body. Therefore, Option 4 was developed to utilize a mass balance between the inviscid flow, as defined by a finite difference calculation, and the boundary layer flow (Figure 4.2). Balancing the mass fluxes at a local station gives for this case:

$$\int_{0}^{\delta} (\rho u)_{inv} dy = \int_{0}^{\delta} (\rho u)_{BL} dy - \int_{0}^{s} h_{g}(\rho v)_{w} ds \qquad (4.90)$$

where  $\delta$  is used as the integration limit for both the inviscid and boundary profiles because the "edge" of the boundary layer must have the same  $\rho$  and u as that which exists in the inviscid flow at that  $\delta$  and the boundary layer mass flux must include that which is entrained from the entropy layer. This equation effectively defines  $\delta$ , which is otherwise unknown and not needed for an integral boundary layer calculation.

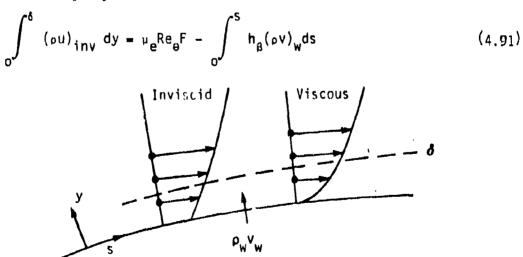


Figure 4.2. Schematic of Viscous and Inviscid Profiles Used in Mass Flux Balance

The right hand side of this equation is known from the boundary layer solution. The solution for & is obtained by constructing the inviscid mass flux as a function of the distance normal to the surface and interpolating in these inviscid data.

#### 4.2.7 INDUCED PRESSURE

The effect of the boundary displacement on the pressure is modeled by a correction to the inviscid values

$$p = p_{inv} + \frac{\Delta p}{\Delta \theta} \frac{d\delta^*}{dx}$$
 (4.92)

where  $d\delta^*/dx$  is the derivative of the displacement thickness with respect to the axial direction. The term  $\Delta p/\Delta \theta$  models the effect of the angle on the wall pressure. This term is evaluated using Linnell's formula (Reference 25) which may be written as:

$$\frac{p}{p_m} = 1 + 0.5 \text{ y (y + 1) } \text{K}^2 \tag{4.93}$$

where K is the hypersonic similarity parameter,  $K = M_{\infty} \sin \theta$ .

The term  $\Delta p/\Delta \theta$  is determined by calculating p at the body angle and at the effective angle:

$$e' = e + \tan^{-1} \left(\Delta \delta^* / \Delta S\right) \tag{4.94}$$

When  $\Theta$  is less than zero, limiting values of  $\Theta = 1^{\circ}$  and  $\Theta' = 2^{\circ}$  are used in calculating  $\Delta p/\Delta \Theta$ .

### 4.2.8 SOLUTIONS OF THE BOUNDARY LAYER INTEGRAL EQUATIONS

As mentioned above, the required input to 3DMEIT are surface shape, boundary layer edge conditions, and wall conditions. These quantities are input in terms of body points and inviscid solution points. A finer grid

in terms of integration points, which include all the inviscid points, is generated by the program to ensure adequate solution accuracy of the integral equations. The boundary layer edge conditions, gas properties and wall conditions at each integration point are obtained by interpolation from the input. The solution procedures of the boundary layer integral Equations (4.1) and (4.2) consist of:

- Start-up solutions at the first integration points
- Finite difference numerical solutions for the rest of the integration points.

The starting values of  $\phi$  and  $\theta$  are defined in the code by:

$$e_1 = \sqrt{\frac{0.245 v_1 (1 + R_1 B_1) z}{(3 + H) \frac{du_e}{ds} |_{1}}} \prod_{II} c_{f,\ell,z}$$
(4.95)

$$\phi_{1} = \sqrt{\frac{0.22 \, v_{1} \, (1 + B_{1}^{i})}{2 \, Pr^{4/3} \, \frac{du_{e}}{ds} \, 1}} \, \frac{z}{\Pi} \, C_{h,\ell,z}$$
 (4.96)

The solutions at the second and third integration points are related to the first integration point by:

$$e = e_1 (1 + a_{\psi}^2)$$
 (4.97)

$$\phi = \phi_1 (1 + b_{\psi}^2) \tag{4.98}$$

where

$$\frac{13 + H_{1}}{4} \frac{\alpha}{\gamma} + \frac{1}{3} - \frac{0.659 (3 + H_{1}) \alpha (\gamma - 1)}{8 + 2H_{1}} - \frac{(H_{1} - 0.614) \alpha (\gamma - 1)}{\gamma} (4.99)$$

$$b = \frac{1}{6} \left[ \frac{3\alpha}{\gamma} + \frac{1}{3} - \frac{2 \times 0.659 \alpha (\gamma - 1)}{\gamma} - \frac{2 (1 - F_{\ell})(1 + B') \alpha (\gamma - 1)}{(1 - T_{W}/T_{1})\gamma} \right] (4.100)$$

$$\psi = s/R_{ref} \tag{4.101}$$

and

$$\alpha = \frac{1 - (p_3/p_1)}{\psi_3^2} \tag{4.102}$$

In the above formulation,  $R_{\text{ref}}$  is an arbitrary constant radius and  $\gamma$  is the isentropic exponent. The subscripts 1 and 3 denote the first and third integration point condition, respectively (e.g.,  $H_1$  is the shape factor at point 1).

The following implicit finite difference scheme is used for the rest of the integration points:

$$F_{x,I} = F_{x,I-1} + 0.5 (F'_{x,I-1} + F'_{x,I})(s_I - s_{I-1}) \times f_{,h}$$
 (4.103)

where:

$$F_f = r \rho_e u_e^2 e$$
 [see Equation (4.1)] (4.104)

$$F_h = r \rho_e u_e (h_{te} - h_w) \phi$$
 [see Equation (4.2)] (4.105)

$$F_{f}^{\dagger} = \frac{dF_{f}}{ds} \tag{4.106}$$

$$F_h' = \frac{dF_h}{ds} \tag{4.107}$$

I is the integration point index and  $F_f$  and  $F_h$  are both evaluated from Equations (4.1) and (4.2), respectively.

The solution is obtained by iteration since the values of  $F_{x,I}$  depend on  $F'_{x,I}$ . This iteration is local because closure is obtained at each integration point before proceeding down the body to the next integration point. Convergence is based on changes of less than 0.1 percent in both the heat and momentum transfer coefficients between successive iterations. If the iteration fails to converge in 30 tries, a local explicit solution is obtained by setting  $F'_{x,I} = F'_{x,I-1}$ , and subsequently reevaluating  $F'_{x,I}$  based on the resulting value of  $F_{x,I}$ . The algorithm then proceeds to the next integration point.

#### 4.3 GEOMETRIC ANALYSES

It is important to describe the geometry with high resolution because the boundary layer integration procedure often needs small step sizes and the surface metrics and normals must be known at each integration step. This surface fitting is accomplished in 3DMEIT by a parametric interpolation method which is described below (Reference 26).

The vehicle surface is separated into a number of basic elements, referred to as patches. Schematically, patches are defined as having four sides, but in some cases one of the sides will be at a single point. The parametric representation of a patch is given by:

$$\vec{r} = [x(u, w), y(u, w), z(u, w)] = \sum_{i=0}^{3} \sum_{j=0}^{3} \vec{a}_{ij} u^{i} w^{i}$$
 (4.108)

where  $0 \le u \le 1$ 

 $0 \le w \le 1$ 

Equation (4.108) transforms the surface of the patch into a unit square in (u - w) space. The advantage of the parametric interpolation scheme is that, once identified, the patches may be treated independently, and therefore, only a single patch is treated in detail in the following discussion.

The physical identity of the 48 coefficients,  $\bar{a}_{ij}$ , which must be found for each patch, can be described by rewriting Equation (4.108) in the following matrix form:

$$\hat{r} = U M \hat{B} M^{T} W^{T}$$
(4.109)

where the superscript, T, refers to the matrix transpose, and where U and W are the vectors  $(u^3, u^2, u, 1)$  and  $(w^3, w^2, w, 1)$ , respectively. In this case, the matrix, M is given by:

$$M = \begin{bmatrix} 2 & -2 & 1 & 1 \\ -3 & 3 & -2 & -1 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$
 (4.110)

The three matrices,  $\vec{B}$ , describe the input quantities, which are specified at the corner points of the patch.

$$B = \begin{bmatrix} \vec{r}(0,0) & \vec{r}(0,1) & \frac{\partial \vec{r}}{\partial w}(0,0) & \frac{\partial \vec{r}}{\partial w}(0,1) \\ \vec{r}(1,0) & \vec{r}(1,1) & \frac{\partial \vec{r}}{\partial w}(1,0) & \frac{\partial \vec{r}}{\partial w}(1,1) \\ \frac{\partial \vec{r}}{\partial u}(0,0) & \frac{\partial \vec{r}}{\partial u}(0,1) & \frac{\partial^2 \vec{r}}{\partial u \partial w}(0,0) & \frac{\partial^2 \vec{r}}{\partial u \partial w}(0,1) \\ \frac{\partial \vec{r}}{\partial u}(1,0) & \frac{\partial \vec{r}}{\partial u}(1,0) & \frac{\partial^2 \vec{r}}{\partial u \partial w}(1,0) & \frac{\partial^2 \vec{r}}{\partial u \partial w}(1,1) \end{bmatrix}$$
(4.111)

Calculating the elements of B for input can be extremely difficult. The first derivatives would require that the parametric form of the curve is explicitly known and cross derivatives would be even more difficult to calculate. Therefore, the 3DMEIT code uses another method which avoids inputing derivatives.

The 48 coefficients  $\vec{a}_{ij}$  in Equation (4.108) are computed in the code using the input locations of 16 points on each patch, which are usually much easier to generate than derivatives. The points are to be uniformly distributed over the patch surface as shown in Figure 4.3, so the input points will map into a uniform grid in the unit square in (u - w) space. Equation (4.109) can be rewritten in the following manner:

$$\hat{r} = U N \hat{P} N^{\mathsf{T}} W^{\mathsf{T}} \tag{4.112}$$

where

$$\vec{r}(0,0) \qquad \vec{r}(0,1/3) \qquad \vec{r}(0,2/3) \qquad \vec{r}(0,1) \\
\vec{r}(1/3,0) \qquad \vec{r}(1/3,1/3) \qquad \vec{r}(1/3,2/3) \qquad \vec{r}(1/3,1) \\
\vec{r}(2/3,0) \qquad \vec{r}(2/3,1/3) \qquad \vec{r}(2/3,2/3) \qquad \vec{r}(2/3,1) \\
\vec{r}(1,0) \qquad \vec{r}(1,1/3) \qquad \vec{r}(1,2/3) \qquad \vec{r}(1,1)$$
(4.113)

and

$$N = \begin{bmatrix} -9/2 & 27/2 & -27/2 & 9/2 \\ 9 & -45/2 & 18 & -9/2 \\ -11/2 & 9 & -9/2 & 1 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$
 (4.114)

Once the network of patch points has been developed, the code gives designation to the curves by requiring that the vector product  $a\vec{r}/au \times a\vec{r}/aw$  produces an outward surface normal.

Where the  $\vec{B}$  matrix input scheme guarantees continuity in slope from one patch to a connecting patch, the  $\vec{P}$  matrix cannot guarantee this. If slope continuity becomes noticeably absent, this is remedied within the 3DMEIT code by matching the unit vectors while retaining the original

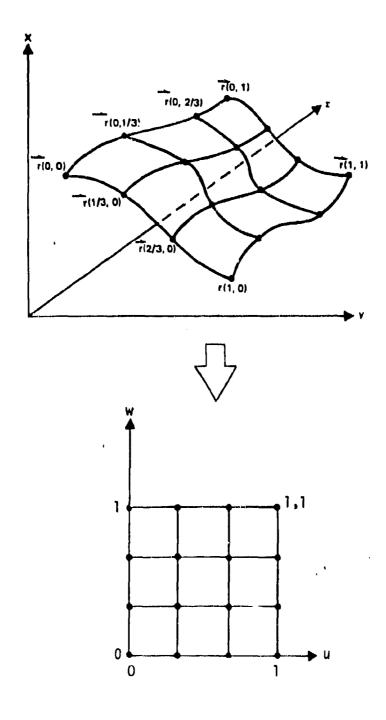


Figure 4.3. Patch Input Geometry

magnitudes. The  $\vec{B}$  matrix for the patch is obtained from the  $\vec{P}$  matrix by the following openation:

$$\vec{B} = M^{-1} N \vec{P} N^{T} (M^{-1})^{T}$$
 (4.115)

If the slopes in the u-direction at the adjacent corners of two patches do not match, continuity is assured by calculating the unit vector  $\hat{\mathbf{t}}$  of the slope at the corner of the first patch and recalculating the value of the new ar/au for the second patch. The new value of  $a\hat{\mathbf{r}}/au$  inserted in the  $\hat{\mathbf{B}}$  matrix for the second patch is given by:

$$\left(\frac{\partial \hat{r}}{\partial u}\right)_{\text{new}} = \left|\frac{\partial \hat{r}}{\partial u}\right|_{\text{old}} \hat{t} \tag{4.116}$$

The new B matrix is then used to determine the coefficients  $\hat{a}_{ij}$  for the patch. Thus, a procedure for generating a parametric interpolation surface from 16 uniformly spaced points has been established.

This procedure allows slope discontinuities to exist in the input data that define the corners of the patches. However, the internal calculations described above remove these slope discontinuities and facilitate reliable boundary layer calculations. This is necessary because boundary layer theory is not generally applicable to bodies with slope discontinuities.

The 3DMEIT computer code limits the number of patches on a vehicle to 60. A vehicle is set up in segments along the w direction. The maximum number of segments is 15. For each segment a maximum of 10 patches can be put around the body, but the overall limit of 60 patches must be observed. Therefore, when 15 segments have been used to describe the body, only four patches can be used around the body for each segment.

If the vehicle is a body of revolution, four points along a meridional curve can be input for each segment and they will be revolved about the axis to generate the required number of patches. Further automation of patch generation is available for spherical sections and certain maneuvering vehicle shapes (see Section 4.4, Input Table 3).

#### 4.4 USER INSTRUCTIONS

This user oriented section describes 3DMEIT inputs and outputs. A complete set of user instructions is presented in Section 4.4.1. The 3DMEIT output format, including variable descriptions, is presented in Section 4.4.2. Section 4.4.3 gives a sample problem and selected listings of input and output.

#### 4.4.1 INPUT INSTRUCTIONS

The details of the input are described below. The basic input for a run consists of:

- One title card
- Eight input tables

Not all eight of the input tables are required for every run. Each table is preceded by a single card containing the identifying table number.

The following sections describe the title card, and the eight input tables.

## Title Information

The first card contains title information in columns 1 through 80.

The contents of the card are printed at the beginning of the boundary layer solution.

The following table describes the format for the first card of the data deck.

Card No.	Columns	Format	Description	<u>Units</u>
1	1-80	8A10	BCD Title card information	(-)
		INPUT TA	BLE 1. GENERAL PROGRAM CONSTANTS	

This table supplies the code with program flags that indicate which options to be subsequently read and other computation information.

Card No.	Columns	Format		<u>Description</u>	Units
1	1-2	12	Enter	Ol (table number)	()
2	1-5	15	NF(12) 0 1	Plot output flag No plots Read Table 8 for plot instructions	(-)
	6~10	15	NF (13) 0 1 2	Output print flag Summary table only Boundary layer output for streamline points Boundary layer output for integration points	()
	11-15	15	IRG 0 1	Property flag Ideal gas properties Real gas properties	(-)
		15 le 04 uired	NF(5) 1 2 3 4 5	Transition criteria flag Laminar flow (Table 04 not required) Critical momentum thickness Reynolds number versus edge Mach number Critical stream length Reynolds versus edge Mach number Axial distance along each streamline Anderson nose criterion	(-)
		le not uired		$Re_{\theta} \left(\frac{k}{e} \frac{1}{\psi}\right)^{0.7} = \begin{cases} 255 \text{ for onset} \\ 215 \text{ for location} \end{cases}$ $\psi = T_{w}/T_{e}$ $LORN \text{ cone criterion}$	

INPUT TABLE 1. GENERAL PROGRAM CONSTANTS (Continued)

Card No.	Columns	Format		Description	Units
2 (cont.	`		6	Anderson nose criterion	
(COIIL.	,	•		$Re_{\theta} \left(\frac{k}{\theta} \frac{1}{\psi}\right)^{0.7} = \begin{cases} 255 \text{ for onset} \\ 215 \text{ for location} \end{cases}$	
		e not ired	{	$\psi = 0.18' + (0.9 + 0.11CARB)$	
				(1 + 0.25B')(pe/pw)	
				LORN cone criterion	
			7	Fully turbulent	
				Positive NREYCR transitional heating	
				Negative NREYCR no transitional heating (abrupt transition)	
	21-25	15	NF(6) O	Carbon flag in PANT transition criterion (NF(5) = 6) Uses 0.9 factor in $\psi$ calculation (recommended for carbon materials)	(-)
			1	Uses 1.0 factor in $\psi$ calculation	
	26-30	15	NF (35)  0  1 2 3	u-integration mesh density for aerodynamic coefficient calculations No aerodynamic coefficient calculation 4 point mesh density 8 point mesh density 16 point mesh density	(-)
-	31-35	15	NF(36) 0 1 2 3	w-integration mesh density for aerodynamic coefficient calculations No aerodynamic coefficient calculati 4 point mesh density 8 point mesh density 16 point mesh density	(-) on

INPUT TABLE 1. GENERAL PROGRAM CONSTANTS (Continued)

Card No.	Columns	Format		Description	<u>Units</u>
2 (cont.	) 3640	15	IENTRP 1 2 3 4	Entropy swallowing flag Normal shock entropy Inviscid wall entropy Streamtube entrainment option Local mass balance option	(-)
	41-45	15	ITWFLG -1 0	Wall temperature flag Wall temperature calculated Constant wall temperature input on next card Wall temperature distribution input in Table 6	(-)
	46-50	15	IBPFLG -1 0 1	Blowing flag B' calculated B' = 0 B' distribution input in Table 6	(-)
	51-55	15	JBLM O 1	Heat transfer blowing correction flag Use GE option Use Aerotherm option	()
3	1–10	F10.3	SCALF 1.0 0.08333	Scale factor for input configuration Input in feet Input in inches	1
	11-20	F10.3	TW	Wall temperature	(°R)
4			This can	rd is necessary only if NF(35) ≠ 0 36) ≠ 0	
	1–10	F10.4	DATAR(1)	Reference area for aerodynamic coefficient calculations	(input <sup>2</sup> units)
	11–20	F10.4	DATAR(2)	Reference length for aerodynamic coefficient calculations	(input units)
	21-30	F10.4	DATAR(3)	) x-coordinate of the center of gravity	(input units)

INPUT TABLE 1. GENERAL PROGRAM CONSTANTS (Concluded)

Card <u>No.</u>	Columns	Format	Description	Units
	31-40	F10.4	DATAR(4) y-coordinate of the center of gravity	(input units)
	41-50	F10.4	DATAR(5) z-coordinate of the center of gravity	(input units)

## INPUT TABLE 2. ENVIRONMENT TABLE

This table inputs environment conditions and the streamlines to be used for the boundary layer solution.

Card No.	Columns	Format		Data	<u>Units</u>
1	1-2	12	Enter 02	(table number)	(-)
2	1-10	F10.2	Т1	Freestream temperature	(°R)
	11-20	F10.2	P1	Freestream pressure	(atm)
	21-30	F10.2	V1	Velocity	(ft/s)
	31-40	F10.2	ALPHAB	Angle of attack	(deg)
	4150	110	NSTREM	Number of streamlines (≤ 50)	(-)
3	1-80	8F10.2	SANGLE (	N), N = 1, NSTREM, Circum- ferenial angles of the stream- lines at the sphere-cone tangency point (windward streamline = 180°)	(deg)

## INPUT TABLE 3. INITIAL CONFIGURATION

Card No.	Columns	Format		Description	Units
1	1-2	15	Enter 0	3 (table number)	(-)
2	1–10	F10.3	RN	Initial nose radius	(in.) or (ft)
	11-20	F10.3	THETC	Initial cone half angle	(deg)
	21-30	F10.3	воа	Height/span ratio 1.0 for circular cross section \$\neq\$ 1.0 for elliptical cross section	
	31-40	F10.3	ZN	Distance from apex of afterbody to nosetip	(in.) or (ft)
	4145	15	NUMNOS	Number of segments on the spherical section of the nosetip	()
	46-50	15	NOSFLG	Nosetip generation flag  O Each segment on nosetip must be individually input  1 Code automatically sets up NUMNOS spherical segments on the nose	(-)
3	1-32	1612	NC arra	у	(-)
			NC(1)	Total number of segments ( $\leq 15$ )	
			NC(I),	I = 2, NC(1) input mode for each segment $1 \le NC \le 5$	
			each se	LG = 1, values must be input for gment but the code will ignore or segments 2 through NUMNOS	
4	1-30	1512	NPATCH(	I) I = 1, 15 number of patches around the body on segment I (user should input a constant number at this stage in code development)	(-)

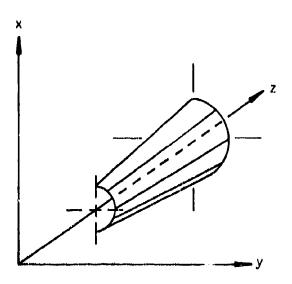
## INPUT TABLE 3. INITIAL CONFIGURATION (Continued)

The optional input modes for the segments are described below. The data for each segment must be ordered to match the mode selection arrangement specified in the NC array. The modes can be separated into three options. For Option 1 (NC  $\leq$  3), a single meridian curve r(z) is described and the code automatically generates NPATCH patches to cover  $180^{\circ}$  circumferentially as shown in Figure 4.4. Option 2 is used to input completely arbitrary patches as also shown in Figure 4.4. Option 3 is used to describe the afterbody of a vehicle with flat sections and cut sections as illustrated in Figure 4.5. The input formats for each of these options are as follows:

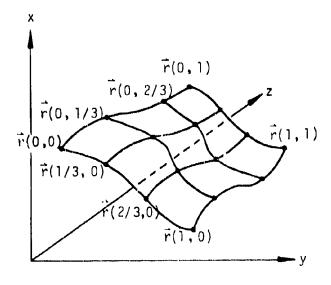
Input Table 3(a). Option 1

NC(I) 1	Format 4F7.3	Description  Conical frustum, imput z <sub>1</sub> , r <sub>1</sub> , z <sub>2</sub> , r <sub>2</sub>	$r_2$ $r_1$ $r_2$ $r_2$ $r_2$ $r_3$
2	5F7.3	Circular arc input $z_1$ , $r_1$ , $z_2$ , $r_2$ , $\theta$ 2  If NOSFLG = 0, each segment cannot turn more than $45^\circ$	$z_1$ $z_2$
3	8F7.3	Arbitrary curve input z <sub>1</sub> , r <sub>1</sub> , z <sub>2</sub> , r <sub>2</sub> , z <sub>3</sub> , r <sub>3</sub> , z <sub>4</sub> , r <sub>4</sub> Note: an attempt should be made to distribute evenly the four points along the	

curve segment

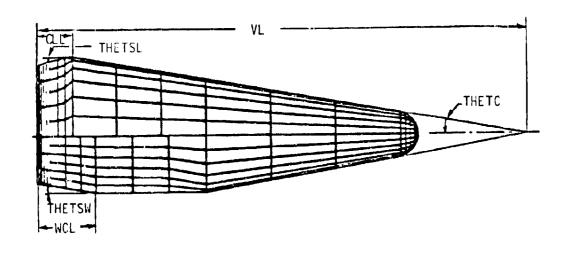


(a) Patch Rotation for Option 1



(b) Patch Description for Option 2

Figure 4.4. Illustrations of Geometry Descriptions



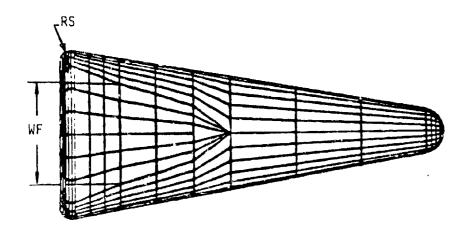


Figure 4.5. Geometry Descriptions for Option 3

## INPUT TABLE 3. INITIAL CONFIGURATION (Continued)

Table 3(b). Option 2: NC(I) = 4

Each patch requires six data cards which are ordered as follows:

Card No.	Format	Description
1	8F9.5	x(0, 0), x(0, 1/3), x(0, 2/3), x(0, 1), x(1/3, 0), x(1/3, 1/3), x(1/3, 2/3), x(1/3, 1)
2	8F <b>9.</b> 5	x(2/3, 0), x(2/3, 1/3), x(2/3, 2/3), x(2/3, 1), x(1, 0), x(1, 1/3), x(1, 2/3), x(1, 1)
3	8F9.5	y(0,0), $y(0, 1/3)$ , $y(0, 2/3)$ , $y(0, 1)$ , $y(1/3, 0)$ , $y(1/3, 1/3)$ , $y(1/3, 2/3)$ , $y(1/3, 1)$
4	8F9.5	y(2/3, 0), y(2/3, 1/3), y(2/3, 2/3), y(2/3, 1), y(1, 0), y(1, 1/3), y(1, 2/3), y(1, 1)
5	8F9.5	z(0,0), $z(0, 1/3)$ , $z(0, 2/3)$ , $z(0, 1)$ , $z(1/3, 0)$ , $z(1/3, 1/3)$ , $z(1/3, 2/3)$ , $z(1/3, 1)$
6	8F <b>9.</b> 5	z(2/3, 0), z(2/3, 1/3), z(2/3, 2/3), z(2/3, 1), z(1, 0), z(1, 1/3), z(1, 2/3), z(1, 1)

Input Table 3(a). Option 3: NC(I) = 5

Columns	Format		Units	
1-7	E7.3	THETAC	Cone half angle	(deg)
8–14	E7.3	VL	Virtual length of the vehicle measured from the apex of the afterbody cone	(in.) or (ft)
15-21	E7.3	WCL	Distance from the end of the body to the windwa: d cut	(in.) or (ft)
22-28	E7.3	WF	Width of the flat	(in.) or (ft)

INPUT TABLE 3. INITIAL CONFIGURATION (Continued)

Columns	Format		Description		
29-35	E7.3	THETWS	Angle of the windward cut	(deg)	
36-42	E7.3	CLL	Distance from the end of the body to the leeward cut	(in.) or (ft)	
43-49	E7.3	THETSL	Angle of the leeward cut	(deg)	
50-56	E7.3	RS	Radius of curvature for the rounded corner of the base	(in.) or (ft)	
57–63	E7.3	BASXP	Exponent describing the cross sectional shape of the base = 2.0 for circular # 2.0 for "super circle"	(-)	
64-65		Not used			
66–70	15	KSTART	Patch number where the interpolation between an exponent of 2 and BASXP begins	(-)	
71–75	15	IFLAT	Flat flag O No flat surface 1 Flat surface on windward side determined by WF	(-)	

The next group of cards control the patch setup to be used to print the boundary layer and surface energy balance results. This option is for future use of 3DMEIT as part of a procedure for predicting shape change. It spline fits a group of patches in a least squares sense and then redefines the coordinates of the body segment patches. It is not operative in the present version of 3DMEIT, but users are advised to enter 1's in all fields to prevent execution errors in the input routines.

Card No.	Columns	Format	Description	Units
4 + NC(1) + 1	1-30	1512	NDISC(I) I = 1, 15 The number of w stations per spline group to be used in the recession analysis	

# INPUT TABLE 3. INITIAL CONFIGURATION (Concluded)

Card No.	Columns	Format	De	scription	Units
	31-60	1512	NDISC(I) I	= 16, 30 The number of body segments per spline group. Up to 15.	(-)
			Note: it is suggested that the entire nosetip (spherical section) be included in one group and the afterbody in another		
	61-62	12	NDISC(31)	Number of groups describing the body	(-)
4 + NC(1) + 2	1-3	13	NTBZ	Number of w locations where boundary layer and surface energy balance results are saved (30 maximum)	(-)
	4-6	13	NTBU	Number of u locations where boundary layer and surface energy balance results are saved (10 maximum)	(-)
4 + NC(1) + 3	1-80	8F10.4	TBZ(I) I =	1, NTBZ w locations where boundary layer and surface energy balance results are saved	(-)
4 + NC(1) + 4 → n	1-80	8F10.4	Continue T	BZ array	()
n + 1	1-80	8F10.4	TBU(I) I =	1, NTBU u locations where boundary layer and surface energy balance results are saved	(-)
n + 2 > m	1-80	8F10.4	Continue T	BU array input	()
m + 1	1-30	3011	IMAT(I, J)	<pre>I = 1, NTBZ Surface material flag for shape change points</pre>	(-)
m + 2 → &			Continue f	or J = 2, NTBU	(-)

### INPUT TABLE 4. TRANSITION TABLE

Enter this table only when NF(5) = 2, 3 or 4. Maximum of 50 entries are allowed in this table.

1. Input for  $Re_{e}$  versus  $M_{e}$ , NF(5) = 2

Card No.	Columns	Format		Description	Units
1	1- 2	12	Ente	r 04 (table number)	(-)
2	1- 2	12		ero entry for the last card he table	(-)
	314	E12.5	AM	Local edge Mach No. (M <sub>e</sub> )	(-)
	15-26	E1.5	REM	Critical momentum thickness Reynolds number (Re <sub>e</sub> )	(-)
3	Same as	Card 2 for	incr	easing M <sub>e</sub>	
(etc.)					

### 2. Input for Re<sub>s</sub> versus $M_e$ , NF(5) = 3

Card No.	Columns	Format		Description	Units
1	1- 2	12	Ente	er 04 (table number)	(-)
2	1- 2	12		ero entry for the last card he table	(~)
	3–14	E12.5	AM	Local edge Mach No. (M <sub>e</sub> )	(-)
	1526	E1.5	REM	Critical stream-length Reynolds number (Re <sub>s</sub> )	(-)
3	Same as	Card 2 for	·incr	reasing M <sub>e</sub>	
(etc.)					

### 3. Input for Transition Location, NF(5) = 4

Card No.	Columns	Format	Description	<u>Units</u>
1	1- 2	12	Enter 04 (table number)	(-)
2	1- 2	12	Nonzero entry for the last card in the table	(-)
	3-14	E12.5	AM Axial location of transition along each streamline specified in Table 2	(in.)

### INPUT TABLE 5. MATERIAL PROPERTIES

Maximum of three material inputs are allowed in this table. Each material input is treated according to the following format.

Card No.	Columns	Format		Description	Units
1	1- 2	12	Enter O	5 (table number)	(-)
2	1- 5	15	MAT	Material index for following table	g (-)
	6–10	15	JROUGH	Laminar heating augmentation flag O No augmentation 1 Transition proximity augmentation	n (-)
3	1- 2		Blank		
	3–14	E12.5	RUFL	Intrinsic roughness height; nonuniform roughness may be input in Table 6	(mil)
	15-26	E12.5	RUFMAX	Maximum turbulent roughness height (k <sub>tmax</sub> )	(mil)
	27-38	E12.5	RUF1	>O White-Grabow scallop law is used:	(mil-psi <sup>0.77</sup> ) = RUFMAX hness of
	39-50	E12.5	EMISS	Emissivity	(-)
	51-62	E12.5	СМН	Ratio of mass to heat transfer coefficients	(-)

### INPUT TABLE 5. MATERIAL PROPERTIES (Concluded)

### Parameters in Blowing Correction to Transfer Coefficients

Card No.	Columns	Format		Description	Default <u>Values</u>	Units
4	1- 2	12	NC	Flag, zero		(-)
	3–14	E12.5	BLS	Laminar shear parameter	0.5	(-)
	15-26	E12.5	BLH	Laminar heating parameter	0.5	(-)
	27-38	E12.5	BTS	Turbulent shear parameter	0.35	(-)
	39-50	E12.5	втн	Turbulent heating parameter	0.35	(-)

If zero is entered, default values are used.

### INPUT TABLE 6. SURFACE DATA

The 3DMEIT code includes approximate techniques to predict surface temperature and blowing rate distributions of ablating surfaces. The user, however, may bypass these computations and enter the desired surface temperature or blowing rate distributions via this table. A nonuniform surface roughness distribution may also be input in this table. Entries for each variable are described in the following subsections. Any combination of one or three subsections can be input.

Card No.	Columns	Format	Description	<u>Units</u>
1	1-2	15	Enter 06 (table number)	(-)
2	1-5	15	ITABL Enter 1 (temperature table)	(-)
3	1-80	SF10.5	Surface temperature for NTBZ w points	(OR)
4	1-80	8F10.5	Same as above for each of NTBU u values	(OR)
m	1-5	15	ITABL Enter 2 (blowing rate table)	
m <b>+1</b>	1-80	8F10.5	Blowing rate (B') = $\rho_W v_W / \rho_e u_e C_m$ for each NTBZ w values	(-)
m+2	1-80	8F10.5	Same as above for each NTBU u value	(-)
n	1-5	15	ITABL Enter 3 (surface roughness)	
n+1	1-80	8F10.5	Surface roughness for NTBZ w points	(mil)
n+2	180	8F10.5	Same as above for each of NTBW w values	(mil)
Last card	1-5	15	ITABL < 0 signifies end of Table 6	(-)

### INPUT TABLE 7. INVISCID DATA

The 3DMEIT code reads inviscid data from tape 23 and stores the needed edge conditions and integrated mass fluxes on tape 22. If a calculation is to be done using the same inviscid data as a previous calculation, one may use the stored values on tape 22 and avoid the cost of integrating the velocity fields and calculating the metrics.

No. Columns For		Format	ormat Description				
1	1- 5	15	IRSTRT	Inviscid data input flag O Read inviscid data from tape 23 1 Read previously defined mass fluxes and metrics from tape 22	(-)		

For IRSTRT = 0, the format on tape 23 is given in the following table:

Card No.	Columns	Format		Description	Units
1	1-13	E13.6	AMINF	Freestream Mach number	(-)
	14-26	E13.6	ALPHA	Angle of attack	(deg)
	27-29	13	MDAT	Number of steamlines	(-)
	30-32	13	NDAT	Number of points through the shock layer	(-)
2	1-13	E13.6	ZDAT	Axial location	(in.)
3 → 3 + MDAT					
	1–13	E13.6	PHDAT	Circumferential angle	(rad)
•	14-26	E13.6	RB	Body radius	(in.)
	27-39	E13.6	RBZ	ar <sub>B</sub> /aZ	(-)

INPUT TABLE 7. INVISCID DATA (Concluded)

Card No.	Columns	Format		Descriptio	<u>n</u>	Units
<b>3 → 3</b>	+ MDAT (co	ont.)				
	40-52	E13.6	RBTH	arg/se		(in.)
	53-65	E13.6	OME GA	tan <sup>-1</sup> (u <sub>6</sub> /u surface	<sub>Z</sub> ) on the	(rad)
	66-78	E13.6	SF	Stream fun	ction	(-)
4 > 4	+ (NDAT *	MDAT)				
	1-13	E13.6	PF	Flowfield	pressure	
				p/p <sub>∞</sub>	IRG = 0	(-)
				p	IRG = 1	(1b <sub>f</sub> /ft <sup>2</sup> )
	14-26	E13.6	T	Temperatur T/T <sub>co</sub>	e IRG = 0 IRG = 1	(-) (°R)
	27-39	E13.6	VR	Radial vel	ocity component	
				$u_r \sqrt{p_{\infty}/p_{\infty}}$	IRG = O	(-)
				ur	IRG = 1	(ft/s)
	40-52	E13.6	۷P	component	ntial velocity	
				u p p r w	IRG = 0 IRG=1	(-) (ft/s)
	53-65	E13.6	٧Z	Axial velo	city component	
				$\frac{u}{u_z} \sqrt{\frac{p_{\infty}}{p_{\infty}}}$	IRG = 0 IRG = 1	(-) (ft/s)
	66-78	E13.6	YR	Distance f	rom body	(in.)

Card sets 2, 3, 4 are repeated for each axial station.

INPUT TABLE 8. PLOT DATA

Card No.	Format	Description	<u>Units</u>
1	15	Enter 08 (table number)	(-)
2	F7.3 F7.3 F7.3 F7.3 F7.3	YL Minimum value of y on the vehicle YR Maximum value of y on the vehicle XB Minimum value of x on the vehicle XT Maximum value of x on the vehicle ZN Minimum value of z on the vehicle ZB Maximum value of z on the vehicle	(ft or in.)
		Note: these six dimensions should form a box completely enclosing the vehicle to aid the system in scaling the plot	
	12 12	NU Number of u-increments to be taken $\leq 10$ NW Number of w-increments to be taken $\leq 10$	(-)
	12	NPLOT Number of views at a given time	()
	12	NI =   O draws complete grid  1 draws only patch boundaries  2 draws profile	(-)
3	F7.3	XBETA View orientation angle defined in Figure 4.6	(deg)
	F7.3	XTHETA View orientation angle defined in Figure 4.6	(deg)
4 <b>→</b> n		Same as card number 3 for NPLOT views	

### End of Input

The end of the input deck is signaled by a single card with a -1 punched in columns 1 and 2.

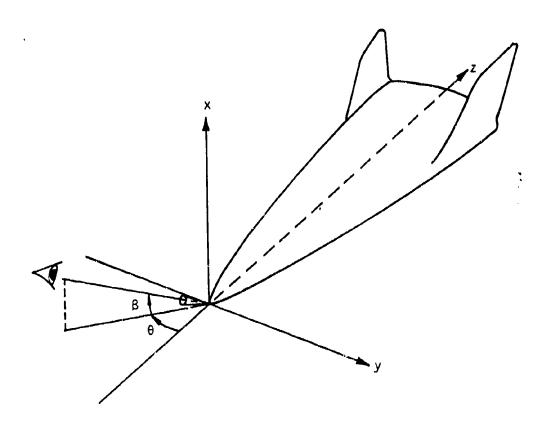


Figure 4.6. View Orientation Angles

### 4.4.2 OUTPUT DESCRIPTION

This section describes the 3DMEIT code output. There are two classes of output from the 3DMEIT code:

- 1. Printout of the input data
- 2. Calculation (results) output

These are described in the following sections.

### 4.4.2.1 Printout of Input Data

Program output begins with a complete printout of the contents of input Tables 1 through 7. Most of this output is fully labeled and is printed exactly as input by the user.

### 4.4.2.2 <u>Calculation Output</u>

The results of the calculation are output in one of three formats.

All three output formats include up to five separate groups of information.

These groups are (1) environment information, (2) fluid properties,

(3) boundary layer results, (4) body geometry and surface quantities

results, and (5) aerodynamic coefficients. The output formats differ in the degree of detail of the boundary layer results. Also, the aerodynamic coefficients are only printed if NF(35) and NF(36) are nonzero. The following sections describe the variables printed in each of the output groups.

### **ENVIRONMENT INFORMATION**

- ENVIRONMENT NUMBER
- DESCRIPTIVE HEADING: input on title card
- MACH NO: current freestream Mach number
- VELOCITY: current freestream velocity (ft/s)
- ANGLE OF ATTACK: current angle of attack (deg)
- UNIT RE NO: current value of freestream unit Reynolds number (per ft)

### LUID PROPERTIES

The following results are printed for the freestream conditions, the conditions behind the normal shock, and the stagnation point conditions:

- PRESSURE (atm)
- TEMPERATURE (OR)
- DENSITY (1bm/ft<sup>3</sup>)
- ENTHALPY (Btu/lbm)
- ENTROPY (Btu/1bm OR)
- ISENTROPIC EXPONENT

### BOUNDARY LAYER RESULTS

The summary output (NF(13) = 0) includes only the first of the following sets of information. The rest of the tables are printed for each streamline at either the streamline points (NF(13) = 1) or, in more detail, at the boundary layer integration points (NF(13) = 2).

### Boundary Layer Summary

- STREAMLINE NO: streamline number
- BETA, deg: initial direction of the streamline from the stagnation point
- SONIC POINT LOCATION, in.: streamlength from the stagnation point to the sonic point, and the Cartesian coordinates
- TRANSITION POINT LOCATION, in.: streamlength from the stagnation point to the transition point, and the Cartesian coordinates
- POINT NO: streamline point number or boundary layer integration point number

- STREAMLINE LOCATION, in. and deg: z-coordinate (measured from initial z-location of the nosetip) and PHI -- the angular location on the body (measured from the positive x-axis in the cross sectional plane)
- METRIC COEFFICIENT, in.: metric coefficient for the streamline coordinate system
- BODY ANGLE, deg: angle that a line tangent to the surface and
  perpendicular to the normal makes with the wind vector
- EDGE PRESSURE, atm: pressure at the edge of the boundary layer
- WALL TEMPERATURE, OR: temperature at the wall
- B--PRIME THERMOCHEM: dimensionless blowing parameter,  $B' \equiv (\rho v)_W/M \text{ due to ablation only, where } M \text{ is the mass}$  transfer coefficient
- RECOVERY ENTHALPY, Btu/lbm:  $h_r = h_e + r (h_t h_e)$ where  $h_t$  is the total enthalpy,  $h_e$  is the edge enthalpy, and r is the recovery factor
- HEAT TRANS COEFFICIENT,  $1bm/ft^2-s$ :  $H = \rho_e u_e^C h = \frac{q_w}{h_r h_w}$ , where  $C_h$  is the Stanton number and  $\dot{q}_w$  is the surface heat flux

### Viscous Flow -- Wall and Boundary Layer Recovery Properties

- BODY PT NO (J): index of the body points
- INTEG PT NO (I): index of the integration point for which the computed parameters are printed
- WALL TEMPERATURE, OR (TW): temperature of the wall
- WALL ENTHALPY, Btu/lbm (HW): enthalpy of the flow at the wall temperature
- WALL DENSITY, 1bm/ft<sup>3</sup> (ROW): density of the flow at the wall temperature

- WALL VISCOSITY, 1bm/ft-s (VISW): viscosity at the wall
- RECOVERY ENTHALPY, Btu/lbm (HR): recovery enthalpy,  $h_r = h_e + r(h_t - h_e)$
- RECOVERY FACTOR (HECOV): recovery factor, r
- SENSBL CONV HEAT FLUX, Btu/ft<sup>2</sup>-s
- CF/2: skin friction coefficient divided by two,  $C_f/2 = \tau_w/\rho_e u_e^2$
- B-PRIME THERMOCHEM: dimensionless blowing parameter, B'  $\equiv$   $(_{P}v)_{W}/M$  due to ablation only, where M is the mass transfer coefficient
- RECOVERY ENTHALPY, Btu/lbm:  $h_r = h_e + r (h_t h_e)$  where  $h_t$  is the total enthalpy,  $h_e$  is the edge enthalpy, and r is the recovery factor
- HEAT TRANS COEFFICIENT,  $1bm/ft^2-s$ :  $H = \rho_e u_e C_h = \frac{q_w}{h_r h_w}$ , where  $C_h$  is the Stanton number and  $\dot{q}_w$  is the surface heat flux Viscous Flow -- Edge Properties Table
  - BODY PT NO (J): index of the body parts
  - INTEG PT NO (I): index of the integration point for which the computed parameters are printed
  - STREAM LENGTH, in. (S): stream length along the nosetip surface from the stagnation point to the integration points
  - VELOCITY, ft/s (UE): velocity at the edge of the boundary layer
  - MACH NO (HCAM): Mach number at the edge of the boundary layer
  - ENTHALPY, Btu/lbm (HE): enthalpy at the edge of the boundary
     layer

- TEMPERATURE, OR (TE): temperature at the edge of the boundary layer
- DENSITY, 1bm/ft<sup>3</sup> (ROE): density at the edge of the boundary layer
- VISCOSITY, 1bm/ft-s (VISE): viscosity at the edge of the boundary layer
- UNIT RE NO, 1/ft (URE): unit Reynolds number at the edge of the boundary layer

### Viscous Flow -- Boundary Layer Solution Table

- BODY PT NO (J): index of the body points
- INTEG PT NO (I): index of the integration point for which the computed parameters are printed
- STREAM LENGTH, in. (S): stream length along the nosetip surface from the stagnation point to the integration points
- MOMENTUM THICKNESS, mil (THE): momentum thickness θ of the boundary layer

$$e = \int_{0}^{\delta} \frac{\rho u}{\rho_{e} u_{e}} \left( 1 - \frac{u}{u_{e}} \right) dy$$

where  $\delta$  is the momentum boundary layer thickness and y is the radial distance from the centerline. For a more general definition of  $\theta$  (also  $\phi$  and  $\delta$ \*) see Reference 1).

 ENERGY THICKNESS, mil (PHI): energy thickness ø of the boundary layer

$$\theta = \int_{0}^{\delta \phi} \frac{\rho u}{\rho_{e} u_{e}} \left( \frac{h_{te} - h_{t}}{h_{te} - h_{w}} \right) dy$$

where  $\mathbf{h}_{t}$  is the total enthalpy and  $\boldsymbol{\epsilon}_{p}$  is thickness of the energy boundary layer

- SHAPE FACTOR (HSF): boundary layer shape factor, H = 6\*/e
- MOM THICK RE NO (RETH): Reynolds number based on the momentum thickness

$$Re_{\theta} = \frac{\rho_{\theta}^{u} e^{\theta}}{\mu_{\theta}}$$

 ENERGY THICK RE NO (REPH): Reynolds number based on the energy thickness,

$$Re_{\phi} = \frac{\rho_{e} u_{e} \phi}{u_{e}}$$

- HEAT TRANS COEFFICIENT,  $1bm/ft^2s$  (RUCH): heat transfer coefficient,  $H = \rho_e u_e C_h = \dot{q}_w/(h_r h_w)$  where  $C_h$  is the Stanton number and  $\dot{q}_w$  is the wall heat flux
- REYNOLDS ANAL FAC (RAF): Reynolds analogy factor  $C_h/(1/2)C_f,$  where  $C_f/2=\tau_w/(\rho_e u_e^2)$  is the friction factor and  $\tau_w$  is the wall shear
- INTERMITTENCY (ADML): boundary layer intermittency factor f, where  $0 \le f \le 1$  for flow ranging from fully laminar to fully turbulent regime
- TRANSITION PARAMETER: Anderson nosetip transition parameter,

TP = Re<sub>e</sub> 
$$\left(\frac{k}{9}, \frac{1}{4}\right)^{0.7}$$

where  $\Psi = 0.1 \text{ B'} + 0.9 (1 + 0.25 \text{ B'}) \rho_e/\rho_W$ 

### Viscous Flow -- Curved Shock and Roughness Effects Table

- BODY PT NO (J): index of the body points
- INTEG PT NO (L): index of the integration point for which the computer parameters are printed
- STREAM LENGTH, in. (S): stream length along the nosetip surface from the stagnation point to the integration points
- EDGE ENTROPY, Btu/1bm OR (ENTR): entropy at the edge of the boundary layer
- EDGE STREAMLINE LOCATION AT SHOCK, in. (YBAR): radial coordinate of the point of intersection of the boundary layer edge streamline with shock wave
- EDGE MASS FLUX AUGMENTATION (ROUE): ratio of the boundary layer edge mass flux, Peue to that for a normal shock
- ROUGHNESS, mil (RUF): surface effective sand grain roughness height
- HEAT TRANSFER AUGMENTATION (RUFSMT): augmentation of the heat transfer coefficient due to:
  - -- transition proximity for the laminar portion, and
  - -- surface roughness effects for the turbulent portion of the boundary layer

### BODY GEOMETRY AND BOUNDARY LAYER RESULTS

This table includes information for all of the u and w locations where the information is saved (TBU and TBZ arrays, see Table 3, input).

 STAGNATION POINT LOCATION: Cartesian coordinates and the normalized surface coordinates of the stagnation point

- MINIMUM Z-COORD LOCATION: Cartesian coordinates and the normalized surface coordinates of the point with the minimum z-coordinate
- SURFACE COORDINATES: non-normalized u and w locations of the points
- CARTESIAN COORDINATES: Cartesian coordinates of the points
- RECOVERY ENTHALPY (same as boundary layer output)
- SURFACE PRESSURE (same as edge pressure in boundary layer)
- HEAT TRANS COEFFICIENT (same as boundary layer output)
- INDUCED PRESSURE: pressure calculated using the boundary displacement thickness (atm)
- SKIN FRICTION: skin friction coefficient,  $C_f/2$
- B-PRIME THERMOCHEM (same as boundary layer output)
- SURFACE TEMPERATURE (same as boundary layer output)

### AERODYNAMIC COEFFICIENTS

This table is printed if the aerodynamic coefficients are calculated (NF(35)  $\neq$  0 and NF(36)  $\neq$  0). The output includes the lift-to-drag ratio, the center of pressure, and the x, y, and z components of: (1) drag, (2) lift, (3) total force, (4) inviscid force, (5) viscous forces (induced pressure and shear), (6) total moment, (7) inviscid moment, and (8) viscous moments.

### 4.4.3 SAMPLE PROBLEM

This section presents input listings and selected output page listings for the flight test case. The complete output is shown for the windward and leeward streamlines, while only the first output table is shown for the remaining streamlines.

```
FLIGHT CALCULATION MACH-16.2
                                   ALPHA=5.0 LU.4/6.0 BICONIC W/ YAW STAU.
         GENERAL CONSTANTS
01
                                     Ź
              1
                    6
                                                           ú
 0.08333
              560.
              W1 . 86
                         0.0
                                     0.0
 415.48
                                               41.0
02
         ENVIRONMENT TABLE
 389.87
          0.074868
                        15609.
                                      5.0
                                                     22
                                                     177.8885
                                            174.2586
                                                                            177.2605
180.0
          179.7351
                      179.1497
                                 178.6070
                                                                  177.6026
176.8858
          176.4636
                     176.0602
                                 175.0483
                                            173.4933
                                                       160.
                                                                  130.
                                                                             110.
          70.
                      50.
                                 30.
90.
                                            10.
                                                       0.0
         GEOMETRY TABLE
03
              10.4
  0.92
                         1.0
                                   4.1764
                                                2
                                                      1
 522114
 4 4 4 4
 4.1764
            0.0 4.9303 0.9049
                                 10.4
 4.9303 0.904931.3304 5.7502
31.3304 5.750280.286410.8957
          11.0971
                                11.5000
                                          10.7331
                                                              11.1300
                                                                       11.2384
10.8957
                     11.2986
                                                    10.9315
                                                                        9.9862
10.2502
          10.4397
                      10.6243
                                10.8187
                                           9.4614
                                                     9.6363
                                                               9.4113
 0.0
           0.0
                       0.0
                                0.0
                                           1.8752
                                                     1.9044
                                                               1.9446
                                                                        1.9772
 3.6945
                                 3.6994
                                                    5.5034
                                                               5.6033
           3.7620
                       3.8311
                                           5.4614
                                                                        5.7012
80.2864
          82.2031
                      84.1147
                                H6.0364
                                          80.2864
                                                    82.2031
                                                              84.1197
                                                                       H6.0364
          82.2031
                                86. 0364
                                          80.2864
                                                    82.2031
                                                              84.1147
                                                                       H6.0364
80.2864
                      84.1197
 9.4614
            9.6363
                       4.6113
                                 4. 4862
                                           7.9372
                                                     8.0788
                                                              8.2255
                                                                        H. 3721
                                                                         4.2500
            6.1152
                                                               4. 2500
 6.0042
                       6.2262
                                 6.3372
                                           4.2500
                                                     4.2500
                                                              7.7450
                                                                        7.4440
 5.4035
           5.5034
                       9.6033
                                 5.7032
                                           7.4697
                                                     7.6078
                                                              10.5669
 4.0921
            9.2601
                       9.4203
                                 9.5963
                                          10.1349
                                                    10.3511
                                                                       10./419
                                80. 0364
                                          80.2864
                                                    82.2031
                                                              84.1197
                                                                       86.0364
80.2864
          82.2031
                      84.1197
                                                                       86.0364
80.2864
          82.2031
                      84.1147
                                86.0364
                                          80.2864
                                                    82.2031
                                                              84.1197
                                           4.2500
                                                     4.2500
                                                                         4.2500
                                                               4.2500
 4.2500
            4.2500
                       4.2500
                                 4.2500
                                                               4.2500
                                                                         4.2500
 4.2500
            4.2500
                       4.2500
                                 4.2500
                                           4.2500
                                                     4.2500
          10.3511
                      10.5669
                                10.7819
                                                              10.7257
                                                                        11.0174
                                          10.1349
                                                    10.4304
10.1349
10.1349
           10.5106
                      10.8846
                                11.2568
                                          10.1349
                                                    10.5404
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### 3-D MIMENTUM ENTRGY INTEGRAL TECHNIZUE

### FLIGHT CALCULATION NACH-16.2 ALPHA-5.0 10.4/6.0 BICENIC W/ YAW STAR.

### --- GENERAL PHIIGRAM FLAGS ---

PLOT OUTPUT FLAG	NF(12) = 0
PRINT OUTPUT FLAG	NF (1 *) - 1
TRANSITION CRITERIA FLAG	, AF (5) = A
CARBUN TRANS. CRIT. FLAG	NI (6) = 0
GAS PROPERTY FLAG	18G = 1
ENTROPY SWALLOWING FLAG	IFNTRP = 4
BLOWING CORRECTION FLAG	JBLM . U

SCALE FACTOR 0.0M33
INITIAL WALL TEMPERATURE (DFG R) 960.0000

## 3-D MIMENTUM ENFROY INTEGRAL TECHNIQUE

## --- GENERAL FNVIRONMENT ---

					176.46	00.05	
¥14.	(nfc)	5.00			176.89	50.00	
•	_				117.26	70.00	
VEL UCIIT	(Sd £)	15609.00			177.60	00.06	
7.4.4.0 Kn	INEG P1	7.87	22		177.49	110.00	
	=	38.	NUMBER OF STREAMLINES -		178.76	130.00	
ととうへいい	(ATM)	0.075	JHBER OF S		18.61	160.00	
2			ž	ANGLES ARE	179.19	173.49	
				<b>SUENTIFYING</b>	1 79.74	175.05 173.49	0.0
				STREAMLINE	180.00	176.06	10.00

## 3-D MIMENIUM FIN'HGY INTEGRAL TECHNIQUE

### --- ROOY GERMETRY ---

NC ( 11 =

8/A . 1.000

	7 d N	NPATCH (I #=	+ + + +						
7	ZRT(8) = 0.417640+01 0.0	101 0.0	0.493030+01	0.493030+01 0.904900+00 0.104000+02 0.0	0.104000+02		0.0	ū.0	
7	ZATEB) = 0.49303D+CE 0.90490D+OU 0.31330D+	00+004400+00	0.313300+02	0.0 10.02020.00 0.0	0.0	0.0	6.0	0.0	
~	ZRT(8) = 0.313300+02 0.575020+01 0.802860+	102 0.575020+01	0.602860+02	.02 0.10896D+02 U.O		0.0	0.0	0.0	
PA TCH	PATCH NUMBER 1								
0.0	0.0 0.210+000.410+000.590+000.0 0.200+ 0.0 0.0 0.0 0.0 0.0 0.0 0.550- 0.420+010.420+010.430+010.440+010.420+010.420+	0.210+000.410+000.590+000.0 0.0 0.0 0.0 0.420+010.430+610.440+010.420		0,200+000,400+000,570+000.0 0,550-010,110+000,150+000.0 0,420+010,430+010,440+010,4	1+010•0 0 1+000•0 0 1+010•450+010	0.18D+000.3AN+000.51N+000.0 0.11D+000.2I0+00\.7P+000.0 0.42N+010.43B+010.44N+010+4	+000_518+00 +000,298+00 +010_448+01	0°0 0°0 0°1 0°4 0°4 0°4	000_40D+000.57D+000.0 0.18D+000.3&D+000.51D+000.0 0.15P+000.7PD+000.17D+000.47D+000.45D+000.0 0.15P+000.7PD+000.47D+000.0 0.15P+000.7PD+000.47D+000.0 0.15P+000.7PD+000.47D+000.0 0.15P+000.7PD+000.47D+000.0 0.15P+000.7PD+000.47D+000.0 0.15P+000.7PD+000.47
PATCH	PATCH NUMBER 2								
0.0 0.0 0.420	0.0 0.150+000.290+000.420+009.0 0.110+ 0.0 0.150+000.290+000.420+000.0 0.140+ 0.420+010.420+010.430+010.440+010.420+010.420+	0.150+000.290+000.420+009.0 0.150+000.290+000.420+000.0 0.420+010.430+010.440+010.420		.c0c.210+cuc.290+cuc.0 .cuc.3+co+coc.510+coc.0 .010.430+010.440+010.4	)+000.0 )+000.0 )+010.420+010	0.558-010.1184J30.158+0A0.0 0.208+000.4 JR+OPA.578+0B0.0 0.428+B10.438+J10.4(8+J19.4)	+J3G -   5D +GD +DOM - 5719+GB +J1G - 44D+J1	0.0 0.0 0.420+01	00G.210+Guo.290+60uG.0 0.550-010.110+J3G.150+000.0 0.7RP-JAG.550-060.7RJ-JAG.560-060.7RJ-JAG.560-360-360-360-360-360-360-360-360-360-3
PATCH	PATCH NUMBER 3								

0.0	0.280-060.550-060.780-060.0	550-01110+00140+000.0		00+074 00+0404 000+031 v
0.0	0.210+000.410+000.590+000.0	0.200+000.400+000.570+000.0		
0.4204	+610.420+010.430+010.440+610.420+	+01 0.420+010.430+0 <b>10.</b> 440+010.420	0.420+510.420+010.430+010.440+610.420+010.420+010.430+010.440+010.420+010.420+010.430+010.430+010.430+010.420+010.430+010.440+0	

### PATCH NUMBER

0.0	150+60 290+00420+000.0	LHD+00360+00510+090.0		
0.0	0.150+666.290+000.420+000.0	0=110+6u0.210+0u0.29n+000.0 +010.420+010.430+010.440+010.420+	0.0 0.150+666.290+000.420+000.0 0.110+606.210+008.290+006.0 0.550-016.110+000.150+000.0 0.420+010.450+010.450+010.420+010.450+010.420+	10+034*010+024*010+0

### FATCH NUMBER

### PATCH NUMBER

### 90.

PATCH NUMBER

--620+00--520+00--600+00--640+00--510+00--640+00--730+00--730+00--570+50--710+00--810+00--870+00--870+00--870+00--970+00--970+00--870+00-

### PATCH NUMBER

### PATCH NUMBER

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1

### PATCH NUMBER 11

0, 120-050, 330-050, 550-050, 760-05-, 230: 70-, 650+00-, 110+01-, 150+00-, 130+01-, 210+01-, 290+01-, 440+01-, 410+01-,

### PATCH NUMBER 12

--64U+0U-.18D+GL-.29D+GL-.4ID+UI-.78D+UG-.27R+UI-.3DH+UI-.8DH+UI-.4UN-.4UN-.4UN-.4UN-.4UN-.9DH+GI-.9DN+GG-.2FR+UI-.4IN-.4IN-.9DH+GI -.9DH+GI-.

### PATCH NUMBER

0.580+010.750+010.920+010.110+020.560+010.720+010.890+010.110+020.500+010.840+010.840+010.410.410.770+01 0.0 0.0 0.310+020.480+020.640+020.800+020.310+020.460+020.640+020.310+020.310+020.640+020.650+010.020.310+020.480+020.480+020.480+020.480+020.480+020.310+020.480+020.480+020.480+020.480+020.480+020.480+020.480+020.30.400

### 6 PATCH NUMBER 14

0.310+020.480+020.640+020.800+020.310+020.460+020.640+020.800+020.310+020.460+020.640+020.800+020.410+020.40+020

### OUTPILL DELETER

### AICH NUMBER 16

### PATCH NUMBER 17

0.0 U.U U.U U.U U.U U.U U.L VIPUTU U.LYUPULU.L 

### PATCH NUMBER 18

0.540+ul0.550+ul0.560+cl0.570+cl0.750+ul0.760+ol0.770+ul0.740+ulu.910+ul0.930+cl0.340+ul0.340+ul0.160+ul0.360+ 0.950+010.960+010.980+010.100+020.790+010.810+010.820+010.820+010.600+010.€10+010.670+010.€30+010.€30+010.€30+010.

### PATCH NUPBER 19

0.100+020.100+020.110+020.110+020.100+020.190+020.110+020.110+020.11111+020.11111+020.1111+020.1111+020.1111+020.11111+020.11111+020.1111+020.1111+020.1111+ 0.430+610.430+010.430+c10.430+c10.430+010.40+010.40

### PATCH NUMBER 20

0. 430+010. 430+010. 430+010. 430+010. 130+010. 130+010. 130+010. 130+010. 130+010. 130+010. 130+010. 130+010. 130+010. 130+010. 130+010. 130+010. 130+010. 130+010. 130+010. 130+010. 130+010. 130+020. 110+020. 110+020. 110+020. 110+020. 110+020. 110+020. 110+020. 110+020. 110+020. 110+020. 120+020+020. 120+020. 120+020. 120+020. 120+020. 120+020. 120+020. 120+0

### PATCH NUMBER 21

--430+01--430+

### PATCH NUMBER 22

--430+01--430+01--430+01--430+01--600+01--610+01--620+01--790+01--790+01--720+01--720+01--720+01--750+01--0.80U+020.82U+020.84D+020.86D+U20.80U+020.870+020.44D+020.44D+020.44D+020.82D+020.43D+020.43D+030.46D+030.46D+030.42D+020.42D+03000.42D+03000.42D+0300.42D+03000.42D+03000.42D+03000.42D+03000.42D+03000.

### OUTPUT DELETED

### 3-D MOMENTUM ENTEGY INTEGRAL TECHNIQUE

### --- MATERIAL PROPERTIES ---

### \*\*\*\*\*\* MATERIAL NUMBER 1 \*\*\*\*\*\*

### --- SURFACE ROUGHNESS ---

ROUGHNESS HEIGHT FOR TRANSITION ROUGHNESS HEIGHT FOR TURBULENT HEATING K-LAM = 0.230 (MIL) K-TURB = 2.000 (MIL)

LAMINAR HEATING AUGMENTATION FLAG

JROUGH = 1

### --- PARAMETERS IN BLOWING CORRECTION TO TRANSFER COEFFICIENTS ---

LAMINAR SHEAR PARAMETER (BLS) = 0.5000 LAMINAR HEATING PARAMETER (BIH) = 0.5000 TURBULENT SHEAR PARAMETER (BTS) = 0.3500 TURBULENT HEATING PARAMETER (BTH) = 0.3500

### 3-D MOMENTUM FRERGY INTEGRAL TECHNIQUE

### ###### MATERIAL NUMBER 2 ######

### --- SURFACE ROUGHNESS ---

ROUGHNESS HEIGHT FOR TRANSITION ROUGHNESS HEIGHT FUR TUPBULENT HEATING

K-LAM \* 0.230 (MIL) K-TURB = 2.000 (MIL)

LAMINAR HEATING AUGMENTATION FLAG

JROUGH = 1

### --- PARAMETERS IN BLOWING CORRECTION TO TRANSFER COEFFICIENTS ---

LAMINAR SHEAR PARAMETER (BLSI = 0.5000 EAMINAR HEATING PARAMETER (BLH) = 0.5000 TURBULENT SHEAR PARAMETER (BTH) = 0.3500

### --- INVISCIO DATA ---

AHINF # 1.62000+01 ALPHA = 5.00000+00 MUAT =36 NDAT =11

2 . 0.0

M	PHDAT	R6	R BZ	HTTH	OMEGA	SF
ı	3-1470+00	0.0	5.5710+08	0. J	0.0	3-1420+00
2	3.1370+00	0.0	5.5710+08	0.0	4.18011-04	3-1370+00
3	3.1320+00	0.0	5.571U+08	V•0	8.43017-04	3-1370+00
4	3-127U+C0	0.0	5.5/10+08	V. U	1.2770-03	3.1270+00
5	3.122D+C0	0.0	5.571D+0H	0.0	1.7300-03	3.1220+00
6	3.1170+00	0.0	5.571U+08	0.0	2.1980-03	3.1170+00
7	3.1110.00	0.0.	5.5/1D+UH	U• U	2.1470-03	3.1110+00
	3 - 1 0 > D + C 0	0.0	5.571D+0A	0.0	3.3310-03	3.1050+00
4	3.1000+00	0.0	5.57LU+UH	0.0	3.7410-03	3.1000+00
10	3.0440+00	0.0	5.5710+08	0.0	4.37011-03	3.0940+00
11	3.0H/U+00	0.0	5.5710+08	0.0	4.91111-03	3.0870+00
12	<b>3.</b> 0HUD+UU	0.0	5.5710+08	0.0	5.5760-03	3.0AUD+U0
13	3.013U+CO	0.0	5.571U+UA	0.0	6.2110-03	3.0730+00
14	3.0650.00	0.0	5.5710+08	0.0	6.4480-03	3.0650+00
15	3.0550.00	0.0	5.5 7LU+0A	V.O	7.8U2N-03	3.0550+00
16	3.0440+00	0.0	5.5710+08	0.0	8。44511-03	3.0440+00
17	3.0280+00	0.0	5.5710+08	O. Q	1.0240-02	3.0280+00
18	2.9950+00	0.0	5.5710+08	0.0	1.3200-02	2.9950+00
19	2.9670+00	0.0	5.571U+0H	0.0	1.5641-02	2 . 96 70 +00
20	2.7430+00	0.0	5.57LD+U8	0.0	3.0880-02	2.7930+00
21	2 - 61 80 + 00	0.0	5.5710+08	0.0	4.5ひをツーひと	2 . 61 81) +00
22	2.4430+00	0.0	5.5710+08	0.0	5.7820-02	2.4430+00
23	2.2640.00	0.0	5.571D+08	0.0	6.4741)-()2	2.2690+00
24	2.0940+00	0.0	5.5710+08	0.0	7.7500-02	2.0940+00
25	1.9200+00	0.0	5.5710+08	0.0	8.3850-02	1.9200+00
26	1.7450+00	0.0	5.5710+08	0.0	8.7620-02	1.7450+00
27	1.5710+00	0.0	5.5710+08	U• 0	8.8720-02	1.5710+00
28	1.3960+00	0.0	5.571D+08	0.0	A.7110-07	1.3960+00
24	1.45550+00	0.0	5.5710+08	0.0	8.2940-02	1.2220+00
30	1.0470+00	0.0	5.5710+08	0.0	7.62711-02	1.0470+00
31	8.7270-01	0.0	5.5710+08	0.0	6.7341-02	# . 72 7D-01
32	6.9810-01	0.0	5.5710+08	0.0	5.6420-02	6.9410-01
33	5.7360-01	0.0	5.5710+08	U. O	4.3940-02	5.2360-01
34	3.4910-01	0.0	5.5710+08	0.0	2.99/11-02	3-491N-01
35	1 - 7450-01	0.0	5.5/10+OH	0.0	1.5209-02	1.7450-01
36	0.0	0.0	5.5710+08	0.0	0.0	0.0

OUTPUT DELETED

## 3-0 MIMENTUM ENERGY INTEGRAL TECHNISHE

FLIGHT CALCULATION MACH-16.2 ALPHA-5.0 10.4/6.0 BICONIC W/ YAW STAR.

	1.24330+07
ANGLE DE AFTACK	2.00
VELOCITY (FT/SEC)	1 5609.00
MACH NO	16.20

FLUID PROPENTIES	PRESSURE	TEMPERATURE	DENSITY	ENTHAL PY	ENTROPY	I SENTPHPIT
	(ATM)	(Degr)	(LBM/FT3)	(BTU/LBM)	(BTU/LBM-DFGR)	EXPONENT
FREESTREAM NORMAL SHOCK STACMATION	24.619	384.870 10554.924 10743.801	0.007617 0.076593 0.080024	93.27 4910.82 4958.94	1.7140 2.4869 2.4869	1.197

## 3-D MOMENTAN ENERGY INTEGRAL TECHNISHE

STREAMLINE	W	BETA	SONIC	POINT	LBCAT ILM	7	TRAN	TRANSITION POINT LOCATION	T LUCAT	E .		
<b>2</b>		(DEC)	5	×	<b>&gt;</b>	7	\$	×	<b>&gt;</b>	~		
		0.0	0.554	-0.591	000.0	0.215	10.026	-2,500	i, 0au	1.445		
BODY PT NU	INTEG PI NO	STREAMLINE Z Z (IN)	LDCAT ION PHI IDEGI	METHIC COEFFICIENT	IC ENT	BOOY ANGLE (DFG)	FUGF PPFSSURE (ATM)	WALL TEMPTHATUME (DFGR)		7M1 44-8 44-14-14-14-14-14-14-14-14-14-14-14-14-1	FRINCIPY FRINCIPY	HEAT TEANS FIFFICE NT [LINK 13-SF]
			,	,		9	ii 1	71 9764	*. *	10-0 6	40°4	1.75.500.000
	_	3.449 R()-03	00.0-	0.0	;	00.00	75.3047	7:71	75.	264:0-01	11.11.09	R. 4776 Paril
7	<b>~</b> 1	1.266819-02	0°0	7.49480-	7 <del>.</del>	87.40	94.17.45	71191 . 79	3.8	10-03-03-03	KO CEDY	F. Acher Of
<b>~</b> , .	٠.	5.34410-02	0000	2 872401-01	5 5	01.54	70-1347	7010-63	40.	10-114 1211-01	4411.57	111-11-11777
• •	# F	10-01-01		5. 30160		55.18	16:0331	689.1.57	2.41	2.417411-01	44.47.48	16-112429-4
n 4	· ·	0-04977	0000	6-52670-01	5 5	45.03	11.4340	67,16.40	7.74!	7.741211-01	48 30.46	4.447111-91
o <b>~</b>	2	4.589GJ-UZ	2	7.571211-01	10	35.08	7.5556	6515.20	7. h.	7.414111-01	4117.00	1,46.4617-31
	9	A.04#GD-01	00.0	8. 34030-01	10.	25.19	4.1233	6.22A.40	2.34	7711-01	4121.11	7.51571-91
. 0		7.5190D-01	0.00	8.42093-01	10.	15.23	2.1174	5634.60	7.4.	2.4.7500-01	46 14.37	0-1.1.0x" -
` =	: .	1.38910+00	กกาก	1.07590+00	00	15.40	2,1252	5147.81	7: 11:	7. 114411-11	45.4.40	1.16.71.5-01
2 =	) K	1	00.0		9	15.40	1.0723	4877.31	2. 201	2. 2016.0-01	4617.11	4. 1145711-07
: 2	77	3.66200+00	0.00	1.69300+00	00.0	15.40	1.444¢	4678.09	2.24	10-416-61	4589.49	7.6 Mthths-0
: :	53	5.02540+00	00.0	2.51550+00	00.	15.40	1.4037	4610.19	2. 7A94P	0.00	4572.75	7.71660-77
1	· ·	6.37810+00	0.00	3.25940+00	00	15.40	1.4545	4616.10	2.78	2.784MD-01	4576 . 54	f. 466 (1) -0.2
5	<u> </u>	7.67020+00	00.0	4.12070+00	00.	15.40	1.5530	\$6.52.28	2.24	2.240MD-01	05.01.5	- (1-(14)-1-)
	3.	8.88090+00	00.0	•	00.	15.40	1.6706	4674.66	7.20	7.24710-01	65.20°.79	A. C. L. C. C. C.
11	3.5	1.0000913+01	00.0	•	00	15.40	1.7941	46HI . 35	0r.2	10-06501	45.45	10-712-11-1
•	36		00.0	7.26910+00	00.	15.40	1716-1	2536.22	7.47	7.4777P-01		1. (70.40.91
6	7 4		00.0	8.54140+00	.00	15.40	2.0110	5856.03	2.13	2.13 TH-01	26.14.34 26.19.34	יי-ויסלנו יל מיינוסקנו נ
20	£3	1.30400+01	00.0	•	200	15.40	2.0824	39.2.86				10.02566 6
17	4.5		00.0	•	<b>1</b>	15.40	2.1.23	07.195	, B.C.	Z. MC4701-01	4551.10	10-11-10-11-E
22	7.4		9	•	5	0,	7.61.7	40 Tana	6 6	7 88630-01	45.1.08	A. 6 7 ( RII - 0)
23	64	1.60230+01	00.0	1046830401	<b>7</b> 5	מיין	7-1106	50 FA 25	7. 44	Z. #7620-01	657H.93	2.478r.11 01
*	16	10+0/ co. 1	00.0	•		07:31	2.1843	506.9.41	2. A 7.	10-050	4517.53	3.42417-01
<b>\$</b> ;	en e	10.00.00.00.00.00.00.00.00.00.00.00.00.0		•	5 5	15.40	2,0659	5967.01	2. H.F.	2.Hr410-01	45.06.36	10-114-13-E
9;	C *					15.40	2,0460	5955.47	2. H.	2. H 1. AO 1 - 0]	4447.27	10-41840r°c
, E		2.18010+01	07.0		5	15.40	2.0366	5450.70	2. HS	Z. N575  -0]	6484.50	10-67505 %
5 6		2. 31450+01	00.0		101	15.40	2.030%	5948,50	2.44	2.44.8HII-01	4447.15	
30	63	2,45670+01	00.0	3.34550+01	5	05.51	2.0286	5941.63	# * ·	2. #4.52H - ft]	6476.49	0 10112
31	65	2.60560+01	00.0		101	15.40	2-11298	54¢1.85	7 × ×	2.84750-nj	16.17.44	ווי-ני/יוי
32	89	2.76420+01	00.0		101	11.00	1.2941	5647.25	7. ft 7	3613-01		10-110-11
33	11	3.00440+01	00.0	4.84320+01	101	11.00	0.4170	9494939	1,1404.4	וח ווייסריי	Or • • • • • • • • • • • • • • • • • • •	
34	75	3.31990+01	00.0	•		11.00	0.78.0	54.36.43		7. 4.154.0.11	4453.17	10-02-0-1
3.5	0.0	3.71701)+01	00.0	•	101		0.8443	2402043		10-03-1-2	71.17	1.66399
36	<b>3</b>	10405861.4	00.0		701	20.	0°44°0			2 51 770-01	24.44	1.700 00-01
37	43	4.73830+01	00.0	•	<b>`</b>	00.11	0.8485	24.74	7.57	7-52419-01	6666.13	10-1107-1
	100	5.306 10 +01	00.00		7D4	-	1674.0	56 18.51	7 4 7	7. 4.397.0-0.1	444424	10-14441-111
36	101	5.88130+01	00.0	•	704		2,470	17 - 7° 7° 5	7	7-51710-01	4444.57	1.400040-01
<b>9</b> :	<b>*</b> 11	10+03/44.9		2 45 15,3407		20-11	1.0176	5411.79	7.54	7. SEFRIN-01	4441.22	10-10724-1
4	177	•		•	, A		1150-1	5476.17	2,55	10-1162 55 2	4447. OF	10.00cd#*]
24	921	Ç,	0.0		704	20.11		5501.63		2-554 FD-01	6444	10-01 [64.]
7 :	137	0.1541U401		10.00+00+00+00+00+00+00+00+00+00+00+00+00	, i	00.33	1 - 0670	5501.56	2.55	2.55670-01	441R.44	10-(10,64*4
;	•		•		<u>;</u>	) )	1 <b>)</b>					

C

VISCOUS FLUM - FUGE PROPERTIES

		7	32.00		>0	10114676	27.000	*********	:
L NO	PI INC	LENGTH	45100111	E ON					PF 27
<b>!</b>	)	INCH.	FT/SEC		BTU/LBM	DEG R	L R4/FT3	LRM/FT-SFC	1751
S	===	(8)	(00)	(HCAN)	(116)	(TE)	(pre)	(AZZE)	LOPE
-	-	0.0	0.0	0.0	4958.9	10743.8	4.0070-02	9.9760-05	0.0
~	1	0.0729	1264.2	0.2486	4475.9	10491.9	1.92411-02	9°-0076-6	1.0100+04
m	•	0.2333	2411.0	0.4771	4842.1	10541.7	7~ 4 700-US	9. A 340-05	1.831016
•	=	0.3936	3729.4	0.7500	4681.2	10250.3	6.61413-02	9.4400-05	7.55911+134
<b>.</b>	13	0.5540	5021.B	£9L0* i	1.4544	9874.2	5. 5 7913-02	9.3440-05	7-047130.36
•	1.5	0.7144	6275.8	1.3373	4177.4	4566	4.25411-112	8,7540-15	2.9410+06
-	1.7	0.8747	746H.4	1.6588	1945.0	6596.0	20-6156.5	11.4HFD-05	7.6850+04
•	<u>5</u>	1.0351	8498.8	1.9753	3516.5	1931.9	20-01-02	\$0-ULUU*	7-1410+04
•	21	1.1891	9258.5	2.2371	1747.0	7410.0	1. 1150-02	7.4070-05	1.401.74.14
≘ :	23	1.8348		1975-2	3045.5	104.8	1.0470-02	70-0551-7	40+44140
f	52	2.8579	10293.5	2.6156	2867.9	6.806.4	R. A 2011-03	7.1200-13	40+02/21
12	17	4.1457		2.1514	1.1697	2.8046	1.91.10-03	60-11/ce.4	4C+0012*1
M .	62 ;	5.5319	7 OKRO1	2.8455	9.4.7	D	7.386B-04	\$0-025K*9	Stantar I
<b>.</b> :	16	2306.9		0454.7	1.047	F-0250	K. 16711-04	VIII-01157 - 4	-0.00-1.
<u>:</u>	2 4	8027.6	L 59961	70°C	737160	0.47.0	7, 10,10-03	10+184-54-4	50.40.16c.
٠.	Ç.,	11644	C*ARC11	30110	77777	6.654	לט-מינוריים	10-11K41-0	
	- 0	CBAC-01		302445	4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	7*7£00	20-01-71-1	F0-0486 Y	30.00.00
<b>0</b> (	<b>7</b> .	94/9911	6.61171	9 2 2 2 6	2000	E	70-04-7-1	- 0-0-2-9	10 11 11 10 10 10 10 10 10 10 10 10 10 1
2 5		2101-21	1 * 5 7 7 1	24.42	1.0001	20.00	201-11-10-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-	- CO- CO - CO - CO - CO - CO - CO - CO	
2 :		13.1003	C*C8971	0.00.00 0.00.00	)	74716.7 E 10E 1	1 4050-03	-0-6355-01 90-0368-3	00.402.E. E.
17	<b>.</b>	1069-11	**/9671	7794.6	K*1001	1.6816	20-0-00-1	10-01-71-4C	
22	70	16 7133	1 1690 7	4. 26.76	1 1 2 4	4510.8	1 - # 400 - 02	5.25.0-05	A. 7290 s.06
5 2	ř	17.1748	1 377 1.5	9164-4	1197.7	4717.6	1.9779-07	50-0100-5	40+0F-64-64
25	53	19.8857		4.7467	1082.6	3897.7	2-1240-02	4.1720-05	8.21.111.36
97	25	20.0545		5.0123	D Fee 3	3572.1	2-2940-02	4.457D-IN	7.2710+04
12	21	21.2474	142#5.7	5.2777	AR 3. 3	3287.1	2.4750-02	4.2150-05	R. 389739 DA
		22.5880	14433.7	5. >462	798.4	3011.5	Z. 58711-02	30-0686	40.17.006
, 62		23.9584	14541	5.780A	736.3	2801.0	2. 11 7511-02	1.7970-05	1.101011
2;	63	25.3999	14635.4	1010.4	C - 1 - 1	2614.6	4.U77n-n2	1.67AB-05	1.24111697
15.	Ç ;	26.9137	**************************************	6.77.49	E	245343	54.78111-02	-0-054 4°	10 40 kW f * 1
3.5	<b>8</b> 2	3096.97		6-0667	669.2	2512.3	1.4040-07	- 50-U-05-1	5. 74RD+06
, m	7.5	34-1076	14829.4	6.5836	567.1	7219.7	1.5540-02	1.25.79-05	7.0350+06
35	50	38.1200	14095.5	7.2469	46.9.2	1861.2	1.4140-17	70-000p-7	9. A9411+U6
36	98	42.9459	15074.6	7.6265	4.70.7	1649.0	2.0900-02	7.1200-05	11.1540+47
3.7	63	48.3 705		1.87.	4.07 . B	1026.1	20-656.1.7	2.6510-05	1.2500007
38	100	54.0846	•	1.8249	398.3	1607.3	2-2 140-02	2.6370-05	10.0705.1
36	101	59.8626		7.8353	39 / e f	1605.2	7.3470-07	20-U119°	1.145911
40	114	65.5005	•	7. 11.07	300.2	1611.0	2.4100-02	2.6 370-05	1.441194.1
14	121	71.3024	15192.6	7.770	403.B	1627.9	7.48011-07	50-6559.2	1.410017
42	128	77.0252	15093.4	1.1264	<b>*</b> 00 <b>*</b>	164k.0	2.5 1.111-02	7.6.170-05	10+01/25-1
<b>4</b> 3	135		15087.8	1.6.162	417.1	1446.2	2.544n-02	7-6-00-4-6	10+UDE 9-1
;	137	83.0364	15087.7	1509-1	412.B	1660.4	2.5440-02	7.6400-05	1.4300+07

## 3-D MIMENTUM ENFRGY INTEGRAL TECHNIQUE

T.

A Part Land

VISCUUS FLOW - MALL AND B. L. RECOVERY PROPERTIES

			•							
BODY	INTEG	STREAM	HALL	HALL	WALI	WALL	RECOVERY	PFCNVFRV	SENSAL CONV	7672
ON Ed	PT NO	LENGTH	TEMPERATURE	ENTHALPY	DENSITY	VI SCOSI TY	ENTHAL PY	FACTOR	HE 47 FLUX	•
S	=======================================	S	CTM)	BTU/LAM (HW)	(RUM)	LRM/F T-SEC (VISW)	BTU/LAM (HP)	(PECOV)	ATU/F12-SFC	
***	-	0.0	7249.3	7626.4	1.3500-01	7.2640-05	4958.9	17440	2.7010.03	1.00001
~	~	0.0729	7171.3	55152	1.36411-01	7.20311-05	1.1561	0. 8367	1.491,0403	7 - 74HD-0
M.	<b>5</b>	0.2333	7091.6	2531.6	10-0192-1	7.1440-05	0.0464	17880	1.6530+03	3.4540-0
<b>+</b> (		•	016.	2500.9	10-0860°1	7.0430-05	4913.6	0.8367	1.5040404	2-1470-0
Λ,	£ :		-	2461.9	R. HOJD-02	7.0170-05	4814.5	0.436.7	1.110.03	2.29An-n
٥ ٠	2:	0.7144	6734.4	2401.2	6.5440-02	6.9050-05	44 10.5	0.8367	1.0.4000.0.1	2.0710.0
~ 1		1 1 2 1	•	7.017	20-6999-4	6.7500-05	4111.0	0.8367	8.55TP+02	1.9507-0
	<u> </u>	1460-1	\$5.87.59 5.50	2169.4	7.8900-02	6.54[0-05	4123.3	3.83£7	6.4250402	1.8947-0
۰.	12	1681.1	-	1636.9	1.4110-02	6.0790-05	4670.3	TAFR.0	<.1170.02	1.7080 0
9 :		1.834B	5187.8	1607.2	I.4040-02	\$.1270-05	4646.4	0. H 7 K 7	3. 5 tHP+0.7	1,0147-4
1:	52	2.8579	6479.3	1457.6	1,3510-02	5.4880-05	4613.3	0.8367	2. Ht 70+07	4.1010-74
12	7.7	4.1457	4678.1	1375.0	1.2179-02	5.3340-05	4589.5	1968.0	2.4490402	6.871D 04
13	29	5.5319	4.01.4	1 346.4	1.2030-02	5,2#10-05	4572.B	0.8367	2. 14 70+02	A.0709-04
<b>*</b>	3	6.9072	4616.1	1348.3	1.2450-02	5.7860-05	4554.5	0.4347	2. 14.30+0.7	5.5470-0
5 7	e ;	8.2208	7.25.04	1362.7	1.31 AD-02	5.3140-25	4.519.5	0.83KF	2.4380+02	5.1800 B
9 :	3.5	9.4517		1340.1	1.4040-02	5.1480-05	4.520.B	U. H367	2.5110.02	4.427:1-04
	76	10.5985	4081.4	1498.9	1.41411-02	5.54619-05	4214.5	0.9414	3.1230+02	5.8 15P-06
<b>8</b> 0 1	39	11.6748	2536.2	1902.2	1.3410-02	6.040-05	6.534.3	0.85AB	4.8450+02	9.477:0 04
61	1,	12.7015	5856.0	2007.0	1.3150-62	6.7570-05	4564.0	0.4724	6.9 AND+02	1.7.10-0
02	Ĵ:		5942.B	2068.4	1.3370-02	6.3190-05	4571.2	0.8794	7.8450+02	ני-פייפר פון
7 .	4.	14.6907	5973.2	2088.9	1.35 10-02	6.36411-05	4564.2	928H-0	8.2250+02	1.0000 1.00
77	-	15.6898	5982.7	2045.2	1.3590-02	4.1720-05	4553.1	0.844i	4.2170.02	1.2560-03
<b>63</b>	<b>5</b>	16.7132	5981.3	2094.6	1.1550-02	6.3710-05	4541.1	0,4850	. 8.4040407	1.1670-03
<b>5</b> 2	<u>بر</u>	17.1748	59 76.2	2091.9	1.3450-02	6.3670-05	452R.9	0. BAS.7	8.1800×U2	1.04.90 0
52	53	18.8857	5969.4	2086.1		6.3620-05	4-217-5	1944.0	5.178P+02	9.7530-04
9 <b>7</b>	55	20.0545	5965.1	2084.0	1.3200-02	6.3560-05	4.50.6. S	0.8465	3.2 70n+02	N. R 7 70-04
27	25	21.2874	. 5955.	1.0%05	1.3100-02	6. 1510-05	4497.3	0. AHA.7	4.21 4D+02	9 COYOU DE
82	53	22.5880	5950.1	7011.7	1.36:0-02	6.3470-05	44 8 H. T	O. 4469	A. I Ann+n2	7. 1700-04
67	19	23.5584	5946.5	2074.4	1.3020-02	6.3440-05	4482.2	1182.0	8.1440+02	6. 1913-04
P :	6	6666.47	5943.6	2072.4	1.3019-02	40-0141.9	4476.5	D. 9H72	8.1190+02	6.27% 04
7 .	٠	76.91.37	H*1966	20/0.9	1.3035-02	6.34017-05	4471.5	D.AHIT	8.0940.02	5.47513-04
35	÷	1095-87	2.2996	# 0161	8. HO40-03	6 • 1 0AI) - US	4447.2	0.AH71	5.669()+0?	7.1470-04
n 4	7.	30.43	55755	1.70.4	6.54.40-03	5.91.01.05	44 15.5	F 1 4 4 6 0	4.451P+02	6.5477-04
P 4	r ;	0101046	1.000	£ 1.71	10-UAK2-9	50-016H-6	446400	C. 48.74	4.1470+02	f. 7197-04
Ç ,	÷ 6	38.1200	5405.4	780.5	6-6240-01	5.9210-05	4443-1	0.H874	4.52ADP02	4.R479-04
9 ;	£ :	64.96.24	2.05	1.6771	(n)-(lt. yi • 9		444H.I	D. HR 74	20.01.16.03	4.41511-05
	÷ :	44.3700	5408.3	1782.6	60-6127-9	5-9/30-05	4:44:4	2 4 B 7 C	4.54511442	4.2119-04
D (	00.	74.0440	7**/*6	4 ° 1 6 7	6.4770-03	•	444.	U.4876	4.4110+02	4.11 [7-05
60,	101	54-8626	54 38.5	1799.0	6.1300-03	50-0156.7	4444.7	U. HR 74	4.6770492	4.0410-04
0 :	<b>*</b> :	65.6005	5454.1	1 408.4	6.92 JD-01	50-0276-6	444th.ii	U. 4876	4. Pinn+112	*0-13*1-0*
·	171	71.3024	5474.3	1421.2	7.1640-03	50-0080.5	4:47.2	0.8877	4.H54P+0.2	4.0119-04
2.	128	٠,		18 30. 4	7.373-03	5.4730-05	664A.O	O. 4877	4.444977	\$******* 04
<b>?</b> ;	(5)	٠,	5501.6	1837.4	7.4773-13	50-011:6.5	4 4 4 B . 4	O. RRIT	4.0580102	\$U-United. * 2
;	137	83.0364	5501.6	1832.3	7.47.10-03	5-9310-05	4.64.4	7.44.0	4.4.70+07	7.47H11-f14

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VISCOUS FLOW - BININDARY LAYER SALUTION

200	INTEG	STREAM	MOMENTUM	ENERGY	SHAPE	MON THICK	ENTRGY THICK	HEAT TPANS	P FYNO! DS	- ENTER-	TPANSITION
PT NO	ON .	LENGTH	THICKNESS	THICKNESS	F AC TOR	AF NO	RF NO	COFFFICIENT	ANA! FAC	A JANS I I I M	#41 4F# 4 <b>F</b> 4
3	=======================================	ENI (S)	THE)	11Hd)	[HSF]	(RETH)	(REPHI	(RUCH)	(RAF)	(APML)	(41)
	•	ć	40.20	. 562-11	1.431	0.0	0.0	1.1590+00	0.8387	0.0	0.0
۰,	<b> •</b>	0.0			1.418	2.6310+01	4.1760101	A.37301-01	1.151.1	0.0	30.161
7 '	~ 0	0 0333	0.379		1.423	5.7760+01	1.0050+02	6.86413-01	6.466.3	0.0	54.034
۰.	<b>)</b> -	1010	104-0	, ,	1.454	8.5500+01	1.55.80+02	6.24111-01	6906.0	0.0	R1.540
• •	- ·	0 5 5 5 0	444 0	•	1.513	1.0970+02	2.06510+02	5,4100-01	0.8576	o•c	451.50
Α,	S .	0.1746	0.529	1.017	1.584	1,3130+02	2.527n+02	10-u2 77°5	0.8744	0.0	94.756
۱ ب	<u>.</u>	477.0	854.0	1.296	1-642	1.4730+02	2.6990+02	3.44.50-0!	0.1796	0.0	42, 196.
٠,	- 0	1.0251	27.4	1.739	1.763	1.60 10+02	3.1740+02	2. 5! 60-01	0.7541	0.0	A0.154
• •	<u>.</u>	10001	1.754		1691	1.67511+12	3.1760+02	10-020-81	0.7756	0.0	A6.1.98
• •	17	H-1-1-1	10864	3.02E	109.1	2.1960+02	3.5600+02	1.16711-01	1.0404	0.0	6.R. 4.94.
? =	, ,	7.8579	76407		1.558	2.65713+02	3.4870+02	9, 0857-07	1.7345	0.0	6, 7 a 9 M 1
1.	7.	4-1457	2.944		1.540	2.9700+02	4.1.46D+02	1.6400-02	1.111	<b>c</b> •0	4 4. 09!
, r	7.4	5.5319	3.094	4.146	1.538	3,22411+117	4.36AD+02	7.2750-07	130.1	0.0	D•0
: =	` <del>~</del>	6.9072	3.044	140.4	1.574	3-4440+02	4.6550+02	7.3670-02	1.4197	<b>5</b> •	
·		8.220B	2,902	13.d3B	1.62B	3.7760+02	20+0566.5	7.6740-02	1.4750	<b>c</b> • c	2.0
2	, 14.	4.4517	2,729	3.594	1.692	4.0850+02	5.3870+02	8.0580-07	36 I 7° I	0.0	0.0
2 ~		10.5985	2,599	3,501	1.970	4.494114117	6.0540+02	10-0710-1	1. 2319	0.0	0.0
			2,794	3. 401	2.649	5.58 311407	7.1460.402	1.7700-01	E 7 % C 1	0.39	0.0
2 2	: 3	12.7015	3.414	4.666	3.541	7.8775+02	1.0170+03	2. 7060-01	0.002.1	2.5	5.0
202	7	13.7003	4.118		4-175	1.0900+03		10-11711-1	\$1.61°1	F 6 0	. c
; =		14.6507	4.692	5.427	4.17h	1.4277003	1.7960+03	3. 17 411-01	# 15 I * I	* (C	
22	14	15.6878	5.121	6.345	5.2H6	1.7680+03	2.1910+03	3.4070-01	804.1	6 6 6 C	0 1
: ~	6.4	16.7132	5.418	6.639	106.5	£0+051 1-2 )	5 .4 [60+03	3. 6377-01	274	<b>*</b> • • • • • • • • • • • • • • • • • • •	•
	: 15	17.7748	5.604		. 465.9	2.5130+01	3.04 50+03	3.4190-01	HEHE .	500	3 3
25	:5	18.8857	5.101	6.403	7.383	2.4770+03	3.6.05()+03	3.4780-01	7/8/1-7	7	0.7
, <del>,</del> 2	55	20.0545	5.727	•	8.271	3.47011+03	4.1810+03	3.4140-01	\$ 1 × 1 · 1	0.47	2 0
7	,	21,2874	~	6.875	9.197	£040020°\$	4 . Ribhn +07	3.3490-0		* C	0.0
28	26	22.5880	5.718	6. 78h	10.223	4.6370+03	5.44811403	3* 492P-01		F 0	) c
53	19	23.4584	5.743	•	11.154	F0+00/2*5	6.2019+03	10-02mt - F	7051.		
2	63	25. 3999	5.151		17.101	5.9550+03	10-01-50-9	3. 4770-01	115101	7 6	
TE	65	26.9137	5.103	•	13.052	6.5968.604	50+01414	,0-000c c	3010	60.0	7.0
32	<b>99</b>	28.5501	10.560	15.597	676.6	5. (210)	50.000		1 2008		0.0
33	7.1	30.9355	12.260	ė	11.17	10400715-5	1190401	10-04141	1.2104	70.0	0.0
34	22	34.1076	11.017	٠	741947	7 7070403	0.4020403	1.6940-01	1.2126	56.0	D.0
35	80	38.1200	4.5.4	2001-11	10.10	E0+0404-8	1.0480406	1 -6-340-1	1.2176	0.44	0.0
36	96	42.5459	010.4	•	007991	EGACINE O	11 40 404	1 - 707.0-01	1.7774	0.00	0.0
37	<b>.</b>	48.3700	9.156	•	17.113	10.10.00	1 1870404	1. 71711-01	1.2757	0.00	C 0
38	1 00	54. UB44	9.465	•	210 - 61	*******	40 m 70 m 70 m 1	74-01-01	1.2279	11.09	0.0
39	101	59. R&26	058.5	11.137	19.430	*0*0*01*1			1676-1	60.00	C.0
40	<b>:</b>	65.6005	10.213	•	RAY OF	*D*******			7000	5	0.0
7	121	•	٠.	11. 735	19.720	*D*64*22*1	4041145 T		10/01		0.0
24	128	• 025	6	٠	. 8. 'JR'	+1)+(1111) * 1			1 2 2 9 7	00-1	2.0
Ē.	135	9 ·	Ġ		18.820	1.1773100	-	10-11-15 T	1.2297	0.	0.0
4.5	137	83.0364	11.53	15.051	19.91	*D*10.16.*1			) )	1	

## 3-D NUMENTUM FRENCY INTEGRAL TECHNIQUE

# VISCOUS FLOW - CORVED SHOCK AND ANUGHNESS EFFETTS

Fig.					CHRYED SHALLK FEFECTS		SIIPFACE	PRUGHNESS EFFECTS	•
	600Y	INTEG DI NO	STREAM	FOGE	-		ROMGHMESS	HFAT TUANSFER Aughentation	PETTONNESS OF THE SERVICE OF THE SER
1   151			I NCH		INCH.		MIL		
1   1   0.00   2.4927   0.004   1.1970   0.2300   1.0000   0.2300   0.020	5	(1)	(5)	(ENTR)	( YRAR )	(RUUE)		- Kith Shi I	
1	-			7.486.88	0.0		0.2300	1.000	0.0
1   0.3334   2.48137   0.0242   1.1134   0.7301   1.0000     2   1   0.3344   2.4776   0.0599   1.1127   0.7301   1.0000     3   1   0.3344   2.4776   0.0599   1.1127   0.7301   1.0000     4   1   1.0351   2.48136   0.0711   1.077   0.7301   1.0000     5   1   1.0351   2.48136   0.0711   1.077   0.7301   1.0000     6   2   1.4841   2.4876   0.0711   1.077   0.2300   1.0000     7   1   1.0351   2.48736   0.0711   1.077   0.2300   1.0000     8   2   1.4871   2.48736   0.0711   1.077   0.2300   1.0000     9   2   1.4874   2.48736   0.0711   1.077   0.2300   1.0000     1   2   2   4.1877   2.48736   0.1870   1.1371   0.7301   1.0000     1   3   4.1871   2.48736   0.1870   1.1371   0.7301   1.0000     1   3   4.1871   2.48736   0.1870   1.1371   0.7301   1.0000     1   3   4.1871   2.48736   0.1870   1.1371   0.7301   1.0000     1   3   4.1871   2.48736   0.1870   0.1870   1.1371   0.7301   1.0000     1   3   4.1871   2.48736   0.1870   0.1870   1.1471   0.7301   1.0000     1   3   4.1871   2.48736   0.1870   0.1870   1.1471   0.7301   1.0000     1   3   4.1871   2.48746   2.48746   0.7874   1.1471   0.7874   1.14	4 6	4 1-	0.0729	4852	10.00%	19191	00.5.0	0000.	7.4.57160
11   0.55540   2.47164   0.0945   1.1272   0.4730   1.0000     12   0.55540   2.47164   0.0945   1.1272   0.4740   1.0000     13   0.55540   2.47164   0.0945   1.1142   0.4740   1.0000   1.0000     14   15   0.6144   2.4716   0.0945   1.1142   0.4740   1.0000   1.0000     15   1.1047   2.4716   0.0947   1.1047   0.4740   1.0000   1.0000     16   22   1.1047   2.4716   0.0047   1.1047   0.2740   1.0000   1.0000     17   2   2.4577   2.4475   0.1147   0.2740   1.0000   1.0000     15   2   2.4577   2.4475   0.1147   0.1777   0.2740   1.0000   1.00	<b>4</b> m	• 0	0.2333	2.48379	0.0242	1.1960	0.7 300	1.0000	00+6126*k
1   1   1   1   1   1   1   1   1   1	٠ ٠	· <u>-</u>	464.0	•	0.0375	1-1331	0.7300	1.0000	80+LZ55**
1   0.1144   0.0739   1.11042   0.0730   1.000	r u	• 17	0.5540		0.0690	1.1220	0017.00	2.000	6. 5715+00
	n •	1 W	7146		0.0585	1.1152	001 2 0	1.0000	4.1127+00
1	0 1	^ ~	0.974.7	•	0.053	1.1069	00.7300	1.0000	2.4577+00
1	٠,	2 -	1100	•	5670	1,0942	0.2300	1.0000	2.5499690
	D (	<u>.</u>		•	0.0711	1.0572	608 5 an	1.0000	7.0210433
1	> :	17	160701		0.0887	1.0172	0.2300	1.0000	1.374000
1	) : -	6.5	02.50 .	7.45755	6.1103	1.1072	0.2300	1,0000	1.1.1.10000
1, 2, 2, 3, 19, 2, 2, 3, 16, 3, 0, 1, 16, 9, 0, 1, 18, 9, 0, 2, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9,	<b>1</b> .	Ci	1170.7		0.1350	11.1371	001.6	1.0000	9. pl 30.01
1	71	- 0	6.5310		0.1670	1.1827	0067.0	1.0000	9.4770-01
35         8-2201         1,333         0,2241         1,333         0,2300         1,0000           35         8-4517         2,3044         0,2564         1,433         0,2700         1,0000           35         9-4517         2,3044         0,2564         1,433         0,2700         1,0000           37         10,5048         2,31779         0,4115         1,4717         1,002         1,0000           43         11,6168         2,21078         0,4115         1,4717         1,007         1,004           43         12,7003         2,2046         0,4115         1,4717         1,007         1,004           43         13,7003         2,2046         0,4115         2,1477         1,007         1,004           43         13,7003         2,2047         1,004         1,004         1,004         1,004           41         15,6003         2,204         1,004         1,004         1,004         1,004           51         1,004         2,004         2,004         2,004         2,004         1,004         1,104           51         1,004         1,004         1,004         1,004         1,004         1,104           51	<u> </u>		4 9077	1.55	0.1918	1.2489	0.2300	00000	10-0511.6
	† ¥	, r		7.19.84	0.2241	1.3338	0.7300	1.0000	1.074019
10   37   10.598   2.314.69   0.3102   1.549   0.3765   1.0100   1.549   1.579   1.0000   1.549   1.579   1.0000   1.579   1.579   1.0000   1.579   1.0000   1.579   1.0000   1.579   1.0000   1.579   1.0000		ń r	0.22.0	PROVE C	0.7584		00r2°u	1.0000	1.0400+00
1		υ, Γ,		0140C87	2011.0	1 - 549 3	4761	1.0000	2.1240400
4.1         1.6.7015         2.2.0998         0.55579         1.64702         1.0956           4.3         1.2.7013         2.2.0161         0.7049         1.9811         1.7017         1.1425           4.3         1.3.7013         2.2.0528         1.6.981         2.3512         1.6647         1.1425           4.7         1.5.6898         2.2.0528         1.6.981         2.3512         1.6449         1.1875           5.1         1.6.778         2.1008         2.5688         1.6.777         2.6749         1.1875           5.1         1.6.778         2.1008         2.5688         1.6.777         1.1875         1.1875           5.1         1.6.778         2.1008         3.4708         3.4708         1.9478         1.1875           5.2         2.2.874         2.00594         2.00594         2.00594         2.00594         1.1875         1.1875           5.2         2.2.874         2.00594         2.00594         2.00594         2.00594         2.00594         1.1875         1.1875           5.2         2.00594         2.00594         2.00594         2.00594         2.00594         2.00594         2.00594         2.00594         2.00594         2.00594         2.00594	~ •	n r	10.7401	04715.5	. 51140	1.6174	0.3265	1.0141	6.0 + L 1.1 + J
43         1.7003         1.7003         1.1647         1.1744         1.1647		, ,	0410-11	2000C C	0.5579	1.8219	1.4702	1.0056	1.1867+01
47         15,6896         2.20528         1.0791         2.1579         1.41647         1.1764           47         15,6896         2.20528         1.0791         2.51579         1.4176         1.1764           47         15,6896         2.20528         1.0791         2.5188         1.4499         1.477         1.1819           51         17.778         2.11205         1.6713         1.4570         2.41008         1.9772         1.1819           53         16,81857         2.11205         1.6714         1.1819         1.1819         1.1819           53         16,81857         2.01405         2.41008         1.9772         1.1819         1.1819           57         21,2874         2.06594         2.41008         1.9773         1.1819         1.1819           57         21,2874         2.06594         2.41008         1.9749         1.1819         1.1819           61         2.51840         2.06594         2.41008         2.41008         1.9759         1.1819           61         2.51840         2.06594         2.41008         2.41008         1.9759         1.1819           62         2.51840         2.06594         2.0400         2.4100         <	<b>3</b> (	- ·	y r	2.2616	0,1709	1185.1	1,7032	1.1425	10.49401
47         15.0900         2.20528         1.0991         2.51512         1.84640         1.1754           49         16.7132         2.1723         1.0504         2.8162         1.49490         1.1809           49         16.7132         2.14495         1.6304         2.4108         1.9712         1.1809           53         18.6857         2.1206         1.6304         3.7548         1.9712         1.1840           53         18.6857         2.00574         2.00594         2.4069         4.5748         1.9769         1.1840           59         2.0.0574         2.00594         2.00594         2.4069         4.5748         1.9769         1.1840           59         2.0.0574         2.00594         2.4069         4.5748         1.9769         1.1840           59         2.0.0574         2.00594         4.5173         1.9764         1.1842         1.1842           61         2.0.0574         2.00594         4.5172         1.9764         1.1842         1.1842           51         2.0.0504         2.00594         4.5172         1.9764         1.1842         1.1842           65         2.0.0760         2.0076         3.500         1.0076	3;	• •	7	22336		2.1579	1. A109	1.1647	10+0659*1
49         16.713.2         2.172.3         1.2370         2.5688         1.44449         1.18.254         2.5688         1.44449         1.18.254         2.6100         1.18.454         1.18.254         2.6100         1.18.454         1.18.254         2.6100         1.18.454         1.18.254         2.6100         1.18.454	:, F	<b>.</b>	, ,	2.30528	1450.1	2.3512	1.8649	1.1754	1.1570+01
51         1.4254         2.8167         1.4254         1.4254         1.4374         1.4374         1.4374         1.4374         1.4374         1.1844	7.5	;	٠.	2-1773	1-2370	2,5688	OHOH • 1	1.1809	1.8040401
53         16.8857         2.12065         1.6304         3.1008         11.6304         11.6497         11.6449         11.64	57	7 -	17.7749	7114445	1.4254	2.8167	1.9212	1.1935	1.8777631
55         20.0545         2.09282         1.8437         3.4208         1.9469         1.9469         1.9469         1.9469         1.9469         1.9469         1.9469         1.9469         1.9469         1.9469         1.9469         1.9469         1.9469         1.9469         1.9469         1.9469         1.1872 <td>, s</td> <td>- "</td> <td>18.885.7</td> <td>7.12065</td> <td>1.6306</td> <td>3.1008</td> <td>1.9372</td> <td>1.1844</td> <td>1.8570+03</td>	, s	- "	18.885.7	7.12065	1.6306	3.1008	1.9372	1.1844	1.8570+03
57         2.06594         2.0998         3.7548         1.9548         1.9548         1.9548         1.9548         1.9559         1.1877         1.9559         1.9559         1.9559         1.9559         1.9571         1.1877         1.9559         1.9759         1.1877         1.9759         1.1877         1.1877         1.9759         1.9759         1.9759         1.9759         1.9759         1.1877 <td>, ,</td> <td>, w</td> <td>241-0545</td> <td>2-09782</td> <td>1,8537</td> <td>3.4208</td> <td>1.9469</td> <td>1.1841</td> <td>10.40178.1</td>	, ,	, w	241-0545	2-09782	1,8537	3.4208	1.9469	1.1841	10.40178.1
\$9 22.5880	2 4 6	\ K	1.297	2.06594	2,0998	3.7548	1.9548	1.1817	1.8417401
6.1 23.9546	4 6	- 0	27.5880	2.04060	2.1706	4,1273	1.25,59	0.81.1	1. AU20401
63 25,3999	0 0	; ;		2-01/40	2.6629	4.4460	1.0714	1.1822	1.40000
65 26.9137 1.97617 3.1038 5.1596 1.9789 1.1791 1.1791 6.6 26.5017 2.06704 3.7160 1.9789 1.1791 1.179	, r		25.25.60	1,44673	2.9H10	4.8142	1.9758	1.1214	10.00.01
68         28.5601         2.06704         3.7140         1.9740         1.1791           71         36.872         3.5882         3.800         3.7140         1.9740         1.0034           71         36.955         2.00748         4.0462         4.0766         1.9740         1.0034           75         34.1076         1.9767         4.0469         1.9410         1.0070           80         38.1200         1.9707         1.0070         1.0070           80         42.9479         6.0436         1.987         1.0070           80         42.9470         1.9876         1.0070         1.0070           80         54.086         1.9876         1.9876         1.0070           101         54.862         1.9876         1.9876         1.0070           101         54.862         1.9876         1.9876         1.0070           114         65.6005         1.9130         10.5617         1.9876           114         65.6005         1.9130         1.9130         1.9136           12         1.9136         1.9136         1.9136         1.9106           12         1.9129         1.9136         1.9107         1.9107 <td>2 7</td> <td>, 4</td> <td>76.9117</td> <td></td> <td>3. 1038</td> <td>5.1596</td> <td><b>ウエトラ・</b></td> <td>1.18(30</td> <td>10.40.4 16.0</td>	2 7	, 4	76.9117		3. 1038	5.1596	<b>ウエトラ・</b>	1.18(30	10.40.4 16.0
Ti         30,9355         2.004773         3.58R2         3.88765         1.97K9         1.0034           Ti         30,9355         2.00748         4.0465         1.97K9         1.0970         1.0970           R0         34,1076         1.995459         4.05365         6.3469         1.98K5         1.0970         1.0970           80         38,1200         1.98079         5.4855         6.0538         1.98K5         1.0970         1.0970           80         42,9459         6.6533         1.98K5         1.0970         1.0964           101         54,8656         1.9130         10.563         1.9870         1.0964           101         59,8656         1.9130         10.563         1.9070         1.0964           114         65,6005         1.9130         10.563         1.9070         1.9060           121         71,2025         1.9136         1.9136         1.9070         1.9060           128         77,025         1.9164         1.9070         1.9060           137         82,0164         1.9164         1.9070         1.9070           138         83,026         1.9072         1.9072         1.9072           138         <	,	) Y	78.5601	2.06704	3. 16.00	3.7140	2H/5"	1.1791	16.50002.
75 34-1076	, ,,		10.9355	2.04773	3.5882	3.R956	1.9740	1.0944	1Cally(in )
80 38.1200 1.95459 4.7635 5.48f9 1.9410 1.0970 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	) <del> </del>	7.5	34.1076	2.00748	4.0.62	4.5149	0472-1	,	
86         42.9459         1.93079         5.6365         6.0638         1.9875         1.90724         1           93         48.3700         1.97093         6.6633         6.6485         1.9767         1.9767         1           100         54.0846         1.91293         7.8376         6.5485         1.9476         1           101         59.8626         1.91393         10.5637         1.9447         1.9446         1           114         65.6005         1.9139         10.5637         1.91295         1.91049         1           121         71.5024         1.91295         12.1200         6.5333         1.9072         1.1073         1           128         77.0252         1.91356         1.5683         1.9073         1         1.9073         1           13         82.9164         1.91426         1.5.7613         1.9072         1.1058         1           137         83.0364         1.9072         1.9072         1.9072         1.1058         1			38.1700	•	4.1635	N. 6 2F. 9	0146-1	15001	
93	9.0	9 9	42.9459		5-6365	6.0438	1. AC 45	0.60.1	10.40.40.1
100         54.0846         1.91620         7.8176         6.4485         11.9175         1.91847         1.91848         1.91	3.7	63	4 H. 3700	1.92093	6.6633	6.3341	I CHT.	******	10.404.0
107   59.8626   1.91393   9.1392   6.5107   1.91991   1.01993   1.91393   1.91393   1.91393   1.91393   1.91393   1.91393   1.91393   1.91393   1.91393   1.91393   1.91393   1.91393   1.91394   1.91394   1.91394   1.91394   1.91394   1.91394   1.91394   1.91428   1.5.7513   6.4727   1.9928   1.1058   1.9164   1.9164   1.91658   1.91658   1.91648   1.91658   1.91688   1.91658   1.91658   1.91658   1.91658   1.91658   1.91658   1.91658   1.91658   1.91658   1.91658   1.91658   1.91658   1.91	38	100	54.0846	1.91020	1.416	6.4485	F 1 2 5 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	******	10467401
114 65-6005   1-91300   10-5634 6-5333   1-9707   1-10	3.9	101	54.8626	1.91393	9.1392	6.5077	07 477	#470 ·	
2	04	*11	65.6005		10.5631	6.5333	20:6-1		
128	7	121	71. 3024	1.91245	12-1700	6.57.83	21661	1.1073	
3		178	71.0252	1.91356	13.8246	6.4985	[:6b*]	20101	
137 83.0364 1.91428 15.7513 6.4727 1.9928 1.1048 1.	- e		A7. R.164	6	15.5R&1	6.4.73	1666	# 10 P = 1	10+11.
	* *		,	3	15.7513	6.4727	8600°1	1.1058	164025171
	,	107	•	7.7.4		1			

# 3-D MOMENTUM ENTRGY INTEGRAL TECHNIQUE

STREAM INE	ii R	(1)661					11111					
			S	×	<b>&gt;</b>	7	~	<b>&gt;</b>	<b>&gt;</b>	7		
		9.26	0.554	-0.591	200 *0	0.215	10.026	-2.530	0.026	9.445		
BGDV PI NO	INTEG PT NO	STREAMLINE  Z  I IM I	LOCAT ION PHI IDEGI	METRIC COFFFICIENT	NT NT	BANGLE FOFG)	EDGE PRESSIPE (ATM)	BALI TEMPI PATURE (DEGR)		Hermaniant	RECOVEDY FNIMALPY (BINZIBM)	FIFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
	-	44690000	0				25. 9645	36 0761	2004	5	40.48.04	0040040
	P-	•	90.0	4.004.00	203	00°00	25.5666	7171.28	3.2432E-0	20-01	12 - 12 54	# 1775 F. B
	- p-	5.34410-02	0.29	33090	: :	15.46	73.7139	7091.73	3.11.340-	£0-01	#6 ct 64	6.8F JRD-01
	gard yard	10-01/12-01	0.23	3.86740-01		65.10	20, 1347	7016.63	3.04320-	10-02	491 1.57	6.24639-11
	· E	2.15050-01	0.24	5.29430-01		55.18	16.0331	6899.57	7.47780-	70-UR	48 7F.4R	10-01629
	51	3.21540-01	6.25	10-01115.9	·	45.03	11.6339	6734.40	7. 19120	10 UZ	4810.46	16-911 234
	11	4.58900-01	0.26	7.56089-01	33	35.08	1.6666	0515°50	2.614In-Ul	10-01	4777.00	3,40,460-01
	19	6.04800-01	0.26	8.3 THAU-01	10	25.09	4, 7232	6728.40	2,197	7n-01	4723.33	7,51570-01
	21	7.53900-01	0.27	8.9087D-01	1.	15.23	2.7766	56.29.48	2.475	10 010	4479.20	1.80150-01
	23	1.38910+00	0.28	1.07440+00	00	15.40	2,1235	5197.59	2.114	(i)-(i)	4646.37	1.11199-11
	25	2.39530+00	0.31	1.40770+00	00	15.40	1.6721	48 FU . 22	2. talen-01	kn-01	4413.30	9, 084511-02
	27	3.66200+00	0.35	1.89050+00	6	15.40	1.4440	4677.95	2.293	10-01	4589.48	7.479113-02
	5.2	5.02540+00	0.40	2.51210+00	20	15.40	1.4027	4619.17	7.7 HOTO-01	10-06	4577.74	70-02-17-1
	31	6.37810+00	0.45	3.25510+00	2	15.40	1.4537	4415.78	2.789	10-01	4554.51	7,36440-02
	33	7.67020+00	0.51	4.11530+00	90	15.40	1.5570	4651.85	2.790	10 11	4434.48	7.47100-02
	35	8.8809D+J3	0.56	5.070RD+00	20	15.40	1.6693	4696.16	2.297	10-01	4520.78	8.05441)-02
	37		0.63	6.12380+00	00	15.44	1.1425	49 RI . 52	2-30600-01	10-00	4514.50	10-01250-1
	34		0.69	7.25980+00	90	15.40	1016.1	55 15.65	2.477	รเก-01	4510,19	1.768211-01
	<b>4</b>		0.76	K. 4906D+00	3	15.40	2.00A2	5H55.19	2.73660-01	4 <b>0-</b> 01	4567.90	7,70719-01
	E		0.43	4.84UID+00	2	15.40	2.0802	2943.11	Z. # 15.	10-01	4511.24	10-05061.
	5		96.0	10+01061-1		15.60	2.1202	5972.58	2. R64 417-111	11. C.	4564.72	le-debite
	-		0.0	10+05062*1	<b>.</b>	03.61	1861.2	26° 1864	Z. RHO	10-01	210154	16-06 t 05 E
	<b>0-</b> •	1.70470401	1.05 1.13	10+0599951	<b>.</b>	15.40	7.1267	50HZ .51	2. AB 2413-	ان از ان از	4241.14	10-45-75
		10.00.00	ייר ר		: 3		7801.7	5040 53			1000	וס-מבאנא ב
	<u>,</u>	104080401	7701	2.1410+01		15-60	7.0637	50 P 1 P 1 P 2 P 2 P 2 P 2 P 2 P 2 P 2 P 2	10-02-798-2	10-00	45.16.62	3.4.22(12(1)
	` <b>`</b>	2-05220+01	56.	2.379401	: =	15.40	2.0455	5454.A6	2.85170	70 · 67	7 7 7 7 7 7 7 3 3	10-03961-1
	20	10+01081*7	65-1	2.67620+01		15.40	2.0179	5444 aR6	2. H 52	10-UH	44.88.54	1,387/11-11
	19	2.31 440 +01	1.59	3.00950401	10	15.40	2.0275	5947.12	2. H5020-01	10-04	4497.1A	10-01871.1
	63	2.45670+01	1.70	3.38170+01	10	15.40	2.0753	5944.16	2. R55	51F J1	44 76.50	3.37771-01
	65	2.60560+01	1.82	3.79460+01	5	15,40	2970-2	16.1308	2.84 320-01	20-01	4471.50	10-07475-E
	89	2.76820+01	45 T	10+06.252**	70	11.00	1.167.1	5641.16	2.633	10-01	44R7.19	10-0-101.2
	7.1	3.00440+0[	2.12	4.8 3A00+01	11	11.00	0.91UA	5 3 4 4 . 43	2.50170	70.01	4475.12	10-010-01
	15	3.31990+01	2.37		11	11.00	0.8693	11.4965	2.4934P-	10-03	4463.99	10-02407-01
	0.8	3.71900+01	2.12	6.98400+U	10	10.49	1568.0	5401.43	2.51 150-01	5 <b>n</b> -01	60 2 5 9 9	1.68610-01
	98	4.19890+01	3.20	B . B 2 120+01	31	10.99	0.836.4	53.54.26	7.513	M-01	444M.07	1.68610-01
	# 5	4. 73830+01	3.50	1.13030+02	02	10.94	U. 8974	2404.40	7.515AI-	A-1-01	4444.24	1.49741-01
	100		4.53	1.446.70+07	25	10.01	0.4173	5419.60	2.522011-0	10-00	444.00	10-011751
	101	5.881 30 +ut	5.36	1.83420+02	20	10.98	0.7403	5437.95	2.52710-01	10-01	4446,11	1,157411-01
	<b>†</b> 11	10+00254*9	67.9	2.79840+07	20	10.01	0.36.30	5449.46	-110£ £ 5 ° Z	เบ-เน	4444.4]	10-07782
	121	7.01930+01	7.36	2.85250+02	75	10.46	1.0055	54.11.33	10-00123.5	10-00	10. 1444	10-112058-1
	128	7.58820+GL	8.57	3.52570+02	25	96*0I	1.69.1	5488.18	7.549	5499B- 01	4447.40	10-(15574-1
	1 35	8.16410401	55.6	4. 10580+02	22	10.42	1.0515	21.5035	2.550	5507!1-UI	46.84.24	10-01014-1

## 3-D MOMENTUM ENEPGY INTEGRAL TECHNIQUE

### 15.76   0.554   -0.591   0.500   0	1	<b>~</b>	*			
INTEG STREAMLINE LUCATION METRIC FT NO L PHI CREFICIE (IN) LDEG)  1 3.449ED-03 -0.00 0.0			e	7		
INTEG   STREAMLINE LUCATION   National Pine   Land   Lan	0.016 0.215	5 10.026	-2.494	0.171 9.445		
1 3.44980-03 -0.00  7 1.26881-02 0.009  9 5.34410-02 1.35  11 2.15090-01 1.50  12 2.15090-01 1.65  13 2.27540-01 1.68  14 4.58000-01 1.86  22 2.39530+00 2.05  23 1.38910+00 2.05  24 2.39530+00 2.05  25 2.39530+00 2.05  27 3.66200+00 2.05  28 8.88000+01 4.36  41 1.20700+01 4.36  42 1.06000+01 5.91  43 1.06000+01 5.91  44 1.20700+01 5.91  45 1.06000+01 5.91  46 1.30600+01 1.92  47 1.50160+01 1.92  48 1.93000+01 11.92  49 2.18010+01 11.92  49 2.18010+01 11.92  40 2.45670+01 11.92  40 3.319900+01 17.77  86 4.198900+01 20.86  10 5.30640+01 24.31  11 5.01600+01 24.31  11 5.01600+01 12.74  11 3.00440+01 11.92  11 3.00440+01 11.93  11 3.00	C 800Y NT ANGLE (DEG)	EDGE PRESSUPE (ATM)	WALL TEMPFPATHRE COEGRI	PHEMOTHEM	PECOVERY Enthal Py (BTU/LAM)	HEAT TRANS EGFFFFFFFNI FERWARTZ-SFEF
7 1.26681-02 0-89 9 5.344[0-02 1.35 11 1.26681-02 0.89 11 1.2170-01 1.50 11 3.215090-01 1.55 12 3.215090-01 1.74 23 1.38410+60 2.32 23 2.39530+60 2.32 23 2.39530+60 2.32 23 2.39530+60 2.32 23 2.39530+60 2.32 23 1.38410+60 2.32 24 3.4620+00 3.71 33 1.66020+00 3.71 34 1.50160+01 6.91 45 1.50160+01 6.91 45 1.50160+01 6.91 47 1.50160+01 6.91 48 1.3060+01 10.56 63 2.45670+01 11.92 65 2.45670+01 11.92 68 2.45670+01 11.92 68 2.45670+01 11.92 69 2.18010+01 11.93 13 3.00440+01 11.274 14 3.00400+01 11.274 15 3.31990+01 17.77 16 5.45570+01 17.77 16 5.45570+01 17.77 17 3.00400+01 17.77 18 4.19890+01 29.31 11 5.45570+01 17.77 11 3.00400+01 17.77 11 3.		75.9665	7249.18	4.48083-03	10.8704	1.15020400
9 5.344[0-02 1.35 11 1.21770-01 1.50 13 2.15090-01 1.54 15 4.58900-01 1.55 19 6.08900-01 1.72 21 7.53900-01 1.72 23 1.38910-00 2.32 25 2.39530+00 2.32 27 3.65201+00 2.32 28 5.02550+00 2.32 29 5.02550+00 2.32 33 7.67020+00 3.71 33 7.67020+00 3.71 34 1.50770+01 6.91 45 1.50770+01 6.91 45 1.50770+01 6.91 46 1.50770+01 6.91 47 1.50770+01 6.91 48 1.50770+01 10.55 49 1.50770+01 10.55 49 1.50770+01 10.55 49 1.50770+01 10.55 49 1.50770+01 10.55 49 1.50770+01 10.55 49 1.50770+01 10.55 49 1.50770+01 10.55 49 1.50770+01 10.55 49 1.50770+01 11.92 40 1.50770+01 11.92 41 1.50770+01 11.92 42 2.18010+01 11.92 43 3.31990+01 17.77 46 6.331990+01 17.77 47 3.31990+01 17.77 48 6.45200+01 17.77 49 5.45570+01 17.77 40 6.93 7.7990+01 17.77 40 6.93 7.7990+01 17.77 40 6.93 7.7990+01 17.77 40 6.93 7.7990+01 17.77 40 6.93 7.7990+01 17.77 40 6.900+01 17.77 40 6.900+01 17.77 40 6.900+01 46.02	- 40	25-5665	07 11 11	3-76-03	4053.76	R. 276.5 De. 11
11   1.21770-01   1.50   13   2.15090-01   1.50		23, 7134	7091-11	3-11170-01	4039.98	A-84970-01
13   2.15090-01   1.59   15   3.27540-01   1.64   177   4.58900-01   1.72   19   6.04800-01   1.72   23   2.39530+00   2.32   2.39530+00   2.32   2.39530+00   2.32   2.39530+00   2.32   2.39530+00   2.32   2.39530+00   2.32   2.39530+00   2.32   2.39530+00   2.32   2.39530+00   2.32   2.39530+00   2.32   2.39530+00   2.32   2.39530+00   2.32   2.39530+00   2.39530+00   2.39530+00   2.39530+00   2.39530+00   2.39530+00   2.39530+00   2.39530+00   2.39530+00   2.39530+00   2.39530+00   2.39530+00   2.39530+00   2.39530+00   2.395300+00   2.395300+00   2.395300+00   2.395300+00   2.395300+00   2.395300+00   2.395300+00   2.395300+00   2.395200+00   2.295200+000   2.295200+000   2.295200+00   2.295200+000   2.295200+00   2.295200+000   2.295200+00		20,3339	7016.45	3.04240-01	4013.47	6-23840-01
15 3.27540-01 1.64 17 4.58900-01 1.72 21 7.53900-01 1.72 23 1.384910+00 2.02 23 2.39530+00 2.02 24 2.39530+00 2.02 29 5.02540+00 2.02 31 6.378100+00 2.03 33 7.67020+00 3.71 34 1.00090901 4.98 41 1.70700+01 4.98 42 1.10670+01 5.44 43 1.20700+01 6.91 44 1.20700+01 6.91 45 1.20700+01 1.98 45 1.20700+01 1.98 46 1.20700+01 1.98 47 1.501600+01 6.91 48 1.300400+01 11.92 48 2.45670+01 11.92 48 4.19890+01 12.74 49 3.31990+01 13.86 49 3.31990+01 17.77 86 4.19890+01 20.86 10 5.30670+01 24.31 115 6.45200+01 24.31 115 6.45200+01 40.02		16.0372	6898. RB	10-01416-5	4876.47	5.47070-01
17    4.58900-01   1.68   19    6.04800-01   1.72   1.53900-01   1.74   23   1.53900-01   1.86   23   2.39530+00   2.65   2.65		11.6130	67 14.45	2. 791 39-01	4830.45	4.44777-01
19	<b>~</b>	T.665B	6514.W	2.61780-01	4774.98	10-05057-6
21 7.539CD-01 1.74 23 1.38910+60 1.86 25 2.395310+60 2.32 27 3.665C10+00 2.32 29 5.0254D+00 2.32 31 7.670C0+00 3.32 33 7.670C0+00 3.37 34 1.00C0910+01 4.98 43 1.306C00+01 4.98 45 1.306C00+01 5.44 45 1.306C00+01 5.44 45 1.306C00+01 5.44 45 1.406C00+01 1.406 65 2.456C00+01 11.92 66 2.456C00+01 11.92 67 3.319900+01 17.77 86 4.198900+01 20.86 93 4.73830+01 24.31 115 6.452C00+01 24.23		4.1221	6227.61	2.39680-61	4723,32	2,51280-01
23 1.38910+60 1.86 25 2.39530+60 2.06 27 3.66261+00 2.32 29 5.02540+00 2.32 31 6.37810+00 3.71 35 1.67020+00 3.71 37 1.00090+01 4.98 43 1.767020+01 4.98 44 1.70770+01 4.98 45 1.40670+01 5.41 47 1.50170+01 5.41 48 1.81669+01 7.46 55 1.81669+01 7.46 57 2.0520+01 11.92 68 2.16670+01 11.92 68 2.45670+01 11.92 68 2.45670+01 11.92 69 2.18010+01 11.92 69 2.18010+01 11.92 69 2.45670+01 11.92 69 2.45670+01 11.92 69 2.45670+01 11.92 69 2.45670+01 11.92 69 2.45670+01 11.92 69 2.45670+01 12.74 75 3.31990+01 17.77 86 4.19890+01 20.86 93 4.73830+01 24.31 115 6.45200+01 46.03		2,1723	56 18, 50	2.47560-01	4679-17	1.7964.1-111
25		2.1198	5185.59	7. 41 6 40 - 01	46.444	1.14010-01
27 3.66260.00 2.32 31 6.37810.00 2.652 33 7.67020.00 3.371 35 8.886260.00 3.371 37 1.00090.01 4.98 41 1.7070.01 4.98 43 1.30600.01 5.44 45 1.40340.01 5.41 47 1.50160.01 5.41 51 1.70470.01 6.41 51 1.70470.01 7.44 52 1.93090.01 7.44 53 2.6620.01 12.74 61 2.31450.01 11.92 61 2.45670.01 11.92 62 2.46670.01 11.92 63 2.46670.01 11.77 63 3.31990.01 17.77 86 4.19890.01 24.86 100 5.30670.01 24.86 115 6.45200.01 24.86	-	1.5707	48 76. 54	2,10150-01	1411.25	9-06-773-02
29 5.02540+00 2.62 31 6.37810+00 2.95 33 7.67020+00 3.37 35 8.88450+00 3.71 37 1.004090+01 4.94 41 1.7070+01 4.94 43 1.30600+01 5.44 45 1.40340+01 5.91 47 1.50160+01 6.40 51 1.40340+01 6.40 52 1.40500+01 1.96 53 2.45670+01 11.92 68 2.45670+01 11.92 68 2.45670+01 11.92 68 2.45670+01 11.92 69 2.18010+01 11.92 68 2.45670+01 11.92 69 3.31990+01 13.86 75 3.31990+01 13.86 76 4.19890+01 24.84 100 5.30640+01 24.84 115 6.45200+01 24.84	-	1.4419	4675.39	2.29300-01	4589.40	7-66161-02
31 6.3781D+00 2.95  33 7.6702D+00 3.32  34 1.060901+01 4.34  41 1.2070+01 4.34  43 1.060901+01 4.34  43 1.30600+01 5.44  45 1.40340+01 5.91  47 1.50160+01 5.91  47 1.50160+01 5.91  51 1.7067000 1 7.46  53 1.40670+01 7.46  54 2.46670+01 11.42  65 2.46670+01 11.42  65 2.46670+01 11.42  68 2.46670+01 11.42  68 2.46670+01 11.42  69 3.319901+01 13.86  10 3.30640+01 17.77  86 4.198901+01 20.86  11 5.45830+01 24.31  115 6.45200+01 46.93  115 6.45200+01 46.23	-		4606-71	2.789AD-01	45.72-04	7.250411-02
33 7.67020+00 3.32 35 8.88090+00 3.71 37 1.004901+01 4.12 39 1.10670+01 4.98 43 1.30640+01 5.91 47 1.50160+01 5.91 47 1.50160+01 5.91 49 1.60230+01 6.91 51 1.70670+01 7.98 53 1.93090+01 7.98 55 1.93090+01 11.92 61 2.45670+01 11.92 62 2.18010+01 11.92 63 2.45670+01 11.92 63 2.45670+01 11.92 64 2.45670+01 11.92 65 2.45670+01 11.92 65 2.45670+01 11.92 66 2.45670+01 11.92 67 3.31991+01 13.88 68 4.19891+01 17.77 86 4.19891+01 20.86 93 4.73830+01 24.31 115 6.45201+01 24.26 110 5.30570+01 24.23	15,39	1.6696	4611.15	2.28960-01	4556.47	7.11740-02
35 8.86C90.000 3.71 37 1.00090.01 4.12 39 1.106.70.01 4.98 43 1.306.00.01 5.44 45 1.306.00.01 5.44 45 1.406.00.01 5.44 47 1.501.60.01 5.41 51 1.706.70.01 7.98 53 1.816.00.01 7.98 55 1.930.90.01 7.98 55 1.930.90.01 11.92 65 2.1601.01 11.92 65 2.456.70.01 11.92 65 2.456.70.01 11.92 68 2.456.70.01 11.97 68 4.19890.01 13.88 75 3.31990.01 17.77 86 4.19890.01 20.86 93 4.73830.01 24.31 115 6.452.00.01 46.02	-	1.5464	4647.47	7.29060-01	45.19, 39	1.04087-02
37 1.00090+01 4,12  39 1.10670+01 4,98  43 1.30600+01 5,44  45 1.40340+01 5,44  47 1.50150+01 6,91  51 1.70670+01 7,44  53 1.81603+01 7,44  55 2.18010+01 9,16  59 2.18010+01 10,46  63 2.45670+01 11,92  68 2.45670+01 11,92  69 2.18010+01 11,92  61 2.45670+01 11,92  62 2.60560+01 11,92  63 2.45670+01 11,92  64 2.45670+01 11,92  65 3.31990+01 17,77  86 4.19890+01 20,86  93 4.73830+01 24,31  115 6.45200+01 46,02	_		4691.03	2.79180-01	4520,49	F.01740-02
39 1.10670*01 4.54 41 1.20770*01 4.98 43 1.30600*01 5.44 45 1.40360*01 5.44 47 1.50160*01 5.41 49 1.60230*01 5.41 51 1.70670*01 7.44 53 1.81600*01 8.56 53 2.18010*01 9.16 54 2.18010*01 10.46 63 2.45670*01 11.92 68 2.7650*01 11.92 68 2.7650*01 11.92 69 2.18010*01 12.74 11 3.00440*01 11.92 69 3.71900*01 17.77 86 4.19890*01 20.84 93 4.73930*01 20.84 93 4.73930*01 20.84 115 6.45200*01 46.02	-	1. 1833	4974. RA	2,10570-08	4514.41	10-02920-01
41 1,2070+01 4,98 43 1,30600+01 5,44 45 1,40340+01 5,44 47 1,50160+01 6,40 49 1,60230+01 6,44 51 1,70670+01 7,98 53 1,81640+01 7,98 55 1,9340+01 17,98 55 2,18010+01 9,79 61 2,31450+01 10,42 65 2,45670+01 11,42 65 2,45670+01 11,42 65 2,45670+01 11,42 65 2,45670+01 11,42 65 2,45670+01 12,74 71 3,00440+01 12,74 86 4,19890+01 20,84 93 4,73830+01 20,84 115 6,45200+01 46,02 115 6,45200+01 46,02	-	1.8903	5523.38	2,46580 01	453A.1R	10-080-1
43 1-30600401 5-44 45 1-40340101 5-91 47 1-60120101 5-91 51 1-40340101 6-40 52 1-60230+01 7-98 53 1-81640+01 7-98 55 1-93050+01 8-56 57 2-05220+01 9-79 61 2-314590+01 11-42 65 2-45670+01 11-42 68 2-45670+01 11-42 68 2-45670+01 11-42 68 2-45670+01 11-42 68 2-45670+01 11-42 68 2-45670+01 12-74 75 3-31997+01 12-74 86 4-19890+01 20-86 100 5-30670+01 24-31 115 6-45200+01 40-02		1.4470	5847.75	10-06621.5	4567.21	2.67250-01
45 1.4034010 5.91  47 1.501603-01 6.40  51 1.706720-01 7.96  53 1.81603-01 7.96  55 1.93090-02 8.56  57 2.05270-01 10.46  63 2.45670-01 11.47  65 2.46670-01 11.42  68 2.76650-01 12.74  71 3.00440-01 12.74  75 3.31997-01 12.74  76 4.19890-01 17.77  86 4.19890-01 20.86  93 77900-01 20.86  93 77900-01 20.86  93 77900-01 20.86  100 5.30670-01 20.86	_	2.0680	5938.39	10-01118.2	45 71 .01	3-107711-01
47 1.501605-01 6.40 49 1.60230+01 6.41 51 1.70670+01 7.44 53 1.81603+01 7.44 55 1.93090+02 8.56 57 2.05270+01 9.79 61 2.31450+01 10.46 63 2.45670+01 11.42 68 2.45670+01 11.42 68 2.45670+01 11.42 68 2.45670+01 11.42 68 4.75870+01 17.77 86 4.19890+01 20.86 93 4.75870+01 20.86 93 4.75870+01 20.86 93 4.75870+01 20.86 93 4.75870+01 20.86 93 4.75870+01 20.86 93 4.75870+01 20.86 93 4.75870+01 20.86 93 4.75870+01 20.86 93 4.75870+01 20.86	<b>,</b>	2.1 082	5968.74	2.46590-01	4564.15	3.24960-01
51 1.70670601 7.44 53 1.81607601 7.44 55 1.93090601 8.56 57 2.05270601 9.16 59 2.18010601 10.46 63 2.45670601 11.92 68 2.45670601 11.92 68 2.45670601 11.92 68 2.45670601 11.92 68 2.45670601 11.92 68 4.1990401 17.77 86 4.1990401 20.84 93 4.73930401 24.86 100 5.30670401 24.86 115 6.45200401 46.02	15,36	2.1216	5978.51	Z-N7750-01	4553.17	3.785711-01
53	~ (	2511.5	59.6165	Z-81990-01	4541.29	3.41610-01
55 1.93090401 8.56 57 2.0520401 9.56 58 2.18018401 9.79 68 2.18018401 10.46 68 2.45670401 11.92 68 2.45670401 11.92 68 2.45670401 11.92 68 2.45670401 11.92 68 2.45670401 11.92 68 2.45670401 12.74 71 3.00440401 13.88 75 3.31990401 17.77 86 4.19891401 20.86 93 4.73830401 20.86 93 5.30670401 24.31 115 6.45200401 46.02	,	2.0473	5973.73	2. R 7500-01	4579,19	3.41750-01
57	-	7.075	16.4306	2.R4850-01	4517.86	3.40FGD-01
59 2.18010+01 9.79 61 2.31670+01 10.46 63 2.45670+01 11.92 68 2.76670+01 11.92 68 2.76670+01 11.92 71 3.00440+01 12.74 71 3.00440+01 12.74 86 3.71900+01 17.77 86 4.73830+01 20.86 100 5.30670+01 24.81 115 6.45200+01 40.02	┥,	\$140°Z	3628	2. P.C. 16.0-01	4204. RI	10-11-766
61 2.31450+01 10.46 63 2.45670+01 10.46 65 2.45670+01 11.92 68 2.76620+01 12.74 71 3.00440+01 12.74 75 3.31990+01 15.49 80 3.71900+01 17.77 86 4.73930+01 24.86 100 5.30670+01 24.86 115 6.45200+01 40.02 115 1.01900+01 40.02	15.33	6160-7	50°1565	2.8540p-01	6497.52	3.17473-91
63 2.45670°01 [1.17] 65 2.45670°01 [1.92] 68 2.76620°01 [1.92] 71 3.00440°01 [1.74] 75 3.31990°01 [15.49] 80 3.71909°01 [17.77] 86 4.719890°01 [7.77] 86 4.73830°01 [24.66] 100 5.30670°01 [24.66] 115 6.45200°01 46.92	•	C - C - C	1741975	10-05-15-2	- 0 × 1 × 1	10-11-11-11-1
65 2.6650.01 11.92 68 2.76620.01 11.92 68 2.76620.01 12.74 71 3.00400.01 12.74 80 3.71900.01 15.49 80 3.71900.01 17.77 86 4.19890.01 20.84 93 4.73830.01 24.84 100 5.30670.01 24.31 115 6.45200.01 46.02	•	2,000.2	5017 43	2 05150	1797644	יייייייייייייייייייייייייייייייייייייי
68 2.76620+01 12.74 71 3.00440+01 12.74 75 3.31990+01 15.49 80 3.71900+01 17.77 86 4.19890+01 20.84 93 4.73930+01 24.66 100 5.30670+01 29.21 108 5.88130+01 46.02	-	1.4289	50.11.08	2-44740-01	4410933	30 4 4 4 5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
71 3.00440.61 13.88 4.771 75 3.31991.401 15.49 5.616 80 3.71900.401 17.77 6.864 86 4.19891.401 20.84 8.623 100 5.30670.401 24.24 1.984 108 5.88130.401 34.31 1.718 115 6.45200.401 40.02 2.1718	~		5630-47	2.62670-01	66 BF . 5.8	7.14840-01
75 3.31990+01 15.49 5.616 80 3.71900+01 17.77 6.864 93 4.73830+01 24.86 1.986 100 5.30670+01 29.21 1.384 108 5.88130+01 34.31 1.718 115 6.45200+01 40.92 2.178	-	0.8419	5374.80	2.49580-01	44.74.A3	1-41110-01
80 3.71900+01 17.77 6.864 86 4.19801+01 20.84 8.623 93 4.73830+01 24.66 1.086 100 5.30670+01 29.21 1.384 108 5.88130+01 34.31 1.718 115 6.45200+01 46.02 2.178	-	0.8474	5379.60	2-48230-01	6663.91	1.55990-01
86 4.19890+01 20.84 8.623 93 4.73830+01 24.86 1.086 100 5.30670+01 29.21 1.384 108 5.88130+01 34.31 1.718 115 6.45200+01 46.02 2.178 122 7.01900+04 46.23 2.553	· ¬	0.4407	5772-14	2.50010-01		10-0115-01
93 4.73830+01 24.66 1.086 100 5.30670+01 29.21 1.384 108 5.88130+01 34.31 1.718 115 6.45200+01 46.02 2.121 122 7.01900+01 46.23 2.553		12480	5167.34	2.44 M9-C1	4444.98	1.61760-01
100 5,30670+01 29,21 1,384 108 5,88130+01 34,31 1,718 115 6,45200+01 46,02 2,121 122 7,01900+01 46,23 2,553	_	0.8271	5345.96	2-48940-01	4445.08	1.5H410-01
108 5.88130+01 34.31 1.718 115 6.45200+01 46.02 2.121 122 7.01900+01 46.23 2.553	10.36	1128.0	5337. TR	. 10-015842	75.3554	1.57440-01
115 6.45200+01 46.02 2.121 122 7.01900+01 46.23 2.553	-	0.1479	51.0.115	2.47270-01	4463.72	10-0445-1
122 T.01900+01 46.23 2.553		U. 76AU	5277.11	10-00455.2	4447,08	10-00015-1
		0.7262	5227.91	2.41770-01		10-08105.1
7.58820401 53.13 2.131		11,4.0	51 50.06	2. 496 19-UE	15.1444	1.27701-01
136 8.16410+01 60.70 2	8.49	0.6192	5049,39	2.37670-01	05.0334	1.17001-01
C14.97   19.09   10.00		****	701000	**************************************		

TREAM INE	INE	BETA	SDNIC	PULL	LUCATION	2	TRAN	TRANSITION POINT ENCATION	I ENCATION	,		
<b>•</b>		(0=0)	2	×	<b>*</b>	7	S	×	>	•	•	
•		2-11	0.554	-0.591	0.020	0.215	10.026	-2.471	0.207 9.	9.145		
800Y PT NO	INTEG PI NO	STREAMLINE L (IN)	LOCAT ION PHI IUEGD	METRIC COEFFICIENT	IC ENT	BODY ANGLE (DEG)	FDSE PRESSIRE (ATM)	WALL TEYPERATURE (DEGR)	A-PP INF THFP MACHEM	PINE	RECOVERY FNHALPY (RTU/LAM)	HEAT TRANS CREFFICITYT (LAM/ETZ-SEC)
	,	1	,	•			4	44, 0344	.04000	[	40.4	1.15910403
<b>-</b>	•	4	0000	0.0	23	90.00	25.5665	7171.38	3.26350-01	10	4953.70	M. 175911-01
~ (	~ 0	1 -Constant	1.00	2.35890-01	7 6	75.46	23-7132	7091.09	3.11160	٠ -	4010.CM	
ი ∢	• ::	1.21.770-02	1.82	1.91710-01	5 6	65,29	20.1315	7016.54	3.04310	-01	4013.57	6.24010-01
•		-05051	8	5.36530-01		55.17	16.0317	6898.45	10-03410-2	-0	44 16.47	5.421511-01
٠.	5	3.27540-01	1.99	6.60550-01		45.02	11.6376	6734.0E	10-05052-21	-01	\$4.0.65	10-0513404
<b>,</b> ~	. 1	4.58900-01	0	7.65410-01		35.08	T.0655	6514.57	2.61310	10-	4776.98	3.46090-01
•	61	COS	2.08	8.47100-01	10	25.09	4.7225	6227.34	2. 39640	-01	4723.31	7.411AD-01
•		0-036E5*	-	9.00130-61	15	15.23	2.771.2	5637.60	2.47410	10-	4479-13	10-00-01
01	~	1.38910+00	2.26	. O.8	00	15.40	2.11RB	5185.79	0F41F.2	- -	4464.70	10-0-0-01
11	52	2,39530+00	Ÿ.	. 42	00	15.40	1.6704	487h.44	2° 301~0	10-	42° 4 10°	70-1112 40" 6
12	27	3.66200+0u	E	96	00	15.39		4676.66	2.29290-0		Brich Mc 4	10-0-0-0-10-10-10-10-10-10-10-10-10-10-1
13	50	02240	~	2.52560+60	αĵ	15.39		4605.66	11164292	-	70 0 7 1 1 1	10-11-11-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-
<b>+</b>	31	•	3.58	3.27340+00	Ş	15.39	•	\$6.11.94	7.25950	-01	040444	7 * 4 4 4 11 13 - 11 2
1.5	33	٠	0	4-13040+00	20 5	5.19	1.5450	4646.59	00000	7 :	F 4 5 F 6 F 6 F	0 01460-01
2	3.5	•	Ç	£ .	<b>3</b> ;	15.38	1099-1	(M. 0) 24			43/0045	1 07840-01
11	3.7	1.00090+01	2.00	-13	0 6	17.38	1.000	10.4764	2 44 700-01		750 000	1.75140-01
8	36	1.10670+01	15.5	. 77	90	75.51	1.8956	01.07.C	100 CER - C	7 5	76.00	2-7-140-01
61	1,	1.207705.1	<b>6.04</b>	3	ē,	15.37	1.9940	UX 4 / 4 / 4	מסטבת כ		16.1014	7 10480-01
20	£3	1.30400+01	6.59	¥ .	8 :	15.36	7.05.64	3436.63	7 8454D	<u> </u>	4471.13	3-10-00-01 3-79590-01
77	43	1.40340401	٠, '		, ,	65.63	7.01.7	E1177 77	7.87697	5 5	76.537	10-0E 18E 7
77	44	•	`•	•		15.33	701107	507H 71	7.87940-01		28-1955	3.41240-0
53	6 1	1040230401	0.00	10400037		15.23	2700 2	5073.00	2.R744D	5 =	4579.77	3.4157:)-01
₹;	14	•	•	Transport H			7.0717	5965-53	2. A6.R00	; <u>-</u>	4417,93	J. 40 : AD - 01
\$ 2	4 u		10.1		. 6	15.31	2.0470	5957.03	2.84050	-01	£0.4027	3.38650-01
2.7		2.05220+01		2.35910+01	10	15.30	2.0246	5948.59	2. A52RD	. c.	4497.67	10-041-31-61
2	. 0	2.18010+91	11.85	\$4	10.	15.29	2.0081	5943.68	2,84901)	<u>.</u>	44 88. R7	Id-Urnar.
2 6	4	•	12.66	16.	10:	15.21	1.9968	5934.14	2.84340	<u>-</u>	5482.15	10-09621.1
) <u>C</u>	63	45670+	13.52	.33	10,	15.25	1.9842	59 33. R3	1) OH L B - 2	<u>-</u>	4476.45	16-400Cr.81
31	65	•	14.43	• 75	10,	15.24	1.9863	59 30.12	2.M3670	10-	24.11.42	3.11950-01
35	67	2.76920+01	15.42	÷1•	10	10.82	1.7672	26.76.02	- (1997497)	- ;	F*****	ים-מכזרויי
33	70	3,00440401	18.91	. 11	ວຸ	10.78	0. AM 3A	7164-13		5 5 1 1	****	
34	*	3. 11990+01	18.76	5.61930+01	10	10.73	7 16 # 0	7 1. H + U6	-116-01-07	5	******	The Hades Co.
35	79	3,71900+01	21.49	10-02/18*9	10.	10.65	0.8454	5356.11	Z. 497 dn-	101	25.7.55	10-05-05-1
39	89	٠١.	25.17	10+01/665-8	10.	10.52	0.11708	5141.06	-11%/ 85 °2	<del>.</del> :	D 5 0 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	10-01-41-01
31		4.73430+01	29.80	£2.	.02	10.34	0.R003	5171.72	7.67HRD-01	<u> </u>	X	10-(13-4-1
3.6	97	. 30h	~	1.35420+02	<b>20</b> .	10.09	0.7786	5296.04	7.44.74	5 6	100,444	10.40/04.1
33	105	30+0	1.2	\$4.	.02	41.6	11 57 0	\$2.56.36 6.67.26		= = = = = = = = = = = = = = = = = = =		10-05-57
0.	711	4.45700+01	7.9	• 05	20.	9 ° ° ¢	0.6941	7000	(			
<b>!</b>	611	9	•	•	20.	H.R?	٠	51.71.40	2. (49) (1-0)	1 2	******	10-11-11-11-1
75	126	.58#2U+	3°T	~ * 5	20	8.27	7405.0	24.00	0 -01 177 6	 	£6.2777	2.40970-71
£,	133	.16410+	0, (	# 15 to	2	20*41	1.4748	36.43.36 56.63.36	10-0190E9-7	; ;	40.444	7.75 4011-111
<b>‡</b>	135	8 .1 86 0D + 0I	10.04	Z • 8 36 3U • U Z	?0.	70.41				5		
						Fish	מונו נונים					
						001100						

### 3-D MOMENTUM ENERGY INTEGRAL TECHNICHE

3.54 0.554 -0  3.54 0.554 -0  INTEG STREAKLINE LUCATION  PI NO	NTEG   STREAMLINE   COATION   COEFFICIENT   ANGLE   THEORETIAN   COATION   COEFFICIENT   ANGLE   THEORETIAN   COATION   COEFFICIENT   ANGLE   THEORETIAN   THEORETIAN   COATION   COEFFICIENT   ANGLE   THEORETIAN	D												
NETE STEGACLINE LOCATION   NETHER   BOTA   NATION   NAT					S		<b>&gt;</b>	~	ĸ	×	<b>&gt;</b>	7		
NITEG   STREAMLINE LOCATION   NETRIC	NITE   STREAKLINE LOCATION   NETRIC   NET   NE	10		3.54	0.554	0	0.033	0.215	10.027	-2.476	0.346	9.44.9		
1.122(1909-01)   3-15	1.12(1909-01)   3-45   3-45(190-01)   3-45   3-45(190-01)   3-45(190-01)   3-45(190-01)   3-45(190-	BODY T NO	INTEG PT NO		LOCAT 10N PHI (OEG)	METRI COEFFICIE	-	BADY NGLF (DEG)	EDGF PRESSUME (ATH)	WALL TEMPFRATUR (DEGP)		N-PRIME	AFCOVERY ENTHALPY (RTU/LBM)	-
1.244480-02   0-00   0-00   0-10   0-111   0-11111   0-1111   0-1111   0-11111   0-11111   0-11111   0-11111   0-1111   0-1111	1.24460-02   -0.00						•	•		6,6		10.03	40.42.04	1587
1.120800001	1.12.0000001	_	-	Ž,	9	٠	,	00.00	27.4643 35.5647	7111.24	7.76	10-07	4953.70	17740
1.217190-01	1.217780-01 3.22 5.5970-01 5.77 10.000	~	<b>-</b> ,	7	•	000		74.00	200: 112	7041.07	7	10.05		Š
11   2.1500/0-10   3.25   5.3410-01   5.01   1.000	11   2.15000-01   3.15   5.35470-01   5.417   5.407   5.414-4   5.74710-01   4.474-4   5.75400-01   3.15470	Α.	7 :	,	•				20.1314	7016.64	3.04	10-066	4913.55	F. B. T.
13	13	•	7 :	10-61/17/1	• •			55.17	16.0292	6 HOB - 80	2.030	10-014	48 7F.44	5.41497-01
1	17	<b>.</b>	M	02041.	7 ~			50.07	11.6301	6733.96	2.79	10.050	4830.42	.44 159
19	1	۱ ن	n •	10-05000	•			35.07	7.6612	6514.43	2.41	10-001	4774.94	10-5,049.1
21         755900-01         354         8.9370-01         15.22         2.1570         5657.44         2.24450-01         4472-01           23         1.18900-01         3.18         1.48170-01         15.39         1.4890         4872-19         2.31450-01         4472-19           23         2.2450-00         4.10         1.59300-00         15.38         1.4840         4672-19         2.3750-01         4872-19           24         5.2650-00         4.10         1.59300-00         15.31         1.4440         4605-21         2.3750-01         4872-19           24         5.2650-00         6.74         4.12,400-00         15.31         1.4440         4605-21         2.3750-00         4872-19           31         6.3750-00         6.74         4.12,400-00         15.31         1.5400-00         15.31         1.5400-00         15.31         1.5400-00         15.31         1.5400-00         15.31         1.5500-00         2.5400-00         15.31         1.5500-00         2.5400-00         15.31         1.5500-00         2.5400-00         15.31         1.5500-00         2.5400-00         15.31         1.5500-00         2.5400-00         15.31         1.5500-00         2.5400-00         1.5500-00         2.5400-00         1.5500-	21         75         8.95420-01         15.45         8.95420-01         15.22         2.1872         2.1872         2.1872         2.31470-01         447201           22         2.29530-00         4.18         1-181670-00         15.39         1-6892         4671.36         2.2970-01         4872.31           23         2.29530-00         4.18         1-181670-00         15.39         1-6892         4671.36         2.2970-01         4872.31           24         2.29530-00         4.18         1-181670-00         15.39         1-6892         4672.30         2.2970-01         4872.31           25         2.2540-00         4.18         1-181670-00         15.31         1-181670-00         2.2970-00         15.31         1-18170-00         2.2970-00         4872.31         2.2970-00         2.2970-00         15.31         1-18710-00         2.2970-00         15.31         1-18710-00         2.2970-00         15.31         1-18710-00         2.2970-00         15.31         1-18710-00         2.2970-00         15.31         1-18710-00         2.2970-00         15.31         1-18710-00         2.2970-00         15.31         1-18710-00         2.2970-00         15.31         1-18710-00         2.2970-00         2.2970-00         15.2970-00 <td< td=""><td>٠.</td><td>- 0</td><td>0-00490</td><td></td><td></td><td></td><td>25.08</td><td>4. 7210</td><td>6777.33</td><td>2.39</td><td>550-01</td><td>4773.2A</td><td>7.51147-01</td></td<>	٠.	- 0	0-00490				25.08	4. 7210	6777.33	2.39	550-01	4773.2A	7.51147-01
2.5   2.195(3)   2.6   1.00   1.00   1.5.30   1.5.30   1.5.40   45.6.40   2.5.50	1	<b>.</b>		10-000000		99.		15.22	2.1670		7.4.2	4 3D-01	46.79.01	1.79810-01
27 3.36573-00 4.10 1.45781-00 15.30 1.4592 4615.0 2.3070-01 4414.1 2.30570-00 5.31 2.52751-00 15.30 1.4592 4615.0 2.257270-01 4414.1 2.50570-00 5.31 2.52751-00 15.30 1.444.4 4605.21 2.527070-01 4517.31 1.4912 4615.24 2.57870-01 4517.31 1.4912 4615.24 2.57870-01 4517.31 1.4912 4615.24 2.57870-01 4517.31 1.4912 4615.24 2.57870-01 4517.31 1.4912 4617.31 1.4912 5.0570-01 7.55 4.4570-01 1.55 1.444.4 4605.21 2.57870-01 4517.31 1.4912 5.0570-01 4517.31 1.4912 5.0570-01 4517.31 1.4912 5.0570-01 7.55 4.4570-01 1.511 8.45791-01 1.511 8.4	25         2.395570-00         4.16         1.45120-00         1.539         1.4592         4618.10         2.307670-01         4618.10         2.307670-01         4618.10         2.307670-01         4618.10         2.307670-01         4618.10         2.307670-01         4618.10         2.307670-01         4618.10         2.307670-01         4618.10         2.307670-01         4618.10         2.307670-01         4618.10         2.307670-01         4618.10         2.307670-01         4618.10         2.307670-01         4618.10         2.307670-01         4618.10         2.307670-01         4618.10         4618.10         2.307670-01         4618.10	٠.	17	90+016HE-1	`	. U.B.	2	15.39	2.1152	5184.29	2.31	10-014	4646.07	10-UC # 5 1 - I
27 3.662@0+00 4.71 1.899@0+00 15.38 1.4472 4657.31 2.229470-01 4577.53 1.4444 4605.21 2.229470-00 5.31 2.22959+000 15.37 1.4444 4605.21 2.229470-01 3.76900+00 15.37 1.4444 4605.21 2.229470-01 3.76900+00 15.37 1.4444 4605.21 2.229470-01 3.76900+00 15.37 1.4444 4605.21 2.229470-01 3.76900+00 15.37 1.4444 4605.21 2.229470-01 3.76900+00 15.34 1.7722 4640.46 2.270470-01 4.77024 33 1.106400+01 10.01 9-22 7.257010+00 15.34 1.7722 4640.46 2.270470-01 4.77024 43 1.20770+01 10.01 9-622.21-01 10.01 9-622.21-01 10.01 9-622.21-01 10.01 9-622.21-01 10.01 9-622.21-01 10.01 9-622.21-01 10.01 9-622.21-01 10.01 9-622.21-01 10.01	27 5.05.20.00 4.70 1.89900000 15.30 1.5072 4005.01 2.2570.01 4575.31 2.2570.00 4.70 1.89900000 15.30 1.5072 4005.01 2.2570.01 4.56 6.1020.000 15.30 1.5072 1.5071 4005.01 2.2570.01 4.56 6.1020.000 15.30 1.5072 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 4005.01 2.2570.00 15.30 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 4005.01 6.30 6.1020.000 15.30 1.5072 4005.01 12.30 6.1020.000 15.30 1.5072 4005.01 12.30 6.1020.000 15.30 1.5072 4005.01 12.30 6.1020.000 15.30 1.5072 4005.01 12.30 6.1020.000 15.30 1.5072 4005.01 12.30 6.1020.000 15.30 1.5072 4005.01 12.30 6.1020.000 15.30 1.5072 4005.01 12.30 6.1020.000 15.30 1.5072 4005.01 12.30 6.1020.000 15.30 1.5072 4005.01 12.30 6.1020.000 15.30 1.5072 4005.01 12.30 6.1020.000 15.30 1.5072 4005.01 12.30 6.1020.000 15.30 1.5072 4005.01 12.30 6.1020.000 15.30 6.1020.00	2 =	, ,	2,39530+00	-	. 4.	5	15.39	1.6690	876.	2.30	150-01		9.08273-02
29         5.05540+00         5.31         2.5260+00         5.31         1.5361         1.5361         2.58050-01         4572.31           31         7.67620+00         6.00         3.75800+00         15.34         1.537         465.24         2.58050-01         4572.31           35         6.00         3.75800+00         15.34         1.6571         466.22         2.58050-01         4572.31           37         1.0000+00         6.12030+00         15.34         1.6571         466.22         2.58050-01         4571           41         1.20070+01         10.11         9.60570+00         15.34         1.00070+0         2.5000-01         4571         1.00070+0         4571         1.00070+0         4571         1.00070+0         4571         1.00070+0         4571         1.00070+0         1.00070+0         1.500         2.00077         4571	29         5.05540+00         5.31         1.25050+00         15.31         1.3961         1.5467         4665,21         2.25030-01         4572,31           31         7.67020+00         6.00         3.2500+00         15.34         1.5497         4662,24         2.26030-01         4572,31           35         8.40000+00         6.1203+00         15.34         1.772         2.0467         2.2946-01         4572           37         1.00000+01         6.1203+00         15.34         1.772         2.0467         2.3956-01         4572           41         1.00000+01         10.21         1.4467         5.16.21         2.3956-01         4571           41         1.20770-01         10.31         1.4447         5.16.22         2.4400-01         4571           41         1.20770-01         10.31         1.4447         5.16.22         2.4400-01         4571           41         1.20770-01         11.01         4.6679-01         15.20         2.0477         2.7770-01         4571.01           47         1.50160-01         11.27         2.0487         597.04         2.86470-01         4571.01           47         1.20160-01         11.27         2.0487         597.04	• ^	27	3-66263+00	07.4	30	2	15.38	1.4372	613.	2.29	10-462	4589.33	7.64 780-07
1	1. 6.174(10+0) 6.00   12.80(10+0)   15.37   1.4444   4602.41   2.7876.01  4570.28     33	, ,,,	50	5-02540+60	5.31	55.	20	15.38	1,3961	4605.21	2.24	10-010	6577.53	70-070474
33 7.67C20************************************	33         7.4702000 6.74         4.12400000         15.36         1.5597         4.664.32         2.79167-0         4.704.0           35         1.00400000         6.1203000         15.34         1.7722         404.44         2.30767-0         4.51.47         1.70400000           37         1.00400000         6.1203000         15.34         1.7722         404.44         2.30767-0         4.51.47         1.7722         404.44         2.30767-0         4.51.47         1.7722         404.44         2.30767-0         4.51.47         1.7724         404.44         2.30767-0         4.51.47         1.7727         404.44         2.30767-0         4.51.47         1.7727         404.44         2.30767-0         4.51.47         1.7727         404.44         2.30767-0         4.61.77         404.47		- 11 - E1	6.37810+00	6.00	.7b	0	15.37	1.5444	4609.31	2.29	10-056		/D-(244/44)
35         8.88809801         7.54         5.016.5301         1.6531         464808         2.3965001         45.35         1.7552         49480800         2.3965001         1.53         1.7570         49480800         2.3965001         1.53         1.18472         5516.82         2.4670000         1.538         1.7570         4948000         2.3965000         1.538         2.04879         5946.22         2.4770000         4.518         2.4770000         1.538         2.04879         5946.22         2.4770000         4.518         2.04879         5946.22         2.4770000         4.518         2.04879         5946.22         2.4770000         4.518         2.04879         5946.22         2.4770000         4.518         2.04879         5946.22         2.4770000         4.518         2.04879         5946.22         2.4770000         4.518         2.04879         5946.22         2.4770000         4.518         2.04879         5946.22         2.4770000         4.518         2.04879         5946.22         2.4770000         4.518         2.04879         5946.22         2.4770000         4.518         2.04879         5946.22         2.4770000         4.518         2.04879         2.04879         2.04879         2.04879         2.04879         2.04879         2.04879         2.048	35         8.00000000         7.54         5.016.7000         15.35         1.65511         46.86.06         2.3766001         45.35         1.7570         49.48.46         2.3766002         1.558         1.75700         1.5780         2.6670001         45.31         1.8472         5.516.82         2.46700001         45.31         1.78400         2.6670001         45.31         1.78400         2.6670001         45.31         1.78400         2.78700001         1.57840         2.6670001         45.31         2.0877         2.0877         2.78700001         45.31         2.0877         2.0877         2.78700001         45.31         2.0877	ar.	33	7.67620+00	41.9	.12	2	15.36	1.5397	4645.24	2.54	10-1-50	27 07 07 0	0-00-00
1,000900-01   6.36 6.12030-00   15.34   1.772   5640-26   2.47400-01   4581.31   2.454400   4.11.01   9.22   7.25530-00   15.34   1.9823   5940-21   2.72700-01   4581.31   2.454400   4.11.01   9.46290-00   15.34   1.9823   5940-34   2.47700-01   4581.31   2.47700-01   4581	37   1.00399941   6.36   6.12919100   15.34   1.1772   5516.02   2.4400-51   4516.31   2.64591   4516.31	9	35	8.880VD+04	7.54	'n.	2	15.35	1.59.1	ACHR. US	2.29	10-091	**************************************	
39 1.106/00010 9.22 7.55/3000 15.33 1.844.2 53/16.02 2.4477001 4566.91 3.74770 1.106/00010 1.101 9.60570.00 15.30 2.0477 543.74 2.477001 457104 3.04750 1.101 9.60570.00 15.30 2.0477 543.74 2.477001 457104 3.04750 1.101 9.60570.001 15.30 2.0477 543.74 2.477001 457104 3.04750 1.101 9.60570.001 15.30 2.0477 543.74 2.477001 4566.91 3.777001 12.92 1.2555.001 15.26 2.0837 54048 2.477001 4566.91 3.777001 4566.01 3.777001 4566.01 3	39         1.100 (0)-0.1         8.725/30+00         15.31         1.4442         2.57701-01         4513.1         2.55470         4513.2         2.55470         4513.2         2.55470         4513.2         2.55470         4513.2         2.55470         4513.2         2.57701-01         4513.1         4513.2         4513.2         2.57701-01         4513.2<	٠.	~	1.00000001	8.36	115	2	15.34	1.7722	4064,84	2. 50	10-044	7, 3, 1, 4	1.024611-1)[
4) 1.500 files 1 1.001 8.465 945 940 1 15.01 1.00	4) 1.207(70+0) 10.11 8-66749403 15-30 1 5-30 2-0477 573-34 2-0477 573-34 2-04770-01 11:01 9-66770+00 15-30 15-30 2-0477 573-34 2-04770-01 11:01 9-66770+00 15-30 2-0477 573-34 2-04770-01 11:02 1-09780+01 15-26 2-0947 5970-37 2-847010-01 45-44 1-5754-01 15-26 2-0947 5970-37 2-847010-01 45-44 1-5754-01 15-26 2-0947 5970-37 2-847010-01 45-47 1-5754-01 15-26 2-0947 5970-37 2-847010-01 45-47 1-5754-01 15-26 2-0947 5970-37 2-847010-01 45-47 1-5754-01 15-26 2-0454 5970-37 2-847010-01 45-47 1-5754-01 15-26 2-0454 5970-37 2-847010-01 45-47 1-5754-01 15-26 2-0454 5970-37 2-847010-01 15-26 2-0454 5970-37 2-847010-01 15-26 2-0417 5970-37 2-847010-01 15-26 2-0417 5970-37 2-847010-01 15-26 2-0417 5970-37 2-847010-01 15-26 2-0417 5970-37 2-847010-01 15-26 2-0417 5970-37 2-847010-01 15-26 2-9	*0	33	10+02901*1	6.22	1.25/30+0	2	15.33	2544.	20.0166		1000	6567.31	2,65450-01
43 1,35601001 11.001 9.601001 15.20 2.0041 5961.48 2.86010-01 6554.47 3.476010-01 15.20 1.2554.001 15.20 2.0041 5961.48 2.86010-01 65.41.85 3.476010-01 15.20 1.2554.001 15.20 2.0041 5961.48 2.86010-01 65.41 3.476010-01 15.20 1.6259.001 15.10 2.0041 5961.49 2.871110-01 64.49.11 3.476010-01 15.10 1.6279.001 15.10 2.0041 5961.49 2.871110-01 64.49.11 3.476010-01 15.10 1.6279.001 15.10 2.0041 5961.49 2.871110-01 64.49.11 3.476010-01 15.10 1.9641 5961.49 2.871110-01 64.49.10 1.7273 5.2052.001 15.10 1.9641 5961.49 2.871110-01 64.49.10 1.7273 5.2052.001 15.10 1.9641 5961.49 2.864110-01 15.10 1.9641 5961.49 2.864110-01 64.49.10 1.977 2.652.0001 15.10 1.9641 5961.49 2.84410-01 2.11.11 2.94410-01 15.10 1.9641 5961.49 2.84410-01 2.11.11 2.94410-01 15.10 1.9641 5961.49 2.84410-01 2.11.11 2.94410-01 15.10 1.9641 5961.49 2.84410-01 2.11.11 2.94410-01 15.10 1.9641 5961.49 2.84410-01 2.11.11 2.94410-01 15.10 1.9641 5961.49 2.84410-01 2.11.11 2.94410-01 15.10 1.9641 5961.49 2.84410-01 2.10 1.96410-01 15.10 1.96410-01 1.9641 2.10 1.96410-01 1.96410	4.3 1.30600101 11.05 9.002//fred0 152.8 2.0849 5966.48 2.66010.01 4564.91 1.27410 4.5 1.4034010 11.095 1.25552010 152.2 2.0841 5970.37 2.4720010-01 4574.85 2.472010-01 15.00 1.6523010 15.20 2.0845 59.0.37 2.4720010-01 4572.8 2.08410-01 15.00 1.6523010 15.20 2.0845 59.0.37 2.4720010-01 45720-01 15.00 1.6523010 11.205 2.0845 59.0.49 2.48410-01 451846 4.74740 2.1386001 15.10 2.07470-01 15.10 2.07470-01 15.10 2.07470-01 15.10 2.07470-01 15.10 2.0463 59.0.45 2.86430-01 4573.35 1.47470 2.1386001 19.47 2.0155 59.0.45 2.86430-01 45.00 4.47470 1.506.00 1.	0	7	1.20770401	10.11	8.4624:141	⊋ !	1.5.31	D 286 T	5. C	/ · · · ·	10-064	46.71.94	2,04750-01
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63 2.45670+01 22.53 3.28159+01 15.01 1.92247 5916.14 2.476471-01 4471-31 2.71570 65 2.60560+01 24.03 3.68270+01 10.51 1.2135 55.00.40 2.47601-01 4471-31 2.71570 67 2.60560+01 25.67 4.12020+01 10.42 0.8197 57.00 2.47601-01 4477-71 1.52440 70 3.00440-01 21.12 5.44797-01 10.28 0.71695 5273.76 2.457901-01 4477-71 1.52440 70 3.00440-01 21.12 5.44797-01 10.28 0.71695 5273.76 2.457901-01 4477-71 1.52440 70 3.00440-01 21.12 5.44797-01 10.07 6.7671 5282.00 2.457901-01 4477-71 1.52440 70 3.00440-01 35.53 6.56090-01 10.07 6.7671 5282.00 2.45790-01 4476-01 1447-01 1447-01 1447-01 10.07 6.7671 5282.00 2.45790-01 4479-01 1.02690-02 1.25220-02 1.26790 1.25220-02 1.26790 1.25220-02 1.26790 1.2	63 2.45670-01 22.53 3.28159-01 15.01 1.9297 5916.10 2.47567-01 4471.83 2.1570 65 2.60560-01 24.03 3.68278-01 16.95 1.9149 5910.14 2.47567-01 4471.83 2.01470 67 2.76820-01 27.95 4.6170-01 10.42 0.4397 5377.06 2.47407-01 4477.71 1.52440 70 3.00450-01 27.95 4.6170-01 10.42 0.4397 5377.06 2.45800-01 4477.71 1.52440 74 3.31940-01 31.12 5.447901 10.07 0.7697 5273.76 2.45800-01 4477.71 1.52440 75 3.00450-01 31.12 5.447901 10.07 0.7697 5273.76 2.45800-01 4477.71 1.52440 76 3.31940-01 31.12 5.447901 10.07 0.7697 5273.76 2.45800-01 4477.71 1.52440 77 3.31940-01 41.48 8.19240-01 0.700 0.7209 52787.00 2.45900-01 444760 1.42740 85 4.19800-01 41.28 1.25200-02 8.47 0.5946.45 2.45700-01 4477.71 1.05040 105 5.88130-01 47.28 1.24200-02 8.47 0.5946.45 2.45700-01 4477.71 1.05040 112 6.45200-01 76.55 1.87570-02 4.1767 2.4001-01 4477.77 7.01400-01 87.00 2.12250-02 6.75 0.5770 4417.65 2.4001-01 4477.77 7.61700 126 7.56820-01 76.55 1.87570-02 4.1767 2.4001-01 4477.77 7.57700 127 8.18400-01 10.9.96 3.004670-02 11.33 4612.15 2.40470-01 4474.77 7.57700	0	79	10+(:6+16*2	21.11	47.	10	90.51	1.4463	91.575	K . 7	10-09	* C * V * V * V * V * V * V * V * V * V	10-01-01-01-01-01-01-01-01-01-01-01-01-0
65 2.60560-01 24.03 3.68270-01 14.95 1.0110-1	65 2.60560+01 24.03 3.68270+01 14.45 1.5135 5559.27	Q	63		22.53	. ≥ я	=	15.01	1.42.1	57.4165	Z. Z.	10.04	44 (0.40	2.215.70=01
67 2.7682601 25.67 4.12020501 10.51 1.524.03 2.47497 2.17497 2.17696-01 4477.71 1.524.03 2.47696-01 4477.71 1.524.03 2.47696-01 31.12 5.46150.01 10.07 0.7695 5273.76 2.454.90-01 4451.43 1.47493 2.47493.14 1.47493 2.47493.14 1.47493 1.474	67 2.7682001 25.67 4.12020001 10.52 0.4192 5.275.0 2.45490-01 4477.71 1.524407 70 3.004407401 27.95 4.68150.01 10.58 0.4192 5.275.0 2.45490-01 4451.70 1.64930 1.47493	=	65	•	24.03	3.682734	ร :	\$ \$ \$ 1	7	7410.13	7. • 7	10-016	20.28.44	08070
70 3.00440.401 21.97 % 66H190.01 10.28 0.7695 \$273.76 245549-01 4461.77 [1.44990	70 3.004407401 21.97 % 60H170701 10.28 0.7695 \$5273.76 2.45540-01 4467.70 [1.44490 1	2	19	. 76	25.67	* 12020 * *	<u>.</u>	10.01	10613	5327. IN	2.47	10-00	4477-71	52440
74 3.31942-01 34.12 5.54742-01 10.07 6.76.71 5.26.715-01 444.60 1.427459  79 3.71900-01 35.53 6.56090501 10.07 6.720 5.246.69 7.44950-01 444.60 1.42759  85 5.30670-01 41.48 8.19250-02 9.73 0.720 5.2496.67 2.4276-01 441.90 1.42759  96 5.30670-01 41.48 8.417560-02 9.73 0.596 5093-91 7.44956-01 441.90 1.42759  97 5.30670-01 41.48 8.41760 1.42750-02 4.4176-01 441.90 1.42759  105 5.88130-01 75.55 1.87570-02 7.95 0.596 4417.85 7.4076-01 441.07 7.42711111 7.01900-01 447.07 7.40790-01 447.07 7.40790-01 447.07 7.44990-01 447.07 7.40790-01 447.07 7.40790-01 447.07 7.40790-01 447.07 7.40790-01 447.07 7.40790-01 447.07 7.40790-01 10.952 3.40490-02 11.33 0.3373 4617.15 2.409170-01 447.07 1.57700-01 10.956 3.00450-02 11.33 0.3373 4617.15 2.409170-01 447.07 1.57700-01 10.956 3.00450-02 11.33 0.3373 4617.15 2.409170-01 447.07 1.57700-01 10.956 3.00450-02 11.33 0.3373 4617.15 2.409170-01 447.07 1.57700-01 10.956 3.00450-02 11.33 0.3373 4617.15 2.409170-01 447.07 1.57700-01 10.956 3.00450-02 11.33 0.3373 4617.15 2.409170-01 447.07 1.57700-0	74 3.31942-01 34.12 5.54142 10.07 6.1621 5246.69 2.44716-01 444.60 1.427459 1.427459 1.427450 1.427459 2.449450-01 444.60 1.427459 1.427459 1.4272340 2.7249 5246.49 2.44950-01 44.46 8.19273402 9.73 0.7204 5940.47 2.42710-01 4430.47 1.2420402 9.73 0.5904 5093.91 2.492410-01 44.31.14 1.0286902 9.73 0.5904 5093.91 2.492410-01 44.31.14 1.058902 9.73 0.5904 5093.91 2.492410-01 44.31.14 1.058902 1.25250402 1.2	~	0	3.00440+01	C 6 4 7 7		<b>.</b>		1404	52713.74	2.45	10-045	4463.70	10-01679
19   3-11910   10   10   10   10   10   10   10	19   3-17900-01   19-25   19-1700	*	<b>7</b>	3.319401	31.16	5	1 6		76.75	5287.00	7.46		64.1544	10-6-51
#\$ 4.19# 41.40   E.1974374   1.07680402   4.28   1.07680402   4.28   1.07680402   4.28   1.07680402   4.38   4.3964341   4.346.41   4.346.40   4.376.43	#\$ 4.19# 41.40	~	5.	3.71900+01	56465	0 6	- ·		2002	5744.49	2.66	450-01	4444.60	16-62754-11
91 4-11611 4439-66 1-242204-32 8-67 0-5996 5073-91 2-1427-01 4439-66 1-242204-32 8-67 0-5996 5073-91 2-1427-01 4439-66 1-242204-32 8-67 0-5196 4971-55 2-1427-01 4434-27 9-04400 12 6-45201-01 76-45 1-674300 2-1422504-02 6-25 0-2540 4617-01 2-1427-01 4434-27 9-04400 119 7-0190-01 87-00 2-1422504-02 6-25 0-2540 4617-01 2-1427-01 4434-27 9-1417-01 119 7-0190-01 97-92 2-140904-02 6-25 0-2540 4617-01 4427-01 4427-01 4427-01 119-25 3-00417-02 11-33 0-3418 442-15 2-30417-01 4424-71 7-52700 135 8-14600-01 109-96 3-004670-02 11-33 0-3373 4617-15 2-30417-01 4424-71 7-52700	91 4.1911-01 4439-66 1.242204-32 8.67 0.5926 5093-91 2.34268-01 4439-66 1.242204-32 8.67 0.5926 5093-91 2.34268-01 4434-67 1.05940 1.05 5.88130401 56.61 1.54310402 7.95 0.5136 4417.65 2.31677-01 4434-27 9.04408 1.12 6.4520401 87.00 2.45250402 6.25 0.533 4617.65 2.3049-01 4474-27 7.01909-01 87.00 2.45250402 6.25 0.2777 4409-16 2.3049-01 4477-59 7.558250401 97.92 2.4609-02 5.78 0.2777 4409-16 2.3049-01 0.3792 1.538 8.16410-01 109-52 3.00490402 11.33 0.3373 4617-15 2.30470-01 4424-71 7.57709 1.33 8.16410-01 109-96 3.004670+02 11.33 0.3373 4617-15 2.30470-01 4424-71 7.57709	<b>.</b>	٠ د :	10+(5-65 L · +	4 4 4 6		<b>-</b> 2	7 0	9979	5150-67	4.6	(0-01 <b>%</b>	4441.90	17630
105 5-88130-01 57-28 1-27220-02 7-95 0-5196 4971-56 2-16275-01 4437-14 1-05940 105 5-88130-01 56-61 1-51430-02 7-95 0-55-0 4617-69 2-16275-01 4434-27 0-04400 112 6-4520-01 76-55 1-82570-02 6-75 0-55-0 4617-09 2-104400 7-92 2-42250-02 6-75 0-55-0 4617-09 7-010-01 4474-27 0-044400 119 7-92 2-42250-02 6-75 0-55-0 4617-09 7-010-01 4474-27 7-61610 119 7-92 2-4290-02 7-92 7-92 133 8-16410-01 109-52 3-08910-02 11-33 0-4418 4474-6 2-109-01 4474-71 7-52700 135 8-18600-01 109-96 3-08650-02 11-33 0-3373 4617-15 2-10910-01 4474-71 7-52700	105 5.888130.401 66.61 1.57430.02 7.95 0.5196 4971.55 2.162701 4434.21 0.04400 11.2 6.4520.401 75.55 1.82570.402 7.15 0.4353 4417.65 2.162701 4434.21 0.04400 11.2 6.4520.401 87.00 2.16250.402 6.25 0.2777 4409.14 2.104001 4427.7 7.01909.01 87.00 2.16250.402 6.25 0.2777 4409.14 2.104001 4427.57 7.56820.401 97.92 2.4040.402 5.28 0.2777 4409.14 2.1090.01 1090.52 3.08810.402 11.33 0.3478 4612.15 2.1047001 4424.71 7.57709 133 8.16410.401 109.95 3.08650.402 11.33 0.3373 4612.15 2.1047001 4424.71 7.57709	-	-1 ; 5 (			0	7,	: N	406.4 O	5007.01	7 . 3 . 4	26.0-01	46.29.66	10-66206.1
112 6-45203-01 76-55 1.825250+02 7.15 0.4353 4817.65 2.1627-01 4434.77 0.04400 112 6-45203-01 76-55 1.82520+02 6-75 0.2530 4617.33 2.30443-01 447.67 7.45173 119 7.01900-01 87.00 2.122530+02 6-75 0.2530 4617.33 2.30130-01 447.59 7.151019 126 7.58820-01 97.92 2.44090+02 11.33 0.3418 4670-16 2.30170-01 4474.47 7.52709 133 8-16413-01 109-52 3.08913+02 11.33 0.3373 4617-15 2.30170-01 4474.71 7.52709	112 6.4520101 76.55 1.8250102 7.15 0.4353 4817.65 2.1620-01 4434.77 0.04400 113 6.4520101 76.55 1.8250102 6.25 0.2530 4617.03 7.044000001 4427.00 2.15000000000000000000000000000000000000	80 c	E 4	* 306 fi) *	9 4 4	747.	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	50.0	0.5196	49 7 1.56		22.0-111	4437.14	. n594D-1
114 7.01900-01 87.00 2.12250-02 6.25 0.2530 4617.0) 2.30040-01 4431.07 7.45130 119 7.01900-01 87.00 2.44090-02 4.28130 4.28130 126 7.4600-01 97.92 2.44090-02 4.28 0.2777 4400.14 240010-01 4427.59 7.151010 133 8.16413-01 109-52 3.00812-02 11.33 0.3418 4672-15 2.30870-01 4424-71 7.52700 135 8.18600-01 109-96 3.008670-02 11.33 0.3373 4617-15 2.30870-01 4424-71 7.52700	119 7.01909-01 87.00 2.12250-02 6.25 0.2570 4617.01 7.0040-01 4427.50 7.45000 1.150000 1.1500000 1.1500000 1.1500000 1.1500000 1.1500000 1.1500000 1.15000000 1.15000000 1.15000000 1.1500000 1.15000000 1.15000000 1.150000000 1.150000000 1.1500000000 1.1500000000 1.15000000000 1.150000000000	<b>.</b> .		460.634	7 5 5 5			. <u></u>	4 77 4 7	4417.FS	7. 1	K75-111	4674,27	.0440
126 7.56800-01 97.92 2.44090+02 5.28 0.2777 4400-14 2.10:11:0-01 4427.59 / 133 8-16413-01 109-52 3.08817+02 11.33 0.1418 4424.86 2.10970-01 4424.94 7 135 8.14600+01 109-96 3.08670+02 11.33 0.3373 4412-15 2.10870-01 4424.71 7	126	) -	7 .		00-78	177	70	6.75	0.3530	46.1 7.33	Dr -2	10-054	44.1.07	Reduced.
133 8-16413-01 109-52 3-08813-02 11-33 0-3418 4674-86 2-30930-01 4424-94 7-61613-0 135 8-16600-01 109-96 3-08650-02 11-33 0-3373 4617-15 2-30870-0 4674-71 7-52700-0	133 8.16413.401 109.52 3.08817402 11.33 0.3418 4674.86 2.30970-01 4424.94 7.61617 135 8.18600.401 109.96 3.08650.402 11.33 0.3373 4617.15 2.30870-01 4424.81 7.52700	1 6	124	58870	25-15	0.44	77	4.78	0.2111	4400.14		10-610	ď	
135 8.18600+01 109-96 3.08650+02 11.33 0.3373 4612-15 2.10870-01 4424-11 (-2,770)-9	135 8.1H600+01 109.96 3.0H650+02 11.33 0.3373 4617.15 2.19H70-01 4474.71 (	7 7	7.	1641	109.52	. C # %	20	11.33	91710	46.74 . HG		10-06	44.24.95	E-61-11-9.
			135	18600+	109.96	OHO.	20	11. 33	0.3373	4417.15		10-UL	11.454	7

## 3-0 YOMENTHM ENERGY INTEGRAL THCHNIJJE

STRFAMLINE	T.	BETA	SON	LWIC	<	7	TRA	TRANSITION POINT	NT LUCATION	T 10%		
NO.		1066)	8	×	<b>,</b>	7	<b>S</b>	×	>	7		
		3.94	0.554	-0.590	0.037	0.215	10.601	-2.569	0.421	10.004		
BODY PT NG	INTEG PT NO	AML (NE	LUCAT ION PHI IDEGS	METRIC COEFFICIENT		BODY ANGLE (DEG)	FUGF PRESSUPE {ATM}	WALL Temperature [Degr]		R-PRIME	PECOVERY FNIHALPY (BIH/LOM)	IIFAT TOAMS COFFFICTOT (LRM/FTZ·SEC)
						1			4	10-040-4	40.88.04	1.15850-00
_	_	3.44980-03	-0.00	0.0		90.09	25.9645	07-6471	7. 76		-	1C-0117F.
~	_	1.26680-02	2.02	7.67430-02		85.45	25.5600	11.1001		180-01	96.01.07	4.85070-01
m	o	5.34410-02	3.05	2.34110-0		75.65	\$117.55 \$000 E 00	7016 22	40.4	240-01	4617.54	6.235.711-01
•	11	1.21770-01	3.40	3.910619-01		65.28	- CO. 3 50 5.	77 40101	9.4	650-01	4874.43	5.47(1911-1)
<b>~</b>	13	-06051•	3.59			71.44	11 4297	(10, 24, 74	2.79	7.79050-01	44 30.41	4.44410-01
•	15		3.71	3		10.54	75 70 9 1 1	4514.75	7.61	2-61360-01	4776.03	3.44.750
_	1	10-00685*4	3.81	70	5.7	90.00	4.7705	6227639	2. 19	2. 19660-01	4723.27	16-01612
<b>=</b> 0	61	6. C4R00-01		•	- ·	23.00	7.758	56.17.06	2.67	2,47410-01	467R.97	1.707611-01
•	7.7		3.94	5 6	1	77.61	7 1161	4184.0A	1.5	10-01416-01	4646.04	1.15870-11
10	23	1.38410+00	4.21	£0.	25	¥6.4C1	14111)	71.77.07	2 20	10-0511	4613.17	4.06.09.9-02
11	52	2,39530+00	4.66	00+0515-1	00	5.48	1 ac 3 L	46.76.61	200	7,24290-01	4589.29	7.65500-07
12	21	3.66200+00	5.24	1.900201000	00	13.38	104 101	3787107	2.28	10-0261	4577.51	70-01167-1
13	5.6	5.02540+00	5.42	2.52000+00	50	10.56	1 6435	44.00 ag	7.78	2,2895P-01	45.6.29	7.37f011-02
-1	31	6.37810+00	6.48	3.76610+00	<b>D</b> O (	13.30		46.64.44	2.2	1040-01	4539.25	7.41250-02
15	33	7.67620+00	7.51	4.11820+00	<b>ာ</b> င်	15.35	1.54	4643436	7. 70	2, 29170-01	45.00.56	7.9895D-U7
16	35	8.88 C90 +00	B.39	5.074613+00	99	17.54	1160.1	47 0467	2 26	10-00-1	4501.20	R. 76740-02
11	3.1	1.0000411+01	9.32	6.12030+00	90	1 1 0 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	0130	5266.06		10-09-11-2	4511.30	וט-מרטור. ו
	39	1.10670+01	10.27	1.2014/9600	9 (	76.67		67.157.4	2.6.	10-01-01	4549.11	10-01056-5
<b>2</b> 05	11	1.20770-01	11.23	\$ ·	2 6	11.78	2.0.78	2205	2. 7.	10-0516	4562.47	10-06556-2
7	43	1.30600+01	12.24	4.544ED400	3 5	1 5.25	2.0750	5951.59	2.A4	.A10-01	00.0724	3.212711-01
	4	10+0340 +01	13.28	1046450401	5 5	15.23	2,0864	5965.44	2. H.C	10-0555	4540.86	10-4-706 F
77			1443	1 479504	3 3	15.21	2,0763	5966.90	7. 44	7. 46410-01	10.0754	3.158AD-01
23	o :	10.06230.1	15-51	1.62200+01		15.18	2.0045	5949.28	2.4	5470-01	4577.69	•
<b>*</b> 2	16	0.0000000000000000000000000000000000000	10.01	1.83600+01		15.15	7.0297	5954.40	7. AL	ነበ-በረሀላ	4517.42	ייל לאנוי-10
52	20.	10400019-1	-	70-01-10-0	; =	11-51	2.0015	69.5.08	2. H	52 FD-01	4506. 75	10-41-0-1
92	ر <u>.</u>	1 06220401	20.52	2.32560+01	10	15.07	1.9737			2.84770-01	4497.69	10-119kb.2°E
17	- 0	10+010+01	<b>V</b> 17	2.59370+01	: <del>-</del> -	15.03	1.9474	1926.34		2. R372D-01	DD - H. T. T.	
0,7		10+05912-6		2,91470+01	10	14.98	1.9256	591H.74	Z. H.	2. HZ9411-01	G7 */E54	10,000,000
7 7	ָּרָ לָּהָ מַרְ	2-45670+01	25.05	3,27700+01	10	14.92	1.9072	5910-74	2	2.82780-01	7001111	7.18660-01
2 2	, 4 4	2.60560+01		3.6/440+01	10,	14.86	1.4905	5903-11	**	7.818411-111		2.04770-01
	74	2-76820+01		4.116.30+01	10.	10.14	1.1973	10.1966	• • •	10-00000	56.74.34	10-0-105-1
, "	70	3.00449+01		4.65040+01	10.	10.28	0.8240	5312013	7	101000	71-6777	1-40710-01
4	. 2	3.31990+01		5.389HD+01	.01	10.12	0.7468	45 - C 4 / C	• • •	10-04-3	54.02.44	1142940-01
	10	3-71900+01		6.56210+01	101	9.85	0.7378	24.67.		10-01-6	10 6777	10-02136-1
3.6	e.	4.19890+01	4	8.03510+01	101	14.6	2189.0	18°9075			78-0777	1.24BAD-01
3.4	7	4.73830+01			101	16.9	0.6224 0	11.60.74		10-01-01	21 B 77	1,11600-01
. 20 1 FC	86	5.30470+01	63.27	1.23710+02	50.	8.22	\$855°0	5071-56		2 32300-01	46.45.24	9-60110-07
0	501	5.88130+01	73.40	1.4973:0+02	70,	7.41	0.4678	OC • 1 HH •	<b>6.5</b>	10-06.	00 2177	A.01540-07
05	112	6.45200+01	84.12		+02	6.50	0.3766	18-7444		10-03606	66.7B.59	K. 52560-02
7	113	0	95.26	÷	•02	5.51	0.7749	06-14-4		10-07-01	44.25-17	5,76850-07
7.5	126	7.58820+01	106.78	• 50	704	4 . F. 3	0.2287	10.1924		10-04-12	6477.47	4.2A1519-37
*	~	10+01+91.8	118.64	_	20 1	3.34	90 L HO4	10 1505			4422.37	4.144.70-02
; ;	135	.18600+0	4		704	1.32	0.1744	49.010.	7.7			•
						OUTPUT	JT DELEIEU					

### 3-D MOMENTIM ENERGY INTEGRAL FECHNIONE

STREAML INE	INE	BETA	SONIC	POINT LOC	AT 1 ON		TRAW		LOCA	ATION		
-DN		(050)	8	<b>A Y</b>		~	\$	×	}	~		
15		50.00	0.582	-0.410 0.	0.426 0.	0.215	12.876	0.604	2.920	12.077		
BODY PI NO	INTEG PT NO	STREAMLINE 2 (IN)	LOCATION PHI (DEG)	METRIC COEFFICIENT	ANGLE (DEGI	<b>a.</b>	FOGE RFSSURE (ATM)	WALL TEMPFRATURE (11EGR)	-	A-PS 1AF INFRAICTER	PECOVERY FNTHALPY EBTU/LAM)	HEAT TOANS COFFESCIENT (LNM/F 12-SFC)
				•								
~		3.44980-33	-0.00	0	90.		25.9644	7233.31	3.43070-	10-01	4958.94	1.056.0000
7	-	1.26680-02	8.1	Ň	5		5.4663	7151.97	12.6	5. 21 (A) PUI	70.000	4 75 350-01
m	٠	5.34410-02	•	•	55.67		9.3210	1081.62	3. Little:	10-61	FE 800 FF	
*	11	1.21770-01	٥,	10-05521*5	63	3.67	2002	69.0669	4.07940	10-01	E L . E . C . C . C . C . C . C . C . C . C	A 2206 13.01
•	13	2.15090-01	o,	••	53.		5.2932	6867.88	100.74	10100	4037 37	4.25850-03
•		3.27540-01	47.46	÷		-	3.78	24.0014	1414	7. [7.10]	1202204	3 2580-01
<b>-</b> -	ha i	4.58461-01	15.85	` '			F/C 0 4	10.0740	7.036	10-04	- 100 c 4 1 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	20 - U U U U C C C C C C C C C C C C C C C
•	<u>•</u> ;	6.04800-01	49.30	٠	67	-	**3636 * * * * * * *	56.23	77 6	10-01	4669.18	1.67001-01
<del>o</del>	21	•	50.00	٦.			67767	77070			41 34 77	10-001-01
10	23	T N	52.86	Õ,	<u>.</u>		1.8658	30.1100	201.		46.01	N. 04520-02
7	25	2,39530+00	65.16	Ţ.	• •		6874.1	46.30.30	7 . 7		4574.65	A. 15140-02
12	27	662 UD+0	63.71	1.69890+00	17.61		24/1-1	400.40	4 C C	7 27870-01	4557.50	5.45600-02
<u>e</u>	<u>٠</u>	70.	74.60	- 4	17 61		0.416.0	4176.71	0.27450	10-05	45.46.67	4. N4430-02
4 :		5. \$7810 •00 7 4 7070 •00		2.84140400			0.8043	50.75.55	2.269	50-05	4521.54	4.41777-02
<u>.</u>	e 1	0040303040	01.70				0.7451	3983.50	2.265711-(	10-01	14.57.4	4.0784D-07
9 :	ς ς ε	10403030	44.60		-01		0.6932	3895.19	2.252	10-00		1,68240-02
- 1	- 0	10+04901-1	97.14	`~			0.6477	3819.74	2.759	10-00		3,40%60-02
-	. 4	10.507071	101-68	3.86740+00	•	9,33	0.6064	3740.20	2.25	10-01:		2,17480-02
1 R	; ;	1.30400+01	105.87	4.01060+00	10		•	3879.12	7.26	10-02:92.2		3.41810-72
	4		110.19	4.17610+90	<b>.</b>		0.5344	3488.50	2.270	10-01	4497.64	4.0419n-32
22	1.4		113.97	6.1875p+00	æ		0.5072	4145.26	2.290	10-UZI	15.0055	6. #01 kii - 02
23	<b>5</b>	.60230+0	118.01	4.29610+00			1114.0	4241.11	2.28	10-025	47.17.74	10-01-01 Tex
54	5.1	.70670+0	121.30	4.25970+00	<b></b> 1	-	6164.0	4331.66	7.291	10-01 10-01	17.5.5	79-11-11-1-5
25	53	10+00918-1	125.67	4.29770+00	~ ,		6525.0	4312.15	2.2	10-01	F. 4.4.4.4.4.4.4.4.4.4.4.4.4.4.4.4.4.4.4	20-03-0-1
58	55		189.621	4.28720+GU			1404-0	4317.US			44.044	700007
17	<b>~</b> (	2,35220+01	133.32	4.23060+00		6.94	2,3843	4381-12	2,29	2,29510-01	6567.46	5.705.10-02
10 C	) () v		170,000	00404040			0.3577	4 344 10	2.79	10-01	4570.36	5.53023-32
5.7 2.7	4 14 0 4	2.45670401	144.08	3. E6.8CH + 00			0.3486	4336.75	2.79	2.29390-01	4574.92	4.67950-07
, F.	3 6	460560+6	147.59	3, 734901+00			0.3394		2.29	10-05666*2	4578.57	5.291911-02
25	6.9	.7682D+0	0	3.84140+00	-1		10*2*0	4017.33	2.29	10-61	4570.37	3.96870-02
33	11	3.00440401	154.64	2.44090+00	<b></b>		0.2253	3965.38	2.2A	2.7802n-01	4460.45	3. 76050-02
34	7.5			•	<b>:</b>		0.2151	3900.42	7.7.7	10-01	45/38.44	10-01-74-8
 	<b>9</b>		~	2,12,060,403	-		51610	3421.23	2.27	10-07	15 T T T T T T T T T T T T T T T T T T T	20-02/74/°
36	Đ Đ	4.19230 +01	le 7.2 7	•	•		× '	3141.12	7.7.7	10-11	* * * * * * * * * * * * * * * * * * *	(1) (1) (1) (1) (1)
37	69	.73830	170.59		<b>∴</b> ,		0.1736	3637.60	7.761	2.26610-01	456H.24	Z. + 1 * 4   1 - 0 Z
<b>6</b>	00 3	06 7U + U	171.27	1.77000+00				20 P V		7 3,07 U	- C	3 45040-03
3.5	0 7	0+06198•	111013	1.7560+00				20.000	. <b>C</b> .(n)	10-07-47 c c	6 5 3 5 4 5 4 5 4 5 4 5 4 5 4 5 4 5 4 5 4	1,20510-07
0 :	<b>∳</b> •	10743 100743	172.02	1.26260+00	<b>~</b> •		11611	2000 Jun	2 29010	10.00	452 B. 64	4.4HPD-02
ed f	77.	0.006.70	0/*7/1	20 + (35 11 2 · 1	-		0-1167		K ( )		4547 44	4. 249811-07
7.4	\$ Z I		7.6		: י		501106	3771.73	``	10-0100	52H.0	4.59170-07
7 \$	131	3 3	7-7	1.26500+60	•		0.1103	4458.71	2. 31.	114-0-01	45 10.41	40-U61 51.05
					č		נו לי ו					
					3	on indico	VELETEV					

### 3-D MOMENTUM ENERGY INTEGRAL TECHNIQUE

M(),	(080)								
				7	~	! !	7		
22	180.00	0.554	0.457 0.	0.000 0.172	166.8	2.285	0.000 A.276	•	
BOOY INTEG PT NO PT NO	STRFAMLINE Z (IN)	LOCAT FON PH1 (DEG)	METRIC COEFFICIENT	BBDY Angle (Deg)	EDGE PRFSSINE (ATM)	WALL TEMPTPATURE (DEGR)	R-PUTMENT	RFCOVERY FNTHAL FY (RTU/LDM)	HFAT TRANS COEFFICIENT (LRM/F 12-SEC)
<b>-</b>	3.44980-03	00*0-	0.0	90.00	25.9645	71.29.17	1.27240-01	70 8307	0-000
<b>*</b>	1.26680-02	180.00	2.21440-01	75.46	23,7139	7080-18	3.08440-01	4040.10	10-00/6-00
•	5.34410-02	180.00	3.75220-01	65.46	20.3347	7019.90	3.05110-01	4911.69	6-79840-01
	1.21770-01	180.00		55.30	16.0331	6902.23	2.94340-01	4876.59	5.46640-01
£ ;	2-15090-01	180.00	. 414	45.18	11.6340	6737.82	2. 79 790-01	4830.42	10-050H+*
S :	3.27540-01	140.00		35.03	7.4666	6514.99	2-41 700-01	4777.00	3,476,0-01
~ :	4.5890D-01	140.00	A .27030-01	25.08	4.7233	6229 <b>-64</b>	10-02661 .5	4777.34	2.52040-01
	6.04.800-01	00.081		15.09	7.1697	5886.56	2.19920-01	4447.67	10-05577.1
7.5		00.041	10-05150-6	٧.	1.4916	5188.67	2.27F09-01	447 M. 00	10-0276 1.1
52	7. 49530405	00.001	10-08-70-6	2.40	1-1745	4627.97	2.29410-01	4603.05	7.27610-02
,,	400744	00.00	1 07070400	0 4 4 6	C#14.0	47.H.C.1.H	2.2 TAKD-01	4511.21	
	5. 02 540 4 60		00400400	0.0	0.707.0	396H . BB	2.26570-01	4542.21	4.894n-112
		180.00		7.40	0.35.0	3773.05	2.255AD-01	4534.15	20-02966-2
. E		180.00	1.18400+00	) • • • • • • • • • • • • • • • • • • •	U.48/D	40.7cce	7.74R70-01	4522.47	2.47150-02
35	8.88080+00	180,00		5.40	0.4145	3466.56	70-01-196 6	DC-+ 15+	20-0314167
3.7		180.00	1.20410+00	5.40	9,3941	3623,35	70-02520-01	40.00.00 40.00.00	2-45/10/10/10
34	10+01 401-1	180.00	1.20320+00	5.40	0.3742	3758.32	2,26270-01	4542.22	3-07510-02
7;	.20770+0	180.00	1.19860+00	5.40	0.3679	386 7.43	2.76AA0-01	4554.88	3.47750-02
5 ¥	10.000001	00.00	761.	2.40	16560	3951.62	2.2 7.50-01	4566.46	3.73480-02
7	0404504	00.041	004040471		0.3523	4015,98	2.27710-01	4574.7B	3.9Arit.n-112
•	10.00.70.1	180.00	1.15780+00	044	7676	4065-19	Z.279HD-01	4585.87	4.17147-112
15	. 706 70+0	180.00	134		0.346.0	41014 4127 20	Ze78700-01	78.503	4.319kn-07
53	10+03414.1	180.00	1.11410+00	5.40	0.3376	41 55. 7R	2.2849D=01	# POOP #	4.6347II-UZ
52		180.00	1.09060+00	5.40	0.3363	4177.56	2.28540-61	4612-6B	4-59250-02
2.5	2.05220+01	180,00	I .0644D+00	5.40	0.3357	41 84.58	2.28650-01	4417.52	4.64001-02
£ 7	2 31433461	180.08		5.40	0.3357	4197.45	7. 286911-01	4521.78	4.47105-32
	2.456.70401	00.001	10.0364.00	04.4	0.3352	4196.A9	2.28710-01	4425.4B	4.68f.10-02
, <u>1</u>	2-60560401	180.00	10-00/2710		U. 35. U.	-0 - K - 10 -	2.7872n-01	46.24.76	4.4R0411-02
99	2.76820+01	180.00			2446	16.47.	10-00/W/*/	46 11 . 54	4.6.7040-02
11	3-00449+01	180.00	8-22640-01		25.42	3717911	10-014792		70-01-527-5
2	3.31990+01	180.00	7-110011-01	20-1	0.2528	3037 46	10-11k117.7	_	3.6 4840-07
96	3.71960+01	180.00	6-56130-01		63460	FB 1015			4,5 H'19'11-02
98	4.19890+01	140.00	6-07230-01		0.21.ne	3767 40	10-01-02-2		4. 20500-UZ
43	6.73930+01	140.00		1.00	0.1877	3660-14	20-01-01	0.000	20-01-01-01-02-02-02-02-02-02-02-02-02-02-02-02-02-
001	5.30670+01	180.00		1.00	0.1683	3572.44	2-26240-01		0-01-01-C
101	5.88130+01	140.00	5.746801-01	6.00	1751.0	3500.74	2, 76,07,0-01		7.1087D-02
<b>† 1 1</b>	6.45200+01	180.00	5.911611-01	00.1	0.1446	3444.70	7.25461-01	659Ha24	70-01-50-2
121	→	0.0		1.00	0.1377	3406.18	25120-	4501.85	1.95779-02
128		180.00	6.340@?-01	1,00	0.1433	3374.42	10-02442-5	4401 . A.Z	1.49110-07
561	₹.	o	6.66080-01	0.99	0.1304	3154.52	7,25540-01	4605.43	1.841411-112

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BCDY	INTEG	STREAM	VELOCITY	MACH	FNTHALPY	TEMPERATURE	OFMSITY	VISCOSITY	THU PA PB
2 2	2		Filse	2	BTU/L BM	DEG R	LRW/FT3	LAM/FT-SEC	1/1
3	(1)	(8)	(Tur)	(HCAM)	(HE)	(TE)	(RNF)	(VISE)	(INE)
_	-	0.0	0.0	0.0	4048.9	10743.8	8.0070-02	9.97An-05	0.0
. ~	•	0.2335	2403.3	0.4756	4843.6	10544.7	7.4 700-02	4.4400-05	1.87411+06
m	<b>~</b>	0.3438	3724.6	0.7490	4681.9	10251.4	6.6150-02	9.6410-05	2.4540+06
•	=======================================	0.5542	5024.5	1.0155	H-95+4	9825.2	5-6-1-8-5	9-1470-05	2.9450+:16
₩	13	0.7146	6217.0	1.3376	4172.1	9258.9	4.2540-07	8-954N-05	7.9470+04
4	51	0.8749	7468.3	1.6588	3845.1	8596.1	3.0510-02	F.484D-04	2.4850+0A
_	11	1.0353	8498.5	1.9752	3516.6	7934.1	20-0190-2	8.0030-05	2.1417+86
•	19	1.1957	5.6556	2,3014	3115.7	7318.E	1.3050-02	7.5790-05	1.6350.94
•	17	1.3496	10072.3	2.5387	2932.9	6869.A	1.1710-01	7.1930-05	1.040 0+04
10	23	1.9954	10445.2	2.6A 16	2780.1	6642.B	6. 1140-01	7.0120-05	9.4417.05
11	52	3.0184	10817.7	2,8358	2621.9	6415.3	5.1780-03	4.4750-05	R. 2070+05
71	2.7	4.3062	11166.3	2.9875	2468.9	6197.3	4.134P-03	6.6410-09	4.9490+05
13	5.6	5.6425	11411.6	3.1012	2358.3	6036.7	3.4790-03	4.5040-05	6.0160.05
<b>±</b>	31	7.0678		3.1760	2286.R	9936°0	3.0410-03	6.4170-05	5.485D+05
1.5	33	8.3814	11470.0	3.2260	2239.1	5867.5	2.8100-03	6.35.80-05	5.1570+05
16	35	9.6123	11740.3	3,2607	2206.3	5817.1	2.6530-03	6.3170-05	\$0 + c   LD • \$
17	3.7	10.7591	11792.3	3.2467	2181.8	5.780.0	50-(1145.2	6.28FD-05	4. 7690+05
1.8	36	11.8354	11831.6	3.3064	2163.3	5752.0	2.4610-03	6.21.10-05	4.64911+05
19	1+	12.86.20	11861.7	3, 3216	2149.0	9.01.15	7. 3993-04	6.2450-05	4.5560+05
20	43	13.8604	11886.6	3, 3333	2138.2	5714.1	2.3500-07	4.2320-05	4.4970+05
71	4.5	14.8512	11901.4	3,3470	2130.2	\$101.6	2. JI [n-n]	4.2210-04	4.4210+05
22	14	15.8503	12413.4	3-3482	5124.5	5692.5	2.2 HUN-03	6.2140-05	\$0.40°1 F. A
23	64	16.8738	. 0.12611	3, 3523	2120.4	56.86.3	2.2560-03	40-0602.4	4.1320+05
24	15	17.9354	11924.9	3,3545	2119.0	. 9.2495	2.2340-03	6.106.D-05	4.7990+05
25	53	19.0462	11925.4	3.3550	7118.A	5681.2	2.2240-03	6.2057-05	4-7740-05
97	55	20.2150	11923.0	3.3541	2119.9	5661.7	2.2150-01	6.704D-05	4.2550+05
2.2	21	21.4480	1.8141	3.3519	2173.2	5643.9	2.2100-03	6.7 UAD-05	4.7470005
28	59	22. 1484	111011	3.3486	2175.6	5687.6	7.20Kn-01	6.2120-05	4.2330+05
53	19	24.1190	11902.2	3,3443	71.74.R	5,2695	7.7045-01	K. 7 [ FD-05	\$0.40075.4
30	63	25.5405	11891.6	3,3392	6.9112	5698.6	7,2170-04	\$0-0122°9	4.77#B#05
31	65	24,04,2	11879.2	5.3333	1.0412	0.000	ta-(:01/*/	CB-1:x2/**	C040/67**
32	<b>29</b>	28.7200	12202.6	3.5017	198.2	7 (E)	1 - 10kg - 1	40-0Kt0-4	CC+01/45*
33	17	31.0460	12210.6	3.5045	I OH ( )	X * D X * C	10-13-13-13	6.0.4(I-05)	
34	75	34.2682	12260.5	3,5303	6.94.6.	7.647.	1. 1.4611-101	6.004n-05	3.3740.03
35	90	38.2405	12324.4	3.5686	1.5.701	5 397 .2	1.6520-03	50-05-05	3.4171717
36	96	43.1064	12404.5	3.6151	1 RB 3 . 5	6.2166	1.0-0702	50-02 10*5	*()+i)/*("u
3.	6	48.5305	12523.5	3.6807	1476.8	F-1925	1.3647-01	5. N. CO. CO.	C040526-2
36	100	54.2451	12004.9	3. 7374	1791.4	5140.3	(U-(I) 7/*)	5. 78 40-64	7, 110011.5
<b>6</b> M	101	60.0232	12650.5	3.7586	1762.9	5163.4	EU-0651-1	5. 7540-05	Z. 774U4U
0	114	45.7610	12646.B	1.7548	1764.1	5135.5	1. 0780-01	50-0671	2.1711114.15
7	121	71.4630	12623.1	3. 7445	1776.4	1.1412	10-05/0-1	4.1460-05	2.2460+05
45	128	18	12543.9	3, 7246	1 746.5	5158.4	9-44111-04	4.7770-05	20100112
43	135	916	1.0521	3.6966	1828.4	5190.6	9.5610-04	5.40411-05	7.0470405
++	137	83.1969	12516.8	3.6941	1830.1	5197.1	9.5670-04	5.HUAD-05	2.06.10+95

VISCOUS FLOW - MALL AND R. 1. RECOVERY PROPERTIES EXTREMOMENTARING MAINTENANCE OF THE PROPERTIES OF THE PROPERTY OF THE PROPER

BODY	INICG	STREAM	WALE	WALL	WALL	VALL	PECOVFRY	RECHYFRY	SFNSHL CFNV	(147)
PT ND	DN 14	LENGTH	TEMPERATURE	ENTHALPY	DENS (17	VISCUSITY	FNISAL PV	FACTOR	MFAT FLIJK ATH/FT2-CF	
7	3	(8)		( HH)	(kux)	INSIAI	CHRI	(PFCNV)		
-		0.0	7179.4	2578.6	1.3470-01	7.2090-05	4958.9	0.8367	2.0070+03	1.0009+10
· ~	~			2523.6	10-06-72-1	7.1350-05	1.000	19FM-0	1.614.0403	1.5400-01
m	0	U. 393 B	7019.9	2503.2		7.096D-05	1.1 1.5	O. A 16.7	1.5140493	2.4117-0.
+	11	0.5542	6402.2	2463.7	8.7950-02	7.0193-05	4.8.7.E.A	1964.0	1.1900	2.3940-0.
W.	13	0.7146	6737.R	2403.6	6.5390-02	6.9080-05	4.01.64	0.R3A.7	1.047703	2.0250 0
•	5 11	0.8749	6517.0	2 308 .4	\$ • \$ 6 6 FP-112	6.1520-05	4777.0	Ú. #367	R. 58171-07	1.7447-0.
•	11	1.0353	6227.6	2170.2	2.4840-02	6.5420-05	4721.3	0.8347	6.4 150+n2	1.826.0-0
•	<u>^</u>	1.1957	•	1495.3	1.16.813-07	6.2811)-05	4657.7	0.4367	4.7 19 D+0?	. d - UO <sub>4</sub> O • 2
Φ.		1.3696	5188.7	1619.3	1.1250-02	5.7340-05	462A.O	U. RJA.	3.5110.02	7.3649-9
01		1.5954	œ.	1356.9	1.0030-02	5.2950-25	4503.B	0.8367	2.16.70.02	1.0740-0
11	25	3.0184	4284.2	1218.2	60-0344 8	5.02711-05	4517.2	7964.0	1.7840+02	A. 2951)-(14
12		4.3062	346A.9	1113.0	6.0450-03	4. 7830-05	4567.7	0.8367	1.3190+02	1.0440-3
£.	62	6269*6	23.	1030.4	5.96.213-03	4.58BD-05	4534.1	0.8367	1.0500+02	6.2370-02
14	31	7.0676	555	0.479	5.4220-03	4.4480-05	4527.5	0.8367	A. 7 70P+01	5.5140-0.
1.5	33	8.3814	430.	934.1	5.1150-03	4.1450-05	4514.7	0. A 1& 7	7. AARD+0}	5.0770-04
16	35		•	4.5.0	4.7310-03	4.3730-05	6.915.5	901 H 0	7.9410+01	5.5370-04
<b>~</b> 1	37	19,7541	3623.4	995.8	4.798n-03	4.5060-05	1.0/54	0.845.7	9.0Acr.6	7.0440-04
91	39		F 5.8	1042.4	3.98417-03	4.6160-05	2.2555	0.8509	1.0760+02	9.4860-01
61	<b>4 1</b>		3861.8	1990.1	3.7570-03	4.7050-05	4554.9	0.8562	1.1940+02	9.740n-04
20	€3	13.8609	451.	1110.0	3, 59011-03	4.1720-05	4564.5	0.8604	1-2920+02	1.0840-0
21	45	14.8512	4016.0	1132.6	3.4649-03	4.4230-05	4576.9	0.8649	1.1/10+07	1.1770-03
75	4.7	15.8503		0 "05 11	3.1700-03	4.8430-05	4545	0.8584	20+01×5*1	1.2470-0
23	04	16.8738	1019	1163.3	3.2990-03	4.8°320-05	4503.9	0.8714	1.4470.07	1.79R9-01
24	<b>.</b>	17.9354	4132.2	1173.5	3.2460-03	50-0516**	44.00.9	0.879 0.879	1,5700+42	1.1629-03
52	. S	19.0462		8"181	1.2070-03	4.9340-05	2-1095	0.8761	20+0654.	1.1760-03
7,0	Ç ,	20.7150	9*2/14	1107.0	3 14 20-03	CO-01/46.4	4017.	0.1.0	2040631	1 4 3/11-0
- 2	- 6	22.1486	41.42.5	0.45.1	1-1410-03	4-9410-05	4671.8	0.00	1.5010100	FO-012-9-1
5.7	61	24,1190	196	1196.3	3.16 10-03	4.9640-05	4625.5	0,4871	1.6970107	1-4750-41
30	63	25.5605	4198.7	1196.9	3.1710-03	4.9480-05	462A.R	0.5811	1.6030+02	1.4140 01
31	65	27.0742	4147.3	1196.4	1.1A713-03	4.9670-05	4631.5	0.593B	1.6040+02	1.4107-03
32	<b>6</b>	28.7206	3472.2	1116.8	2.4640-03	4. 7860-05	4614.6	0.4862	1.40101	1.5240-07
33	1	31.0940	951.	1109.3	2.5100-03	4.7e.70-05	4616.7	0.8451	1.2760+02	10-0161.1
34	75	34.2682	3937.4	1104.6	2.537.0-03	4.1590-05	4616.3	0.8H59	1.7410002	1.76RD-07
35	E	38.2806	•	1077.0		4.6960-05	2.4194	0.8864	1.1690.02	FD-024 F.
36	86	43.1064	•	1039.4	7.22111-03	4.6110-05	4610.7	G. AHSA	\$0.0 m	10-4101.1
37	93	48.5305	-	1004.1	2-0320-03	50-0115.4	4604.8	0.8469	4.5410+03	1.2479-01
34	100	1542.451	512.	4/4.3	1.86 70-04	4.45401-05	4400.2	0.44.0	8. A 725+01	1.7640-03
34	101	60.6232	500	453.7	1.7470-U	4. 149D-US	4.594.0	0.8471	10.401 10.p	1.25-01-21
<b>\$</b>	*:	65. 1610	***	436.1	1.6550-03	4.3430-05	6.50B.7	0.887]	7.5210101	1.2 ART-11
1+	171	W.	06.	423.9	[•ed Ju-03	4. 1200-05	4.50.4	144.0	7.1.75.000	10-0-5-1
45	12 E	7-185	319.	915.6	1.56 30-03	4.2980-05	4401.8	0.4871	6.9710+01	1.2500-61
F -	135	7	<b>د دی</b>	6. #07	1.5347-03	4.2407-05	400%	0.8871	6. Antipeol	10-10-10-1
;		63.1469	3 550.0	1.606	1.54[0-03	4.2 RED-05	4405.6	0.8471	1041150K*G	1.0-110-1

### 3-0 MONFALUM EN! RGY INTEGNAL TECHNIQUE

VISCOUS FIRM - AMINDAPY LAYER SOLUTION

1		בריים ביים	FACTUR	R E NO		COFFEIGHNT	ROAL TAL	MILLEMA	PANACETE
	(THE)	(PHI)	(HSF)	(RETH)	(MEPH)	(e)(CH)	(FAF)	( YOU'S	(19)
	0.286	0.552	1:4:1	0.0	0.0	8.4320-01	0.8392	0.0	9.0
	0.396	0.659	1.470	10+0110*9	1.0070+02	6.644.D-01	1.0657	0.0	5A.746
	0.398	0.173	1.460	8.4760+01	1.5390+02	6.29RD-01	9606.0	0.0	F1.199
M S T T T T T T T T T T T T T T T T T T	*	0.834	1.514	I.0400+02	2.0470402	5.4660-01	0.8638	0.0	04.400
	0.525	100.1	065.1	1.3050+02	2.5030+02	4. 4810-01	0. #786	0.0	44.44
	0.657	1.290	1.682	1.4710+02	2.8860+07	3.4760-01	0.7830	c.	95.24
	0.878	1.735	1.763	1.4030+02		2.57:00-01	0.7587	0.0	#0.1 1E
	1.234	5,469	1.822	1.5840+02		1.7730-01	0.7083	0.0	45.219
22222222222222222222222222222222222222	1.913	3.658	1.674	L. 7240+02		10-6721-1	0.7312	0.0	41.619
2007 2007	2.172	4.685	1.496	2.1410+02	3.6860+02	7.2760-07	1.0229	0.0	\$3.023
	4.037	6.217	604.1	7.7610+02		5.111n-07	1.1431	0.0	57.953
\$2 m m m m m m m m m m m m m m m m m m m	5.596	8.294	1.126	3.2400+02	4.803n+02	1.8010-07	1.1484	0.0	50° 678
ままである 4 4 4 4 5 5 5 5 5 6 6 6 6 6 7 7 8 7 7 7 7 7 7 7 7 7 7 7 7	7.194	10.434	1.254	3.6060+02	5.2310+02	2-9466-02	1.2278	0.0	0.0
**************************************	115.8	12.238	1.199	3.91 811+02	5.5930+02	2.4710-07	1.2686	0.0	0.0
	9.769	13.783	1.157	4.1980+07	5.42311+02	2.1420-02	1.1005	0.0	0 0
7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	1 G. R 70	15, 332	1.246	4.4670+07	6.300n+02	2.22.0-02	1.7890	50.0	0.0
96 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	12.076	17.125	1.451	4. ROW) +UZ	6.8060+02	2-6640-07	1.7592	11.0	0.0
44444444444444444444444444444444444444	13,421	14.051	1.650	5.2000.402	7,3810+02	3.0750-07	1.7445	0.78	0.0
2444 25 24 25 26 26 26 26 26 26 26 26 26 26 26 26 26	14.902	21.093	1.816	5.65AD+02	R.008/1002	4-UMF4-F	1.2178	0.38	0.0
2444 2544 2544 2544 2544 2544 2544 2544	16.521	23.244	1.955	6.1700+02	A.6810+02	3.7490-02	1.2354	7.0	0.0
7 4 4 7 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	18.284	75.524	2.068	6.1340+07	9.4040+02	3.940JD-02	1.2152	2.5	٥.٢
40 533 533 533 534 535 537 537 537 537 537 537 537 537 537	20.202	17.94.1	7.161	7. MOD +02	1.0180+03	4.1715-02	1.2358	0.67	0.0
553 553 553 554 554 554 1154 1154 1154	5	30.545	2.736	8.0440+02	1.1030+03	4. 17 (IN-n.)	1.270	C. F.	0.0
553 554 555 555 556 557 557 557 557 557 557 557	24.596	33, 356	5.799	9.8120+02	1.1950+03	4.4350-02	1.2487	0.73	0.0
55 54 54 55 65 77 80 77 80 80 11 11 12 13 13	27.125	36.408	2.356	9.6670+02	1.2970103	4.5740-07	1.2395	0.17	٥.ر.
57 65 65 65 77 77 80 80 80 110 110 110 110 110 110 110	29.915	39,731	204.2	1.040320-1	1.4090+03	4. 49-07-02	1.2401	14.0	0.0
59 63 65 65 73 73 80 80 100 1100 1100 1100 1100 1100	32,993	43,360	2.437	1-1660+03	1.5330+03	4-6419-02	1.2407	0.84	0.0
61 63 73 73 73 73 80 80 100 1100 1100 1100 1100 1100 110	36.382	726 *1*	2.463	1.2830+03	1.6690+03	4-6710-07	1.2415	0.86	0.0
63 75 75 87 75 80 80 100 110 110 110 110 110 110	101.03	919.15	2.480	1.4130+03	1.8200+03	4.6A6.0-02	1.7421	0 . A	0.6
659 75 75 80 80 80 80 100 110 110 110 110 110 110	44.163	54.316	16.5.2	1.5560+03	1.9840+03	4.4890-02	1.7431	16.0	o •
68 75 75 86 86 80 100 110 110 110 110 110 110 110	48.254	61.302	2.445	1.7020+01	2.1640+03	4.6AUT-07	1.2571	ZD*0	0.0
71 31.096 75 34.206 80 38.206 86 43.106.0 93 68.530 140 54.245 167 60.023 114 65.761 128 77.463	62.162	63.140	\$14.5	1.40505.1	2.592(11.04	30-0521-62	(2)1-1	, , , , , , , , , , , , , , , , , , ,	•
75 34.265 80 38.265 86 48.5106 93 48.530 100 54.245 110 65.245 114 65.761 112 71.965 135 82.975	70.542	92.7AI	2.673	£0+09H0*2	2040957	7.54M0-07	48//		÷ c
80 38-280 85 48-530 140 54-245 110 60-0245 114 65-023 118 71-185 135 82-975		E 44 - 401	7.00.7	2040405	3.46403403	76-06-5	1.27.00		) 
86 43.105 93 48.530 100 54.245 1107 60.023 114 65.761 121 71.463 135 82.975	916.401	1.36.766	2.681	50+09H6*2	3.84701403	(0-0)/0-01	1.2144	5.0	) ) )
93 46.530 Luo 54.245 LG7 60.023 114 65.761 121 71.463 135 82.975	õ	171.251	20102	504075446		20-1111-15-27	79.70		
100 54.245 117 60.023 114 65.023 121 71.463 135 82.975	155.034	277.507	001.7	3. 7.42.413		/ D=1:11:49 /	מבמלייו		•
114 60.025 114 65.761 121 71.185 128 77.185	162.911	4C1.4C2	7.1.7	E0+0014*5	7. SEC.114.03	7 10:00 C	*****		
114 676161 121 716463 128 776185 135 826975	CX 5 - 7 - 7 - 7 - 7 - 7 - 7 - 7 - 7 - 7 -	200.V-2	COH- 2	10-11-10-4		701-07-07-07	77.6		
128 77.185 138 77.185 135 82.975	6 4 1 4 1 6 1 6 1 6 1 6 1 6 1 6 1 6 1 6	TC 20112	7 1 1	**************************************	•	1 0500-00	2174	E 0	
135 82.975	. (	100-007	2.703	\$04000 Y	10+0-54 t v	1.8417-02	1.7143		0.0
C1 6 70 CC 7	334 384	200 000		•	נטילוובמל א	1 0410-07	1 2212	# 5 ° C	0.0
701 43 761		200.000	(	£0402004	5.2910.00	1-4420-02	1.2213	E 6 - 5	0.0
		;							

### 3-D HOMENTOM ENERGY INTEGRAL TECHNIQUE

# VISCOUS FLOW - CURVED SHOCK AND ANUGHNESS FFFECTS

				CHRVED SHOCK EFFECTS		SUPFACE	ROUGHNESS FFFETTS	
BOOY	INTEG	STREAM	FOGE	STRFAM	EDGE MASS FLUX	ROUGHMF SS	HEAT TRANSFER	PINIGHME SS
DN 14		LENGTH		LOCATION AT SHOCK	AUGHENTATION	12.11	AIN THE MENT AT THE	
17	=	INCH S S	GIUZLBA-DEG R (ENIR)	(4848)	(ROUF)	(RIJE)	(PUFSMT)	(RFKP)
	<b>4</b> 44	0.0	2.48688	0.0	1.0000	0.2309	1.0000	0.0
• ~	, 🎮		2.48386	0.0247	1.1920	00.2.0	1 *0000	3.7400+90
· ~	•	0.3434	2.48121	0.0368	1.1315	0.2360	0000-1	4.5440+00
•	-	U. 5542	2,41113	0.0461	1.121.1	0.7300	1.0000	4.571n+00
		0.7146	2.47371	0.0579	1.1153	0°5 400	1 • חמטיי	4.1340.00
•	2	0.8749	2,47034	9.0647	1.104	0,1300	0000° F	3.4540+00
~	11	1.0353	2.46790	2690.0	1.0941	00.2300	1.0000	7.1447400
•	6		2.46599	0.0711	ISEO. I	00£2°0	1 • 0000	1.97400
•	12	1.3496	2.47910	0.0100	1.0246	0.7300	1.0390	1.4777+00
2	23	1.9954	2,47514	0.0797	1.0380	0.7300	1.0000	9, 6410-01
=	25	3.0184	2,46956	0.0917	1.0532	0.2300	1.0000	7. # 7An-01
12	2.5	4.3062	2,46643	0.1006	1.0606	00.2.00	1 • 0000	6.4040-01
	52	5.6925	2.46473	1101.0	1.0616	0.7300	1.0000	5.3H70-01
=	i e	1.0678	2,46333	0.1172	1.0647	0.2300	1.0000	4. 74.01-01
51	33	8.3814	2.46218	0.1164	1.0672	00.7.00	i <b>-</b> 0000	4. 1760-nl
9	3.5	9.6123	2.46125	0.1244	1.06.86	0.1749	00001	6. JA 211-01
1	3.7	10.7591	2.46052	0.1377	1.9696	0.5249	1.0000	1, 7047+00
=	25	_	2.45948	0.1511	1.0704	0.1779	+000 <b>+1</b>	1.4000
5	14	12.8620	2.45961	0.1644	1.0709	0. 9048	1.0000	1.7970.00
70	43	13.8509	2.45939	0.1773	1.0711	1.0657	0000-1	2,1150+60
21	4.5	15.8512	2.45934	0.1900	1.0708	1.2053	1.0000	7.40%1.00
22	Į. <b>4</b>	15.8503	2,45943	0.2024	1.0704	1.1764	1.0000	7.66411900
23	<b>6</b>	16.8738	2.45964	0.2146	1.0695	1.4794	1.6000	2.454000
<b>5</b> *	15	17.9354	2.45996	0.2768	L . 05 R6	1.5181	1000-1	00+00±0°2
2.5	53	19-0462	2.45057	0.7386	1.0674	2465	1.0009	1. 1 R 3D+00
92	55	20.7150	2,46087	0.2504	1.0641	1.6.593	1.00.1	3, 31,571,00
27	2.5	21.4480	49 194.2	0.2673	1.0646	1.7146	1-00-1	1.4240+00
82	54	22.7486	2.46205	15220	1.06 30	1.741		4,5710+00
62	19	24.119d	2.46272	0.2858	1.0413	1. A005	1-0042	3.6010+00
30	63	5095.52	25.45.7	0.7974	5650-1	1.00334	At 000 1	
31	φ. •	27.075	91444-7	C. 101.0	1.0216	055 F 81	1.00-1	7. 18 70+00
אר ב ב	D -	31 0045	0001107	00.37.50	1.0726	71001	1,001	3. [940004)
, ,	· 1	34-2682	7.45127	0.31	1.00.13	1.9292	1.0013	7.2310+0U
<u> </u>	0.00	78. 2806	95655-2	0.3519	1.0426	1644.	1.0004	3.!050+00
2	80	-	2.45019	0.3627	1.0016	1. 45.04	1.0000	7.4447400
37	63	4.5305	2.44111	0.3713	1.0986	1. 44.65	1.0003	2, 7.150+40
34	100	5 : 2451	2.44666	0.1789	1.1002	1.2694	1.0000	7. 51 511+00
33	101	60.0232	2.44878	0.3960	1.0942	1.9704	1.0000	2.1640+00
0	114	65.7610	2.45299	0.3924	1.0414	1.9700	1 - 10:00	7.74.404.30
7	121	11.4630	2.45866	0.1993	1.0669	1.9710	1.0000	7. 1 (5 MI) + 10
4.2	128	7.1.85	2.46577	51012	1.051	1.9710	1 . Octo	7.1110+00
\$	135	P2.9769	•	0.4155	1.0375	0 1/0 1	6.000-1	
;	131	8 1- 1969	2.47529	0.4159	1.0319	1.9710	1.6000	7-07(5)4017

### 3-0 MEMENTUM ENFRGY INTEGRAL TECHNIQUE

BODY GEUMETRY AND SURFACE QUANTY RESULTS

	SHRFACE TEMPERATHPE (OFG R)		7113.75	701 A. 09	7019.57	70.74.95	70.0.07	1042,41	7066-48	7076.42	70H5.10	70A9.3A	6740.A1	674R.14	6745.7R	6797.11	6A24, 71	6.85 3.81	687H.47	6896. 12	02.1059	6520.61	64.10.79	61.4559	6540.37	66.46.39	6677.18	6705.8h	6727.RS	4777.41
	R-PRIME THERMOCHEN		3.1230-01	3.0440-01	3.05@n-01	3.0560-01	₹044:1-0}	3.0740-01	3.0810-01	J. 095D-01	3°1040-01	3.1110-01	2.4010-01	7.8050-01	7.8.70:0-0I	2.8420-01	2.8700-01	2.8469-01	2.7180-01	2°4330-01	2.9400-01	2.6700-01	2.6270-01	2.6440-01	2.6.7nn-01	2,7040-01	2, 1110-01	7.7660-01	2.7850-01	7.1940-01
MORMALIZED SURFACE CODRDINATES U 1.4000 0.1233 4 1.4000 0.0	SKIN FRICTION CF/2		0.012		F00.0		0.0n1		F00.0		400.0	0°004			2000			200.0			0.002	0.002		0.000		0.007				
D SURFACE 16 0.1233	INDINCED PRESSURF (ATM)		25.2057	20.2123	1941.04	20.7258	21,2992	27.0109	22,4,55	23.1169	1344.65	23.4146	11.7222	11.9014	12.3289	13.0129	13.8821	16.6901	15.4031	15.4981	16-1176	7.7385	574H-7	8.7816	R.4073	9.1050	10.4245	11.0594	11.5166	11.716
MURMALIZE U 1.40000	HEAT TRANS RATE (ATU/F T2-SFC)		2.01730+03	1.51200+03	1,51750+03	1.52870+63	1.54800+03	1.54870+03	1.59640+03	1.415AD+C3	1.61740+03	1.64830+03	1.09170+03	1.10040-03	1.12110+03	1.15520+03	1.1990:3+63	1.24060+03	1.27810+03	1.30250+03	1,31460+03	8-61990+02	A. 70670+02	8.90900+02	9.236271402	9-66280+02	1.00780+03	1.04600401	1.67770+03	1.08410+03
2 ( IN ) U.OU34 U.OU34	SURFACE PRESSURE (A) 1) ((		25.1906	20.1954	20.3525	20. 7097	21.2842	21.9970	22.6246	23.1055	23.4446	23.604.5	11.7139	11.8432	17, 3704	13,0052	13.8754	14,6832	15.394.5	15,8918	16.1114	7-7317	7. H'104	8.2750	B. 8054	9.6989	10.41 H7	11.0527	1115-11	11.7061
¥ (111) 0.0000	RFCOVERY ENTHALPY (81U/LBM)		4-0564	4912.5	4913.7	4916.4	4920.8	4974.2	4931.3	4935.2	4937.9	4939.1	4831.3	4633.3	4838.0	4865.4	4854.7	4 N63.2	4870.3	4875.I	4877.2	4111.9	4780.4	47.86.3	4795.4	4806. S	F. 15. 0	7 1 2 17	4879.0	4831.2
K 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	KCH)	~	-0* 000	0.055	0.055	0.055	0.055	0,055	0.055	0.055	0.055	0.055	0.213	0.213	0.213	0.213	0-213	0.213	0.213	0.213	0.213	0.326	3.26	35.4.0	6.326	226	226	936 0	0.176	0.326
LOCATION	CARTESIAN COORDINATES (INCH)	<b>-</b>	0.0	0.0	0.120	0.221	0.789	0.313	9.289	0.221	0.120	0.000	c	0.224	0.414		0.5×9	445.0	0.416	0.225	0.0	5	240	107.0	A44.0	707	70.0		0.754	0.000
INTEREST FOR	COORDI	×	0.0	111	2.280	0.221	0-1-0	00000	-0-120	-0.221	-0.289	-0.313	9	498	0.416	0.22	0.0	-0.225	-0.416	-0.544	-0.589	100	20.00	200	246		0.000	407 · 0	75.0-	-0.102
STAGNATION POINT MENIMUN 2-CORD.	SURFACE COORDINATES		0.0	•				5	5			0	-	2 -	-			-		0.1	0.1	-	7 -	֓֞֞֜֜֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֡֓֓֓֓֓֓֓֡֓֡֓֡֓֡	•		•	3 :	· ·	1.3
STAGN	SURI COORUI	3	0.0	6	) v			, ,	7.6	0.0		•	c		-			7		5	0.4	•				• 1	7.	(*)		

6235.92 6743.94 6775.94 6375.94 6436.77 6679.68 6518.19	5897.38 5913.94 5951.96 6007.57 6138.33 6223.20	5188.67 5214.07 5264.69 53.19.67 55.73.69 55.73.69 56.70.51	3555.55 3666.92 3743.95 3885.70 4067.92 4256.96 4426.31	3784.05 3693.08 3691.76 3743.17 3058.07 4388.07 5616.76
2.4170-01 2.4170-01 2.4140-01 7.4640-01 7.5120-01 7.5540-01 7.5090-01	2,2050-01 2,2140-01 7,3140-01 7,3620-01 7,3000-01 2,3140-01 2,340-01 2,4050-01	2.3280-01 2.3460-01 2.3460-01 2.3460-01 2.4760-01 2.4790-01 2.4540-01 2.4760-01	2.2510-01 2.2510-01 2.2510-01 2.2510-01 2.2710-01 2.2710-01 2.2810-01	2.2440-01 2.7540-01 2.7540-01 2.2570-01 2.2550-01 2.3740-01 2.3740-01
0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002	0.007 0.007 0.007 0.007 0.007 0.007 0.007	0.002 0.002 0.002 0.002 0.002 0.003 0.003 0.003 0.003 0.003	100.0 100.0 100.0 100.0 100.0 100.0	100.0 100.0 100.0 100.0 100.0 100.0 100.0
4.7933 4.8976 5.1521 5.5628 6.0988 6.05875 7.2030 7.5953	2.7775 2.8531 3.0399 3.3448 3.7497 4.1240 4.4621 4.87171	1.4915 1.5433 1.6455 1.8137 2.0367 2.2900 2.5209 2.7071 2.7000	0.5074 0.5210 0.5612 0.6479 0.7781 1.3515 1.4475	0.3775 0.3867 0.5362 0.5362 0.7611 1.635 1.637 1.7705
6.48410+02 6.56430+02 6.75470+02 7.07700+02 7.91500+02 7.91500+02 8.76450+02 8.56490+02	4.79700402 4.84400407 5.02290402 5.27480402 5.59870402 6.20119402 6.40870402	3,533405-02 3,60420-02 3,761405-02 4,004411-02 4,59930-02 4,59890-02 5,03400-02 5,11759-02	9.21465-01 9.73150+01 1.07630-02 1.24239-02 1.48100+02 1.75920-02 2.25330-02 2.25330-02	1, 10520+02 9, 12190+01 H, 24510+01 9, 77550+01 1, 42040+02 2, 17790+02 7, 99720+02 4,68740+02 5, 34480+02
4.7876 4.8919 5.1465 5.5573 6.0935 6.6170 7.5904	2.7732 2.8488 3.0355 3.3405 3.7454 4.1196 4.7128	1.54916 1.5414 1.6433 1.8107 2.0335 2.2870 2.5178 2.46389	0.5066 0.5297 0.5603 0.6419 0.9620 1.1741 1.3575	0.31766 0.3876 0.4109 0.5176 0.7605 1.6317 1.7696
4724.5 4726.7 4731.9 4740.0 4759.9 4759.9 4758.5	6669.4 4617.2 4617.7 4699.3 4709.0 4722.8 4722.8	4628.0 4630.2 4634.5 4641.5 4651.9 4662.1 4670.5	4525.4 4524.5 4524.5 4527.9 453.3 4543.3 4551.5 4558.0	45445.3 454714.6 454714.6 45474.6 45476.2 45476.2 45476.3 455476.3
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0.0 0.304 0.562 0.733 0.794 0.962 0.304	0.0 0.330 0.610 0.796 0.863 0.756 0.610	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0	0.0 0.717 1.325 1.731 1.874 1.325 0.717	0.0 1.088 2.010 2.625 2.943 2.525 2.625 2.625 2.625 2.625
0.794 0.733 0.562 0.304 0.000 -0.304 -0.562 -0.733	0.863 0.746 0.610 0.330 0.000 -0.330 -0.510 -0.510	0.405 0.835 0.640 0.346 0.000 -0.346 -0.940	1.874 1.731 1.325 0.717 0.000 -0.717 -1.325 -1.325	2.643 2.645 2.010 1.068 0.000 -1.098 -2.010
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10-0185.5	2 3830-01	10 0111	10-0116-7	וח הונישפיי	10-016-2	10-03-03	7.85HD-01	7.A 7AD-01	2.2A7D-01	2.2AMD-01	7.30411-01	2.1910-01	7.4840-01	2.6210-01	2.7540-01	7.8 760-01	10-0158.5	2.7870-01	2.2900-61	7.4160-01	7.37*0-01	2.4870-01	10-0529-2	2.7410-01	2.8770-01	2.8450-01	2.2810-01	2.2840-01	10-0RPC.2	10-0116.6	2.4240-01	2.5140-01	7.6070-01	2.6580-01	2.6 770-01	2.2740-01	7.2400-01	7.2840-01	2.3140-01	7.1440-01	10-0414.5	7.44 311-01	7.5040-01	7.5790-01
100.0		1000	100.0	10.00	- C-	1000	100 <b>.</b> 0	100.0	100.00	0.001	0.001	100.0	100.0	0.01	100.0	100.0	100.0	100.0	100.0	100.0	100.0	110.0	100.0	100.0	100.0	100.0	0.002	100.0	100.0	10.0	100.0	100.0	100.0	0•001	0.001	100.0	100.0	100.00	1000	100.0	0.001	1 LU 0	100-0	0.00
0.3428	1000			27.65	595771	¥C 400 = 1	2.0223	22122	9.1378	0.1436	0.3975	0.6215	0. Hd 26	1.2776	1.6625	1.94 78	2.0418	0.3395	0.3403	0.4197	9055-0	0.9120	1.2923	1.6726	1.9361	2.0347	0.2679	0.7621	0.3271	0.4468	0.6997	0.9577	1.2037	1.1819	1.4515	0.7544	0.2379	0.2505	0.1465	0.5014	0.6565	0.#10	0.0195	0.4913
1.50270+02	7041166444	20.00.10.1 20.00.10.1	20+00-24-2	4.UARRU+02	5.37960+32	70+IP(-)41-0	8.07950+62	8.39270+02	1.40110+02	1.45200+02	2.02750+02	1.25850+02	4. 3578D+32	5.80270+02	7.01410402	7.90200+02	8.17810+02	1.609203+02	1.68040+02	7.247AD+02	3.178IN+02	20+05152**	5.91580+02	7.10080+02	7.431 70+02	A.11980+02	1.36650+02	1.41580+02	1.59880+02	2.54070402	3*10950+02	4.61940+02	20+09145.5	6.04020+02	6.20900+62	1,28120+02	1.30629402	1,55210+07	2.12680+02	2.87740+02	3.53960+02	4.08 190 +02	4.50420+62	4.69020+02
0.3411	0.000	2875 O	0.5730	0.8476	1.2339	1.5478	2.0187	2.1185	15160	0.3417	6.1952	0.6163	0.8786	1.25.80	1.6574	1.9424	2,0363	0.3372	47110	0.4147	0.5866	0.4074	1.2871	1.6668	1.9300	2°0598	Q.266T				0.6958		1.1940	1.3759	1.4456	0.2535	0.2378			07650		0.6036	0.9326	0.9844
\$597.7	0.4164	47.5G.4	4510.5	4534.6	4537.8	4537.U	4535.7	4536.6	4622.0	1.0004	4564.5	4533.7	4509.3	4500.9	4443.6	4488.7	4488.2	4628.6	4604.0	4557.0	4512.3	4494.3	4486.7	4479.1	4476.9	4476.7	4618.1	4590.8	4531.2	. 1.5644	4490.8	4485.8	44BI.0	4482.1	4484.0	4616.3	4574.5	4518.2	4690.8	*****	4478.0	4673.6	4474.3	4477-T
16.594	å.	ė	÷	ġ	ġ,		16.594	16.594	21.874			21.874	21.874	21.874	21.874	21.874	21.874	24.514	24.514		24.514	4.51		;	24.514	24.514	27,154	27,154	27.154	27.154	27.154	27.154	27.15	-	27.154	29.602	79.602	23.602	29,662	29-602	29.602	29-602	29.602	29,602
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3947,64	3924.51	100.2.76	4286.91	140 1.0A	06,0104	5185.19	5377.07	5378.02	78.2195	74 - A7 ME			2000	rr 01 r 1	54 - 70 P		63776	4 2 A () 4 2 4	3845.74		70.710	100111	46777		27.57	36 036	(7.11.6.6	12.66	3671.73	1699.00	4001.R3	4104.56	4607.29	495H.15	5217.74	7	5407.65	3579.49	3645.46	51.1161	4177.9A	.5 AU. 07	4961.58	718.8R	4276.61	
	2.7 787-01							10-0664								10-61-4-6			. 2740-01	•					יייייייייייייייייייייייייייייייייייייי						_						_				2.29In-01					
2 10000				100.		0.001	2 100.0		2,601			<b>.</b> .		[ .	[ ]			נ ויטיח	5 100.0						7 000			000*0			100	100.					000	0.001					000	000	010	2
0.2544	0.7196	0.2074	0.3148	9044-0	1495.0	0.7048	0.4373	0.8947	0.2480	0.2052	1001	21.61.0		1174-0	PC 2 C 2 D	0.5 HC-1	0.8302	0.4877	0.2376	1056	11.2035	C 20.20	0.4126		767690	2 2 2 2		- 402-	0.1918	0.1549	0.7260	0.2971	0.36PZ	0.5187	1664.0	0.8444	0.9040	0.1613	0.1539	0.1927	0.7314	0.3486	0.5188	0.7176	0.8729	
1.26630+02	1.24400+02	1.15620+02	1.98120+02	2.61 120+02	1.16990+02	3.64000+02	4.19200+02	4.39 /BD+02	50+01152-1	1.19850+02	1 20003103	70.44.49.4	1 5 10 60 50 50 50 50 50 50 50 50 50 50 50 50 50	2040km/L=/	20+0544006	30+020-405		4-42020+02	1.175:00+02	1.11930402	1.35470402	20101011	7.56550402	2010166	304077777	20-07 1-195	20100705**	204116 H16 94	9.66790+01	1.01330+02	1.50761)+02	1.94090+02	2.34650+02	3.01460+02	3.79000+02	4.31010+02	4.54170+02	10+62412-8	9.81650+01	1.12300+02	1-61550+02	2.26990+02	7.03300+02	1.81170+02	4.40370402	42
0.2534	0.2185	0.2051	0,3111	0.4354	0.5598	0.6975	0.8319	0.8869	0.2470	0.7048	1000		20.00	2010	0.7543	- 2 - C	0.827's	0. A BO6	1.276.3	7 1 866	450 T-0	0 1010	0.5100	7/15-0	0.3184	2010.0	N 10 10 10 10 10 10 10 10 10 10 10 10 10	- ex e - n				0.7925				0.4378	0.8975	0.1599	0.1512	0.1 RH 7	0.2262			0.1045	0.8670	> ::::>
4616.5	4567.0	4488.4	4484.0	4476.7	44694	4465.8	4468.7	4468.2	4615.6	4554	1 0077	7 0 2 7 7	C 8 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	60144	-1000	- K - + -	1.0.754	4460.5	4614.3	6 10 4	46 MG. 7	1 1004	4417.0	V	44000	*****	101044	442548	4605.5	4511.2	4.88.6	4466.0	4443.5	443H.9	4442.1	4.645.4	4446.6	4598.9	4509.3	4474.5	4439.6	4432.2	44.36.9	4442.0	4445.0	207
2	32.050	2	2.0	2	0	2.	2	32.050	34.497							16.491	7	34.497		٠. ٥				•	30. 947	•	å,	ř	46. 736	46.736	46.736	46.736	46.730	46.736	46. 736	46.136	•	56.528		-	56.528	NO.			56.576	٠
0.0	2.397	4.430	5.785	6.265	5.785	4.430	2.397	0.00	0,0	2.40A		710.	220.0	776-4	770.0	719.6	964.7	000.0	C	7 5 9 6	107	֓֞֝֓֜֓֜֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֡֓֓֓֓֓֓֡֓֓֓֡	07.	•	09740		* (	9	0.0	٦,	٠,	7.210	7	7	٠,	₹,	್ಳ	0-0	3.382	6-2+9	8.160	8-837	8-160	6.249	4.347	
6.265	5.785	4.4 30	2,398	0.000	-2.397	-4.430	-5, 785	-6.265	4.522	6.077	777	710.	2000	000.0	574471	710	7/0 -9-	-6.32	779	•	707-9	****		;,	PAC-7-	; ,	007.9-	å		5	Š	2.988	٠,	2.9	5.5	7	7.8		10	2.4	3,382	00		6.24	-	
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3-D MIMENTUM LNERGY INTEGRAL TECHNIQUE

3417.50	36.4.75	375H. 76	4113.93	4464.01	4949.01	K130 1K		76.1045	5461.84		£1.0614	3544.66	3757.51	4137.63	4550.66	4967.90			2478.14	5482.93		1757.71	34 17.62	40 211.77	4444.21	5247. AS	54.17.07	5076	46.673	740	,
2.2540-01	2.24.00-01	2.2760-01	7.2900-01	2.2070-01	2.3479-01	10 CORV F	10-11414-7	7.5110-01	2.5400-01	-	2.2577-01	2.2670-01	2.2750-01	7.2910-01	2.1050-01	7 2410-01	10-11-6-2	7.44.30-01	2.5270-01	2.5510-01		2.2550-01	7.2470-01	J0-07H7-01	10-0106.5	2.5010-01	2.5.7HD-01			7.5170-61	10-0555.6
100.0	0.00!	£01:0	0.000	000.0	000.0		0000	0000	0.000		100.0	100.0	0000	0000	מיים ס		0.00	0.000	0,000	0.000		100.0	0,000	00000	0.000	0-000	000			0.000	0.000
0.1438	0.1331	0.1402	0.2156	0.3425	5188		0.7113	1516.0	6966*0		G.1363	0.1170	0.1385	0.2136	Sacr o		DC2C*A	0.7560	0.9554	0. 40.1	1	0.1314	0.1122	0.1871	0. 4007	0.4716	1 1 050	0.6101	0.6797	1036.0	1.071
7.41820401	9.84750+01	1.04 150+02	1.56760+02	2.2350402	1 000 1040 1	Static units	3.84860+02	4, 51 450+02	4.78200+02		7.05:300+01	10.16350+01	1.08 340+02	1.56620+02		20+0646142	70411976697	3.90120+02	4.67050+32	4.89810402		6.79720+01	8.39460+01	1.37000000	2.uk 700+02	4.40.240.40.2	10.00	20401 161.6	7.341.80+02	4.59451402	4.94 1613+112
0.1424	0.1295	0.1358	0.2104	2270		חכזרים	0.7256	0.9103	1166.0		0.1350	0.1125	0-1346	70 P.		0.3268	0.14 r	Q. 7505	4056.0	1.0381		0.1303	Q.10H4	0.1781	0.2434		100.	1.1975	0.6238	0.9545	1.0675
4598.7	1.0844	4438-6	4437 1	101744	****	** 22 **	4442.2	6465.5	4444.8		4601.0	5-1599	44.74.8	2 3 2 7 7	000 744	4430.1	4417.5	4442.9	1.444	4441.7		4.505.6	4664.6	4477.4	1,4644		N • 65 P P	*****	1.0555	4666.4	444H.4
66. 319	66. 119	11.00	600.00	68.51.4	916 90	66.319	66, 319	016.44	66.319	1	73,662	72 667	73006	700.61	79006	13.662	73.662	73,662	73. 45.7	13 663	300 . 6	81.860	۱ ـ ۱		B1 . B. A.O.		000.00	81°860	B1.860		
5	2.778			0110	4.867	9.10	116.9	2 7 7 6	0.000		0			77601	9.662	10.638	9.823	7.573	4.071			c	440	440	11 337	. 77011	711.77	11.227	446.0	5.044	0.000
0 067		7.1.0		3.115	00000	-3,175	216-9-		-9-867		10.428		7,000	676.7	4.071	0000	-4.071	-1-522	10 B 7 B	67046	10.038		176			70.70	0.00	-4-250	-5.466	-10.335	-11.500
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### 3-D MINENTON ENFROY INTEGRAL LECHNIQUE

### AERODYNAMIC COEFFICIENTS

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12210-0-	INDUCED PI	NDUCED #RESS V 0.0001
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	INVISCID  X  Y  0.1442 0.0	X X 0.0
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### SECTION 5

### RESULTS

The two-dimensional version of MEIT has been verified by many comparisons with data and other calculations (References 6 to 10).

Therefore, testing of 3DMEIT has been concentrated on data from biconic configurations at angle-of-attack. Three runs from References 27 and 28 were selected as test cases for 3DMEIT. The conditions of these three test cases are summarized in Table 5-1. A demonstration calculation was also done at flight conditions on a biconi; configuration with yaw stabilizers. This calculation exercised the ablation model to predict wall temperature and blowing parameters.

Figure 5-1 compares an early zero angle-of-attack heat transfer prediction with the experimental data. In general, this prediction is higher than the data, which is believed to be due to the ideal gas properties used in this calculation. The local calculated stagnation temperature was 1,982°R, which is higher than the measured stilling chamber temperature of 1,894°R. The measured local freestream stagnation temperature was 1,796°R which indicates some losses from the stilling chamber conditions. Therefore, the freestream conditions for the calculations were modified as shown in Table 5-1 to more closely match the measured local stagnation temperature. This resulted in much better agreement with the experimental data, as shown in subsequent comparisons.

Table 5-1. Test Case Conditions

Comments	Ideal gas, laminar		Ideal gas, laminar		Ideal gas, turbulent, boundary layer trips	Real gas, turbulent, ablation model
T <sub>o</sub> (0R)	1,982	1,764	1,989	1,764	1,355	10,743
(deg)	0	0	ι¢	ഹ	10	ഗ
<b>E</b> 8	10	10	10	10	&	16.2
٧ (ft/s)	4,767	4,498	4,775	4,498	3,890	15,609
T(0R)	94.54	84.14	94.88	84.14	98.4	389.97
p <sub>∞</sub> (atm)	0.000681	0.000681	0.001361	0.001361	0.005913	0.074868
Configuration	14 <sup>0</sup> /7 <sup>0</sup> Biconic 0.5 Rn L = 28.283 in.		14 <sup>0</sup> /7 <sup>0</sup> Biconic 0.5 Rn L = 28.283 in.		10.5 <sup>0</sup> /7 <sup>0</sup> Biconic 0.5 Rn L = 31.006 in.	10.4 <sup>0</sup> /6 <sup>0</sup> Biconic 0.92 Rn L = 8
Data Group	Phase Y GR 159	Modified	Phase V Groups 96, 97, 136-158	Modified	Phase V Groups 71-75 261-265	Flight
Case	Н		2		m	4

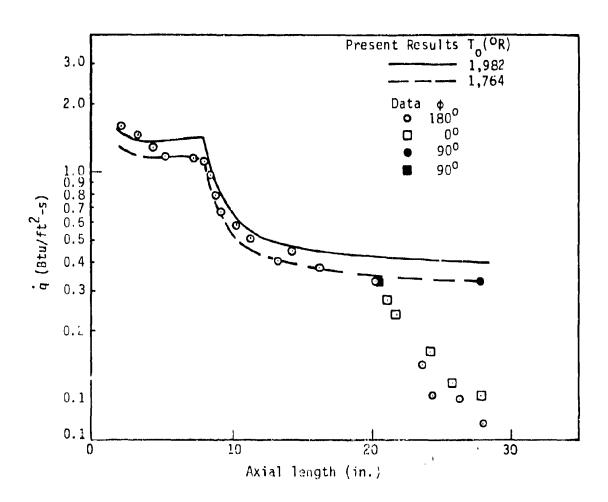


Figure 5-1. Comparison of 3DMEIT with HYTAC Data Group 159, Laminar, M = 10,  $\alpha$  = 0

Figures 5-2 and 5-3 show the laminar calculation of 5° angle-of-attack. Again, a stagnation temperature of 1,998°R gives predictions greater than the data. However, with the modified stagnation conditions, the predictions are quite good, except on the leeward side. Figure 5-3 shows that this discrepancy occurs where viscous interactions would be expected to affect the inviscid pressure.

The solution for turbulent flow at  $\alpha=10^{0}$  is shown in Figures 5-4 through 5-7. Figure 5-4 illustrates the effect of entropy swallowing and shows a significant increase in heating on the windward side compared to isentropic flow. The predictions with entropy swallowing are in good agreement with the experiment.

Like the laminar predictions, those for turbulent flow are poorer on the leeward side. Figures 5-6 and 5-7 compare the inviscid pressure and the experimental data. Again, the inviscid procedure underpredicts the pressure on the forecone and overpredicts the pressure on the aft cone because of viscous interaction effects on the leeward side.

The fourth case is a demonstration of the flight capabilities of 3DMEIT. This case used real gas properties, ablation modeling and a complex configuration with yaw stabilizers on the aft-cone. The patch geometry used in the calculation is shown in Figure 5-8. Figures 5-9 and 5-10 give the heat transfer on this configuration.

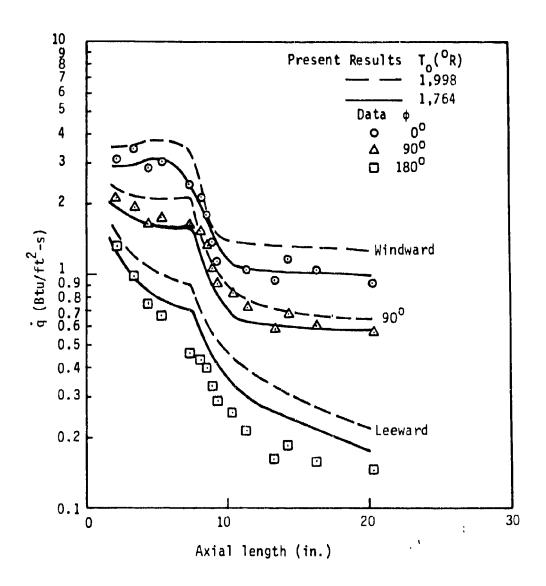


Figure 5-2. Axial Heat Transfer Distributions, Groups 96, 97, 136 to 158 Laminar, M=10,  $\alpha=5$ 

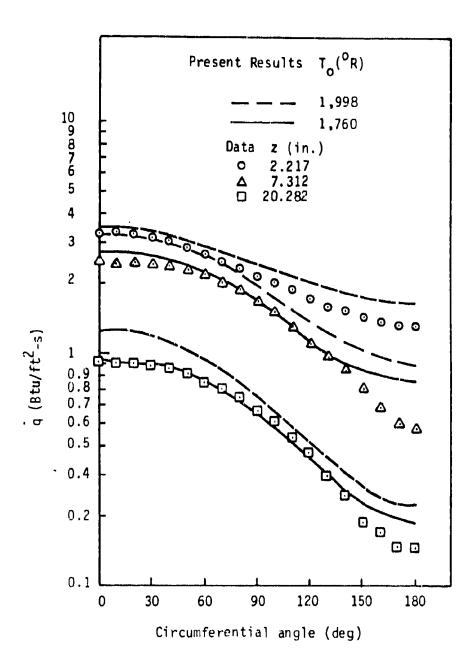


Figure 5-3. Circumferential Heat Transfer Distributions, Groups 96, 97, 136 to 158 Laminar, M = 10,  $\alpha$  = 50

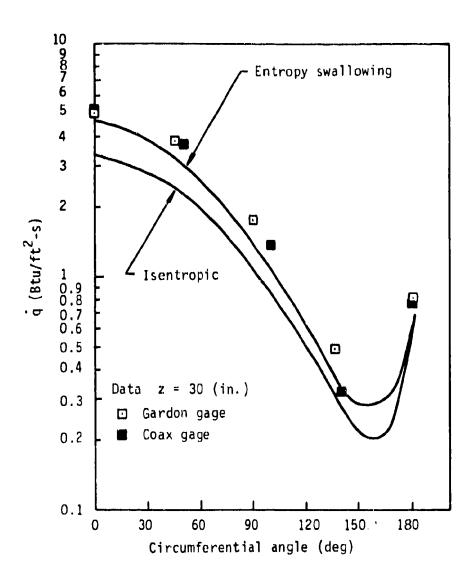


Figure 5-4. Circumferential Heat Transfer Distributions, Phase IV, Turbulent, M=8,  $\alpha=10^{\circ}$ 

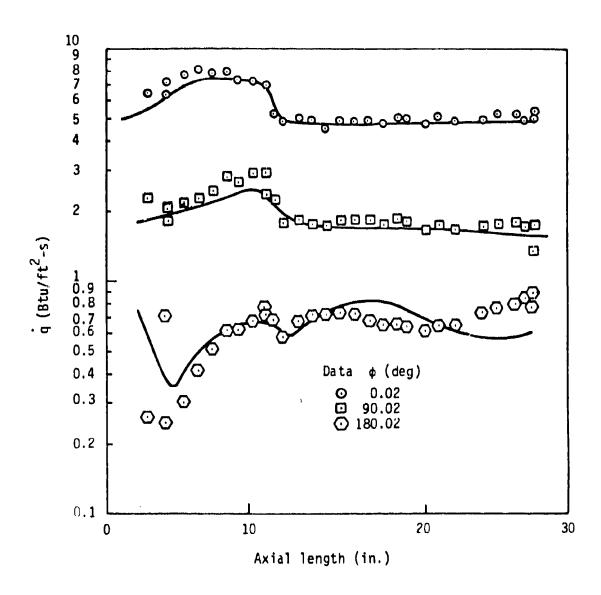


Figure 5-5. Axial Heat Transfer Distributions, Phase IV, Turbulent, M=8,  $\alpha=10^{\circ}$ 

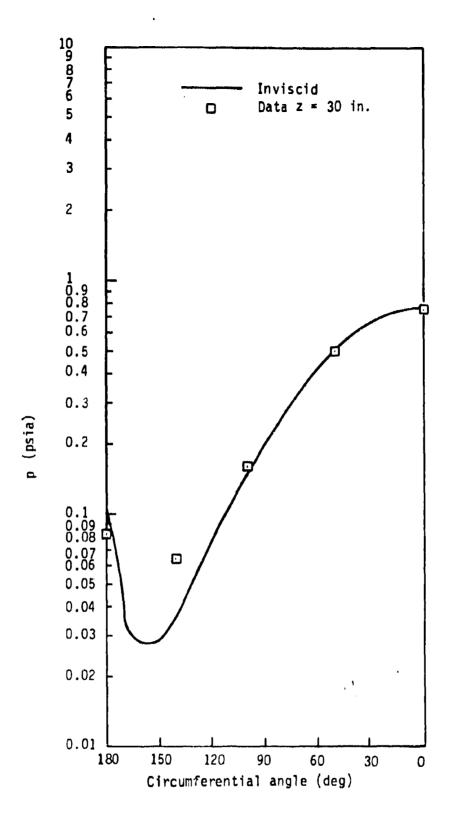


Figure 5-6. Inviscid Surface Pressure Distribution Compared with HYTAC Data, M = 8,  $\alpha$  = 100

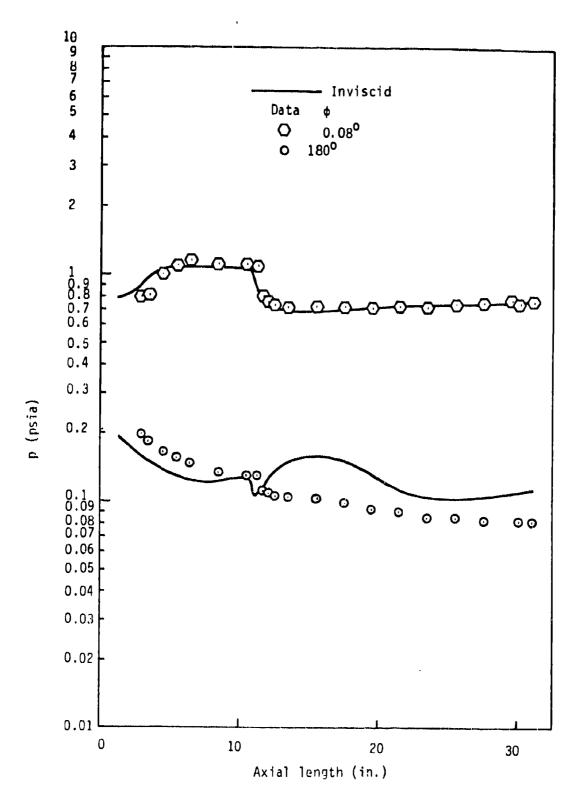


Figure 5-7. Inviscid Surface Pressure Distributions Compared with HYTAC Data, M = 8,  $\alpha$  = 10°

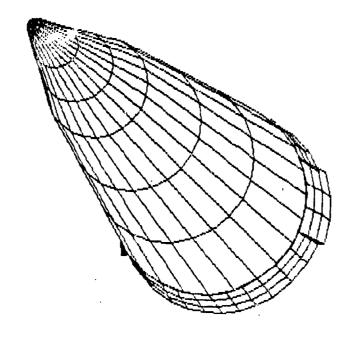


Figure 5-8. Flight Case Geometry with Yaw Stabilizers

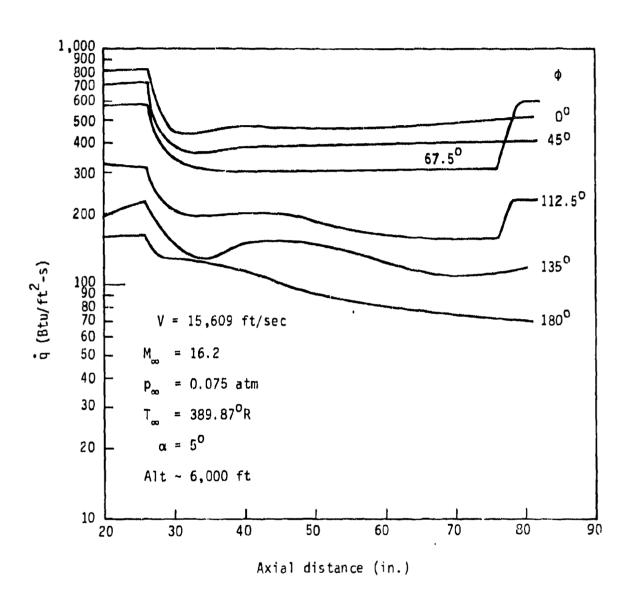


Figure 5-9. Predicted Axial Heating Distributions at Flight Conditions, 10.4/6.0 Biconic with Yaw Stabilizers, M = 16.2,  $\alpha$  = 50

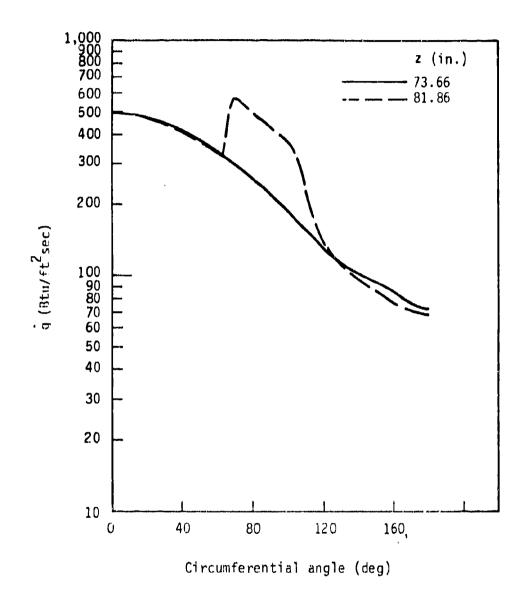


Figure 5-10. Predicted Circumferential Heating Distributions at Flight Conditions, 10.4/6.0 Biconic with Yaw Stabilizers, M = 16.2,  $\alpha$  = 50

### SECTION 6

### CONCLUSIONS

This report documents the initial efforts in the development of a coupled inviscid-boundary layer flow field solution procedure specifically designed to treat maneuvering reentry vehicles. The resultant code, which consists of the 3IS inviscid flow field code, a buffer code, and the 3DMEIT integral boundary layer code, can treat equilibrium air thermodynamics, laminar, transitional, or turbulent flows, and models the effects of surface roughness and mass addition from ablating heatshields on the boundary layer flow. Approximate models are provided to automatically determine the wall temperature and mass addition rates over the entire vehicle, for a variety of heatshield materials.

This coupled inviscid-boundary layer flow field procedure represents an extension to the capabilities of such techniques, obtained by making maximum use of the detailed inviscid flow field information available. Specifically, this approach has allowed:

- Direct calculation of the inviscid surface streamlines
   in the finite-difference inviscid afterbody code (3IS),
   and
- Accurate definition of the boundary layer edge properties
   through the use of the detailed inviscid flow field
   profiles near the wall, rather than using a stream tube
   mass balance technique (which is difficult to apply to
   a three-dimensional flow).

The flow field technique resulting from this effort provides a reliable method for engineering predictions of aerodynamic loads and heating on maneuvering reentry vehicles, while being efficient enough (through the use of an integral boundary layer procedure) to allow its routine use in both vehicle design and analysis.

It is recommended that future efforts be conducted to 1) extend the 3DMEIT method for body geometry description in order to enable calculations to be performed at sideslip and 2) allow for an interface between the buffer code and the output of a CM3DT solution in order to treat non-spherical, asymmetric nosetip shapes.

### SECTION 7

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ACUREX CORPORATION
ATTN: Chuck Nardo
485 Clyde Avenue
Mountain View CA 94040

AEDC/DOT Arnold AFS TN 37389

Aerospace Corp ATTN: Al Robertson P.O. Box 95085 Los Angeles, CA 90045

AFOSR/NA Bolling AFB DC 20332

AFWAL/FIMG Wright-Patterson AFB OH 45433

Arete Association ATTN: Steve Lubard P.O. Box 350 Encino, CA 91316

AVCO CORPORATION ATTN: Noel Thyson 201 Lowell Street Wilmington MA 01887

Ballistic Missile Defense Adv Tech Cutr ATTN: Jim Papadopoulos (ATC-M) P.O. Box 1500 Huntsville AL 35807

CALSPAN CORPORATION-AEDC ATTN: Billy Griffith Arnold AFS TN 37389

General Dynamics - Convair ATTN: Archie Gay P.O. Box 80847 San Diego, CA 92138

DNC/AFATL Eglin AFB FL 32542

GENERAL ELECTRIC COMPANY/RESD ATTN: Robert Neff 3198 Chestnut Street Philadelphia PA 19101 Lockheed Missiles and Space Company ATTN: Gerald Chrusciel Dept 81-11 P.O. Box 504 Sunnyvale, CA 94086

Martin Marietta Corporation ATTN: John Carmichael P.O. Box 5837 Orlando FL 32805

McDONNEL DOUGLAS ASTRONAUTICS COMPANY ATTN: Jim Xerikos 5301 Bolsa Avenue Huntington Beach CA 92647

Commander MICON
U.S. Army Missile Research & Dev Command
ATTN: R. A. Deep, DRDMI-TDK
Redstone Arsenal AL 35809

NASA Langley Research Center ATTN: Dennis Bushnell Hampton VA 23665

NASA Ames Research Center ATTN: Paul Cutler Moffett Field, CA 94035

Naval Surface Weapons Center ATTN: Frank Moore Dahlgren VA 22448

Naval Surface Weapons Center ATTN: Carson Lyons White Oak Laboratory Silver Springs MD 20910

PDA ENGINEERING ATTN: Jim Dunn 1560 Brookhollow Drive Santa Ana CA 92705

SANDIA LABORATORIES ATTN: Al Bustamonte P.O. Box 5800 Albuquerque NM 87185

TRW Defense & Space Systems Group ATTN: Jack Ohrenberger, Bldg 4, Rm 1158 One Space Park Redondo Beach CA 90278

TRW/E & DS - Ballistic Missile Div ATTN: Tony Lin ATTN: Dave Farlow P.O. Box 1310 San Bernardino CA 92402