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DEVELOPMENT OF ANALYTICAL METHODS OF PREDICTING THE PRESSURE DISTRIBUTION ABOUT A NACELLE AT TRANSONIC SPEEDS - EXACT SOLUTION

Final Report and Computer Program Documentation

by

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1. INTRODUCTION

The objective of this contract is to develop a computer program to predict the inviscid, transonic flow field about isolated nacelles. Furthermore, the problem is to be formulated to solve Euler's equations without any approximation (such as small disturbances) and hence the terminology "exact" solution.

The flow field is complicated by the presence of imbedded shock waves, an engine-inlet interface and exhaust plumes. Furthermore, the transonic nacelles of interest have a very slender but blunt cowl lip. This creates two distinct length scales, the length of the nacelle and the cowl lip radius that can differ by several orders of magnitude. These aspects of the flow field present many numerical difficulties.

Our approach to the problem is to calculate the nacelle flow field using the method of time-dependent computations (TDC). Although at the time of the issuance of this contract, other approaches to transonic flow calculations existed, we felt that TDC offered the most effective means of meeting the goals of the contract.

This report is divided into two major sections: Section 2, the Final Report and Section 3, the Computer Program Documentation. The Final Report contains a discussion of our approach, the mathematical formulation of the problem, some results and conclusions. The Computer Program Documentation contains one section geared toward the engineering user of the program and a second section for programming considerations.

2. FINAL REPORT

2.1 GENERAL FEATURES

2.1.1 Approach

Our basic approach to solving the inviscid transonic flow field about an isolated nacelle consists of using the method of time-dependent computations (TDC). A time-dependent flow can be analyzed by solving an initial and boundary value problem, that is well suited for numerical solution. Steady state solutions are obtained from asymptotic, large time results. This technique has been used successfully in the past in a number of relatively simple transonic problems such as the supersonic blunt body flow (Ref. 1), the flow in a choked nozzle (Ref. 2), and the flow past a boattail (Ref. 3).

Another feature of our approach is the handling of imbedded shock waves. We feel that the most accurate and efficient procedure is to consider all shocks as discontinuities, across which the Rankine-Hugoniot relations must be satisfied. Successful computations of this type have been made for one dimensional flows (Ref. 4) and for a few selected two dimensional transonic problems (Ref. 3).

The details of our basic approach are discussed in Section 2.2. Many of these techniques have been evolved from the work described in Refs. 3 and 5. Other specific features have been developed by necessity throughout the course of this effort, which will be discussed in the next section.

2.1.2 History

Our first attempt at solving the transonic nacelle problem consisted in using the approach in Refs. 6 and 7. Namely, a blunt nacelle was considered to accelerate from rest to the free stream Mach number in a specified time interval. The computation would be performed between the body surface and the perturbation wave front, shown schematically in Fig. 2.1. Several problems appeared using this formulation. Firstly, as the wave front moved further from the body, the mesh resolution deteriorated severely. It was necessary to maintain sufficient resolution immediately behind the wave front which caused a further loss in resolution near the body surface. Secondly, we had a polar toroidal coordinate system adjacent to a cylindrical coordinate system. The interface between these two systems had to be treated very carefully to avoid error. These problems were greatly amplified when we began to treat nacelles approaching the leading edge radii of the test case, r/L 0.05-0.010. For these cases there was no way to maintain resolution within the limitations of the storage of the computer. Furthermore, it was observed that the perturbation front was extremely weak and, thus, not essential for the computation.

Therefore, since it would be necessary to have the program handle thin-nosed nacelles, the first approach had to be dropped. While problems were developing with the original computation procedure, an attempt was made to compute nacelles as if they had an infinitely thin, cusped-cowl lip. This approach, shown schematically in Fig. 2.2 considered the entire infinite domain surrounding the nacelle. The basic methodology used here was an extension of Ref. 3. The results for the subsonic, flow-through nacelle were encouraging.

The next step was to modify the cusped nose nacelle with an actual blunt nose. Here it was decided to use the same coordinate system stretchings of the cusped nose case with a small overlapped

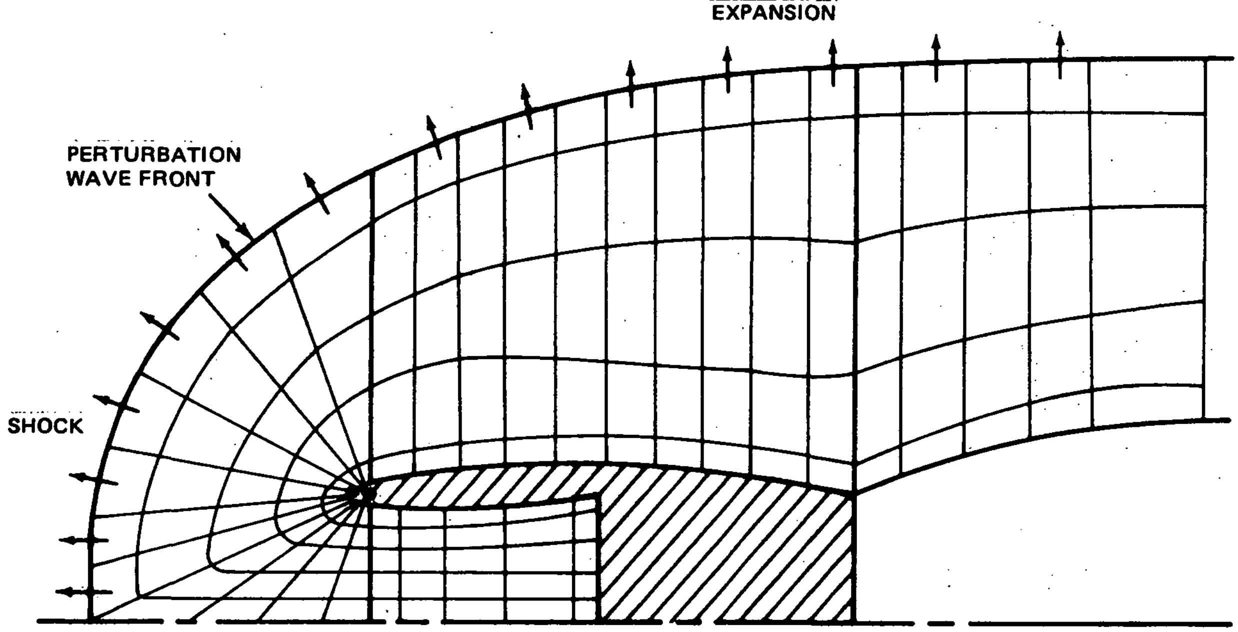

Fig. 2.1 Coordinate System – First Approach

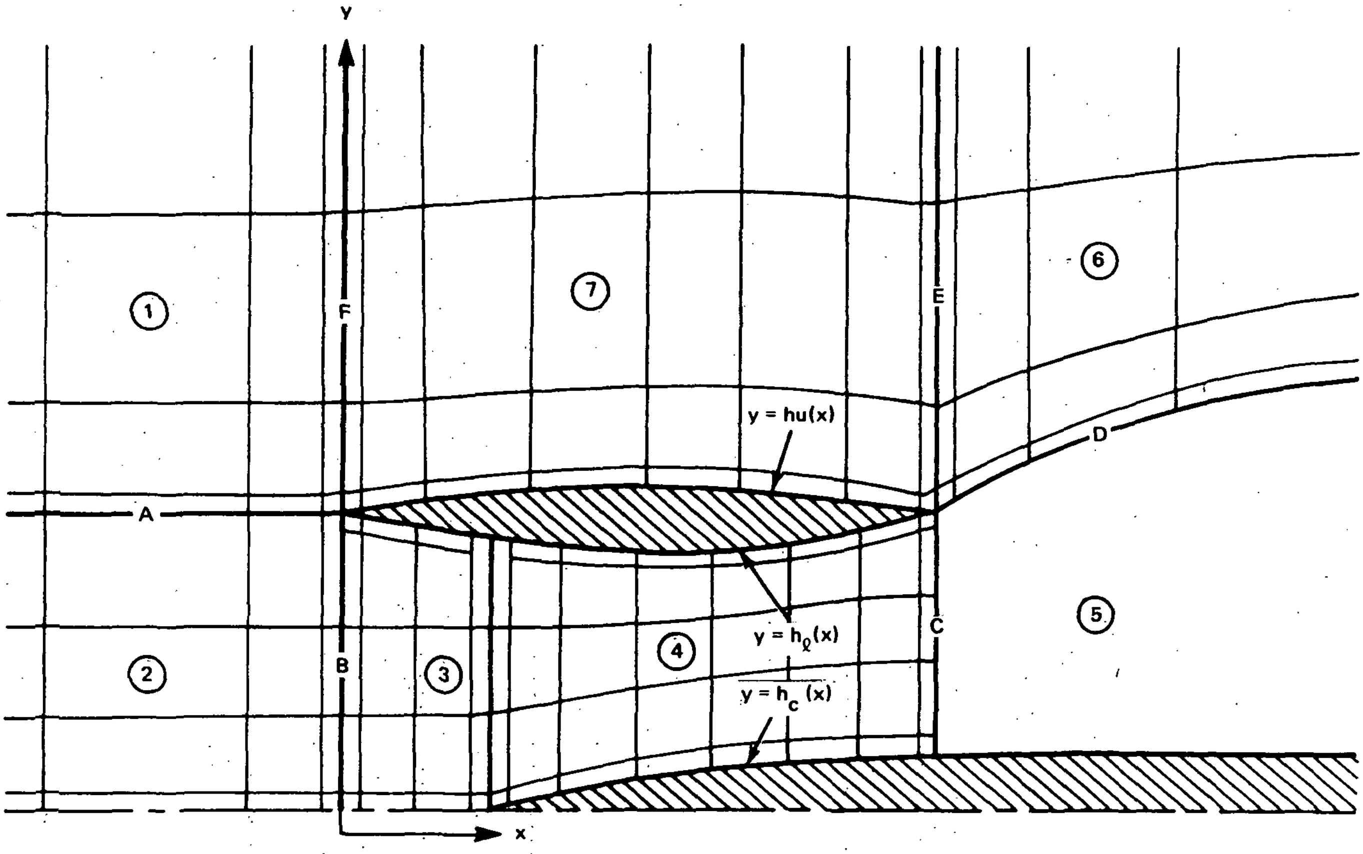

Fig. 2.2 Cusped – Nacelle Formulation

region of very fine mesh point resolution near the nose as in Fig. 2.3. The nose computation was carried on independently of the computation external to the nose with spacial and temporal interpolation at the interface boundaries. This procedure allowed us to have very fine resolution near the nose with a corresponding small time step and a more sparse mesh outside the nose region with a correspondingly large time step. This approach, that was successfully implemented for the very slender nosed nacelles used in the experiments, was adopted as our "final" approach. It is described in detail in Section 2.2.

The final approach has been applied successfully to several test cases with a subsonic free stream and the results are described in Section 2.3. When higher free stream Mach numbers or lower inlet mass flow ratios were attempted, problems developed. Namely, during the transient phase of the computation the flow goes supersonic inside the cowl lip. This situation appears to be valid on physical grounds. A shock should form inside the cowl lip and move upstream eventually "popping" out of the inlet. The stagnation streamline would then move inside to cowl lip and the flow would be subsonic inside the inlet. However, this process causes severe numerical problems. The shock must move upstream through the inlet past the cowl lip and away from the nacelle. It must pass through the overlapped nose region. The complexities of nose computation seem to preclude the representation of this "starting" shock as a discontinuity.

Although we generally feel that it is desirable to represent shocks as discontinuities on the basis of accuracy and efficiency factors, we did make some attempts at "smearing" this shock. As a first step, we tried to change the entire formulation of the equations to conservation form. A preliminary study of using this

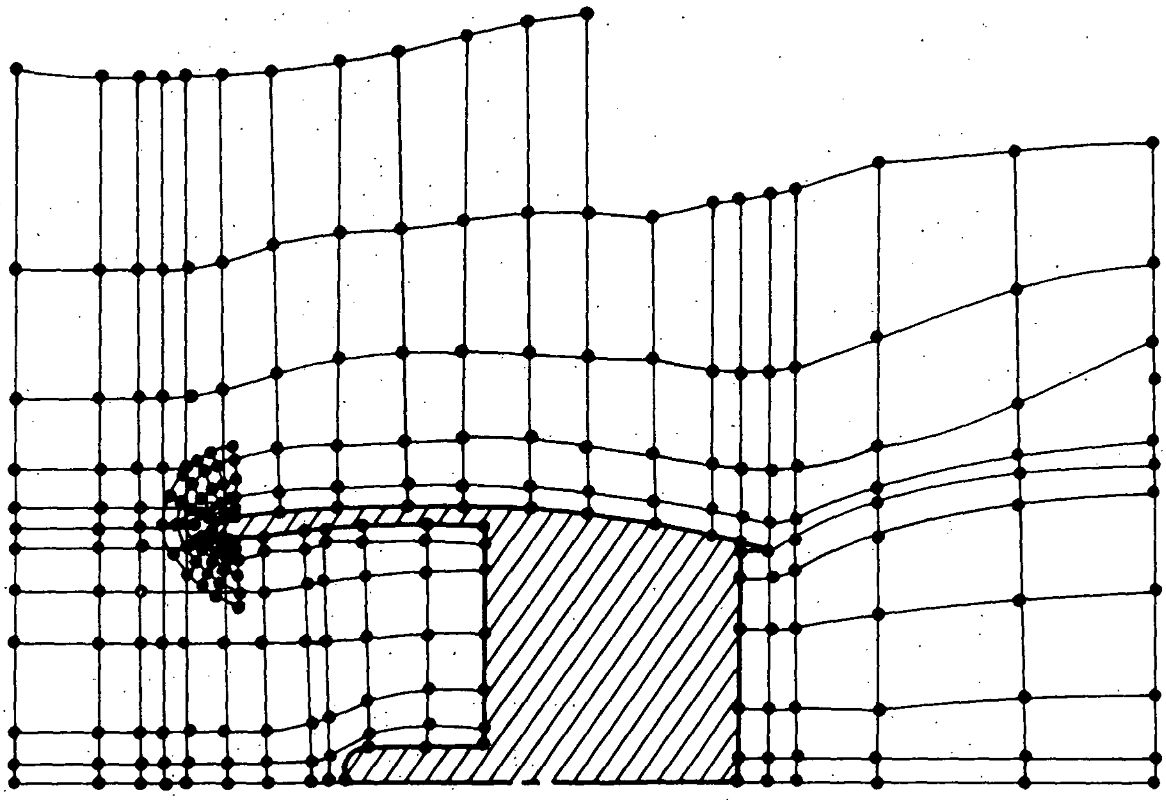

Fig. 2.3 Schematic Mesh Point Distribution

approach was performed on a simplified isolated boattail and the results were encouraging. However, when the procedure was used in the complete nacelle, computation problems developed. The calculation deteriorated in the vicinity of the nose region interface. This situation existed even without the presence of any imbedded shock waves. Apparently, the nose region interpolation procedure did not work properly with the conservation form variables so the approach was dropped.

In another attempt to handle this starting shock, we considered a crude smearing procedure. The points where the flow decelerated from supersonic to subsonic Mach numbers were determined. The last supersonic point was computed using upwind differences. Since the shock could not pop out of the inlet, the appropriate value of the mass flow was never achieved. An example of this case is discussed in Section 2.3.

Even if problems with the starting shock could be solved, there would be other difficulties in the transonic regime. Shocks also appear on the cowl outer surface. During the transient, at low mass flow ratios, these shocks may start right at the cowl lip and progress around the nose and downstream until the steady state position is obtained. Thus, similar difficulties to those for the starting shock are obtained. We have attempted to overcome the problems of the shock appearing at the nose by using the smearing technique just discussed. This procedure works adequately to delay the difficulties until the shock is located downstream of the nose. At this point, we feel the shock should be fit as a discontinuity. Once again, this situation presents a problem. Most of our experience with imbedded shocks in two space dimensions (Ref. 3) consists of having the shock as a fixed internal boundary and having the mesh points move with the shock. However, complications at the nose region seem to preclude this approach. The alternative of having a shock move between node points has not been fully investigated and it appears to require further study before it can be applied to this problem.

Our conclusions regarding the treatment of imbedded shocks for the transonic nacelle problem will be discussed in Section 2.4.

2.2 MATHEMATICAL FORMULATION

The basic aspects of the flow field for the nacelle are shown schematically in Fig. 2.4. Important features of the problem consist of: a long, thin nacelle with a blunt cowl lip of small radius of curvature, a blunt centerbody located inside the cowl, an inlet-engine interface where the mass flow is specified, an under-expanded supersonic jet plume and flow field boundaries extending to infinity. The details of the formulation of these problems now follow.

2.2.1 Basic Nacelle Computation

The formulation of the basic nacelle computation includes the stretching of the flow field from the body surface to infinity and handling of the blunt cowl lip with a radius of curvature which is very small compared with the length of the nacelle. We feel that an efficient means of modeling the flow field is to first formulate the problem as if the nose of the nacelle were a cusp and then to modify the computation to include the effects of the blunt nose. Note that we are not approximating the nose shape, nor are we actually computing it as a cusp, but we are merely formulating the problem with a cusp and then modifying it. This feature will become clear when the nose region computation is discussed in Section 2.2.2.

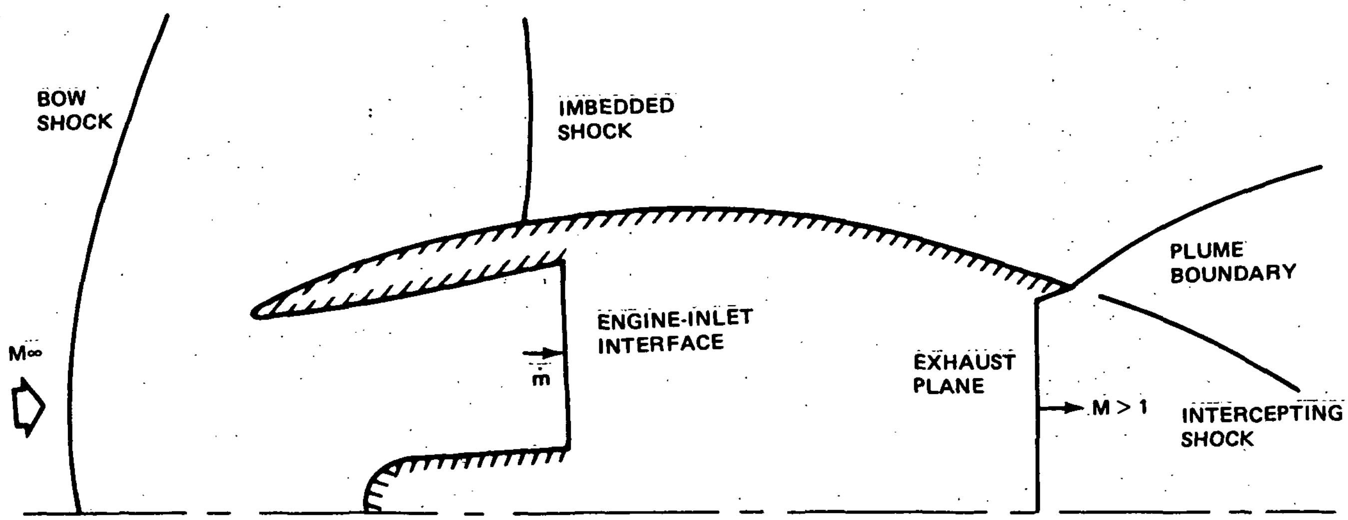

Fig. 2.4 Transonic Nacelle – Flowfield Description

Consider the flow field for a cusp-nosed nacelle shown in Fig. 2.2. For convenience in the mapping functions that will be discussed later, the flow field is divided into seven regions. Regions 1 and 2 are upstream of the nacelle, Regions 3 and 4 are inside the inlet, Region 5 is the plume, Region 6 is downstream of the nacelle, and Region 7 is exterior to the nacelle. The origin of a cylindrical coordinate system, $x,y,$ is located at the tip of the cusped cowl lip at the centerline. We wish to have a mesh point distribution in the physical plane that concentrates mesh points near the nacelle surface and near the centerbody or axis. We also require the mesh points to be concentrated near the leading and trailing edges of the nacelle, near the leading edge of the centerbody, and extending towards infinity (both upstream and downstream) with a sparse mesh point distribution. The appropriate mesh point distributions and stretchings to infinity can be accomplished using techniques discussed in Refs. 3 and 6. We map each region to a computational square where uniform mesh spacing in the computational plane results in the desired mesh point spacing in the physical plane. The stretching functions for each region are tabulated in Table 2-1. The parameters in the transformations x_o, x_1, x_2, x_3, y_o, y_2, α_1, α_2, α_3, α_4 may be selected by specifying the mesh spacing in the physical planes and will be explained in Section 3.1.

The governing equations in the physical plane for the time-dependent inviscid flow over the nacelle may be written as

$$
\begin{aligned}
&P_t + uP_x + vP_y + \gamma(u_x + v_y + j\,\frac{v}{y}) = 0 \\
&u_t + uu_x + vu_y + \tau P_x + \ddot{X}_o(t) = 0 \\
&v_t + uv_x + vv_y + \tau P_y = 0 \\
&S_t + uS_x + vS_y = 0
\end{aligned}
\qquad (1)
$$

Table 2-1

Coordinate Stretchings

Region	Domain	x =	y =
1	$-\infty < x \leq 0$ $y_A \leq y \leq \infty$	$G(X;x_o,x_2)$	$y_A - G(1 - Y;y_o,y_2)$
2	$-\infty < x \leq 0$ $0 \leq y \leq y_A$	$G(X;x_o,x_2)$	$y_A F(Y;\alpha_1)$
3	$0 \leq x \leq x_c$ $0 < y < h_\ell(x)$	$x_c F(X;\alpha_2)$	$h_\ell(x) F(Y;\alpha_1)$
4	$x_c \leq x \leq x_e$ $h_c(x) \leq y \leq h_\ell(x)$	$x_c + (x_e - x_c) F(X;\alpha_3)$	$h_c(x) + \left[h_\ell(x) - h_c(x)\right] F(Y;\alpha_1)$
6	$x_e \leq x < \infty$ $h_u(x) \leq y < \infty$	$x_e - G(1 - X;x_1,x_3)$	$h_u(x) - G(1 - Y;y_o,y_2)$
7	$0 \leq x \leq x_e$ $h_u(x) \leq y < \infty$	$x_e F(X;\alpha_4)$	$h_u(x) - G(1 - Y;y_o,y_2)$

$$F(Z;\alpha) = \tfrac{1}{2}\left[1 + \frac{\tanh \alpha(Z - 0.5)}{\tanh (0.5\alpha)}\right]$$

$$G(Z;a_1,a_2) = \left[a_1 + a_2 \log(Z)\right] \log(Z)$$

where $P = \log p$, $R = \log \rho$, $S = P - \gamma R$, $\tau = \exp\left[\left(\frac{\gamma - 1}{\gamma}\right)P + \frac{1}{\gamma} S\right]$, and where p,ρ are the pressure and density nondimensionalized by the free stream values, p_∞, ρ_∞; u and v are the velocities in the x and y directions, respectively, nondimensionalized by $\sqrt{p_\infty/\rho_\infty}$ and $j = 0$ for two dimensional flow, and $j = 1$ for axisymmetric flow. The acceleration function $\ddot{X}_o(t)$ will be discussed at the end of this subsection in connection with initial conditions.

The governing equations in the computational plane which are defined in Table 2-1 as

$$\begin{aligned} X &= X(x) \\ Y &= Y(x,y) \\ T &= t \end{aligned} \tag{2}$$

now become

$$\begin{aligned} &P_T + FP_X + GP_Y + \gamma(Au_X + Bu_Y + Dv_Y + H) = 0 \\ &u_T + Fu_X + Gu_Y + T(AP_X + BP_Y) + \ddot{X}_o = 0 \\ &v_T + Fv_X + Gv_Y + TDP_Y = 0 \\ &S_T + FS_X + GS_Y = 0 \end{aligned} \tag{3}$$

where $A = X_x$, $B = Y_x$, $D = Y_y$, $F = uA$, $G = uB + vD$, $H = j\ v/y$, and the derivatives of the stretching functions X_x, Y_x, Y_y are tabulated in Table 2-2.

To solve Eqs. (3) numerically, a second order accurate finite difference approximation is used. Following the discussion of Ref. 8, a two level scheme used elsewhere by MacCormack (Ref. 9) is adopted. This two level scheme adapts to the regional makeup of our mesh point distribution. Namely, the flow field at points

Table 2-2

Derivatives of Coordinate Stretchings

Region	$A = X_x$	$D = Y_y$	$B = Y_x$
1	$1/G'(X;x_o,x_2)$	$1/G'(1 - Y;y_o,y_2)$	0
2	$1/G'(X;x_o,x_o)$	$1/y_a F'(Y;\alpha_1)$	0
3	$1/x_c F'(X;\alpha_2)$	$1/h_\ell F'(Y;\alpha_1)$	$- Y_y F(Y;\alpha_1) h'_\ell(x)$
4	$1/(x_e - x_c)F'(X;\alpha_3)$	$1/(h_\ell - h_c)F'(Y;\alpha_1)$	$Y_y\left[F(Y;\alpha_1)(h'_c - h'_\ell) - h'_c\right]$
6	$1(G'(1 - X;x_1,x_3)$	$1(G'(1 - Y;y_o,y_2)$	0
7	$1/x_e F'(X;\alpha_4)$	$1/G'(1 - Y;y_o,y_2)$	$- Y_y h'_u(x)$

$$F'(Z,\alpha) = \frac{\alpha}{2\tanh(0.5\alpha)}\left[1 - (2F - 1)^2 \tanh^2(0.5\alpha)\right.$$

$$G'(Z;a_1,a_2) = (a_1 + 2a_2 \log Z)/Z$$

along the computational interfaces labeled A, B, E, F, G in Fig. 2.2 may be evaluated in one region for the predictor stage and in the neighboring region for the corrector. For example, consider interface F. The predictor stage uses backward differences for the X-derivatives and the flow is determined along the interface from the equations in Region 1. The corrected values are then obtained from forward differences in Region 7. There will be no loss in accuracy provided the mesh spacings in the physical plane on each side of the interval are identical.

A stable time step, Δt, is obtained by satisfying the Courant-Fredrichs-Lewy criterion. Namely,

$$\Delta t = \frac{\min(\Delta x, \Delta y)}{\sqrt{u^2 + v^2} + \sqrt{\gamma \tau}}$$

where

$$\Delta x = \frac{\partial x}{\partial X} \Delta X$$

$$\Delta y = \frac{\partial y}{\partial X} \Delta X + \frac{\partial y}{\partial Y} \Delta Y \quad .$$

The boundary conditions at the surface of the nacelle are the vanishing of the velocity normal to the wall. A procedure identical to that discussed in Ref. 3 is employed here. At the axis, the term $H = j\ v/y$ is replaced by $H = jDv_Y$.

Initially, at $T = 0$, the nacelle is assumed to be stationary in a gas at rest; it accelerates to a transonic velocity in a finite period of time. The acceleration function is

$$\ddot{X}_o = \begin{cases} -u_\infty \omega\pi \sin(\omega\pi T) \big/ 2 & 0 \leq T < 1/\omega \\ 0 & T \geq 1/\omega \end{cases} \tag{4}$$

where X_o is the abscissa of a reference point on the body with respect to a fixed frame. A more detailed discussion of the initial conditions appears in Ref. 3.

2.2.2 Nose Modifications

Our technique for accurately computing the flow field near the blunt cowl consists of patching a small region over the cusped nacelle nose as shown in Fig. 2.5. The outer boundary of the nose region is a circle of radius, $r = c$.

The computation procedure is as follows:

1. Compute the entire flow field for the nacelle at $t_{new} = t_{old} + \Delta t$ as if the nose were cusped for one time step. This time step, Δt, is the largest allowable, satisfying the C-F-L conditions, not including the nose region.

2. Determine the largest allowable time step in the nose region. This time step will be smaller than the one used in step 1. Choose $K_t = \Delta t/\Delta t_{nose}$ to be an integer. Typically, this value may be two or three.

3. Determine the flow field at the outer boundary of the nose region by interpolation.

4. Compute the flow field inside the nose region at $t = t_{old} + \Delta t_{nose}$, using a polar coordinate system centered about the nacelle nose.

5. Repeat steps 3 and 4 until $t_{nose} = t_{new}$.

6. Determinate the flow field at the mesh points of the cusped nose formulation that is interior to the nose region.

7. Repeat steps 1-6 for each time step, Δt.

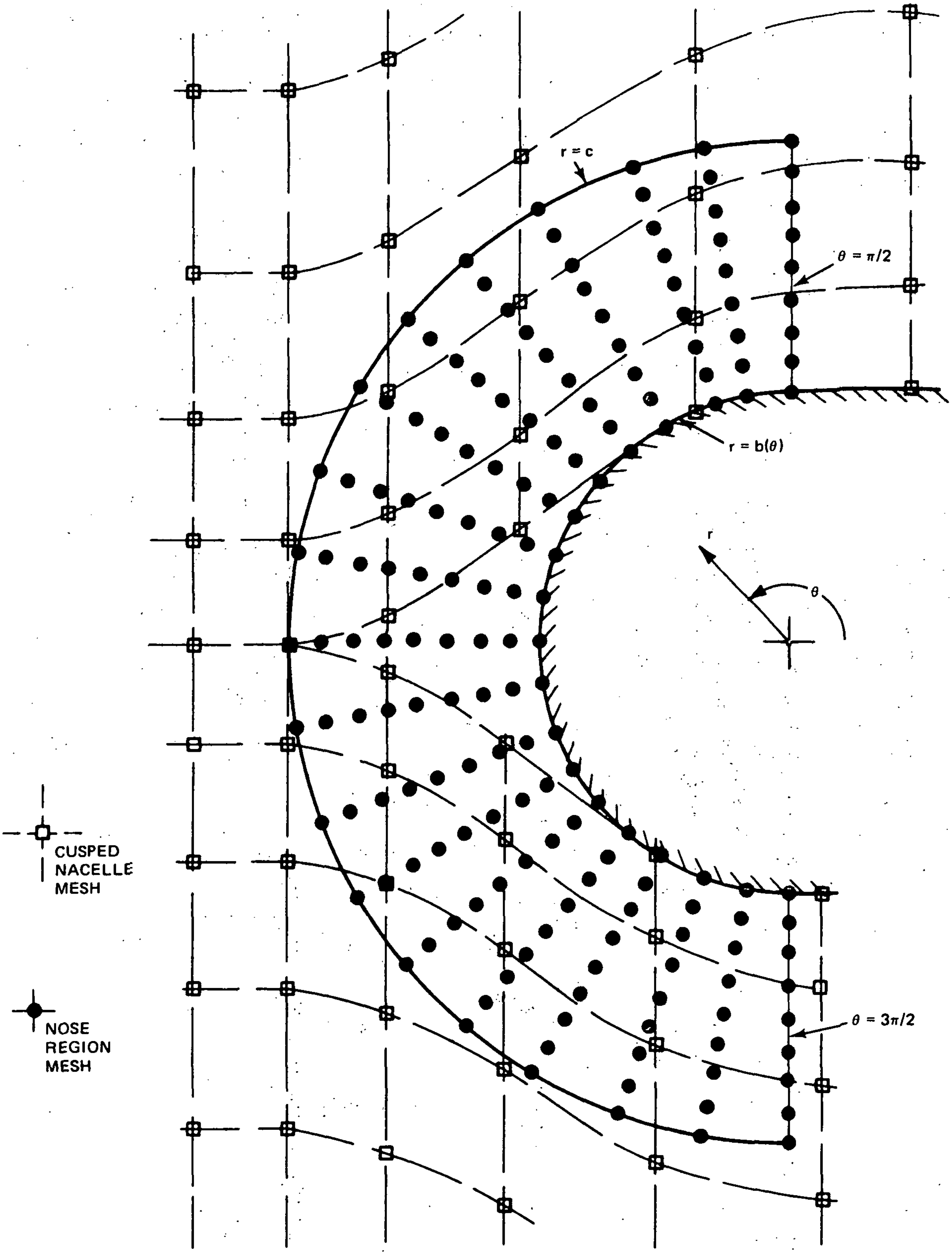

Fig. 2-5 Nose Region Mesh Distribution

The governing equations in the nose region are the basic Euler equations written in a polar-toroidal (r,θ) coordinate system (see Fig. 2.5). A computational plane (X,Y) (unit square) is obtained with the following transformation

$$X = \frac{\theta - \pi/2}{\pi}$$

$$Y = \frac{r - b(\theta)}{c - b(\theta)} \tag{5}$$

$$T = t$$

where $r = b(\theta)$ is the surface of the cowl lip and $r = c$ (a circle) is the outer boundary of the nose region. The governing equations may now be written as

$$P_T + EP_Y + FP_X + \gamma\left[Au_Y + \frac{u}{r} + \frac{Bu_X}{r} + \frac{Dv_Y}{r} + j\,\frac{u \sin\theta + v\cos\theta}{H + r\sin\theta}\right] = 0$$

$$u_T + Eu_Y + Fu_X - \frac{v^2}{r} + \tau AP_Y - \ddot{X}_o \cos\theta = 0$$

$$v_T + Ev_Y + Fv_X + \frac{uv}{r} + \frac{\tau}{r}(BP_X + DP_Y) + \ddot{X}_o \cos\theta = 0 \tag{6}$$

$$S_T + ES_Y + FS_X = 0$$

where $B = 1/\pi$, $A = 1/(c-b)$, $D = (Y-1)b'/(c-b)$, $E = uA + (v/r)D$, $F = Bv/r$, and

$$j = \begin{cases} 0 & \text{2-D} \\ 1 & \text{Axisymmetric} \end{cases}$$

and $\ddot{X}_o$ is the acceleration of the body that has been discussed in connection with the initial conditions. Here, u and v are the nondimensional velocities in the radial and azimuthal directions, respectively.

The C-F-L conditions for the nose region may be written as

$$\Delta T_{nose} = \frac{\min(r\Delta\theta, r)}{\sqrt{u^2 + v^2} + \sqrt{\gamma\tau}}$$

where

$$r\Delta\theta = \pi r \Delta X$$

$$\Delta r = (c - b)\Delta Y - (Y - 1)b'\pi\Delta X \quad .$$

We will now discuss the interpolations necessary for the nose region computation. First, the values of the flow field at the outer boundary of the nose region must be determined from the values in the cusped nacelle formulation. Three typical situations appear as shown in Fig. 2.6. Cases 1 and 2 correspond to mesh situations near $r = c$ and case 3 corresponds to the boundary $\theta = \pi/2$ or $\theta = 3\pi/2$. Cusp nacelle mesh points 1 and 2 are found as the nearest set of nodes at least one of which is located exterior to the nose region. We designate f_{old} and f_{new} as values of any function at these node points at time t_{old} and $t_{new} = t_{old} + \Delta t$. The values of f at $t_{nose} = t_{old} + n\Delta t_{nose}$ are interpolated so that

$$f^i = f^i_{old} + (n/K_t)(f^i_{new} - f^i_{old})$$

where $n = 1, 2, \ldots, K_t$ and $i = 1$ or 2 corresponds to points 1 and 2. Point a corresponds to the boundary value whose value at $t = t_{old} + n\Delta t_{nose}$ remains to be determined. Point c corresponds to the nearest mesh point interior to the outer boundary. The values of the flow field at point c can be computed since they only depend upon the flow at point a at a time $t = t_{old} +$ $(n - 1)\Delta t_{nose}$. Point b corresponds to a point exterior to the nose region between points 1 and 2 along $\theta = \theta_a = \theta_c$ in cases 1

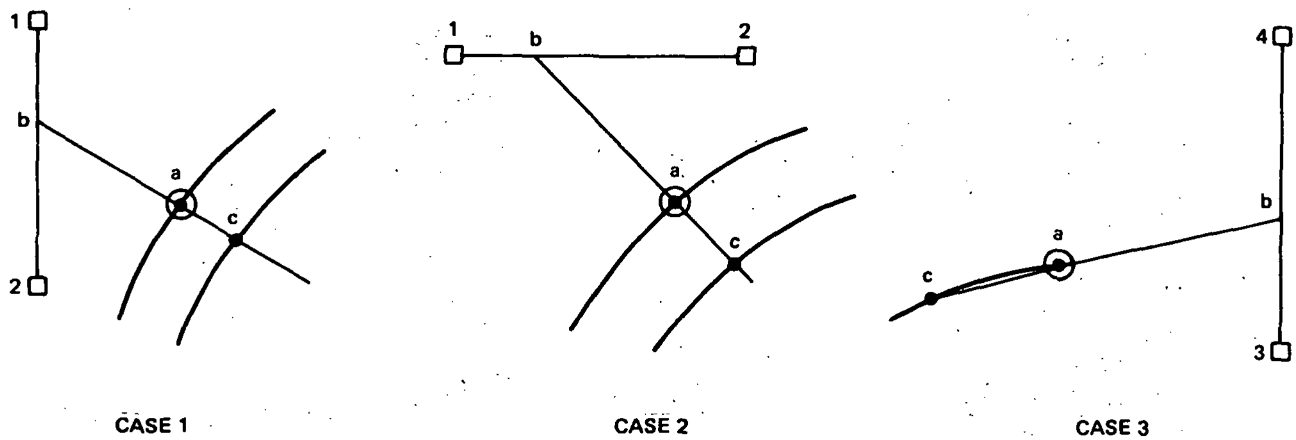

Fig. 2.6 Nose Region Interface Interpolation

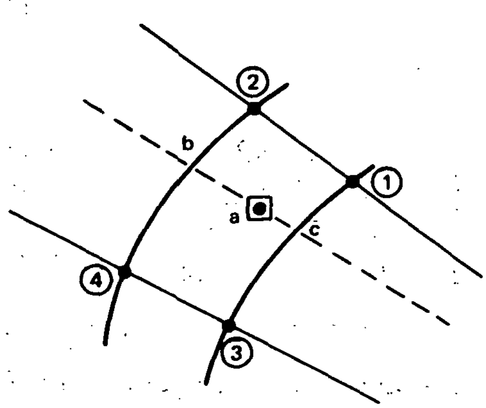

Fig. 2.7 Nose Region Interior Interpolation

and 2, and along $r = r_a = r_c$ in case 3. For cases 1 and 2, the value of f at point a, at $t = t_{old} + n\Delta t_{nose}$, is

$$f_a = f_c + \left(\frac{r_a - r_c}{r_b - r_c}\right)(f_b - f_c) \qquad (7)$$

where for case 1,

$$f_b = f_1 + \left(\frac{y_b - y_1}{y_2 - y_1}\right)(f_2 - f_1)$$

and for case 2,

$$f_b = f_1 + \left(\frac{x_b - x_1}{x_2 - x_1}\right)(f_2 - f_1) \quad .$$

Similarly, for case 3,

$$f_a = f_c + \left(\frac{x_a - x_c}{x_1 - x_c}\right)(f_b - f_c) \qquad (8)$$

where

$$f_b = f_1 + \left(\frac{y_b - y_3}{y_4 - y_3}\right)(f_2 - f_1) \quad .$$

Now all the nose region may be computed K steps until a time $t_{new} = t_{old} + K\Delta t_{nose}$ is reached. The values of the cusped nacelle points interior to the nose region may now be updated by interpolation of the nose region points. The interpolation is illustrated in Fig. 2.7. Points 1, 2, 3, and 4 are the node points in the nose region surrounding the cusped nacelle point a. Points b and c are points defined at $\theta = \theta_a$ at $r = r_2 = r_4$ and $r = r_1 = r_3$, respectively. By linear interpolation we obtain

$$f_b = f_2 + \left(\frac{\theta_a - \theta_1}{\theta_3 - \theta_1}\right)(f_4 - f_2)$$

$$f_c = f_1 + \left(\frac{\theta_a - \theta_1}{\theta_3 - \theta_1}\right)(f_3 - f_1)$$

and

$$f_a = f_b + \tfrac{1}{2}\left[\left(\frac{r_a - r_2}{r_1 - r_2}\right) + \left(\frac{r_a - r_4}{r_3 - r_4}\right)\right](f_c - f_b) \quad . \tag{9}$$

The entire cycle is repeated for successive time steps.

2.2.3 Engine-Inlet Interface

The mass flow going through the engine at the engine-inlet interface is a boundary condition on the nacelle computation. From this specified mass flow the values of the flow variables P, u, v, S along interface C of Fig. 2.2 must be found. One technique consists of using unsteady characteristic compatibility relations coupled with conservation of mass along streamlines. This technique turns out to be quite cumbersome in practice. In order to avoid this difficulty, we have devised the computational device diagrammed in Fig. 2.8. Here we assume a choked convergent-divergent nozzle follows the interface. This is not the actual exhaust nozzle, but is merely a computational technique to specify the required mass flow through the interface by fixing the area of the throat. Namely, the throat radius r^* is found to be

$$\frac{r^*}{H} = \left\{\dot{m}_r M_\infty \left[\frac{2}{\gamma + 1}\left(1 + \frac{\gamma - 1}{2} M_\infty^2\right)\right]^{\frac{-(\gamma+1)}{2(\gamma-1)}}\right\}^{j/2} \tag{10}$$

where $\dot{m}_r$ is the mass flow ratio, H is the height of the cowl lip above the centerline, and $j = 0$ for 2-D and $j = 1$ for axisymmetric flow.

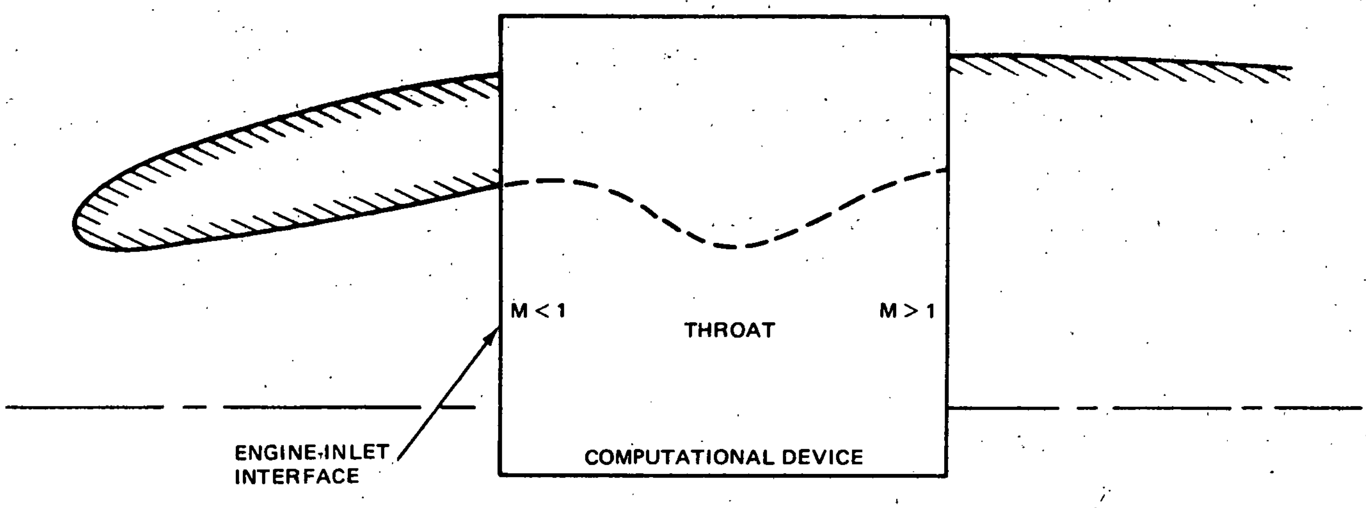

Fig. 2.8 Computational Device to Determine Engine-Inlet Conditions

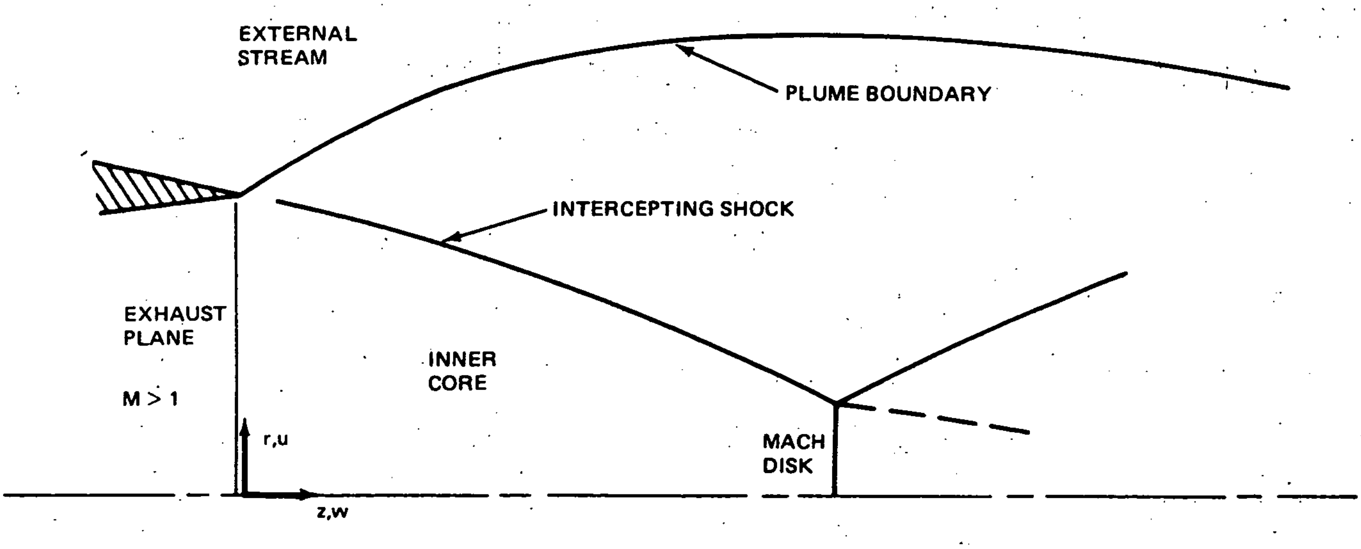

Fig. 2.9 Exhaust Plume for an Underexpanded Nozzle

Once the stream is accelerated to a supersonic velocity, the computation may be terminated by extrapolating the flow in the supersonic region. This device allows us to determine all the fluid properties at the interface by only specifying the mass flow. The detail of the flow through this nozzle (the computational device) is not pertinent to the nacelle calculation.

2.2.4 Plume Computation

The major objective of including the plume calculation is to determine the effect of the plume shape on the nacelle surface pressure distribution. We feel that this goal can be most effectively achieved using a quasi-steady approach. Namely, the supersonic under-expanded jet (the case of interest) is computed using steady state equations with the plume boundary pressure distribution specified and the shape of the plume boundary resulting from the computation. This new jet boundary is then used in the time-dependent nacelle calculations for a specified number of time steps (typically about 100). Then the resulting pressure distribution from the nacelle calculation is input to the plume program and a new plume boundary results. This procedure is repeated until the plume boundary pressure distribution and shape reach steady values. This approach should converge since relatively large changes in the pressure distribution will produce only very minor changes in the plume shape.

The basic features of an under-expanded supersonic exhaust plume are illustrated in Fig. 2.9. This computation considers the flow field downstream to near the Mach disk. At this point, the shape of the plume boundary is extrapolated. The intercepting shock is handled as a discontinuity satisfying the Rankine-Hugoniot relations.

2.2.4.1 Equations, Transformation

The governing inviscid, steady Euler equations are written as

$$\begin{aligned} &uP_r + wP_z + \gamma(u_z + w_z + j\,\frac{u}{r}) = 0 \\ &uu_r + wu_z + \tau P_r = 0 \\ &uw_r + ww_z + \tau P_z = 0 \\ &uS_r + wS_z = 0 \end{aligned} \tag{11}$$

where $P = \log(p/p_{ref})$, $R = \log(\rho/\rho_{ref})$, $S = P - \gamma R$, $\tau = \exp\left[\left(\frac{\gamma - 1}{\gamma}\right)P + \frac{1}{\gamma} S\right]$ and u and w are the velocities in the r and z directions, respectively, nondimensionalized by $\sqrt{p_{ref}/\rho_{ref}}$.

Note here that a change in notation has been made for the plume calculation discussion. The computer program for the plume was written independently of the nacelle program and, hence, used somewhat different variable names. For consistency, we will now adopt the notation of the plume program. The following chart lists the major changes.

Plume		Nacelle
z	→	x
r	→	y
u	→	v
w	→	u

Furthermore, the nondimensionalization of the variables is different. For the nacelle, $p_{ref} = p_\infty$, $\rho_{ref} = \rho_\infty$, and $Q_{ref} = \sqrt{p_\infty/\rho_\infty}$. For the plume, $p_{ref} = p_{jet}$, $\rho_{ref} = \rho_{jet}$, and $Q_{ref} = \sqrt{p_{jet}/\rho_{jet}}$, where the subscript jet corresponds to the conditions at the nozzle exhaust plane. The relationship of p_{jet}, ρ_{jet} to p_∞, ρ_∞ and the chamber conditions are

$$p_{jet} = p_\infty P_r \frac{\left[\left(1 + \frac{\gamma - 1}{2} M^2\right)^{\gamma/\gamma - 1}\right]_\infty}{\left[\left(1 + \frac{\gamma - 1}{2} M^2\right)^{\gamma/\gamma - 1}\right]_{jet}}$$

$$\rho_{jet} = \frac{p_{jet}\rho_\infty}{T_r p_\infty} \frac{\left[\left(1 + \frac{\gamma - 1}{2} M^2\right)/R\right]_{jet}}{\left[\left(1 + \frac{\gamma - 1}{2} M^2\right)/R\right]_\infty} \tag{12}$$

where P_r is the stagnation pressure ratio and T_r is the stagnation temperature ratio of the jet to the free stream.

In general, the plume flow field will contain an intercepting shock as shown in Fig. 2.9. Here the flow field is split into two regions, I and II. Region I is bounded by the axis of the jet b(I) and the imbedded shock c(I). Region II is bounded by the imbedded shock b(II) = c(I) and the plume boundary c(II). When there is no intercepting shock, there will only be one region bounded by b(I), the plume axis, and c(I), the plume boundary. A computational frame for either region is obtained with the following transformation

$$X = \frac{r - b}{c - b}$$

$$Z = z \quad . \tag{13}$$

The equations are then transformed and rearranged to give the Z-derivatives explicitly as

$$P_Z = \frac{wR_1 - \gamma R_2}{w^2 - \gamma\tau}$$

$$w_Z = \frac{wR_2 - \tau R_1}{w^2 - \gamma\tau}$$

$$u_Z = \frac{1}{w}\left[- u_X(uX_r + wX_z) - \tau P_X X_r\right] \tag{14}$$

$$S_Z = - \frac{1}{w} S_x(uX_r + wX_z)$$

where

$$R_1 = - \left[P_X(uX_r + wX_z) + \gamma(u_X X_r + w_X X_z + j \frac{\gamma u}{r}\right]$$

$$R_2 = - \left[w_X(uX_r + wX_z) + \tau P_X X_z\right] .$$

The equations are differenced using the MacCormack scheme described in Section 2.2.1. A marching procedure in the Z-direction can be used, provided $w^2 > \gamma\tau$ or the Mach number in the z-direction is supersonic.

2.2.4.2 Characteristics

The evaluation of the jet boundary and the imbedded shock require the use of characteristics. In general, the characteristic direction and compatibility relations in the computational plane can be developed using standard methods. The characteristic direction is

$$\lambda = X_r\left[\frac{X_z}{X_r} + \frac{uw \pm a^2\beta}{w^2 - a^2}\right]$$

where

$$a^2 = \gamma\tau$$

$$\beta = \sqrt{M^2 - 1}$$

$$M^2 = \frac{u^2 + w^2}{a^2}$$

and the compatibility equation is

$$\pm \beta\tau(P_Z + \lambda P_X) + w^2(\theta_z + \lambda\theta_X) = - \frac{ua^2}{r} \frac{u \pm w\beta}{w^2 - a^2} \qquad (15)$$

where $\theta = u/w$. The C-F-L rule for this case can be represented as

$$\Delta Z = \min\left(\frac{\Delta X}{\lambda}\right) \quad .$$

2.2.4.3 Jet Boundary

The pertinent characteristic reaching the plume boundary from inside the jet is λ^+ as shown in the sketch in Fig. 2.10. This boundary is a streamline so that $c_z = u/w$ and $X = 1$, whereby

$$X_z = X_r\left(- \frac{u}{w}\right)$$

so that

$$\lambda^+ = X_r\left[- \theta + \frac{\theta w^2 + \beta a^2}{w^2 - a^2}\right] \quad . \qquad (16)$$

The compatibility relation becomes

$$\theta_Z = - \lambda^+\theta_X + \frac{1}{w^2}\left[- \beta\tau(P_Z + \lambda^+P_X) - \frac{ua^2}{r} \frac{u + w\beta}{w^2 - a^2}\right] \qquad (17)$$

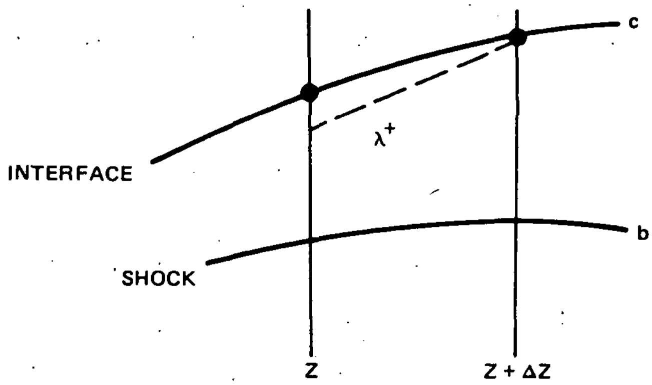

Fig. 2.10 Plume Boundary Computation

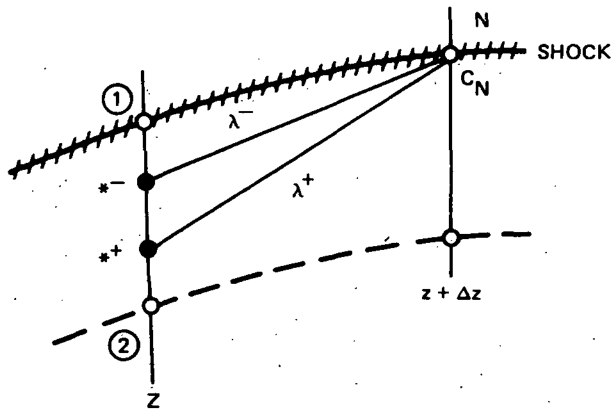

Fig. 2.11 Low Pressure Side of Shock

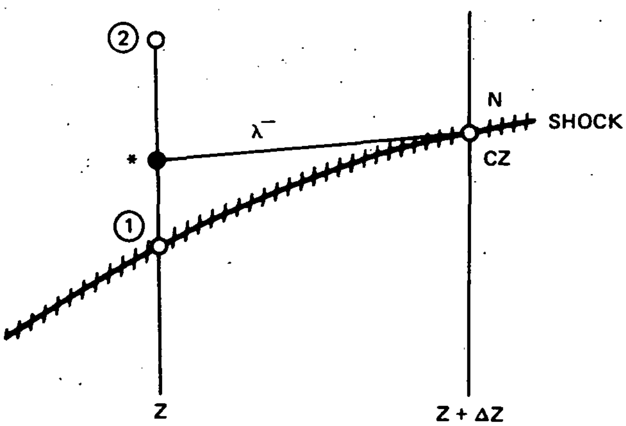

Fig. 2.12 High Pressure Side of Shock

with P_Z prescribed from the nacelle computation. The above equation is integrated to give the position of the plume boundary at $Z_{new} = Z + dZ$.

2.2.4.4 Imbedded Shock

In general, the intercepting shock does not immediately begin at the nozzle lip. Its presence is detected at a position downstream of the nozzle exit by monitoring the pressure distribution in the r-direction at each z location. When the maximum pressure gradient grows in three consecutive z steps, a shock is fit. Initially, the shock is taken to be coincident with the λ^- characteristic at the point of maximum gradient. Namely,

$$c_z = \lambda^- = \frac{uw - a^2\beta}{w^2 - a^2} \quad . \tag{18}$$

As the shock develops, the values on the low pressure side are computed from the two characteristics reaching the shock (see Fig. 2.11). The values at the two points $*^+$ and $*^-$ are obtained by interpolation.

$$\begin{aligned} P_*^\pm &= P_2 + \epsilon^\pm(P_1 - P_2) \\ \theta_*^\pm &= \theta_2 + \epsilon^\pm(\theta_1 - \theta_2) \end{aligned} \tag{19}$$

where

$$\epsilon^\pm = \frac{c_N - r_2 - \lambda_2^\pm \Delta z}{\Delta r + \Delta z(\lambda_1^\pm - \lambda_2^\pm)} \quad .$$

The two characteristic compatibility relations may be simultaneously solved to get P_N and θ_N in terms of $P_*^\pm, \theta_*^\pm$ and the other flow quantities at the $*$ points.

$$\theta_N = \frac{E_3 - \frac{E_1}{D_1} D_3}{E_2 - \frac{E_1}{D_1} D_2}$$

$$P_N = \frac{D_3 - D_2\theta_N}{D_1} \tag{20}$$

where

$$D_1 = (\tau\beta)^+ \quad , \quad E_1 = -(\tau\beta)^-$$

$$D_2 = (w^2)^+ \quad , \quad E_2 = -(w^2)^-$$

$$D_3 = \left[-\frac{ua^2}{r}\left(\frac{u + w\beta}{w^2 - a^2}\right)\right]^+ \Delta z + D_1 P_*^+ + D_2\theta_*^+$$

$$E_3 = \left[-\frac{ua^2}{r}\left(\frac{u - w\beta}{w^2 - a^2}\right)\right]^- \Delta z + E_1 P_*^- + E_2\theta_*^- \quad .$$

The flow properties on the high pressure side at the shock are found from one characteristic relation combined iteratively with the Rankine-Hugoniot relations. The pertinent characteristic reaching the shock from the high pressure side is λ as shown in Fig. 2.12. The values at the * point are found by interpolating between points 1 and 2, whereby

$$P_* = P_1 + \epsilon(P_2 - P_1)$$

$$\theta_* = \theta_1 + \epsilon(\theta_2 - \theta_1)$$

where

$$\epsilon = \frac{c_N - c - \lambda_1\Delta z}{\Delta r + \Delta z(\lambda_2^- - \lambda_1^-)} \quad .$$

The resulting compatibility relation may be integrated between the shock and the $*$ point to yield

$$P_{N_{Hi}} = \left[P_* + \frac{w^2\theta_*}{\beta r} - \frac{u\gamma}{\beta r} \frac{(w - u\beta)}{(w^2 - a^2)} \Delta r \right] + \frac{w^2}{\beta r} \theta_{N_{Hi}} \tag{21}$$

where Hi corresponds to the high pressure side of the shock. The Rankine-Hugoniot relations may be written as

$$P_{N_{Hi}} = P_{N_{Lo}} + \log\left(\frac{2\gamma M_{n_1}^2 - (\gamma - 1)}{\gamma + 1} \right) \tag{22}$$

where

$$M_{n_1}^2 = \frac{\tilde{u}_1^2}{a_1}$$

$$a_1^2 = \gamma T_{N_{Lo}} \quad ,$$

$\tilde{u}_1$ is the normal component of the velocity to the shock on the low pressure side of the shock, and Lo refers to the low pressure side of the shock.

$$\tilde{u}_1 = u_{N_{Lo}} N_1 + w_{N_{Lo}} N_2$$

$$N_1 = - \frac{1}{\sqrt{1 + c_z^2}} \quad , \quad N_2 = \frac{c_z}{\sqrt{1 + c_z^2}} \quad .$$

In addition, $\theta_{N_{Hi}}$ is also a function of c_z. We take $\tilde{u}_2, \tilde{v}_2$ to be the normal and tangential components, respectively, on the high pressure side of the shock. From the Rankine-Hugoniot relations

$$\frac{\tilde{u}_2}{\tilde{u}_1} = \frac{(\gamma - 1)M_{n_1}^2 + 2}{(\gamma + 1)M_{n_1}^2}$$

and

$$\tilde{v}_2 = \tilde{v}_1 = u_{N_{Lo}} N_2 - w_{N_{Lo}} N_1$$

whereby

$$\theta_{N_{Hi}} = \frac{u_{N_{Hi}}}{w_{N_{Hi}}} = \frac{\tilde{u}_2 N_1 + \tilde{v}_2 N_2}{\tilde{u}_2 N_2 - \tilde{v}_2 N_1} \quad . \qquad (23)$$

The above Eqs. (21), (22), and (23), are solved in a trial and error procedure to determine c_z at the new shock point.

An example of these procedures for a plume computation will be presented in Section 2.3.

2.3 DISCUSSION OF RESULTS

The applications of the numerical procedures presented in Section 2.2 are now discussed. The examples include three computations of axisymmetric nacelle flow fields about a given geometry with different mass flow ratios and Mach numbers and one computation of an isolated boattail with a plume.

The nacelle geometry for all cases considered was the forebody of the NACA 1-85-100 nacelle designated Inlet No. 8 of NASA LRC test 264 as sketched in Fig. 2.13. Although the actual nacelle was 54 in. long, only the first 18 in. were used in the calculations with a straight pipe assumed to be following aft of the cowl. The computations did not include the centerbody as shown in Fig. 2.13 and included a "throat" within the inlet to specify

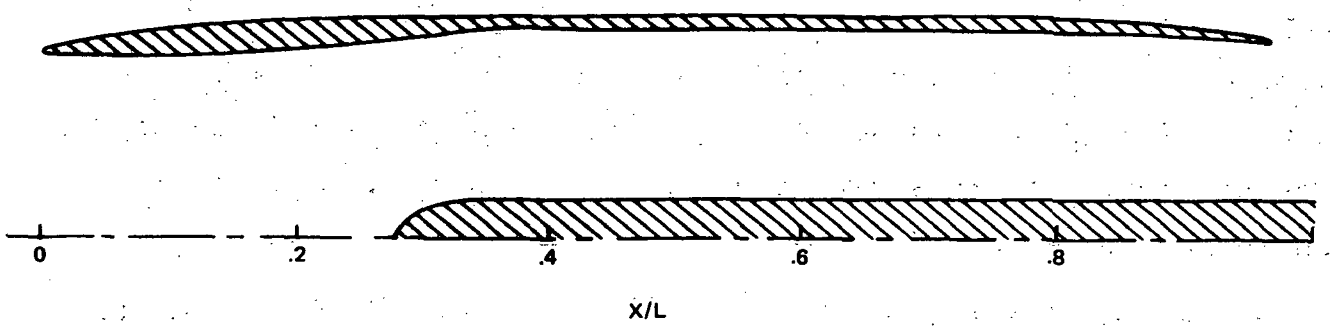

Fig. 2.13 Nacelle Geometry (NACA 1-85-100)

the appropriate mass flow as discussed in Section 2.2.3. The geometry was approximated with a series of 13 cubic fits with values of radius and slope at intersection points agreeing with the experimental geometry. The geometry routine is discussed in Section 3.

All the nacelle calculations used approximately 2150 node points in the entire field with approximately 80 points on the surface of the nacelle and 19 of these on the cowl lip. The details of the mesh point distributions are found in the test case in Section 3.

The first case computed is the flow field about the nacelle geometry discussed above at $M = 0.4$ and $\dot{m}_r = 0.847$. The results of the calculation after 2000 time steps, $T = 2.43$, are shown in Fig. 2.14. Values of C_p versus x/L axial distance near the cowl lip are shown compared to experimental data from run 20 Test 264 NASA LRC.

As a second example, the $M = 0.7$, $\dot{m}_r = 0.8715$ flow over the same nacelle geometry as the first case was computed. Figure 2.15 shows the calculated values of C_p versus x near the cowl lip after 1600 time steps corresponding to a nondimensional time, $T = 2.94$. The experimental data of point 47, run 20 of the Langley test are in good agreement with the numerical results. The details of the computation in the vicinity of the cowl lip are shown in the isobar plot, Fig. 2.16.

Next we attempted to compute the $M = 0.9$, $\dot{m}_r = 0.885$ flow over the same nacelle. In this calculation, a shock formed inside the cowl lip. As discussed previously in Section 2.1, we attempted to "smear" this shock. However, the shock remained inside the inlet and did not "pop" out. The effective result was that the mass flow

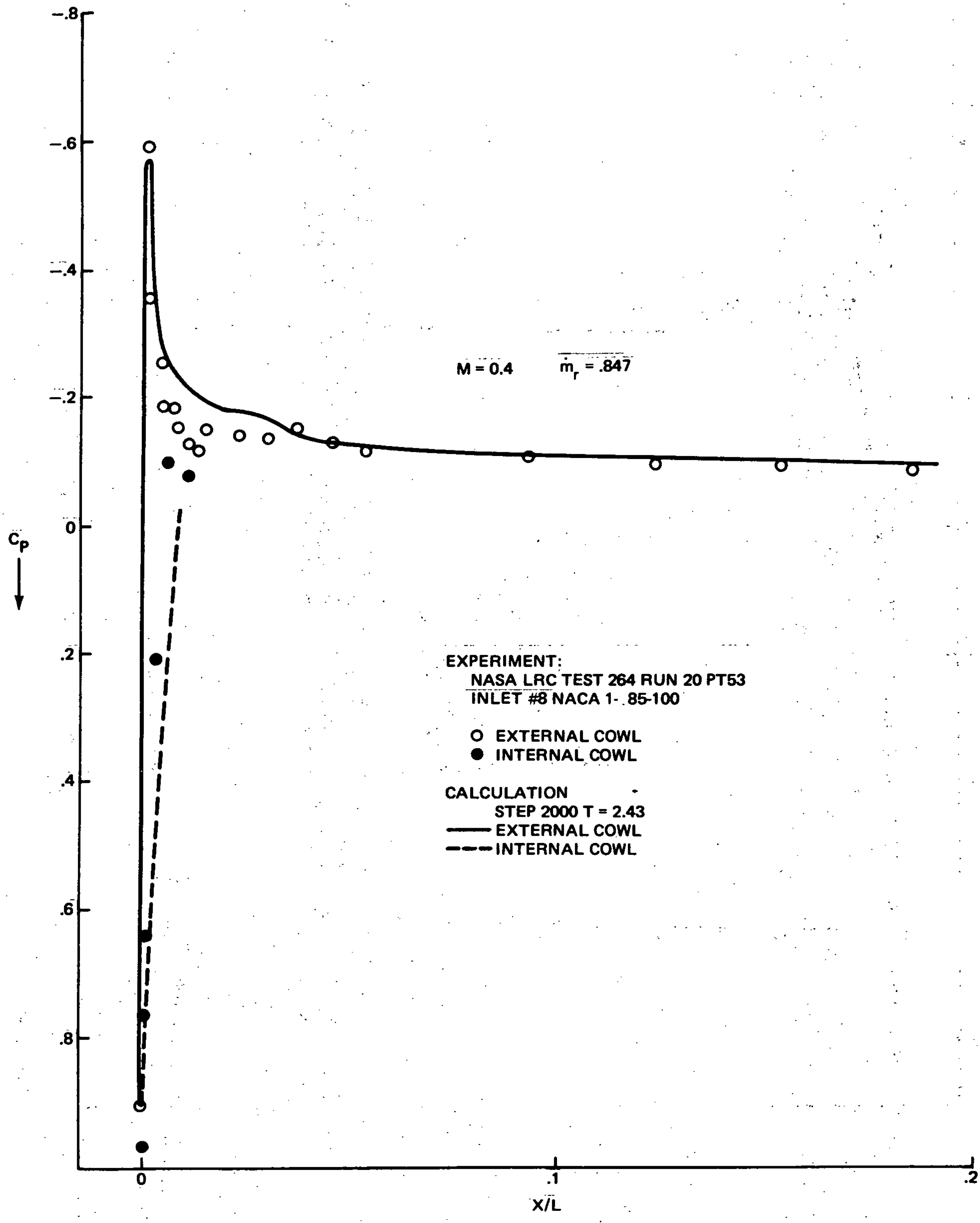

Fig. 2.14 Nacelle Surface Pressure Distribution Cowl Lip

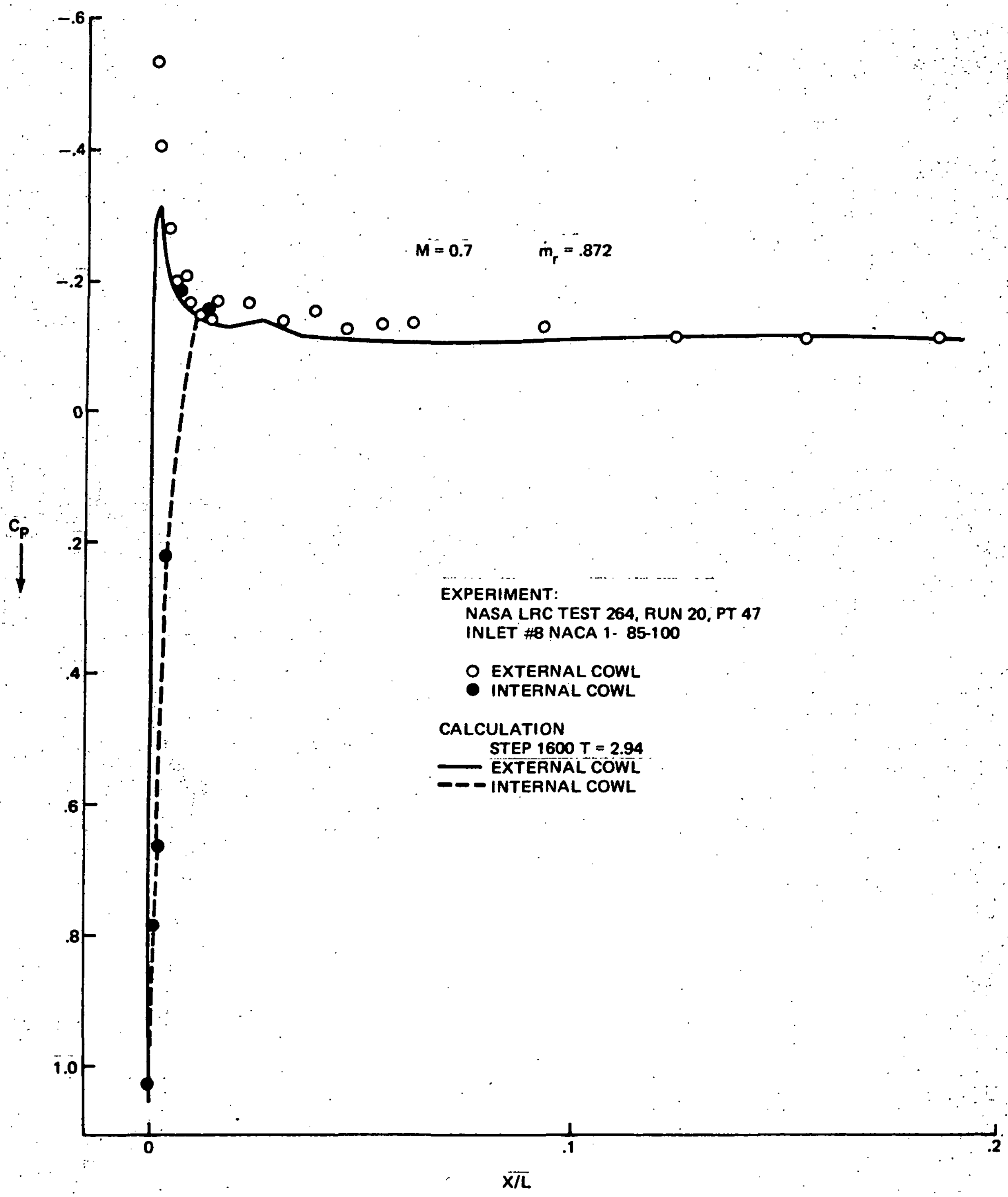

Fig. 2.15 Nacelle Surface Pressure Distribution Cowl Lip

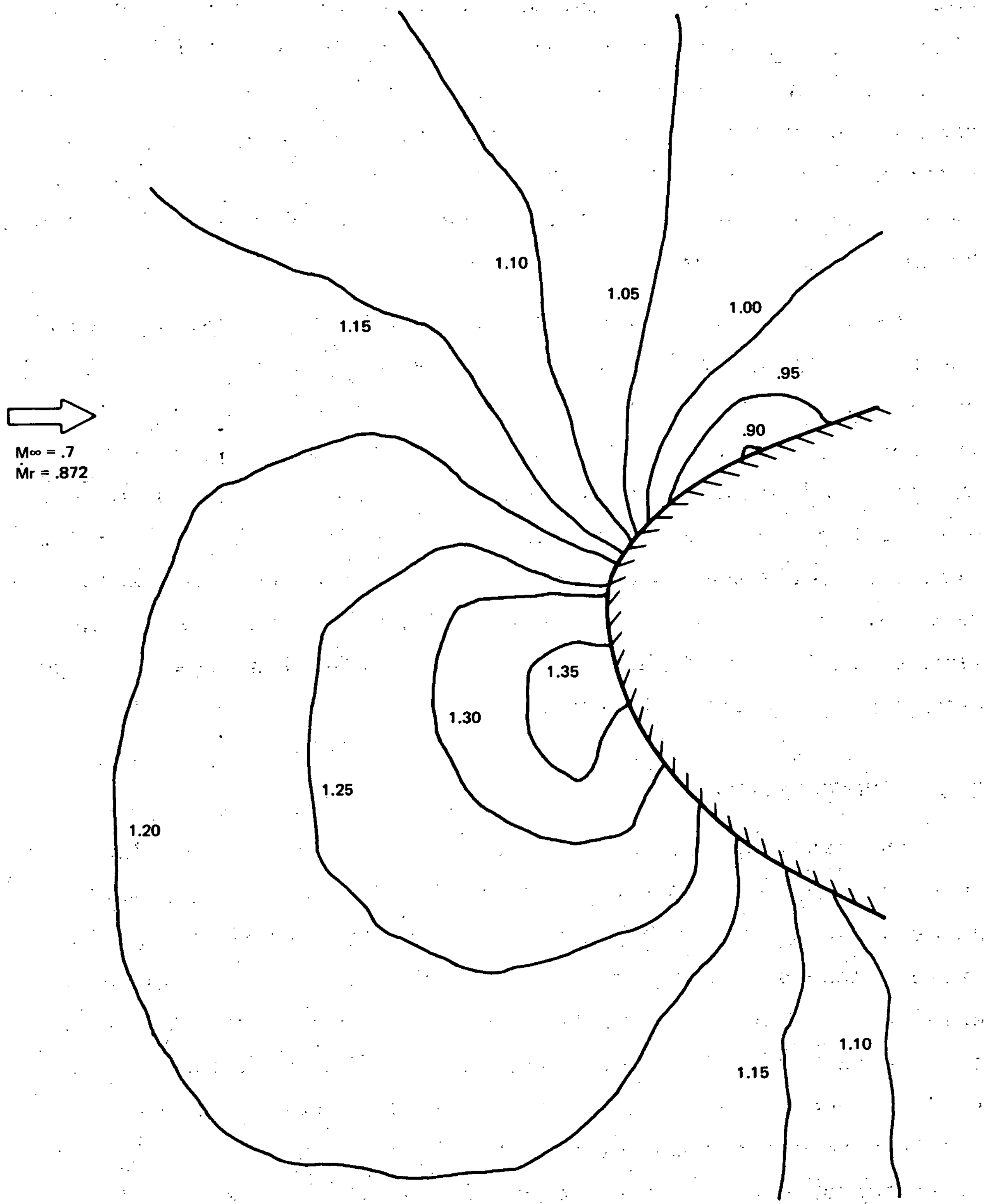

Fig. 2.16 Isobars (p/p∞) Nacelle Cowl Lip

going into the inlet was not sufficiently low. Although the mass flow specified by the engine-inlet interface was 0.885, the actual calculated mass flow entering the inlet was 0.930. This fact is in evidence in the computed surface pressure distribution shown in Fig. 2.17. Here, the shape of the C_p versus x curve agrees with the data but is displaced. This phenomenon corresponds to an incorrectly matched mass flow.

As an example of the boattail plume computation, we considered the flow over a straight semi-infinite pipe at $M_\infty = 0.7$. The jet had an initial Mach number of 3.0 with a ratio of jet static pressure to free stream static pressure of 3.0. The results of the computed plume shape, imbedded shock location and Mach number distributions within the jet are shown in Fig. 2.18. The calculation ran 500 steps to a time T = 12.4 with the plume shape revised every 50 steps. The number of plume iterations was more than sufficient with the plume shape changing less than two percent during the final iteration.

2.4 CONCLUSIONS

The basic objectives of this task have been to develop a computer program for predicting the inviscid transonic flow field about a nacelle. Furthermore, it was desired to obtain an extremely accurate solution to this problem. Our previous experience in calculating transonic flows over simple bodies dictated our approach of using the method of time-dependent computations (TDC). However, as we have described in Sections 2.1, 2.2, and 2.3, the inherent complexities of this problem coupled with our basic approach have prevented us from obtaining a satisfactory solution at this time.

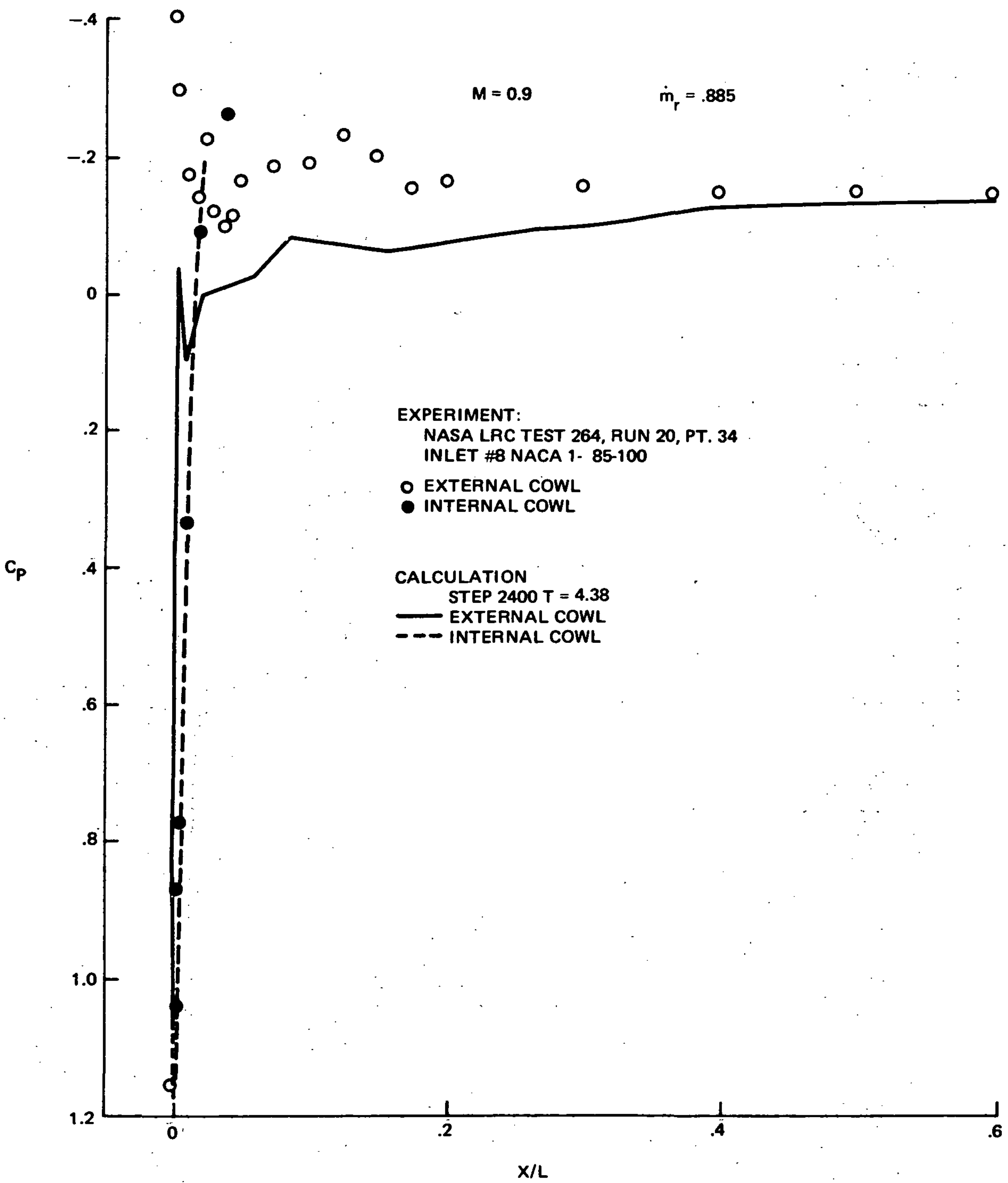

Fig. 2.17 Nacelle Surface Pressure Distribution Cowl Lip

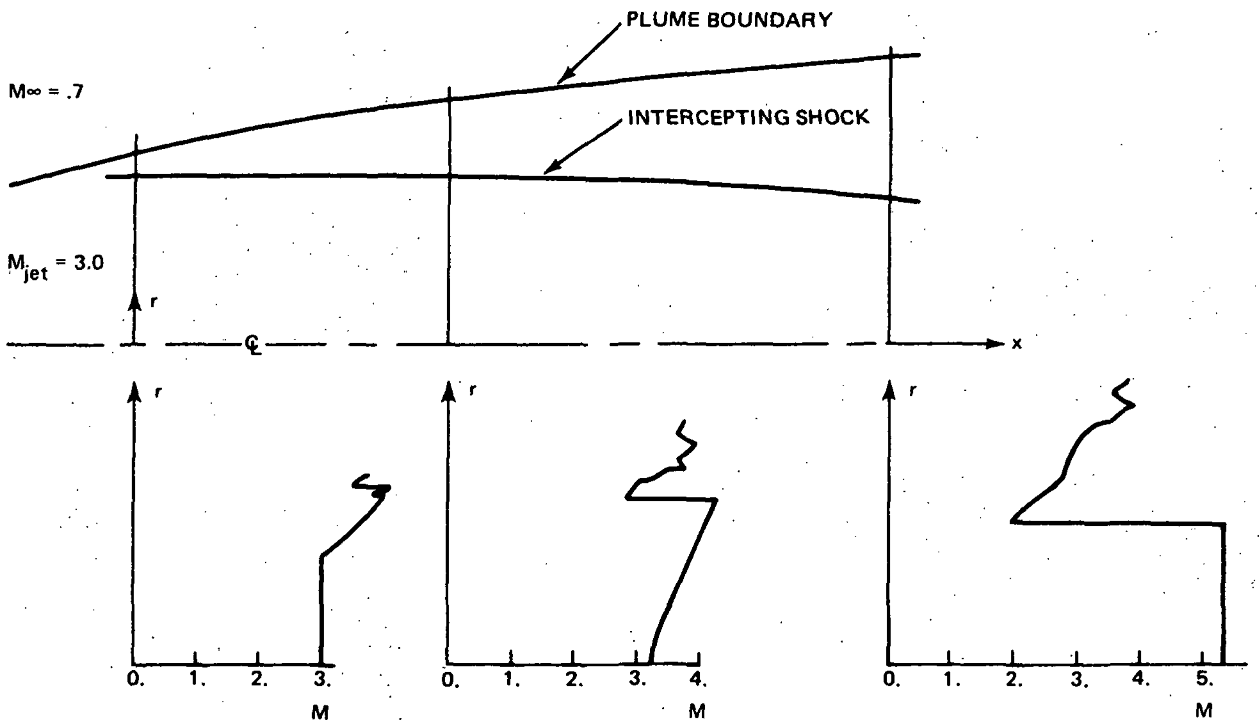

Fig. 2.18 Boattail – Plume Computation $\overline{p_{jet}/p_\infty} = 3.0$

We do not feel that there is anything fundamentally wrong with our methods. Rather, the sum total of complex features due to geometry, engine-inlet interfaces, exhaust plume and coordinate stretchings have combined to form an extremely complicated program. This type of program cannot accommodate our shock fitting procedures and, hence, the difficulties at transonic Mach numbers. Nontheless, the numerical techniques developed here will find some applications for the calculation of subsonic nacelle flow fields.

In order to solve the transonic nacelle problem at this time, we feel that another approach may be found more suitable. Relaxation methods have proven quite effective in solving two and three dimensional transonic airfoil problems (e.g., Jameson's work) and more recently for axisymmetric boattails (e.g., J. South). However, some important technical details have to be developed before a relaxation approach can be used for the nacelle problem. Some examples are the determination of a suitable mapping so that the nacelle surface becomes a coordinate surface at the transformed plane, and the development of procedures to specify the inlet mass flow and to handle the exhaust plume computation.

At present we feel that TDC has limited applicability for complicated transonic flow calculations. Ultimately, however, for transonic flows with strong shock waves and for time-varying flow fields, time-dependent methods should prove to be quite useful.

2.5 REFERENCES

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3. COMPUTER PROGRAM DOCUMENTATION

3.1 USER ORIENTED DOCUMENTATION

In this section we discuss all the details necessary to enable the engineering user to run the computer program for the time-dependent nacelle calculation. Firstly, the general features and over-all logic flow are presented. The program usage and operation are then explained in terms of a complete discussion of program inputs. Finally, the accuracy and limitations of the program will be described.

3.1.1 General Features and Over-all Logic Flow

Here we present a qualitative description of all features of the computer program pertinent to the engineering user. A discussion of the options, nacelle geometry, mesh point distribution, plume geometry, output options, plume computation, and over-all logic flow now follow.

3.1.1.1 Options

The basic computer program for the time-dependent computation of the inviscid flow field about a nacelle is designated program 15C. This program has several major options. Namely, it can handle either a complete nacelle or an isolated boattail. There are also options for including an exhaust plume and for specifying either two dimensional or axisymmetric flow. In addition, the program may be started from time $T = 0$ directly or from a tape input generated in a previous run. The implementation of these features will be discussed in the section dealing with input and output. Other critical factors necessary to run the program consist of the geometry and mesh point distribution.

3.1.1.2 Nacelle Geometry

The geometry routine supplied as part of the computer program, called SUBROUTINE WALL, is relatively simple to implement. The nacelle surface is divided into three areas, the cowl lip, external cowl, and internal cowl, as shown in Fig. 3.1. Each of these areas is divided into an arbitrary number of sections. The user inputs the number of divisions for each region and the value of y and dy/dx at each division point. In addition, a parameter is input at each point denoting whether a cubic or a straight line is to be fit between successive divisions. The program automatically performs the appropriate curve fits. The details of the user geometry input now follow.

Firstly, the length $\bar{L}$ of the nacelle, the radius of the cowl lip $\bar{r}_n$, and the height above the centerline of the center of the cowl lip, $\bar{H}$. Note that all barred qualities discussed here are dimensional. All lengths in the program will then be nondimensionalized with respect to $\bar{L}$. The radius of the cowl lip is taken from the nacelle blueprint. It is not necessary for this lip to be circular and the value of $\bar{r}_n$ is somewhat arbitrary. However, the smaller the $\bar{r}_n$, the greater the resolution near the nose, that also corresponds to increased computer running time. Typically, for the NACA 1-185-100 inlet, we used an $\bar{r}_n = 0.2$ in. as is shown in Section 3.2.4.

Next, the cowl lip must be considered. This region is divided into JNOS intervals as shown in Fig. 3.2. The values of x,y and dy/dx are input at each division. These values must be in order starting at $J = 1$ corresponding to $\bar{x} = \bar{r}_n$ on the upper surface to $J = JNOS$ which is $\bar{x} = \bar{r}_n$ on the lower surface. The program automatically curve fits r as a cubic in θ between each interval.

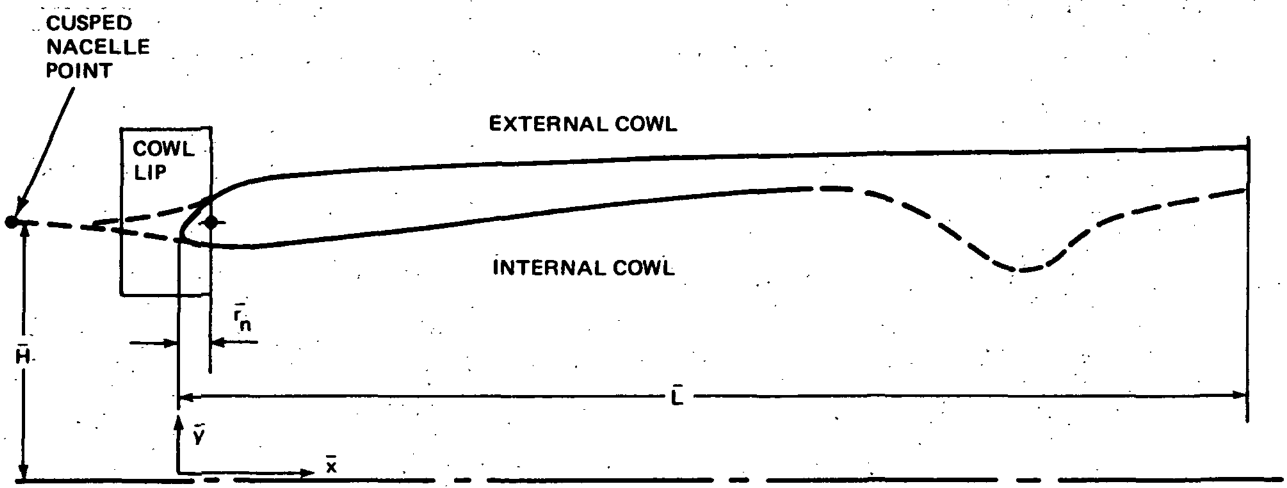


Fig. 3.1 Nacelle Geometry Notation

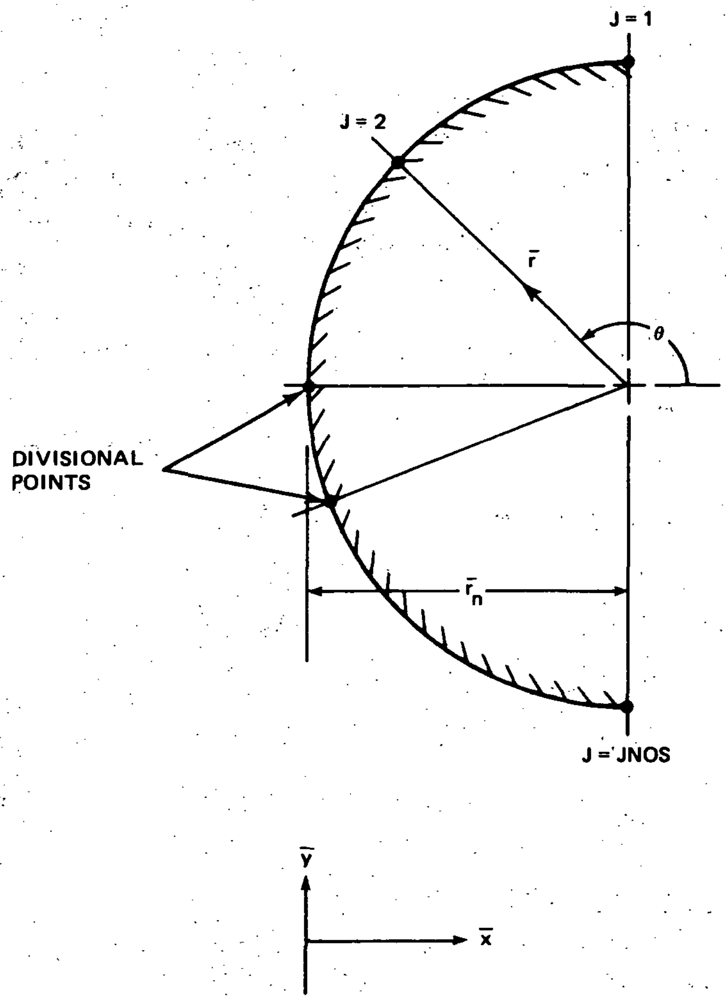


Fig. 3.2 Cowl Lip Notation

Note that Cartesian values of $\bar{x}$, $\bar{y}$, $d\bar{y}/d\bar{x}$ are input, with the program automatically converting to polar coordinates. It is recommended that one interval should correspond to $\bar{x} = 0$ (the value of dy/dx at this point is infinite and any finite input value will be accepted). Generally three to five intervals in the nose region should be adequate.

The next part of the geometry input is the external cowl. Here, there are JOUT divisional points as shown in Fig. 3.3. The first intersection J = 1 corresponds to the cusped nacelle point and is automatically input as $x = -r_o + r_n$ and $y = H$, $dy/dx = 0$. A cubic fit is used between J = 1 and J = 2. From J = 2 to J = JOUT values of x, y, dy/dx must be input along with the value of the parameter LOUT(J). LOUT(J) = 3 for a cubic fit between J and J + 1 and LOUT(J) = 1 for a straight line between J and J + 1. Also it is necessary to input the actual number of intersection points which are to be input called JOUTB. Since J = 1 is specified in the program, JOUTB = JOUT-1. Note that we define $r_o = 3r_n$.

The last region to be considered is the internal cowl as depicted in Fig. 3.4. Here we have JINB divisional points with x, y, and dy/dx input for each point. Also LIN(J) is input, which determines the type of curve fit to be used between J and J + 1. The values at J = 1 are preset with $x = -r_o + r_n$, $y = H$, $dy/dx = 0$, and LIN(1) = 3. Furthermore, values at the next to last intersection point JIN-1 are predetermined from the mass flow specification (Section 2.2.3) and the last value of JIN where $x = L$, $y = H$, and $dy/dx = 0$. Thus, only values between J = 2 and J = JIN-2 need to be input. The total number of input intersectional points JINB = JIN-3.

When the boattail option of the program is used, only the data for the external cowl need to be input. The plume geometry input

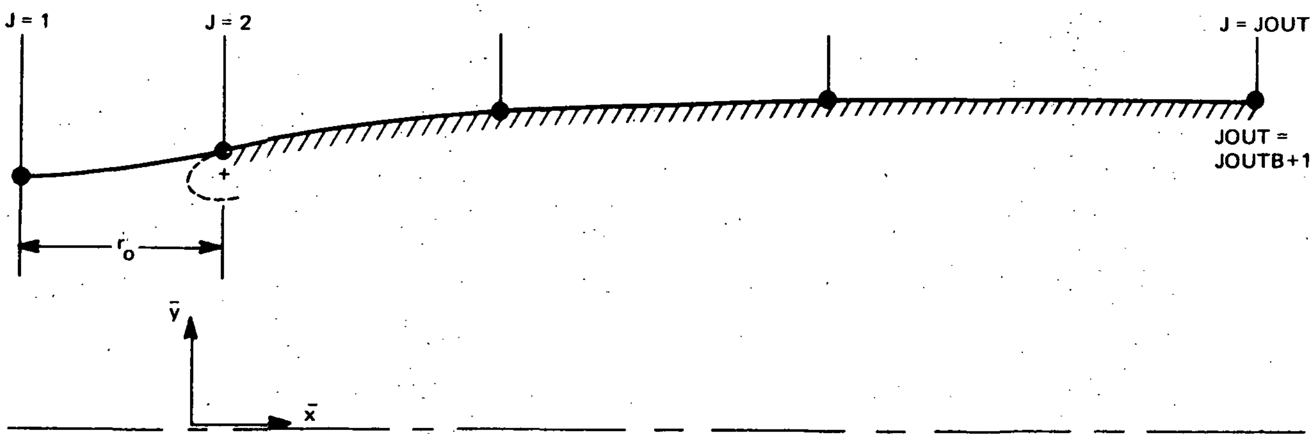


Fig. 3.3 External Cowl Notation

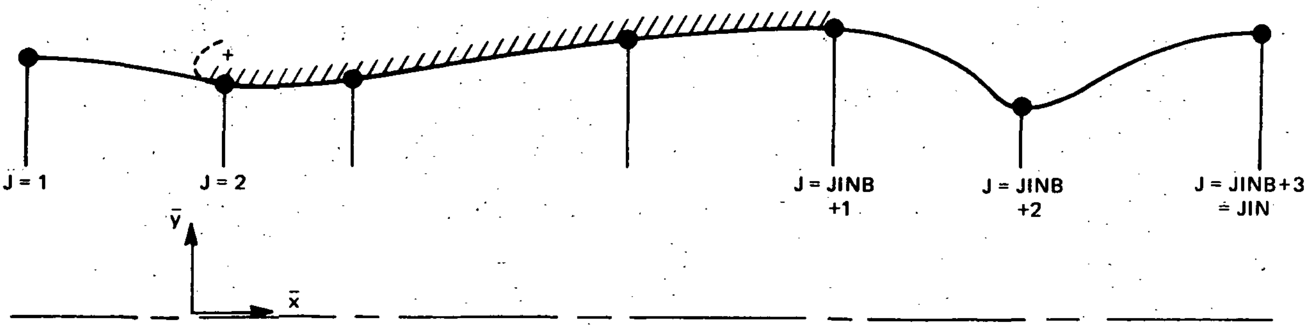


Fig. 3.4 Internal Cowl Notation

will be discussed separately. The nacelle geometry routine does not explicitly have a centerbody, although provisions for this situation have been maintained throughout the computer program.

The nacelle geometry inputs will be summarized in Section 3.1.2.

3.1.1.3 <u>Mesh Point Distribution and Coordinate Stretchings</u>

Regions 1, 2, 3, 4, 6, and 7 shown in Fig. 2.2 have NC(LREG) mesh points in the x-direction and MC(LREG) mesh points in the y-direction. Region 8 has MC(8) mesh points in the r-direction and NC(8) in the θ-direction. Values of NC(LREG) and MC(LREG) are input into the program. Within the present DIMENSION statements, the maximum value of MC(LREG) is 19 and the maximum value of NC(LREG) is 40 with the additional constraint of

$$\sum_{LREG=1}^{8} NC(LREG) = 150 \quad .$$

Thus, the maximum number of mesh points used in the nacelle computation is 2850. This does not include the points within the plume which will be discussed separately. Region 8 corresponds to the nose region.

Increasing the number of mesh points in each region increases the resolution. To simplify the choice we have built into the program two sets of mesh distributions: one set for the complete nacelle calculation and the other set for the boattail option. The values of NC and MC of any region may be input to change any of the preset values. The values of NC and MC for the nacelle calculation are

NC(1) = 18	MC(1) = 18
NC(2) = 18	MC(2) = 18
NC(3) = 25	MC(3) = 18
NC(4) = 16	MC(4) = 18
NC(6) = 18	MC(6) = 18
NC(7) = 32	MC(7) = 18
NC(8) = 19	MC(8) = 9

For the boattail option

NC(1) = 20	MC(1) = 15
NC(2) = 1	MC(2) = 1
NC(3) = 1	MC(3) = 1
NC(4) = 1	MC(4) = 1
NC(6) = 20	MC(6) = 15
NC(7) = 20	MC(7) = 15
NC(8) = 1	MC(8) = 1

Note that all the values of NC and MC are not independent. The constraints are

$$MC(4) = MC(3) = MC(2)$$
$$MC(7) = MC(6) = MC(1)$$
$$NC(2) = NC(1)$$

Once the number of mesh points are selected, the actual mesh point distribution in the physical plane is determined from the values of the stretching parameters. The stretching parameters x_o, x_1, x_2, x_3, y_o, y_2, α_1, α_2, α_3, and α_4 are determined from physical mesh point locations DD(J), $J = 1 \rightarrow 6$. The lengths DD are shown in Fig. 3.5. Shown here are the regional interfaces and the first and last grid lines (in the physical space). Values of DD are as shown in Fig. 3.5. Again, to simplify the running of

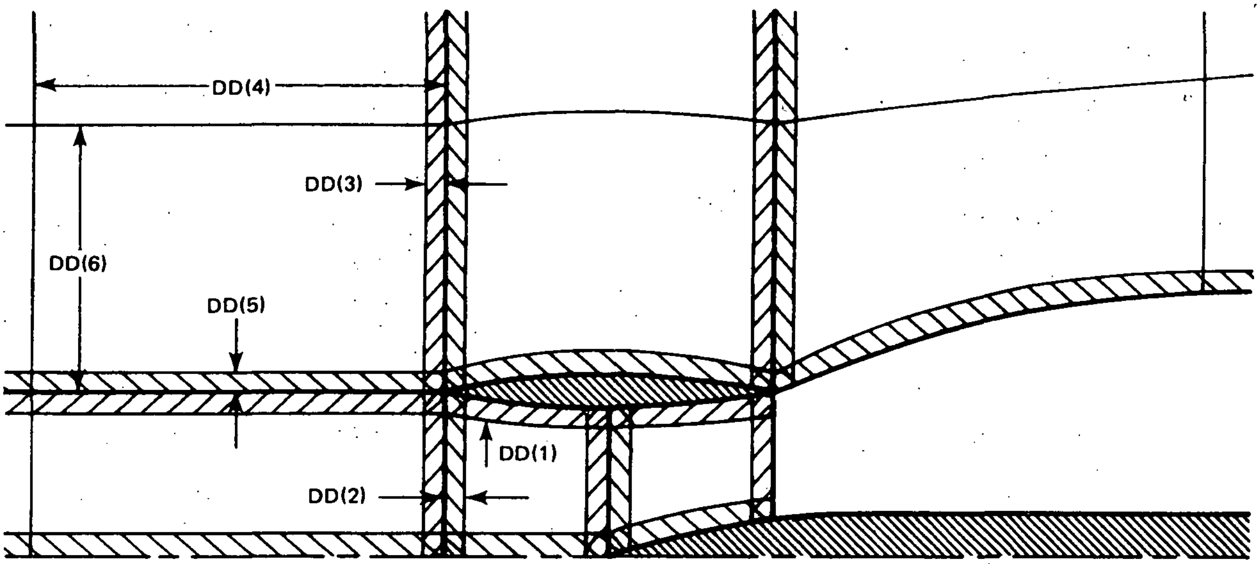


Fig. 3.5 Stretching Parameters

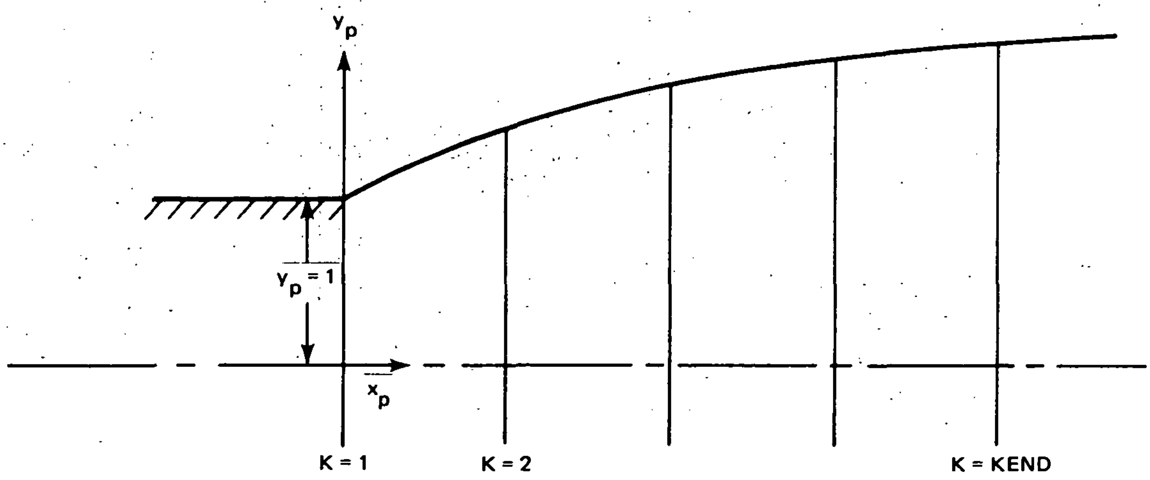


Fig. 3.6 Plume Geometry

the program, two sets of values of DD are built into the program.

Complete Nacelle Calculation		Boattail Option	
DD(1) = 0.005	DD(4) = 4.0	DD(1) = 0	DD(4) = 10
DD(2) = 0.005	DD(5) = 0.005	DD(2) = 0.05	DD(5) = 0.05
DD(3) = 0.005	DD(6) = 4.0	DD(3) = 0.05	DD(6) = 10

Note that the numbers 1-6 are only an index and do not correspond to any particular region.

3.1.1.4 Plume Geometry

Initially, the shape of the plume in Cartesian coordinates is input into the program. These coordinates, x_p and y_p, are scaled to the initial radius of the jet as in Fig. 3.6. A piecewise parabolic fit is made to the coordinates extending to downstream infinity. After the plume computation has been made, the new boundary shape is curve fit automatically.

3.1.1.5 Flow Field Output

There are two basic output options, the surface flow field output and the complete nacelle flow field. For the surface flow field, values of the Cartesian coordinate position, x,y, pressure p, Mach number M, flow deflection $\tau = v/u$, and pressure coefficient C_p are given for each mesh point along the surfaces of the outer cowl, inner cowl, and plume boundary (outside the plume). For the complete flow field, output values of the entire field are given for x, y, p, a (speed of sound), u, v (velocity components), M, ρ (density), C_p and S (entropy). The output is divided into regions as in Fig. 2.2. Note that for regions 1-7, u,v are the Cartesian velocities and for region 8, u,v are the polar velocities. All the outputs are nondimensional as discussed in Section 2.2. The pressure is scaled by p_∞, the density by ρ_∞, all velocities by $\sqrt{p_\infty/\rho_\infty}$, and all lengths by $\bar{L}$, the length of the nacelle.

In addition, the mass flow going through the inlet is numerically integrated (trapezoidal rule) and output whenever the complete flow field output is called.

3.1.1.6 Tape Input and Output

The program has a restart capability. At the end of a given run, the contents of all common blocks are dumped onto Tape Unit 12. At the start of the next run, the data are read from Tape Unit 11. The implementation of input parameters to use this option is discussed in Section 3.1.2.

3.1.1.7 Plume Calculation

The plume is computed every KPLUME number of time steps. If KPLUME = - 1 there will be no plume and a straight pipe will be assumed to extend downstream of the body. The plume routines have been written as a separate independent program. It is made part of the entire nacelle program through subroutines BOUND and PLUBO. BOUND takes the values of the pressure along the plume outer surface (obtained in the nacelle calculation) and converts the results into a form suitable for the PLUME routine. PLUBO curve fits the computed plume shape into a form compatible with the nacelle calculation. The plume is computed to a specific value of length which is input. This length should be shorter than the distance to the Mach disk.

The plume routine output values of $\bar{Z}$, r, p, u, w, θ, M, S, and τ, where quantities are nondimensional with respect to nozzle exhaust plane conditions (Section 2.2.4). The major input conditions are M, γ, PRATIO. Note that here PRATIO is the ratio of static pressures of the jet to the free stream. This quantity is related to the stagnation pressure ratio P_r by

$$\text{PRATIO} = \frac{p_\infty}{p_{jet}} = \frac{1}{P_r} \frac{\left\{(1 + \frac{\gamma - 1}{2} M^2)^{\gamma/\gamma - 1}\right\}_\infty}{\left\{(1 + \frac{\gamma - 1}{2} M^2)^{\gamma/\gamma - 1}\right\}_{jet}} .$$

[Note that the stagnation temperature ratio is only required to rescale the variables to free stream conditions as in Eqs. (12)].

3.1.1.8 Over-all Logic Flow

The details of computer program logic are presented in Sections 3.2.1 and 3.2.2. Here we will describe some of the important features of the logic flow.

The program begins by receiving input data on the basic parameters associated with the run, all options, and mesh point distributions. Following this, initial data for all variables are computed. The coordinate stretchings are found in subroutine STRECH. The values of the body geometry are calculated in WALL and the initial value of the plume shape is given in PLUBO. The interpolations for the nose region are set up in SETNOS.

Then the major time loop is entered. The size of the new time step is determined and the value of time incremented. Within the time loop, the entire calculation for the cusped nacelle is performed in POINT. A time sub-loop is set up for the nose region and is computed in NOSE. If the option for the plume is in effect and this is the appropriate time step for its computation, subroutine PLUME is called. This routine acts as a main routine for the plume computation with the main calculation taking place in SUPER and the plume output given in OUTP. Once a new plume shape is determined, it is curve fit in PLUBO and the stretchings for the nacelle calculation redetermined in STRECH. Now, except for some optional output for the nacelle in OUTPUN, the step of the major time loop is completed.

After a specified number of time steps, KA, the computation, is completed. Finally, there are optional outputs in OUTPUN and optional saving of the data on tape in TAPER.

3.1.2 Program Usage and Operation

In order to explain the usage of the program, we present a summary and description of all input data. The order of the discussion follows the order of the data cards. Examples of all data input are shown in Section 3.2.4. Some of the input is of the NAMELIST type. This input procedure has the advantages of being easily identifiable and does not require all the data mentioned in the namelist declaration to be input. Thus, much of the input is optional and these paraemeters will be denoted by an asterisk (*). The values of the optional input parameters are denoted default options and will be discussed below.

3.1.2.1 Program Input

NAMELIST/RUN/NRUN, NDATE, EM, GAMMA, RMFLO, LA, LSYM, KPLUME, STAB

NRUN		Run number, Integer 1-99,999
NDATE		Rundate, dimensioned NDATE(3), typical input NDATE = 2,19,73
EM	M_∞	Free stream Mach number

GAMMA*	γ	Free stream ratio of specific heats, default value 1.4
RMFLO	$\dot{m}_r$	Mass flow ratio at engine-inlet interface
LA		= 0 two dimensional, = 1 axisymmetric
LSYM		= 0 complete nacelle, = 1 boattail option
KPLUME*		The number of time steps between plume computations, typically 100. If equal to -1 no plume computation will be made, default value -1
STAB*		Stability parameter (for time step determination). Typically 0.75-1.0, default value 1.0

3.1.2.2 Input/Output Parameters

NAMELIST/INOUT/MREAD, MRITE, KA, JA, JB, MB, LOUT1, LOUT2

MREAD*	Tape read parameter, integer value represents number of read cycles, = 0 no tape input, default value 0
MRITE*	Tape write parameter, = 0 do not write on tape, = 1 write on tape, = -1 rewind tape and write on tape, default value 0
KA	Total number of time steps
JA	Number of time steps between surface flow, field outputs, = -1 for no output
JB*	Number of time steps between complete flow field outputs, = -1 for no output, default value -1
MB*	Number of mesh points from nacelle surface in complete flow field output, = -1 all mesh points. default value = 1 (surface values only)
LOUT1*	= 1 for surface output at end of computation, = 0 no output, default value 0
LOUT2*	= 1 for complete flow field output at end of computation, = 0 no output, default value 0

3.1.2.3 Mesh Point Parameters

NAMELIST/MESH/NC, MC, DD

NC*	Number of mesh points in x-directions, dimensioned NC(8), full discussion in Section 3.1.1
MC*	Number of mesh points in y-directions, dimensioned MC(8), full discussion in Section 3.1.1
DD*	Mesh point distribution parameters, dimensioned DD(6), full discussion in Section 3.1.1

3.1.2.4 Geometry Input

1. General Description A Format(20A4)

A	Alphanumeric description, 80 characters long

2. General Parameters ELL, HBAR, RNBAR, JNOSB, JOUTB, JINB Format (3F10.4, 3I10)

ELL	$\bar{L}$	Length of the nacelle
HBAR	$\bar{H}$	Height of nominal center of cowl lip above centerline, same dimensions as $\bar{L}$
RNBAR	$\bar{r}_n$	Radius of cowl lip (nominal), same dimensions as $\bar{L}$
JNOSB		Number of divisional points to be input for cowl lip, = 0 for boattail option
JOUTB		Number of divisional points to be input for external cowl
JINB		Number of divisional points to be input for internal cowl, = 0 for boattail option

3. Cowl Lip Data XBAR, YBAR, YPBAR Format (3F10.4, 3I10)

XBAR	$\bar{x}$	Cartesian position and slope of divisional points along cowl lip. Same dimensions as $\bar{L}$.
YBAR	$\bar{y}$	
YPBAR	$\frac{d\bar{y}}{d\bar{x}}$	

There will be JNOSB input cards of this type.

4. External Cowl Data XBAR, YBAR, YPBAR, LFUNO(J)
Format (3F10.4, 3I10)

XBAR	$\bar{x}$	Cartesian position and slope of divisional points along external cowl.
YBAR	$\bar{y}$	
YPBAR	$\frac{d\bar{y}}{d\bar{x}}$	

LFUNO(J) = 3 for cubic fit between J and J + 1;
= 1 for straight line between J and J + 1

There will be JOUTB input cards of this type.

5. Internal Cowl Data XBAR, YBAR, YPBAR, LFUNI(J)
Format (3F10.4, 3I10)

XBAR	$\bar{x}$	Cartesian position and slope of divisional points along internal cowl.
YBAR	$\bar{y}$	
YPBAR	$\frac{d\bar{y}}{d\bar{x}}$	

LFUNI(J) = 3 for cubic fit between J and J + 1;
= 1 for straight line between J and J + 1

There will be JINB input cards of this type.

3.1.2.5 Plume Geometry Input (Initial)

1. General Description AW Format (20A4)

AW		Alphanumeric description, 80 characters long

2. Number of Intervals KK Format (1015)

KK		Number of intervals for plume geometry. Corresponds to the number of input cards to follow. If KK = 1 the plume will be a straight pipe.

3. Plume Shape XPP, YPP Format (2F10.4)

XPP	x_p	Cartesian coordinates of initial plume shape. Scaling shown of Fig. 3.6. There will be KK of these cards.
YPP	y_p	

3.1.2.6 Plume Calculation Input

NAMELIST/JET/NA, MA, KA, KOUT, PRATIO, DIST, GAMMA, STAB, ACH

NA*		Number of mesh intervals in the r-direction NA(1) low pressure side of the shock, NA(2) high pressure side of shock, maximum value = 30
KA		Maximum number of ΔZ steps in calculation, not crucial, calculation should stop at Z = DIST
KOUT		Number of steps between plume output
PRATIO		Static pressure ratio p_{jet}/p_∞. Discussed in Section 3.1.1
DIST		Distance to end of jet computation. Should be before Mach disk forms
GAMMA*	γ	Ratio of specific heats for jet
STAB*		C-F-L parameter, usually = 1
ACH	M_{jet}	Mach number at exhaust plane of nozzle

A schematic of the card data input is shown in Fig. 3.7.

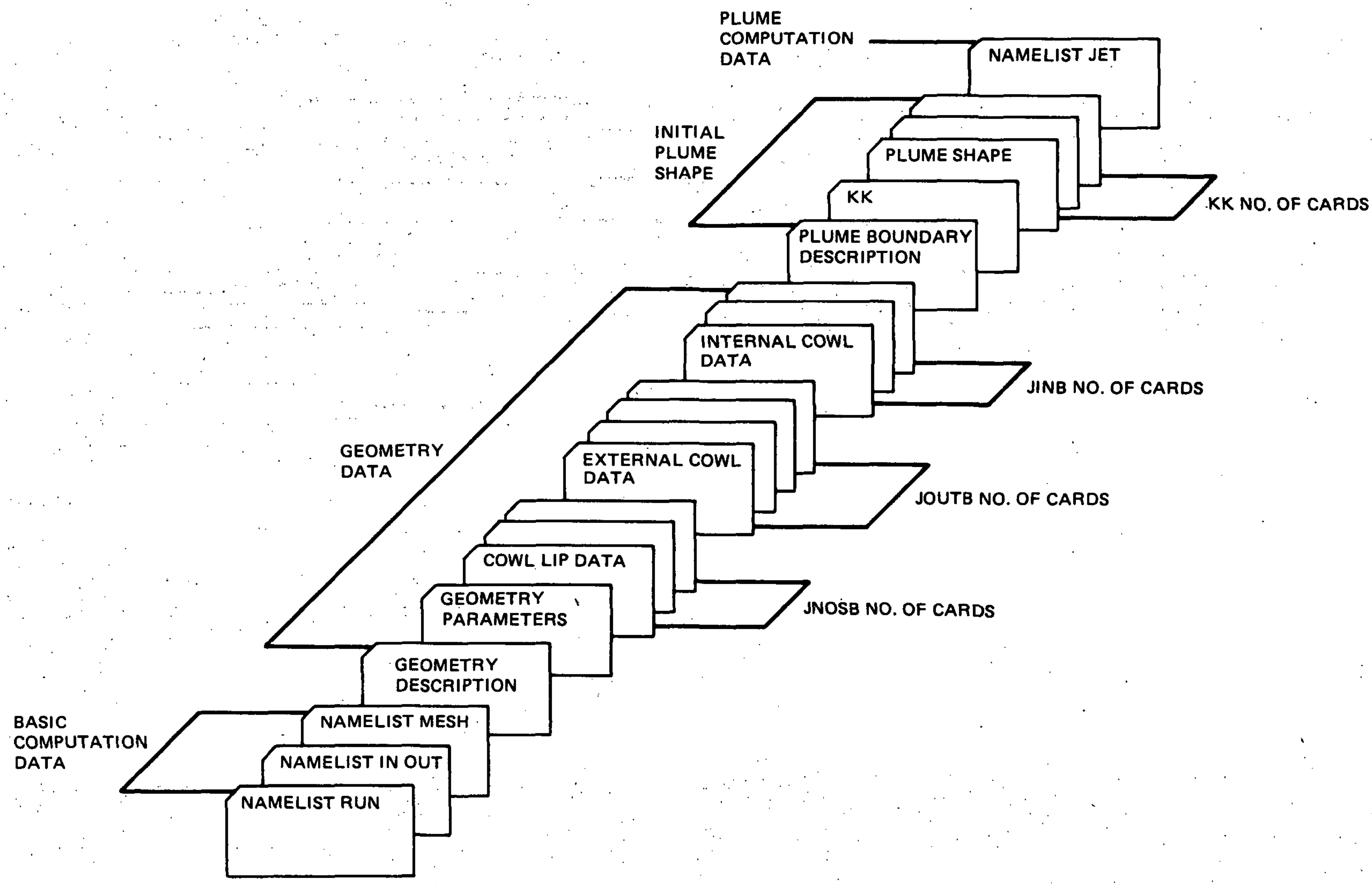


Fig. 3-7 Card Input Data

3.1.3 Accuracy and Limitations

The basic numerical methods for this computation are essentially second-order accurate. However, the boundary conditions and the interpolations at the nose region tend to reduce this level of accuracy. Another factor affecting the accuracy is the spatial mesh point resolution. The resolution is determined by the number of mesh points and the stretching parameters. Improving the resolution by increasing the number of mesh points increases the computational time and core storage. The values of the stretching parameters suggested as default options in the computer program should be sufficient for most applications. In general, the only effective means of evaluating the accuracy of a computational approach of this complexity is by comparing with other analytical methods and with experimental data. Caution must be exercised in comparing an inviscid computation with data because of viscous effects. Regarding the nacelle computation, an indication of the accuracy of the approach is given by the data comparisons in Section 2.3.

There are several limitations to this computational program. Namely, accurate results can only be assured for subcritical free stream Mach numbers. Furthermore, even at high subcritical Mach numbers, when the mass flow ratio is low, problems may develop. The reasons for these limitations are discussed in Section 2. Since there are no provisions for a bow shock, the program will not work for supersonic free streams.

The basic program is written to handle a cusped centerbody. However, the geometry routine would have to be modified to run this case. In addition, the program cannot handle the short cowl nacelle. An approximation of the short cowl can be made by treating the plume with a specified internal solid boundary which represents the jet plume. The remainder of the plume would correspond to the fan jet. This computation requires a change in the plume geometry input procedure and the plume computation routine.

3.2 PROGRAM ORIENTED DOCUMENTATION

In this section, we attempt to present enough detailed information about the computer program to enable the user to understand and possibly to change the source language code. Firstly, the structure of the program is schematically described by flow charts of the main program and all major subroutines. A subroutine tree diagram is also presented. Then each subroutine is discussed followed by a description of input/output files. Lastly, the input and a partial output for two test cases are presented along with a FORTRAN source program listing.

3.2.1 Program Flow Charts

The flow charts for Program 15C are shown in Figs. 3.8-3.18. A subroutine tree diagram is presented in Fig. 3.19.

3.2.2 Subroutine Description

POINT — Computes one time step for all interior points in the cusped-nacelle formulation of the problem. All solid boundary conditions, free stream conditions, and interface matchings are handled here. Included is a separate computation for the cusped-nacelle point.

STRECH — First calculates all coordinate stretching parameters. Develops coordinates and derivatives of mesh points for cusped nacelle formulation in the physical plane. Obtains information from WALL and PLUBO. After major

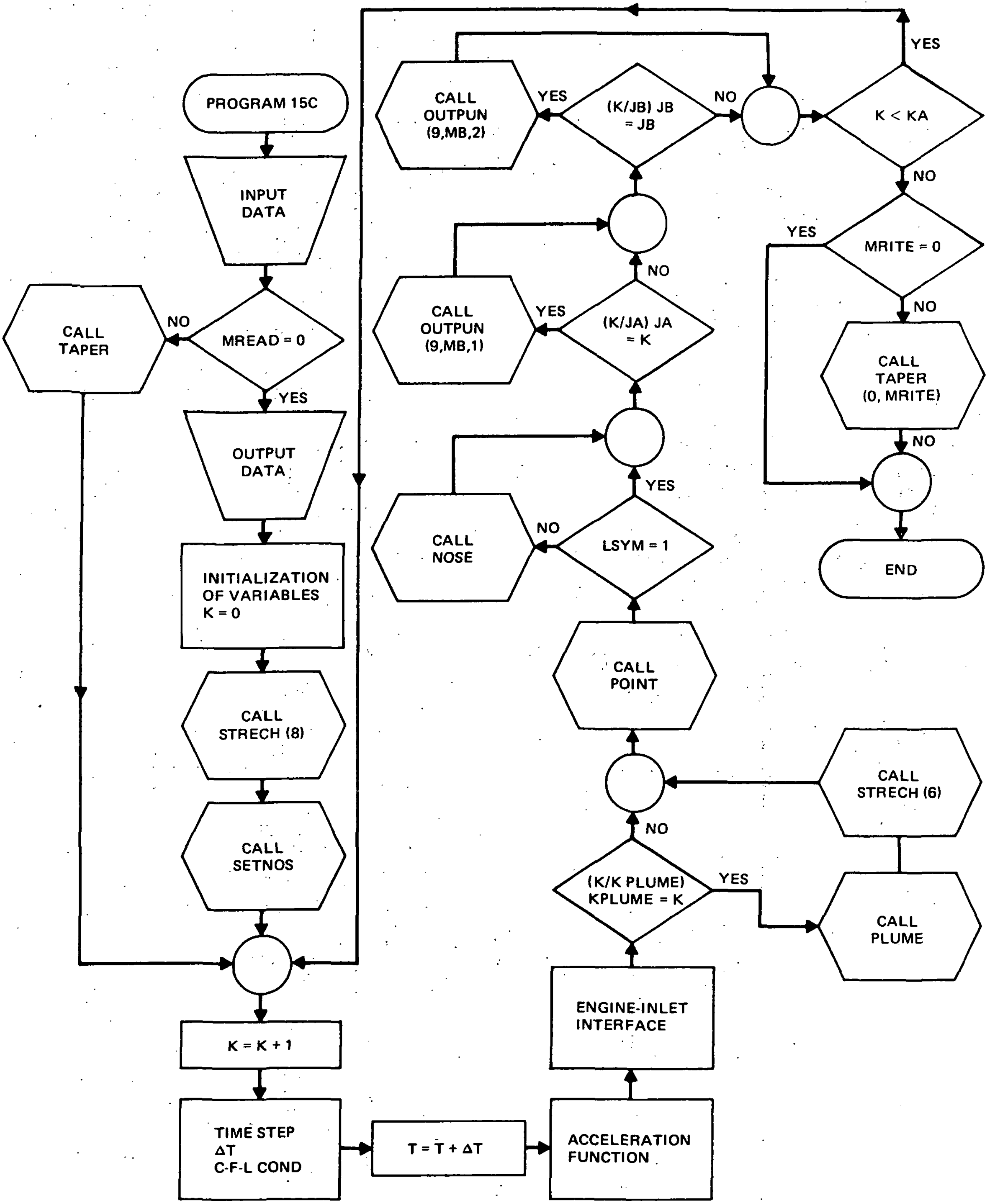


Fig. 3.8 Main Program

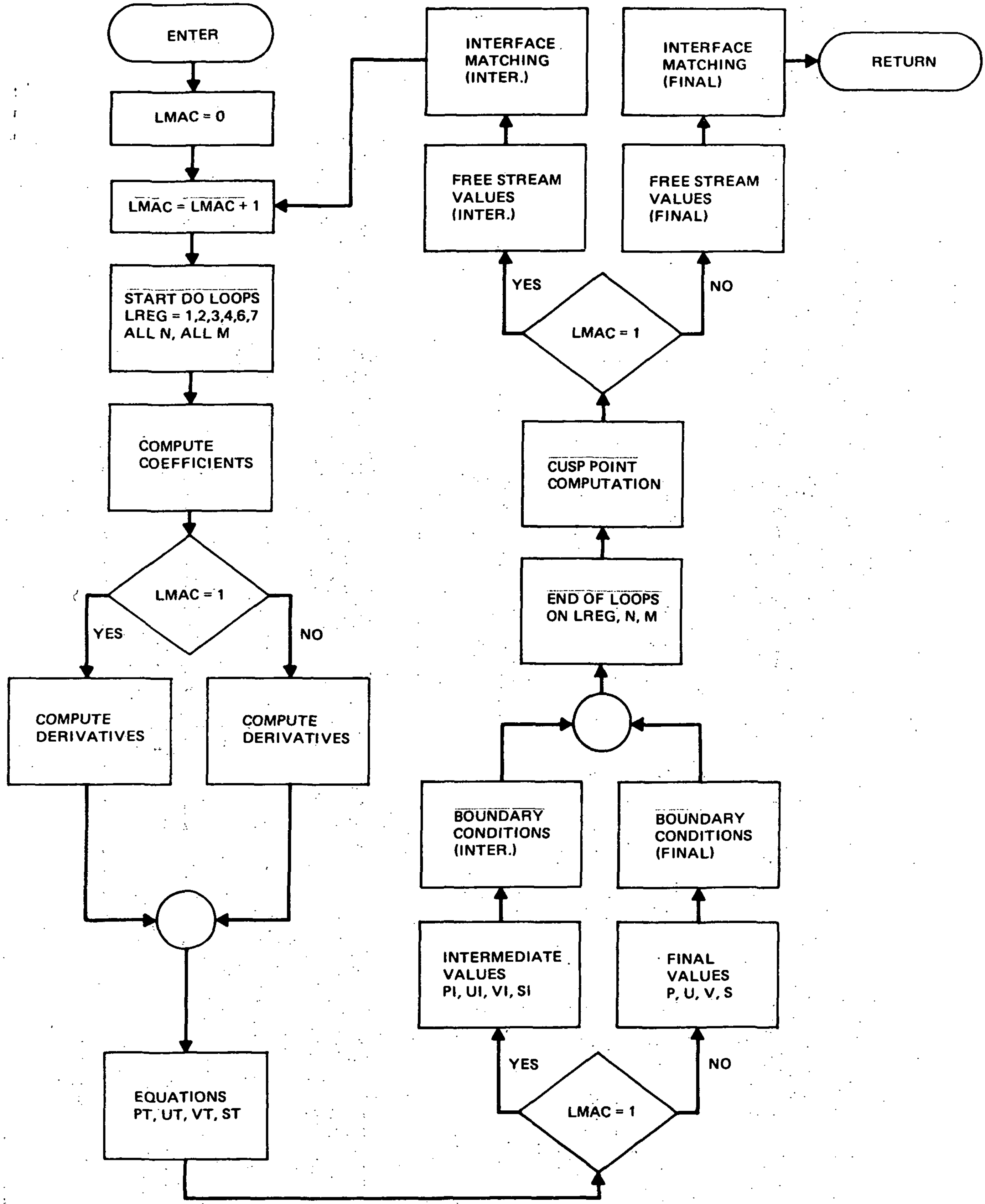
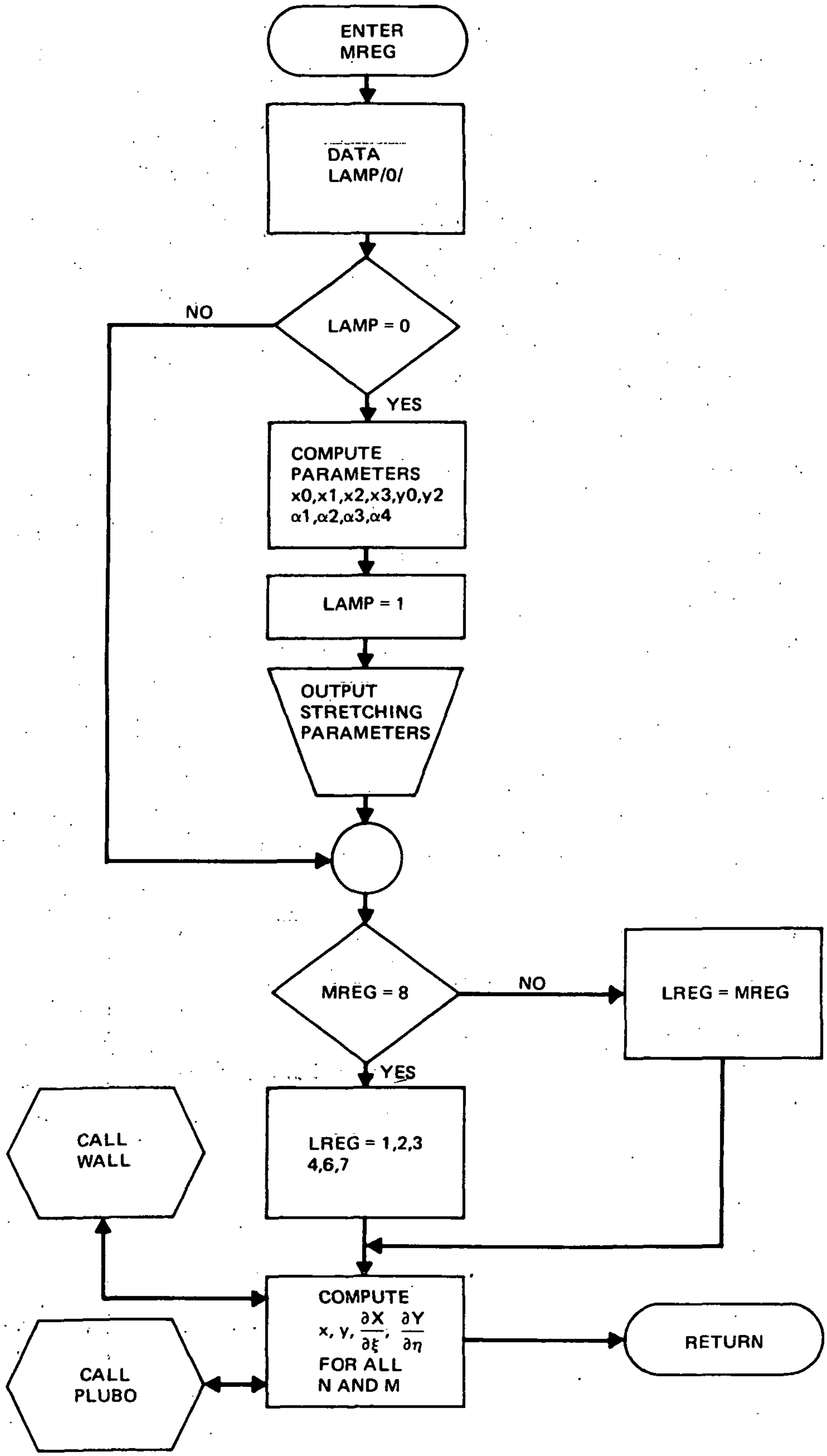


Fig. 3.9 Subroutine Point



Fib. 3.10 Subroutine Strech (MREG)

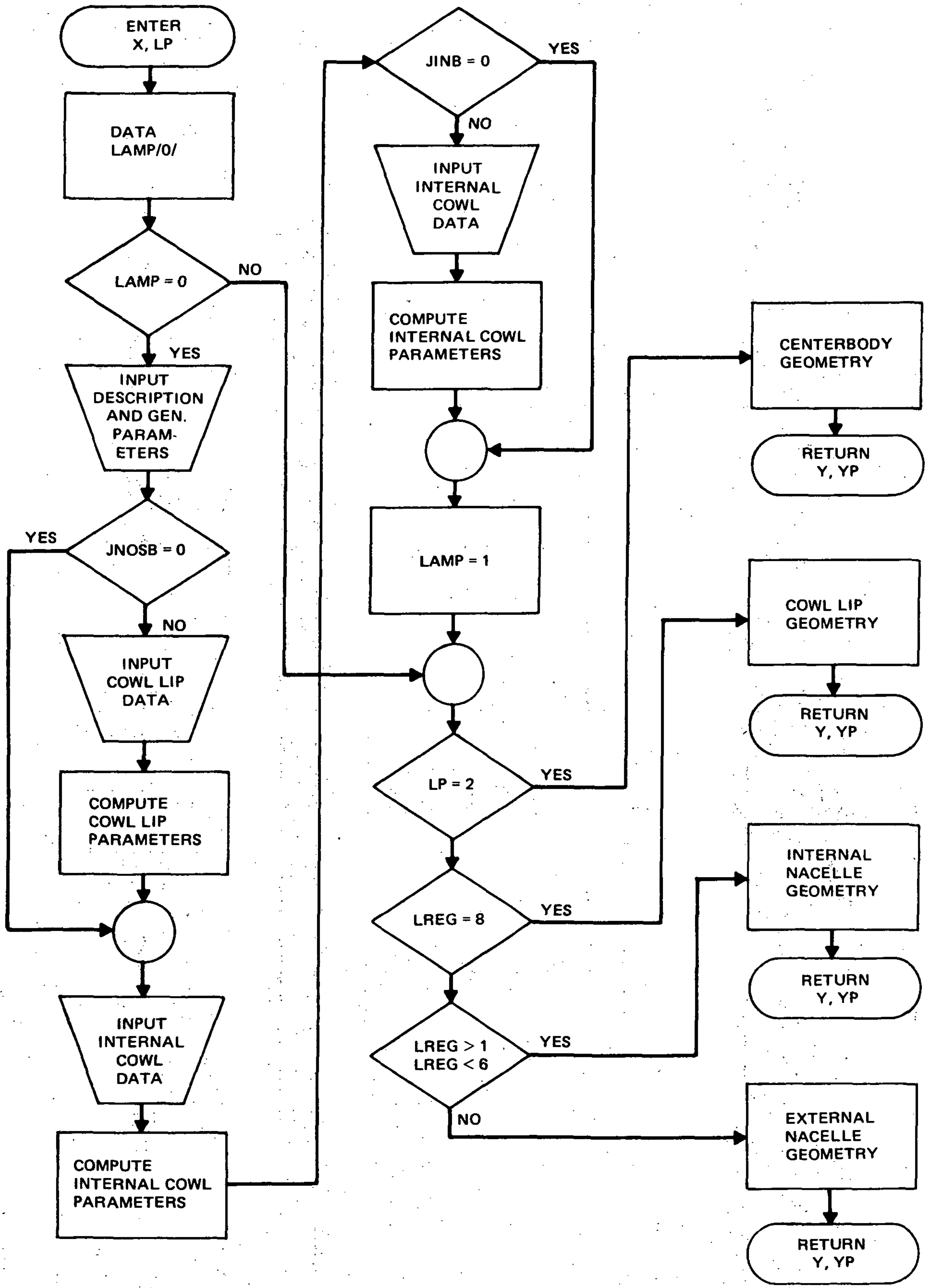


Fig. 3.11 Subroutine Wall (IREG, X, Y, YP, LP)

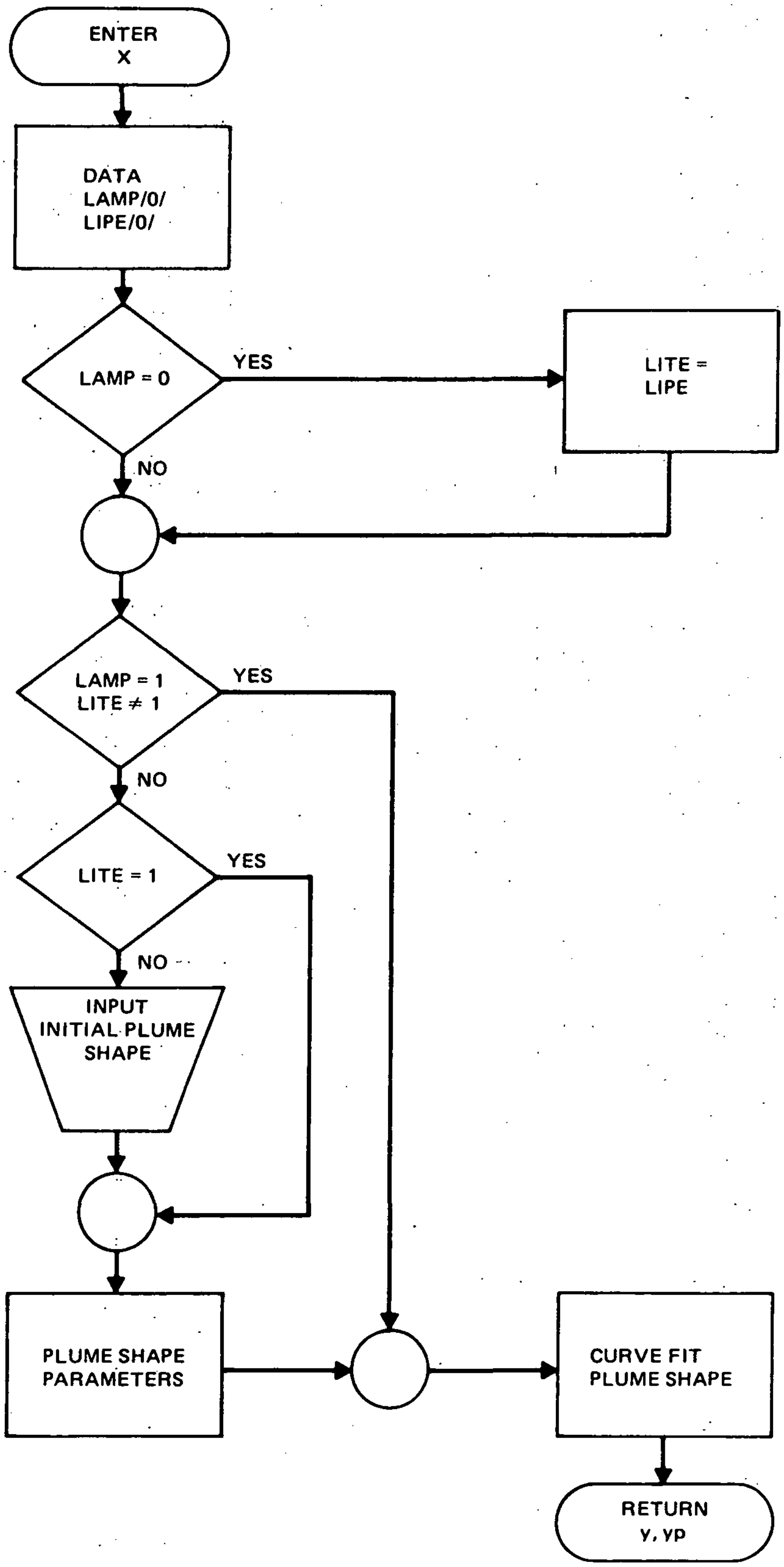


Fig. 3.12 Subroutine Plubo (x, y, yp)

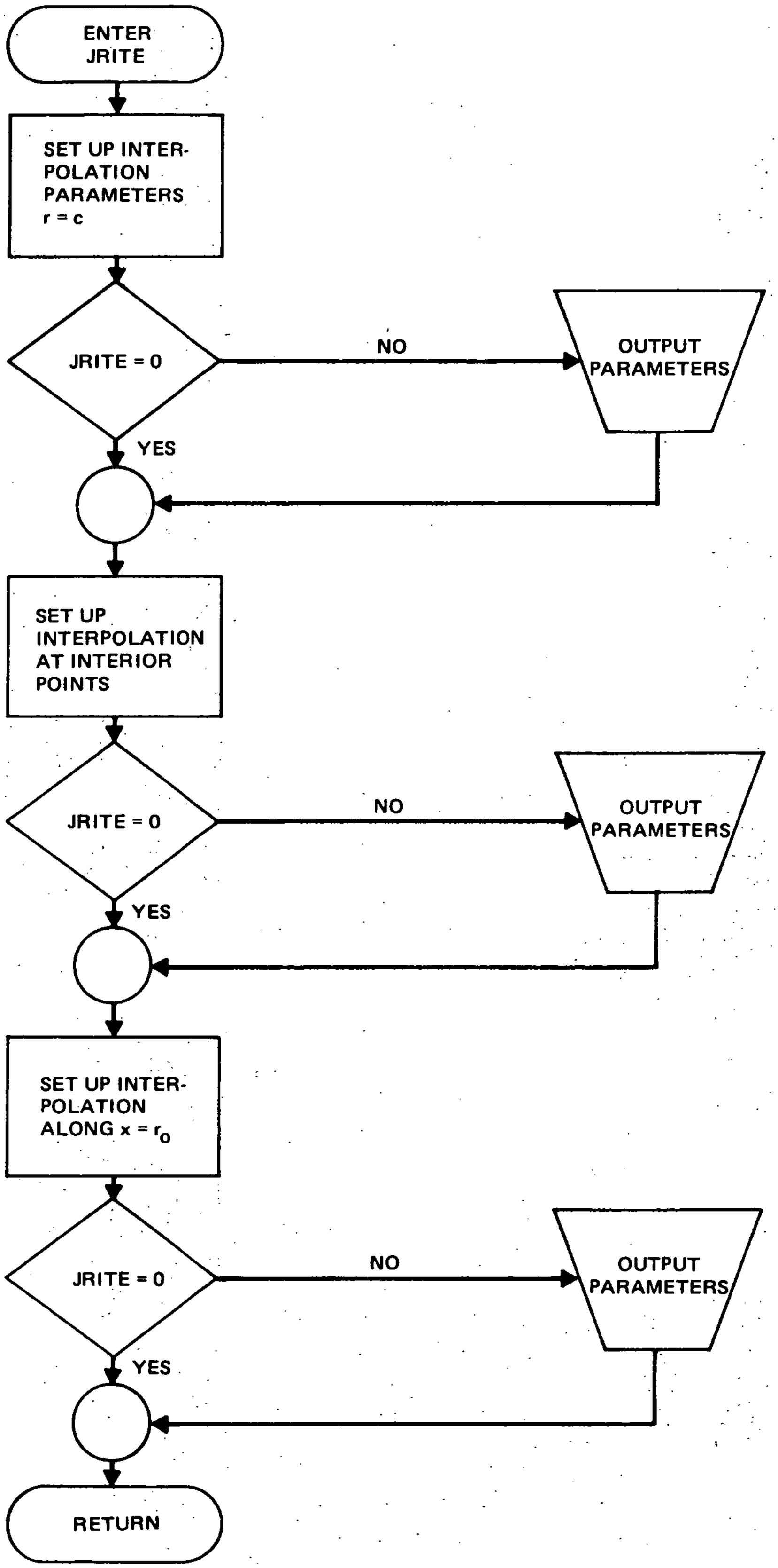


Fig. 3.13 Subroutine Setnos (JRITE)

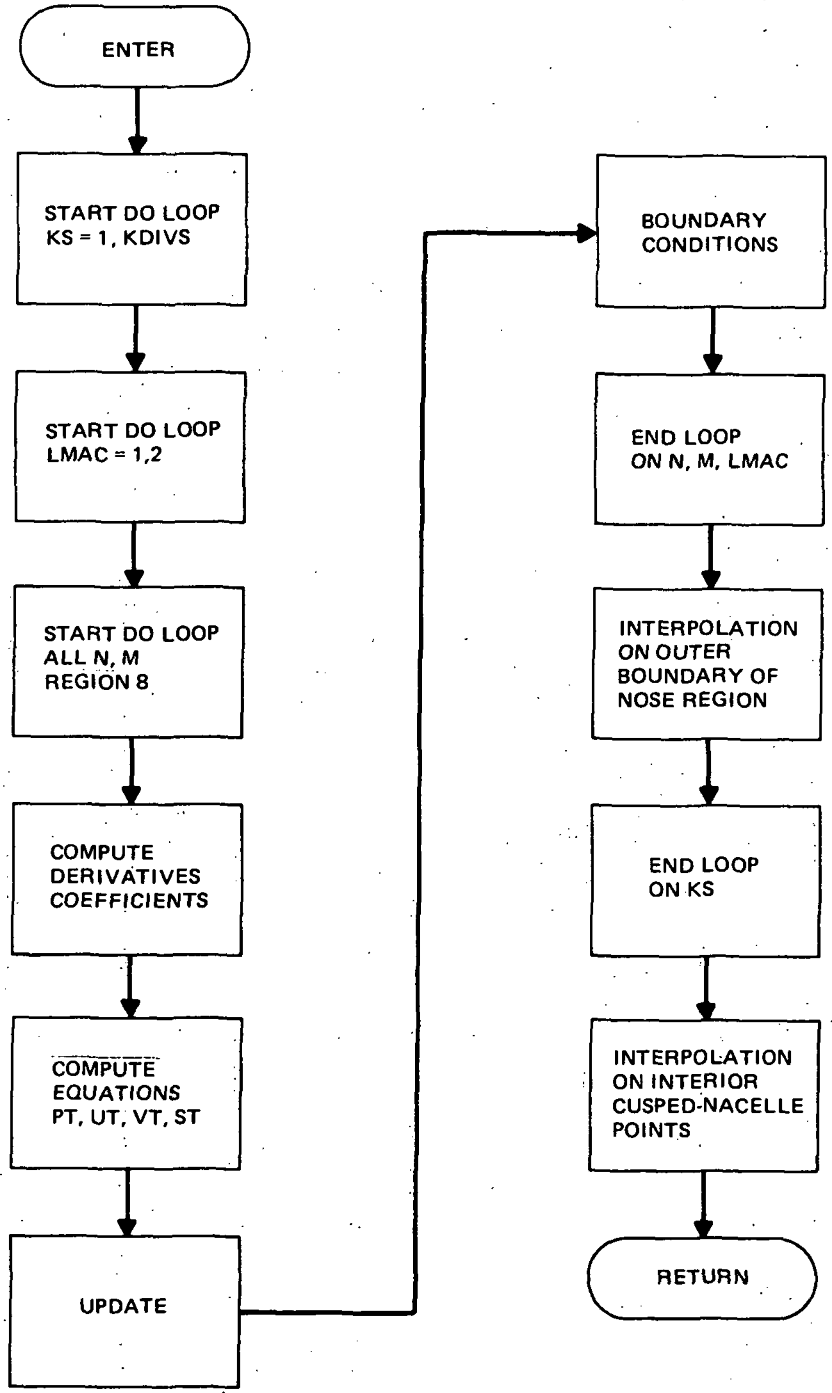


Fig. 3.14 Subroutine Nose

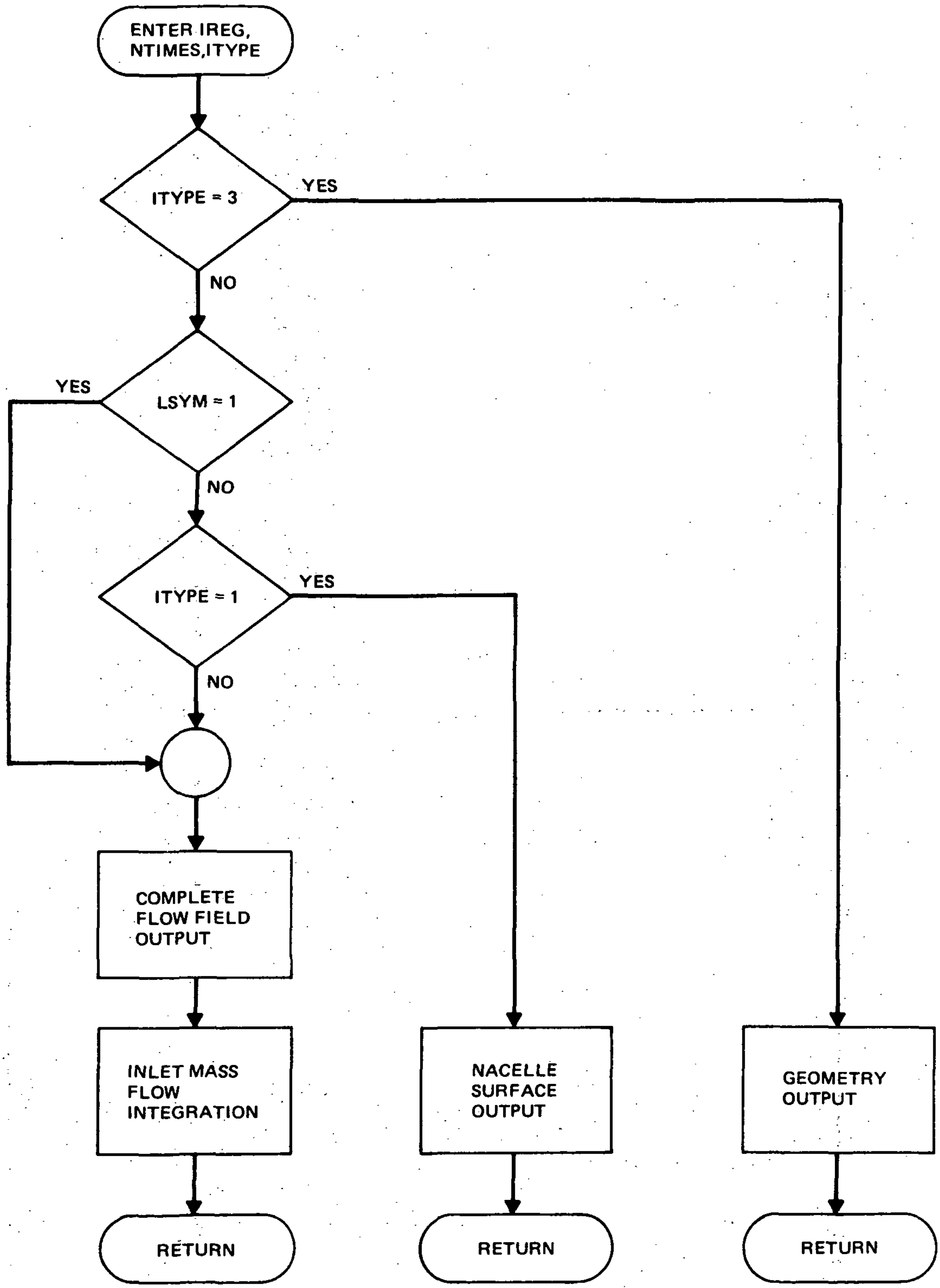


Fig. 3.15 Subroutine Outpun (IREG, NTIMES, ITYPE)

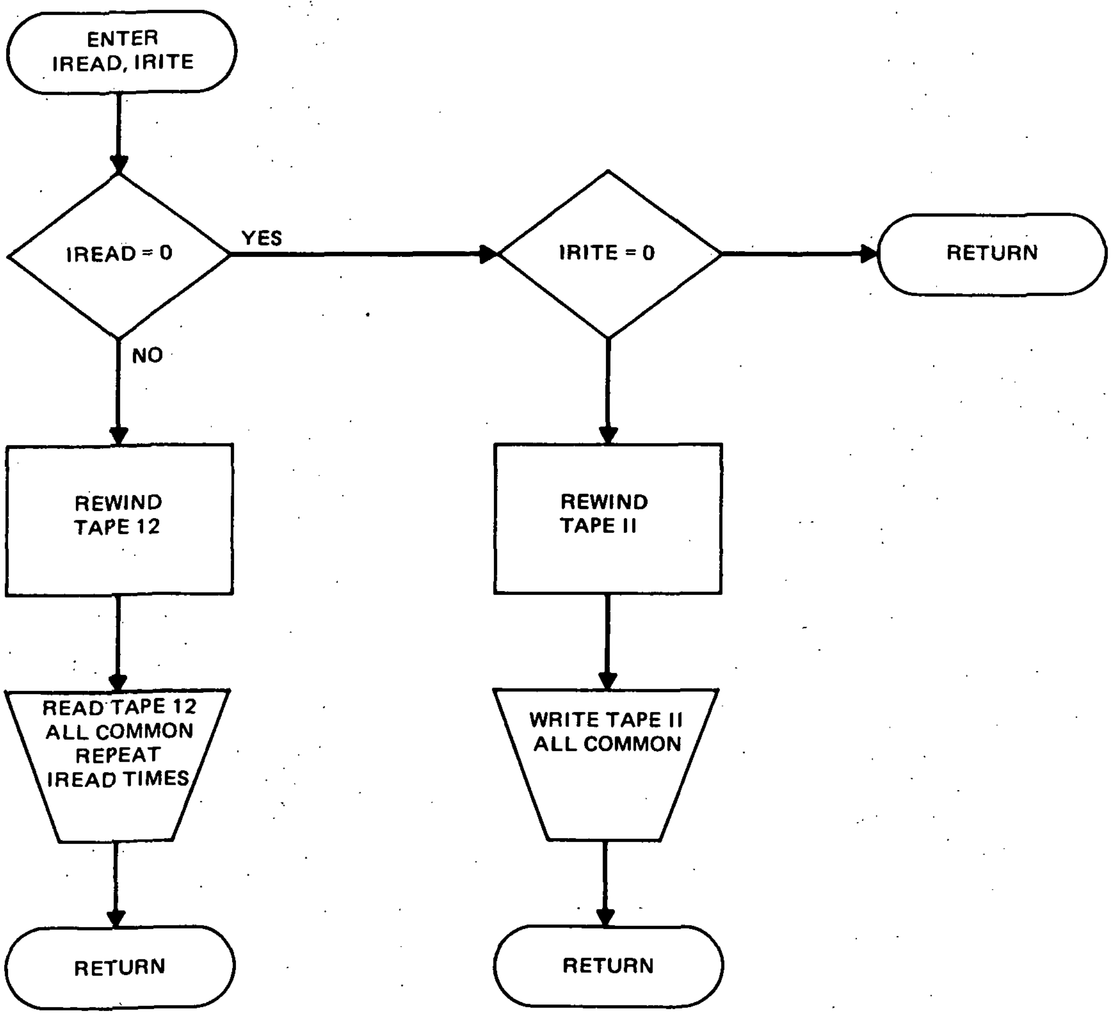


Fig. 3.16 Subroutine Taper (I Read, I Rite)

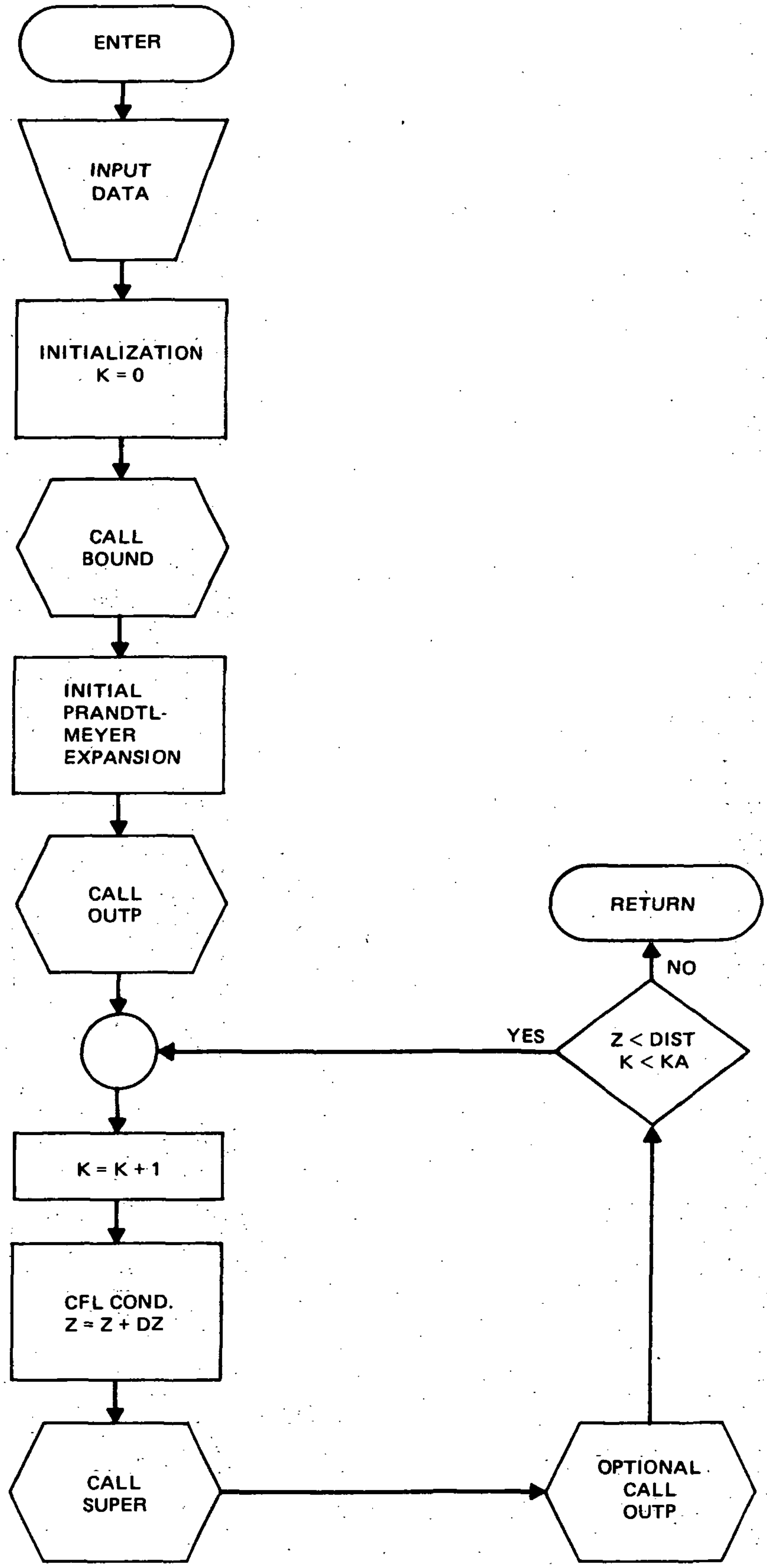


Fig. 3.17 Subroutine Plume

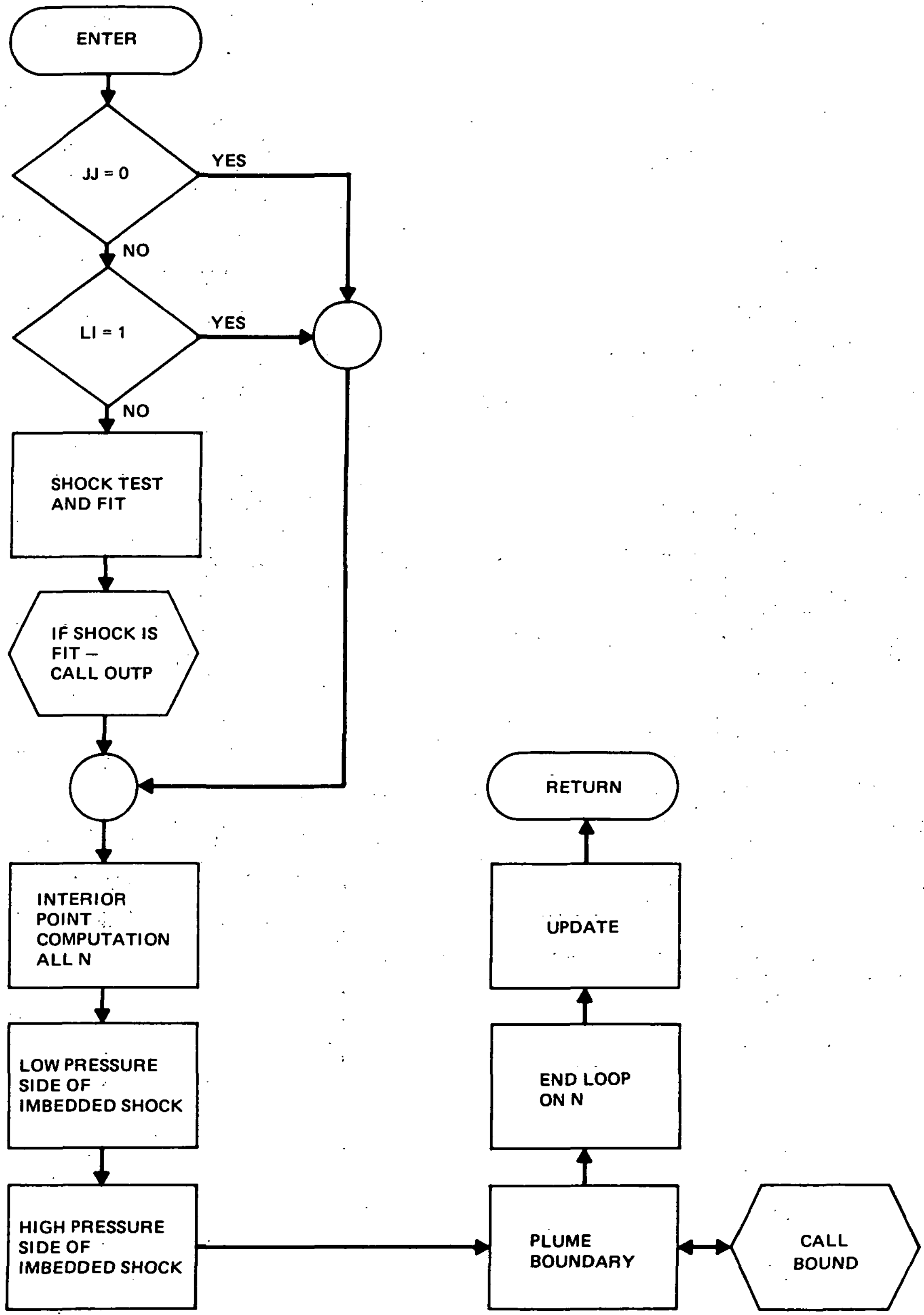


Fig. 3.18 Subroutine Super

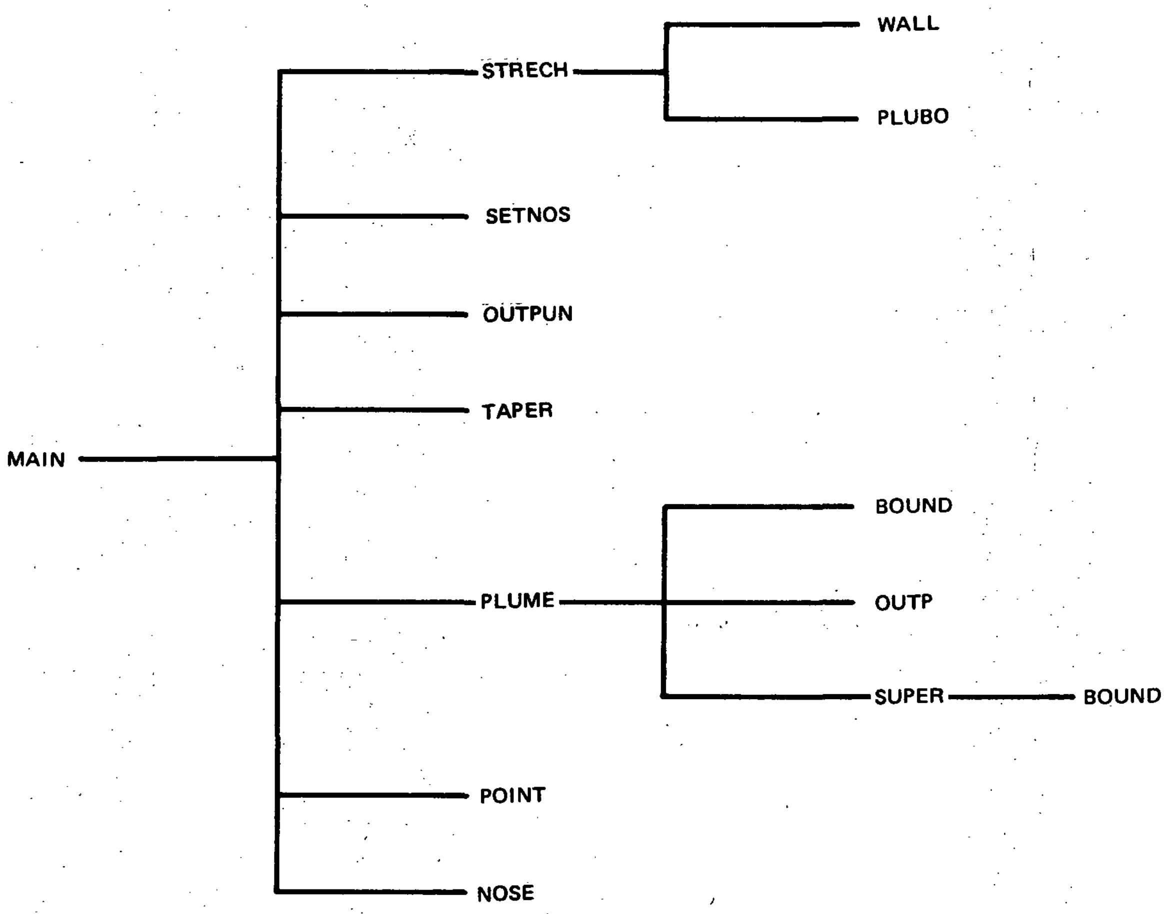


Fig. 3.19 Subroutine Tree Diagram

computation begins, this routine modifies the coordinates after each new plume computation.

WALL	Performs curve fit to nacelle geometry.
PLUBO	Performs curve fit to plume shape, either from input data or as the result of the plume computation.
SETNOS	Sets up all interpolations used in the nose region computation.
NOSE	Computes all points in the nose region. Performs all small time steps for one complete time step. Handles all interpolations at the boundaries.
OUTPUN	Handles all program output from the nacelle calculation (excluding the plume).
TAPER	All tape input/output for restart capability.
PLUME	Complete plume computation MAIN routine.
SUPER	Computes all points for the plume calculations. Handles shock points, axis points and plume boundary points. Predicts and fits the imbedded shock.
BOUND	Takes static pressure solution along plume boundary from nacelle calculation and converts to plume nondimensionalization. Interpolates pressures for plume boundary computation in SUPER.
OUTP	Handles all output from plume computation.

3.2.3 Input/Output Files

The entire program can be run using the standard input/output files (Tape 5 for input and Tape 6 for outputs). During the computer program run, no intermediate tapes or disks are used. However, the restart capability of the program does utilize tapes or permanent disk files.

All output to the tape or disk is on TAPE Unit 12 and all input on TAPE Unit 11. Schematically, a typical sequence of runs may be as follows

NRUN	MREAD	MRITE	INPUT	OUTPUT
1	0	1	TAPE 5	TAPE 12
2	1	1	TAPE 11	TAPE 12
3	1	1	TAPE 11	TAPE 12
4	1	0	TAPE 11	-

Note: MREAD and MRITE are parameters for subroutine TAPER and are described in Section 3.1.2. Also standard output on TAPE Unit 6 will be produced for all the above runs as discussed in Section 3.1.

3.2.4 Test Cases

Sample Input - Nacelle Calculation

```
 $RUN NRUN=112,NDATE=1,8,73,EM=.9,RMFLO=.8852,LA=1,LSYM=0 $END
 $INOUT KA=400,JA=100,JB=100,MB=-1,LOUT1=1,LOUT2=1,MREAD=0,MRITE=0  $
 $MESH  $
  INLET NO. 8    NACA 1-85-100   (C.R.=1.093)
18.        7.682      0.200           4          4          4
.200       7.825      0.37037
.072       7.770      .6111
0.0        7.682      1.0
.200       7.455      -.4270
.200       7.825      .37037          3
.720       7.966      0.2222          3
2.7        8.280      0.1222          3
18.        9.         0.              3
.200       7.455      -.4270          3
0.761      7.348      0.0174          1
4.5        7.413      0.0174          3
8.10       7.527      0.0             3
        NO PLUME
      1
```

Sample Input - Boattail/Plume Calculation

```
 $RUN NRUN=108,NDATE=1,22,73,EM=.7,LA=1,LSYM=1,KPLUME=50$
 $INOUT KA=500,JA=-1,JB=50,MB=4   $
 $MESH  NC(1)=20,NC(6)=20,NC(7)=20,MC(1)=15   $
  BOATTAIL,   STRAIGHT PIPE
1.         .5         0.              0          1          0
1.         .5         0.              1
 PLUME DATA
   2
2.         1.15
4.         1.24
 $JET KOUT=10,PRATIO=3.,TTOT=1,KMAP=10,KA=190,NA(1)=15,NA(2)=10,DIST=4.   $END
```

Sample Output - Nacelle Calculation

```
PROGRAM 15C

TRANSONIC NACELLE COMPUTATION

RUN  112              1/ 8/73

MACH= .900         MFLO= .8852

INPUT DATA
NC        18  18  25  16   1  18  32  19
MC        18  18  18  18  18  18  18   9
CD          .005   .005   .005   4.000   .005   4.000
PREAD= 0   MRITE= 0   KA=  400   JA=100   IB=100
KPLUME=  =1

AXISYMMETRIC FLOW

INLET NO. 8   NACA 1-85-100  (C.R.=1.093)
 GEOMETRY INPUT
 L= 18.000      HBAR= 7.6820      RNBAR=  .2000
 COWL LIP
   XBAR       YBAR       YPR
   .2000     7.8250     .3704
   .0720     7.7700     .6111
  0.0000     7.6820    1.0000
  -.2000     7.4550    -.4270
 EXTERNAL COWL
   XBAR       YBAR       YPR          LFUN
   .2000     7.8250     .3704          3
   .7200     7.9660     .2222          3
  2.7000     8.2800     .1222          3
-18.0000     9.0000    0.000           3
 INTERNAL COWL
   XBAR       YBAR       YPR          LFUN
   .2000     7.4550    -.4270          3
   .7610     7.3480     .0174          1
  4.5000     7.4130     .0174          3
  8.1000     7.5270    0.000           3

 STRECHING PARAMETERS
  X0=   .5341E-01   X1=   .5341E-01   X2=  -.4795E+00   X3=  -.4795E+00   Y0=   .5341E-01   Y2=  -.4795E+00
 AL1=   .3886E+01  AL2=   .3452E+01  AL3=   .4468E+01  AL4=   .4180E+01
 BE1=   .9598E+00  BE2=   .9386E+00  BE3=   .9773E+00  BE4=   .9699E+00
   NO PLUME
1
 NOSE REGION INTERPOLATION
  B=C
     N   NN1   NN2    M1    M2  ISIT      EP1          EP2
     2   100   101     4     4    2    .7878E+00    .6896E+00
     3   100   101     4     4    2    .2344E+00    .7461E+00
     4    99   100     4     4    2    .5643E+00    .6048E+00
     5    99    99     4     3    1    .2132E+00    .7083E+00
     6    98    98     4     3    1    .3331E+00    .4460E+00
     7    97    97     4     3    1    .6456E+00    .3713E+00
     8    97    97     3     2    1    .2244E+00    .5779E+00
     9    97    97     3     2    1    .9046E+00    .8459E+00
    10    97    97     1     2    1    0.           .1000E+01
    11    37    37    16    17    1    .8888E+00    .8440E+00
    12    37    37    16    17    1    .7646E-01    .5664E+00
    13    37    37    15    16    1    .4384E+00    .3525E+00
    14    38    38    15    16    1    .8346E-01    .4300E+00
    15    39    39    15    14    1    .2901E-01    .7719E+00
```

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	39	39	14	15	1	.3229E+00	.2089E+00
17	40	40	14	15	1	.5539E+00	.2957E+00
18	40	41	14	14	2	.4690E+00	.1402E+00

INTERIOR

N	M	I1	I2	L1	L3	EP3	EP4
2	1	7	8	137	138	.9539E+00	.7204E+00
2	2	7	8	136	137	.9608E+00	.5106E+00
2	3	8	9	135	136	.3166E+00	.4614E+00
3	1	5	6	137	138	.7081E+00	.9397E+00
3	2	5	6	136	137	.4597E+00	.5589E+00
3	3	6	7	134	135	.5457E+00	.3904E-01
4	1	2	3	136	137	.7645E+00	.5346E+00
4	2	3	4	135	136	.2762E-01	.6846E+00
4	3	5	6	132	133	.9383E+00	.4078E+00
5	1	1	2	132	133	.4204E-01	.1021E+01
5	2	2	3	130	131	.8405E+00	.5535E+00
5	3	5	6	130	131	.4910E-01	.7905E+00
2	18	7	8	138	139	.9736E-01	.7752E+00
2	17	7	8	139	140	.9589E-01	.5821E+00
2	16	8	9	140	141	.4916E+00	.7233E+00
3	18	4	5	138	139	.6006E+00	.4673E-01
3	17	5	6	139	140	.8398E+00	.6537E+00
3	16	6	7	141	142	.4268E+00	.4042E+00
4	18	2	3	140	141	.3625E+00	.5830E+00
4	17	3	4	141	142	.8668E+00	.6398E+00
4	16	5	6	143	144	.3605E+00	.6854E+00
4	15	8	9	144	145	.5518E+00	.1463E+00
5	18	1	2	145	146	.5086E+00	.9629E+00
5	17	2	3	145	146	.9479E+00	.2100E+00
5	16	5	6	146	147	.2771E+00	.5984E+00

X=R0

M	MR	NNC	N	M3	M4	EP5	EP6
2	2	6	1	2	1	.5232E+00	.1657E+00
3	3	6	1	3	2	.2303E-01	.2051E+00
4	4	6	1	3	2	.3288E+00	.2409E+00
5	5	6	1	3	2	.6470E+00	.2736E+00
6	6	6	1	3	2	.9725E+00	.3037E+00
7	7	6	1	4	3	.1954E+00	.3313E+00
8	8	6	1	4	3	.4106E+00	.3568E+00
9	9	6	1	4	3	.6272E+00	.3805E+00
2	21	6	19	18	17	.4164E+00	.1940E+00
3	22	6	19	18	17	.4559E-01	.2220E+00
4	23	6	19	17	16	.7588E+00	.2481E+00
5	24	6	19	17	16	.4691E+00	.2725E+00
6	25	6	19	17	16	.1666E+00	.2954E+00
7	26	6	19	16	15	.9039E+00	.3169E+00
8	27	6	19	16	15	.6930E+00	.3371E+00
9	28	6	19	16	15	.4787E+00	.3562E+00

GEOMETRY TEST

COWL LIP

X	Y	THE	R	DPR
.0111	.4347	1.5708	.0079	-.0029
.0098	.4342	1.7453	.0076	-.0015
.0086	.4337	1.9199	.0074	-.0001
.0074	.4333	2.0944	.0075	.0011
.0061	.4328	2.2689	.0078	.0023
.0048	.4321	2.4435	.0083	.0033
.0033	.4313	2.6180	.0090	.0048
.0018	.4302	2.7925	.0099	.0054
.0005	.4286	2.9671	.0107	.0038
0.0000	.4268	3.1416	.0111	.0000

.0002	.4249	3.3161	.0111	-.0004
.0008	.4230	3.4907	.0110	-.0006
.0017	.4213	3.6652	.0109	-.0005
.0028	.4198	3.8397	.0108	-.0002
.0042	.4185	4.0143	.0108	.0004
.0056	.4173	4.1888	.0110	.0013
.0073	.4162	4.3633	.0113	.0024
.0091	.4151	4.5379	.0118	.0038
.0111	.4142	4.7124	.0126	.0054

OUTER COWL

X	Y	YPR
.0428	.4378	.2889
.0596	.4420	.2232
.0808	.4464	.1938
.1073	.4511	.1615
.1398	.4559	.1347
.1790	.4608	.1206
.2256	.4662	.1096
.2794	.4717	.0975
.3399	.4773	.0848
.4059	.4824	.0718
.4756	.4870	.0592
.5466	.4908	.0476
.6163	.4937	.0373
.6823	.4959	.0286
.7429	.4974	.0216
.7967	.4984	.0160
.8432	.4991	.0117
.8825	.4995	.0085
.9150	.4997	.0061
.9414	.4998	.0044
.9626	.4999	.0031
.9795	.5000	.0021
.9927	.5000	.0014
1.0031	.5000	.0009
1.0112	.5000	.0005
1.0174	.5000	.0002
1.0222	.5000	0.0000

INNER COWL

X	Y	YPR
.0438	.4106	-.2590
.0606	.4082	-.0294
.0810	.4085	.0174
.1055	.4089	.0174
.1338	.4094	.0174
.1657	.4100	.0174
.2002	.4106	.0174
.2361	.4112	.0174
.2721	.4118	.0174
.3066	.4127	.0340
.3384	.4140	.0422
.3667	.4152	.0435
.3912	.4162	.0403
.4117	.4170	.0344
.4284	.4175	.0274
.4419	.4178	.0204
.4525	.4180	.0139
.4608	.4181	.0084
.4673	.4182	.0037
.4722	.4182	0.0000
.4722	.4182	0.0000
.4773	.4181	-.0073
.4863	.4180	-.0195
.5019	.4176	-.0387

MOORE BUSINESS FORMS, INC., HO FORM 1412 T PRINTED IN U.S.A. 12"

MOORE BUSINESS FORMS, INC., NO FORM 1412 T PRINTED IN U.S.A.

[illegible]	[illegible]	[illegible]
.5281	.4162	-.0650
.5694	.4129	-.0917
.6292	.4070	-.0983
.7056	.4009	-.0515
.7888	.4014	.0757
.8652	.4104	.1444
.9250	.4190	.1347
.9664	.4239	.0954
.9925	.4259	.0568
1.0081	.4266	.0287
1.0171	.4268	.0107
1.0222	.4268	.0000

PLUME BOUNDARY

X	Y	YPR
1.0222	.5000	0.0000
1.0272	.5000	0.0000
1.0364	.5000	0.0000
1.0507	.5000	0.0000
1.0711	.5000	0.0000
1.0990	.5000	0.0000
1.1363	.5000	0.0000
1.1856	.5000	0.0000
1.2501	.5000	0.0000
1.3349	.5000	0.0000
1.4471	.5000	0.0000
1.5979	.5000	0.0000
1.8056	.5000	0.0000
2.1033	.5000	0.0000
2.5575	.5000	0.0000
3.3324	.5000	0.0000
5.0222	.5000	0.0000
500.0000	.5000	0.0000

10	1	.422E-02	2	.422E-02	3	.406E-02	4	.228E-02	5	.100E+01	6	.422E-02	7	.407E-02
10	3	.759E-03												
20	1	.422E-02	2	.422E-02	3	.405E-02	4	.238E-02	5	.100E+01	6	.422E-02	7	.407E-02
20	3	.793E-03												
30	1	.421E-02	2	.421E-02	3	.405E-02	4	.244E-02	5	.100E+01	6	.421E-02	7	.406E-02
30	3	.813E-03												
40	1	.420E-02	2	.420E-02	3	.403E-02	4	.238E-02	5	.100E+01	6	.420E-02	7	.405E-02
40	3	.793E-03												
50	1	.419E-02	2	.419E-02	3	.402E-02	4	.237E-02	5	.100E+01	6	.419E-02	7	.404E-02
50	3	.791E-03												
60	1	.418E-02	2	.418E-02	3	.399E-02	4	.239E-02	5	.100E+01	6	.418E-02	7	.403E-02
60	3	.797E-03												
70	1	.416E-02	2	.416E-02	3	.397E-02	4	.235E-02	5	.100E+01	6	.416E-02	7	.401E-02
70	3	.784E-03												
80	1	.414E-02	2	.414E-02	3	.393E-02	4	.245E-02	5	.100E+01	6	.414E-02	7	.399E-02
80	3	.818E-03												
90	1	.412E-02	2	.412E-02	3	.388E-02	4	.233E-02	5	.100E+01	6	.412E-02	7	.397E-02
90	3	.778E-03												
100	1	.410E-02	2	.410E-02	3	.382E-02	4	.229E-02	5	.100E+01	6	.410E-02	7	.395E-02
100	3	.764E-03												

NACELLE SURFACE FLOW FIELD

STEP 100 TIME= .239

OUTER COWL

X	Y	P	M	TAU	CP	PT
0.0000	.4268	1.0049	.0012	0.0000	.0087	1.0049
.0005	.4286	1.0046	.0098	1.7606	.0081	1.0047
.0018	.4302	1.0044	.0173	.8761	.0078	1.0046
.0033	.4313	1.0046	.0216	.6161	.0082	1.0050
.0048	.4321	1.0048	.0234	.5360	.0085	1.0053

.0061	.4328	1.0048	.0249	.4418	.0085	1.0053
.0074	.4333	1.0050	.0255	.3961	.0088	1.0054
.0086	.4337	1.0050	.0261	.3862	.0088	1.0055
.0098	.4342	1.0051	.0268	.3876	.0090	1.0056
.0111	.4347	1.0051	.0279	.3718	.0090	1.0057
.0205	.4378	1.0054	.0354	.2889	.0095	1.0062
.0374	.4420	1.0064	.0376	.2232	.0113	1.0074
.0586	.4464	1.0063	.0356	.1938	.0111	1.0072
.0850	.4511	1.0060	.0354	.1615	.0106	1.0069
.1175	.4559	1.0056	.0343	.1347	.0098	1.0064
.1568	.4608	1.0051	.0330	.1206	.0090	1.0059
.2033	.4662	1.0046	.0325	.1096	.0080	1.0053
.2571	.4717	1.0040	.0324	.0975	.0071	1.0047
.3177	.4773	1.0035	.0324	.0848	.0061	1.0042
.3837	.4824	1.0029	.0323	.0718	.0052	1.0037
.4534	.4870	1.0024	.0321	.0592	.0043	1.0032
.5244	.4908	1.0020	.0320	.0476	.0035	1.0027
.5941	.4937	1.0016	.0319	.0373	.0027	1.0023
.6601	.4959	1.0012	.0318	.0286	.0021	1.0019
.7206	.4974	1.0009	.0317	.0216	.0016	1.0016
.7744	.4984	1.0007	.0316	.0160	.0012	1.0014
.8210	.4991	1.0005	.0316	.0117	.0009	1.0012
.8602	.4995	1.0004	.0315	.0085	.0007	1.0011
.8927	.4997	1.0003	.0315	.0061	.0005	1.0010
.9192	.4998	1.0002	.0315	.0044	.0004	1.0009
.9404	.4999	1.0002	.0315	.0031	.0003	1.0009
.9572	.5000	1.0001	.0314	.0021	.0002	1.0008
.9705	.5000	1.0001	.0314	.0014	.0002	1.0008
.9809	.5000	1.0001	.0314	.0009	.0002	1.0008
.9889	.5000	1.0001	.0314	.0005	.0001	1.0008
.9952	.5000	1.0001	.0314	.0002	.0001	1.0008
1.0000	.5000	1.0001	.0314	0.0000	.0001	1.0008

INNER COWL

X	Y	P	M	TAU	CP	PT
0.0000	.4268	1.0049	.0012	0.0000	.0087	1.0049
.0002	.4249	1.0049	.0070	-4.6130	.0086	1.0049
.0008	.4230	1.0047	.0145	-2.3381	.0083	1.0049
.0017	.4213	1.0044	.0210	-1.5548	.0078	1.0047
.0028	.4198	1.0041	.0264	-1.1521	.0072	1.0046
.0042	.4185	1.0037	.0308	-.9070	.0065	1.0044
.0056	.4173	1.0033	.0343	-.7432	.0058	1.0041
.0073	.4162	1.0028	.0371	-.6234	.0050	1.0038
.0091	.4151	1.0019	.0395	-.5236	.0033	1.0030
.0111	.4142	1.0031	.0441	-.4515	.0054	1.0044
.0216	.4106	1.0091	.0690	-.2590	.0161	1.0125
.0383	.4082	1.0053	.0551	-.0294	.0093	1.0074
.0588	.4085	1.0026	.0386	.0174	.0046	1.0036
.0833	.4089	1.0013	.0341	.0174	.0023	1.0021
.1116	.4094	1.0007	.0328	.0174	.0012	1.0014
.1434	.4100	1.0000	.0322	.0174	.0000	1.0007
.1779	.4106	.9996	.0318	.0174	-.0007	1.0003
.2139	.4112	.9992	.0316	.0174	-.0015	.9999
.2498	.4118	.9990	.0318	.0174	-.0017	.9998
.2843	.4127	.9986	.0316	.0340	-.0024	.9993
.3162	.4140	.9986	.0312	.0422	-.0025	.9993
.3445	.4152	.9987	.0309	.0435	-.0023	.9994
.3690	.4162	.9990	.0305	.0403	-.0018	.9996
.3894	.4170	.9993	.0302	.0344	-.0013	.9999
.4062	.4175	.9995	.0300	.0274	-.0009	1.0001
.4197	.4178	.9997	.0298	.0204	-.0005	1.0003
.4303	.4180	.9998	.0296	.0139	-.0003	1.0005
.4386	.4181	.9999	.0296	.0084	-.0001	1.0005
.4451	.4182	1.0000	.0295	.0037	-.0000	1.0006
.4500	.4182	1.0000	.0294	0.0000	.0000	1.0006

MOORE BUSINESS FORMS, INC., HO FORM 1412 T PRINTED IN U.S.A.

PLUME BOUNDARY

X	Y	P	M	TAU	CP	PT
1.0000	.5000	1.0001	.0314	0.0000	.0001	1.0008
1.0050	.5000	1.0001	.0314	0.0000	.0001	1.0008
1.0142	.5000	1.0001	.0314	0.0000	.0001	1.0007
1.0284	.5000	1.0000	.0313	0.0000	.0001	1.0007
1.0488	.5000	1.0000	.0313	0.0000	.0001	1.0007
1.0768	.5000	1.0000	.0313	0.0000	.0000	1.0007
1.1141	.5000	1.0000	.0313	0.0000	.0000	1.0007
1.1633	.5000	1.0000	.0313	0.0000	.0000	1.0007
1.2279	.5000	1.0000	.0313	0.0000	.0000	1.0007
1.3127	.5000	1.0000	.0313	0.0000	.0000	1.0007
1.4249	.5000	1.0000	.0313	0.0000	.0000	1.0007
1.5757	.5000	1.0000	.0313	0.0000	.0000	1.0007
1.7834	.5000	1.0000	.0313	0.0000	.0000	1.0007
2.0811	.5000	1.0000	.0313	0.0000	-.0000	1.0007
2.5353	.5000	1.0000	.0313	0.0000	.0000	1.0007
3.3102	.5000	1.0000	.0313	0.0000	-.0000	1.0007
5.0000	.5000	1.0000	.0313	0.0000	.0000	1.0007
499.9778	.5000	1.0000	.0313	0.0000	0.0000	1.0007

NACELLE COMPLETE FLOW FIELD

STEP 100 TIME= .2388E+00 DT= .2292E-02

REGION NO. 1

M= 1

I	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	-500.02222	.42678	1.00000	1.18322	.03704	0.00000	.03130	0.00000	1.00000	0.00000	0.00000
2	-4.02222	.42678	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
3	-2.33240	.42678	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
4	-1.55749	.42678	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
5	-1.10329	.42678	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
6	-.80564	.42678	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
7	-.59788	.42678	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
8	-.44709	.42678	1.00000	1.18322	.03703	.00000	.03130	.00000	1.00000	.00000	0.00000
9	-.33490	.42678	1.00001	1.18322	.03702	.00000	.03129	.00001	1.00001	.00002	0.00000
10	-.25012	.42678	1.00008	1.18323	.03696	.00000	.03124	.00005	1.00006	.00014	0.00000
11	-.18556	.42678	1.00033	1.18327	.03673	.00001	.03104	.00018	1.00023	.00058	0.00000
12	-.13633	.42678	1.00085	1.18336	.03620	.00001	.03059	.00035	1.00060	.00149	0.00000
13	-.09899	.42678	1.00148	1.18347	.03546	.00000	.02996	.00010	1.00105	.00261	0.00000
14	-.07105	.42678	1.00207	1.18356	.03461	-.00005	.02924	-.00131	1.00148	.00364	0.00000
15	-.05067	.42678	1.00269	1.18367	.03352	-.00013	.02832	-.00392	1.00192	.00475	0.00000
16	-.03642	.42678	1.00325	1.18377	.03213	-.00022	.02714	-.00675	1.00232	.00574	0.00000
17	-.02722	.42678	1.00367	1.18383	.03067	-.00032	.02591	-.01040	1.00262	.00647	0.00000
18	-.02222	.42678	1.00416	1.18392	.02932	-.00022	.02477	-.00759	1.00297	.00734	0.00000

M= 2

I	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	-500.02222	.43178	1.00000	1.18322	.03704	0.00000	.03130	0.00000	1.00000	0.00000	0.00000
2	-4.02222	.43178	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
3	-2.33240	.43178	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
4	-1.55749	.43178	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
5	-1.10329	.43178	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
6	-.80564	.43178	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
7	-.59788	.43178	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
8	-.44709	.43178	1.00000	1.18322	.03703	.00000	.03130	.00000	1.00000	.00000	0.00000
9	-.33490	.43178	1.00001	1.18322	.03702	.00000	.03129	.00001	1.00001	.00002	0.00000

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
10	-.25012	.43178	1.00008	1.18323	.03696	.00000	.03124	.00009	1.00006	.00014	0.00000
11	-.18556	.43178	1.00033	1.18327	.03672	.00001	.03104	.00037	1.00023	.00058	0.00000
12	-.13633	.43178	1.00084	1.18336	.03620	.00004	.03059	.00098	1.00060	.00149	0.00000
13	-.09899	.43178	1.00148	1.18347	.03544	.00009	.02994	.00173	1.00106	.00261	0.00000
14	-.07105	.43178	1.00209	1.18357	.03453	.00009	.02918	.00247	1.00149	.00368	0.00000
15	-.05067	.43178	1.00273	1.18368	.03335	.00014	.02817	.00410	1.00195	.00482	0.00000
16	-.03642	.43178	1.00333	1.18378	.03197	.00026	.02700	.00828	1.00238	.00587	0.00000
17	-.02722	.43178	1.00378	1.18385	.03058	.00050	.02584	.01626	1.00270	.00664	0.00000
18	-.02222	.43178	1.00424	1.18393	.02971	.00123	.02511	.04156	1.00303	.00749	0.00000

M= 3

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	-500.02222	.44097	1.00000	1.18322	.03704	0.00000	.03130	0.00000	1.00000	0.00000	0.00000
2	-4.02222	.44097	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
3	-2.33240	.44097	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
4	-1.55749	.44097	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
5	-1.10329	.44097	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
6	-.80564	.44097	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
7	-.59788	.44097	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
8	-.44709	.44097	1.00000	1.18322	.03703	.00000	.03130	.00000	1.00000	.00000	0.00000
9	-.33490	.44097	1.00001	1.18322	.03702	.00000	.03129	.00003	1.00001	.00002	0.00000
10	-.25012	.44097	1.00008	1.18323	.03696	.00001	.03124	.00019	1.00006	.00014	0.00000
11	-.18556	.44097	1.00033	1.18327	.03673	.00003	.03104	.00088	1.00023	.00058	0.00000
12	-.13633	.44097	1.00085	1.18336	.03620	.00010	.03059	.00264	1.00060	.00149	0.00000
13	-.09899	.44097	1.00149	1.18347	.03545	.00020	.02996	.00569	1.00106	.00262	0.00000
14	-.07105	.44097	1.00209	1.18357	.03457	.00037	.02921	.01067	1.00149	.00368	0.00000
15	-.05067	.44097	1.00274	1.18368	.03346	.00067	.02827	.02015	1.00196	.00484	0.00000
16	-.03642	.44097	1.00335	1.18378	.03229	.00117	.02729	.03638	1.00239	.00591	0.00000
17	-.02722	.44097	1.00379	1.18385	.03125	.00179	.02644	.05725	1.00270	.00668	0.00000
18	-.02222	.44097	1.00416	1.18392	.03077	.00264	.02609	.08585	1.00297	.00733	0.00000

M= 4

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	-500.02222	.45522	1.00000	1.18322	.03704	0.00000	.03130	0.00000	1.00000	0.00000	0.00000
2	-4.02222	.45522	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
3	-2.33240	.45522	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
4	-1.55749	.45522	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
5	-1.10329	.45522	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
6	-.80564	.45522	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
7	-.59788	.45522	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
8	-.44709	.45522	1.00000	1.18322	.03703	.00000	.03130	.00000	1.00000	.00000	0.00000
9	-.33490	.45522	1.00001	1.18322	.03702	.00000	.03129	.00004	1.00001	.00002	0.00000
10	-.25012	.45522	1.00008	1.18323	.03697	.00001	.03124	.00031	1.00005	.00014	0.00000
11	-.18556	.45522	1.00031	1.18327	.03674	.00005	.03105	.00140	1.00022	.00055	0.00000
12	-.13633	.45522	1.00081	1.18335	.03625	.00016	.03063	.00445	1.00058	.00143	0.00000
13	-.09899	.45522	1.00144	1.18346	.03555	.00038	.03004	.01055	1.00103	.00258	0.00000
14	-.07105	.45522	1.00204	1.18356	.03480	.00073	.02941	.02086	1.00145	.00359	0.00000
15	-.05067	.45522	1.00264	1.18366	.03398	.00126	.02873	.03709	1.00188	.00465	0.00000
16	-.03642	.45522	1.00316	1.18375	.03328	.00197	.02817	.05920	1.00225	.00557	0.00000
17	-.02722	.45522	1.00351	1.18381	.03283	.00262	.02782	.07968	1.00251	.00620	0.00000
18	-.02222	.45522	1.00375	1.18385	.03266	.00323	.02772	.09897	1.00267	.00661	0.00000

M= 5

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	-500.02222	.47561	1.00000	1.18322	.03704	0.00000	.03130	0.00000	1.00000	0.00000	0.00000
2	-4.02222	.47561	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
3	-2.33240	.47561	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
4	-1.55749	.47561	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
5	-1.10329	.47561	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
6	-.80564	.47561	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
7	-.59788	.47561	1.00000	1.18322	.03704	.00000	.03130	.00000	1.00000	.00000	0.00000
8	-.44709	.47561	1.00000	1.18322	.03703	.00000	.03130	.00001	1.00000	.00000	0.00000
9	-.33490	.47561	1.00001	1.18322	.03703	.00000	[illegible]	[illegible]	[illegible]	[illegible]	0.00000

Sample Output

```
                     PROGRAM 15C
            TRANSONIC NACELLE COMPUTATION
            RUN  108                1/22/73
            MACH= .700         MFLO=1.0000

INPUT DATA
NC        20  20   1   1   1  20  20   1
KC        15   1   1   1   1  15  15   1
CD        0.000   .050    .050  10.000    .050  10.000
MREAD= 0   MRITE= 0   KA=  500   JA= -1   IB= 50
KPLUME=  50

AXISYMMETRIC FLOW

BOATTAIL OPTION

BOATTAIL,   STRAIGHT PIPE
GEOMETRY INPUT
L=  1.000     HBAR=  .5000     RNBAR= 0.0000
EXTERNAL COWL
 XBAR      YBAR      YPR          LFUN
1.0000     .5000    0.0000         1

STRECHING PARAMETERS
 X0=   .8785E+00    X1=   .8785E+00    X2=  -.8551E+00    X3=  -.8551E+00    Y0=   .5847E+00    Y2=  -.1214E+01
 AL1=  0.           AL2=  0.           AL3=  0.           AL4=   .8620E+00
 BE1=  0.           BE2=  0.           BE3=  0.           BE4=   .4062E+00
PLUME DATA
 2
 2.0000    1.1500
 4.0000    1.2400
 2   0   0     .2000E+01     .5750E+00     -.1500E-01     .6000E-01
 3   0   0     .3000E+01     .6200E+00     -.1500E-01     .3000E-01
  10   1  .401E-01 2  .100E+01 3  .100E+01 4  .100E+01 5  .100E+01 6  .401E-01 7  .381E-01
  20   1  .352E-01 2  .100E+01 3  .100E+01 4  .100E+01 5  .100E+01 6  .351E-01 7  .335E-01
  30   1  .309E-01 2  .100E+01 3  .100E+01 4  .100E+01 5  .100E+01 6  .308E-01 7  .294E-01
  40   1  .279E-01 2  .100E+01 3  .100E+01 4  .100E+01 5  .100E+01 6  .277E-01 7  .265E-01
  50   1  .261E-01 2  .100E+01 3  .100E+01 4  .100E+01 5  .100E+01 6  .259E-01 7  .247E-01

PLUME INPUT DATA

PRATIO= 3.000     MACH= 3.000     TTOT=   1.000

NA(1)=15     NA(2)=10     MA=10     KA= 193     KOUT=  10     KMAP=  10
DIST= 4.000     GAMMA= 1.400     STAR= 1.000

PLUME STRUCTURE
XSTEP    0       X=   1.050     DX=   .5000E-01

      Y          P          V          U         TAU         M          S          T
 REGION   1
2  0.00000    1.00000    0.00000    3.54965    0.00000    3.00000    0.00000    1.00000
3   .03405    1.00000    0.00000    3.54965    0.00000    3.00000    0.00000    1.00000
4   .06810    1.00000    0.00000    3.54965    0.00000    3.00000    0.00000    1.00000
5   .10216    1.00000    0.00000    3.54965    0.00000    3.00000    0.00000    1.00000
```

	Y	P	V	U	TAU	M	S	T
6	.13621	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
7	.17026	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
8	.20431	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
9	.23837	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
10	.27242	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
11	.30647	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
12	.34052	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
13	.37457	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
14	.40863	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
15	.44268	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
16	.47673	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
17	.51078	.35259	.52373	2.42867	.21565	2.43498	0.00000	.74242

PLUME STRUCTURE
XSTEP 5 X= 1.304 DX= .7693E-01

	Y	P	V	U	TAU	M	S	T
REGION 1								
2	0.00000	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
3	.03829	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
4	.07659	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
5	.11488	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
6	.15317	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
7	.19146	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
8	.22976	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
9	.26805	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
10	.30634	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
11	.34464	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
12	.38293	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
13	.42122	.59440	.39366	3.65395	.10773	3.34563	0.00000	.86189
14	.45951	.41112	.69728	3.67571	.17882	3.58310	0.00000	.77572
15	.49781	.28703	.86746	3.62497	.23930	3.76505	0.00000	.70004
16	.53610	.25997	.85807	3.34150	.25679	3.53448	0.00000	.68051
17	.57439	.34442	.88319	3.71385	.21627	3.73952	0.00000	.73746

PLUME STRUCTURE
XSTEP 5 X= 1.304 DX= .7693E-01

	Y	P	V	U	TAU	M	S	T
REGION 1								
2	0.00000	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
3	.03829	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
4	.07659	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
5	.11488	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
6	.15317	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
7	.19146	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
8	.22976	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
9	.26805	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
10	.30634	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
11	.34464	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
12	.38293	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
13	.42122	.59440	.39366	3.65395	.10773	3.34563	0.00000	.86189
14	.45951	.41112	.69728	3.67571	.17882	3.58310	0.00000	.77572
15	.49781	.28703	.86746	3.62497	.23930	3.76505	0.00000	.70004
16	.53610	.25997	.85807	3.34150	.25679	3.53448	0.00000	.68051
REGION 2								
1	.53610	.25997	.85807	3.34150	.25679	3.53448	0.00000	.68051
2	.53993	.26739	.85258	3.37874	.25234	3.55575	0.00000	.68601
3	.54376	.27512	.84709	3.41597	.24798	3.57684	0.00000	.69154
4	.54759	.28286	.84160	3.45320	.24372	3.59777	0.00000	.69712
5	.55142	.29093	.83611	3.49044	.23954	3.61853	0.00000	.70275
6	.55525	.29923	.83063	3.52767	.23546	3.63013	0.00000	.70842

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7	.55908	.30777	.82514	3.56491	.23146	3.65955	0.00000	.71413
8	.56290	.31655	.81965	3.60214	.22755	3.67980	0.00000	.71990
9	.56673	.32558	.81416	3.63938	.22371	3.69088	0.00000	.72570
10	.57056	.33487	.80867	3.67661	.21995	3.71978	0.00000	.73156
11	.57439	.34442	.80319	3.71385	.21627	3.73952	0.00000	.73746

PLUME STRUCTURE

XSTEP 10 X= 1.435 DX= .1171E-01

	Y	P	V	U	TAU	M	S	T
REGION 1								
2	0.00000	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
3	.03808	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
4	.07616	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
5	.11425	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
6	.15233	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
7	.19041	1.00000	.00000	3.54965	.00000	3.00000	0.00000	1.00000
8	.22849	.99999	.00001	3.54965	.00000	3.00001	0.00000	1.00000
9	.26657	.99955	.00036	3.54977	.00010	3.00030	0.00000	.99987
10	.30465	.99152	.00652	3.55204	.00184	3.00568	0.00000	.99757
11	.34274	.92327	.06449	3.57138	.01803	3.05349	0.00000	.97745
12	.38082	.67946	.29133	3.63959	.08004	3.26100	0.00000	.89546
13	.41890	.47752	.54919	3.68979	.14884	3.50392	0.00000	.80962
14	.45698	.35687	.73677	3.71121	.19853	3.70487	0.00000	.74498
15	.49506	.26951	.91523	3.69192	.24790	3.87691	0.00000	.68755
16	.53314	.24224	.97255	3.73975	.26006	3.99902	0.00000	.66692
REGION 2								
1	.53314	.24997	.95079	3.73971	.25424	3.88724	.06285	.70383
2	.53993	.26085	.99456	4.01452	.24774	4.15220	.05667	.70868
3	.54672	.27313	.97391	4.04325	.24087	4.18409	.03115	.70571
4	.55351	.29597	.89742	3.62561	.23097	3.73777	.00864	.71057
5	.56030	.31558	.75158	3.35600	.22395	3.42574	.00120	.71988
6	.56709	.33297	.72536	3.34924	.21657	3.38885	.00007	.73041
7	.57388	.33081	.68122	3.43868	.19810	3.46091	.00000	.72902
8	.58067	.32443	.67517	3.53054	.18274	3.56245	0.00000	.72497
9	.58746	.32940	.66108	3.60359	.18345	3.62875	0.00000	.72812
10	.59425	.33377	.67981	3.67482	.18499	3.69563	0.00000	.73043
11	.60104	.34346	.68342	3.73829	.18282	3.74154	0.00000	.73688

PLUME STRUCTURE

XSTEP 20 X= 1.576 DX= .1624E-01

	Y	P	V	U	TAU	M	S	T
REGION 1								
2	0.00000	1.00000	0.00000	3.54965	0.00000	3.00000	0.00000	1.00000
3	.03810	1.00000	.00000	3.54965	.00000	3.00000	0.00000	1.00000
4	.07620	1.00000	.00000	3.54965	.00000	3.00000	0.00000	1.00000
5	.11430	.99999	.00001	3.54965	.00000	3.00001	0.00000	1.00000
6	.15240	.99986	.00010	3.54969	.00003	3.00009	0.00000	.99996
7	.19051	.99883	.00091	3.54998	.00026	3.00078	0.00000	.99966
8	.22861	.99212	.00602	3.55187	.00169	3.00528	0.00000	.99774
9	.26671	.96224	.02994	3.56030	.00841	3.02570	0.00000	.98906
10	.30481	.87172	.11368	3.58618	.02891	3.09255	0.00000	.96132
11	.34291	.70852	.26316	3.63212	.07245	3.23304	0.00000	.90624
12	.38101	.52254	.47692	3.69228	.12952	3.44298	0.00000	.83073
13	.41911	.39852	.65863	3.71036	.17751	3.63218	0.00000	.76885
14	.45721	.31543	.81483	3.73578	.21544	3.80850	0.00000	.71917
15	.49532	.24730	.94034	3.70171	.25403	3.94794	0.00000	.67087
16	.53342	.22612	.99233	3.74671	.26485	4.05583	0.00000	.65392
REGION 2								
1	.53342	.23258	.97304	3.74682	.25970	3.94043	.05627	.68624
2	.54272	.25171	.99151	3.69954	.24368	3.84307	.05491	.70123

	Y	P	V	U	TAU	M	S	T
3	.55242	.27373	.83750	3.69544	.22663	3.77519	.06124	.72149
4	.56132	.30692	.81655	3.99416	.20444	3.98409	.06579	.74790
5	.57262	.32717	.77337	4.01121	.19280	3.98865	.04274	.74924
6	.57992	.33147	.69062	3.63386	.19005	3.64644	.01525	.73742
7	.58922	.33374	.64233	3.40999	.18837	3.42774	.00302	.73199
8	.59852	.33842	.64696	3.42767	.18291	3.43758	.00031	.73393
9	.60782	.34028	.63646	3.53013	.18029	3.53432	.00002	.73492
10	.61713	.34017	.67746	3.63796	.18622	3.64835	.00000	.73485
11	.62643	.34279	.70421	3.73482	.18855	3.74297	0.00000	.73646

PLUME STRUCTURE
XSTEP 3 X= 1.771 DX= .2223E-01

	Y	P	V	U	TAU	M	S	T
REGION 1								
2	0.00000	.99993	0.00000	3.54967	0.00000	3.00005	0.00000	.99998
3	.03826	.99987	.00008	3.54969	.00002	3.00009	0.00000	.99996
4	.07652	.99932	.00048	3.54984	.00013	3.00046	0.00000	.99980
5	.11478	.99672	.00239	3.55057	.00067	3.00219	0.00000	.99906
6	.15304	.98670	.00981	3.55340	.00276	3.00893	0.00000	.99618
7	.19129	.95685	.03272	3.56183	.00919	3.02965	0.00000	.98748
8	.22955	.88927	.08605	3.58100	.02403	3.07855	0.00000	.96703
9	.26781	.77967	.18343	3.61214	.05078	3.16739	0.00000	.93136
10	.30607	.64262	.31848	3.65122	.08723	3.29955	0.00000	.88131
11	.34433	.51097	.47780	3.68781	.12956	3.45921	0.00000	.82544
12	.38259	.40395	.63367	3.71556	.17055	3.62597	0.00000	.77183
13	.42085	.32974	.75739	3.72513	.20332	3.76562	0.00000	.72790
14	.45911	.27266	.87511	3.76151	.23265	3.92980	0.00000	.68984
15	.49736	.22181	.98019	3.72379	.26322	4.03552	0.00000	.65033
16	.53562	.20472	1.01886	3.75668	.27121	4.12626	0.00000	.63561
REGION 2								
1	.53562	.21524	.98495	3.75716	.26215	3.94451	.10014	.69258
2	.54811	.26630	.87016	3.80764	.22065	3.90357	.05508	.71270
3	.56060	.31766	.69724	3.74396	.18623	3.73763	.04012	.74156
4	.57309	.31432	.67256	3.59908	.18687	3.58489	.05100	.74509
5	.58558	.31139	.72297	3.86149	.18723	3.82741	.06868	.75255
6	.59807	.31569	.74009	4.03478	.18343	4.00509	.05715	.74931
7	.61056	.31711	.67854	3.73469	.18169	3.74497	.02612	.73382
8	.62304	.32091	.61989	3.46859	.17871	3.49479	.00652	.72609
9	.63553	.33062	.59826	3.47189	.17232	3.48456	.00080	.72932
10	.64802	.33714	.60921	3.60744	.16888	3.61148	.00007	.73301
11	.66051	.34211	.62391	3.74946	.16640	3.74441	0.00000	.73604

PLUME STRUCTURE
XSTEP 40 X= 2.012 DX= .2509E-01

	Y	P	V	U	TAU	M	S	T
REGION 1								
2	0.00000	.98923	0.00000	3.55269	0.00000	3.00722	0.00000	.99691
3	.03824	.98559	.00635	3.55372	.00179	3.00968	0.00000	.99586
4	.07649	.96738	.02056	3.55888	.00578	3.02213	0.00000	.99057
5	.11473	.92798	.04990	3.57008	.01398	3.04995	0.00000	.97887
6	.15297	.86086	.10205	3.58930	.02843	3.10039	0.00000	.95810
7	.19122	.76947	.18003	3.61566	.04979	3.17429	0.00000	.92786
8	.22946	.66467	.27891	3.64611	.07650	3.27423	0.00000	.88985
9	.26770	.56061	.39241	3.67617	.10674	3.39389	0.00000	.84760
10	.30595	.46636	.51217	3.70278	.13832	3.52294	0.00000	.80417
11	.34419	.38598	.62955	3.72372	.16907	3.65674	0.00000	.76186
12	.38243	.32242	.73898	3.74616	.19726	3.79347	0.00000	.72369
13	.42068	.27391	.84771	3.73818	.22142	3.89343	0.00000	.69074
14	.45892	.23491	.92115	3.77461	.24404	4.03868	0.00000	.66109
15	.49716	.19696	1.01417	3.75849	.26984	4.14967	0.00000	.62863

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	Y	P	V	U	TAU	M	S	T
16	.53541	.18247	1.04688	3.76811	.27783	4.21453	0.00000	.61505
REGION 2								
1	.53541	.28246	.74637	3.76169	.19841	2.84357	.87187	1.29921
2	.55172	.29382	.69869	3.72926	.18735	3.15881	.62208	1.09900
3	.56803	.29719	.70031	3.82745	.18297	3.47710	.32919	.89446
4	.58434	.28087	.73376	3.81587	.19229	3.75654	.13159	.76428
5	.60065	.29954	.64567	3.60949	.17888	3.60288	.06036	.73985
6	.61696	.30354	.67119	3.81946	.17573	3.79152	.06749	.74645
7	.63327	.31667	.67273	4.01218	.16776	3.96216	.06149	.75230
8	.64959	.32720	.59816	3.70356	.16151	3.68216	.02809	.74146
9	.66590	.33063	.55179	3.47549	.15877	3.47607	.00602	.73205
10	.68221	.33664	.54943	3.56775	.15399	3.56319	.00082	.73309
11	.69852	.34137	.56474	3.75925	.15023	3.74598	0.00000	.73559

PLUME STRUCTURE
XSTEP 50 X= 2.294 DX= .3171E-01

	Y	P	V	U	TAU	M	S	T
REGION 1								
2	0.00000	.81459	0.00000	3.60533	0.00000	3.13764	0.00000	.94309
3	.03778	.79871	.05954	3.60998	.01649	3.15597	0.00000	.93780
4	.07555	.75147	.12855	3.62386	.03547	3.19233	0.00000	.92161
5	.11333	.68605	.22297	3.64329	.05571	3.25448	0.00000	.89793
6	.15111	.61144	.28454	3.66571	.07762	3.33364	0.00000	.86888
7	.18889	.53664	.37095	3.68831	.10057	3.42425	0.00000	.83708
8	.22666	.46640	.46050	3.70943	.12414	3.52277	0.00000	.80419
9	.26444	.40284	.55095	3.72796	.14779	3.62667	0.00000	.77123
10	.30222	.34720	.64067	3.74529	.17106	3.73521	0.00000	.73916
11	.34000	.29963	.74575	3.75186	.19344	3.83448	0.00000	.70869
12	.37777	.26083	.80765	3.77507	.21394	3.95327	0.00000	.68116
13	.41555	.22855	.87663	3.76659	.23274	4.03565	0.00000	.65592
14	.45333	.20193	.94438	3.77739	.25001	4.13572	0.00000	.63312
15	.49111	.17378	1.05973	3.78442	.27210	4.25860	0.00000	.60584
16	.52888	.15987	1.06399	3.78446	.28115	4.31723	0.00000	.59225
REGION 2								
1	.52888	.26066	.73296	3.77844	.19398	2.78476	.97290	1.36447
2	.54989	.26111	.74678	3.78166	.19219	2.74080	1.00901	1.40083
3	.57090	.26427	.69835	3.71553	.18795	2.72784	.97509	1.37200
4	.59191	.27672	.61681	3.84468	.17604	3.03410	.74854	1.18246
5	.61292	.29693	.61600	3.81531	.16146	3.39520	.37732	.92550
6	.63393	.29927	.58178	3.61671	.16086	3.49124	.14613	.78638
7	.65494	.31234	.59700	3.90821	.15275	3.82488	.08705	.76315
8	.67595	.31855	.58456	3.93382	.14860	3.87870	.05662	.75095
9	.69696	.32717	.51876	3.57384	.14291	3.55547	.01858	.73643
10	.71797	.33314	.49187	3.53893	.13899	3.52849	.00368	.73240
11	.73898	.34057	.50903	3.76765	.13510	3.74767	0.00000	.73510

PLUME STRUCTURE
XSTEP 67 X= 2.659 DX= .3943E-01

	Y	P	V	U	TAU	M	S	T
REGION 1								
2	0.00000	.38337	0.00000	3.77855	0.00000	3.66221	0.00000	.76039
3	.03738	.37897	.10747	3.77933	.02864	3.67751	0.00000	.75788
4	.07475	.37116	.21027	3.77918	.05564	3.68550	0.00000	.75338
5	.11213	.35646	.31869	3.78028	.08219	3.71467	0.00000	.74474
6	.14951	.33687	.40520	3.78541	.10713	3.75568	0.00000	.73280
7	.18689	.31389	.49298	3.78549	.13023	3.80714	0.00000	.71816
8	.22426	.28878	.57515	3.79007	.15175	3.86892	0.00000	.70125
9	.26164	.26314	.69166	3.79264	.17182	3.93575	0.00000	.68287
10	.29902	.23846	.74453	3.80212	.19056	4.01464	0.00000	.66393
11	.31640	.21533	.79108	3.79003	.20823	4.08410	0.00000	.64485

12	.37377	.19523	.85288	3.80558	.22411	4.16246	0.00000	.62704
13	.41115	.17693	.94191	3.81151	.23925	4.24206	0.00000	.60966
14	.44853	.16140	.96930	3.81026	.25282	4.31824	0.00000	.59386
15	.48591	.14241	1.03427	3.80825	.27159	4.40593	0.00000	.57300
16	.52328	.13281	1.07339	3.81088	.28167	4.46857	0.00000	.56071
REGION 2								
1	.52328	.23872	.67907	3.80227	.17860	2.63147	1.17644	1.53885
2	.54944	.25440	.61922	3.83757	.16136	2.77330	1.02185	1.40326
3	.57560	.26733	.56103	3.79260	.14793	2.74121	.99697	1.39721
4	.60175	.26946	.53968	3.72424	.14491	2.59831	1.09058	1.49827
5	.62791	.27389	.54822	3.91302	.14010	2.86581	.94625	1.35782
6	.65406	.28384	.49191	3.71307	.13248	3.13822	.52801	1.01749
7	.68022	.29224	.47864	3.73549	.12813	3.51130	.21711	.82168
8	.70638	.30372	.50033	4.01819	.12452	3.91318	.10128	.76481
9	.73253	.31925	.44550	3.71709	.11985	3.67464	.03779	.74138
10	.75869	.32842	.41813	3.53220	.11838	3.51250	.00947	.73244
11	.78484	.33930	.43454	3.77769	.11503	3.75739	0.00000	.73431

PLUME STRUCTURE

XSTEP 70 X= 3.074 DX= .4389E-01

	Y	P	V	U	TAU	M	S	T
REGION 1								
2	0.00000	.15973	0.00000	3.93134	0.00000	4.31795	0.00000	.59210
3	.03632	.15931	.08999	3.93069	.02290	4.32301	0.00000	.59165
4	.07264	.15864	.17941	3.92828	.04567	4.32332	0.00000	.59094
5	.10896	.15670	.27055	3.92486	.06893	4.33290	0.00000	.58887
6	.14528	.15480	.35775	3.91986	.09127	4.34265	0.00000	.58682
7	.18160	.15276	.44350	3.91309	.11334	4.35596	0.00000	.58383
8	.21792	.14861	.54687	3.90802	.13482	4.37403	0.00000	.58002
9	.25425	.14446	.60599	3.89789	.15547	4.39530	0.00000	.57534
10	.29057	.13974	.68119	3.89196	.17502	4.42337	0.00000	.56991
11	.32689	.13432	.73229	3.88637	.19357	4.45676	0.00000	.56350
12	.36321	.12848	.81551	3.87764	.21031	4.48761	0.00000	.55689
13	.39953	.12279	.87508	3.86954	.22615	4.52424	0.00000	.54924
14	.43585	.11779	.94436	3.86626	.23908	4.56831	0.00000	.54276
15	.47217	.10871	.99087	3.86234	.25655	4.62703	0.00000	.53046
16	.50849	.10232	1.02817	3.85652	.26920	4.67475	0.00000	.52135
REGION 2								
1	.50849	.22849	.51183	3.83002	.13364	2.28866	1.58596	2.03611
2	.54024	.23563	.48991	3.82577	.12805	2.38884	1.44857	1.86209
3	.57199	.24415	.47830	3.90645	.12244	2.66748	1.18195	1.55488
4	.60373	.25653	.46863	3.75761	.11407	2.67236	1.04554	1.43060
5	.63548	.26482	.42031	3.85300	.10909	2.61718	1.15989	1.56653
6	.66723	.27188	.40572	3.86007	.10511	2.76999	.99442	1.40241
7	.69898	.28173	.36642	3.65459	.10026	3.07475	.53439	1.01923
8	.73072	.29218	.38283	3.98377	.09610	3.73252	.21637	.82120
9	.76247	.30969	.34512	3.84736	.08970	3.76348	.07075	.75249
10	.79422	.32421	.32027	3.54551	.08469	3.50921	.01855	.73437
11	.82597	.33752	.30994	3.79097	.08176	3.75422	0.00000	.73321

PLUME STRUCTURE

XSTEP 80 X= 3.542 DX= .4874E-01

	Y	P	V	U	TAU	M	S	T
REGION 1								
2	0.00000	.07368	0.00000	4.03455	0.00000	4.94925	0.00000	.47466
3	.03384	.07357	.06851	4.03412	.01698	4.95348	0.00000	.47446
4	.06769	.07341	.13652	4.03270	.03385	4.95240	0.00000	.47417
5	.10153	.07318	.20380	4.03003	.05057	4.95479	0.00000	.47375
6	.13538	.07302	.26973	4.02702	.06698	4.95740	0.00000	.47345
7	.16922	.07256	.33670	4.02146	.08373	4.96124	0.00000	.47260

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8	.20307	.07214	.4 244	4.01719	.10018	4.96756	0.00000	.47181
9	.23691	.07165	.46743	4.01139	.11652	4.97396	0.00000	.47088
10	.27076	.07113	.52091	4.00322	.13262	4.97877	0.00000	.46992
11	.31460	.07050	.59360	3.99475	.14860	4.98555	0.00000	.46872
12	.33845	.07075	.63320	3.98734	.16382	4.99247	0.00000	.46785
13	.37229	.06912	.71432	3.97944	.17950	5.00513	0.00000	.46608
14	.40613	.06941	.76278	3.96957	.19216	5.00106	0.00000	.46664
15	.43998	.06792	.85302	3.95876	.20790	5.01812	0.00000	.46375
16	.47382	.06658	.88147	3.94960	.22318	5.03983	0.00000	.46053
REGION 2								
1	.47382	.19461	.19978	3.87258	.05159	1.95263	2.10464	2.81701
2	.51218	.20220	.20514	3.83270	.05352	2.09310	1.86613	2.40184
3	.55153	.21246	.20850	3.93198	.05303	2.29334	1.66204	2.10561
4	.58888	.22356	.21132	3.89212	.05429	2.58232	1.28104	1.62743
5	.62723	.23783	.22351	3.82673	.05318	2.63719	1.14981	1.50824
6	.66559	.25149	.20734	3.97304	.05219	2.63739	1.23217	1.62536
7	.70394	.26417	.19961	3.68159	.05150	2.71502	.91783	1.31688
8	.74229	.27827	.20594	3.90768	.05270	3.39435	.43882	.94930
9	.78065	.30133	.20280	3.94615	.05139	3.77322	.13792	.78332
10	.81900	.31939	.18111	3.56763	.05077	3.51827	.03446	.73972
11	.85735	.33556	.19068	3.79996	.05018	3.75864	0.00000	.73199

PLUME STRUCTURE

XSTEP 96 X= 4.045 DX= .5065E-01

	Y	P	V	U	TAU	M	S	T
REGION 1								
2	0.00000	.03841	0.00000	4.10389	0.00000	5.52534	0.00000	.39404
3	.02818	.03841	.04549	4.10359	.01109	5.52511	0.00000	.39407
4	.05637	.03846	.09073	4.10286	.02211	5.52419	0.00000	.39420
5	.08455	.03847	.13639	4.10113	.03326	5.52338	0.00000	.39423
6	.11274	.03845	.18228	4.10009	.04446	5.52484	0.00000	.39416
7	.14092	.03836	.22853	4.09779	.05577	5.52461	0.00000	.39391
8	.16911	.03835	.27334	4.09451	.06676	5.52418	0.00000	.39387
9	.19729	.03829	.31832	4.09138	.07780	5.52753	0.00000	.39370
10	.22548	.03825	.36273	4.08838	.08872	5.52940	0.00000	.39357
11	.25366	.03813	.40759	4.08482	.09978	5.53265	0.00000	.39324
12	.28184	.03822	.44921	4.08008	.11010	5.53328	0.00000	.39350
13	.31003	.03790	.49596	4.07481	.12171	5.53722	0.00000	.39254
14	.33821	.03814	.53574	4.06883	.13167	5.53297	0.00000	.39297
15	.36640	.03830	.57376	4.06327	.14121	5.52711	0.00000	.39373
16	.39458	.03822	.61654	4.05776	.15194	5.52980	0.00000	.39349
REGION 2								
1	.39458	.16527	-.20794	3.86472	-.06933	1.55364	2.80732	4.44109
2	.44230	.16988	-.21050	3.86423	-.05447	1.82073	2.34922	3.22696
3	.49001	.17992	-.19313	3.90798	-.04942	1.99054	2.09473	2.73511
4	.53773	.18917	-.17889	3.99514	-.03982	2.30186	1.73751	2.14970
5	.58545	.20199	-.16340	3.84419	-.03210	2.57279	1.29460	1.59632
6	.63316	.21657	-.09446	4.04549	-.02335	2.68310	1.29134	1.62464
7	.68088	.23050	-.09034	3.78685	-.01593	2.58563	1.19096	1.53846
8	.72860	.24386	-.05951	3.85507	-.00765	3.09319	.71001	1.10956
9	.77631	.27021	-.00552	4.02544	-.00137	3.74587	.25392	.82489
10	.82403	.30346	-.00443	3.60168	-.00123	3.52666	.06487	.74500
11	.87175	.33431	.00476	3.80546	.00125	3.76117	0.00000	.73121

PLUME BOUNDARY

	X	Y
1	1.00000	.50000
2	1.11137	.52514
3	1.16938	.54149
4	1.23343	.55795

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5	1.30366	.57439
6	1.38060	.59066
7	1.39088	.59267
8	1.40120	.59467
9	1.41212	.59675
10	1.42343	.59888
11	1.43514	.60104
12	1.44725	.60325
13	1.45979	.60549
14	1.47275	.60777
15	1.48613	.61008
16	1.49994	.61245
17	1.51419	.61493
18	1.52889	.61757
19	1.54407	.62038
20	1.55976	.62334
21	1.57600	.62643
22	1.59281	.62958
23	1.61020	.63278
24	1.62819	.63601
25	1.64678	.63929
26	1.66599	.64263
27	1.68581	.64604
28	1.70626	.64954
29	1.72732	.65312
30	1.74898	.65678
31	1.77121	.66051
32	1.79397	.66429
33	1.81720	.66810
34	1.84081	.67192
35	1.86472	.67575
36	1.88887	.67957
37	1.91318	.68338
38	1.93765	.68717
39	1.96228	.69095
40	1.98711	.69473
41	2.01219	.69852
42	2.03761	.70233
43	2.06345	.70618
44	2.08978	.71006
45	2.11669	.71400
46	2.14426	.71800
47	2.17255	.72206
48	2.20162	.72619
49	2.23154	.73039
50	2.26233	.73465
51	2.29404	.73898
52	2.32668	.74337
53	2.36027	.74783
54	2.39480	.75235
55	2.43025	.75692
56	2.46657	.76154
57	2.50372	.76620
58	2.54159	.77089
59	2.58009	.77557
60	2.61911	.78023
61	2.65854	.78484
62	2.69829	.78939
63	2.73833	.79384
64	2.77865	.79820
65	2.81930	.80246
66	2.86032	.80661
67	2.90181	.81067
68	2.94383	.81463
69	2.98643	.81849
70	3.02967	.82227

71	3.07355	.82597
72	3.11810	.82957
73	3.16328	.83309
74	3.20906	.83652
75	3.25539	.83985
76	3.30222	.84308
77	3.34950	.84619
78	3.39718	.84918
79	3.44522	.85205
80	3.49361	.85477
81	3.54235	.85735
82	3.59143	.85977
83	3.64086	.86201
84	3.69064	.86406
85	3.74075	.86591
86	3.79115	.86753
87	3.84179	.86891
88	3.89258	.87004
89	3.94344	.87089
90	3.99426	.87146
91	4.04491	.87175

2	1	2	.1111E+01	.5251E+00	.3326E+00	.2627E+00
3	1	2	.1169E+01	.5415E+00	-.6927E+00	.3013E+00
4	1	2	.1233E+01	.5579E+00	.3067E+00	.2126E+00
5	1	2	.1304E+01	.5744E+00	-.5752E+00	.2556E+00
6	1	2	.1381E+01	.5907E+00	.2818E+01	.1671E+00
7	1	2	.1391E+01	.5927E+00	-.3063E+01	.2251E+00
8	1	2	.1401E+01	.5947E+00	.2648E+01	.1618E+00
9	1	2	.1412E+01	.5968E+00	-.2808E+01	.2197E+00
10	1	2	.1423E+01	.5989E+00	.2464E+01	.1562E+00
11	1	2	.1435E+01	.6010E+00	-.2627E+01	.2139E+00
12	1	2	.1447E+01	.6032E+00	.2293E+01	.1502E+00
13	1	2	.1460E+01	.6055E+00	-.2466E+01	.2077E+00
14	1	2	.1473E+01	.6078E+00	.2167E+01	.1438E+00
15	1	2	.1486E+01	.6101E+00	-.2178E+01	.2018E+00
16	1	2	.1500E+01	.6125E+00	.2272E+01	.1416E+00
17	1	2	.1514E+01	.6149E+00	-.1843E+01	.2064E+00
18	1	2	.1529E+01	.6176E+00	.2172E+01	.1522E+00
19	1	2	.1544E+01	.6204E+00	-.1854E+01	.2181E+00
20	1	2	.1560E+01	.6233E+00	.1835E+01	.1600E+00
21	1	2	.1576E+01	.6264E+00	-.1897E+01	.2195E+00
22	1	2	.1593E+01	.6296E+00	.1619E+01	.1558E+00
23	1	2	.1610E+01	.6328E+00	-.1793E+01	.2121E+00
24	1	2	.1628E+01	.6360E+00	.1545E+01	.1476E+00
25	1	2	.1647E+01	.6393E+00	-.1629E+01	.2050E+00
26	1	2	.1666E+01	.6426E+00	.1496E+01	.1425E+00
27	1	2	.1686E+01	.6460E+00	-.1502E+01	.2018E+00
28	1	2	.1706E+01	.6495E+00	.1415E+01	.1403E+00
29	1	2	.1727E+01	.6531E+00	-.1426E+01	.1999E+00
30	1	2	.1749E+01	.6568E+00	.1326E+01	.1382E+00
31	1	2	.1771E+01	.6605E+00	-.1370E+01	.1971E+00
32	1	2	.1794E+01	.6643E+00	.1260E+01	.1347E+00
33	1	2	.1817E+01	.6681E+00	-.1324E+01	.1933E+00
34	1	2	.1841E+01	.6719E+00	.1225E+01	.1308E+00
35	1	2	.1865E+01	.6758E+00	-.1291E+01	.1894E+00
36	1	2	.1889E+01	.6796E+00	.1211E+01	.1270E+00
37	1	2	.1913E+01	.6834E+00	-.1267E+01	.1860E+00
38	1	2	.1938E+01	.6872E+00	.1202E+01	.1240E+00
39	1	2	.1962E+01	.6909E+00	-.1244E+01	.1832E+00
40	1	2	.1987E+01	.6947E+00	.1183E+01	.1214E+00
41	1	2	.2012E+01	.6985E+00	-.1213E+01	.1808E+00
42	1	2	.2038E+01	.7023E+00	.1149E+01	.1191E+00
43	1	2	.2063E+01	.7062E+00	-.1172E+01	.1785E+00
44	1	2	.2090E+01	.7101E+00	.1101E+01	.1168E+00
45	1	2	.2117E+01	.7140E+00	-.1123E+01	.1760E+00
46	1	2	.2144E+01	.7180E+00	.1043E+01	.1141E+00

MOORE BUSINESS FORMS, INC., HO FORM 1412 T PRINTED IN U.S.A.

47	1	2	.2173E+01	.7221E+00	-.1069E+01	.1731E+00
48	1	2	.2202E+01	.7262E+00	.9820E+00	.1109E+00
49	1	2	.2232E+01	.7304E+00	-.1013E+01	.1696E+00
50	1	2	.2262E+01	.7346E+00	.9242E+00	.1072E+00
51	1	2	.2294E+01	.7390E+00	-.9567E+00	.1659E+00
52	1	2	.2327E+01	.7434E+00	.8727E+00	.1034E+00
53	1	2	.2360E+01	.7478E+00	-.9034E+00	.1620E+00
54	1	2	.2395E+01	.7523E+00	.8285E+00	.9963E-01
55	1	2	.2430E+01	.7569E+00	-.8572E+00	.1584E+00
56	1	2	.2467E+01	.7615E+00	.7907E+00	.9609E-01
57	1	2	.2504E+01	.7662E+00	-.8238E+00	.1548E+00
58	1	2	.2542E+01	.7709E+00	.7592E+00	.9242E-01
59	1	2	.2580E+01	.7756E+00	-.8051E+00	.1509E+00
60	1	2	.2619E+01	.7802E+00	.7347E+00	.8805E-01
61	1	2	.2659E+01	.7848E+00	-.7973E+00	.1460E+00
62	1	2	.2698E+01	.7894E+00	.7169E+00	.8260E-01
63	1	2	.2738E+01	.7938E+00	-.7915E+00	.1400E+00
64	1	2	.2779E+01	.7982E+00	.7023E+00	.7617E-01
65	1	2	.2819E+01	.8026E+00	-.7803E+00	.1333E+00
66	1	2	.2860E+01	.8066E+00	.6871E+00	.6923E-01
67	1	2	.2902E+01	.8107E+00	-.7617E+00	.1262E+00
68	1	2	.2944E+01	.8146E+00	.6703E+00	.6223E-01
69	1	2	.2986E+01	.8185E+00	-.7383E+00	.1193E+00
70	1	2	.3030E+01	.8223E+00	.6529E+00	.5550E-01
71	1	2	.3074E+01	.8260E+00	-.7145E+00	.1128E+00
72	1	2	.3118E+01	.8296E+00	.6360E+00	.4915E-01
73	1	2	.3163E+01	.8331E+00	-.6939E+00	.1066E+00
74	1	2	.3209E+01	.8366E+00	.6209E+00	.4309E-01
75	1	2	.3255E+01	.8399E+00	-.6781E+00	.1006E+00
76	1	2	.3302E+01	.8431E+00	.6080E+00	.3711E-01
77	1	2	.3349E+01	.8465E+00	-.6673E+00	.9461E-01
78	1	2	.3397E+01	.8492E+00	.5964E+00	.3097E-01
79	1	2	.3445E+01	.8520E+00	-.6601E+00	.8828E-01
80	1	2	.3494E+01	.8548E+00	.5846E+00	.2439E-01
81	1	2	.3542E+01	.8574E+00	-.6548E+00	.8137E-01
82	1	2	.3591E+01	.8598E+00	.5719E+00	.1709E-01
83	1	2	.3641E+01	.8620E+00	-.6505E+00	.7362E-01
84	1	2	.3691E+01	.8641E+00	.5589E+00	.8866E-02
85	1	2	.3741E+01	.8659E+00	-.6483E+00	.6488E-01
86	1	2	.3791E+01	.8675E+00	.5481E+00	-.4696E-03
87	1	2	.3842E+01	.8689E+00	-.6477E+00	.5504E-01
88	1	2	.3893E+01	.8700E+00	.5417E+00	-.1076E-01
89	1	2	.3943E+01	.8709E+00	-.6510E+00	.4434E-01
90	1	2	.3994E+01	.8715E+00	.5410E+00	-.2182E-01
91	1	2	.4045E+01	.8717E+00	-.1649E-01	.3298E-01

BOATTAIL COMPLETE FLOW FIELD

STEP 50 TIME= .1592E+01 DT= .2474E-01

REGION NO. 1

M= 1

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	-500.00000	.50000	1.00000	1.18322	.74617	0.00000	.63063	0.00000	1.00000	0.00000	0.00000
2	-10.00000	.50000	1.00001	1.18322	.74603	0.00000	.63051	0.00000	1.00001	.00004	0.00000
3	-6.31140	.50000	1.00000	1.18322	.74602	0.00000	.63050	0.00000	1.00000	.00000	0.00000
4	-4.53491	.50000	1.00000	1.18322	.74602	0.00000	.63050	0.00000	1.00000	.00000	0.00000
5	-3.44484	.50000	1.00000	1.18322	.74602	0.00000	.63050	0.00000	1.00000	.00000	0.00000
6	-2.69678	.50000	1.00000	1.18322	.74602	0.00000	.63050	0.00000	1.00000	.00000	0.00000
7	-2.14878	.50000	1.00000	1.18322	.74602	0.00000	.63050	0.00000	1.00000	.00000	0.00000
8	-1.72980	.50000	1.00000	1.18322	.74602	0.00000	.63050	0.00000	1.00000	.00000	0.00000

MOORE BUSINESS FORMS, INC., HO FORM 1412 T PRINTED IN U.S.A.

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
9	-1.39972	.50000	1.00000	1.18322	.74602	0.00000	.63050	0.00000	1.00000	.00000	0.00000
10	-1.13387	.50000	1.00000	1.18322	.74602	0.00000	.63050	0.00000	1.00000	.00000	0.00000
11	-.91616	.50000	1.00000	1.18322	.74602	0.00000	.63050	0.00000	1.00000	.00000	0.00000
12	-.73558	.50000	1.00000	1.18322	.74602	0.00000	.63050	0.00000	1.00000	.00000	0.00000
13	-.58428	.50000	1.00000	1.18322	.74602	0.00000	.63050	0.00000	1.00000	.00000	0.00000
14	-.45654	.50000	1.00000	1.18322	.74602	0.00000	.63050	0.00000	1.00000	.00000	0.00000
15	-.34803	.50000	1.00002	1.18322	.74601	0.00000	.63049	0.00000	1.00001	.00001	0.00000
16	-.25546	.50000	1.00005	1.18322	.74598	0.00000	.63046	0.00000	1.00004	.00005	0.00000
17	-.17623	.50000	1.00012	1.18324	.74592	0.00000	.63041	0.00000	1.00008	.00014	0.00000
18	-.11829	.50000	1.00022	1.18325	.74583	0.00000	.63032	0.00000	1.00016	.00034	0.00000
19	-.05000	.50000	1.00036	1.18328	.74571	0.00000	.63021	0.00000	1.00025	.00066	0.00000
20	-.00000	.50000	1.00050	1.18330	.74558	0.00000	.63008	0.00000	1.00036	.00104	0.00000

M= 2

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	-500.00000	.55000	1.00000	1.18322	.74617	0.00000	.63063	0.00000	1.00000	0.00000	0.00000
2	-10.00000	.55000	1.00001	1.18322	.74603	.00000	.63051	.00000	1.00001	.00004	0.00000
3	-6.31160	.55000	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
4	-4.53491	.55000	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
5	-3.44484	.55000	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
6	-2.69678	.55000	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
7	-2.14878	.55000	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
8	-1.72980	.55000	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
9	-1.39972	.55000	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
10	-1.13387	.55000	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
11	-.91616	.55000	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
12	-.73558	.55000	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
13	-.58428	.55000	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
14	-.45654	.55000	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
15	-.34803	.55000	1.00002	1.18322	.74601	.00000	.63049	.00000	1.00001	.00001	0.00000
16	-.25546	.55000	1.00005	1.18322	.74598	.00000	.63046	.00000	1.00004	.00005	0.00000
17	-.17623	.55000	1.00012	1.18324	.74592	.00000	.63041	.00001	1.00008	.00014	0.00000
18	-.11829	.55000	1.00022	1.18325	.74582	.00001	.63032	.00001	1.00016	.00034	0.00000
19	-.05000	.55000	1.00036	1.18328	.74570	.00001	.63020	.00002	1.00026	.00066	0.00000
20	-.00000	.55000	1.00051	1.18330	.74557	.00002	.63008	.00002	1.00036	.00104	0.00000

M= 3

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	-500.00000	.61899	1.00000	1.18322	.74617	0.00000	.63063	0.00000	1.00000	0.00000	0.00000
2	-10.00000	.61899	1.00001	1.18322	.74603	.00000	.63051	.00000	1.00001	.00004	0.00000
3	-6.31160	.61899	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
4	-4.53491	.61899	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
5	-3.44484	.61899	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
6	-2.69678	.61899	1.00000	1.18322	.74602	-.00000	.63050	-.00000	1.00000	.00000	0.00000
7	-2.14878	.61899	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
8	-1.72980	.61899	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
9	-1.39972	.61899	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
10	-1.13387	.61899	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
11	-.91616	.61899	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
12	-.73558	.61899	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
13	-.58428	.61899	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
14	-.45654	.61899	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
15	-.34803	.61899	1.00001	1.18322	.74601	.00000	.63049	.00000	1.00001	.00001	0.00000
16	-.25546	.61899	1.00005	1.18322	.74598	.00000	.63046	.00000	1.00003	.00004	0.00000
17	-.17623	.61899	1.00011	1.18324	.74592	.00001	.63041	.00001	1.00008	.00014	0.00000
18	-.11829	.61899	1.00022	1.18325	.74583	.00002	.63032	.00002	1.00015	.00033	0.00000
19	-.05000	.61899	1.00035	1.18327	.74572	.00003	.63021	.00004	1.00025	.00063	0.00000
20	-.00000	.61899	1.00049	1.18330	.74559	.00004	.63009	.00006	1.00035	.00101	0.00000

M= 4

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	-500.00000	.71143	1.00000	1.18322	.74617	0.00000	.63063	0.00000	1.00000	0.00000	0.00000
2	-10.00000	.71143	1.00001	1.18322	.74603	.00000	.63051	.00000	1.00001	.00004	0.00000

3	-6.31160	.71163	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
4	-4.53491	.71163	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
5	-3.44484	.71163	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
6	-2.69678	.71163	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
7	-2.14878	.71163	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
8	-1.72980	.71163	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
9	-1.39972	.71163	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
10	-1.13387	.71163	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
11	-.91616	.71163	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
12	-.73558	.71163	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
13	-.58428	.71163	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00000	0.00000
14	-.45654	.71163	1.00000	1.18322	.74602	.00000	.63050	.00000	1.00000	.00001	0.00000
15	-.34803	.71163	1.00001	1.18322	.74601	.00000	.63049	.00000	1.00001	.00004	0.00000
16	-.25546	.71163	1.00004	1.18322	.74599	.00001	.63047	.00001	1.00003	.00012	0.00000
17	-.17623	.71163	1.00010	1.18323	.74593	.00001	.63042	.00002	1.00007	.00030	0.00000
18	-.11829	.71163	1.00020	1.18325	.74585	.00003	.63034	.00004	1.00014	.00058	0.00000
19	-.05000	.71163	1.00032	1.18327	.74574	.00005	.63024	.00006	1.00023	.00094	0.00000
20	-.00000	.71163	1.00046	1.18329	.74562	.00007	.63012	.00009	1.00033	.00133	0.00000

REGION NO. 6

M= 1

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	1.00000	.50000	1.09693	1.19422	.65225	.12304	.55581	.18864	1.04736	.19513	0.00000
2	1.05000	.51026	1.10248	1.19982	.66201	.14490	.56518	.22190	1.07217	.29877	0.00000
3	1.11829	.52433	1.09773	1.19908	.67177	.17511	.57896	.26068	1.06887	.28491	0.00000
4	1.17623	.54353	1.09771	1.19908	.66960	.19540	.58172	.29181	1.06886	.28486	0.00000
5	1.25546	.56278	1.07728	1.19587	.69671	.15751	.59730	.22608	1.05461	.22530	0.00000
6	1.34803	.58460	1.06987	1.19469	.70836	.14493	.60521	.20460	1.04942	.20370	0.00000
7	1.45654	.60494	1.06540	1.19397	.71655	.13813	.61119	.19277	1.04629	.19066	0.00000
8	1.58428	.62811	1.06327	1.19363	.72207	.13583	.61555	.18811	1.04480	.18447	0.00000
9	1.73558	.65468	1.05988	1.19309	.72853	.12849	.62005	.17637	1.04241	.17457	0.00000
10	1.91616	.68392	1.05976	1.19307	.73126	.13046	.62260	.17840	1.04233	.17422	0.00000
11	2.13387	.71669	1.04762	1.19110	.74166	.10192	.62852	.13742	1.03378	.13882	0.00000
12	2.39972	.75286	1.03933	1.18975	.74868	.08069	.63291	.10778	1.02794	.11466	0.00000
13	2.72980	.79270	1.04442	1.19059	.74737	.09550	.63283	.12778	1.03153	.12951	0.00000
14	3.14878	.83168	1.03054	1.18831	.75366	.06646	.63669	.08818	1.02172	.08903	0.00000
15	3.69678	.86414	1.0 682	1.18437	.75575	.01188	.63819	.01573	1.00487	.01988	0.00000
16	4.44484	.88230	1.00669	1.18434	.74934	.01483	.63283	.01979	1.00477	.01950	0.00000
17	5.53491	.88824	1.00046	1.18329	.74652	0.00000	.63088	0.00000	1.00033	.00134	0.00000
18	7.31160	.88824	.99975	1.18317	.74563	0.00000	.63020	0.00000	.99982	-.00074	0.00000
19	11.00000	.88824	1.00268	1.18367	.74669	0.00000	.63083	0.00000	1.00192	.00782	0.00000
20	500.00000	.88824	1.00000	1.18322	.74617	0.00000	.63063	0.00000	1.00000	0.00000	0.00000

M= 2

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	1.00000	.55000	1.05450	1.19222	.68807	.02863	.57763	.04161	1.03863	.15888	0.00000
2	1.05000	.56026	1.04416	1.19054	.70413	.04554	.59267	.06468	1.03134	.12873	0.00000
3	1.11829	.57433	1.04070	1.18998	.71205	.04902	.59979	.06885	1.02890	.11868	0.00000
4	1.17623	.59353	1.03683	1.18934	.71978	.05110	.60671	.07100	1.02617	.10737	0.00000
5	1.25546	.61278	1.03353	1.18880	.72641	.05125	.61257	.07056	1.02384	.09776	0.00000
6	1.34803	.63460	1.03125	1.18843	.73175	.05103	.61723	.06973	1.02223	.09112	0.00000
7	1.45654	.65484	1.02924	1.18810	.73612	.05004	.62101	.06798	1.02080	.08526	0.00000
8	1.58428	.67811	1.02757	1.18782	.73972	.04831	.62408	.06531	1.01962	.08038	0.00000
9	1.73558	.70448	1.02600	1.18756	.74301	.04592	.62685	.06180	1.01850	.07579	0.00000
10	1.91616	.73392	1.02428	1.18728	.74603	.04277	.62938	.05733	1.01728	.07078	0.00000
11	2.13387	.76669	1.02241	1.18697	.74902	.03880	.63188	.05180	1.01596	.06533	0.00000
12	2.39972	.80286	1.02039	1.18663	.75219	.03371	.63452	.04481	1.01452	.05946	0.00000
13	2.72980	.84270	1.01693	1.18606	.75453	.02705	.63657	.03584	1.01206	.04936	0.00000
14	3.14878	.88168	1.01175	1.18519	.75630	.01850	.63832	.02446	1.00838	.03425	0.00000
15	3.69678	.91414	1.00522	1.18410	.75479	.00491	.63746	.00915	1.00373	.01523	0.00000
16	4.44484	.93230	1.00102	1.18339	.74937	.00022	.63324	.00029	1.00073	.00296	0.00000
17	5.53491	.93824	1.00046	1.18329	.74652	.00004	.63088	.00005	1.00033	.00135	0.00000
18	7.31160	.93824	.99975	1.18317	.74563	.00000	.63020	.00000	.99982	-.00074	0.00000

MOORE BUSINESS FORMS, INC., HO FORM 1412 T PRINTED IN U.S.A.

19	11.00000	.93824	1.00268	1.18367	.74669	.00000	.63083	.00000	1.00192	.00782	0.00000
20	500.00000	.93824	1.00000	1.18322	.74617	0.00000	.63063	0.00000	1.00000	0.00000	0.00000

M= 3

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	1.00000	.61899	1.03646	1.18928	.70868	.02448	.59630	.03736	1.02591	.10628	0.00000
2	1.05000	.62995	1.03699	1.18937	.71167	.03274	.59899	.04600	1.02629	.10785	0.00000
3	1.10829	.64332	1.03463	1.18898	.71667	.03743	.60358	.05223	1.02461	.10098	0.00000
4	1.17623	.66251	1.03303	1.18872	.72135	.03985	.60775	.05524	1.02349	.09631	0.00000
5	1.25546	.68177	1.03074	1.18835	.72647	.04139	.61232	.05697	1.02186	.08963	0.00000
6	1.34803	.70359	1.02914	1.18808	.73070	.04244	.61606	.05808	1.02073	.08495	0.00000
7	1.45654	.72383	1.02752	1.18781	.73465	.04252	.61952	.05788	1.01958	.08025	0.00000
8	1.58428	.74710	1.02614	1.18759	.73823	.04167	.62261	.05645	1.01860	.07621	0.00000
9	1.73558	.77366	1.02483	1.18737	.74167	.04006	.62555	.05401	1.01767	.07238	0.00000
10	1.91616	.80291	1.02337	1.18713	.74489	.03769	.62828	.05060	1.01664	.06815	0.00000
11	2.13387	.83568	1.02179	1.18687	.74801	.03455	.63091	.04619	1.01552	.06352	0.00000
12	2.39972	.87185	1.02005	1.18658	.75117	.03037	.63357	.04042	1.01428	.05845	0.00000
13	2.72980	.91169	1.01687	1.18605	.75342	.02466	.63557	.03273	1.01202	.04918	0.00000
14	3.14878	.95047	1.01204	1.18524	.75515	.01727	.63730	.02287	1.00859	.03510	0.00000
15	3.69678	.98312	1.00562	1.18416	.75395	.00694	.63673	.00920	1.00401	.01637	0.00000
16	4.44484	1.00129	1.00117	1.18341	.74912	.00054	.63302	.00072	1.00084	.00342	0.00000
17	5.53491	1.00723	1.00046	1.18329	.74651	.00008	.63087	.00011	1.00033	.00135	0.00000
18	7.31160	1.00723	.99975	1.18317	.74543	.00000	.63020	.00001	.99982	-.00074	0.00000
19	11.00000	1.00723	1.00268	1.18367	.74669	.00000	.63083	.00000	1.00192	.00782	0.00000
20	500.00000	1.00723	1.00000	1.18322	.74617	0.00000	.63063	0.00000	1.00000	0.00000	0.00000

M= 4

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	1.00000	.71143	1.02730	1.18778	.72057	.01833	.60685	.02544	1.01943	.07961	0.00000
2	1.05000	.72189	1.02760	1.18783	.72198	.02338	.60813	.03238	1.01964	.08048	0.00000
3	1.10829	.73596	1.02806	1.18790	.72374	.02704	.60968	.03736	1.01996	.08181	0.00000
4	1.17623	.75515	1.02764	1.18783	.72633	.02999	.61200	.04129	1.01966	.08057	0.00000
5	1.25546	.77441	1.02681	1.18770	.72924	.03215	.61459	.04409	1.01908	.07817	0.00000
6	1.34803	.79623	1.02603	1.18757	.73224	.03384	.61725	.04621	1.01852	.07588	0.00000
7	1.45654	.81647	1.02508	1.18741	.73542	.03462	.62003	.04707	1.01785	.07313	0.00000
8	1.58428	.83974	1.02417	1.18726	.73851	.03457	.62271	.04682	1.01721	.07047	0.00000
9	1.73558	.86631	1.02323	1.18710	.74151	.03382	.62529	.04561	1.01654	.06772	0.00000
10	1.91616	.89555	1.02209	1.18692	.74431	.03234	.62768	.04344	1.01573	.06441	0.00000
11	2.13387	.92832	1.02081	1.18670	.74706	.03009	.63003	.04028	1.01482	.06067	0.00000
12	2.39972	.96449	1.01937	1.18646	.74992	.02686	.63247	.03582	1.01380	.05647	0.00000
13	2.72980	1.00433	1.01654	1.18599	.75195	.02214	.63431	.02944	1.01178	.04821	0.00000
14	3.14878	1.04331	1.01217	1.18526	.75353	.01594	.63589	.02116	1.00868	.03547	0.00000
15	3.69678	1.07577	1.00603	1.18423	.75276	.00693	.63568	.00920	1.00430	.01758	0.00000
16	4.44484	1.09393	1.00138	1.18345	.74875	.00086	.63269	.00114	1.00099	.00403	0.00000
17	5.53491	1.09987	1.00047	1.18329	.74649	.00013	.63085	.00018	1.00033	.00136	0.00000
18	7.31160	1.09987	.99975	1.18317	.74543	.00001	.63020	.00001	.99982	-.00074	0.00000
19	11.00000	1.09987	1.00268	1.18367	.74669	.00000	.63083	.00000	1.00192	.00782	0.00000
20	500.00000	1.09987	1.00000	1.18322	.74617	0.00000	.63063	0.00000	1.00000	0.00000	0.00000

REGION NO. 7

M= 1

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	0.00000	.50000	1.00050	1.18330	.74558	0.00000	.63008	0.00000	1.00036	.00146	0.00000
2	.04748	.50000	1.00066	1.18333	.74544	0.00000	.62995	0.00000	1.00047	.00191	0.00000
3	.09657	.50000	1.00086	1.18336	.74525	0.00000	.62977	0.00000	1.00062	.00252	0.00000
4	.14714	.50000	1.00112	1.18340	.74501	0.00000	.62955	0.00000	1.00080	.00326	0.00000
5	.19904	.50000	1.00143	1.18346	.74472	0.00000	.62927	0.00000	1.00102	.00417	0.00000
6	.25210	.50000	1.00182	1.18352	.74435	0.00000	.62893	0.00000	1.00130	.00530	0.00000
7	.30615	.50000	1.00229	1.18360	.74390	0.00000	.62850	0.00000	1.00164	.00668	0.00000
8	.36097	.50000	1.00288	1.18370	.74333	0.00000	.62797	0.00000	1.00205	.00839	0.00000
9	.41635	.50000	1.00360	1.18382	.74262	0.00000	.62731	0.00000	1.00257	.01049	0.00000
10	.47208	.50000	1.00450	1.18397	.74173	0.00000	.62647	0.00000	1.00321	.01311	0.00000

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11	.52792	.50000	1.00562	1.18416	.74060	0.00000	.62542	0.00000	1.00401	.01638	0.00000
12	.58365	.50000	1.00704	1.18440	.73916	0.00000	.62407	0.00000	1.00502	.02053	0.00000
13	.63903	.50000	1.00888	1.18471	.73729	0.00000	.62233	0.00000	1.00633	.02586	0.00000
14	.69385	.50000	1.01127	1.18511	.73479	0.00000	.62002	0.00000	1.00804	.03285	0.00000
15	.74790	.50000	1.01457	1.18566	.73140	0.00000	.61687	0.00000	1.01038	.04247	0.00000
16	.80096	.50000	1.01901	1.18640	.72650	0.00000	.61235	0.00000	1.01355	.05544	0.00000
17	.85286	.50000	1.02620	1.18760	.71945	0.00000	.60581	0.00000	1.01865	.07639	0.00000
18	.90343	.50000	1.03622	1.18924	.70786	0.00000	.59522	0.00000	1.02574	.10559	0.00000
19	.95252	.50000	1.04410	1.19053	.67867	0.00000	.57006	0.00000	1.03130	.12857	0.00000
20	1.00000	.50000	1.06693	1.19422	.65225	.12304	.55581	.18864	1.04736	.19513	0.00000

Ms 2

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	0.00000	.55000	1.00050	1.18330	.74557	.00002	.63008	.00002	1.00036	.00147	0.00000
2	.04748	.55000	1.00066	1.18333	.74543	.00002	.62994	.00003	1.00047	.00193	0.00000
3	.09657	.55000	1.00087	1.18336	.74523	.00003	.62976	.00004	1.00062	.00254	0.00000
4	.14714	.55000	1.00113	1.18341	.74500	.00004	.62954	.00006	1.00080	.00328	0.00000
5	.19984	.55000	1.00144	1.18346	.74470	.00006	.62925	.00008	1.00103	.00420	0.00000
6	.25210	.55000	1.00183	1.18353	.74432	.00008	.62890	.00010	1.00131	.00534	0.00000
7	.30615	.55000	1.00231	1.18361	.74386	.00010	.62847	.00014	1.00165	.00674	0.00000
8	.36097	.55000	1.00290	1.18371	.74327	.00014	.62792	.00018	1.00207	.00847	0.00000
9	.41635	.55000	1.00364	1.18383	.74254	.00018	.62724	.00024	1.00260	.01060	0.00000
10	.47208	.55000	1.00455	1.18398	.74162	.00024	.62638	.00033	1.00325	.01327	0.00000
11	.52792	.55000	1.00570	1.18418	.74045	.00033	.62529	.00044	1.00407	.01661	0.00000
12	.58365	.55000	1.00715	1.18442	.73895	.00045	.62389	.00061	1.00510	.02084	0.00000
13	.63903	.55000	1.00902	1.18474	.73701	.00063	.62208	.00086	1.00644	.02631	0.00000
14	.69385	.55000	1.01145	1.18514	.73444	.00093	.61971	.00127	1.00817	.03339	0.00000
15	.74790	.55000	1.01477	1.18570	.73100	.00139	.61652	.00190	1.01053	.04307	0.00000
16	.80096	.55000	1.01914	1.18642	.72627	.00231	.61215	.00318	1.01363	.05580	0.00000
17	.85286	.55000	1.02589	1.18754	.71983	.00359	.60616	.00498	1.01842	.07546	0.00000
18	.90343	.55000	1.03467	1.18899	.71044	.00770	.59755	.01083	1.02464	.10108	0.00000
19	.95252	.55000	1.04153	1.19011	.68909	.01240	.57911	.01800	1.02949	.12109	0.00000
20	1.00000	.55000	1.05450	1.19222	.68807	.02863	.57763	.04161	1.03863	.15888	0.00000

Ms 3

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	0.00000	.61899	1.00049	1.18330	.74559	.00004	.63009	.00006	1.00035	.00142	0.00000
2	.04748	.61899	1.00064	1.18332	.74545	.00006	.62996	.00008	1.00046	.00187	0.00000
3	.09657	.61899	1.00085	1.18336	.74526	.00008	.62978	.00010	1.00061	.00248	0.00000
4	.14714	.61899	1.00110	1.18340	.74503	.00011	.62957	.00014	1.00078	.00320	0.00000
5	.19984	.61899	1.00141	1.18345	.74474	.00014	.62929	.00019	1.00101	.00411	0.00000
6	.25210	.61899	1.00179	1.18352	.74438	.00019	.62895	.00025	1.00128	.00522	0.00000
7	.30615	.61899	1.00226	1.18360	.74393	.00025	.62853	.00033	1.00161	.00658	0.00000
8	.36097	.61899	1.00283	1.18369	.74337	.00033	.62801	.00044	1.00202	.00824	0.00000
9	.41635	.61899	1.00354	1.18381	.74268	.00044	.62736	.00059	1.00253	.01033	0.00000
10	.47208	.61899	1.00442	1.18396	.74180	.00058	.62654	.00078	1.00316	.01289	0.00000
11	.52792	.61899	1.00551	1.18415	.74071	.00078	.62553	.00105	1.00393	.01607	0.00000
12	.58365	.61899	1.00688	1.18438	.73933	.00106	.62423	.00144	1.00491	.02006	0.00000
13	.63903	.61899	1.00861	1.18467	.73758	.00144	.62261	.00195	1.00614	.02510	0.00000
14	.69385	.61899	1.01080	1.18503	.73532	.00207	.62051	.00282	1.00770	.03149	0.00000
15	.74790	.61899	1.01361	1.18550	.73251	.00284	.61789	.00387	1.00970	.03968	0.00000
16	.80096	.61899	1.01712	1.18609	.72878	.00445	.61445	.00610	1.01220	.04991	0.00000
17	.85286	.61899	1.02166	1.18684	.72461	.00574	.61055	.00792	1.01542	.06314	0.00000
18	.90343	.61899	1.02680	1.18770	.71892	.01169	.60539	.01625	1.01907	.07815	0.00000
19	.95252	.61899	1.03193	1.18854	.71365	.01390	.60055	.01948	1.02270	.09309	0.00000
20	1.00000	.61899	1.03646	1.18928	.70868	.02648	.59630	.03736	1.02591	.10628	0.00000

Ms 4

	X	Y	P	A	U	V	M	SLOPE	RHO	CP	S
1	0.00000	.71163	1.00046	1.18329	.74562	.00007	.63012	.00009	1.00033	.00133	0.00000
2	.04748	.71163	1.00060	1.18332	.74549	.00009	.63000	.00012	1.00043	.00175	0.00000
3	.09657	.71163	1.00080	1.18335	.74531	.00012	.62983	.00016	1.00057	.00232	0.00000
4	.14714	.71163	1.00103	1.18339	.74510	.00016	.62963	.00022	1.00074	.00301	0.00000

MOORE BUSINESS FORMS, INC., HO FORM 1412 T PRINTED IN U.S.A. 22"

5	.19904	.71163	1.00132	1.18344	.74483	.00022	.62937	.00029	1.00095	.00386	0.00000
6	.25210	.71163	1.00168	1.18350	.74449	.00029	.62906	.00039	1.00120	.00491	0.00000
7	.30615	.71163	1.00213	1.18357	.74407	.00039	.62867	.00052	1.00152	.00624	0.00000
8	.36097	.71163	1.00267	1.18367	.74356	.00051	.62818	.00069	1.00190	.00778	0.00000
9	.41635	.71163	1.00333	1.18378	.74292	.00068	.62759	.00092	1.00238	.00971	0.00000
10	.47208	.71163	1.00414	1.18391	.74214	.00090	.62685	.00121	1.00296	.01208	0.00000
11	.52792	.71163	1.00514	1.18408	.74116	.00121	.62594	.00163	1.00367	.01498	0.00000
12	.58365	.71163	1.00636	1.18429	.73998	.00159	.62483	.00215	1.00454	.01855	0.00000
13	.63903	.71163	1.00786	1.18454	.73849	.00216	.62344	.00293	1.00561	.02291	0.00000
14	.69385	.71163	1.00971	1.18485	.73672	.00289	.62179	.00393	1.00692	.02830	0.00000
15	.74790	.71163	1.01191	1.18522	.73449	.00399	.61971	.00543	1.00849	.03471	0.00000
16	.80096	.71163	1.01466	1.18568	.73199	.00534	.61738	.00730	1.01045	.04275	0.00000
17	.85286	.71163	1.01752	1.18615	.72874	.00747	.61441	.01025	1.01248	.05107	0.00000
18	.90343	.71163	1.02132	1.18679	.72586	.01031	.61168	.01420	1.01518	.06218	0.00000
19	.95252	.71163	1.02369	1.18718	.72277	.01392	.60892	.01926	1.01687	.06908	0.00000
20	1.00000	.71163	1.02730	1.18778	.72057	.01833	.60685	.02544	1.01943	.07961	0.00000

X= 1.1083 MDOT= .1018

X= 1.5843 MDOT= .1238

60	1	.251E-01	2	.100E+01	3	.100E+01	4	.100E+01	5	.100E+01	6	.247E-01	7	.238E-01
70	1	.249E-01	2	.100E+01	3	.100E+01	4	.100E+01	5	.100E+01	6	.242E-01	7	.236E-01
80	1	.249E-01	2	.100E+01	3	.100E+01	4	.100E+01	5	.100E+01	6	.242E-01	7	.236E-01
90	1	.249E-01	2	.100E+01	3	.100E+01	4	.100E+01	5	.100E+01	6	.242E-01	7	.236E-01
100	1	.249E-01	2	.100E+01	3	.100E+01	4	.100E+01	5	.100E+01	6	.242E-01	7	.236E-01

PLUME STRUCTURE

XSTEP 0 X= 1.050 DX= .5000E-01

	Y	P	V	U	TAU	M	S	T
REGION 1								
2	0.00000	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
3	.03397	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
4	.06794	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
5	.10191	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
6	.13588	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
7	.16985	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
8	.20382	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
9	.23778	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
10	.27175	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
11	.30572	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
12	.33969	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
13	.37366	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
14	.40763	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
15	.44160	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
16	.47557	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
17	.50954	.40065	.46243	2.42406	.19077	2.37679	0.00000	.77002

PLUME STRUCTURE

XSTEP 5 X= 1.309 DX= .7731E-01

	Y	P	V	U	TAU	M	S	T
REGION 1								
2	0.00000	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
3	.03802	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000
4	.07603	1.00000	0.00000	3.54965	1.00000	3.00000	0.00000	1.00000

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3.2.5 Source Language Listing

```
      PROGRAM NACELL(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE11,TAPE12)
C     TRANSONIC NACELLE CALCULATION
C     THIN,BLUNT COWL LIP
      COMMON/BLK1/NC(8),MC(8),NC1,NC2,NC3,NC4,NC5,NC6,NC7,NC8,MC1,MC2
     1,MC3,MC4,MC5,MC6,MC7,MC8,NREG(8),NMC(2),MMC(80,2),NMAX,MMAX
     2,GAMMA,GA,GB,GC,GD,GE,GF,X(40,8),Y(19,8),XXP(130)
     3,YYP(130,19),HH,XE,YE,YA,XC,R0,RD,RMFLO,TT,CC,EM,PII
     4,SINTHE(20),COSTHE(20),R(20,19),LSYM,LA,DX(8),DY(8)
      COMMON/BLK2/P(150,19),U(150,19),V(150,19),S(150,19),PI(150,19)
     1,UI(150,19),VI(150,19),SI(150,19),NS(8,2),NF(8,2)
     2,MS(8,2),MF(8,2),TIME,DT,K,J,XOTT(2),QINF,QINFN,KDIVS,DTS
      COMMON/BLK3/YET(130,19),XCS(130),X0,X1,X2,X3,Y0,Y2,ALP(4),DD(6)
     1,BET(4),LSLP,HU(130),HL(130),HC(130),HUPR(130),HLPR(130),HCPR(130)
      COMMON/BLK4/EP1(20),EP2(20),EP3(100),EP4(100),EP5(38),EP6(38)
     1,NN1(20),NN2(20),M1(20),M2(20),M3(38),M4(38),L1(100),L3(100)
     2,I1(100),I2(100),JR(80,19),B(20),BPR(20)
      COMMON/BLK6/ XPL(200),PPL(200),KPP
      COMMON/BLK8/ PRATIO,PDIST,PRAD,KPLUME,JJ
      COMMON/BLK9/QQ,WW,STAB,NNMAX,NTH,NNTH
      DIMENSION DIT(7),NDATE(3)
      NAMELIST/RUN/NRUN,NDATE,EM,GAMMA,RMFLO,LA,LSYM,KPLUME,STAB
      NAMELIST/INOUT/MREAD,MRITE,KA,JA,JB,MB,LOUT1,LOUT2
      NAMELIST/MESH/NC,MC,RD
      CALL ERRSET(208,256,-1,1,0,0)
 1001 FORMAT(1H1,29X,11HPROGRAM 15C//20X,29HTRANSONIC NACELLE COMPUTATIO
     1N //20X,3HRUN,I5,13X,I2,1H/,I2,1H/,I2//20X,5HMACH=,F5.3,8X,5HMFLO=
     2,F6.4///4X,10HINPUT DATA/4X,2HNC,5X,8I4/4X,2HMC,5X,8I4/4X,2HDD
     3,5X,6F8.3/4X,6HMREAD=,I2,3X,6HMRITE=,I2,3X,3HKA=,I5,3X,3HJA=,I3
     4,3X,3HJB=,I3/4X,7HKPLUME=,I4/)
 1002 FORMAT(4X,21HTWO-DIMENSIONAL FLOW /)
 1003 FORMAT(4X,17HAXISYMMETRIC FLOW /)
 1004 FORMAT(4X,16HBOATTAIL OPTION /)
 1005 FORMAT(2X,I6,2X,7(I2,E10.3))
C     INPUT DATA
      GAMMA=1.4
      RMFLO=1.
      STAB=1.
      KPLUME=-1
      READ(5,RUN)
      MREAD=0
      MRITE=0
      MB=1
      JB=-1
      LOUT1=0
      LOUT2=0
      READ(5,INOUT)
      IF(MREAD.NE.0) GO TO 80
      IF(LSYM.EQ.1) GO TO 10
      MC(1)=18
      MC(2)=18
      NC(1)=18
      NC(3)=25
      NC(4)=16
      NC(6)=18
      NC(7)=32
```

```
      NC(8)=19
      MC(8)=9
      DD(1)=.005
      DD(2)=.005
      DD(3)=.005
      DD(4)=4.
      DD(5)=.005
      DD(6)=4.
      GO TO 20
   10 MC(1)=10
      MC(2)=1
      MC(8)=1
      NC(1)=10
      NC(3)=1
      NC(3)=1
      NC(4)=1
      NC(6)=10
      NC(7)=10
      NC(8)=1
      DD(1)=0.
      DD(2)=.05
      DD(3)=.05
      DD(4)=10.
      DD(5)=.05
      DD(6)=10.
   20 READ(5,MESH)
      JJ=LA
C     CONSTANTS
      MC(3)=MC(2)
      MC(4)=MC(2)
      MC(5)=MC(2)
      MC(6)=MC(1)
      MC(7)=MC(1)
      NC(2)=NC(1)
      NC(5)=1
      WRITE(6,1001) NRUN,NRATE,EM,RMFLO,NC,MC,DD,MREAD,MRITE,KA,JA,JB
     1,KPLUME
      IF(LA.EQ.0) WRITE(6,1002)
      IF(LA.EQ.1) WRITE(6,1003)
      IF(LSYM.EQ.1) WRITE(6,1004)
      NC1=NC(1)
      NC2=NC(2)
      NC3=NC(3)
      NC4=NC(4)
      NC5=NC(5)
      NC6=NC(6)
      NC7=NC(7)
      NC8=NC(8)
      MC1=MC(1)
      MC2=MC(2)
      MC3=MC(3)
      MC4=MC(4)
      MC5=MC(5)
      MC6=MC(6)
      MC7=MC(7)
```

```
      MC8=MC(8)
      NREG(1)=0
      DO 30 LREG=2,8
   30 NREG(LREG)=NREG(LREG-1)+NC(LREG-1)
      NS(1,1)=2
      NS(1,2)=2
      NS(2,1)=2
      NS(2,2)=2
      NS(3,1)=2
      NS(3,2)=1
      NS(4,1)=2
      NS(4,2)=1
      NS(5,1)=2
      NS(5,2)=1
      NS(6,1)=2
      NS(6,2)=1
      NS(7,1)=2
      NS(7,2)=1
      NS(8,1)=1
      NS(8,2)=2
      NF(1,1)=NC1
      NF(1,2)=NC1-1
      NF(2,1)=NC2
      NF(2,2)=NC2-1
      NF(3,1)=NC3
      NF(3,2)=NC3-1
      NF(4,1)=NC4
      NF(4,2)=NC4
      NF(5,1)=NC5-1
      NF(5,2)=NC5-1
      NF(6,1)=NC6-1
      NF(6,2)=NC6-1
      NF(7,1)=NC7
      NF(7,2)=NC7-1
      NF(8,1)=NC8
      NF(8,2)=NC8-1
      MS(1,1)=1
      MS(1,2)=1
      MS(2,1)=1
      MS(2,2)=1
      MS(3,1)=1
      MS(3,2)=1
      MS(4,1)=1
      MS(4,2)=1
      MS(5,1)=1
      MS(5,2)=1
      MS(6,1)=1
      MS(6,2)=1
      MS(7,1)=1
      MS(7,2)=1
      MS(8,1)=1
      MS(8,2)=1
      MF(1,1)=MC1-1
      MF(1,2)=MC1-1
      MF(2,1)=MC2
```

```
      MF(2,2)=MC2-1
      MF(3,1)=MC3
      MF(3,2)=MC3
      MF(4,1)=MC4
      MF(4,2)=MC4
      MF(5,1)=MC5
      MF(5,2)=MC5
      MF(6,1)=MC6-1
      MF(6,2)=MC6-1
      MF(7,1)=MC7-1
      MF(7,2)=MC7-1
      MF(8,1)=MC8
      MF(8,2)=MC8-1
C     **************
C     THE FOLLOWING THREE CARDS MUST BE CHANGED ACCORDING TO DIMENSIONS
      NMAX=40
      NNMAX=150
      MMAX=19
C     **************
      GA=GAMMA/(GAMMA-1.)
      GB=1./(GAMMA-1.)
      GC=(GAMMA+1.)/(GAMMA-1.)
      GD=(GAMMA-1.)/2.
      GE=(GAMMA+1.)/2.
      GF=SQRT(GAMMA)
      Q0=GF*EM
      PII=4.*ATAN(1.)
      K=0
      J=0
      TIME=0.
      DT=1.
      DO 40 LREG=1,8
      IF(NC(LREG).LE.1) GO TO 35
      IF(MC(LREG).LE.1)GO TO 35
      DX(LREG)=1./FLOAT(NC(LREG)-1)
      DY(LREG)=1./FLOAT(MC(LREG)-1)
      GO TO 40
   35 DX(LREG)=0.
      DY(LREG)=0.
   40 CONTINUE
      DO 50 LREG=1,8
      DO 42 M=1,MMAX
   42 Y(M,LREG)=(M-1)*DY(LREG)
      DO 44 N=1,NMAX
   44 X(N,LREG)=(N-1)*DX(LREG)
   50 CONTINUE
      LSUB=0
      NTH=NC4/2
      NNTH=NREG(4)+NTH
      KPP=NC6
      CALL WALL(1,0.,YD,DUM,1)
      YA=YD
      CALL WALL(6,10.,YD,DUM,1)
      YE=YD
      XO=XE
```

```
      CALL WALL(7,XD,YD,CUM)
      PRAM=YD
      PDIST=XE
C     INITIALIZATION
      DO 60 N=1,NNMAX
      DO 60 M=1,MMAX
      P(N,M)=0.
      U(N,M)=0.
      V(N,M)=0.
      S(N,M)=0.
      PI(N,M)=0.
      UI(N,M)=0.
      VI(N,M)=0.
   60 SI(N,M)=0.
      NN4=NREG(4)+NC4
      DO 70 M=1,MC4
      P(NN4,M)=-2.3
   70 S(NN4,M)=0.
      WW=.5
      QINF=0.
      QINFN=0.
      XOTI(1)=0.
      XOTI(2)=0.
C
      CALL STRECH(8)
      IF(LSYM.NE.1) CALL SETNOS(LOUT1)
      IF(LOUT1.NE.0) CALL OUTPUN(1,1,3)
C
      GO TO 100
   80 CALL TAPER(MREAD,MRITE)
C     MAIN LOOP
  100 K=K+1
C     TIME STEPSIZE DETERMINATION
C     C-F-L RULE
      DT=1.
      DO 120 LREG=1,7
      DTT(LREG)=1.
      IF(LREG.EQ.5) GO TO 120
      NCC=NC(LREG)
      MCC=MC(LREG)
      MREG=1
      IF(LREG.EQ.1.OR.LREG.GE.6) MREG=2
      IF(LSYM.EQ.1.AND.MREG.EQ.1) GO TO 120
      DO 110 N=2,NCC
      NN=NREG(LREG)+N
      IF(MREG.EQ.2) GO TO 102
      M=MC2
      L=M
      GO TO 104
  102 M=1
      L=M+1
  104 A=GF*SQRT(EXP(P(NN,M)/GA+S(NN,M)/GAMMA))
      QPA=SQRT(U(NN,M)**2+V(NN,M)**2)+A
      DYR=ABS(YYP(NN,L)-YYP(NN,L-1))
      DXR=SQRT((XXP(NN)-XXP(NN-1))**2+(YYP(NN,M)-YYP(NN-1,M))**2)
```

```
      DS=AMIN1(DXR,DYR)
      DT1=STAB*DS/QPA
      DTT(LREG)=AMIN1(DTT(LREG),DT1)
      IF(MREG.EQ.1.AND.M.EQ.MC2) GO TO 102
  110 CONTINUE
  120 DT=AMIN1(DT,DTT(LREG))
      IF(K.LE.-1) DT=DT/2.
      IF((K/10)*10.EQ.K) WRITE(6,1005)K,(LREG,DTT(LREG),LREG=1,7)
      IF(DT.GT.1.E-5) GO TO 130
      CALL OUTPUN(9,-1,2)
      CALL EXIT
  130 DXX=DX(8)
      IF(LSYM.EQ.1) GO TO 150
      DYY=DY(8)
      M=1
      DTS1=1.
      DO 140 N=1,NC8
      NN=NREG(8)+N
      A=GF*SQRT(EXP(P(NN,M)/GA+S(NN,M)/GAMMA))
      QPA=SQRT(U(NN,M)**2+V(NN,M)**2)+A
      RDTH=R(N,M)*PII*DXX
      DRR=(CC-B(N))*DYY-(Y(M,8)-1.)*BPR(N)*PII*DXX
      DT1=STAB*AMIN1(DRR,RDTH)/QPA
  140 DTS1=AMIN1(DTS1,DT1)
      KDIVS=1+DT/DTS1
      DTS=DT/KDIVS
      IF((K/10)*10.EQ.K)WRITE(6,1005) K,KDIVS,DTS
  150 TIME=TIME+DT
C     ACCELERATION FUNCTION
      LACC=0
      IF(TIME.GE.1./WW)GO TO 160
      DUM=WW*PII*TIME
      XOTT(2)=-Q0*WW*PII*SIN(DUM)/2.
      QINFN=+Q0*.5*(1.-COS(DUM))
      GO TO 170
  160 LACC=1
      XOTT(2)=0.
      QINFN=Q0
  170 CONTINUE
C
      IF(LSUP.EQ.2) GO TO 180
      LSUP=0
      MSUP=0
  172 NNT=NREG(4)+NC4
      GO TO 176
  174 NNT=NNTH+3
      MSUP=1
  176 AS=GF*SQRT(EXP(P(NNT,MC4)/GA+S(NNT,MC4)/GAMMA))
      DUM=SQRT(U(NNT,MC4)**2+V(NNT,MC4)**2)/AS
      IF(DUM.GT.1.05) LSUP=LSUP+1
      IF(LSUP.EQ.0) GO TO 180
      IF(LSUP.EQ.1.AND.MSUP.EQ.0) GO TO 174
      IF(LSUP.EQ.1.AND.MSUP.EQ.1) GO TO 180
      NC4=NTH+3
      NC(4)=NC4
```

```
      NF(4,1)=NC4
      NF(4,2)=NC4
  180 CONTINUE
C
      IF(KPLUME.EQ.-1) GO TO 200
      IF((K/KPLUME)*KPLUME.NE.K) GO TO 200
      DO 190 N=1,NC6
      NN=NREG(6)+N
      PPL(N)=EXP(P(NN,1))
  190 XPL(N)=XXP(NN)
      CALL PLUME
      CALL STRECH(6)
  200 CONTINUE
C
      CALL POINT
      IF(LSYM.NE.1) CALL NOSE
C
      XOTT(1)=XOTT(2)
      QINF=QINFN
C
      IF(JA.EQ.-1) GO TO 210
      IF((K/JA)*JA.EQ.K) CALL OUTPUN(9,MB,1)
  210 IF(JB.EQ.-1) GO TO 220
      IF((K/JB)*JB.EQ.K) CALL OUTPUN(9,MB,2)
  220 IF(K.LT.KA)GO TO 100
      CALL TAPER(0,MRITE)
      IF(LOUT2.EQ.1) CALL OUTPUN(9,MB,2)
      STOP
      END

      SUBROUTINE TAPER(IREAD,IRITE)
      COMMON/BLK1/DUM1(3733)
      COMMON/BLK2/DUM2(22874)
      COMMON/BLK3/DUM3(3401)
      COMMON/BLK4/DUM4(2433)
      COMMON/BLK5/DUM5(402)
      COMMON/BLK6/DUM6(401)
      COMMON/BLK7/DUM7(1)
      COMMON/BLK8/DUM8(5)
      COMMON/BLK9/DUM9(6)
 1001 FORMAT(1X,10HTAPE READ ,I5)
 1002 FORMAT(1X,11HTAPE WRITE ,I5)
      IF(IREAD.EQ.0) GO TO 100
      REWIND 12
      DO 50 J=1,IREAD
      WRITE(6,1001)IREAD
   50 READ(12) DUM1,DUM2,DUM3,DUM4,DUM5,DUM6,DUM7,DUM8,DUM9
      RETURN
  100 IF(IRITE.EQ.0) RETURN
      IF(IRITE.EQ.-1) REWIND 12
      WRITE(6,1002)IRITE
      WRITE(11) DUM1,DUM2,DUM3,DUM4,DUM5,DUM6,DUM7,DUM8,DUM9
      RETURN
      END
```

```
      SUBROUTINE POINT
C     COMPUTES ALL INTERIOR AND BOUNDARY POINTS
      COMMON/BLK1/NC(8),MC(8),NC1,NC2,NC3,NC4,NC5,NC6,NC7,NC8,MC1,MC2
     1,MC3,MC4,MC5,MC6,MC7,MC8,NREG(8),NMC(2),MMC(80,2),NMAX,MMAX
     2,GAMMA,GA,GB,GC,GD,GE,GF,X(40,8),Y(19,8),XXP(130)
     3,YYP(130,19),HH,XE,YE,YA,XC,RO,RD,DMFLO,TT,CC,EM,PII
     4,SINTHE(20),COSTHE(20),R(20,19),LSYM,LA,DX(8),DY(8)
      COMMON/BLK2/P(150,19),U(150,19),V(150,19),S(150,19),PI(150,19)
     1,UI(150,19),VI(150,19),SI(150,19),NS(8,2),NF(8,2)
     2,MS(8,2),MF(8,2),TIME,DT,K,J,XOTT(2),QINF,QINFN,KDIVS,DTS
      COMMON/BLK3/YET(130,19),XCS(130),X0,X1,X2,X3,Y0,Y2,ALP(4),DD(6)
     1,BET(4),LSLP,HU(130),HL(130),HC(130),HUPR(130),HLPR(130),HCPR(130)
      DIMENSION POLD(80,19),UOLD(80,19),VOLD(80,19),SOLD(80,19)
      NR1=NC1
      NR2=NREG(2)+NC2
      NR3=NREG(3)+1
      NR7=NREG(7)+1
      NL8=(NC8+1)/2
      NM8=NREG(8)+NL8
      DO 20 L=1,2
      LREG=3
      IF(L.EQ.2) LREG=7
      NFIN=NC(LREG)
      MFIN=MC(LREG)
      DO 10 N=1,NFIN
      NM=(L-1)*NMAX+N
      NN=NREG(LREG)+N
      DO 10 M=1,MFIN
      POLD(NM,M)=P(NN,M)
      UOLD(NM,M)=U(NN,M)
      VOLD(NM,M)=V(NN,M)
   10 SOLD(NM,M)=S(NN,M)
   20 CONTINUE
      DO 1000 LMAC=1,2
      DO 405 LREG=1,7
      NSTA=NS(LREG,LMAC)
      NFIN=NF(LREG,LMAC)
      MSTA=MS(LREG,LMAC)
      MFIN=MF(LREG,LMAC)
      DXX=DX(LREG)
      DYY=DY(LREG)
      IF(LSYM.NE.1) GO TO 102
      IF(LREG.GT.1.AND.LREG.LT.6) GO TO 405
  102 CONTINUE
      DO 400 M=MSTA,MFIN
      L=M-1+LMAC
      IF(L.EQ.1)L=2
      IF(L.EQ.MC(LREG)+1)L=MC(LREG)
      YY=Y(M,LREG)
      DO 400 N=NSTA,NFIN
      IF(LREG.EQ.5) GO TO 400
  105 NN=NREG(LREG)+N
      IF(LSYM.EQ.1) GO TO 108
      IF(NN.EQ.NR1.AND.M.EQ.1) GO TO 400
      IF(NN.EQ.NR7.AND.M.EQ.1) GO TO 400
```

```
      IF(NN.EQ.NR2.AND.M.EQ.MC2) GO TO 400
      IF(NN.EQ.NR3.AND.M.EQ.MC3) GO TO 400
  108 CONTINUE
      I=NN-1+LMAC
      IF(LMAC.EQ.2.AND.N.EQ.NC(LREG)) I=NN
      XX=X(N,LREG)
      GO TO (110,120,130,140,150,160,170),LREG
C     COEFFICIENTS
  110 CSXP=1.
      ETYP=-1.
      ETXP=0.
      GO TO 200
  120 CSXP=1.
      ETYP=1./YA
      ETXP=0.
      GO TO 200
  130 CSXP=1./XC
      ETYP=1./HL(NN)
      ETA=YYP(NN,M)*ETYP
      ETXP=-ETA*HLPR(NN)*ETYP
      GO TO 200
  140 CSXP=1./(XE-XC)
      ETYP=1./(HL(NN)-HC(NN))
      ETA=(YYP(NN,M)-HC(NN))*ETYP
      ETXP=((ETA-1.)*HCPR(NN)-ETA*HLPR(NN))*ETYP
      GO TO 200
  150 CSXP=-1.
      ETYP=1./(YE-HC(NN))
      ETA=(YYP(NN,M)-HC(NN))*ETYP
      ETXP=(ETA-1.)*HCPR(NN)*ETYP
      GO TO 200
  160 CSXP=-1.
      ETYP=-1.
      ETXP=HUPR(NN)
      GO TO 200
  170 CSXP=1./XE
      ETYP=-1.
      ETXP=HUPR(NN)
  200 GO TO (225,250),LMAC
C     DERIVATIVES
  225 PY=(P(NN,L)-P(NN,L-1))/DYY
      UY=(U(NN,L)-U(NN,L-1))/DYY
      VY=(V(NN,L)-V(NN,L-1))/DYY
      SY=(S(NN,L)-S(NN,L-1))/DYY
      PX=(P(I,M)-P(I-1,M))/DXX
      UX=(U(I,M)-U(I-1,M))/DXX
      VX=(V(I,M)-V(I-1,M))/DXX
      SX=(S(I,M)-S(I-1,M))/DXX
      PP=P(NN,M)
      UU=U(NN,M)
      VV=V(NN,M)
      SS=S(NN,M)
      GO TO 300
  250 PY=(PI(NN,L)-PI(NN,L-1))/DYY
      UY=(UI(NN,L)-UI(NN,L-1))/DYY
```

```
      VY=(VI(NN,L)-VI(NN,L-1))/DYY
      SY=(SI(NN,L)-SI(NN,L-1))/DYY
      IF(LREG.NE.3) GO TO 255
      IF(LMAC.NE.2) GO TO 255
      IF(N.EQ.1) GO TO 255
      ACH =SQRT((U(NN ,M)**2+V(NN ,M)**2)/(GAMMA*EXP(P(NN ,M)/GA+S(NN ,M
     1)/GAMMA)))
      IF(ACH.GT.1.01) I=NN
  255 CONTINUE
      PX=(PI(I,M)-PI(I-1,M))/DXX
      UX=(UI(I,M)-UI(I-1,M))/DXX
      VX=(VI(I,M)-VI(I-1,M))/DXX
      SX=(SI(I,M)-SI(I-1,M))/DXX
      PP=PI(NN,M)
      UU=UI(NN,M)
      VV=VI(NN,M)
      SS=SI(NN,M)
      PO=P(NN,M)
      UO=U(NN,M)
      VO=V(NN,M)
      SO=S(NN,M)
  300 CONTINUE
      XP=XXP(NN)
      YP=YYP(NN,M)
      AA=CSXP*XCS(NN)
      AB=ETXP*YET(NN,M)
      AD=ETYP*YET(NN,M)
      AF=UU*AA
      AG=UU*AB+VV*AD
      AT=EXP(PP/GA+SS/GAMMA)
      AH=0.
        LAX=1
        IF(ABS(YP).LT.1.E-5)LAX=0
        MREG=1
        IF(LREG.LE.1.OR.LREG.GE.6) MREG=2
      IF(LA.NE.1) GO TO 310
      IF(LAX.EQ.0) AH=AD*VY
      IF(LAX.NE.0) AH=VV/YP
C     EQUATIONS
  310 PT=-(AF*PX+AG*PY+GAMMA*(AA*UX+AB*UY+AD*VY+AH))
      UT=-(AF*UX+AG*UY+AT*(AA*PX+AB*PY))-XOTT(LMAC)
      VT=-(AF*VX+AG*VY+AT*AD*PY)
      ST=-(AF*SX+AG*SY)
      GO TO (350,375),LMAC
  350 PI(NN,M)=PP+PT*DT
      UI(NN,M)=UU+UT*DT
      VI(NN,M)=VV+VT*DT
      SI(NN,M)=SS+ST*DT
      IF(MREG.EQ.1.AND.M.EQ.1) GO TO 360
      IF(MREG.EQ.1.AND.M.EQ.MC2) GO TO 362
      IF(MREG.EQ.2.AND.M.EQ.1) GO TO 364
      GO TO 400
  360 HPRI=HCPR(NN)
      GO TO 370
  362 IF(LREG.EQ.2) GO TO 400
```

```
      HPRI=HLPR(NN)
      GO TO 370
  364 IF(LREG.EQ.1.AND.LSYM.NE.1) GO TO 400
      HPRI=HUPR(NN)
  370 SQR=SQRT(1.+HPRI**2)
      TA1=1./SQR
      TA2=HPRI*TA1
      VW=UU*TA1+VV*TA2
      VWT=UT*TA1+VT*TA2
      VWI=VW+VWT*DT
      UI(NN,M)=VWI*TA1
      VI(NN,M)=VWI*TA2
      GO TO 400
  375 P(NN,M)=.5*(PP+PO+PT*DT)
      U(NN,M)=.5*(UU+UO+UT*DT)
      V(NN,M)=.5*(VV+VO+VT*DT)
      S(NN,M)=.5*(SS+SO+ST*DT)
      IF(MREG.EQ.1.AND.M.EQ.1) GO TO 380
      IF(MREG.EQ.1.AND.M.EQ.MC2) GO TO 382
      IF(MREG.EQ.2.AND.M.EQ.1) GO TO 384
      GO TO 395
  380 HPRI=HCPR(NN)
      GO TO 390
  382 IF(LREG.EQ.2 ) GO TO 395
      HPRI=HLPR(NN)
      GO TO 390
  384 IF(LREG.EQ.1.AND.LSYM.NE.1) GO TO 400
      HPRI=HUPR(NN)
  390 SQR=SQRT(1.+HPRI**2)
      TA1=1./SQR
      TA2=HPRI*TA1
      VW=UU*TA1+VV*TA2
      VWO=UO*TA1+VO*TA2
      VWT=UT*TA1+VT*TA2
      VWN=.5*(VW+VWO+VWT*DT)
      U(NN,M)=VWN*TA1
      V(NN,M)=VWN*TA2
  395 CONTINUE
  400 CONTINUE
  405 CONTINUE
C     CUSP POINT
      IF(LSYM.EQ.1.AND.LMAC.EQ.1) GO TO 500
      IF(LSYM.EQ.1.AND.LMAC.EQ.2) GO TO 600
      NA1=NC1-1
      MA3=MC3-1
      MM8=7
      YP=YYP(NR1,1)
      AH=0.
      GO TO (410,420),LMAC
  410 DXP=XXP(NR1)-R0+R(NL8,MM8)
      DYP=YYP(NR3,MC3)-YYP(NR3,MA3)
      PXP=(P(NR1,1)-P(NM8,MM8))/DXP
      UXP=(U(NR1,1)+U(NM8,MM8))/DXP
      VXP=(V(NR1,1)+V(NM8,MM8))/DXP
      SXP=(S(NR1,1)-S(NM8,MM8))/DXP
```

```
      PYP=(P(NR1,1)-P(NR3,MA3))/DYP
      UYP=(U(NR1,1)-U(NR3,MA3))/DYP
      VYP=(V(NR1,1)-V(NR3,MA3))/DYP
      SYP=(S(NR1,1)-S(NR3,MA3))/DYP
      PP=P(NR1,1)
      UU=U(NR1,1)
      VV=V(NR1,1)
      SS=S(NR1,1)
      GO TO 430
  420 DXP=XXP(NR1)-XXP(NA1)
      DYP=YYP(NR1,2)-YYP(NR1,1)
      PXP=(PI(NR1,1)-PI(NA1,1))/DXP
      UXP=(UI(NR1,1)-UI(NA1,1))/DXP
      VXP=(VI(NR1,1)-VI(NA1,1))/DXP
      SXP=(SI(NR1,1)-SI(NA1,1))/DXP
      PYP=(PI(NR1,2)-PI(NR1,1))/DYP
      UYP=(UI(NR1,2)-UI(NR1,1))/DYP
      VYP=(VI(NR1,2)-VI(NR1,1))/DYP
      SYP=(SI(NR1,2)-SI(NR1,1))/DYP
      PP=PI(NR1,1)
      UU=UI(NR1,1)
      VV=VI(NR1,1)
      SS=SI(NR1,1)
      PO=P(NR1,1)
      UO=U(NR1,1)
      VO=V(NR1,1)
      SO=S(NR1,1)
  430 IF(LA.NE.1) GO TO 440
      AH=VV/YP
  440 AT=EXP(PP/GA+SS/GAMMA)
      PT=-(UU*PXP+VV*PYP+GAMMA*(UXP+VYP+AH))
      UT=-(UU*UXP+VV*UYP+AT*PXP+XOTT(LMAC))
      VT=-(UU*VXP+VV*VYP+AT*PYP)
      ST=-(UU*SXP+VV*SYP)
      GO TO (450,460),LMAC
  450 PI(NR1,1)=PP+PT*DT
      UI(NR1,1)=UU+UT*DT
      VI(NR1,1)=VV+VT*DT
      SI(NR1,1)=SS+ST*DT
      PCC=PI(NR1,1)
      UCC=UI(NR1,1)
      VCC=VI(NR1,1)
      SCC=SI(NR1,1)
      PI(NR7,1)=PCC
      UI(NR7,1)=UCC
      VI(NR7,1)=VCC
      SI(NR7,1)=SCC
      PI(NR2,MC2)=PCC
      UI(NR2,MC2)=UCC
      VI(NR2,MC2)=VCC
      SI(NR2,MC2)=SCC
      PI(NR3,MC3)=PCC
      UI(NR3,MC3)=UCC
      VI(NR3,MC3)=VCC
      SI(NR3,MC3)=SCC
```

```
      GO TO 500
  460 P(NR1,1)=.5*(PP+PO+PT*DT)
      U(NR1,1)=.5*(UU+UO+UT*DT)
      V(NR1,1)=.5*(VV+VO+VT*DT)
      S(NR1,1)=.5*(SS+SO+ST*DT)
      PCC=P(NR1,1)
      UCC=U(NR1,1)
      VCC=V(NR1,1)
      SCC=S(NR1,1)
      P(NR7,1)=PCC
      U(NR7,1)=UCC
      V(NR7,1)=VCC
      S(NR7,1)=SCC
      P(NR2,MC2)=PCC
      U(NR2,MC2)=UCC
      V(NR2,MC2)=VCC
      S(NR2,MC2)=SCC
      P(NR3,MC3)=PCC
      U(NR3,MC3)=UCC
      V(NR3,MC3)=VCC
      S(NR3,MC3)=SCC
      GO TO 800
C     FREE STREAM
  500 CONTINUE
      DO 510 M=1,MC1
  510 UI(1,M)=QINF
      DO 520 N=1,NC1
  520 UI(N,MC1)=QINF
      NN2=NREG(2)+1
      DO 530 M=1,MC2
  530 UI(NN2,M)=QINF
      NN5=NREG(5)+NC5
      DO 540 M=1,MC5
  540 UI(NN5,M)=QINF
      NN6=NREG(6)+NC6
      DO 550 M=1,MC6
  550 UI(NN6,M)=QINF
      DO 560 N=1,NC6
      NN=NREG(6)+N
  560 UI(NN,MC6)=QINF
      DO 570 N=1,NC7
      NN=NREG(7)+N
  570 UI(NN,MC7)=QINF
  600 CONTINUE
C     INTERFACE A
      IF(ISYM.EQ.1) GO TO 615
        NC1L=NC1-1
      DO 610 N=1,NC1L
      NN=NREG(2)+N
      PI(N,1)=PI(NN,MC2)
      UI(N,1)=UI(NN,MC2)
      VI(N,1)=VI(NN,MC2)
  610 SI(N,1)=SI(NN,MC2)
C     INTERFACE B
  615 CONTINUE
```

```
      NN2=NREG(2)+NC2                                                   P 03240
      NN3=NREG(3)+1                                                     P 03250
      DO 620 M=1,MC2                                                    P 03260
      PI(NN3,M)=PI(NN2,M)                                               P 03270
      UI(NN3,M)=UI(NN2,M)                                               P 03280
      VI(NN3,M)=VI(NN2,M)                                               P 03290
  620 SI(NN3,M)=SI(NN2,M)                                               P 03300
C     INTERFACE C                                                       P 03310
      NN4=NREG(4)+NC4                                                   P 03320
      IF(LSUP.GT.0) GO TO 632                                           P 03330
      DO 630 M=1,MC4                                                    P 03340
      PI(NN4,M)=-2.3                                                    P 03350
  630 SI(NN4,M)=0.                                                      P 03360
      GO TO 638                                                         P 03370
  632 NN4L1=NN4-1                                                       P 03380
      NN4L2=NN4-2                                                       P 03390
      DO 635 M=1,MC4                                                    P 03400
      PI(NN4,M)=2.*PI(NN4L1,M)-PI(NN4L2,M)                              P 03410
      UI(NN4,M)=2.*UI(NN4L1,M)-UI(NN4L2,M)                              P 03420
      VI(NN4,M)=2.*VI(NN4L1,M)-VI(NN4L2,M)                              P 03430
  635 SI(NN4,M)=2.*SI(NN4L1,M)-SI(NN4L2,M)                              P 03440
  638 CONTINUE                                                          P 03450
C     INTERFACE E                                                       P 03460
      NN6=NREG(6)+1                                                     P 03470
      NN7=NREG(7)+NC7                                                   P 03480
      DO 650 M=1,MC6                                                    P 03490
      PI(NN6,M)=PI(NN7,M)                                               P 03500
      UI(NN6,M)=UI(NN7,M)                                               P 03510
      VI(NN6,M)=VI(NN7,M)                                               P 03520
  650 SI(NN6,M)=SI(NN7,M)                                               P 03530
C     INTERFACE F                                                       P 03540
      NN7=NREG(7)+1                                                     P 03550
      DO 660 M=1,MC7                                                    P 03560
      PI(NN7,M)=PI(NC1,M)                                               P 03570
      UI(NN7,M)=UI(NC1,M)                                               P 03580
      VI(NN7,M)=VI(NC1,M)                                               P 03590
  660 SI(NN7,M)=SI(NC1,M)                                               P 03600
C     INTERFACE G                                                       P 03610
      NN3=NREG(3)+NC3                                                   P 03620
      NN4=NREG(4)+1                                                     P 03630
      DO 670 M=1,MC3                                                    P 03640
      PI(NN4,M)=PI(NN3,M)                                               P 03650
      UI(NN4,M)=UI(NN3,M)                                               P 03660
      VI(NN4,M)=VI(NN3,M)                                               P 03670
  670 SI(NN4,M)=SI(NN3,M)                                               P 03680
      GO TO 1000                                                        P 03690
C     FREE STREAM                                                       P 03700
  800 CONTINUE                                                          P 03710
      DO 810 M=1,MC1                                                    P 03720
  810 U(1,M)=QINFN                                                      P 03730
      DO 820 N=1,NC1                                                    P 03740
  820 U(N,MC1)=QINFN                                                    P 03750
      NN2=NREG(2)+1                                                     P 03760
      DO 830 M=1,MC2                                                    P 03770
  830 U(NN2,M)=QINFN                                                    P 03780
```

```
      NN5=NREG(5)+NC5
      DO 840 M=1,MC5
  840 U(NN5,M)=QINFN
      NN6=NREG(6)+NC6
      DO 850 M=1,MC6
  850 U(NN6,M)=QINFN
      DO 860 N=1,NC6
      NN=NREG(6)+N
  860 U(NN,MC6)=QINFN
      DO 870 N=1,NC7
      NN=NREG(7)+N
  870 U(NN,MC7)=QINFN
  900 CONTINUE
C      INTERFACE A
      IF(LSYM.EQ.1) GO TO 915
      NC1L=NC1-1
      DO 910 N=1,NC1L
      NN=NREG(2)+N
      P(NN,MC2)=P(N,1)
      U(NN,MC2)=U(N,1)
      V(NN,MC2)=V(N,1)
  910 S(NN,MC2)=S(N,1)
C      INTERFACE B
  915 CONTINUE
      NN2=NREG(2)+NC2
      NN3=NREG(3)+1
      DO 920 M=1,MC2
      P(NN2,M)=P(NN3,M)
      U(NN2,M)=U(NN3,M)
      V(NN2,M)=V(NN3,M)
  920 S(NN2,M)=S(NN3,M)
C      INTERFACE C
      NN4=NREG(4)+NC4
      IF(LSUP.GT.0) GO TO 932
      DO 930 M=1,MC4
      P(NN4,M)=-2.3
  930 S(NN4,M)=0.
      GO TO 938
  932 NN4L1=NN4-1
      NN4L2=NN4-2
      DO 935 M=1,MC4
      P (NN4,M)=2.*P (NN4L1,M)-P (NN4L2,M)
      U (NN4,M)=2.*U (NN4L1,M)-U (NN4L2,M)
      V (NN4,M)=2.*V (NN4L1,M)-V (NN4L2,M)
  935 S(NN4,M)=2.*S(NN4L1,M)-S(NN4L2,M)
  938 CONTINUE
C      INTERFACE E
      NN6=NREG(6)+1
      NN7=NREG(7)+NC7
      DO 950 M=1,MC6
      P(NN7,M)=P(NN6,M)
      U(NN7,M)=U(NN6,M)
      V(NN7,M)=V(NN6,M)
  950 S(NN7,M)=S(NN6,M)
C      INTERFACE F
```

```
      NN7=NREG(7)+1
      DO 960 M=1,MC7
      P(NC1,M)=P(NN7,M)
      U(NC1,M)=U(NN7,M)
      V(NC1,M)=V(NN7,M)
  960 S(NC1,M)=S(NN7,M)
C     INTERFACE G
      NN3=NREG(3)+NC3
      NN4=NREG(4)+1
      DO 970 M=1,MC3
      P(NN3,M)=P(NN4,M)
      U(NN3,M)=U(NN4,M)
      V(NN3,M)=V(NN4,M)
  970 S(NN3,M)=S(NN4,M)
 1000 CONTINUE
      DO 1020 L=1,2
      LREG=3
      IF(L.EQ.2) LREG=7
      NFIN=NC(LREG)
      MFIN=MC(LREG)
      DO 1010 N=1,NFIN
      NM=(L-1)*NMAX+N
      NN=NREG(LREG)+N
      DO 1010 M=1,MFIN
      PI(NN,M)=PCLD(NM,M)
      UI(NN,M)=UCLD(NM,M)
      VI(NN,M)=VCLD(NM,M)
 1010 SI(NN,M)=SCLD(NM,M)
 1020 CONTINUE
      DO 1030 L=1,2
      LREG=3
      IF(L.EQ.2) LREG=4
      MFIN=MC(LREG)
      NFIN=NC(LREG)-1
      DO 1028 M=1,MFIN
      DO 1024 N=1,NFIN
      NN=NREG(LREG)+N
      ACH =SQRT((U(NN ,M)**2+V(NN ,M)**2)/(GAMMA*EXP(P(NN ,M)/GA+S(NN ,M
     1)/GAMMA)))
      IF(ACH.LT.1.01) GO TO 1024
      N1=N+1
      NL1=NN+1
      ACH1=SQRT((U(NL1,M)**2+V(NL1,M)**2)/(GAMMA*EXP(P(NL1,M)/GA+S(NL1,M
     1)/GAMMA)))
      IF(ACH1.LT.1.01) GO TO 1026
      GO TO 1024
 1026 N2=N+2
      NL2=NN+2
      P(NL1,M)=(P(NN,M)+P(NL2,M))/2.
      U(NL1,M)=(U(NN,M)+U(NL2,M))/2.
      V(NL1,M)=(V(NN,M)+V(NL2,M))/2.
      S(NL1,M)=(S(NN,M)+S(NL2,M))/2.
 1024 CONTINUE
 1028 CONTINUE
 1030 CONTINUE
```

```
      NN3=NREG(3)+NC3
      NN4=NREG(4)+1
      DO 1032 M=1,MC3
      P(NN3,M)=P(NN4,M)
      U(NN3,M)=U(NN4,M)
      V(NN3,M)=V(NN4,M)
 1032 S(NN3,M)=S(NN4,M)
      RETURN                                                            P   04630
      END                                                               P   04640
```

```
      SUBROUTINE NOSE                                                   NOS00010
      COMMON/BLK1/NC(8),MC(8),NC1,NC2,NC3,NC4,NC5,NC6,NC7,NC8,MC1,MC2   NOS00020
     1,MC3,MC4,MC5,MC6,MC7,MC8,NREG(8),NMC(2),MMC(80,2),NMAX,MMAX       NOS00030
     2,GAMMA,GA,GB,GC,GD,GE,GF,X(40,8),Y(19,8),XXP(130)                 NOS00040
     3,YYP(130,19),HH,XE,YE,YA,XC,RO,RD,EMFLO,TT,CC,EM,PII              NOS00050
     4,SINTHE(20),COSTHE(20),R(20,19),LSYM,LA,DX(8),DY(8)               NOS00060
      COMMON/BLK2/P(150,19),U(150,19),V(150,19),S(150,19),PI(150,19)    NOS00070
     1,UI(150,19),VI(150,19),SI(150,19),NS(8,2),NF(8,2)                 NOS00080
     2,MS(8,2),MF(8,2),TIME,DT,K,J,XOTT(2),QINF,QINFN,KDIVS,DTS         NOS00090
      COMMON/BLK4/EP1(20),EP2(20),EP3(100),EP4(100),EP5(38),EP6(38)     NOS00100
     1,NN1(20),NN2(20),M1(20),M2(20),M3(38),M4(38),L1(100),L3(100)      NOS00110
     2,I1(100),I2(100),JR(80,19),B(20),BPR(20)                          NOS00120
      DYY=DY(8)                                                         NOS00130
      DXX=DX(8)                                                         NOS00140
      DO 500 KS=1,KDIVS                                                 NOS00150
      DO 500 LMAC=1,2                                                   NOS00160
      XACL=(FLOAT(KS-2+LMAC)/FLOAT(KDIVS))*(XOTT(2)-XOTT(1))+XOTT(1)    NOS00170
      NSTA=NS(8,LMAC)                                                   NOS00180
      NFIN=NF(8,LMAC)                                                   NOS00190
      MSTA=MS(8,LMAC)                                                   NOS00200
      MFIN=MF(8,LMAC)                                                   NOS00210
      DO 150 M=MSTA,MFIN                                                NOS00220
      L=M-1+LMAC                                                        NOS00230
      IF(M.EQ.1) L=2                                                    NOS00240
      DO 150 N=NSTA,NFIN                                                NOS00250
      NN=NREG(8)+N                                                      NOS00260
      I=NN-1+LMAC                                                       NOS00270
      IF(I.EQ.NREG(8)+1) I=I+1                                          NOS00280
      RR=R(N,M)                                                         NOS00290
      AA=1./(CC-B(N))                                                   NOS00300
      AB=1./PII                                                         NOS00310
      AD=(Y(M,8)-1.)*BPR(N)*AA                                          NOS00320
      GO TO (25,50),LMAC                                                NOS00330
   25 PY=(P(NN,L)-P(NN,L-1))/DYY                                        NOS00340
      UY=(U(NN,L)-U(NN,L-1))/DYY                                        NOS00350
      VY=(V(NN,L)-V(NN,L-1))/DYY                                        NOS00360
      SY=(S(NN,L)-S(NN,L-1))/DYY                                        NOS00370
      PX=(P(I,M)-P(I-1,M))/DXX                                          NOS00380
      UX=(U(I,M)-U(I-1,M))/DXX                                          NOS00390
      VX=(V(I,M)-V(I-1,M))/DXX                                          NOS00400
      SX=(S(I,M)-S(I-1,M))/DXX                                          NOS00410
      PP=P(NN,M)                                                        NOS00420
      UU=U(NN,M)                                                        NOS00430
      VV=V(NN,M)                                                        NOS00440
      SS=S(NN,M)                                                        NOS00450
```

```
      GO TO 160
   50 PY=(PI(NN,L)-PI(NN,L-1))/DYY
      UY=(UI(NN,L)-UI(NN,L-1))/DYY
      VY=(VI(NN,L)-VI(NN,L-1))/DYY
      SY=(SI(NN,L)-SI(NN,L-1))/DYY
      PX=(PI(I,M)-PI(I-1,M))/DXX
      UX=(UI(I,M)-UI(I-1,M))/DXX
      VX=(VI(I,M)-VI(I-1,M))/DXX
      SX=(SI(I,M)-SI(I-1,M))/DXX
      PP=PI(NN,M)
      UU=UI(NN,M)
      VV=VI(NN,M)
      SS=SI(NN,M)
  160 AE=UU*AA+VV/RR*AD
      AF=VV/RR*AB
      AT=EXP(PP/GA+SS/GAMMA)
      AK=(UU*SINTHE(N)+VV*COSTHE(N))/(HH+RR*SINTHE(N))
      PT=-(AE*PY+AF*PX+GAMMA*(AA*UY+UU/RR+AB*VX/RR+AD*VY/RR))
      IF(LA.EQ.1)PT=PT-GAMMA*AK
      UT=-(AE*UY+AF*UX-VV**2/RR+AT*AA*PY+XACC*COSTHE(N))
      VT=-(AE*VY+AF*VX+UU*VV/RR+AT*(AB*PX+AD*PY)/RR
     1-XACC*SINTHE(N))
      ST=-(AE*SY+AF*SX)
      GO TO (110,120),LMAC
  110 PI(NN,M)=PP+PT*DTS
      UI(NN,M)=UU+UT*DTS
      VI(NN,M)=VV+VT*DTS
      SI(NN,M)=SS+ST*DTS
      IF(M.NE.1) GO TO 150
      SQR=SQRT(1.+(BPR(N)/B(N))**2)
      TA2=1./SQR
      TA1=TA2*BPR(N)/B(N)
      VW=UU*TA1+VV*TA2
      VWT=UT*TA1+VT*TA2
      VWN=VW+VWT*DTS
      UI(NN,M)=VWN*TA1
      VI(NN,M)=VWN*TA2
      GO TO 150
  120 P(NN,M)=.5*(PP+P(NN,M)+PT*DTS)
      S(NN,M)=.5*(SS+S(NN,M)+ST*DTS)
      IF(M.EQ.1) GO TO 140
      U(NN,M)=.5*(UU+U(NN,M)+UT*DTS)
      V(NN,M)=.5*(VV+V(NN,M)+VT*DTS)
      GO TO 150
  140 SQR=SQRT(1.+(BPR(N)/B(N))**2)
      TA2=1./SQR
      TA1=TA2*BPR(N)/B(N)
      VW=U(NN,M)*TA1+V(NN,M)*TA2
      VWI=UU*TA1+VV*TA2
      VWT=UT*TA1+VT*TA2
      VWN=.5*(VW+VWI+VWT*DTS)
      U(NN,M)=VWN*TA1
      V(NN,M)=VWN*TA2
  150 CONTINUE
  200 CONTINUE
```

```
C     INTERPOLATION AT OUTER BOUNDARY  R.C
      DEL=FLOAT(KS)/FLOAT(KDIVS)
      MA8=MC8-1
      NA8=NC8-1
      DO 300 N=2,NA8
      LL1=NN1(N)
      LL2=NN2(N)
      J1=M1(N)
      J2=M2(N)
      EPS1=EP1(N)
      EPS2=EP2(N)
      NN=NREG(8)+N
      P1=DEL*(P(LL1,J1)-PI(LL1,J1))+PI(LL1,J1)
      U1=DEL*(U(LL1,J1)-UI(LL1,J1))+UI(LL1,J1)
      V1=DEL*(V(LL1,J1)-VI(LL1,J1))+VI(LL1,J1)
      S1=DEL*(S(LL1,J1)-SI(LL1,J1))+SI(LL1,J1)
      P2=DEL*(P(LL2,J2)-PI(LL2,J2))+PI(LL2,J2)
      U2=DEL*(U(LL2,J2)-UI(LL2,J2))+UI(LL2,J2)
      V2=DEL*(V(LL2,J2)-VI(LL2,J2))+VI(LL2,J2)
      S2=DEL*(S(LL2,J2)-SI(LL2,J2))+SI(LL2,J2)
      PB=P1+EPS1*(P2-P1)
      UB=U1+EPS1*(U2-U1)
      VB=V1+EPS1*(V2-V1)
      SB=S1+EPS1*(S2-S1)
      UC=U(NN,MA8)*COSTHE(N)-V(NN,MA8)*SINTHE(N)
      VC=U(NN,MA8)*SINTHE(N)+V(NN,MA8)*COSTHE(N)
      P(NN,MC8)=P(NN,MA8)+EPS2*(PB-P(NN,MA8))
      S(NN,MC8)=S(NN,MA8)+EPS2*(SB-S(NN,MA8))
      UA=UC+EPS2*(UB-UC)
      VA=VC+EPS2*(VB-VC)
      U(NN,MC8)=UA*COSTHE(N)+VA*SINTHE(N)
  300 V(NN,MC8)=-UA*SINTHE(N)+VA*COSTHE(N)
      DO 490 L=1,2
      IF(L.EQ.2) GO TO 410
      LREG=7
      NAA=1
      NCC=2
      GO TO 420
  410 LREG=3
      NAA=NC8
      NCC=NC8-1
  420 NNB=NREG(LREG)+NNC(L)
      NNA=NREG(8)+NAA
      NLC=NREG(8)+NCC
      DO 450 M=1,MC8
      MR=(L-1)*MMAX+M
      MM3=M3(MR)
      MM4=M4(MR)
      EPS5=EP5(MR)
      EPS6=EP6(MR)
      P3=DEL*(P(NNB,MM3)-PI(NNB,MM3))+PI(NNB,MM3)
      U3=DEL*(U(NNB,MM3)-UI(NNB,MM3))+UI(NNB,MM3)
      V3=DEL*(V(NNB,MM3)-VI(NNB,MM3))+VI(NNB,MM3)
      S3=DEL*(S(NNB,MM3)-SI(NNB,MM3))+SI(NNB,MM3)
      P4=DEL*(P(NNB,MM4)-PI(NNB,MM4))+PI(NNB,MM4)
```

```
      U4=DEL*(U(NNB,MM4)-UI(NNB,MM4))+UI(NNB,MM4)                       NOS01560
      V4=DEL*(V(NNB,MM4)-VI(NNB,MM4))+VI(NNB,MM4)                       NOS01570
      S4=DEL*(S(NNB,MM4)-SI(NNB,MM4))+SI(NNB,MM4)                       NOS01580
      PB=P3+EPS5*(P4-P3)                                                NOS01590
      UB=U3+EPS5*(U4-U3)                                                NOS01600
      VB=V3+EPS5*(V4-V3)                                                NOS01610
      SB=S3+EPS5*(S4-S3)                                                NOS01620
      UC=U(NLC,M)*COSTHE(NCC)-V(NLC,M)*SINTHE(NCC)                      NOS01630
      VC=U(NLC,M)*SINTHE(NCC)+V(NLC,M)*COSTHE(NCC)                      NOS01640
      P(NNA,M)=P(NLC,M)+EPS6*(PB-P(NLC,M))                              NOS01650
      S(NNA,M)=S(NLC,M)+EPS6*(SB-S(NLC,M))                              NOS01660
      UA=UC+EPS6*(UB-UC)                                                NOS01670
      VA=VC+EPS6*(VB-VC)                                                NOS01680
      U(NNA,M)=UA*COSTHE(NAA)+VA*SINTHE(NAA)                            NOS01690
  450 V(NNA,M)=-UA*SINTHE(NAA)+VA*COSTHE(NAA)                           NOS01700
  490 CONTINUE                                                          NOS01710
      DO 498 M=1,MCB
      DO 492 N=3,NCB
      NN=NREG(8)+N
      ACH =SQRT((U(NN ,M)**2+V(NN ,M)**2)/(GAMMA*EXP(P(NN ,M)/GA+S(NN ,M
     1)/GAMMA)))
      IF(ACH.LT.1.01) GO TO 492
      N1=N-1
      NL1=NN-1
      ACH1=SQRT((U(NL1,M)**2+V(NL1,M)**2)/(GAMMA*EXP(P(NL1,M)/GA+S(NL1,M
     1)/GAMMA)))
      IF(ACH1.LT.1.01) GO TO 494
  492 CONTINUE
      GO TO 499
  494 N2=N-2
      NL2=NN-2
      UCN =U(NN,M)*COSTHE(N)-V(NN,M)*SINTHE(N)
      VCN =U(NN,M)*SINTHE(N)+V(NN,M)*COSTHE(N)
      UCN2=U(NL2,M)*COSTHE(N2)-V(NL2,M)*SINTHE(N2)
      VCN2=U(NL2,M)*SINTHE(N2)+V(NL2,M)*COSTHE(N2)
      P(NL1,M)=(P(NN,M)+P(NL2,M))/2.
      S(NL1,M)=(S(NN,M)+S(NL2,M))/2.
      UCN1=(UCN+UCN2)/2.
      VCN1=(VCN+VCN2)/2.
      U(NL1,M)=UCN1*COSTHE(N1)+VCN1*SINTHE(N1)
      V(NL1,M)=-UCN1*SINTHE(N1)+VCN1*COSTHE(N1)
  498 CONTINUE
  499 CONTINUE
  500 CONTINUE                                                          NOS01720
C     INTERPOLATION AT INTERIOR POINTS                                  NOS01730
      DO 700 L=1,2                                                      NOS01740
      NSTA=2                                                            NOS01750
      NFIN=NNC(L)-1                                                     NOS01760
      DO 700 N=NSTA,NFIN                                                NOS01770
      NR=(L-1)*NMAX+N                                                   NOS01780
      IF(L.EQ.2) GO TO 520                                              NOS01790
      NN=NREG(7)+N                                                      NOS01800
      MFIN=MMC(NR+1)-1                                                  NOS01810
      MSTA=1                                                            NOS01820
      GO TO 530                                                         NOS01830
```

```
 520 MSTA=MMC(NR,2)+1
     MFIN=MC3
     NN=NREG(3)+N
 530 DO 700 M=MSTA,MFIN
     JJ=JR(NR,M)
     LL1=L1(JJ)
     LL3=L3(JJ)
     II1=I1(JJ)
     II2=I2(JJ)
     EPS3=EP3(JJ)
     EPS4=EP4(JJ)
     LJ1=LL1-NREG(A)
     LJ3=LL3-NREG(A)
     U1C=U(LL1,II1)*COSTHE(LJ1)-V(LL1,II1)*SINTHE(LJ1)
     U2C=U(LL1,II2)*COSTHE(LJ1)-V(LL1,II2)*SINTHE(LJ1)
     U3C=U(LL3,II1)*COSTHE(LJ3)-V(LL3,II1)*SINTHE(LJ3)
     U4C=U(LL3,II2)*COSTHE(LJ3)-V(LL3,II2)*SINTHE(LJ3)
     V1C=U(LL1,II1)*SINTHE(LJ1)+V(LL1,II1)*COSTHE(LJ1)
     V2C=U(LL1,II2)*SINTHE(LJ1)+V(LL1,II2)*COSTHE(LJ1)
     V3C=U(LL3,II1)*SINTHE(LJ3)+V(LL3,II1)*COSTHE(LJ3)
     V4C=U(LL3,II2)*SINTHE(LJ3)+V(LL3,II2)*COSTHE(LJ3)
     PB=P(LL1,II2)+EPS3*(P(LL1,II2)-P(LL1,II2))
     UB=U2C+EPS3*(U4C-U2C)
     VB=V2C+EPS3*(V4C-V2C)
     SB=S(LL1,II2)+EPS3*(S(LL1,II2)-S(LL1,II2))
     PC=P(LL1,II1)+EPS3*(P(LL3,II1)-P(LL1,II1))
     UC=U1C+EPS3*(U3C-U1C)
     VC=V1C+EPS3*(V3C-V1C)
     SC=S(LL1,II1)+EPS3*(S(LL3,II1)-S(LL1,II1))
     P(NN,M)=PB+EPS4*(PC-PB)
     S(NN,M)=SB+EPS4*(SC-SB)
     U(NN,M)=UB+EPS4*(UC-UB)
     V(NN,M)=VB+EPS4*(VC-VB)
 700 CONTINUE
     RETURN
     END
```

```
      SUBROUTINE PLUBO(X,Y,YPR)
      COMMON/BLK5/XP(200),YP(200),KE,LITE
      DIMENSION A(200),B(200)
      DIMENSION AW(20)
      DATA LAMP/ /
      DATA LIPE/ /
  100 FORMAT(20A4)
  101 FORMAT(2F10.4)
  102 FORMAT(1X,3I4,4E16.4)
  103 FORMAT(10I5)
       IF(LAMP.EQ.0) LITE=LIPE
       IF(LAMP.EQ.1.AND.LITE.NE.1) GO TO 50
       IF(LITE.EQ.1) GO TO 25
      READ(5,100) AW
      WRITE(6,100) AW
      XP(1)=1.
      YP(1)=.5
      READ(5,103) KK
      WRITE(6,103) KK
      KK1=KK+1
      DO 10 K=2,KK1
      READ(5,101)          XPP,YPP
      IF(EOF(5))20,2
    2 CONTINUE
      XP(K)=XPP/2.+1.
      YP(K)=YPP/2.
      WRITE(6,101) XPP,YPP
   10 CONTINUE
   20 KEND=KK1
      GO TO 29
   25 KEND=KE
      LITE=2
   29 IF(KEND.LT.3) GO TO 40
      KEND1=KEND-1
      KENDP=KEND+1
      A(2)=((YP(3)-YP(2))/(XP(3)-XP(2))-(YP(1)-YP(2))
     1/(XP(1)-XP(2)))/(XP(3)-XP(1))
      B(2)=(YP(1)-YP(2)-A(2)*(XP(1)-XP(2))**2)/(XP(1)-XP(2))
      IF(KEND1.LT.3) GO TO 35
      DO 30 K=3,KEND1
      B(K)=2.*A(K-1)*(XP(K)-XP(K-1))+B(K-1)
   30 A(K)=((YP(K+1)-YP(K))-B(K)*(XP(K+1)-XP(K)))/(XP(K+1)
     1-XP(K))**2
   35 XP(KENDP)=XP(KEND)+1.
      B(KEND)=2.*A(KEND1)*(XP(KEND)-XP(KEND1))+B(KEND1)
      A(KEND)=-B(KEND)/(2.*(XP(KENDP)-XP(KEND)))
      XEND=XP(KENDP)
      YEND=A(KEND)*(XEND-XP(KEND))**2+B(KEND)*(XEND-XP(KEND))+YP(KEND)
      WRITE(6,102)(K,LAMP,LITE,XP(K),YP(K),A(K),B(K),K=2,KEND)
   40 LAMP=1
   50 IF(KEND.LT.3) GO TO 80
      IF(X.GE.XEND) GO TO 75
      DO 60 K=3,KENDP
      IF(X.LT.XP(K)) GO TO 70
   60 CONTINUE
```

```
   70 LL=K-1
      Y=A(LL)*(X-XP(LL))**2+B(LL)*(X-XP(LL))+YP(LL)
      YPR=2.*A(LL)*(X-XP(LL))+B(LL)
      RETURN
   75 Y=YEND
      YPR=0.
      RETURN
   80 Y=YP(1)
      YPR=0.
      RETURN
      END

      SUBROUTINE OUTP
      COMMON/BLK7/R(30,2),U(30,2),W(30,2),P(30,2),S(30,2),PN(30,2)
     1,UN(30,2),WN(30,2),SN(30,2),T(30,2),PO(30,2),UO(30,2),WO(30,2)
     2,SO(30,2),MA,KA,GAMMA,GA,GB,GC,GD,GE,GF,GG,PI,TTOT
     3,DZ,K,DX(2),DDX(2),NCM,C(2),B(2),CN(2),BN(2),I,IA,NA(2),BZ(2)
     4,CZ(2),X(3 ,2),SOF,BETAF,Z,NASAVE,ZN,L1,NSO,NS,KOUNT,DPMAXO
      COMMON/BLK2/PRATIO,PRIST,PRAD,KPLUME,JJ
 1001 FORMAT(///4X,15HPLUME STRUCTURE /4X,5HXSTEP,I5,5X,2HX=
     1,F8.3,5X,3HDX=,E12.4,//9X,1HY,9X,1HP,9X,1HV,9X,1HU,8X,3HTAU
     2,8X,1HM,9X,1HS,9X,1HT)
 1002 FORMAT(4X,6HREGION ,I4)
 1003 FORMAT(I3,11F10.5)
      WRITE(6,1001)K,Z,DZ
      DO 10 I=1,IA
      WRITE(6,1002)I
      NC=NA(I)+1
      IF(I.EQ.1)NC=NC+1
      DO 10 N=1,NC
      IF(I*N.EQ.1)GO TO 10
      TAU=U(N,I)/W(N,I)
      AMACH=SQRT((U(N,I)**2+W(N,I)**2)/GAMMA/T(N,I))
      PRES=EXP(P(N,I))
      WRITE(6,1003)N,R(N,I),PRES,U(N,I),W(N,I),TAU,AMACH,S(N,I),T(N,I)
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PLUME                                                  PLU00010
C     PLUME DECK                                                        PLU00020
      COMMON/BLK7/R(30,2),U(30,2),W(30,2),P(30,2),S(30,2),PN(30,2)      PLU00030
     1,UN(30,2),WN(30,2),SN(30,2),T(30,2),PO(30,2),UO(30,2),WO(30,2)    PLU00040
     2,SO(30,2),MA,KA,GAMMA,GA,GB,GC,GD,GE,GF,GG,PI,TTOT                PLU00050
     3,DZ,K,DX(2),DDX(2),NAM,C(2),B(2),CN(2),BN(2),I,IA,NA(2),BZ(2)     PLU00060
     4,CZ(2),X(30,2),SQF,BETAF,Z,NASAVE,ZN,L1,NSO,NS,KOUNT,DPMAXO       PLU00070
      COMMON/BLK8/PRATIO,PDIST,PRAD,KPLUME,JJ                           PLU00080
      COMMON/BLK5/ZP(200),RP(200),KP,LITE                               PLU00090
      DIMENSION RK(200),PK(200),UK(200),WK(200)                         PLU00110
      NAMELIST/JET/NA,MA,KA,KOUT,PRATIO,PDIST,GAMMA,STAB,ACH,TTOT,KMAP  PLU00100
      DATA LAMP/0/                                                      PLU00120
 1001 FORMAT(///4X,16HPLUME INPUT DATA //4X,7HPRATIO=,F6.3,5X,5HMACH=   PLU00130
     1,F6.3,5X,5HTTOT=,F8.3//4X,6HNA(1)=,I2,5X,6HNA(2)=,I2,5X,3HMA=     PLU00140
     2,I2,5X,3HKA=,I4,5X,5HKOUT=,I4,5X,5HKMAP=,I4/4X,5HDIST=,F6.3       PLU00150
     3,5X,6HGAMMA=,F6.3,5X,5HSTAB=,F6.3)                                PLU00160
 1002 FORMAT(///4X,14HPLUME BOUNDARY //11X,1HX,9X,1HY)                  PLU00170
 1003 FORMAT(1X,I4,2F10.5)                                              PLU00180
      IF(LAMP.NE.0) GO TO 10                                            PLU00190
      NA(1)=20                                                          PLU00200
      NA(2)=15                                                          PLU00210
      MA=10                                                             PLU00220
      KA=100                                                            PLU00230
      DIST=5.                                                           PLU00240
      GAMMA=1.4                                                         PLU00250
      STAB=1.                                                           PLU00260
      ACH=3.                                                            PLU00270
      KMAP=-1                                                           PLU00280
      READ(5,JET)                                                       PLU00290
      WRITE(6,1001) PRATIO,ACH,TTOT,NA,MA,KA,KOUT,KMAP,DIST,GAMMA,STAB  PLU00300
      LAMP=1                                                            PLU00310
      NA1=NA(1)
      NA2=NA(2)
   10 CONTINUE                                                          PLU00320
      NA(1)=NA1
      NA(2)=NA2
      LITE=1                                                            PLU00330
      LL=1                                                              PLU00340
      NS=3                                                              PLU00350
      NSO=3                                                             PLU00360
      DPMAXO=0.                                                         PLU00370
      KOUNT=0                                                           PLU00380
      ZP(1)=PDIST                                                       PLU00390
      CP(1)=PRAD                                                        PLU00400
      NASAVE=NA(2)                                                      PLU00410
      GB=1./(GAMMA-1.)                                                  PLU00420
      GA=GAMMA*GB                                                       PLU00430
      GD=.5/GB                                                          PLU00440
      GE=1.+GD                                                          PLU00450
      GC=GE/GD                                                          PLU00460
      GF=SQRT(GAMMA)                                                    PLU00470
      GG=SQRT(GC)                                                       PLU00480
      PI=4.*ATAN(1.)                                                    PLU00490
      ZN=PDIST                                                          PLU00500
      CALL BOUND(ZN,RDUM)                                               PLU00510
```

```
      PA=PDUM
      TTOT=1.+GD*ACH**2
      P0=TTOT**GA
      SMF=(TTOT*EXP(-PA/GA)-1.)/GD
      DZ=.05
      DUM=(SMF-ACH**2)/200.
      DO 20 K=1,200
      DOM=K*DUM
      DEM=SQRT(DOM)
      SMK=ACH**2+DOM
      C11=ACH**2-1.
      C22=SMK-1.
      ENUN=GG*ATAN(SQRT(C11/GC))-ATAN(SQRT(C11))
      ENUK=GG*ATAN(SQRT(C22/GC))-ATAN(SQRT(C22))-ENUN
      PSIK=ENUK-ATAN(1./SQRT(C22))
      DIM=1.+GD*SMK
      RK(K)=PRAD+DZ*TAN(PSIK)
      PK(K)=GA*ALOG(TTOT/DIM)
      QK=SQRT(GAMMA*GE*SMK/DIM)
      WK(K)=QK*COS(ENUK)
      UK(K)=QK*SIN(ENUK)
   20 CONTINUE
      RF=PRAD+DZ*TAN(ENUK)
      DR=RF/NA(1)
      NC=NA(1)+2
      NCM=NC-1
      DDX(1)=NA(1)
      DX(1)=1./DDX(1)
      DO 80 N=2,NC
      R(N,1)=(N-2)*DR
      X(N,1)=(N-2)*DX(1)
      IF(R(N,1).GT.RK(1))GO TO 30
      K=1
      EPS=0.
      UK(K)=0.
      WK(K)=ACH*GF
      PK(K)=0.
      GO TO 70
   30 IF(R(N,1).LT.RK(200))GO TO 40
      K=199
      EPS=1.
      GO TO 70
   40 DO 50 K=1,199
      IF((R(N,1)-RK(K))*(R(N,1)-RK(K+1)).LE.0.)GO TO 60
   50 CONTINUE
   60 EPS=(R(N,1)-RK(K))/(RK(K+1)-RK(K))
   70 U(N,1)=UK(K)+EPS*(UK(K+1)-UK(K))
      W(N,1)=WK(K)+EPS*(WK(K+1)-WK(K))
      P(N,1)=PK(K)+EPS*(PK(K+1)-PK(K))
      S(N,1)=0.
      X(N,1)=DX(1)*(N-2)
   80 T(N,1)=EXP(P(N,1)/GA+S(N,1)/GAMMA)
      U(1,1)=-U(3,1)
      W(1,1)=W(3,1)
      S(1,1)=S(3,1)
```

```
      P(1,1)=P(3,1)
      T(1,1)=T(3,1)
      BETAF=SQRT(SMF-1.)
      SQF=-SMF*GAMMA*T(NC,1)
      U(2,1)=0.
      K=0
      Z=DZ+PDIST
      IA=1
      B(1)=0.
      U(1,1)=-U(3,1)
      X(1,1)=-DX(1)
      BZ(1)=0.
      C(1)=R(NC,1)
      CZ(1)=(C(1)-PRAD)/DZ
      CALL OUTP
      LL=0
  100 K=K+1
      LL=LL+1
      DZ=1.
      DO 110 I=1,IA
      NC=NA(I)+1
      IF(I.EQ.1)NC=NC+1
      DO 110 N=1,NC
      DEN=W(N,I)**2-GAMMA*T(N,I)
      DUM=SQRT((U(N,I)**2+W(N,I)**2)/GAMMA/T(N,I)-1.)
      DIM=(-BZ(I)-X(N,I)*(CZ(I)-BZ(I)))
      DEM=ABS(DIM+(U(N,I)*W(N,I)+GAMMA*T(N,I)*DUM)/DEN)
      DAM=ABS(DIM+(U(N,I)*W(N,I)-GAMMA*T(N,I)*DUM)/DEN)
      IF(DAM.GT.DEM) DEM=DAM
      DZ1=STAB*UX(I)*(C(I)-B(I))/DEM
      IF(DZ1.GT.DZ)GO TO 110
      DZ=DZ1
  110 CONTINUE
      IF(DZ.GT.1.E-8)GO TO 120
      CALL OUTP
      STOP
  120 ZN=Z+DZ
      CALL SUPER
      ZP(LL)=ZN
      CP(LL)=C(IA)
  130 CONTINUE
      IF((K/KOUT)*KOUT.EQ.K) CALL OUTP
      IF(Z.LT.DIST.AND.K.LE.KA) GO TO 100
      KP=LL
      WRITE(6,1002)
      WRITE(6,1003)(KK,ZP(KK),CP(KK),KK=1,KP)
      RETURN
      END
```

```
      SUBROUTINE SUPER
      COMMON/BLK7/R(30,2),U(30,2),W(30,2),P(30,2),S(30,2),PN(30,2)
     1,UN(30,2),WN(30,2),SN(30,2),T(30,2),PO(30,2),UO(30,2),WO(30,2)
     2,SO(30,2),MA,KA,GAMMA,GA,GB,GC,GD,GE,GF,GG,PI,TTOT
     3,DZ,K,DX(2),DDX(2),NCM,C(2),B(2),CN(2),BN(2),I,IA,NA(2),BZ(2)
     4,CZ(2),X(30,2),SOF,BETAF,Z,NASAVE,ZN,L1,NSO,NS,KOUNT,DPMAXO
      COMMON/BLK2/PRATIO,PRIST,PRAD,KPLUME,JJ
      DIMENSION PR(30),D2P(40),CO(2),TRY(2),ERR(2)
 1001 FORMAT(1X,30HWARNING, ITERATION FAILS AT K=,I5,2X,2HZ=,F10.5)
 1002 FORMAT(20I5)
      PBOUN=P(NC,IA)
      IF(JJ.EQ.0) GO TO 60
      IF(L1.EQ.1) GO TO 60
      DPMAX=.0
      NC=NA(1)+2
      DO 10 N=4,NC
      PGR=P(N,1)-P(N-1,1)
      IF(PGR.LT.DPMAX) GO TO 10
      DPMAX=PGR
      NS=N
   10 CONTINUE
      IF(NS.NE.NSO) KOUNT=0
      IF(NS.NE.NSO) GO TO 60
      IF(DPMAX.LT.DPMAXO) GO TO 60
      KOUNT=KOUNT+1
      IF(KOUNT.LT.3)GO TO 60
   20 CONTINUE
      CALL OUTP
      IA=2
      NCSA=NA(1)+2
      NA(1)=NS-3
      NC=NA(1)+2
      DDX(1)=NA(1)
      DX(1)=1./DDX(1)
      C(2)=C(1)
      CZ(2)=CZ(1)
      C(1)=R(NC,1)
      CZ(1)=(U(NC,1)*W(NC,1)-GAMMA*T(NC,1)*SQRT((U(NC,1)**2+W(NC,1)**2
     1)/GAMMA/T(NC,1)-1.))/(W(NC,1)**2-GAMMA*T(NC,1))
      BZ(2)=CZ(1)
      B(2)=C(1)
      NC=NA(2)+1
      DDX(2)=NA(2)
      DX(2)=1./DDX(2)
      DO 40 N=1,NC
      X(N,2)=DX(2)*(N-1)
      R(N,2)=B(2)+(C(2)-B(2))*X(N,2)
      NSM=NS-1
      IPRO=0
      DO 30 NN=NSM,NCSA
      DUM=R(N,2)-R(NN,1)
      IF(IPRO.EQ.1) GO TO 30
      IF(DUM.GT.0.0) GO TO 30
      EP=(R(N,2)-R(NN-1,1))/(R(NN,1)-R(NN-1,1))
      P(N,2)=P(NN-1,1)+EP*(P(NN,1)-P(NN-1,1))
```

```
      U(N,2)=U(NN-1,1)+EP*(U(NN,1)-U(NN-1,1))
      W(N,2)=W(NN-1,1)+EP*(W(NN,1)-W(NN-1,1))
      S(N,2)=S(NN-1,1)+EP*(S(NN,1)-S(NN-1,1))
      T(N,2)=EXP(P(N,2)/GA+S(N,2)/GAMMA)
      IPPO=1
   30 CONTINUE
   40 CONTINUE
      NC=NA(1)+2
      DO 50 N=2,NC
      X(N,1)=(N-2)*DX(1)
   50 CONTINUE
      P(1,2)=P(NSM,1)
      U(1,2)=U(NSM,1)
      W(1,2)=W(NSM,1)
      S(1,2)=S(NSM,1)
      T(1,2)=T(NSM,1)
      NC=NA(2)+1
      P(NC,2)=P(NCSA,1)
      U(NC,2)=U(NCSA,1)
      W(NC,2)=W(NCSA,1)
      S(NC,2)=S(NCSA,1)
      T(NC,2)=T(NCSA,1)
      L1=1
      CALL OUTP
   60 CONTINUE
      NSO=NS
      DPMAXO=DPMAX
      LOOP=0
   70 DO 210  I=1,IA
      NC=NA(I)+1
      IF(I.EQ.1)NC=NC+1
      DO 200 N=1,NC
      IF(N*I.EQ.1) GO TO 200
      NM1=N-LOOP
      IF(N.EQ.1)NM1=N
      IF(N.EQ.NC)NM1=N-1
      NP1=NM1+1
      PX=(P(NP1,I)-P(NM1,I))*DDX(I)
      UX=(U(NP1,I)-U(NM1,I))*DDX(I)
      WX=(W(NP1,I)-W(NM1,I))*DDX(I)
      SX=(S(NP1,I)-S(NM1,I))*DDX(I)
      QX=WX/W(N,I)
      AA=1./(W(N,I)**2-GAMMA*T(N,I))
      IF(IA.EQ.2.AND.I.EQ.1.AND.N.EQ.NC) GO TO 140
      IF(I.EQ.2.AND.N.EQ.NA(2))SX=(S(N,2)-S(N-1,2))*DDX(2)
      IF(I.NE.1.OR.N.NE.2)GO TO 80
      PX=0.
      SX=0.
      WX=0.
      QX=0.
   80 TAU=U(N,I)/W(N,I)
      AB=AA*W(N,I)**2*TAU
      AC=GAMMA*AA*W(N,I)
      AD=AA*TAU*T(N,I)
      XR=1./(C(I)-B(I))
```

```
      XZ=XR*(BZ(I)*(X(N,I)-1.)-CZ(I)*X(N,I))                            SUP01110
      AE=XZ+AB*XR                                                       SUP01120
      AF=XZ+TAU*XR                                                      SUP01130
      AG=GAMMA*AA*T(N,I)/W(N,I)                                         SUP01140
      IF(I.EQ.2.AND.N.EQ.1)GO TO 100                                    SUP01150
      IF(I.EQ.IA.AND.N.EQ.NC) GO TO 150                                 SUP01160
      DUM=-AC*UX*XR                                                     SUP01170
      DOM=AG*UX*XR                                                      SUP01180
      PZ=-AE*PX+GAMMA*AB*QY*XR+DUM+JJ*DUM                               SUP01190
      QZ=-AE*QX+AU*PX*XR+DOM+JJ*DOM                                     SUP01200
      IF(JJ.EQ.0)GO TO 90                                               SUP01210
      IF(JJ*I.EQ.1.AND.N.EQ.2)GO TO 90                                  SUP01220
      PZ=PZ-(AB*GAMMA/R(N,I)+DUM)*JJ                                    SUP01230
      QZ=QZ+(AD*GAMMA/R(N,I)-DOM)*JJ                                    SUP01240
   90 SZ=-AF*SX                                                         SUP01250
      UZ=-AF*UX-T(N,I)/W(N,I)*XR*PX                                     SUP01260
      WZ=W(N,I)*SZ                                                      SUP01270
      GO TO 180                                                         SUP01280
  100 IF(LOOP.EQ.1) GO TO 500                                           SUP01290
      NC1=NA(1)+2                                                       SUP01300
      BETA1=SQRT((U(1,2)**2+W(1,2)**2)/GAMMA/T(1,2)-1.)                 SUP01310
      BETA2=SQRT((U(2,2)**2+W(2,2)**2)/GAMMA/T(2,2)-1.)                 SUP01320
      AA1=AA                                                            SUP01330
      TAU1=TAU                                                          SUP01340
      TAU2=U(2,2)/W(2,2)                                                SUP01350
      AA2=1./(W(2,2)**2-GAMMA*T(2,2))                                   SUP01360
      ALAM1=(U(1,2)*W(1,2)-GAMMA*T(1,2)*BETA1)*AA1                      SUP01370
      ALAM2=(U(2,2)*W(2,2)-GAMMA*T(2,2)*BETA2)*AA2                      SUP01380
      EPS=(CN(1)-C(1)-ALAM1*DZ)/(DX(2)/XR+(ALAM2-ALAM1)*DZ)             SUP01390
      IF(EPS.LT.0) EPS=.0E                                              SUP01400
      PSTAR=P(1,2)+EPS*(P(2,2)-P(1,2))                                  SUP01410
      TAUS=TAU1+EPS*(TAU2-TAU1)                                         SUP01420
      AL=.5                                                             SUP01430
      TAU3=U(3,2)/W(3,2)                                                SUP01440
      PPTAR=2.*P(2,2)-P(3,2)+EPS*(P(3,2)-P(2,2))                        SUP01450
      TTUS=2.*TAU2-TAU3+EPS*(TAU3-TAU2)                                 SUP01460
      PSTAR=AL*PSTAR+(1.-AL)*PPTAR                                      SUP01470
      TAUS=AL*TAUS+(1.-AL)*TTUS                                         SUP01480
      DUM1=W(1,2)**2/BETA1/T(1,2)                                       SUP01490
      DUM2=W(2,2)/BETA2/T(2,2)                                          SUP01500
      DUM=DUM1+EPS*(DUM2-DUM1)                                          SUP01510
      DOM1=U(1,2)*(U(1,2)-W(1,2)*BETA1)*AA1/BETA1                       SUP01520
      DOM2=U(2,2)*(U(2,2)-W(2,2)*BETA2)*AA2/BETA2                       SUP01530
      DOM=DOM1+EPS*(DOM2-DOM1)                                          SUP01540
      DOM=DOM*GAMMA/C(1)*DZ                                             SUP01550
      DAM=PSTAR-DUM*TAUS+DOM                                            SUP01560
      KIP=1                                                             SUP01570
      ME=1                                                              SUP01580
      TRY(1)=CZ(1)                                                      SUP01590
      TRY(2)=CZ(1)*.99                                                  SUP01600
  110 SQR=SQRT(1.+TRY(ME)**2)                                           SUP01610
      EN1=1./SQR                                                        SUP01620
      EN3=-TRY(ME)*EN1                                                  SUP01630
      TA1=-EN3                                                          SUP01640
      TA3=EN1                                                           SUP01650
```

```
      VWNC=UN(NC1,1)*TA1+WN(NC1,1)*TA3
      UWNC=UN(NC1,1)*EN1+WN(NC1,1)*EN3
      SMNC=UWNC**2/GAMMA/T(NC1,1)
      PN2N=PN(NC1,1)+ALOG((GAMMA*SMNC-GD)/GE)
      UWN=UWNC*(GU*SMNC+1.)/GE/SMNC
      UN(1,2)=UWN*EN1+VWNC*TA1
      WN(1,2)=UWN*EN3+VWNC*TA3
      SN(1,2)=SN(NC1,1)+PN2N-PN(NC1,1)+GAMMA*ALOG(UWNC/UWN)
      TAU2N=UN(1,2)/WN(1,2)
      PN(1,2)=DAM+DUM*TAU2N
      ERR(ME)=PN(1,2)-PN2N
      IF(ME.EQ.2) GO TO 120
      ME=2
      GO TO 110
  120 IF(ABS(ERR(ME)).LT.1.E-6) GO TO 130
      IF(ABS(ERR(2)-ERR(1)).GT.1.E-8) GO TO 122
      TRYA=.99*TRY(2)
      GO TO 124
  122 TRYA=TRY(1)-ERR(1)*(TRY(2)-TRY(1))/(ERR(2)-ERR(1))
  124 ERR(1)=ERR(2)
      TRY(1)=TRY(2)
      TRY(2)=TRYA
      KIP=KIP+1
      IF(KIP.LT.20) GO TO 110
      WRITE(6,1001) K,Z
  130 CONTINUE
      CZN=TRYA
      GO TO 200
  140 CONTINUE
      IF(LOOP.EQ.1) GO TO 500
      CN(1)=C(1)+CZ(1)*DZ
      NC=NA(1)+2
      NCM=NC-1
      AA1=1./(W(NC ,1)**2-GAMMA*T(NC ,1))
      AA2=1./(W(NCM,1)**2-GAMMA*T(NCM,1))
      BETA1=SQRT((U(NC ,1)**2+W(NC ,1)**2)/GAMMA/T(NC ,1)-1.)
      BETA2=SQRT((U(NCM,1)**2+W(NCM,1)**2)/GAMMA/T(NCM,1)-1.)
      ALAM1P=(U(NC ,1)*W(NC ,1)+GAMMA*T(NC ,1)*BETA1)*AA1
      ALAM1M=(U(NC ,1)*W(NC ,1)-GAMMA*T(NC ,1)*BETA1)*AA1
      ALAM2P=(U(NCM,1)*W(NCM,1)+GAMMA*T(NCM,1)*BETA2)*AA2
      ALAM2M=(U(NCM,1)*W(NCM,1)-GAMMA*T(NCM,1)*BETA2)*AA2
      EPSP=(CN(1)-R(NCM,1)-ALAM2P*DZ)/(DX(1)/XR+(ALAM1P-ALAM2P)*DZ)
      EPSM=(CN(1)-R(NCM,1)-ALAM2M*DZ)/(DX(1)/XR+(ALAM1M-ALAM2M)*DZ)
      DUM1=BETA1*T(NC,1)
      DUM2=BETA2*T(NCM,1)
      D1=ULM2+EPSP*(DUM1-DUM2)
      E1=-(DUM2+EPSM*(DUM1-DUM2)    )
      DOM1=W(NC,1)**2
      DOM2=W(NCM,1)**2
      D2=DOM2+EPSP*(DOM1-DOM2)
      E2=DOM2+EPSM*(DOM1-DOM2)
      PSTARP=P(NCM,1)+EPSP*(P(NC,1)-P(NCM,1))
      PSTARM=P(NCM,1)+EPSM*(P(NC,1)-P(NCM,1))
      TAU1=U(NC,1)/W(NC,1)
      TAU2=U(NCM,1)/W(NCM,1)
```

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      TAUSP=TAU2+EPSP*(TAU1-TAU2)                                       SUP02210
      TAUSM=TAU2+EPSM*(TAU1-TAU2)                                       SUP02220
      DEM1=-(U(NC,1)*GAMMA*T(NC,1)/R(NC,1)*(U(NC,1)+W(NC,1)*BETA1)*AA1) SUP02230
      DEM2=-(U(NCM,1)*GAMMA*T(NCM,1)/R(NCM,1)*(U(NCM,1)+W(NCM,1)*BETA2) SUP02240
     1*AA2)                                                             SUP02250
      DIM1=-(U(NC,1)*GAMMA*T(NC,1)/R(NC,1)*(U(NC,1)-W(NC,1)*BETA1)*AA1) SUP02260
      DIM2=-(U(NCM,1)*GAMMA*T(NCM,1)/R(NCM,1)*(U(NCM,1)-W(NCM,1)*BETA2) SUP02270
     1*AA2)                                                             SUP02280
      AKP=DEM2+EPSP*(DEM1-DEM2)                                         SUP02290
      AKM=DIM2+EPSM*(DIM1-DIM2)                                         SUP02300
      AKP=AKP*DZ                                                        SUP02310
      AKM=AKM*DZ                                                        SUP02320
      D3=AKP+D1*ESTARP+D2*TAUSP                                         SUP02330
      E3=AKM+E1*ESTARM+E2*TAUSM                                         SUP02340
      TAUN=(E3-E1/D1*D3)/(E2-E1/D1*D2)                                  SUP02350
      PN(NC,1)=(D3-D2*TAUN)/D1                                          SUP02360
      TEMP=EXP(PN(NC,1)/GA)                                             SUP02370
      Q2=2.*GA*(TTOT-TEMP)                                              SUP02380
      WN(NC,1)=SQRT(Q2/(1.+TAUN**2))                                    SUP02390
      UN(NC,1)=WN(NC,1)*TAUN                                            SUP02400
      SN(NC,1)=.0                                                       SUP02410
      GO TO 200                                                         SUP02420
  150 CONTINUE                                                          SUP02430
      CALL BOUND(ZN,PBB)                                                SUP02440
      PN(N,I)=PBB                                                       SUP02450
      PZBOUN=(PN(N,I)-PBOUN)/DZ                                         SUP02460
      TAUX=UX/W(N,I)-TAU*QX                                             SUP02470
      SMF=(TTOT*EXP(-PN(N,I)/GA)-1.)/GO                                 SUP02480
      T(N,I)=EXP(PN(N,I)/GA+S(N,I)/GAMMA)                               SUP02490
      BETAF=SQRT(SMF-1.)                                                SUP02500
      SQF=SMF*GAMMA*T(N,I)                                              SUP02510
      ALAM=AE+AG*W(N,I)*BETAF*XR                                        SUP02520
      TAUZ=-(T(N,I)*BETAF/W(N,I)**2*(PX+PZBOUN/ALAM)+TAUX)*ALAM         SUP02530
     1-JJ*GAMMA*AU/R(N,I)*(BETAF+TAU)                                   SUP02540
      SN(N,I)=S(N,I)                                                    SUP02550
      IF(LOOP.EQ.1)GO TO 160                                            SUP02560
      TAUN=TAU+TAUZ*DZ                                                  SUP02570
      TAUO=TAU                                                          SUP02580
      CN(IA)=C(IA)+TAU*DZ                                               SUP02590
      CO(IA)=C(IA)                                                      SUP02600
      CZ(IA)=TAUN                                                       SUP02610
      TAU=TAUN                                                          SUP02620
      GO TO 170                                                         SUP02630
  160 TAUN=.5*(TAUO+TAU+TAUZ*DZ)                                        SUP02640
      CZ(IA)=TAUN                                                       SUP02650
      CN(IA)=.5*(CO(IA)+C(IA)+.5*(TAUO+TAUN)*DZ)                        SUP02660
  170 WN(N,I)=SQRT(SQF/(1.+TAUN**2))                                    SUP02670
      UN(N,I)=TAUN*WN(N,I)                                              SUP02680
      GO TO 200                                                         SUP02690
  180 IF(LOOP.EQ.1)GO TO 190                                            SUP02700
      PN(N,I)=P(N,I)+PZ*DZ                                              SUP02710
      SN(N,I)=S(N,I)+SZ*DZ                                              SUP02720
      UN(N,I)=U(N,I)+UZ*DZ                                              SUP02730
      WN(N,I)=W(N,I)+WZ*DZ                                              SUP02740
      GO TO 200                                                         SUP02750
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190 PN(N,I)=.5*(PO(N,I)+P(N,I)+PZ*DZ)
    SN(N,I)=.5*(SO(N,I)+S(N,I)+SZ*DZ)
    UN(N,I)=.5*(UO(N,I)+U(N,I)+UZ*DZ)
    WN(N,I)=.5*(WO(N,I)+W(N,I)+WZ*DZ)
200 CONTINUE
210 CONTINUE
    BN(1)=B(1)
    BN(2)=CN(1)
    Z=ZN
    IF(IA.EQ.2) CZ(1)=CZN
    BZ(2)=CZN
    DO 250 I=1,IA
    NC=NA(I)+1
    IF(I.EQ.1)NC=NC+1
    B(I)=BN(I)
    C(I)=CN(I)
    IF(LOOP.EQ.1)GO TO 230
    DO 220 N=1,NC
    PO(N,I)=P(N,I)
    UO(N,I)=U(N,I)
    WO(N,I)=W(N,I)
220 SO(N,I)=S(N,I)
230 PN(1,1)=PN(3,1)
    WN(1,1)=WN(3,1)
    SN(1,1)=SN(3,1)
    UN(1,1)=-UN(3,1)
    UN(2,1)=0.
    DO 240 N=1,NC
    P(N,I)=PN(N,I)
    U(N,I)=UN(N,I)
    W(N,I)=WN(N,I)
    S(N,I)=SN(N,I)
    T(N,I)=EXP(P(N,I)/GA+S(N,I)/GAMMA)
240 R(N,I)=B(I)+X(N,I)*(C(I)-B(I))
250 CONTINUE
    IF(LOOP.EQ.1)RETURN
    LOOP=1
    GO TO 70
    END
```

```
    SUBROUTINE OUTPUN(IREG,NTIMES,ITYPE)
    COMMON/BLK1/NC(8),MC(8),NC1,NC2,NC3,NC4,NC5,NC6,NC7,NC8,MC1,MC2
   1,MC3,MC4,MC5,MC6,MC7,MC8,NREG(8),NNC(2),MMC(80,2),NMAX,MMAX
   2,GAMMA,GA,GB,GC,GD,GE,GF,X(40,8),Y(19,8),XXP(130)
   3,YYP(130,19),HH,XE,YE,YA,XC,RO,RD,DMFLO,TT,CC,EM,PII
   4,SINTHE(20),COSTHE(20),R(20,19),LSYM,LA,DX(8),DY(8)
    COMMON/BLK2/P(150,19),U(150,19),V(150,19),S(150,19),PI(150,19)
   1,UI(150,19),VI(150,19),SI(150,19),NS(8,2),NF(8,2)
   2,MS(8,2),MF(8,2),TIME,DT,K,J,XOTT(2),QINF,QINFN,KDIVS,DTS
    COMMON/BLK3/YET(130,19),XCS(130),X0,X1,X2,X3,Y0,Y2,ALP(4),DD(6)
   1,BET(4),LSLP,HU(130),HL(130),HC(130),HUPR(130),HLPR(130),HCPR(130)
    COMMON/BLK4/EP1(20),EP2(20),EP3(100),EP4(100),EP5(38),EP6(38)
   1,NN1(20),NN2(20),M1(20),M2(20),M3(38),M4(38),L1(100),L3(100)
   2,I1(100),I2(100),JR(80,19),B(20),BPR(20)
    FPRES(PP)=EXP(PP)
```

```
      FDENS(PP,SS)=EXP((PP_SS)/GAMMA)
      FAS(PP,SS)=GF*SQRT(EXP(PP/GA+SS/GAMMA))
      FACH(UU,VV,AA)=SQRT(UU**2+VV**2)/AA
      FCP(PRE)=2.*(PRE-1.)/(GAMMA*EM**2)
      FPTOT(PRE,AM)=PRE*(1.+GD*AM**2)**GA
 1001 FORMAT(//4X,4HSTEP,I5,10X,5HTIME=E12.4,10X,3HDT=E12.4)
 1002 FORMAT(/4X,10HREGION NO.I2)
 1003 FORMAT(/5X,2HM=I3//9X,1HX,9X,1HY,9X,1HP,9X,1HA,9X,1HU,9X,1HV,9X
     1,1HM,7X,5HSLOPE,6X,3HRHO,7X,2HCP,8X,1HS)
 1004 FORMAT(I3,11F10.5)
 1005 FORMAT(//4X,27HBOATTAIL SURFACE FLOW FIELD /)
 1006 FORMAT(//4X,28HBOATTAIL COMPLETE FLOW FIELD /)
 1007 FORMAT(//4X,27HNACELLE COMPLETE FLOW FIELD /)
 1008 FORMAT(/4X,26HNACELLE SURFACE FLOW FIELD  //4X,5HSTEP
     1,I5,5X,5HTIME=,F6.3)
 1009 FORMAT(/4X,10HOUTER COWL )
 1010 FORMAT(/4X,10HINNER COWL )
 1011 FORMAT(/4X,14HPLUME BOUNDARY )
 1012 FORMAT(13X,1HX,11X,1HY,11X,1HP,11X,1HM,10X,3HTAU,10X,2HCP,10X,2HPTO
     1/)
 1013 FORMAT(4X,7F12.4)
 1014 FORMAT(//4X,13HGEOMETRY TEST /)
 1015 FORMAT(//4X,8HCOWL LIP /13X,1HX,11X,1HY,10X,3HTHE,10X,1HB,10X
     1,3HBPR)
 1016 FORMAT(13X,1HX,11X,1HY,10X,3HYPR)
 1017 FORMAT(/4X,8HBOATTAIL)
      IF(ITYPE.EQ.3) GO TO 210
      IF(LSYM.EQ.1) GO TO 2
      IF(ITYPE.EQ.1) GO TO 100
      GO TO 4
C     COMPLETE FLOW FIELD OUTPUT
    2 IF(ITYPE.EQ.1)WRITE(6,1005)
      IF(ITYPE.EQ.2)WRITE(6,1006)
      GO TO 6
    4 WRITE(6,1007)
    6 WRITE(6,1001)K,TIME,DT
      IRS=IREG
      IRF=IREG
      IF(IREG.NE.9) GO TO 10
      IRS=1
      IRF=8
   10 DO 90 LREG=IRS,IRF
      IF(LREG.EQ.5) GO TO 90
      MCC=MC(LREG)
      NCC=NC(LREG)
      IF(LREG.EQ.8) GO TO 30
      IF(LREG.GT.1.AND.LREG.LT.6) GO TO 20
      MSTA=1
      MFIN=NTIMES
      IF(NTIMES.EQ.-1) MFIN=MC(LREG)
      GO TO 40
   20 MSTA=MCC+1-NTIMES
      IF(NTIMES.EQ.-1) MSTA=1
      MFIN=MCC
      IF(LSYM.EQ.1) GO TO 80
```

```
      GO TO 40
   30 MSTA=1
      MFIN=NTIMES
      IF(NTIMES.EQ.-1) MFIN=MC(LREG)
      IF(LSYM.NE.1) GO TO 40
      IF(LSYM.EQ.1) GO TO 80
   40 WRITE(6,1002) LREG
      DO 70 M=MSTA,MFIN
      WRITE(6,1003)M
      YY=Y(M,LREG)
      DO 70 N=1,NCC
      XX=X(N,LREG)
      NN=NREG(LREG)+N
      PRES=FPRES(P(NN,M))
      DENS=FDENS(P(NN,M),S(NN,M))
      AS=FAS(P(NN,M),S(NN,M))
      ACH=FACH(U(NN,M),V(NN,M),AS)
      ENT=S(NN,M)*1000
      CP=FCP(PRES)
      IF(LREG.NE.8) GO TO 50
      SLOPE=0.
      UCAR=U(NN,M)*COSTHE(N)-V(NN,M)*SINTHE(N)
      VCAR=U(NN,M)*SINTHE(N)+V(NN,M)*COSTHE(N)
      IF(ABS(UCAR).GT.1.E-8) SLOPE=VCAR/UCAR
      XP=R(N,M)*COSTHE(N)+60-RD
      YP=R(N,M)*SINTHE(N)+GH
      GO TO 60
   50 CONTINUE
      XP=XXP(NN)-RD
      YP=YYP(NN,M)
      SLOPE=0.
      IF(ABS(U(NN,M)).GT.1.E-8)SLOPE=V(NN,M)/U(NN,M)
   60 WRITE(6,1004)N,XP,YP,PRES,AS,U(NN,M),V(NN,M),ACH,SLOPE,DENS,CP,ENT
   70 CONTINUE
   80 CONTINUE
      DUM=1./(GF*EM*HH)
      IF(LA.EQ.1) DUM=2.*DUM/HH
      DO 90 L=1,2
      NNM=NREG(3)+6
      IF(L.EQ.2) NNM=NREG(4)+10
      XEM=XXP(NNM)
      EMDOT=0.
      EMI=0.
      DO 85 M=2,MC3
      EMI1=EMI
      DEL=YYP(NNM,M)-YYP(NNM,M-1)
      DENS=FDENS(P(NNM,M),S(NNM,M))
      AS=FAS(P(NNM,M),S(NNM,M))
      ACH=FACH(U(NNM,M),V(NNM,M),AS)
      EMI=DENS*AS*ACH
      IF(LA.EQ.1) EMI=EMI*YYP(NNM,M)
   85 EMDOT=EMDOT+(EMI+EMI1)*DEL/2.
      EMDOT=EMDOT*DUM
      WRITE(6,1018) XEM,EMDOT
 1018 FORMAT(//4X,2HX=,F7.4,5X,5HMDOT=,F8.4//)
```

```
   90 CONTINUE
      J=0
      RETURN
C     SURFACE FLOW FIELD - NACELLE
  100 WRITE(6,1008) K,TIME
      DO 200 L=1,5
      GO TO (110,120,130,140,150),L
  110 WRITE(6,1009)
      WRITE(6,1012)
      LREG=8
      NSTA=1
      NFIN=NC8/2+1
      M=1
      GO TO 160
  120 LREG=7
      NSTA=NNC(1)
      NFIN=NC7
      M=1
      GO TO 160
  130 WRITE(6,1010)
      WRITE(6,1012)
      LREG=8
      NSTA=NC8/2+1
      NFIN=NC8
      M=1
      GO TO 160
  140 LREG=3
      NSTA=NNC(2)
      NFIN=NC3
      M=MC3
      GO TO 160
  150 WRITE(6,1011)
      WRITE(6,1012)
      LREG=6
      NSTA=1
      NFIN=NC6
      M=1
  160 DO 190 NL=NSTA,NFIN
      N=NL
      IF(L.EQ.1) N=NFIN-NL+1
      NN=NREG(LREG)+N
      PRES=FPRES(P(NN,M))
      AS=FAS(P(NN,M),S(NN,M))
      ACH=FACH(U(NN,M),V(NN,M),AS)
      CP=FCP(PRES)
      PTOT=FPTOT(PRES,ACH)
      IF(LREG.EQ.8) GO TO 170
      XP=XXP(NN)-RD
      YP=YYP(NN,M)
      SLOPE=0.
      IF(ABS(U(NN,M)).GT.1.E-8)SLOPE=V(NN,M)/U(NN,M)
      GO TO 180
  170 XP=R(N,M)*COSTHE(N)+A0-RD
      YP=R(N,M)*SINTHE(N)+AH
      SLOPE=0.
      UCAR=U(NN,M)*COSTHE(N)-V(NN,M)*SINTHE(N)
```

```
      VCAR=U(NN,M)*SINTHE(N)+V(NN,M)*COSTHE(N)
      IF(ABS(UCAR).GT.1.E-8) SLOPE=VCAR/UCAR
  180 WRITE(6,1013) XP,YP,BRES,ACH,SLOPE,CP,PTOT
  190 CONTINUE
  200 CONTINUE
      RETURN
C     GEOMETRY TEST
  210 WRITE(6,1014)
      IF(LSYM.EQ.1) GO TO 225
      WRITE(6,1015)
      DO 220 N=1,NCB
      THE=PII*X(N,8)+PII/2.
      XP=B(N)*COSTHE(N)+RO-RD
      YP=B(N)*SINTHE(N)+HO
  220 WRITE(6,1013) XP,YP,THE,B(N),BPR(N)
  225 DO 290 L=1,4
      GO TO (230,240,250,260),L
  230 IF(LSYM.EQ.1) GO TO 232
      WRITE(6,1009)
      WRITE(6,1016)
      NSTA=NNC(1)
      GO TO 234
  232 WRITE(6,1017)
      WRITE(6,1009)
      NSTA=1
  234 NFIN=NC7
      LREG=7
      M=1
      GO TO 270
  240 IF(LSYM.EQ.1) GO TO 290
      WRITE(6,1010)
      WRITE(6,1016)
      NSTA=NNC(2)
      NFIN=NC3
      LREG=3
      M=MC3
      GO TO 270
  250 IF(LSYM.EQ.1) GO TO 290
      NSTA=1

      NFIN=NC4
      LREG=4
      M=MC4
      GO TO 270
  260 WRITE(6,1011)
      WRITE(6,1016)
      NSTA=1
      NFIN=NC6
      LREG=6
      M=1
  270 DO 280 N=NSTA,NFIN
      NN=NREG(LREG)+N
      IF(L.EQ.1.OR.L.EQ.4) HPR=HUPR(NN)
      IF(L.EQ.2.OR.L.EQ.3) HPR=HLPR(NN)
  280 WRITE(6,1013) XXP(NN),YYP(NN,M),HPR
  290 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SETNOS(JRITE)
      COMMON/BLK1/NC(8),MC(8),NC1,NC2,NC3,NC4,NC5,NC6,NC7,NC8,MC1,MC2
     1,MC3,MC4,MC5,MC6,MC7,MC8,NREG(8),NMC(2),MMC(80,2),NMAX,MMAX
     2,GAMMA,GA,GB,GC,GD,GE,GF,X(40,8),Y(19,8),XX(130)
     3,YY(130,19),HH,XE,YE,YA,XC,R0,RD,RVFLO,TT,CC,EM,PII
     4,SINTHE(20),COSTHE(20),R(20,19),LSYM,LA,DX(8),DY(8)
      COMMON/BLK4/EP1(20),EP2(20),EP3(10),EP4(100),EP5(38),EP6(38)
     1,NN1(20),NN2(20),M1(50),M2(20),M3(38),M4(38),L1(100),L3(100)
     2,I1(100),I2(100),JR(80,19),B(20),BPR(20)
 1001 FORMAT(4X,25HNOSE REGION INTERPOLATION/4X,3HR=C/8X,1HN,2X
     1,3HNN1,2X,3HNN2,3X,2HM1,3X,2HM2,1X,4HISIT,6X,3HEP1,9X,3HEP2)
 1002 FORMAT(4X,8HINTERIOR/8X,1HN,4X,1HM,3X,2HI1,3X,2HI2,3X,2HL1
     1,3X,2HL3,6X,3HEP3,9X,3HEP4)
 1003 FORMAT(4X,4HX=R0/8X,1HM,3X,2HMR,2X,3HNNC,4X,1HN,3X,2HM3,3X
     1,2HM4,6X,3HEP5,9X,3HEP6)
 1004 FORMAT(4X,6I5,2E12.4)
C     SET UP FOR INTERPOLATION AT R=C
      CC=R0
      DO 10 N=1,NC8
      THE=PII*X(N,8)+PII/2.
      CALL WALL(R,THE,BB,BBPR,3)
      B(N)=BB
      BPR(N)=BBPR
      COSTHE(N)=COS(THE)
      SINTHE(N)=SIN(THE)
      DO 10 M=1,MC8
      R(N,M)=Y(M,8)*(CC-BB)+BB
   10 CONTINUE
      NA8=NC8-1
      NM=NC8/2+1
      IF(JRITE.NE.0) WRITE(6,1001)
      DO 500 N=2,NA8
      IF(N.EQ.NM) GO TO 13?
      THE=PII*X(N,8)+PII/2.
      XA=CC*COS(THE)+R0
      YA=CC*SIN(THE)+HH
      IF(THE.GT.PII) GO TO 20
      LREG=7
      MREG=1
      GO TO 30
   20 LREG=3
      MREG=2
   30 NCC=NC(LREG)
      DO 50 L=1,NCC
      LL=NREG(LREG)+L
      IF(XX(LL).GT.XA) GO TO 60
   50 CONTINUE
   60 L11=L-1
      LL1=LL-1
      XB=XX(LL1)
      RB1=(XB-R0)/COS(THE)
      X11=XB
      IF(MREG.EQ.2) GO TO 80
      DO 70 M=1,MC7
      RR1= SQRT((X11-R0)**2+(YY(LL1,M)-HH)**2)
```

```
      IF(RR1.GT.CC) GO TO 75                                            SET00560
   70 CONTINUE                                                          SET00570
   75 MM=M                                                              SET00580
      GO TO 90                                                          SET00590
   80 DO 84 LM=1,MC3                                                    SET00600
      M=MC3-LM+1                                                        SET00610
      RR1= SQRT((X11-R0)**2+(YY(LL1,M)-HH)**2)                          SET00620
      IF(RR1.GT.CC) GO TO 85                                            SET00630
   84 CONTINUE                                                          SET00640
   85 MM=M                                                              SET00650
   90 THE11=ATAN2(YY(LL1,MM)-HH,X11-R0)                                 SET00660
      IF(THE11.LT.0.) THE11 =2.*PII+THE11                               SET00670
      LL2=LL1+1                                                         SET00680
      IF(THE11.LT.THE.AND.MREG.EQ.1) LL2=LL1-1                          SET00690
      IF(THE11.GT.THE.AND.MREG.EQ.2) LL2=LL1-1                          SET00700
      IF(LL2.LT.NREG(LREG),1) LL2=LL1+1                                 SET00710
      X22=XX(LL2)                                                       SET00720
      Y22=YY(LL2,MM)                                                    SET00730
      Y11=YY(LL1,MM)                                                    SET00740
      DEL=(Y22-Y11)/(X22-X11)                                           SET00750
      RB2=(Y11-HH+DEL*(R0-X11))/(SIN(THE)-DEL*COS(THE))                 SET00760
      IF(L11.EQ.1) RB2=10.                                              SET00770
      IF(RB2.GE.CC) GO TO 91                                            SET00780
      MM=MM-(2*MREG-3)                                                  SET00790
      GO TO 9                                                           SET00800
   91 CONTINUE                                                          SET00810
      ISIT=1                                                            SET00820
      IF(RB2.LT.RB1) ISIT=2                                             SET00830
      IF(ISIT.EQ.2) GO TO 120                                           SET00840
      IF(MREG.EQ.2) GO TO 105                                           SET00850
      DO 100 M=1,MC1                                                    SET00860
      IF(YY(LL1,M).GT.YA) GO TO 104                                     SET00870
  100 CONTINUE                                                          SET00880
  104 MM1=M                                                             SET00890
      MM2=M-1                                                           SET00900
      GO TO 118                                                         SET00910
  105 DO 110 LM=1,MC7                                                   SET00920
      M=MC7-LM+1                                                        SET00930
      IF(YY(LL1,M).LT.YA) GO TO 115                                     SET00940
  110 CONTINUE                                                          SET00950
  115 MM1=M                                                             SET00960
      MM2=M+1                                                           SET00970
  118 YB=HH+RB1*SIN(THE)                                                SET00980
      EP1(N)=(YB-YY(LL1,MM1))/(YY(LL1,MM2)-YY(LL1,MM1))                 SET00990
      NN1(N)=LL1                                                        SET01000
      NN2(N)=LL1                                                        SET01010
      M1(N)=MM1                                                         SET01020
      M2(N)=MM2                                                         SET01030
      RB=RB1                                                            SET01040
      GO TO 150                                                         SET01050
  120 XB=RB2*COS(THE)+R0                                                SET01060
      EP1(N)=(XB-X11)/(X22-X11)                                         SET01070
      NN1(N)=LL1                                                        SET01080
      NN2(N)=LL2                                                        SET01090
      M1(N)=MM                                                          SET01100
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      M2(N)=MM
      RB=RB2
      GO TO 150
  130 NN1(N)=NREG(7)+1
      NN2(N)=NREG(7)+1
      M1(N)=1
      M2(N)=2
      EP1(N)=C.
      RB=CC
  150 RC=(CC-B(N))*Y(MC8-1,8)+B(N)
      EP2(N)=(CC-RC)/(RB-RC)
      IF(JRITE.NE.0)
     1WRITE(6,1004) N,NN1(N),NN2(N),M1(N),M2(N),ISIT,EP1(N),EP2(N)
  200 CONTINUE
C     SET UP FOR INTERIOR POINT INTERPOLATION
      JJ=0
      IF(JRITE.NE.0) WRITE(6,1002)
      DO 400 LI=1,2
      IF(LI.EQ.2) GO TO 210
      LREG=7
      GO TO 220
  210 LREG=3
  220 NCC=NC(LREG)
      MCC=MC(LREG)
      DO 350 N=2,NCC
      NR=(LI-1)*NMAX+N
      NN=NREG(LREG)+N
      IF(XX(NN).GT.R0) GO TO 360
      DO 340 LM=1,MCC
      M=LM
      IF(LI.EQ.2) M=MCC-LM+1
      XA=XX(NN)
      YA=YY(NN,M)
      RA=SQRT((XA-R0)**2+(YA-HH)**2)
      IF(RA.GT.CC) GO TO 345
      THEA=ATAN2(YA-HH,XA-R0)
      IF(THEA .LT.0.) THEA  =2.*PII+THEA
      JJ=JJ+1
      JR(NR,M)=JJ
      DO 250 L=1,NCA
      THE=PII*X(L,8)+PII/2.
      IF(THE.GT.THEA) GO TO 260
  250 CONTINUE
  260 L3(JJ)=L+NREG(8)
      L1(JJ)=L+NREG(8)-1
      THE3=THE
      THE1=PII*X(L-1,8)+PII/2.
      DO 270 I=1,MCA
      RR=(CC-B(L-1))*Y(I,8)+B(L-1)
      IF(RR.GT.RA) GO TO 280
  270 CONTINUE
  280 IF(I.EQ.1) I=2
      I2(JJ)=I
      I1(JJ)=I-1
      RR2=(CC-B(L-1))*Y(I,8)+B(L-1)
```

```
      RR1=(CC-B(L-1))*Y(I-1,8)+B(L-1)
      RR3=(CC-B(L))*Y(I-1,8)+B(L)
      RR4=(CC-B(L))*Y(I   ,8)+B(L)
      EP3(JJ)=(THEA-THE1)/(THE3-THE1)
      EP4(JJ)=.5*((RA-RR2)/(RR1-RR2)+(RA-RR4)/(RR3-RR4))
      IF(WRITE.NE.0) WRITE(6,1004)N,M,I1(JJ),I2(JJ),L1(JJ),L3(JJ)
     1,EP3(JJ),EP4(JJ)
  340 CONTINUE
  345 MMC(NR,LI)=M
  350 CONTINUE
  360 NNC(LI)=N
  400 CONTINUE
C     SET UP FOR INTERPOLATION ALONG X=R:
      IF(WRITE.NE.0) WRITE(6,1003)
      DO 600 LI=1,2
      NRC=NNC(LI)
      IF(LI.EQ.2) GO TO 51:
      N=1
      N1=2
      LREG=7
      GO TO 520
  510 N=N:8
      N1=NC8-1
      LREG=3
  520 MCC=MC(LREG)
      NNRC=NREG(LREG)+NRC
      XAA=R0
      DO 590 M=1,MC8
      MR=(LI-1)*MMAX+M
      YAA=R(N,M)*SINTHE(N)+HH
      YCC=R(N1,M)*SINTHE(N1)+HH
      XCC=R(N1,M)*COSTHE(N1)+R0
      XBB=XX(NNRC)
      YBB=((XBB-XCC)/(XAA-XCC))*(YAA-YCC)+YCC
      IF(M.EQ.1) GO TO 550
      DO 530 MM=1,MCC
      IF(YY(NNRC,MM).GT.YBB) GO TO 540
  530 CONTINUE
  540 MM4=MM
      MM3=MM-1
      Y44=YY(NNRC,MM4)
      Y33=YY(NNRC,MM3)
      EP5(MR)=(YBB-Y33)/(Y44-Y33)
      EP6(MR)=(XAA-XCC)/(XBB-XCC)
      M3(MR)=MM4
      M4(MR)=MM3
      IF(WRITE.NE.0)
     1WRITE(6,1004) M,MR,NOC,N,M3(MR),M4(MR),EP5(MR),EP6(MR)
      GO TO 590
  550 IF(LI.EQ.2) GO TO 56:
      M3(MR)=1
      M4(MR)=2
      GO TO 570
  560 M3(MR)=MC3
      M4(MR)=MC3-1
```

```
  570 EP5(MR)=0.
      EP6(MR)=(XAA-XCC)/(XAB-XCC)
  590 CONTINUE
  600 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE STRECH(MREG)
      COMMON/BLK1/NC(8),MC(8),NC1,NC2,NC3,NC4,NC5,NC6,NC7,NC8,MC1,MC2
     1,MC3,MC4,MC5,MC6,MC7,MC8,NREG(8),NMC(2),MMC(80,2),NMAX,MMAX
     2,GAMMA,GA,GB,GC,GD,GE,GF,X(40,8),Y(19,8),XXP(130)
     3,YYP(130,19),HH,XE,YE,YA,XC,RO,RD,EMFLO,TT,CC,EM,PII
     4,SINTHE(20),COSTHE(20),R(20,19),LSYM,LA,DX(8),DY(8)
      COMMON/BLK3/YET(130,19),XCS(130),X0,X1,X2,X3,Y0,Y2,ALP(4),DD(6)
     1,BET(4),LSLP,HU(130),HL(130),HC(130),HUPR(130),HLPR(130),HCPR(130)
      DIMENSION AL(2),ERR(5)
      DATA LAMP/0/
 1001 FORMAT(/4X,21HSTRECHING PARAMETERS  /4X,4H X0=,E12.4,3X
     1,4H X1=,E12.4,3X,4H X2=,E12.4,3X,4H X3=,E12.4,3X,4H Y0=,E12.4
     2,3X,4H Y2=,E12.4/4X,4HAL1=,E12.4,3X,4HAL2=,E12.4,3X,4HAL3=
     3,E12.4,3X,4HAL4=,E12.4/4X,4HBE1=,E12.4,3X,4HBE2=,E12.4,3X
     4,4HBE3=,E12.4,3X,4HBE4=,E12.4)
      F1(F,AL,BE)=.5*(1.+TANH(AL*(F-.5))/BE)
      F2(G,AL,BE)=2.*BE/(AL*(1.-(2.*G-1.)**2*BE**2))
      G1(F,A1,A2)=(A1+A2*ALOG(F))*ALOG(F)
      G2(F,A1,A2)=(A1+2.*A2*ALOG(F))/F
      IF(LAMP.NE.0) GO TO 102
C     STRETCHING PARAMETERS
      DO   4 L=1,2
      IF(L.EQ.2) GO TO   1
      DEL=DX(1)
      D1=DD(3)
      D2=DD(4)
      GO TO   2
    1 DEL=DY(1)
      D1=DD(5)
      D2=DD(6)
    2 DEL1=1.-DEL
      DLOG=ALOG(DEL)
      D1LOG=ALOG(DEL1)
      DET=DLOG-D1LOG
      DUM1=(D2*D1LOG/DLOG-D1*DLOG/D1LOG)/DET
      DUM2=(D1/D1LOG-D2/DLOG)/DET
      IF(L.EQ.2) GO TO   3
      X0=DUM1
      X2=DUM2
      GO TO   4
    3 Y0=DUM1
      Y2=DUM2
    4 CONTINUE
      X1=X0
      X3=X2
      DO   5 L=1,4
      ALP(L)=0.
    5 BET(L)=0.
      DO  20 L=1,4
```

```
      GO TO( 11, 12, 13, 14),L                                          STR00500
   11 IF(LSYM.EQ.1) GO TO  20                                           STR00510
      DEL=DY(2)                                                         STR00520
      DIM=DEL*HH                                                        STR00530
      IF(DD(1).GT..9*DIM) DD(1)=.9*DIM                                  STR00540
      DUM=2.*DD(1)/HH-1.                                                STR00550
      GO TO  15                                                         STR00560
   12 IF(LSYM.EQ.1) GO TO  20                                           STR00570
      DEL=DX(3)                                                         STR00580
      DIM=DEL*XC                                                        STR00590
      IF(DD(2).GT..9*DIM) DD(2)=.9*DIM                                  STR00600
      DUM=2.*DD(2)/XC-1.                                                STR00610
      GO TO  15                                                         STR00620
   13 IF(LSYM.EQ.1) GO TO  20                                           STR00630
      DEL=DX(4)                                                         STR00640
      DIM=DEL*(XE-XC)                                                   STR00650
      IF(DD(2).GT..9*DIM) DD(2)=.9*DIM                                  STR00660
      DUM=2.*DD(2)/(XE-XC)-1.                                           STR00670
      GO TO  15                                                         STR00680
   14 DEL=DX(7)                                                         STR00690
      DIM=DEL*XE                                                        STR00700
      IF(DD(2).GT..9*DIM) DD(2)=.9*DIM                                  STR00710
      DUM=2.*DD(2)/XE-1.                                                STR00720
   15 AL(1)=.5                                                          STR00730
      AL(2)=.6                                                          STR00740
      ME=1                                                              STR00750
      KIP=1                                                             STR00760
   16 EF=TANH(AL(ME)*(DEL-.5))/TANH(.5*AL(ME))                          STR00770
      ERR(ME)=EF-DUM                                                    STR00780
      IF(ABS(ERR(ME)).LT.1.E-3) GO TO  18                               STR00790
      IF(ME.EQ.2)GO TO  17                                              STR00800
      ME=2                                                              STR00810
      GO TO  16                                                         STR00820
   17 ALBAR=AL(1)-ERR(1)*(AL(2)-AL(1))/(ERR(2)-ERR(1))                  STR00830
      ALBAR=ABS(ALBAR)                                                  STR00840
      AL(1)=AL(2)                                                       STR00850
      AL(2)=ALBAR                                                       STR00860
      ERR(1)=ERR(2)                                                     STR00870
      KIP=KIP+1                                                         STR00880
      IF(KIP.LE.20)GO TO  16                                            STR00890
      CALL EXIT                                                         STR00900
   18 ALP(L)=AL(ME)                                                     STR00910
      BET(L)=TANH(.5*ALP(L))                                            STR00920
   20 CONTINUE                                                          STR00930
      LAMP=1                                                            STR00940
      WRITE(6,1001)X0,X1,X2,X3,Y0,Y2,ALP,BET                            STR00950
C     STRETCHING DERIVATIVES AND BODY GEOMETRY                          STR00960
  102 IF(MREG.NE.8) GO TO 104                                           STR00970
      MSTA=1                                                            STR00980
      MFIN=7                                                            STR00990
      GO TO 108                                                         STR01000
  104 MSTA=MREG                                                         STR01010
      MFIN=MREG                                                         STR01020
  108 DO 200 LREG=MSTA,MFIN                                             STR01030
      NCC=NC(LREG)                                                      STR01040
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      MCC=MC(LREG)                                                      STR01050
      DO 195 N=1,NCC                                                    STR01060
      NN=NREG(LREG)+N                                                   STR01070
      XX=X(N,LREG)                                                      STR01080
      DO 195 M=1,MCC                                                    STR01090
      YY=Y(M,LREG)                                                      STR01100
      GO TO (110,120,130,140,150,160,170),LREG                          STR01110
  110 IF(N.EQ.1)GO TO 111                                               STR01120
      XXP(NN)=G1(XX,X0,X2)                                              STR01130
      XCS(NN)=1./G2(XX,X0,X2)                                           STR01140
      GO TO 112                                                         STR01150
  111 XXP(NN)=-500.                                                     STR01160
      XCS(NN)=0.                                                        STR01170
  112 IF(M.EQ.MCC)GO TO 113                                             STR01180
      YYP(NN,M)=YA-G1(1.-YY,Y0,Y2)                                      STR01190
      YET(NN,M)=-1./G2(1.-YY,Y0,Y2)                                     STR01200
      GO TO 114                                                         STR01210
  113 YYP(NN,M)=500.                                                    STR01220
      YET(NN,M)=0.                                                      STR01230
  114 CALL WALL(1,XXP(NN),AH,AHPR,1)                                    STR01240
      HU(NN)=AH                                                         STR01250
      HUPR(NN)=AHPR                                                     STR01260
      GO TO 190                                                         STR01270
  120 IF(LSYM.EQ.1) GO TO 190                                           STR01280
      IF(N.EQ.1)GO TO 121                                               STR01290
      XXP(NN)=G1(XX,X0,X2)                                              STR01300
      XCS(NN)=1./G2(XX,X0,X2)                                           STR01310
      GO TO 122                                                         STR01320
  121 XXP(NN)=-500.                                                     STR01330
      XCS(NN)=0.                                                        STR01340
  122 ETA=F1(YY,ALP(1),BET(1))                                          STR01350
      YYP(NN,M)=YA*ETA                                                  STR01360
      YET(NN,M)=F2(ETA,ALP(1),BET(1))                                   STR01370
      CALL WALL(2,XXP(NN),AH,AHPR,1)                                    STR01380
      HL(NN)=AH                                                         STR01390
      HLPR(NN)=AHPR                                                     STR01400
      CALL WALL(2,XXP(NN),AH,AHPR,2)                                    STR01410
      HC(NN)=AH                                                         STR01420
      HCPR(NN)=AHPR                                                     STR01430
      GO TO 190                                                         STR01440
  130 IF(LSYM.EQ.1) GO TO 190                                           STR01450
      CSI=F1(XX,ALP(2),BET(2))                                          STR01460
      XXP(NN)=XC*CSI                                                    STR01470
      XCS(NN)=F2(CSI,ALP(2),BET(2))                                     STR01480
      CALL WALL(3,XXP(NN),AH,AHPR,1)                                    STR01490
      HL(NN)=AH                                                         STR01500
      HLPR(NN)=AHPR                                                     STR01510
      CALL WALL(3,XXP(NN),AH,AHPR,2)                                    STR01520
      HC(NN)=AH                                                         STR01530
      HCPR(NN)=AHPR                                                     STR01540
      ETA=F1(YY,ALP(1),BET(1))                                          STR01550
      YYP(NN,M)=ETA*HL(NN)                                              STR01560
      YET(NN,M)=F2(ETA,ALP(1),BET(1))                                   STR01570
      GO TO 190                                                         STR01580
  140 IF(LSYM.EQ.1) GO TO 190                                           STR01590
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      CSI=F1(XX,ALP(3),BET(3))                                          STR01600
      XXP(NN)=XC+(XE-XC)*CSI                                            STR01610
      XCS(NN)=F2(CSI,ALP(3),BET(3))                                     STR01620
      CALL WALL(4,XXP(NN),AH,AHPR,1)                                    STR01630
      HL(NN)=AH                                                         STR01640
      HLPR(NN)=AHPR                                                     STR01650
      CALL WALL(4,XXP(NN),AH,AHPR,2)                                    STR01660
      HC(NN)=AH                                                         STR01670
      HCPR(NN)=AHPR                                                     STR01680
      ETA=F1(YY,ALP(1),BET(1))                                          STR01690
      YYP(NN,M)=HC(NN)+(HL(NN)-HC(NN))*ETA                              STR01700
      YET(NN,M)=F2(ETA,ALP(1),BET(1))                                   STR01710
      GO TO 190                                                         STR01720
  150 IF(LSYM.EQ.1) GO TO 190                                           STR01730
      IF(N.EQ.NCC)GO TO 151                                             STR01740
      XXP(NN)=XE-G1(1.-XX,X1,X3)                                        STR01750
      XCS(NN)=-1./G2(1.-XX,X1,X3)                                       STR01760
      GO TO 152                                                         STR01770
  151 XXP(NN)=500.                                                      STR01780
      XCS(NN)=0.                                                        STR01790
  152 CALL WALL(5,XXP(NN),AH,AHPR,1)                                    STR01800
      HL(NN)=AH                                                         STR01810
      HLPR(NN)=AHPR                                                     STR01820
      CALL WALL(5,XXP(NN),AH,AHPR,2)                                    STR01830
      HC(NN)=AH                                                         STR01840
      HCPR(NN)=AHPR                                                     STR01850
      ETA=F1(YY,ALP(1),BET(1))                                          STR01860
      YYP(NN,M)=HC(NN)+(YE-HC(NN))*ETA                                  STR01870
      YET(NN,M)=F2(ETA,ALP(1),BET(1))                                   STR01880
      GO TO 190                                                         STR01890
  160 IF(N.EQ.NCC)GO TO 161                                             STR01900
      XXP(NN)=XE-G1(1.-XX,X1,X3)                                        STR01910
      XCS(NN)=-1./G2(1.-XX,X1,X3)                                       STR01920
      GO TO 162                                                         STR01930
  161 XXP(NN)=500.                                                      STR01940
      XCS(NN)=0.                                                        STR01950
  162 CALL PLUBO(XXP(NN),AH,AHPR)                                       STR01960
      HU(NN)=AH                                                         STR01970
      HUPR(NN)=AHPR                                                     STR01980
      IF(M.EQ.MCC)GO TO 163                                             STR01990
      YYP(NN,M)=HU(NN)-G1(1.-YY,Y0,Y2)                                  STR02000
      YET(NN,M)=-1./G2(1.-YY,Y0,Y2)                                     STR02010
      GO TO 190                                                         STR02020
  163 YYP(NN,M)=500.                                                    STR02030
      YET(NN,M)=0.                                                      STR02040
      GO TO 190                                                         STR02050
  170 CSI=F1(XX,ALP(4),BET(4))                                          STR02060
      XXP(NN)=XE*CSI                                                    STR02070
      XCS(NN)=F2(CSI,ALP(4),BET(4))                                     STR02080
      CALL WALL(7,XXP(NN),AH,AHPR,1)                                    STR02090
      HU(NN)=AH                                                         STR02100
      HUPR(NN)=AHPR                                                     STR02110
      IF(M.EQ.MCC)GO TO 171                                             STR02120
      YYP(NN,M)=HU(NN)-G1(1.-YY,Y0,Y2)                                  STR02130
      YET(NN,M)=-1./G2(1.-YY,Y0,Y2)                                     STR02140
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      GO TO 190                                                         STR02140
  171 YYP(NN,M)=500.                                                    STR02150
      YET(NN,M)=0.                                                      STR02160
  190 CONTINUE                                                          STR02170
  195 CONTINUE                                                          STR02180
  200 CONTINUE                                                          STR02190
                                                                        STR02200
      RETURN                                                            STR02210
      END                                                               STR02220
      SUBROUTINE WALL(LREG,X,Y,YP,LP)                                   WAL00010
      COMMON/BLK1/NC(8),MC(8),NC1,NC2,NC3,NC4,NC5,NC6,NC7,NC8,MC1,MC2   WAL00020
     1,MC3,MC4,MC5,MC6,MC7,MC8,NREG(8),NNC(2),MMC(80,2),NMAX,MMAX       WAL00030
     2,GAMMA,GA,GB,GC,GD,GE,GF,XX(40,8),YY(19,8),XXP(130)               WAL00040
     3,YYP(130,19),HH,XF,YF,YA,XC,R0,RD,RMFLO,TT,CC,EM,PII              WAL00050
     4,SINTHE(20),COSTHE(20),P(20,19),LSVM,LA,DX(8),DY(8)               WAL00060
      DIMENSION THE(9),BNOS(9),BPNOS(9),AN1(9),AN2(9),XOUT(9),YOUT(9),  WAL00070
     1YPOUT(9),LFUNO(9),AO1(9),AO2(9),XIN(9),YIN(9),YPIN(9),LFUNI(9)    WAL00080
     2,AI1(9),AI2(9),A(20)                                              WAL00090
      ACUB(XL,XR,YL,YR,YLP,YRP)=((YLP+YRP)*(XL-XR)-2.*(YL-YR))/(XL-XR)  WAL00100
     1**3                                                               WAL00110
      BCUB(XL,XR,YL,YR,YLP,YRP)=(3.*(YL-YR)-(YLP+2.*YRP)*(XL-XR))/(XL-XRWAL00120
     1)**2                                                              WAL00130
      YCUB(XP,XR,YR,YRP,AA,BB)=AA*(XP-XR)**3+BB*(XP-XR)**2+YRP*(XP-XR)  WAL00140
     1+YR                                                               WAL00150
      YPCUB(XP,XR,YRP,AA,BB)=3.*AA*(XP-XR)**2+2.*BB*(XP-XR)+YRP         WAL00160
 1000 FORMAT(20A4)                                                      WAL00170
 1001 FORMAT(3F10.4,3I10)                                               WAL00180
 1002 FORMAT(4X,14HGEOMETRY INPUT/4X,2HL=,F7.3,5X,5HHBAR=,F7.4,5X       WAL00190
     1,6HRNBAR=,F7.4)                                                   WAL00200
 1003 FORMAT(4X,8HCOWL LIP/5X,4HXBAR,6X,4HYBAR,6X,3HYPR)                WAL00210
 1004 FORMAT(4X,13HEXTERNAL COWL/5X,4HXBAR,6X,4HYBAR,6X,3HYPR           WAL00220
     1,10X,4HLFUN)                                                      WAL00230
 1005 FORMAT(4X,13HINTERNAL COWL/5X,4HXBAR,6X,4HYBAR,6X,3HYPR           WAL00240
     1,10X,4HLFUN)                                                      WAL00250
      DATA LAMP/0/                                                      WAL00260
      IF(LAMP.NE.0) GO TO 100                                           WAL00270
      READ(5,1000) A                                                    WAL00280
      WRITE(6,1000) A                                                   WAL00290
      PIO2=PII/2.                                                       WAL00300
      TPIO2=3.*PIO2                                                     WAL00310
      READ(5,1001) ELL,HBAR,RNBAR,JNOSB,JOUTB,JINB                      WAL00320
      WRITE(6,1002)ELL,HBAR,RNBAR                                       WAL00330
      RN=RNBAR/ELL                                                      WAL00340
      R0=3.*RN                                                          WAL00350
      RD=R0-RN                                                          WAL00360
      HH=HBAR/ELL                                                       WAL00370
      XF=4.*RD                                                          WAL00380
      DUM=RMFLO*EM*((1.+GD*EM**2)/GE)**(-GC/2.)                         WAL00390
      TT=HH*DUM                                                         WAL00400
      IF(LA.EQ.1) TT=HH*SQRT(DUM)                                       WAL00410
      EP=.00001                                                         WAL00420
C     COWL LIP DATA                                                     WAL00430
      JNOS=JNOSB                                                        WAL00440
      IF(JNOS.EQ.0) GO TO 55                                            WAL00450
      WRITE(6,1003)                                                     WAL00460
      DO 10 J=1,JNOS                                                    WAL00470
      READ(5,1001) XBAR,YBAR,YPBAR                                      WAL00480
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      WRITE(6,1001)XBAR,YBAR,YPBAR
      XNOS=XBAR/ELL+RD
      YNOS=YBAR/ELL
      IF(J.EQ.1) GO TO 5
      IF(J.EQ.JNOS) GO TO 6
      THE(J)=PII-ATAN((YNOS-HH)/(RD-XNOS))
      GO TO 7
    5 THE(J)=PIO2
      GO TO 7
    6 THE(J)=TPIO2
    7 IF(THE(J).GT.PII-EP.AND.THE(J).LT.PII+EP) THE(J)=PII
      BNOS(J)=SQRT((XNOS-RD)**2+(YNOS-HH)**2)
      BPNOS(J)=0.
      IF(THE(J).NE.PII)BPNOS(J)=(YPBAR    *(HH-YNOS)/(SIN(THE(J))*(SIN(
     1THE(J))-COS(THE(J))*YPBAR))-BNOS(J)*COS(THE(J)))/SIN(THE(J))
   10 CONTINUE
      JNOS1=JNOS-1
      DO 20 J=1,JNOS1
      AN1(J)=ACUB(THE(J),THE(J+1),BNOS(J),BNOS(J+1),BPNOS(J),BPNOS(J+1))
   20 AN2(J)=BCUB(THE(J),THE(J+1),BNOS(J),BNOS(J+1),BPNOS(J),BPNOS(J+1))
C     EXTERNAL COWL DATA
   25 JOUT=JOUTB+1
      XOUT(1)=0.
      YOUT(1)=HH
      YPOUT(1)=0.
      LFUNO(1)=3
      WRITE(6,1004)
      DO 30 J=2,JOUT
      READ(5,1001) XBAR,YBAR,YPOUT(J),LFUNO(J)
      WRITE(6,1001)XBAR,YBAR,YPOUT(J),LFUNO(J)
      XOUT(J)=XBAR/ELL+RD
   30 YOUT(J)=YBAR/ELL
      YE=YOUT(JOUT)
      JOUT1=JOUT-1
      DO 40 J=1,JOUT1
      IF(LFUNO(J).EQ.1) GO TO 35
      AO1(J)=ACUB(XOUT(J),XOUT(J+1),YOUT(J),YOUT(J+1),YPOUT(J),YPOUT(J+1
     1))
      AO2(J)=BCUB(XOUT(J),XOUT(J+1),YOUT(J),YOUT(J+1),YPOUT(J),YPOUT(J+1
     1))
      GO TO 40
   35 AO1(J)=0.
      AO2(J)=0.
   40 CONTINUE
C     INTERNAL COWL DATA
      IF(JINB.EQ.0) GO TO 65
      JIN=JINB+3
      JINB1=JINB+1
      JINB2=JINB+2
      XIN(1)=0.
      YIN(1)=HH
      YPIN(1)=0.
      LFUNI(1)=3
      WRITE(6,1005)
      DO 50 J=2,JINB1
```

```
      READ(5,1001) XBAR,YBAR,YPIN(J),LFUNI(J)
      WRITE(6,1001)XBAR,YBAR,YPIN(J),LFUNI(J)
      XIN(J)=XBAR/ELL+RD
   50 YIN(J)=YBAR/ELL
      XC=XIN(JIN81)
      XIN(JINB2)=(XF+XC)/2.
      YIN(JINB2)=TT
      YPIN(JINB2)=0.
      LFUNI(JINB2)=3
      XIN(JIN)=XF
      YIN(JIN)=HH
      YPIN(JIN)=0.
      LFUNI(JIN)=3
      DO 60 J=1,JINB2
      IF(LFUNI(J).EQ.1)GO TO 55
      AI1(J)=ACUB(XIN(J),XIN(J+1),YIN(J),YIN(J+1),YPIN(J),YPIN(J+1))
      AI2(J)=BCUB(XIN(J),XIN(J+1),YIN(J),YIN(J+1),YPIN(J),YPIN(J+1))
      GO TO 60
   55 AI1(J)=0.
      AI2(J)=0.
   60 CONTINUE
   65 LAMP=1
  100 IF(LP.EQ.2) GO TO 400
      IF(LREG.EQ.8) GO TO 300
      IF(LREG.GT.1.AND.LREG.LT.6) GO TO 200
C     EXTERNAL COWL DATA
      IF(X.LT.0.)GO TO 120
      IF(X.GT.XF)GO TO 130
      DO 110 J=2,JOUT
      L=J
      IF(X.LT.XOUT(J))GO TO 115
  110 CONTINUE
  115 Y=YCUB(X,XOUT(L),YOUT(L),YPOUT(L),AO1(L-1),AO2(L-1))
      YP=YPCUB(X,XOUT(L),YPOUT(L),AO1(L-1),AO2(L-1))
      RETURN
  120 Y=HH
      YP=0.
      RETURN
  130 Y=YE
      YP=0.
      RETURN
C     INTERNAL COWL GEOMETRY
  200 IF(X.LT.0..OR.X.GT.XF) GO TO 220
      DO 210 J=2,JIN
      L=J
      IF(X.LT.XIN(J))GO TO 215
  210 CONTINUE
  215 Y=YCUB(X,XIN(L),YIN(L),YPIN(L),AI1(L-1),AI2(L-1))
      YP=YPCUB(X,XIN(L),YPIN(L),AI1(L-1),AI2(L-1))
      RETURN
  220 Y=HH
      YP=0.
      RETURN
C     COWL LIP GEOMETRY
  300 DO 310 J=2,JNOS
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                                                                      WAL01580
      L=J                                                             WAL01590
      IF(X.LT.THE(J))GO TO 315                                        WAL01600
  310 CONTINUE                                                        WAL01610
  315 Y=YCUB(X,THE(L),BNOS(L),BPNOS(L),AN1(L-1),AN2(L-1))            WAL01620
      YP=YPCUB(X,THE(L),BPNOS(L),AN1(L-1),AN2(L-1))                  WAL01630
      RETURN                                                          WAL01640
C     CENTERBODY GEOMETRY                                             WAL01650
  400 Y=0                                                             WAL01660
      YP=0                                                            WAL01670
      RETURN                                                          WAL01680
      END                                                             WAL01690

      SUBROUTINE BOUND(Z,P)                                           BOU00010
      COMMON/BLK8/PRATIO,RDIST,PRAD,KPLUME,JJ                         BOU00020
      COMMON/BLK6/ ZK(200),PK(200),KEND                               BOU00030
  101 FORMAT(2F10.4)                                                  BOU00040
  102 FORMAT(1X,I5,3E16.4)                                            BOU00050
   30  DO 40 K=2,KEND                                                 BOU00060
       IF(ZK(K).GT.Z) GO TO 50                                        BOU00070
   40  CONTINUE                                                       BOU00080
   50  L1=K-1                                                         BOU00090
       L2=K                                                           BOU00100
       EP=(Z-ZK(L1))/(ZK(L2)-ZK(L1))                                  BOU00110
       PRES=PK(L1)+EP*(PK(L2)-PK(L1))                                 BOU00120
       P=ALOG(PRES/PRATIO)                                            BOU00130
       RETURN                                                         BOU00140
       END                                                            BOU00150
```