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A COMPUTER PROGRAM FOR THE AERODYNAMIC DESIGN OF AXISYMMETRIC AND PLANAR NOZZLES FOR SUPERSONIC AND HYPERSONIC WIND TUNNELS

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A computer program is presented for the aerodynamic design of axisymmetric and planar nozzles for supersonic and hypersonic wind tunnels. The program is the culmination of the effort expended at various times over a number of years to develop a method of designing a wind tunnel with an inviscid contour which has continuous curvature and which is corrected for the growth of the boundary layer in a manner such that uniform parallel flow can be

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20. ABSTRACT (Continued)

expected at the nozzle exit. The continuous curvature is achieved through specification of a centerline distribution of velocity (or Mach number) which has first and second derivatives that 1) are compatible with a transonic solution near the throat and with radial flow near the inflection point and 2) approach zero at the design Mach number. The boundary-layer growth is calculated by solving a momentum integral equation by numerical integration.

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PREFACE

The work reported herein was conducted by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC). The results of the research were obtained by ARO, Inc., AEDC Division (a Sverdrup Corporation Company), operating contractor for the AEDC, AFSC, Arnold Air Force Station, Tennessee, under ARO Project Numbers V33A-A8A and V32A-P1A. The Air Force project manager was Mr. Elton R. Thompson. The manuscript was submitted for publication on September 12, 1978.

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1.0 INTRODUCTION

Supersonic and hypersonic wind tunnel nozzles can be placed in two general categories, planar (also called two-dimensional) and axisymmetric. Early supersonic nozzles (circa 1940) were planar for many reasons: the state of the art was new with regard to both the design and the fabrication; the expansion of the air - the usual medium - was in one plane only, thereby simplifying the calculations and requiring two contoured walls for each test Mach number and two flat walls which could be used for all the Mach numbers; and the relatively low stagnation temperature and pressure requirements did not create dimensional stability problems in the throat region. Dimensional stability would in later years become a primary factor in the development of axisymmetric nozzles.

Prandtl and Busemann, Ref. 1, laid the foundation for determining the inviscid nozzle contours by the method of characteristics. Foelsch, Ref. 2, simplified the calculation of the contour by assuming that the flow in the region of the inflection point was radial, as if the flow came from a theoretical source as illustrated in Fig. 1. The downstream boundary of the radial flow is the right-running characteristic AC from the inflection point, A, to the point, C, on the axis of symmetry where the design Mach number is first reached. The flow properties along this characteristic can be readily calculated; and inasmuch as all left-running characteristics downstream of the radial flow region are straight lines in planar flow, the entire downstream contour can be determined analytically. Upstream of the inflection point, it was assumed that the source flow could be produced by a contour which was a simple analytic curve. In the Foelsch design the Mach number gradient on the axis is discontinuous at the juncture of the radial flow region and the beginning of the parallel flow region. This discontinuity produces a discontinuity in curvature of the contour at the inflection point and at the theoretical exit of the nozzle.

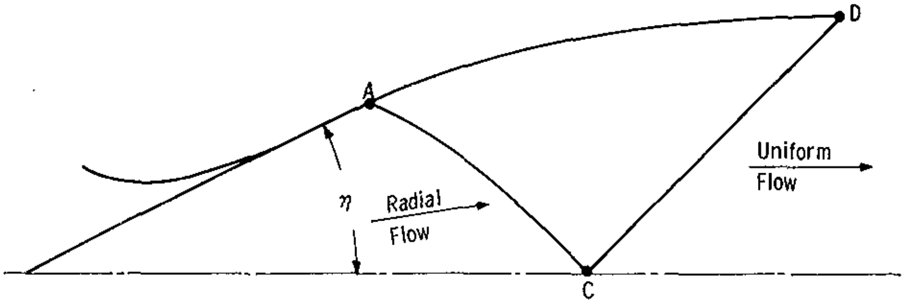

Figure 1. A Foelsch-type nozzle with radial flow at the inflection point.

As the state of the art progressed, it became desirable to cover a range of Mach numbers without fabricating different nozzle blocks for each Mach number. A limited range of Mach numbers could be covered by using blocks with unsymmetrical contours which could be translated relative to each other to vary the mean Mach number in the test section. The widest range of Mach numbers with acceptably uniform flow in the test section has been obtained in wind tunnels in which the contoured walls consist of flexible plates supported by jacks which can be adjusted to vary the contour to suit each Mach number. Inasmuch as the curvature of a plate so supported must be continuous, methods of calculating contours with continuous curvature were developed (Refs. 3, 4, and 5) by introducing a transition region, A B C J, downstream of the radial flow region (see Fig. 2). The shape of the wall between points A and J was controlled to give continuous curvature. The contours used for the von Kármán Gas Dynamics Facility 40- by 40-in. Supersonic Wind Tunnel (A) at AEDC were obtained by the method of Ref. 5. Not only is a continuous-curvature contour easier to match with a jack-supported plate, but it also satisfies the potential flow criterion for zero vorticity,

$$dq/dn = Kq \tag{1}$$

where q is the velocity measured along a streamline of curvature K and n is the distance normal to the streamline. Inasmuch as the inviscid contour is a streamline, this criterion implies that the flow will be disturbed where a contour has a discontinuity in curvature.

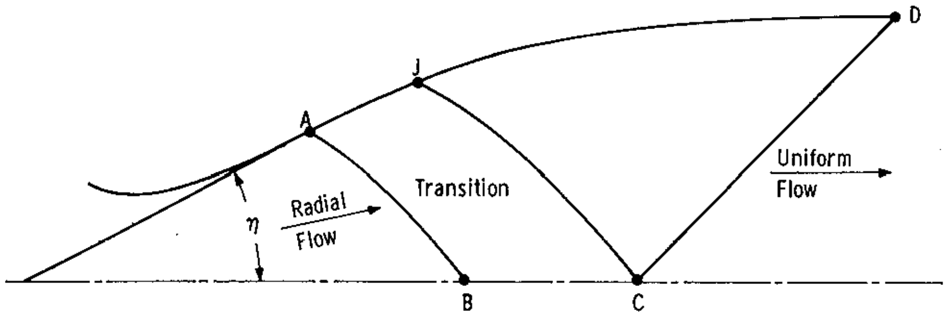

Figure 2. Nozzle with radial flow and a transition region to produce continuous curvature.

The usual wind tunnel criterion concerning temperature is that the constituents of the gas should not liquefy during the expansion process required to reach the test Mach number. For the usual pressure levels involved, ambient stagnation temperatures can be used up to a Mach number of about five. As the stagnation temperature is raised, dimensional stability becomes more difficult to maintain in a planar nozzle. Therefore, axisymmetric nozzles are used when elevated stagnation temperatures are involved. Axisymmetric nozzles have also been used for low-density tunnels (Ref. 6) because their boundary-layer growth is more uniform than that of planar nozzles, which inherently have transverse pressure gradients on the flat walls. The obvious disadvantage of axisymmetric nozzles is that each one must be designed for a particular Mach number. Moreover, disturbances created by imperfections in the contour tend to be focused on the centerline.

Before the advent of high-speed digital computers, it was extremely time consuming (Ref. 7) to calculate axisymmetric nozzle flow by the method of characteristics (Ref. 8). Inasmuch as the assumption of source flow saved time in designing a planar nozzle, it was logical to use source flow as a starting point in the design of an axisymmetric nozzle. In Ref. 9, Foelsch develops an approximate method of converting the radial flow to uniform flow. Beckwith et al., Ref. 7, show that Foelsch's approximations were quite inaccurate but utilized the idea of a region of radial flow followed immediately on the axis by uniform flow, as in Fig. 1. As in the case of planar flow, the discontinuity in Mach number gradient on the axis produces a discontinuity in curvature on the contour (Ref. 10). Such discontinuities have been eliminated by the design methods of Refs. 10, 11, and 12; here, an axial distribution of Mach number (or velocity) between points B and C (Fig. 2) introduces a transition region between the radial and parallel flow regions, thus gradually reducing the gradient and/or second derivative to zero from the radial flow values at the beginning of the parallel flow. As shown in Fig. 3, the upstream boundary of the radial flow region is a left-running characteristic from the inflection point, G, to the axis at point E. The flow angle is the same at points G and A. Both are shown to illustrate a general nozzle design. As described in Ref. 12, the contour upstream of the inflection point can be calculated for an axial distribution of velocity in the region between points I and E, which makes the transition from sonic values to radial flow values. On the axis, the sonic values of first and second derivatives of velocity with respect to axial distance were calculated by an adaptation of the transonic theory of Hall, Ref. 13, or Kliegel and Levine, Ref. 14. The upstream limit of these calculations was the left-running characteristic from the sonic point on the axis.

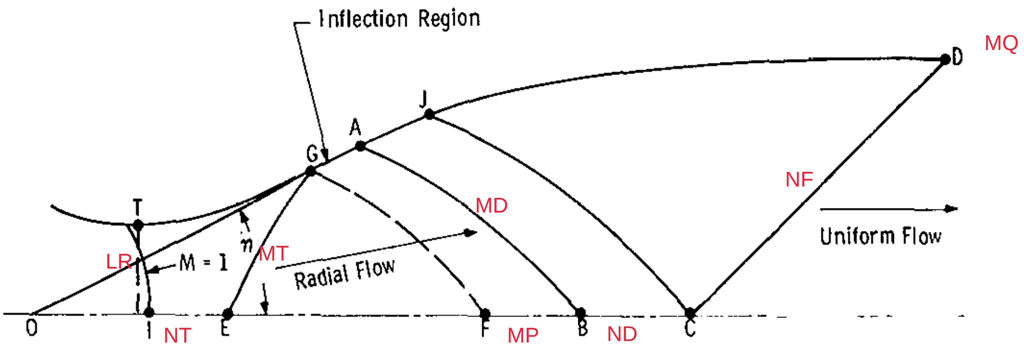

Figure 3. Nozzle illustrating design method of Ref. 13.

This characteristic is also called a branch line. Between the theoretical location of the throat and the intersection of the branch line with the contour was a region which was not calculated but which increased in size as the throat curvature increased. This gap in the contour has been eliminated by the method described herein which utilizes a right-running characteristic originating at the throat as shown in Fig. 4 (where point I has been moved from the sonic line to the throat characteristic). With this latest improvement upon the method of Ref. 12, contours can be designed which have throat radii of curvature of the same order of magnitude as the throat radii although such an extreme curvature would not normally be recommended from other standpoints. A recent (1975) design of a Mach 6 nozzle utilized this method with a throat radius of curvature of about 5.5 times the throat radius.

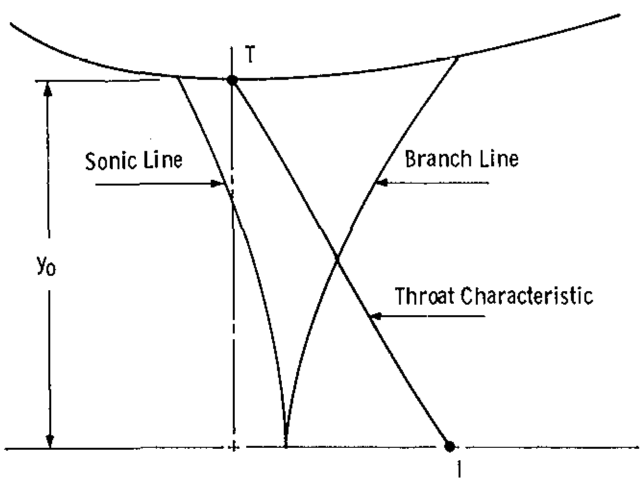

Figure 4. Nozzle throat region.

After the design method was developed for axisymmetric nozzles, it was adapted for planar nozzles having a prescribed centerline distribution of Mach number (or velocity). This approach to such a design is considerably different from that of Ref. 5. The current design method is incorporated into the computer program included herein. As an option in the program, a complete centerline Mach number distribution can be used which does not include a radial flow region. Parts of the computer program are subroutines for computing the boundary-layer correction to the inviscid contour, for smoothing the contour, and for interpolating points at even axial positions by means of a cubic spline fit of the contour.

2.0 TRANSONIC SOLUTION

In many early nozzle designs, it was assumed that the flow at the throat was uniform (M = 1) and parallel. This assumption implies that the wall curvature is zero and that the acceleration of the flow is zero (i.e., the acceleration starts from zero at the beginning of the contraction, reaches a maximum in the contraction but is reduced to zero again at the throat, and must be increased again in the beginning of the supersonic contour and reduced to zero at the nozzle exit). A nozzle so designed therefore becomes considerably longer than one in which the flow reaches its maximum acceleration in the vicinity of the throat, where it is approximately proportional to the reciprocal of the square root of the radius of curvature. The above argument indicates the fallacy of some so-called "minimum length" nozzles, although some designers have combined a contraction having a relatively high throat curvature with the supersonic section having zero throat curvature.

For a throat with a finite radius of curvature there have been many transonic solutions. Hall, Ref. 13, developed a small perturbation transonic solution for irrotational, perfect gas flow, in both two-dimensional and axisymmetric nozzles, by means of expansions in inverse powers of R, the ratio of the throat radius of curvature to the throat half-height, or radius. His solution gives the normalized (with the velocity at the sonic point) axial and normal velocity components in the form

$$u = 1 + \frac{u_a(y,z)}{R} + \frac{u_b(y,z)}{R^2} + \frac{u_c(y,z)}{R^3} + \ldots . \qquad (2)$$

$$v = \left[\frac{\gamma + 1}{(1+\sigma) R}\right]^{\frac{1}{2}} \left[\frac{v_a(y,z)}{R} + \frac{v_b(y,z)}{R^2} + \frac{v_c(y,z)}{R^3} + \ldots\right] \tag{3}$$

where

$$z = \left[\frac{(1+\sigma) R}{\gamma + 1}\right]^{\frac{1}{2}} x \tag{4}$$

and x and y are coordinates normalized with the throat half-height or radius, y_o. The value of σ is zero for two-dimensional flow and one for axisymmetric flow. Kliegel and Levine in Ref. 14 extended the applicability of Hall's axisymmetric solution to lower values of R essentially by making the substitution

$$R^{-1} = S^{-1} + S^{-2} + S^{-3} + \ldots \tag{5}$$

where S = R + 1, into Eqs. (2) and (3). In the method used herein, the same substitution is made in Eq. (4) for two-dimensional flow as well as for axisymmetric flow and therefore becomes a special case of the general transonic solution described in Ref. 15. The complete general equations in terms of S are given in Appendix A.

At the throat, x = 0, $y = y_o$, v = 0, for planar flow,

$$u = 1 + \frac{1}{3S} - \frac{(14\gamma - 75)}{270S^2} + \frac{(274\gamma^2 - 861\gamma + 4464)}{17010S^3} + \ldots \tag{6}$$

$$\frac{du}{dx/y_o} = \lambda\left[1 + \frac{1}{S} - \frac{(32\gamma^2 + 87\gamma - 561)}{540S^2} + \ldots\right] \tag{7}$$

and, for axisymmetric flow,

$$u = 1 + \frac{1}{4S} - \frac{(14\gamma - 57)}{288S^2} + \frac{(2364\gamma^2 - 3915\gamma + 14337)}{82944S^3} + \ldots \tag{8}$$

$$\frac{du}{dx/y_o} = \lambda\left[1 + \frac{7}{8S} - \frac{(64\gamma^2 + 117\gamma - 1026)}{1152S^2} + \ldots\right] \tag{9}$$

where the derivatives are with respect to x nondimensionalized by the throat half-height or radius, respectively, and

$$\lambda = \left[\frac{1+\sigma}{(\gamma-1)S} \right]^{\frac{1}{2}} \tag{10}$$

On the axis, y = 0, v = 0, for planar flow,

$$\begin{aligned} u = {} & 1 - \frac{1}{6S} + \frac{\gamma-15}{270S^2} - \frac{782\gamma^2 + 3507\gamma + 7767}{272160S^3} + \ldots \\ & + \frac{x\lambda}{y_o}\left(1 + \frac{134\gamma^2 + 429\gamma + 123}{4320S^2} + \ldots\right) + \\ & \left(\frac{x\lambda}{y_o}\right)^2 \left(-\frac{2\gamma-3}{6} - \frac{5\gamma}{36S} + \ldots\right) + \\ & \left(\frac{x\lambda}{y_o}\right)^3 (2\gamma^2 - 33\gamma + 9)/72 + \ldots \end{aligned} \tag{11}$$

and, for axisymmetric flow,

$$\begin{aligned} u = {} & 1 - \frac{1}{4S} + \frac{10\gamma-15}{288S^2} - \frac{2708\gamma^2 + 2079\gamma + 2115}{82944S^2} + \ldots \\ & + \frac{x\lambda}{y_o}\left(1 - \frac{1}{8S} + \frac{92\gamma^2 + 180\gamma - 9}{1152S^2} + \ldots\right) + \\ & \left(\frac{x\lambda}{y_o}\right)^2 \left(-\frac{2\gamma-3}{6} - \frac{\gamma+1}{16S} + \ldots\right) + \\ & \left(\frac{x\lambda}{y_o}\right)^3 (4\gamma^2 - 57\gamma + 27)/144 + \ldots \end{aligned} \tag{12}$$

Because the sonic line is curved for finite values of R, the mass flow through the throat is reduced by the factor C_D (discharge coefficient), which is the ratio of actual mass flow to that which could flow if R were infinite and the sonic line were straight. For planar flow,

$$C_D = 1 - \frac{\gamma+1}{90S^2}\left[1 - \frac{4\gamma-24}{21S} + \frac{334\gamma^2 - 457\gamma + 4353}{3780S^2} + \ldots\right] \tag{13}$$

and, for axisymmetric flow,

$$C_D = 1 - \frac{\gamma+1}{96S^2}\left[1 - \frac{8\gamma-27}{24S} + \frac{754\gamma^2 - 757\gamma + 3615}{2880S^2} + \ldots\right] \tag{14}$$

The flow which passes through the throat also passes through the sonic area of the source flow which is at a distance r_1 from the source. In planar flow,

$$y^* = y_o\, C_D = \eta\, r_1 \tag{15}$$

or

$$y_o/r_1 = \eta/C_D \tag{16}$$

where the inflection angle, η, is in radians.

In axisymmetric flow,

$$\pi y^{*2} = \pi y_o^2\, C_D = 2\pi\, r_1^2\,(1 - \cos\eta) \tag{17}$$

or

$$y_o/r_1 = 2\,\sin(\eta/2)/C_D^{\frac{1}{2}} \tag{18}$$

In the calculation of the throat characteristic used herein, the value at x = 0, y = y_o, Eq. (6), is the starting point. The half-height or radius, y_o, is divided into 240 equally spaced values of y. Inasmuch as the characteristic is right running, its slope at each point is

$$dy/dx = \tan(\phi - \mu) \tag{19}$$

where

$$\sin\mu = 1/M \tag{20}$$

Also

$$W = M\left(\frac{2}{\gamma+1} + \frac{\gamma-1}{\gamma+1}\,M^2\right)^{-\frac{1}{2}} \tag{21}$$

$$\sin\phi = v/W \tag{22}$$

and

$$d\psi + d\phi = \frac{\sigma\,\sin\phi\,\sin\mu}{y}\; d\,\xi \tag{23}$$

$$d\xi = dx/\cos(\phi - \mu) = dy/\sin(\phi - \mu) \tag{24}$$

The term ψ is the Prandtl-Meyer angle in two-dimensional flow,

$$\psi = \left(\frac{\gamma+1}{\gamma-1}\right)^{\frac{1}{2}} \tan^{-1}\left[\frac{\gamma-1}{\gamma+1}(M^2 - 1)\right]^{\frac{1}{2}} - \tan^{-1}(M^2 - 1)^{\frac{1}{2}} \tag{25}$$

Equations (19) and (23) are the characteristic equations and are solved by finite differences. If all values are known at point 1, the values at point 2 are found (y is known at both points) by

$$x_2 = x_1 + \frac{2(y_2 - y_1)}{\tan(\phi_1 - \mu_1) + \tan(\phi_2 - \mu_2)} \tag{26}$$

$$\Delta\xi = \left[(y_2 - y_1)^2 + (x_2 - x_1)^2\right]^{\frac{1}{2}} \tag{27}$$

$$\psi_2 = \psi_1 + \phi_1 - \phi_2 + \frac{\alpha}{2}\left[\frac{v_1}{W_1 y_1 M_1} + \frac{v_2}{W_2 y_2 M_2}\right]\Delta\xi \tag{28}$$

At the starting point W is the value of u because v = 0. Values of v_2 are calculated at each point (x_2, y_2) from the transonic solution, and Eqs. (26) to (28) are iterated until convergence is reached. For evaluating the term in brackets in Eq. (28), the ratio v/y is defined by the transonic solution even on the axis where both v and y are zero. This fact eliminates the general problem in axisymmetric characteristics solutions of evaluating the indeterminate sin ϕ/y in Eq. (23) on the axis of symmetry.

It may be noted that the value of W as calculated from the characteristic value from Eq. (21) differs from the value $(u^2 + v^2)^{1/2}$ calculated from the transonic equations, but the difference decreases with increasing R. For the final point of the throat characteristic which lies on the axis, the value of d^3u/dx^3 from the transonic solution for the axial distribution is "corrected" to make u = W for the axisymmetric case for values of R less than 12. The correction is about 16 percent for R = 1 and decreases rapidly as R increases. This correction is made so that values of du/dx and d^2u/dx^2 can be calculated from the transonic solution for later application. The correction is believed to be justified inasmuch as the accuracy of the transonic solution is limited, particularly for low values of R, because the series expression for u is truncated after the x^3 term.

3.0 CENTERLINE DISTRIBUTION

In the radial flow region, the distance r, measured from the source, is related to the local Mach number by

$$\left(\frac{r}{r_1}\right)^{1+\sigma} = M^{-1}\left(\frac{2}{\gamma+1} + \frac{\gamma-1}{\gamma+1} M^2\right)^{\frac{\gamma+1}{2(\gamma-1)}} \tag{29}$$

or

$$\left(\frac{r}{r_1}\right)^{1+\sigma} = W^{-1}\left(\frac{\gamma+1}{2} - \frac{\gamma-1}{2} W^2\right)^{\frac{-1}{\gamma-1}} \tag{30}$$

First, second, and third derivatives of W or M with respect to r/r_1 can be obtained as described in Ref. 12. Along the axis $x = r$ when x is measured from the source. Inasmuch as all coordinates must be normalized by the same factor, r_1, the transonic equation in terms of x/y_o and y/y_o can be transormed by Eqs. (16) and (18), after which the distance from the source to the throat station must be taken into account. This latter distance is generally unknown until after the distance from point I to point E is determined.

In radial flow, the term on the right-hand side of Eq. (23) can be evaluated simply. Inasmuch as $\sin\phi = y/r$ and $d\xi = dr/\cos\mu$,

$$\frac{\sin\phi \sin\mu \, d\xi}{y} = \tan\mu \frac{dr}{r}$$

but

$$\tan\mu = (M^2 - 1)^{-\frac{1}{2}}$$

and, from Eq. (29) for $\sigma = 1$,

$$\frac{dr}{r} = \frac{(M^2 - 1)}{2\left(1 + \frac{\gamma-1}{2} M^2\right)} \frac{dM}{M}$$

Thus

$$\tan\mu \frac{dr}{r} = \frac{(M^2 - 1)^{\frac{1}{2}}}{2\left(1 + \frac{\gamma-1}{2} M^2\right)} \frac{dM}{M}$$

From Eq. (25),

$$d\psi = \frac{(M^2 - 1)^{\frac{1}{2}}}{\left(1 + \frac{\gamma-1}{2} M^2\right)} \frac{dM}{M}$$

therefore, Eq. (23), in radial flow, becomes

$$d\psi + d\phi = \frac{\sigma}{2} d\psi \tag{31}$$

which applies for characteristic AB or GF. Similarly, for the left-running characteristic EG,

$$d\psi - d\phi = \frac{\sigma}{2} d\psi \tag{32}$$

Therefore,

$$\psi_B - \psi_A = (\sigma + 1)\eta = \psi_F - \psi_G \tag{33}$$

and

$$\psi_G - \psi_E = (\sigma + 1)\eta \tag{34}$$

and, from the design values η and M_B (and/or M_F), M_A, M_G, M_E, W_E, and the necessary derivatives can be calculated.

Within the accuracy of Eqs. (11) and (12), the second derivative of velocity ratio at the sonic point is negative for values of R less than 11.767 for planar flow and 10.525 for axisymmetric flow. The second derivative of Mach number at the sonic point is positive for all values of R. Inasmuch as the second derivative of either W or M is negative for source flow, it seems better to use a velocity distribution rather than a Mach number distribution between points I and E. On the other hand, a Mach number distribution between points B and C is preferable because the velocity ratio approaches the constant value of $[(\gamma + 1)/\gamma - 1)]^{1/2}$ as the Mach number increases to infinity; therefore, the change in velocity between points B and C becomes small relative to the change in Mach number.

The velocities and their first and second derivatives at points I and E are used to determine the coefficients of the general fifth degree polynomial

$$W = C_1 + C_2 X + C_3 X^2 + C_4 X^3 + C_5 X^4 + C_6 X^5 \qquad (35)$$

where

$$X = (x - x_I)/(x_E - x_I) \qquad (36)$$

Similarly, the Mach numbers and their first and second derivatives at points B and C are used to determine the coefficients of the polynomial

$$M = D_1 + D_2 X + D_3 X^2 + D_4 X^3 + D_5 X^4 + D_6 X^5 \qquad (37)$$

where, in this case,

$$X = (x - x_B)/(x_C - x_B) \qquad (38)$$

and the first and second derivatives at point C are usually set equal to zero.

In these equations, the lengths $(x_E - x_I)$ and $(x_C - x_B)$ must be specified, but can be determined by the conditions that C_6 and D_6 equal zero, thereby reducing the polynomials to fourth-degree ones. If the velocity at point E is determined by iteration, the third derivative at point I or E can be included as a criterion for the fourth-degree polynomial; or, by setting $C_5 = 0$, one can find a third-degree polynomial with a constant third derivative. In either case, the Mach number at point B is found from Eqs. (33) and (34) after the value at point E is found. All of these options are included in the program, but unless there are other factors involved, the preferred options are the cubic between points I and E and the quartic between points B and C.

For the cubic distribution for axisymmetric flow, the Mach number at point E is related to the radius ratio as shown in Fig. 5 for $\gamma = 1.4$ for various values of inflection angle. Cross plotted are lines of constant values of the ratio ψ_E/η. Such values for most axisymmetric nozzles lie in the range covered in this figure, and inasmuch as $\psi_F/\eta = \psi_E/\eta + 4$, values of M_F can also be obtained.

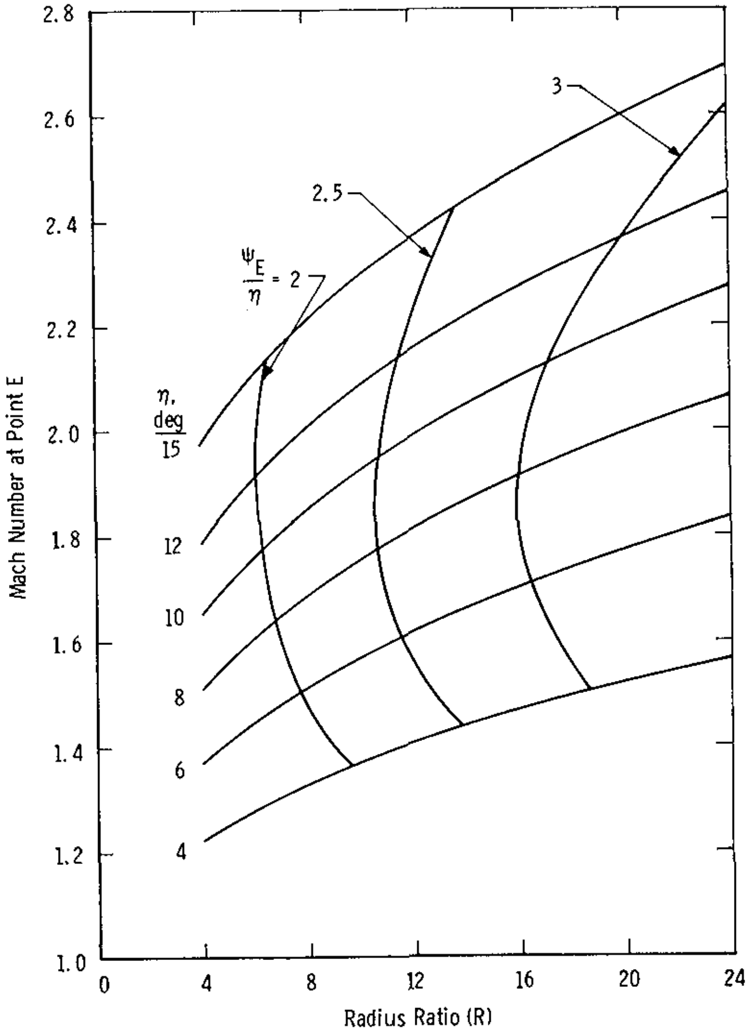

Figure 5. Relationships obtained from cubic distribution of velocity from sonic point to point E for axisymmetric nozzle.

In determining the length of the segment between points B and C, using the fourth-degree polynomial distribution, there is a minimum value of the Mach number at point B for the design Mach number at point C. As given in Ref. 12,

$$M_{B_{min}} = M_C + 0.75 \; M_B'^2 / M_B'' \tag{39}$$

where the primes indicate derivatives with respect to r/r_1. This relationship is shown in Fig. 6. For an axisymmetric nozzle designed for a Mach number greater than about 3.4, the minimum Mach number at

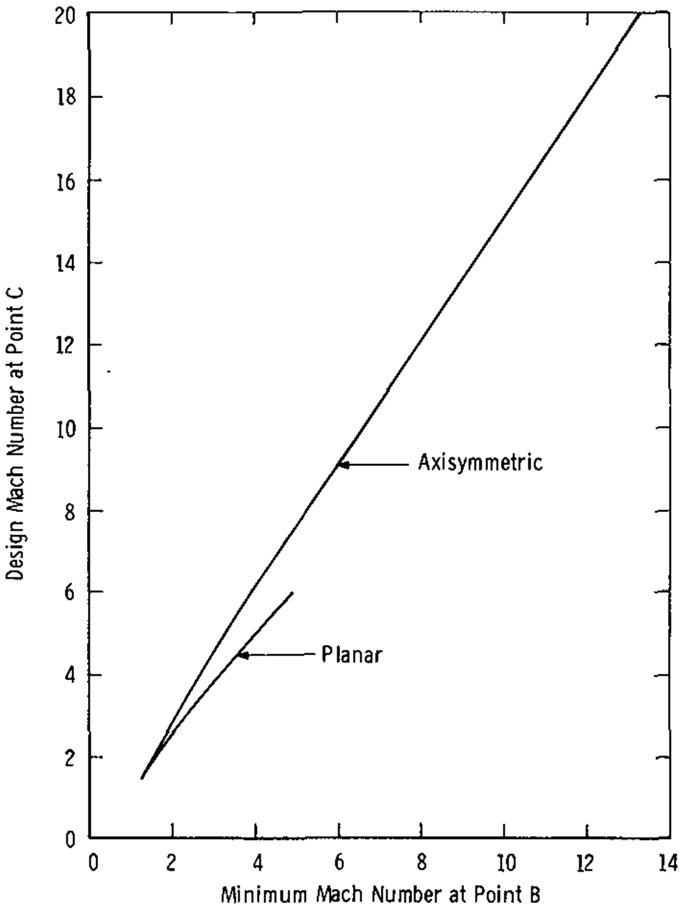

Figure 6. Limitations of fourth-degree distribution of Mach number from Eq. (39).

point B is about two-thirds of the design Mach number. Using such a value usually causes the length to be excessive, and more realistic values of M_B are 75 to 80 percent of M_C. It is important, however, as illustrated in Ref. 16, that the distance between points B and C be sufficient to allow for accurate machining of the contour between points A and J, which lie on the characteristics through points B and C, respectively.

4.0 INVISCID CONTOUR

The flow properties are determined at a desired number of points along the key characteristics (i.e., the throat characteristic, TI, as described earlier (a sub-multiple of 240 is used for subsequent calculations), the characteristics EG and AB bounding the radial flow region by Eqs. (33) and (34) for equal increments in η, and the final characteristic CD along which the Mach number is constant and the flow angle is zero). The flow properties are also determined at axial points from Eqs. (35) and (37). The network of characteristics is then calculated in the region TIEG starting at point E and progressing upstream and in the region ABCD starting at point B and progressing downstream.

The equations for a right-running characteristic were given previously.

$$dy/dx = \tan(\phi - \mu) \tag{19}$$

$$d\psi + d\phi = \frac{\sigma \sin\phi \sin\mu}{y}\, d\xi \tag{23}$$

where

$$d\xi = dx/\cos(\phi - \mu) = dy/\sin(\phi - \mu) \tag{24}$$

For a left-running characteristic, the equations are

$$dy/dx = \tan(\phi + \mu) \tag{40}$$

$$d\psi - d\phi = \frac{\sigma \sin\phi \sin\mu}{y}\, d\zeta \tag{41}$$

where

$$d\zeta = dx/\cos(\phi + \mu) = dy/\sin(\phi + \mu) \tag{42}$$

Also

$$d\psi = \frac{\cot\mu}{(1 + \frac{\gamma-1}{2} M^2)} \frac{dM}{M} = \cot\mu \frac{dW}{W} \tag{43}$$

Values of x, y, ϕ, and M are known at the general point 1 on the right-running characteristic, ξ, and at the general point 2 on the left-running characteristic, ζ. The characteristics intersect at the general point 3 where the values are calculated by numerical integration of Eqs. (23) and (41) along the respective characteristics.

$$\psi_3 - \psi_2 - (\phi_3 - \phi_2) = P_2 =$$

$$\frac{\sigma}{2}\left(\frac{\sin\phi_3 \sin\mu_3}{y_3} + \frac{\sin\phi_2 \sin\mu_2}{y_2}\right)\Delta\zeta \tag{44}$$

where

$$\Delta\zeta = (x_3 - x_2) \sec\beta \tag{45}$$

and

$$\frac{y_3 - y_2}{x_3 - x_2} = \tan\beta = \frac{1}{2}\tan(\phi_3 + \mu_3) + \frac{1}{2}\tan(\phi_2 + \mu_2) \tag{46}$$

$$\psi_3 - \psi_1 + (\phi_3 - \phi_1) = P_1 =$$

$$\frac{\sigma}{2}\left(\frac{\sin\phi_3 \sin\mu_3}{y_3} + \frac{\sin\phi_1 \sin\mu_1}{y_1}\right)\Delta\xi \tag{47}$$

where

$$\Delta\xi = (x_3 - x_1) \sec\alpha \tag{48}$$

and

$$\frac{y_3 - y_1}{x_3 - x_1} = \tan\alpha = \frac{1}{2}\tan(\phi_3 - \mu_3) + \frac{1}{2}\tan(\phi_1 - \mu_1) \tag{49}$$

Adding, substracting, and rearranging gives

$$\psi_3 = \frac{1}{2}(\psi_2 + \psi_1 - \phi_2 + \phi_1 + P_2 + P_1) \tag{50}$$

$$\phi_3 = \frac{1}{2}(\psi_1 - \psi_2 + \phi_1 + \phi_2 + P_1 - P_2) \tag{51}$$

In planar flow, $P_1 = P_2 = 0$ because $\sigma = 0$ and Eqs. (50) and (51) can be solved directly, M_3 is obtained from ψ_3 by the inverse application of Eq. (25), and $\mu_3 = \sin^{-1}(1/M_3)$. In axisymmetric flow, the equations must be solved by iteration. A useful first approximation for P_1 and P_2 is the radial flow values, $P_1 = (\psi_3 - \psi_1)/2$ and $P_2 = (\psi_3 - \psi_2)/2$.

At all points except on the axis in axisymmetric flow, Eqs. (44) and (47) are defined because y_2 and y_1 are nonzero. On the axis, the terms $\sin \phi_2/y_2$ and $\sin \phi_1/y_1$ are indeterminate with the form zero/zero. These indeterminates can be evaluated by assuming that the general points 1 and 2 on the axis are very close together and that $\mu_1 \approx \mu_2 \approx \mu_3$ and $W_1 \approx W_2 \approx W_3$. Equation (41) can be written

$$\cot \mu \frac{dW}{W} = d\phi + \frac{\sin \phi \sin \mu \, dx}{y \cos (\phi + \mu)} \tag{52}$$

and Eq. 23 can be written

$$\cot \mu \frac{dW}{W} = -d\phi + \frac{\sin \phi \sin \mu \, dx}{y \cos (\phi - \mu)} \tag{53}$$

as

$$\phi \to 0 \, , \quad \phi \to \sin \phi \, , \quad \phi \pm \mu \to \pm \mu$$

and

$$\tan \mu_3 = \frac{y_3}{x_3 - x_2} = \frac{y_3}{x_1 - x_3}$$

In finite-difference form,

$$\frac{\cot \mu_3}{W_3} (W_3 - W_2) = \phi_3 + \frac{\sin \phi_3 \tan \mu_3 (x_3 - x_2)}{y_3}$$

$$\to \frac{\phi_3 \tan \mu_3 (x_3 - x_2)}{y_3} + \frac{\sin \phi_3 \tan \mu_3 (x_3 - x_2)}{y_3} \tag{54}$$

$$\to 2 \sin \phi_3 \tan \mu_3 (x_3 - x_2)/y_3 \tag{55}$$

Similarly

$$\frac{\cot \mu_3}{W_3} (W_1 - W_3) = \phi_3 + \sin \phi_3 \tan \mu_3 (x_1 - x_3)/y_3 \tag{56}$$

$$\to 2 \sin \phi_3 \tan \mu_3 (x_1 - x_3)/y_3 \tag{57}$$

Adding Eqs. (55) and (57) and rearranging,

$$\lim_{y \to 0} \frac{\sin \phi}{y} = \frac{1}{2} \frac{\cot^2 \mu}{W} \frac{dW}{dx} \tag{58}$$

and

$$\frac{\sin \phi_2 \sin \mu_2}{y_2} = \frac{(M_2^2 - 1)}{2M_2 W_2} \left(\frac{dW}{dx} \right)_2 \tag{59}$$

for use in Eq. (44) when point 2 is on the axis, and

$$\frac{\sin \phi_1 \sin \mu_1}{y_1} = \frac{(M_1^2 - 1)}{2W_1 W_1} \left(\frac{dW}{dx}\right)_1 \tag{60}$$

for use in Eq. (47) when point 1 is on the axis.

In starting the calculation of the network of characteristics in the region TIEG, point E becomes point 1 and the first axis point upsteam of point E becomes point 2. The complete left-running characteristic approximately parallel to EG is calculated, and the point on the contour is determined from mass flow considerations as described in Ref. 17. The flow properties along this characteristic are then used to calculate the next left-running characteristic, again starting on the axis. This process is repeated until point I is reached, after which the starting point for each left-running characteristic is a point on the throat characteristic as illustrated in Fig. 7. The process in region ABCD is similar except that right-running characteristics are calculated for each point on the contour.

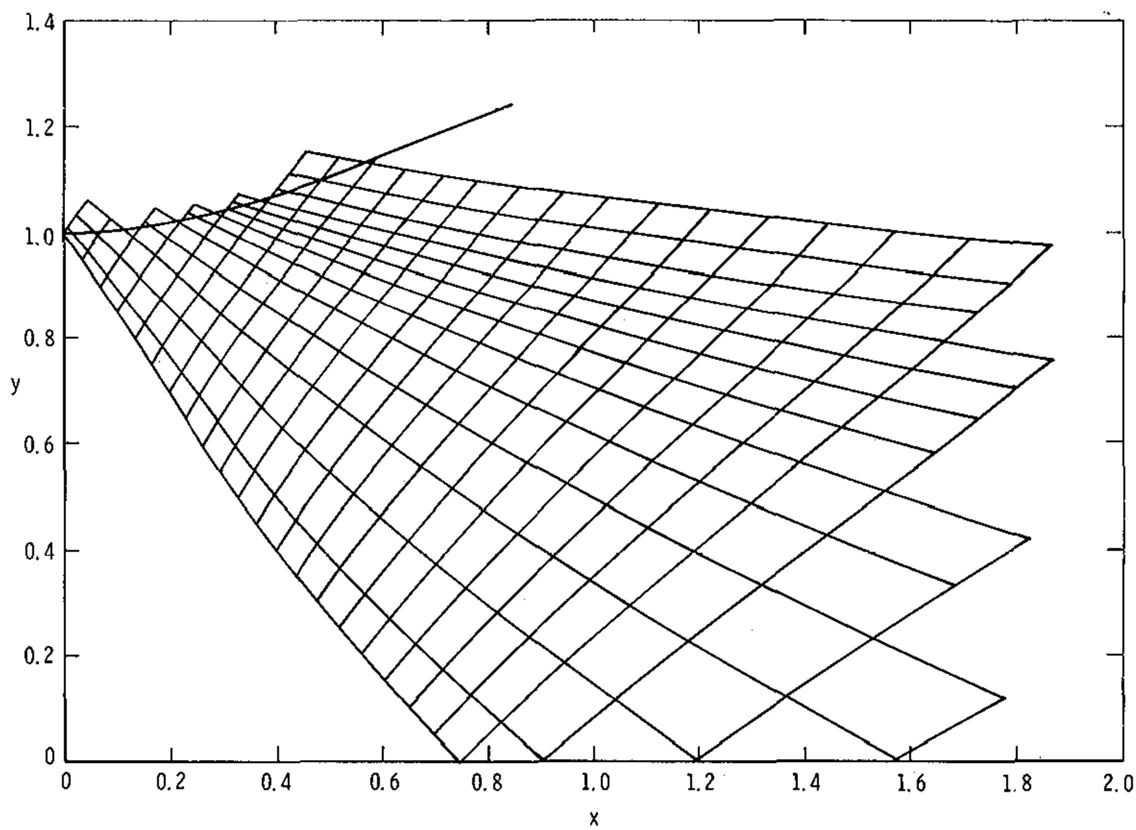

Figure 7. Characteristics near throat of nozzle with R = 1.

5.0 BOUNDARY-LAYER CORRECTION

To each ordinate of the inviscid contour must be added a correction for the boundary-layer growth to obtain the viscid or physical contour of the nozzle. Except for very low stagnation pressures, the boundary layer is assumed to be turbulent. Generally, the boundary-layer correction will be made for one design condition of stagnation pressure and temperature although it is theoretically possible to reshape a flexible-plate type of planar nozzle to account for different boundary-layer thicknesses corresponding to different stagnation conditions. The correction for a planar nozzle is usually applied to the contoured walls only, but the correction also allows for the growth of the boundary layer on the parallel walls in order to maintain a constant Mach number along the test section centerline. Therefore, the correction applied is greater than the displacement thickness on the contoured walls, and the flow in the test section is diverging in the longitudinal plane normal to the contoured walls. In the longitudinal plane normal to the parallel walls, the flow is converging because of the boundary-layer growth; moreover, there is a tendency for the boundary layer to be thicker on the wall centerline because of the transverse pressure gradients present on the parallel walls. Although these physical effects make a true correction impossible for a planar nozzle, the calculations described herein are made as if the cross section were circular, with the circumference at each station equal to the periphery of the actual rectangular cross section.

The method of calculating the boundary-layer growth is based on obtaining a solution to the von Kármán momentum equation written for axisymmetric flow.

$$\frac{d\theta}{dx} + \theta\left[\frac{2 - M^2 + H}{M\left[1 + (\gamma - 1)M^2/2\right]}\frac{dM}{dx} + \frac{1}{r_w}\frac{dr_w}{dx}\right] = \frac{C_f}{2}\sec\phi_w \tag{61}$$

The term $\left[(1/r_w)(dr_w/dx)\right]$ becomes an effective one for planar flow as just described. For either type of nozzle, the inviscid value is used as a first approximation. The entire solution is iterated several times with new values of r_w and $dr_w/dx = \tan \phi_w$ obtained each time by adding vectorially the displacement thickness to the inviscid contour.

The value of momentum thickness used in Eq. (61) is defined by

$$\theta = \int_0^\delta \left(1 - \frac{z \cos \phi_w}{r_w}\right)\left(\frac{\rho q}{\rho_e q_e}\right)\left(1 - \frac{q}{q_e}\right) dz \tag{62}$$

where z is measured normal to the wall.

Also

$$\delta^* = H\theta = \int_0^\delta \left(1 - \frac{z \cos \phi_w}{r_w}\right)\left(1 - \frac{\rho q}{\rho_e q_e}\right) dz \tag{63}$$

The quantities δ^* and θ may be considered to be the displacement and momentum thicknesses when the boundary-layer thickness is small with respect to the radius, r_w. These values are related to total values δ_a^* and θ_a, obtained from mass-defect and momentum-defect considerations by

$$\delta^* = \delta_a^* - \delta_a^{*2} \cos \phi_w / 2 r_w \tag{64}$$

and

$$\theta = \theta_a - \theta_a^2 \cos \phi_w / 2 r_w \tag{65}$$

Because $r_w = \delta_\alpha^* \cos \phi_w + y$, where y is the inviscid radius, Eq. (64) may be rearranged to give

$$\delta_a^* = \delta^* + (\delta^{*2} + y^2 \sec^2 \phi_w)^{\frac{1}{2}} - y \sec \phi_w \tag{66}$$

For the final correction, the value $\delta_a^* \sec \phi_w$ is added to the inviscid radius in order that no correction be made to the longitudinal location.

The integrations of Eqs. (62) and (63) are performed numerically using Gauss' 16-point formula, with the assumption of the power-law velocity distribution

$$q/q_e = (z/\delta)^{1/N} \tag{67}$$

and

$$\rho/\rho_e = T_e/T \tag{68}$$

where

$$T = T_w + \alpha (T_{aw} - T_w)\, q/q_e + \left[T_e - \alpha (T_{aw} - T_w) - T_w\right] (q/q_e)^2 \tag{69}$$

which is Crocco's quadratic temperature distribution if $\alpha = 1$. However, as shown in Ref. 12, a value of $\alpha = 0$ gives a parabolic distribution which agrees better with data obtained in hypersonic wind tunnels with water-cooled walls. The same distribution is obtained if $T_w = T_{aw}$, which is likely to be the case for planar, flexible-plate nozzles. Before using the Gaussian integration, one must replace the values of z and dz with $\delta(q/q_e)^N$ and $N\delta(q/q_e)^{N-1}\, d(q/q_e)$, respectively, in order to avoid the infinite slope, dq/dz, when q and z equal zero.

The value of the compressible skin friction coefficient, C_f, in Eq. (61) is assumed to be related to an incompressible value, C_{f_i}, by a factor F_c, introduced by Spalding and Chi, Ref. 18,

$$F_c\, C_f = C_{f_i} \tag{70}$$

and C_{f_i} is related to an incompressible Reynolds number, R_{θ_i}, which is related to the compressible value, R_{θ_c}, by a factor F_{R_δ},

$$F_{R_\delta} R_{\theta_c} = R_{\theta_i} \tag{71}$$

The factor F_c, also used by van Driest, Ref. 19, is given by

$$F_c = \left[\int_0^1 (\rho/\rho_e)^{\frac{1}{2}}\, d(q/q_e) \right]^{-2} \tag{72}$$

which uses Eqs. (68) and (69). In Refs. 18 and 19, a value of $\alpha = 1$ was implied, but Eq. (72) is used herein with $\alpha = 0$ also, to give a "modified" value of F_c. The factor F_c may be considered to be the ratio of a reference temperature to the free-stream temperature. The factor F_{R_δ}, as used by van Driest, is

$$F_{R_\delta} = \mu_e/\mu_w \tag{73}$$

The compressible momentum thickness, θ_c, upon which R_{θ_c} is based is the flat-plate value

$$\theta_c = \int_0^{\delta} \left(1 - \frac{q}{q_e}\right) \frac{\rho q}{\rho_e q_e}\, dz \tag{74}$$

because the values of F_c and F_{R_δ} were developed to correlate flat-plate data.

The equation used herein for incompressible skin-friction coefficient is that of Ref. 20,

$$C_{f_i} = \frac{0.0773}{(\log R_{\theta_i} + 4.561)(\log R_{\theta_i} - 0.546)} \tag{75}$$

This equation is believed to agree with experimental data slightly better than the von Kármán-Schoenherr equation,

$$C_{f_i} = \frac{(0.242)^2}{(\log R_{\theta_i} + 1.1696)(\log R_{\theta_i} + 0.3010)} \tag{76}$$

at high Reynolds numbers. Also as shown in Ref. 20, Eq. (75) agrees with the equation, Ref. 21, based on Coles' law of the wall and law of the wake,

$$\kappa\,(2/C_{f_i})^{\frac{1}{2}} = \ell n\, R_\delta + 0.5\, \ell n\,(C_{f_i}/2) + \kappa C + 2\Pi \tag{77}$$

if Π varies as shown in Fig. 8 from about 0.41 at $R_{\theta_i} = 400$ to a maximum of 0.5885 at $R_{\theta_i} = 50{,}000$ and then decreases to about 0.49 at $R_{\theta_i} = 10^7$. In order for Eq. (76) to agree with Eq. (77), Π must continually increase with increasing R_{θ_i} as shown in Fig. 8. The data shown in Fig. 8 were computed by Coles in Ref. 21 from Wieghardt's flat plate data, Ref. 22. A comparison of friction coefficients from Eqs. (75) and (76) is shown in Fig. 9 together with Wieghardt's values as recomputed by Coles. The constants κ and C are 0.41 and 5.0, respectively. The relationship between θ_i and δ is obtained from the logarithmic velocity profile by neglecting the laminar sublayer, representing the wake function by a sine^2 distribution, and integrating to obtain

$$\frac{\delta_i^*}{\delta} = \frac{1 + \Pi}{\kappa} \left(\frac{C_{f_i}}{2}\right)^{\frac{1}{2}} \tag{78}$$

and

$$\frac{\theta_i}{\delta} = \frac{\delta_i^*}{\delta} - \frac{C_{f_i}}{2\kappa} (2 + 3.179\,\Pi + 1.5\,\Pi^2) \tag{79}$$

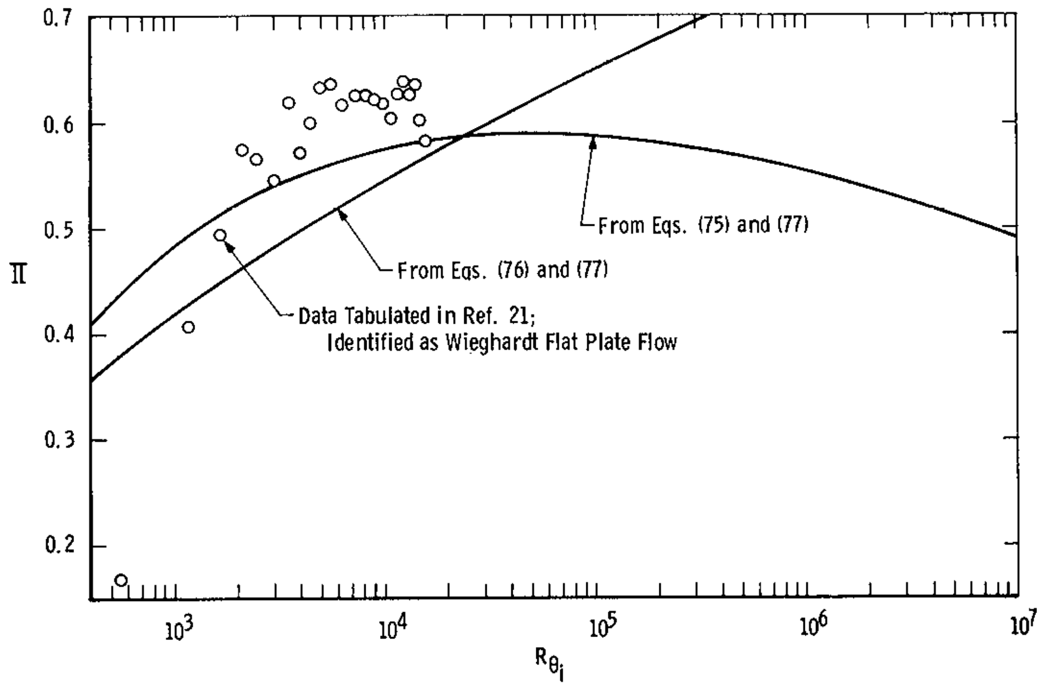

Figure 8. Variation of wake parameter, Π, with Reynolds number (incompressible).

The value of N in Eq. (67) is assumed to be a function of Reynolds number based on the actual boundary thickness, not corrected by F_{R_δ}, and is evaluated through the use of the kinematic momentum thickness

$$\theta_k = \int_0^\delta \frac{q}{q_e} \left(1 - \frac{q}{q_e}\right) dz \tag{80}$$

from which

$$\theta_k/\delta = N/(N^2 + 3N + 2) \tag{81}$$

or

$$N = \frac{1}{2} \left\{ \frac{\delta}{\theta_k} - 3 + \left[\frac{\delta}{\theta_k} \left(\frac{\delta}{\theta_k} - 6 \right) + 1 \right]^{\frac{1}{2}} \right\} \tag{82}$$

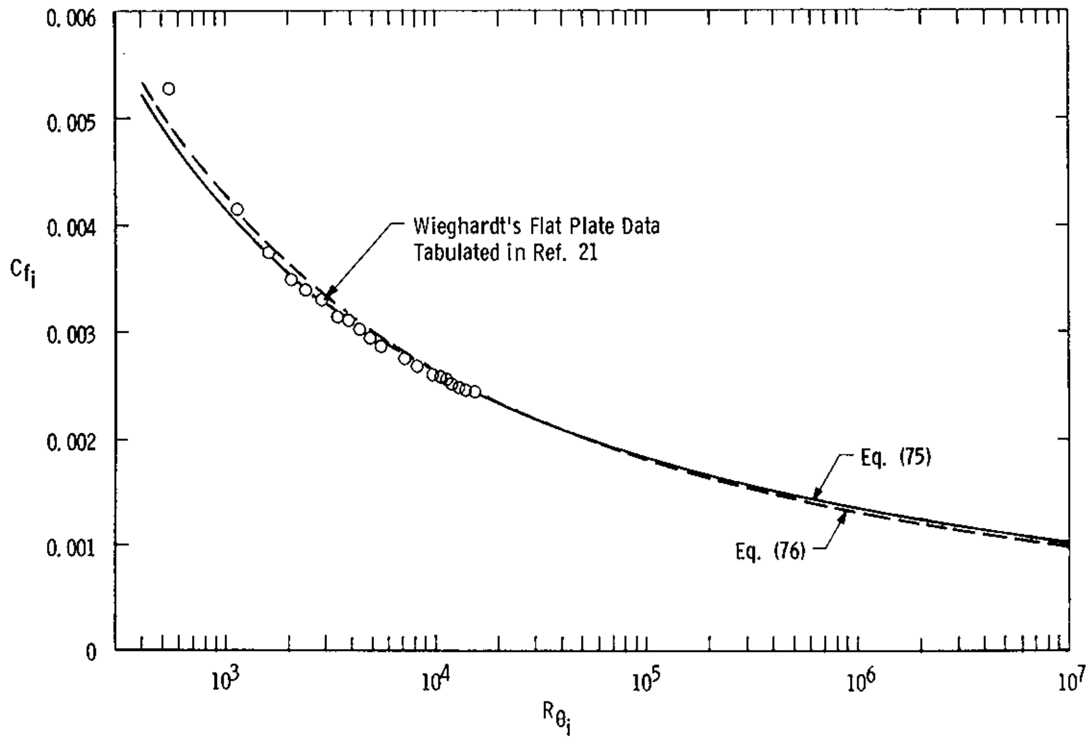

Figure 9. Variation of skin-friction coefficient with Reynolds number (incompressible).

The value of θ_k/δ is obtained from Eq. (79), where the value of Π is evaluated from Eqs. (75) and (77) with θ_k used instead of θ_i. The resulting variation of N with R_δ is shown in Fig. 10.

Two options contained in the program subroutine for the boundary layer utilize Coles' law of corresponding stations (Ref. 23),

$$\frac{C_{f_i} R_{\theta_i}}{C_f R_{\theta_c}} = \frac{T_w \mu_e}{T_e \mu_w} \tag{83}$$

If $C_{f_i}/C_f = F_c$ is calculated from Eq. (72) for $\alpha = 0$ or $\alpha = 1$, then one option gives

$$F_{R_\delta} = T_w \mu_e/(F_c T_e \mu_w) \tag{84}$$

The second option divdes Eq. (83) into the two parts,

$$C_{f_i}/C_f = T_w \mu_e/T_e \mu_w \tag{85}$$

and

$$R_{\theta_i}/R_{\theta_c} = \mu_e/\mu_c \tag{86}$$

where μ_c is evaluated at the temperature

$$T_c = T_w + 17.2\,(C_{f_i}/2)^{\frac{1}{2}}\,\alpha(T_{aw} - T_w) - 305(C_{f_i}/2)\left[\alpha(T_{aw} - T_w) + T_w - T_e\right] \tag{87}$$

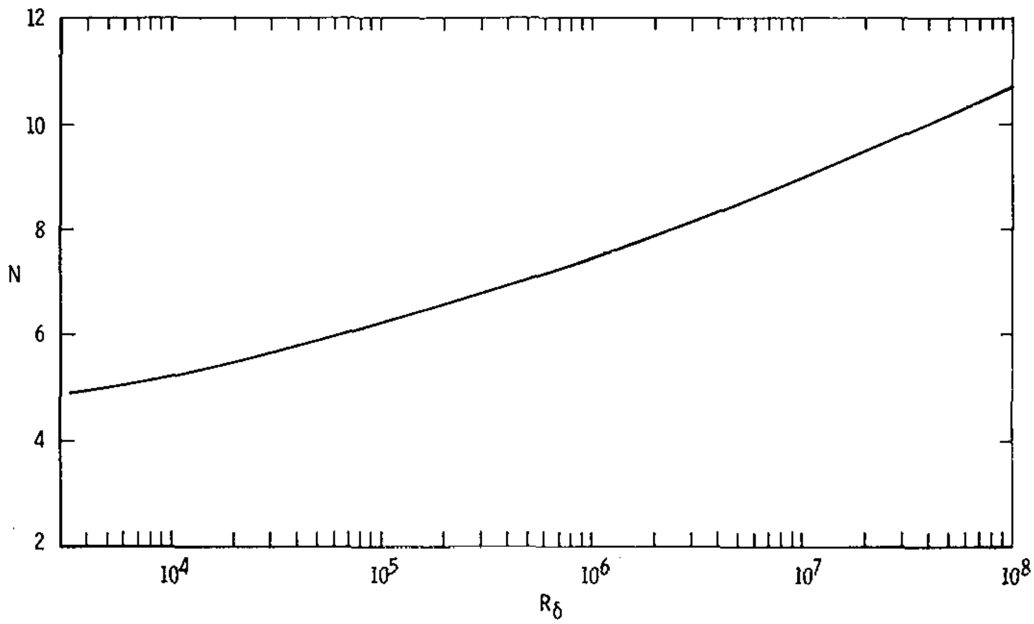

Figure 10. Variation of velocity profile exponent with Reynolds number based on boundary-layer thickness.

Still another option defines the incompressible skin-friction coefficient as

$$C_{f_i} = \frac{0.0888}{(\log R_{\delta_i} + 4.6221)\,(\log R_{\delta_i} - 1.4402)} \tag{88}$$

where

$$R_{\delta_i}/R_\delta = T_e^{\frac{1}{2}}\,\mu_e \Big/ (F_c^{\frac{1}{2}}\,T_w^{\frac{1}{2}}\,\mu_w) \tag{89}$$

and F_c is calculated from Eq. (72).

The wall temperature in the above equations can be the adiabatic wall temperature or can be allowed to vary between a throat wall temperature, T_{w_T}, and a nozzle-exit wall temperature, T_{w_D}, both of which are input to the program. Two options are available for the variation of wall temperature,

$$T_w = T_{w_D} + \frac{(T_{w_T} - T_{w_D})}{(A_c/A^*)^m - 1}\left[\left(\frac{A_c/A^*}{A/A^*}\right)^m - 1\right] \tag{90}$$

where m can be 1/2 or 1, A/A* is the area ratio corresponding to local Mach number, and A_C/A^* is the area ratio corresponding to the design Mach number at the nozzle exit. Equation (90) is used in lieu of more accurate values and approximates the way the heat transfer decreases as the Mach number increases from 1 at the throat to the design value at the exit. For a water-cooled throat, the value of T_{w_T} can also be calculated by the program,

$$T_{w_T} = \frac{h_a T_{aw} + Q(T_{w_D} - 15)}{h_a + Q} \tag{91}$$

where h_a is the airside heat-transfer coefficient at the throat as calculated by Reynolds analogy from the throat skin-friction coefficient

$$h_a = \rho_e q_e C_p P_r^{-2/3} C_f/2 \tag{92}$$

with a constant specific heat based on the thermochemical BTU

$$C_p = \frac{\gamma R_g}{(\gamma - 1)\, 777.64885} \tag{93}$$

and Q is an input which is a function of the properties of the throat material, the cooling water, and the geometry and would be a constant if the properties were constant. The assumption is made that the bulk temperature of the water is 15°F less than T_{w_D} and that $P_r^{2/3}$ is the square of the recovery factor used to obtain the adiabatic wall temperature, T_{aw}.

For the integration of Eq. (61), the values of x, y, dy/dx, M, and dM/dx are obtained from the inviscid contour at unevenly spaced points as a result of the characteristics solution. With the inputs of stagnation pressure and temperature, gas constant, and recovery factor, the unit Reynolds number and static and adiabatic wall temperatures can be calculated at the same points as functions of Mach number with Sutherland's equation used for viscosity. With the inputs of T_{w_T} and T_{w_D}, the wall temperatures can also be calculated as functions of Mach number, although T_{w_T} may need to be obtained by interation if the option to input a value of Q is exercised. Sutherland's equation is also used with wall temperatures to obtain the viscosities at the wall. For any static temperature below the Sutherland temperature, 198.72°R as used herein, the viscosity variation with temperature is assumed to be linear.

The integration of Eq. (61) is started at the throat where it is assumed that $d\theta/dx = 0$ in order to obtain a value of θ. Iteration is involved at each point because C_f is a function of Reynolds number based upon θ, and the relations θ/δ and δ^*/δ depend upon the value of N, which is a function of Reynolds number based upon δ. After all iterations converge within specified tolerances, the value of δ_a^* is calculated from the value of δ^*, and the values of θ and $d\theta/dx$ are used in the calculation at subsequent points. The values of $d\theta/dx$ are integrated numerically to obtain the increment in θ to be added to a previously determined value of θ. The trapezoidal rule is used to determine the second point, the parabolic rule for the third point, and cubic integration for the fourth and subsequent points.

For convenience, Eq. (61) may be written $\theta' + \theta P = Q$. The general integration for the nth point is

$$\theta_n = \theta_{n-3} + G_{n-3}\,\theta'_{n-3} + G_{n-2}\,\theta'_{n-2} + G_{n-1}\,\theta'_{n-1} + G_n\,\theta'_n \tag{94}$$

where the G's are functions of the spacings s, t, and u between the points and are given in Appendix B. Except for θ_n and θ_n', the other values in Eq. (94) are known from previous calculations. Inasmuch as

$$\theta_n' = Q_n - P_n \theta_n \tag{95}$$

Eq. (92) can be rearranged to give

$$\theta_n = \frac{(\theta_{n-3} + G_{n-3}\theta_{n-3}' + G_{n-2}\theta_{n-2}' + G_{n-1}\theta_{n-1}' + G_n Q_n)}{(1 + G_n P_n)} \tag{96}$$

After convergence of the iterations, Eq. (95) is used to obtain $d\theta/dx$. Inasmuch as Eq. (94) depends upon the knowledge of θ_{n-3}, the value of θ_{n-2} is calculated by

$$\theta_{n-2} = \theta_{n-3} + F_{n-3}\theta_{n-3}' + F_{n-2}\theta_{n-2}' + F_{n-1}\theta_{n-1}' + F_n\theta_n \tag{97}$$

which becomes the θ_{n-3} for the next point to be calculated. The values of the F's are also given in Appendix B. The values of θ_2 and θ_3 obtained from Eq. (95) are used in the calculation of δ^* and δ_a^* instead of the initial values obtained by the trapezoidal or parabolic integration.

The success of the above type of integration depends upon the spacing of the points. The values of the increments s, t, and u must be of the same order of magnitude, although t is usually larger than s and smaller than u if the parameters involved in the characteristics solution are selected with care.

After the values of $\delta_a^* \sec \phi_w$ are calculated, the values of $d(\delta_a^* \sec \phi_w)/dx$ are obtained by parabolic differentiation and added to the inviscid values of dy/dx to obtain dr_w/dx. This procedure is believed to be more accurate than differentiating the value $(\delta_a^* \sec \phi_w + y)$ because dy/dx is obtained directly from the characteristics solution and not by differentiating y with respect to x.

In general, the boundary-layer correction at the throat will have a gradient such that the viscid throat will be slightly upstream of the inviscid throat. This displacement and the value of the viscid curvature at the throat are calculated using the assumption that both the inviscid throat and the boundary-layer correction are parabolic in shape.

6.0 DESCRIPTION OF PROGRAM

The computer program is written in Fortran IV for use with the IBM 370/165 Computer. The program consists of a main section, three functions, and 16 subroutines arranged so that the program can be overlaid to conserve computer storage. The four overlays consist of AXIAL, CONIC, SORCE, and TORIC; PERFC; BOUND and HEAT; SPLIND and XYZ. The input data cards are described in Appendix C, and a listing of the program is given in Appendix D.

Program MAIN. MAIN calls for the various overlays. The title card is read in with the designation as to whether the nozzle is planar or axisymmetric. A card defining the gas properties and a few pertinent dimensions is then read in. The first subroutine called is AXIAL, in which the upstream axial distribution is defined. PERFC is called to calculate the upstream contour. AXIAL is recalled to define the downstream distribution, and PERFC is recalled to calculate the downstream contour. BOUND is called to calculate the boundary-layer growth. SPLIND is called to determine the coefficients of cubic equations to fit the unevenly spaced points along the contour, and XYZ uses these coefficients to obtain ordinates at evenly spaced points along the axis or, in the case of the planar nozzle, at discrete points along the surface of the flexible plate at which the supporting jacks are located.

Subroutine AXIAL. In this subroutine, cards are read in with the parameters used to define the axial distributions of velocity and/or Mach number and with integers which define the number and spacing of the points on the axis and on the key characteristics and the sequence of subsequent calculations. If the throat characteristic is called for, the upstream end of the upstream distribution starts at the intersection of the throat characteristic and the axis. An option can be exercised to not use the throat characteristic and thereby start the distribution at the point where M = 1. This option would normally be used for a nozzle with a large throat radius of curvature, e.g. a planar nozzle, or if it were desired to repeat a calculation as in Ref. 13. Another option is to avoid a radial flow section altogether by using a polynomial distribution from the throat to the beginning of the test cone or rhombus. Other options will be described in Appendix C when the input cards are discussed.

Subroutine BOUND. This subroutine is used to calculate the turbulent boundary-layer correction to the inviscid contour. The stagnation conditions are input, as are the parameters to describe the wall temperature distribution, the temperature distribution in the boundary layer, and the factors relating the compressible skin-friction coefficients to incompressible values.

Subroutine CONIC. This subroutine is used within AXIAL to give the derivatives of Mach number with respect to r/r_1 in radial flow from Eq. (29).

Function CUBIC. This subroutine is used to obtain the smallest positive root of a cubic equation.

Function FMV. This subroutine determines the Mach number for a given Prandtl-Meyer angle.

Subroutine FVDGE. This subroutine is used within PERFC in conjunction with NEO to smooth the inviscid coordinates as desired.

Subroutine HEAT. This subroutine is a dummy called by BOUND but is included so that with a more elaborate subroutine a heat balance can be made to determine the wall temperature if the material conductivity is specified and the cooling water passage geometry and quantity of flow are specified.

Subroutine NEO. This subroutine is used with PERFC in conjunction with FVDGE to smooth the inviscid coordinates as desired by modifying the ordinate such that the second derivative is more nearly linear after smoothing than beforehand.

Subroutine OFELD. This subroutine is used within PERFC to calculate the properties at the intersection of a left- and a right-running characteristic.

Subroutine OREZ. This subroutine is used to make all values of an array equal to zero prior to a new calculation.

Subroutine PERFC. In this subroutine, the properties along the key characteristics are first calculated to go with those along the axis. The intermediate characteristics are then calculated and the contour points obtained by integrating the mass flow crossing each characteristic. If desired, certain designated intermediate characteristics may be printed out. If smoothing of the ordinates is desired, the inputs associated with the smoothing are read and the smoothing applied. Inasmuch as the wall angle is interpolated from mass-flow considerations, independently of the coordinates, the wall slopes are integrated from the inflection point toward the throat for comparison with the interpolated ordinates. Parabolic integration is used for this purpose as well as for the mass flow. Also calculated for comparison are the ordinates of a parabola and a hyperbola which have the same radius ratio, R, inasmuch as the transonic solution should be equally applicable to these shapes for the number of terms retained in the series, Eqs. (2) and (3). Finally, the scale factor, the value of r_1 in inches, is applied to obtain the inviscid coordinates in inches, and the abscissas are also shifted as desired.

Subroutine PLATE. This subroutine is also a dummy to allow additional calculations to be made for a flexible plate contour after the coordinates at each jack location have been interpolated by SPLIND and XYZ.

Subroutine SCOND. This subroutine is used in BOUND, NEO, and PERFC for parabolic differentiation of coordinates to obtain the slopes, or of slopes and abscissas to obtain second derivatives. Three points at a time are used to establish the parabola, and the slope is obtained at the center point. The slopes at the first and last point are also obtained, but with less accuracy.

Subroutine SORCE. This subroutine is used within AXIAL to give the derivatives of velocity ratio, W, with respect to r/r_1 in radial flow from Eq. (30).

Subroutine SPLIND. This subroutine computes the coefficients of cubic equations that fit the unevenly spaced points obtained from the characteristics solution. The initial and final slopes are used together with the coordinates to determine the cubic coefficients.

Function TORIC. If the velocity gradient is known at the axial point where M = 1, this function gives the value of radius ratio, R, which would produce such a gradient from the transonic theory used. This function is used in AXIAL if the option is exercised of specifying the Mach number at point F but not specifying the value of R. It is also used to determine the value of R for calculating streamlines other than the contour itself.

Subroutine TRANS. This subroutine calculates the throat characteristic from the transonic theory. In AXIAL, at the point where the throat characteristic intersects the axis, the derivatives of velocity and Mach number are used to determine the coefficients of the polynomial describing the axial distribution. In PERFC, the flow properties along this key characteristic are used at the number of points specified as one plus a submultiple of 240.

Subroutine TWIXT. This subroutine is used in PERFC and BOUND to interpolate the ordinate and other properties at a specified point. A four-point Lagrangian interpolation is used with two points on either side of the specified point.

Subroutine XYZ. This subroutine uses the cubic coefficients obtained in SPLIND for calculating the ordinate, slope, and second derivative at specified values of the abscissa read as inputs in the MAIN section of the program. The points may be at even intervals in the abscissa or at arbitrary uneven intervals. The points may be the same points as those input to SPLIND if a comparison is desired between the derivatives so determined and those obtained elsewhere in the program.

7.0 SAMPLE NOZZLE DESIGN

The design of a Mach 4 axisymmetric nozzle is selected to illustrate use of the computer program. The input cards for the sample design are given in Table 1. An axisymmetric nozzle is specified by leaving JD blank (JD = 0) on Card 1. Leaving SFOA blank on Card 2 specifies that the upstream axial velocity distribution is not a fifth-degree polynomial. Leaving FMACH blank on Card 3 specifies that the value of FMACH will be computed by the program, and leaving IX blank on Card 4 specifies a cubic distribution. The computed value of FMACH is 3.0821543, which is greater than the value of BMACH specified on Card 3;

therefore, BMACH also becomes 3.0821543. The negative value of SF means that the inviscid exit radius of the nozzle is 12.25 in. The value of PP means that the inflection point will be 60 in. downstream of an arbitrary point. Leaving XC blank specifies the downstream axial distribution will be a fourth-degree polynomial, and the positive value of IN on Card 4 specifies a Mach number distribution. The values of MT, NT, MD, ND, NF, and LR determine the number of points on the key characteristics and are all odd numbers because each includes both end points of each distribution which is divided into an even number of increments. The negative value of NF specifies the contour points to be smoothed according to Card 5, and the negative value of LR specifies that the transonic distribution be printed as the first page of the sample output. The NX value of 13 specifies the spacing of the axial points between points I and E to be close together near Point I with the last increment about 3.17 times as large as the first increment, $(20^{1.3} - 19^{1.3})$. The JC value of 10 specifies that every 10th left-running characteristic will be printed for the upstream contour together with the right-running characteristic through Point E. The smoothing integers on Card 5 are used to control the smoothing subroutine.

Table 1. Input Cards for Sample Design

CARD 1

ITLE	JD
M A C H 4	

CARD 2

GAM	AR	ZO	RO	VISC	VISM	SFOA	XBL
1.4	1716.563	1.	0.896	2.26968E-8	198.72		1000.

CARD 3

ETAD	RC	FMACH	BMACH	CMC	SF	PP	XC
8.67	6.		3.	4.	-12.25	60.	

CARD 4

MT	NT	IX	IN	IQ	MD	ND	NF	MP	MQ	JB	JX	JC	IT	LR	NX
41	21		10		41	49	-61			1		10		-21	13

CARD 5

NOUP	NPCT	NODO
50	85	50

CARD 6

PPQ	TO	TWT	TWAT	QFUN	ALPH	IHT	IR	ID	LV
200.	1638.	900.	540.	.38				1	5

CARD 7

XST	XLOW	XEND	XINC	BJ	XMID	XINC2	CN
1000.	46.	172.	2.				

For the boundary-layer calculations for stagnation conditions of 200 psia and 1638R, the value of QFUN of 0.38 overrides the specified throat temperature of 900R and produces the throat temperature of 866R as indicated on the output. Leaving ALPH blank causes the temperature distribution in the boundary to be parabolic for both the calculation of the boundary-layer parameters and the calculation of the reference temperature. Leaving IHT blank causes the longitudinal distribution of wall temperature to vary as a square-root function of the area ratio corresponding to the local Mach number; m = 1/2 in Eq. (90). Leaving IR blank causes the transformation from incompressible to compressible values of skin friction coefficient to be calculated using a modified Spalding-Chi reference temperature and a Van Driest reference Reynolds number. Specifying ID = 1 takes into account that the boundary-layer thickness is not negligible relative to the radius of the inviscid core, and its positive value causes the boundary-layer calculations to be printed for the first and last iteration; the number of iterations is specified by the absolute value of LV (LV = 5 for the example).

For the final coordinates, interpolated at even intervals, specifying XST = 1,000 (the same value as XBL on Card 2) keeps the X-coordinates consistent with the location of the inviscid inflection point at 60 in. downstream of an arbitrary point.

The main parameters selected for the sample problem were the inflection angle, the curvature ratio, and the Mach number at the point B. The selected values of 8.67 deg, 6, and 3.0821543 (computed), respectively, are not necessarily optimum but result in a nozzle with an upstream length of about 14 in. from the throat to the inflection point, a length of about 31 in. from the inflection point to point J (see Fig. 3), and nearly 120 in. from the inflection point to the theoretical end of the nozzle. Such downstream lengths are probably conservative and could be reduced to some degree although experience with Mach 4 axisymmetric nozzles is very limited.

The number of points used on the key characteristics should be consistent with the number of points used in the axial distributions in order that the individual nets in the characteristics network should not become too elongated (e.g., see Fig. 7). The spacing of the points on the final contour should also progress in an orderly manner. Several trials may be necessary to optimize the various inputs to the program.

8.0 SUMMARY

A method and computer program have been presented for the aerodynamic design of planar and axisymmetric supersonic wind tunnel nozzles. The method uses the well-known analytical solution for radial source flow and connects this radial flow region to the throat and test section regions via the method of characteristics. Continuous curvature over the entire contour is attained by specifying polynomial distributions of the centerline velocity or Mach number and matching various derivatives of these polynomials at the extremities of the radial flow region, the test section, and a throat characteristic. The inviscid contour is obtained by initiating characteristics outward from the centerline and then integrating the mass flux along these characteristics to compute the inviscid nozzle boundary. The final wall contour is then obtained by adding to the inviscid coordinates a boundary-layer correction based on displacement thickness computed by integrating the von Kármán momentum equation. To illustrate the method, a sample design calculation was presented along with the associated input and output data. A listing of the computer program and an input description are included.

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APPENDIX A
TRANSONIC EQUATIONS

When Eq. (5) is substituted into Eqs. (2),(3) and (4), Eq. (2) can be written as:

$$
\begin{aligned}
u = 1 &- \frac{1}{2(3-\sigma)S} - \frac{GR}{S^2} - \frac{GS}{S^3} + \ldots \\
&+ \lambda x\left(1 - \frac{\sigma}{8S} + \frac{GT}{S^2} + \ldots\right) \\
&+ \frac{\lambda^2 x^2}{2}\left(1 - \frac{2\gamma}{3} - \frac{GV}{S} + \ldots\right) + \frac{\lambda^3 x^3}{3} GK + \ldots \\
&+ \frac{y^2}{2S} + \frac{U_{42}\, y^4 - U_{22}\, y^2}{S^2} + \frac{U_{63}\, y^6 - U_{43}\, y^4 + U_{23}\, y^2}{S^3} \\
&+ \lambda x\left(\frac{y^2}{S} + \frac{U_{P2}\, y^4 - U_{P0}\, y^2}{S^2} + \ldots\right) \\
&+ \frac{\lambda^2 x^2 y^2}{2}\left(\frac{3\sigma - (10 - 3\sigma)\gamma}{4S}\right) + \ldots
\end{aligned}
\tag{A-1}
$$

where the coefficients are written in the terminology of the program and x and y are normalized with respect to y_o. For planar flow,

$$GR = (15 - \gamma)/270 \tag{A-2}$$

$$GS = (782\,\gamma^2 + 3507\,\gamma + 7767)/272160 \tag{A-3}$$

$$GT = (134\,\gamma^2 + 429\,\gamma + 123)/4320 \tag{A-4}$$

$$GV = 5\,\gamma/18 \tag{A-5}$$

$$GK = (2\gamma^2 - 33\gamma + 9)/24 \tag{A-6}$$

$$U_{42} = (\gamma + 6)/18 \tag{A-7}$$

$$U_{22} = \gamma/9 \tag{A-8}$$

$$U_{63} = (362\ \gamma^2 + 1449\ \gamma + 3177)/12960 \tag{A-9}$$

$$U_{43} = (194\ \gamma^2 + 549\ \gamma - 63)/2592 \tag{A-10}$$

$$U_{23} = (854\ \gamma^2 + 807\ \gamma + 279)/12960 \tag{A-11}$$

$$U_{P2} = (26\ \gamma^2 + 27\ \gamma + 237)/288 \tag{A-12}$$

$$U_{P0} = (26\ \gamma^2 + 51\ \gamma - 27)/144 \tag{A-13}$$

For axisymmetric flow,

$$GR = (15 - 10\ \gamma)/288 \tag{A-14}$$

$$GS = (2708\ \gamma^2 + 2079\ \gamma + 2115)/82944 \tag{A-15}$$

$$GT = (92\ \gamma^2 + 180\ \gamma - 9)/1152 \tag{A-16}$$

$$GV = (\gamma + 1)/8 \tag{A-17}$$

$$GK = (4\ \gamma^2 - 57\ \gamma + 27)/48 \tag{A-18}$$

$$U_{42} = (2\ \gamma + 9)/24 \tag{A-19}$$

$$U_{22} = (4\ \gamma + 3)/24 \tag{A-20}$$

$$U_{63} = (556\ \gamma^2 + 1737\ \gamma + 3069)/10368 \tag{A-21}$$

$$U_{43} = (388\ \gamma^2 + 777\ \gamma + 153)/2304 \tag{A-22}$$

$$U_{23} = (304\ \gamma^2 + 255\ \gamma - 54)/1728 \tag{A-23}$$

$$U_{P2} = (52\ \gamma^2 + 51\ \gamma + 327)/384 \tag{A-24}$$

$$U_{P0} = (52\ \gamma^2 + 75\ \gamma - 9)/192 \tag{A-25}$$

The first part of Eq. (A-1), which is independent of y, can be recognized as Eq. (11) for planar flow or Eq. (12) for axisymmetric flow inasmuch as x and y are normalized here with the value of y_o.

In a similar manner, Eq. (3) can be written as

$$
\begin{aligned}
v = \frac{y}{\lambda S} \Bigg\{ & \frac{(y^2 - 1)}{2(3 - \sigma)S} + \frac{V_{42}\, y^4 - V_{22}\, y^2 + V_{02}}{S^2} \\
& + \frac{V_{63}\, y^6 - V_{43}\, y^4 + V_{23}\, y^2 - V_{03}}{S^3} + \ldots \\
& + \lambda x \Bigg[1 + \frac{(2\gamma + 12 - 3\sigma)y^2 - 2\gamma - 1.5\sigma}{(9 - 3\sigma)S} \\
& + \frac{6\, U_{63}\, y^4 - 4\, U_{43}\, y^2 + 2\, U_{23}}{S^2} + \ldots \Bigg] \\
& + \frac{\lambda^2 x^2}{2} \left(2 + \frac{4\, U_{P2}\, y^2 - 2\, U_{PO}}{S} + \ldots \right) \\
& + \frac{\lambda^3 x^3}{3} \left(\frac{3\sigma - 10\gamma - 3\sigma\gamma}{4} + \ldots \right) + \ldots \Bigg\}
\end{aligned}
\tag{A-26}
$$

For planar flow,

$$V_{42} = (22\,\gamma + 75)/360 \tag{A-27}$$

$$V_{22} = (10\,\gamma + 15)/108 \tag{A-28}$$

$$V_{02} = (34\,\gamma - 75)/1080 \tag{A-29}$$

$$V_{63} = (6574\,\gamma^2 + 26481\,\gamma + 40059)/181440 \tag{A-30}$$

$$V_{43} = (2254\,\gamma^2 + 6153\,\gamma + 2979)/25920 \tag{A-31}$$

$$V_{23} = (5026\,\gamma^2 + 7551\,\gamma - 4923)/77760 \tag{A-32}$$

$$V_{03} = (7570\,\gamma^2 + 3087\,\gamma + 23157)/544320 \tag{A-33}$$

For axisymmetric flow,

$$V_{42} = (\gamma + 3)/9 \tag{A-34}$$

$$V_{22} = (20\ \gamma + 27)/96 \tag{A-35}$$

$$V_{02} = (28\ \gamma - 15)/288 \tag{A-36}$$

$$V_{63} = (6836\ \gamma^2 + 23031\ \gamma + 30627)/82944 \tag{A-37}$$

$$V_{43} = (3380\ \gamma^2 + 7551\ \gamma + 3771)/13824 \tag{A-38}$$

$$V_{23} = (3424\ \gamma^2 + 4071\ \gamma - 972)/13824 \tag{A-39}$$

$$V_{03} = (7100\ \gamma^2 + 2151\ \gamma + 2169)/82944 \tag{A-40}$$

APPENDIX B
CUBIC INTEGRATION FACTORS

If a curve through four points with ordinates a, b, c, and d, spaced at uneven increments in abscissa, s, t, and u, is defined by a cubic equation, the area under each section of the curve can be found in the following manner:

$$\text{Area}_{a-b} = F_{as}\ a + F_{bs}\ b + F_{cs}\ c + F_{ds}\ d \tag{B-1}$$

$$\text{Area}_{b-c} = F_{at}\ a + F_{bt}\ b + F_{ct}\ c + F_{dt}\ d \tag{B-2}$$

$$\text{Area}_{c-d} = F_{au}\ a + F_{bu}\ b + F_{cu}\ c + F_{du}\ d \tag{B-3}$$

$$\text{Area}_{total} = G_a\ a + G_b\ b + G_c\ c + G_d\ d \tag{B-4}$$

where

$$F_{as} = \frac{s}{2} - \frac{s^2(3s + 4t + 2u)}{12(s + t)(s + t + u)} \tag{B-5}$$

$$F_{bs} = \frac{s}{2} + \frac{s^2(s + 4t + 2u)}{12\ t(t + u)} \tag{B-6}$$

$$F_{cs} = -\frac{s^3(s + 2t + 2u)}{12tu(s + t)} \tag{B-7}$$

$$F_{ds} = \frac{s^3(s + 2t)}{12(s + t + u)(t + u)u} \tag{B-8}$$

$$F_{at} = -\frac{t^3(t + 2u)}{12s(s + t)(s + t + u)} \tag{B-9}$$

$$F_{bt} = \frac{t}{2} + \frac{t^2(t + 2u - 2s)}{12s(t + u)} \tag{B-10}$$

$$F_{ct} = \frac{t}{2} + \frac{t^2(2s + t - 2u)}{12u(s + t)} \tag{B-11}$$

$$F_{dt} = -\frac{t^3(2s + t)}{12u(t + u)(s + t + u)} \tag{B-12}$$

$$F_{au} = \frac{u^3(2t + u)}{12s(s + t)(s + t + u)} \tag{B-13}$$

$$F_{bu} = -\frac{u^3(2s + 2t + u)}{12st(t + u)} \tag{B-14}$$

$$F_{cu} = \frac{u}{2} + \frac{u^2(2s + 4t + u)}{12t(s + t)} \tag{B-15}$$

$$F_{du} = \frac{u}{2} - \frac{u^2(2s + 4t + 3u)}{12(t + u)(s + t + u)} \tag{B-16}$$

$$G_a = F_{as} + F_{at} + F_{au} \tag{B-17}$$

$$G_b = F_{bs} + F_{bt} + F_{bu} \tag{B-18}$$

$$G_c = F_{cs} + F_{ct} + F_{cu} \tag{B-19}$$

$$G_d = F_{ds} + F_{dt} + F_{du} \tag{B-20}$$

If all increments are equal, then

$$s = t = u = h \tag{B-21}$$

$$F_{ds} = -F_{at} = -F_{dt} = F_{au} = h/24 \tag{B-22}$$

$$F_{cs} = F_{bu} = -5h/24 \tag{B-23}$$

$$F_{bs} = F_{cu} = 19h/24 \tag{B-24}$$

$$F_{as} = F_{du} = 9h/24 \tag{B-25}$$

$$F_{bt} = F_{ct} = 13h/24 \tag{B-26}$$

$$G_a = G_d = 3h/8 \tag{B-27}$$

$$G_b = G_c = 9h/8 \tag{B-28}$$

The values of G's in Eq. (96) correspond to those in Eq. (B-4). The value of F's in Eq. (97) correspond to those in Eq. (B-1).

APPENDIX C
INPUT DATA CARDS

Input	Columns	
<u>Card 1</u>		
ITLE	2-12	Title
JD	14-15	Blank (0) for axisymmetric contour, -1 for planar.
<u>Card 2</u>		
GAM	1-10	Specific heat ratio.
AR	11-20	Gas constant, ft^2/sec^2 R.
ZO	21-30	Compressibility factor for an axisymmetric nozzle, constant for entire contour. Or, for a planar nozzle, ZO is half the distance (in.) between the parallel walls, and the compressibility factor is one.
RO	31-40	Turbulent boundary-layer recovery factor.
VISC	41-50	Constant in viscosity law.
VISM	51-60	Constant in viscosity law. If VISM is equal to or less than one, $\mu = \text{VISC}*\ T^{\text{VISM}}$ lb-sec/ft^2 If VISM is greater than one, $\mu = \dfrac{\text{VISC}*\ T^{1.5}}{T + \text{VISM}}$ lb-sec/ft^2. If T is greater than VISM, $\mu = \dfrac{\text{VISC}*\ T}{2\ \text{VISM}^{1/2}}$; $T \leq \text{VISM}$.
SFOA	61-70	Used for nozzle with radial flow region if 5th-deg axial velocity distribution is desired. If positive, the distance, in inches, from the throat to Point A

		on the characteristic diagram. If negative, absolute value is distance from the throat to Point G. If Blank, 3rd- or 4th-deg distribution is used depending on value of IX on Card 4.
XBL	71-80	Station (in.) where interpolation is desired (e.g., the end of a truncated nozzle). If XBL=1000., the spline fit subroutines are used to obtain values at increments evenly spaced in length.

<u>Card 3</u>

ETAD	1-10	Inflection angle in degrees if radial flow region is desired. Two characteristic solutions are obtained, one upstream and one downstream of Point A. If ETAD = 60., the entire centerline velocity distribution is specified and only one solution is obtained and the inflection point must be interpolated. If ETAD = 60., IQ = 1, IX = 0, on Card 4.
RC	11-20	Ratio of throat radius of curvature to throat radius. Must be given if ETAD = 60. or FMACH = 0. If FMACH is given, RC is calculated. If LR = 0, IX = 0 gives third-deg equation between Mach 1 and EMACH, matching first and second derivations at each end. If LR ≠ 0, the value of RC found for LR = 0 is used with given value of FMACH to define a fourth-deg equation. If IX = ±1 and FMACH is given, RC is calculated to define a fourth-deg equation. If LR ≠ 0, a new value of FMACH is found, compatible with the value of RC calculated for LR = 0.
FMACH	21-30	Mach number at Point F if ETAD ≠ 60. Negative value specifies Prandtl-Meyer angle at Point F as |FMACH| *ETAD (usually around -7). If FMACH and RC are given, IX = 0 and 4th-deg distribution is used. If FMACH = 0 and IX = 0, a 3rd-deg distribution is used. If FMACH = 0. and IX = ±1, a 4th-deg distribution is used. FMACH is calculated if not given. If ETAD = 60., Point F is not defined.

BMACH	31-40	Mach No. at Point B if ETAD $\neq$ 60.
CMC	41-50	Absolute value is design Mach No. at Point C. If ETAD $\neq$ 60, positive CMC gives $d^2M/dx^2 = 0$, and negative CMC gives $d^2M/dx^2 \neq 0$. If ETAD = 60., CMC is positive.
SF	51-60	Scale factor by which nondimension coordinates are multiplied to give dimensions in inches. If SF = 0, nozzle will have an inviscid throat radius (or half-height) of 1 in. If negative, nozzle will have an inviscid exit radius (or half-height) of $\lvert SF \rvert$ in.
PP	61-70	Station (in.) at Point A. PP = 0 gives coordinates relative to geometric throat. Negative PP gives coordinates relative to source or radial flow (ETAD $\neq$ 60.).
XC	71-80	Nondimensional distance from source to Point C. XC = 1. requires centerline Mach No. distribution from Point B to Point C to be read in as input data on Unit 9. Otherwise, positive XC gives 5th-deg distribution if CMC positive and 4th-deg if CMC negative. XC = 0 gives 4th-deg distribution if CMC positive and 3rd-deg if CMC negative. Negative XC and IN gives 3rd-deg distribution with d^2W/dx^2 not matching source flow at Point B. If ETAD = 60. and XC > 1, XC is ratio of length, from throat to Point C, to throat height. Negative XC gives 3rd-deg distribution in M; XC = 0 gives 4th-deg distribution; XC > 1 gives 5th-deg distribution. XC = 1. requires centerline Mach No. distribution to be read in as input data on Unit 9.

<u>Card 4</u>

MT	1-5	Number of points on characteristic EG if ETAD $\neq$ 60. or CD if ETAD = 60. Maximum value about 125. Use odd number. A zero or negative value stops calculation after centerline distribution is calculated if NT positive.

NT	6-10	Number of points on axis IE. Maximum value is 149-LR. Use odd number. A zero or negative value stops calculation before centerline distribution is calculated but after parameters and coefficients of distribution are calculated.
IX	11-15	Determines if third derivative of velocity distribution is matched. IX = 1 matches third derivative with transonic solution. IX = -1 matches third derivative with source flow value. IX = 0 does not match third derivative but gives constant third derivative if RC = 0 or FMACH = 0.
IN	16-20	Determines type of distribution from Point B to Point C, positive for Mach No. distribution, negative for velocity distribution. IN = 0 for throat only. If XC is greater than 1., the downstream value of the second derivative at Point B is 0.1* |IN| times the radial flow value. Similarly, if ETAD = 60., the second derivative at Point I is 0.1*IN times the transonic value.
IQ	21-25	Zero for a complete contour if ETAD ≠ 60., 1 for throat only or if ETAD = 60., -1 for downstream only.
MD	26-30	Number of points on characteristic AB. Maximum value about 125. Use odd number. A zero or negative value stops calculation similarly to MT.
ND	31-35	Number of points on axis BC. Maximum value is 150. A zero or negative value acts like NT.
NF	36-40	Absolute value is number of points on characteristic CD for ETAD ≠ 60. Maximum value is 149 or 200 - ND - MP - |MQ| - number of points on upstream contour. Negative value calls for smoothing subroutine.
MP	41-45	Number of points on conical section GA if FMACH ≠ BMACH. Use value to give desired increments in contour - usually not known for initial calculation.

MQ	46-50	Number of points downstream of Point D if parallel inviscid contour desired. A negative value can be used to eliminate the inviscid printout.
JB	51-55	Positive number if boundary-layer calculation is desired before spline fit. Negative number transfers control of program to JX. Absolute values greater than one are used to approximately halve the number of points on the upstream contour even though LR + NT - 1 points are calculated from characteristic network if LR > 2, or (NT + 1) points if LR = 0.
JX	56-60	Positive number calls for calculation of streamlines, zero calls for repeat of inviscid calculations requiring new cards 3 and 4, or, if XBL = 1000., for spline fit after inviscid calculation, negative number calls for repeat of calculations requiring new cards 1, 2, 3, and 4.
JC	61-65	If not zero, calls for printout of intermediate characteristics within upstream contour if JC is positive and downstream contour if JC is negative. Characteristics are (NT - 1)/JC or (ND - 1)/(-JC). Opposite running characteristic through Point E (or B) is also printed.
IT	66-70	Number of points at which spline fit is desired if points are not evenly spaced, such as jack locations for a flexible plate. Used only for a planar nozzle, inasmuch as a nonzero value calculates distance along curved plate surface. Positive value of IT requires additional cards to be read in (8 points per card) after boundary layer is calculated.
LR	71-75	Absolute value is number of points on throat characteristic used in characteristics solution. Negative values give printout of transonic solution. LR = 0 gives M = 1 at Point I.
NX	76-80	Number from 10 to 20 determines spacing of points on axis for upstream contour. NX = 10 gives linear spacing. NX > 10 gives closer spacing of points at upstream end than at downstream end. NX = 0 same as NX = 20. Ratio of downstream

increment to upstream increment is $(NT - 1)^{NX/10} - (NT - 2)^{NX/10}$. Optimum values, usually 13 to 15, determined by trial and error for specific contour desired. Negative NX used with negative LR limits printout to transonic solution.

NOTE: A zero value of MT, NT, MD, or ND will allow a repeat of calculations for parameters specified by new cards Nos. 3 and 4. A negative value will allow a repeat of calculations for new cards Nos. 1, 2, 3, and 4.

Card 5

NOUP	1-5	If smoothing is desired, negative NF. Number of times upstream contour is smoothed.
NPCT	6-10	Smoothing factor in percent. Smoothing factor = NPCT/100.
NODO	11-15	Number of times downstream contour is smoothed.

Card 5 or	If boundary-layer calculation is desired using inviscid points calculated from characteristics solution. (No smoothing).
Card 6 or	If boundary-layer calculation is desired using evenly spaced points interpolated from spline fit of points from characteristics solution.
Card 7	If boundary-layer calculation is desired using evenly spaced points interpolated from spline fit of smoothed points.

PPQ	1-10	Stagnation pressure (psia).
TO	11-20	Stagnation temperature, Rankine.
TWT	21-30	Throat wall temperature, Rankine, if QFUN = 0. If TWT = 0, the wall temperature is assumed to be the adiabatic value.
TWAT	31-40	Wall temperature, Rankine, at Point D. For water-cooled wall, the bulk water temperature is assumed to be 15° lower than specified TWAT. The cooled wall temperature distribution is assumed to be

$$TW = TWAT + \frac{(TWT - TWAT)}{\sqrt{Ac/A^*} - 1} \times \left(\sqrt{\frac{Ac/A^*}{A/A^*}} - 1\right)$$

where A/A* is the area ratio corresponding to local value of Mach number and Ac refers to Point C.

For negative IHT

$$TW = TWAT + \frac{(TWT - TWAT)}{Ac/A^* - 1} \times \left(\frac{Ac/A^*}{A/A^*} - 1\right)$$

QFUN 41-50 Heat-transfer function at the throat.

$$QFUN = \frac{ha(Taw - TWT)}{TWT - TWAT + 15}$$

where ha has dimensions of BTU/sec/sq ft/R and is obtained by Reynolds analogy from the skin-friction coefficient. If QFUN is specified, input value of TWT is ignored and TWT is calculated from QFUN.

ALPH 51-60 Parameter specifying temperature distribution in boundary layer. ALPH = 1. uses quadratic distribution both in the calculation of the reference temperature TP and the calculation of boundary-layer shape parameters. ALPH = 0 uses parabolic distribution in both calculations. ALPH = -1. uses quadratic distribution for TP and parabolic in the calculation of boundary-layer shape parameters. Within boundary layer,

$$T = Tw + \alpha(Taw - TW)\ (U/U_e) + \left[Te - \alpha(Taw - Tw) - Tw\right] (U/Ue)^2$$

where $\alpha = 1$ for quadratic dist.

$\alpha = 0$ for parabolic dist.

IHT 61-65 Integer which determines temperature distribution (see TWAT). If nonzero, IHT determines how often subroutine HEAT is called. An absolute value of IHT greater than KO, the number of points on the upstream contour, will prevent HEAT from being called but will allow the choice of temperature distribution to be made.

NOTE: HEAT is a special purpose subroutine for determining heat-transfer values for the upstream contour. The subroutine HEAT incorporated in this program is a dummy.

IR	66-70	Integer, parameter specifying transformation from incompressible to compressible values. If IR = 2, Coles' transformation is used for C_f and Re_θ. If IR = 1, TP is calculated by a modification of the Spalding-Chi (Van Driest) method. If IR = 0, the Van Driest value of Re_{θ_i} is used, but if IR = -1, Coles' law of corresponding stations is used. $$C_f = C_{f_i} * TE/TP,\ Re_{\theta_i} = FRD*Re_\theta.$$
ID	71-75	Integer. If ID = ±1, axisymmetric effects are included in momentum equation and in calculation of boundary-layer parameters (δ not negligible relative to coordinate normal to axis). If ID = 0, these effects are omitted. Negative ID suppresses the printout of the boundary-layer calculations.
LV	76-80	Integer. Absolute value, usually 5, determines number of times boundary-layer solution is iterated so that radius terms in momentum equation refer to viscid radius instead of inviscid radius. Value of 0 or absolute value of 1 uses inviscid radius. Positive LV repeats boundary-layer calculations for new set of parameters on a new card if XBL ≠ 1000.
Card 5		If streamlines are desired, JX positive. (No smoothing.)
ETAD	1-10	Inflection angle in degrees for streamline desired if ETAD ≠ 60. for Card 3. If ETAD = 60. on Card 3, use ETAD = 60 on this card.
QM	11-20	Fraction of contour desired if ETAD = 60. Otherwise, QM = ETAD on Card 5 divided by ETAD on Card 3.
XJ	21-30	Value to update JX for subsequent calculation, JX = XJ.

Card 5 or		If SPLIND used after inviscid calculation (JX zero or negative and JB zero or negative). (No smoothing.)
Card 6 or		If SPLIND used after viscid contour (JB positive and LV zero or negative). No smoothing of inviscid contour. Or, if inviscid contour is smoothed before SPLIND is used.
Card 7		If inviscid contour is smoothed, boundary layer is added and SPLINE is desired.
XST	1-10	Station (in.) for throat value of X. If XST = 1000., program uses value previously determined by specifying PP on Card 3. Otherwise, value of XST is used to shift contour points by desired increments for arbitrary Station 0.
XLOW	11-20	Starting value for interpolation. Second value of interpolated X = XLOW + XINC.
XEND	21-30	End value for interpolation. If zero, SPLIND is used to calculate slope and d^2y/dx^2 at same points as previously defined.
XINC	31-40	Increment in X for interpolation. If zero, and BJ > 10, contour is divided into BJ increments.
BJ	41-50	Value to update JB for subsequent calculation. JB = BJ. If negative and XEND = 0, interpolation is made at discrete points read in on subsequent cards similar to case when IT > 0.
XMID	51-60	Intermediate value for interpolation. Distance (XMID-XLOW) is divided into increments defined by XINC, and distance (XEND-XMID) is divided into increments defined by XINC2.
XINC2	61-70	Increments in X between XMID and XEND if different than XINC.
CN	71-80	Number of copies desired of final tabulation of coordinates if more than one copy is desired.

APPENDIX D
COMPUTER PROGRAM

```
C      MAIN PART OF
C      PROGRAM CONTUR(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C      NOZZLE CONTOUR PROGRAM VEV00028 FOR AXISYMMETRIC OR PLANAR FLOW
C      WITH RADIAL FLOW REGION AND/OR WITH CENTER-LINE VELOCITY OR MACH
C      NUMBER DISTRIBUTIONS DEFINED BY POLYNOMIALS.
C
C      CORRECTION APPLIED FOR GROWTH OF TURBULENT BOUNDARY LAYER.
C      PERFECT GAS IS ASSUMED WITH CONSTANT SPECIFIC HEAT RATIO, GAM,
C      COMPRESSIBILITY FACTOR, ZO, AND RECOVERY FACTOR, RO, AS INPUTS.
C      ALSO INPUT IS GAS CONSTANT, AR, IN SQ FT PER SQ SECOND PER DEG R.
C      IF VISM IS SUTHERLANDS TEMPERATURE, VISCOSITY FOLLOWS SUTHERLANDS
C      LAW ABOVE VISM, BUT IS LINEAR WITH TEMPERATURE BELOW VISM.
C      IF(VISM.LE.1.D+0) VISCOSITY=VISC*TEMPERATURE**VISM
C
       IMPLICIT REAL*8(A-H,O-Z)
       COMMON /GG/ GAM,GM,G1,G2,G3,G4,G5,G6,G7,G8,G9,GA,RGA,QT
       COMMON /COORD/ S(200),FS(200),WALTAN(200),SD(200),WMN(200),TTR(200
      1),DMDX(200),SPR(200),DPX(200),SREF(200),XBIN,XCIN,GMA,GMB,GMC,GMD
       COMMON /CORR/ DLA(200),RCO(200),DAX(200),DRX(200),SL(200),DR2
       COMMON /PROP/ AR,ZO,RO,VISC,VISM,SFOA,XBL,CONV
       COMMON /PARAM/ ETAD,RC,AMACH,BMACH,CMACH,EMACH,GMACH,FRC,SF,WWO,WW
      1OP,QM,WE,CBET,XE,ETA,EPSI,BPSI,XO,YO,RRC,SDO,XB,XC,AH,PP,SE,TYE,XA
       COMMON /JACK/ SJ(30),XJ(30),YJ(30),AJ(30)
       COMMON /CONTR/ ITLE(3),IE,LR,IT,JB,JQ,JX,KAT,KBL,KING,KO,LV,NOCON
       DATA ZRO/0.0D+0/,ONE/1.D+0/,TWO/2.D+0/,DC7/8HCURVATUR/
       DATA DC1/8H D2Y/DX2/,DC2/8H        /,DC3/8H   ANGLE/
       DATA DC4/8H   DY/DX/,DC5/8H   DY/DS/,DC6/8H   DX/DS/
       DATA L1/4H   X/,L2/4H   Y/,L3/4H   S/,L4/4H    /,L5/4HDIFF/
       CONV=90.D+0/DARSIN(ONE)
       IT=0
       NC=0
       LA=L1
       LB=L4
       DCA=DC4
       DCB=DC2
       JJ=1000
       DCC=DC1
C
1      READ (5,30,END=24) ITLE,JD
       IF (ITLE(1).EQ.L4) GO TO 24
       IE=1+JD
       QT=ONE/(1+IE)
C
       READ (5,28) GAM,AR,ZO,RO,VISC,VISM,SFOA,XBL
C      FOR GAMMA=1.4, G9=5, G8=.2, G7=1.2, G6=5/6, G5=1/6, G4=1/SQRT(6),
C      G3=1.5, G2=SQRT(6), G1=2.5
       GM=GAM-ONE
       G1=ONE/GM
       G9=TWO*G1
       G8=ONE/G9
       G7=ONE+G8
       G6=ONE/G7
       G5=G8*G6
       RGA=TWO*G5
       GA=ONE/RGA
```

```
      G4=DSQRT(G5)
      G3=GA/TWO
      G2=ONE/G4
      IF (IE.EQ.0) AH=ZO
      IF (IE.EQ.0) ZO=ONE
      QM=ONE
      JX=0
2     JQ=0
      LV=0
3     CALL AXIAL
      IF (LV.LT.0) GO TO 1
      CALL PERFC
      IF (NOCON.NE.0) GO TO 24
      IF ((JQ.GT.0).OR.(JX.GT.0)) GO TO 3
      IF (JB.GT.0) CALL BOUND
      IF (XBL.EQ.1.D+3) GO TO 5
      IF (IT.LT.1) GO TO 4
      LA=L3
      DCA=DC5
      DCC=DC7
      KUP=IT
      KAP=KUP+1
      XEND=ZRO
C
      READ (5,28,END=24) (SJ(K),K=1,KUP),XST
      CSK=ONE/DSQRT(ONE+DRX(KAT)**2)
      SNK=CSK*DRX(KAT)
      CALL SPLIND (SL,RCO,ZRO,SNK,KAT)
      GO TO 6
4     IF (LV.GT.0) GO TO 24
      IF (JX.LT.0) GO TO 1
      GO TO 2
5     CONTINUE
C
      READ (5,28,END=24) XST,XLOW,XEND,XINC,BJ,XMID,XINC2,CN
      IF (XST.EQ.XBL) XST=S(1)
      NC=CN-ONE
      IF (JB.LE.0) CALL SPLIND (S,FS,WALTAN(1),WALTAN(KING),KING)
      IF (JB.GT.0) CALL SPLIND (S,RCO,DRX(1),DRX(KAT),KAT)
      IF (XEND.GT.ZRO) GO TO 6
      LB=L5
      DCB=DC4
6     SLONG=S(KING)-S(1)
      IPP=0
      WRITE (6,25) ITLE,SLONG
      WRITE (6,31) LA,L2,DCA,DC3,DCC,DCB,LB
      IF (JB.GT.0) GO TO 7
      WRITE (6,26) XST,FS(1),WALTAN(1),ZRO,SD(1)
      XMAX=SLONG+XST
      YMAX=FS(KING)
      TMAX=WALTAN(KING)
      GO TO 8
7     WRITE (6,26) XST,RCO(1),DRX(1),ZRO,DR2
      XMAX=S(KAT)-S(1)+XST
      YMAX=RCO(KAT)
      TMAX=DRX(KAT)
```

```
8     IF (IT.GT.0) GO TO 11
      JB=BJ
      IF (XEND.GT.ZRO) GO TO 10
      IF (JB.LT.0) GO TO 9
      KUP=KING-1
      KAP=KING-1
      GO TO 11
9     KUP=-JB
      KAP=KUP+1
C
      READ (5,28,END=24) (SJ(K),K=1,KUP)
      GO TO 11
10    IF (XINC.GT.ZRO) KUP=(XEND-XLOW)/XINC+1.D-2
      IF (XMID.NE.ZRO) JJ=(XMID-XLOW)/XINC+1.D-2
      IF (XMID.NE.ZRO) KUP=JJ+(XEND-XMID)/XINC2+1.D-2
      IF (JB.GT.10) KUP=JB
      IF (JB.GT.10) XINC=SLONG/BJ
      KAP=(XMAX-XLOW)/XINC+1
      IF (XMID.NE.ZRO) KAP=JJ+(XMAX-XMID)/XINC2+1
11    DO 19 K=1,KUP
      IF (XEND.EQ.ZRO) GO TO 12
      X=XLOW+K*XINC
      IF (K.GT.JJ) X=XMID+(K-JJ)*XINC2
      GO TO 13
12    IF (IT.LT.1.AND.JB.GE.0) X=S(K+1)
      IF (IT.GT.0.OR.JB.LT.0) X=SJ(K)
13    XX=X-XST+S(1)
      IF (K.LT.KAP) CALL XYZ (XX,YY,YYP,YYPP)
      IF (K.EQ.KAP) X=XMAX
      IF (K.GE.KAP) YY=YMAX
      IF (K.GE.KAP) YYP=TMAX
      IF (K.GE.KAP) YYPP=ZRO
      IF (IT.LT.1) GO TO 16
      IF (IPP.GT.0) GO TO 14
      YJ(K)=YY
      AJ(K)=DARSIN(YYP)
      WANG=CONV*AJ(K)
      CURV=YYPP/DCOS(AJ(K))
      WRITE (6,26) X,YY,YYP,WANG,CURV
      GO TO 18
14    YY=YY-S(1)+XST
      XJ(K)=YY
      WANG=CONV*DARCOS(YYP)
      WRITE (6,26) X,YY,YYP,WANG
      GO TO 18
16    WANG=CONV*DATAN(YYP)
      IF (XEND.EQ.ZRO.AND.JB.GE.0) DY=YYP-WALTAN(K+1)
      IF (JB.LE.0) GO TO 17
      FS(K+1)=YY
      WALTAN(K+1)=YYP
      SD(K+1)=YYPP
17    IF (XEND.GT.ZRO.OR.JB.LT.0) WRITE (6,26) X,YY,YYP,WANG,YYPP
      IF (XEND.EQ.ZRO.AND.JB.GE.0) WRITE (6,26) X,YY,YYP,WANG,YYPP,DY
18    IF (MOD(K,10).EQ.0) WRITE (6,29)
      IF (MOD(K,50).NE.0) GO TO 19
      WRITE (6,25) ITLE,SLONG
```

```
      WRITE (6,31) LA,L2,DCA,DC3,DCC,DCB,LB
   19 CONTINUE
      IF (IT.GT.0.AND.IPP.EQ.1) CALL PLATE
      IF (IPP.GE.NC) GO TO 20
      IPP=IPP+1
      WRITE (6,25) ITLE,SLONG
      WRITE (6,31) LA,L2,DCA,DC3,DCC
      WRITE (6,26) XST,RCO(1),DRX(1),ZRO,DR2
      GO TO 11
   20 IF ((IPP.GT.0).OR.(JX.LT.0)) GO TO 1
      IF (IT.EQ.0) GO TO 21
      IPP=1
      CALL SPLIND (SL,S,ONE,CSK,KAT)
      WRITE (6,29)
      WRITE (6,31) L3,L1,DC6,DC3
      WRITE (6,26) XST,XST,ONE,ZRO
      GO TO 11
   21 IF (JB) 1,2,22
   22 CALL SPLIND (S,WMN,DMDX(1),DMDX(KING),KING)
      DO 23 K=1,KUP
      X=XLOW+K*XINC
      IF (XEND.EQ.ZRO) X=S(K+1)
      XX=X-XST+S(1)
      IF (K.LT.KAP) CALL XYZ (XX,YY,YYP,YYPP)
      IF (K.GE.KAP) YY=CMACH
      IF (K.GE.KAP) YYP=ZRO
      S(K+1)=X
      WMN(K+1)=YY
      TTR(K+1)=ONE+G8*YY**2
      SPR(K+1)=ONE/TTR(K+1)**(ONE+G1)
      DMDX(K+1)=YYP
   23 DPX(K+1)=-GAM*YY*YYP*SPR(K+1)/TTR(K+1)
      S(1)=XST
      KAT=KUP+1
      KBL=KAT+4
      KO=1
      CALL BOUND
      IF (JB.EQ.7) STOP
      IF (JB.GT.10) GO TO 1
      WRITE (6,25) ITLE,SLONG
      WRITE (6,31) L1,L2,DC4
      WRITE (6,27) (S(K),RCO(K),DRX(K),K=1,KAT)
      GO TO 1
   24 STOP
C
   25 FORMAT (1H1,9X,3A4,' COORDINATES AND DERIVATIVES, LENGTH =',F12.7)
   26 FORMAT (1H ,8X,2F15.6,1P4E20.8)
   27 FORMAT (10(9X,0P2F15.6,1PE20.8/))
   28 FORMAT (8E10.0)
   29 FORMAT (1H )
   30 FORMAT (3A4,I3)
   31 FORMAT (1H0,14X,A4,'(IN)',7X,A4,'(IN)',6X,A8,12X,A8,14X,A8,9X,A8,2
     1X,A4 /)
      END
      SUBROUTINE AXIAL
C
```

```
C     TO OBTAIN THE AXIAL DISTRIBUTIUN OF VELOCITY AND/OR MACH NUMBER
C
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /FG/ GC,GD,GE,GF,GH,GI,HA,HB,HC,HE
      COMMON /GG/ GAM,GM,G1,G2,G3,G4,G5,G6,G7,G8,G9,GA,RGA,QT
      COMMON /CLINE/ AXIS(5,150),TAXI(5,150),WIP,X1,FRIP,ZONK,SEO,CSE
      COMMON /PROP/ AR,ZO,RO,VISC,VISM,SFOA,XBL,CONV
      COMMON /PARAM/ ETAD,RC,AMACH,BMACH,CMACH,EMACH,GMACH,FRC,SF,WWO,WW
     1OP,QM,WE,CBET,XE,ETA,EPSI,BPSI,XO,YO,RRC,SDO,XB,XC,AH,PP,SE,TYE,XA
      COMMON /CONTR/ ITLE(3),IE,LR,IT,JB,JQ,JX,KAT,KBL,KING,KO,LV,NOCON,
     1IN,MC,MCP,IP,IQ,ISE,JC,M,MP,MQ,N,NP,NF,NUT,NR,LC,MD,MF,MT,ND,NT
      DATA ZRO/0.0D+0/,ONE/1.D+0/,TWO/2.D+0/,SIX/6.D+0/,HALF/5.D-1/
      DATA THR/3.D+0/,FOUR/4.D+0/,FIV/5.D+0/,TEN/1.D+1/,TLV/1.2D+1/
      DATA SEV/7.D+0/,EIT/8.D+0/,FFTN/1.5D+1/,TRTY/3.D+1/,SXTY/6.D+1/
      DATA M1/4HGMAC/,M2/4HZ-D /,IAXIS/4HAXIS/,NS/4H SPE/,NC/4HCIAL/
      DATA N3/4H 3RD/,N4/4H 4TH/,N5/4H 5TH/,N0/4H-DEG/
      DIMENSION C(6), D(4), AX(150), AXM(150), AXMP(150)
C
      HPI=9.D+1/CONV
      IF (JQ.EQ.0.AND.JX.EQ.0) CALL OREZ (AXIS,2*750)
      IF (JQ.GT.0) GO TO 50
      IF (JX.EQ.0) GO TO 2
C
C     CARD USED TO OBTAIN INTERNAL STREAMLINES (JX > 0)
C
      READ (5,93,END=91) ETAD,QM,XJ
C
      JX=XJ
      IF (ETAD.EQ.SXTY) GO TO 1
      ETA=ETAD/CONV
      IF (IE.EQ.0) SE=ETA
      IF (IE.EQ.1) SE=TWO*DSIN(HALF*ETA)
      CSE=DCOS(ETA)
      APSI=BPSI-ETA/QT
      AMACH=FMV(APSI)
      RA=((G6+G5*AMACH**2)**GA/AMACH)**QT
      GPSI=EPSI+ETA/QT
      GMACH=FMV(GPSI)
      RG=((G6+G5*GMACH**2)**GA/GMACH)**QT
      MP=ONE+THR*(RA-RG)
      GO TO 14
1     SE=QM*SEO
      GO TO 14
C
C     CONSTANTS USED IN TRANSONIC SOLUTION
2     GC=(TWO*GAM/QT-THR)/SIX/(3+IE)
      GE=(THR*(8+IE)-FOUR*GAM/QT)/THR/(7+IE)
      GH=(FFTN+(2-6*IE)*GAM)/TLV/(5+IE)
      GJ=(GAM*(GAM+9.25D+0*IE-26.5D+0)+.75D+0*(6-IE))/TLV/(3-IE)
      GK=(GAM*(GAM+2.25D+0*IE-16.5D+0)+2.25D+0*(2+IE))/SIX
      GR=(FFTN-(1+9*IE)*GAM)/(15+IE)/18.D+0
      HB=(14.D+0*GAM-75.D+0+18*IE)/(270.D+0+18*IE)
      IF (IE.EQ.0) GO TO 3
      GD=(GM*(652.D+0*GM+1319.D+0)+1000.D+0)/6912.D+0
      GF=(3612.D+0+GM*(751.D+0+GM*754.D+0))/2880.D+0
      GI=(909.D+0+GAM*(270.D+0+GAM*412.D+0))/10368.D+0
```

```
      GS=(GAM*(GAM*2708.D+0+2079.D+0)+2115.D+0)/82944.D+0
      HC=(GAM*(2364.D+0*GAM-3915.D+0)+14337.D+0)/82944.D+0
      HE=(GAM*(64.D+0*GAM+117.D+0)-1026.D+0)/1152.D+0
      GO TO 4
C
C     AXISYM FLOW, IE=1, QT=0.5, GAM=1.4, GC=0.10833333, GD=0.236099537,
C     GE=0.65833333, GF=1.40036111, GH=0.13055556, GI=0.2020177469,
C     GJ=-0.76833333, GK=-1.87333333, GR=0.003472222, GS=0.1245814043,
C     HB=-0.12986111, HC=0.1626331019, HE=-0.6395486111
C
3     GD=(GM*(32.D+0*GM-14.D+0)+221.D+0)/1080.D+0
      GF=(4230.D+0+GM*(211.D+0+GM*334.D+0))/3780.D+0
      GI=(738.D+0+GAM*(273.D+0-GAM*82.D+0))/7560.D+0
      GS=(GAM*(GAM*782.D+0+3507.D+0)+7767.D+0)/272160.D+0
      HC=(GAM*(274.D+0*GAM-861.D+0)+4464.D+0)/17010.D+0
      HE=(GAM*(32.D+0*GAM+87.D+0)-561.D+0)/540.D+0
C
C     PLANAR FLOW, IE=0, QT=1.0, GAM=1.4, GC=-0.011111, GD=0.2041851852,
C     GE=0.8761904762, GF=1.155513228, GH=0.29666667, GI=0.1269153439,
C     GJ=-0.85111111, GK=-2.7733333, GR=0.05037037037, GS=0.05221017049,
C     HB=-0.2051851852, HC=0.2231416814, HE=-0.6971851852
C
C     CARD USED TO ESTABLISH INVISCID PARAMETERS
C
4     READ (5,93,END=91) ETAD,RC,FMACH,BMACH,CMC,SF,PP,XC
C
C     CARD USED TO CONTROL CALCULATIONS
C
      READ (5,92) MT,NT,IX,IN,IQ,MD,ND,NF,MP,MQ,JB,JX,JC,IT,LR,NX
C
      LC=XC
      IF(XC.GT.ONE)LC=XC+ONE
      NR=SIX*RC
      MF=FMACH
      IF (IE.EQ.1) MC=M1
      IF (IE.EQ.0) MC=M2
      NOCON=0
      ETA=ETAD/CONV
      IF (IE.EQ.0) SE=ETA
      IF (IE.EQ.1) SE=TWO*DSIN(HALF*ETA)
      IF (ETAD.EQ.SXTY) SE=ONE
      SEO=SE
      ISE=SE
      CSE=DCOS(ETA)
      RT=RC+ONE
      AM=ONE
      WI=ONE
      WIPP=ZRO
      MCP=CMC
      CMACH=DABS(CMC)
      CBET=DSQRT(CMACH*CMACH-ONE)
      FRC=((G6+G5*CMACH**2)**GA/CMACH)**QT
      TYE=FRC*SE
      IF (SF.LT.ZRO) SF=-SF/TYE
      IF (ISE.EQ.0) GO TO 5
C
```

```
C       NON-RADIAL FLOW AT INFLECTION POINT
        IQ=1
        AMACH=CMACH
        BMACH=CMACH
        EMACH=CMACH
        FMACH=CMACH
        GMACH=CMACH
        IF (IE.EQ.1) AH=GMACH
        WE=G2*EMACH/DSQRT(EMACH**2+G9)
        DW=WE-WI
        XO=ZRO
        EOE=ZRO
        GO TO 15
C
C       RADIAL FLOW AT INFLECTION POINT
5       IF (IN.EQ.0) GO TO 6
        IF (LC.LT.0.AND.IN.LT.0) IN=-1
        IF (LC.EQ.0.OR.MCP.LT.0) IN=ISIGN(10,IN)
6       BBET=DSQRT(BMACH*BMACH-ONE)
        BPSI=G2*DATAN(G4*BBET)-DATAN(BBET)
        IF (FMACH) 9,8,7
7       FBET=DSQRT(FMACH*FMACH-ONE)
        FPSI=G2*DATAN(G4*FBET)-DATAN(FBET)
        GO TO 10
8       FMACH=-BPSI/ETA
        IF (BPSI/ETA.GT.7.5D+0) FMACH=-7.5D+0
9       FPSI=-FMACH*ETA
        FMACH=FMV(FPSI)
10      EPSI=FPSI-TWO*ETA/QT
        EMACH=FMV(EPSI)
        WE=G2*EMACH/DSQRT(EMACH*EMACH+G9)
        DW=WE-WI
        CALL SORCE (WE,D)
        XE=D(1)
        WEP=D(2)
        WEPP=D(3)
        WRPPP=D(4)
        IF (NR.NE.0) GO TO 15
        IF (LR.NE.0.OR.IQ.LT.0) GO TO 11
        IF (IX.EQ.0) WRITE (6,106) ITLE,N3
        IF (IX.NE.0) WRITE (6,106) ITLE,N4
C
C       ITERATION TO DETERMINE RC IF NOT SPECIFIED (NR = 0)
11      EA=WRPPP
        EB=-FIV*WEPP-WIPP
        EC=TLV*WEP
        ED=-TLV*DW
        XIE=CUBIC(EA,EB,EC,ED)
        IF (XIE.LE.ZRO) GO TO 89
12      WIP=TWO*(WE-ONE)/XIE-WEP+(WEPP-WIPP)*XIE/SIX
13      NOCON=NOCON+1
        IF (NOCON.GT.100) GO TO 90
14      RT=TORIC(WIP,SE)
        RC=RT-ONE
15      TK=(ONE-G7*(ONE+(GE+GF/RT)/RT)/RT**2/(15+IE)/THR)**QT
        YO=SE/TK
```

```
      AA=DSQRT(QT*(GAM+ONE)*RT)
      IF (QM.NE.ONE) GO TO 19
      WHPP=(ONE-GAM/1.5D+0+GJ/RT)/(AA*YO)**2
      IF (NR.NE.0.OR.ISE.EQ.1) GO TO 18
      IF (DABS(WHPP-WIPP).LT.1.D-10) GO TO 18
      WIPP=WHPP
      IF (IX) 11,17,16
16    EA=GK/(AA*YO)**3
      EB=THR*(WIPP+WEPP)
      EC=-TLV*WEP
      ED=TLV*DW
      XIE=CUBIC(EA,EB,EC,ED)
      IF (XIE.LE.ZRO) GO TO 89
      GO TO 12
17    H=(EIT*WIP+SEV*WEP)/(THR*WIPP-TWO*WEPP)
      HH=TRTY*DW/(THR*WIPP-TWO*WEPP)
      XIE=HH/(DSQRT(H*H+HH)+H)
      WIP=WEP-HALF*XIE*(WEPP+WIPP)
      GO TO 13
C
C     ITERATION FOR RC COMPLETED, REMAINDER OF TRANSONIC VALUES COMPUTED
18    WIP=(ONE-(GC-GD/RT)/RT)/YO/AA
      WHP=WIP
      WIPP=WHPP
      AMP=G7*WIP
      AMPP=G7*(WHPP+THR*G8*WIP**2)
19    XOI=YO*DSQRT(G7/TWO/(9-IE)/RT)*(ONE+(GH+GI/RT)/RT)
      IF (QM.NE.ONE) GO TO 21
      IF (ISE.EQ.1) XI=XOI
      XO1=XOI
      WO=ONE-(HALF/(3-IE)+(GR+GS/RT)/RT)/RT
      OM=WO/DSQRT(G7-G8*WO**2)
      WOPPP=GK/(AA*YO)**3
      IF (LR.EQ.0) GO TO 21
C
C     CALL FOR THROAT CHARACTERISTIC VALUES
      CALL TRANS (RT,TK,WO,AM,AMP,AMPP,WI,AWP,AWPP,AWPPP,XI)
      IF (NX.LT.0.AND.NT.LT.0) GO TO 87
      IF (NX.LT.0) GO TO 4
      AMP=AMP/SE
      AMPP=AMPP/SE**2
      WAP=AWP/SE
      WAPP=AWPP/SE**2
      WOPPP=AWPPP/SE**3
      IF (ISE.EQ.1) GO TO 21
      DW=WE-WI
      XOI=XI*SE
      IF (NR.GT.0) GO TO 20
      X1=XE-XIE
      XO=XE-XIE-XO1
      C2=XIE*WIP
      C3=HALF*WIPP*XIE**2
      C4=WE-ONE-C2-C3
      IF (IX.NE.0) C4=FOUR*C4+TWO*C3+C2-XIE*WEP
      IF (IQ.LT.0) GO TO 20
      WRITE (6,110) ITLE,N4,LR
```

```
      WRITE (6,96) XIE,C2,C3,C4,XI
20    WIP=WAP
      WIPP=WAPP
21    WWO=ONE+(ONE/(IE+3)-(HB-HC/RT)/RT)/RT
      WWOP=(ONE+(ONE-IE/EIT-HE/RT)/RT)/YO/AA
      RRC=ONE/RC
      SDO=RRC/YO
      ZONK=QM+1.0D-03
      NP=ZONK*(IABS(NF)-1)+1
      IF (SF.GT.ZRO) GO TO 22
      SF=ONE/YO
22    IF (IQ.LT.0) GO TO 31
      IP=0
      JQ=0
      M=ZONK*(MT-1)+1
      N=NT
      IF (QM.EQ.ONE) GO TO 23
      XO=X1-XOI
      RETURN
23    CALL OREZ (C,6)
      IF (ISE.EQ.0) GO TO 31
C
C     LENGTH OF AXIAL DISTRIBUTION FOR NON-RADIAL FLOW
      X1=XOI
      AEM=EMACH-AM
      C(1)=AM
      IF (LC) 25,24,27
24    AMSQ=AMP**2+AEM*AMPP*FOUR/THR
      IF (LR.EQ.0) WRITE (6,122) ITLE,N4,NO
      IF (LR.NE.0) WRITE (6,107) ITLE,N4,NO,LR
      IF (AMSQ.LT.ZRO) GO TO 28
      XIE=FOUR*AEM/(DSQRT(AMSQ)+AMP)
      XE=XIE+XI
      C(5)=THR*AEM-AMP*XIE
      GO TO 26
25    XIE=THR*AEM/AMP
      XE=XIE+XI
      IF (LR.EQ.0) WRITE (6,122) ITLE,N3,NO
      IF (LR.NE.0) WRITE (6,107) ITLE,N3,NO,LR
26    C(2)=AMP*XIE
      C(3)=SIX*AEM-THR*C(2)
      C(4)=THR*C(2)-EIT*AEM
      GO TO 46
27    IF (LC.EQ.1) GO TO 29
      XE=XC/TK
      XIE=FIV*AEM/(DSQRT(AMP**2+IN*AEM*AMPP/EIT)+AMP)
      IF (XE.GT.XI+XIE) XE=XI+XIE
      XIE=XE-XI
      C(2)=AMP*XIE
      C(3)=HALF*IN*AMPP*XIE**2/TEN
      C(4)=TEN*AEM-SIX*C(2)-THR*C(3)
      C(5)=-FFTN*AEM+EIT*C(2)+THR*C(3)
      C(6)=SIX*AEM-THR*C(2)-C(3)
      IF (LR.EQ.0) WRITE (6,122) ITLE,N5,NO
      IF (LR.NE.0) WRITE (6,107) ITLE,N5,NO,LR
      GO TO 46
```

```
28    C(2)=TWO*AEM
      C(4)=-C(2)
      C(5)=AEM
      XIE=TWO*AEM/AMP
      XE=XIE+XI
      GO TO 46
29    DO 30 J=1,NT
      K=NT+1-J
      READ (9) AX(K),AXM(K),AXMP(K)
      IF (J.EQ.1) DX=XI-AX(K)
30    AXIS(1,K)=AX(K)+DX
      AXM(NT)=AM
      AXMP(NT)=AMP
      XE=AXIS(1,1)
      XIE=XE-XI
      IF (LR.EQ.0) WRITE (6,122) ITLE,NS,NC
      IF (LR.NE.0) WRITE (6,107) ITLE,NS,NC,LR
      GO TO 46
C
C     LENGTH OF UPSTREAM AXIAL DISTRIBUTION FOR RADIAL FLOW
31    IF (SFOA.EQ.ZRO) GO TO 32
      IF (LR.EQ.0) WRITE (6,106) ITLE,N5
      IF (LR.NE.0) WRITE (6,110) ITLE,N5,LR
      GO TO 44
32    IF (LR.EQ.0) GO TO 33
      IF (NR.EQ.0.AND.IX.EQ.0) GO TO 41
      IF (NR.EQ.0.AND.IX.NE.0) MF=0
      IF (MF.NE.0) GO TO 40
      IF (IQ.LT.0.OR.NR.EQ.0) GO TO 35
      IF (IX.EQ.0) WRITE (6,110) ITLE,N3,LR
      IF (IX.NE.0) WRITE (6,110) ITLE,N4,LR
      GO TO 35
33    IF (MF.EQ.0) GO TO 34
      IF (NR.EQ.0) GO TO 45
      IF (IQ.GE.0) WRITE (6,106) ITLE,N4
      GO TO 41
C
C     ITERATION FOR EMACH IF NOT SPECIFIED (MF = 0)
34    IF (IQ.LT.0) GO TO 35
      IF (IX.EQ.0) WRITE (6,106) ITLE,N3
      IF (IX.NE.0) WRITE (6,106) ITLE,N4
35    IF (NOCON.GT.100) GO TO 90
      IF (IX) 41,36,37
36    XIE=SIX*DW/(DSQRT((WIP+WEP+WEP)**2-SIX*DW*WEPP)+WIP+WEP+WEP)
      FXW=HALF*XIE*(WEPP+WIPP)/(WEP-WIP)
      IF (FXW.LE.ZRO) EW=WE+.1D+0
      IF (FXW.LE.ZRO) GO TO 39
      IF (FXW.LT.ONE) EW=WI+DW*(FOUR+FXW**2)/FIV
      IF (FXW.GT.ONE.OR.IE.EQ.0) EW=WI+DW*(9.D+0+FXW)/TEN
      GO TO 39
37    EA=WOPPP
      EB=FIV*WIPP+WEPP
      EC=TLV*WIP
      ED=-TLV*DW
      XIE=CUBIC(EA,EB,EC,ED)
      IF (XIE.GT.ZRO) GO TO 38
```

```
      EW=WE-.1D+0
      IF (EW.GT.WI) GO TO 39
      WRITE (6,113)
      GO TO 4
38    EW=WI+HALF*XIE*(WIP+WEP+XIE*(WIPP-WEPP)/SIX)
39    WE=EW
      IF (WE.GT.G2) GO TO 79
      IF (DABS(EW-DW-WI).LT.1.D-9) GO TO 43
      DW=WE-WI
      CALL SORCE (WE,D)
      XE=D(1)
      WEP=D(2)
      WEPP=D(3)
      WRPPP=D(4)
      NOCON=NOCON+1
      GO TO 35
40    IF (IQ.LT.0) GO TO 41
      WRITE (6,110) ITLE,N4,LR
41    H=THR*(WEP+WIP)/(WIPP-WEPP)
      HH=TLV*DW/(WIPP-WEPP)
      XIE=HH/(DSQRT(H*H+HH)+H)
      IF (MF) 44,42,45
42    EW=WI+XIE*(WIP+THR*WEP-XIE*(WEPP-XIE*WRPPP/SIX))/FOUR
      GO TO 39
43    EMACH=WE/DSQRT(G7-G8*WE*WE)
C
C     ITERATION FOR EMACH COMPLETED
      EBET=DSURT(EMACH*EMACH-ONE)
      EPSI=G2*DATAN(G4*EBET)-DATAN(EBET)
      FPSI=EPSI+TWO*ETA/QT
      FMACH=FMV(FPSI)
44    IF (BMACH.GT.FMACH) GO TO 45
      BMACH=FMACH
      BPSI=FPSI
      MP=0
45    GPSI=FPSI-ETA/QT
      GMACH=FMV(GPSI)
      IF (IE.EQ.1) AH=GMACH
      RG=((G6+G5*GMACH**2)**GA/GMACH)**QT
      APSI=BPSI-ETA/QT
      AMACH=FMV(APSI)
      RA=((G6+G5*AMACH**2)**GA/AMACH)**QT
      XA=RA*CSE
      IF (SFOA.GT.ZRO) XIE=SFOA/SF+XE-XA-XOI
      IF (SFOA.LT.ZRO) XIE=XE-SFOA/SF-RG*CSE-XOI
      XI=XE-XIE
      XO=XI-XOI
      X1=XO+XOI
      IF (IQ.LT.0) GO TO 48
      XB=((G6+G5*BMACH**2)**GA/BMACH)**QT
      IF (LC.LT.2) XC=((G6+G5*CMACH**2)**GA/CMACH)**QT
      C(1)=WI
      C(2)=XIE*WIP
      C(3)=HALF*WIPP*XIE*XIE
      C(4)=TEN*DW-XIE*(FOUR*WEP-HALF*XIE*WEPP)-SIX*C(2)-THR*C(3)
      C(5)=XIE*(SEV*WEP+EIT*WIP-XIE*(WEPP-THR*WIPP/TWO))-FFTN*DW
```

```
      C(6)=SIX*DW-THR*XIE*(WEP+WIP)+HALF*XIE*XIE*(WEPP-WIPP)
      IF (MF.EQ.0.AND.IX.EQ.0) C(5)=ZRO
      IF (NR.EQ.0.AND.IX.EQ.0.AND.LR.EQ.0) C(5)=ZRO
      IF (SFOA.EQ.ZRO) C(6)=ZRO
      EOE=EPSI/ETA
      WIPPP=SIX*C(4)/XIE/XIE/XIE
      WEPPP=SIX*(C(4)+FOUR*C(5)+TEN*C(6))/XIE/XIE/XIE
46    WRITE (6,99) M,N,EOE,BMACH,CMACH,GAM,ETAD,RC,SF
      WRITE (6,102) SE,TK,WWO,WWOP,EMACH,FMACH,MC,AH
      IF (LR.NE.0) WRITE (6,123) WI,WAP,WAPP,AM,AMP,AMPP
      IF (ISE.EQ.1.AND.LR.EQ.0) WRITE (6,123) WI,WIP,WHPP,AM,AMP,AMPP
      IF (ISE.EQ.1) GO TO 47
      WRITE (6,101) WI,WIP,WIPP,WIPPP,WOPPP
      WRITE (6,98) WE,WEP,WEPP,WEPPP,WRPPP
47    WRITE (6,94) C(1),C(2),C(3),C(4),C(5),C(6)
      WRITE (6,95) XOI,XI,XO,YO,XIE,XE,NOCON
      IF (ISE.EQ.1) XC=XE
      IF (ISE.EQ.1) XA=XE+TYE*CBET
48    NOCON=0
      WIP=WHP
      IF (QM.NE.ONE) GO TO 49
      IF (PP.LT.ZRO) FRIP=ZRO
      IF (PP.EQ.ZRO) FRIP=-XO*SF
      IF (PP.GT.ZRO) FRIP=PP-SF*XA
      IF (IQ.LT.0) GO TO 50
      XOIN=SF*XO+FRIP
      X1IN=SF*X1+FRIP
      XIIN=SF*XI+FRIP
      WRITE (6,125) OM,XOIN,X1IN,AM,XIIN
      IF (IQ.GT.0) GO TO 67
49    IF (N) 87,50,68
50    M=ZONK*(MD-1)+1
      JQ=1
      N=ND
      IP=IN
      IF (QM.NE.ONE) RETURN
      CALL OREZ (C,6)
      IF (IQ.LT.0) GO TO 51
      IF (MQ.GE.0.AND.N.GT.0) GO TO 51
      WRITE (6,104)
      GO TO 52
51    WRITE (6,105)
52    IF (IP) 53,67,58
C
C     LENGTH OF DOWNSTREAM VELOCITY DISTRIBUTION, RADIAL FLOW
53    WC=G2*CMACH/DSQRT(CMACH*CMACH+G9)
      WB=G2*BMACH/DSQRT(BMACH*BMACH+G9)
      WCB=WC-WB
      CALL SORCE (WB,D)
      XB=D(1)
      WBP=D(2)
      WSPP=D(3)
      WSPPP=D(4)
      C(1)=WB
      WCP=ZRO
      IF (LC) 54,55,56
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```
54    XBC=THR*WCB/WBP
      WBPP=-TWO*WBP/XBC
      WRITE (6,109) ITLE,N3
      GO TO 57
55    WBPP=WSPP
      IF (MCP.LT.0) WRITE (6,109) ITLE,N3
      IF (MCP.LT.0) XBCN=THR*WCB/WBP
      IF (MCP.LT.0) XBCM=-TWO*WBP/WBPP
      IF (MCP.GT.0) WRITE (6,109) ITLE,N4
      IF (MCP.GT.0) XBCN=FOUR*WCB/WBP
      IF (MCP.GT.0) XBCM=-THR*WBP/WBPP
      ABCM=ONE-XBCN/XBCM
      IF (ABCM.LT.ZRO) GO TO 88
      XBC=XBCN/(DSQRT(ABCM)+ONE)
      GO TO 57
56    WBPP=-WSPP*IP/TEN
      IF (MCP.GT.0) XBCMN=CUBIC(WSPPP/THR,THR*WBPP,TLV*WBP,-TWO*TEN*WCB)
      IF (MCP.LT.0) XBCMN=CUBIC(WSPPP/SIX,WBPP,THR*WBP,-FOUR*WCB)
      XBCMX=FIV*WCB/(DSQRT(WBP**2-IP*WCB*WSPP/EIT)+WBP)
      IF (XC.GT.XB+XBCMX) XC=XB+XBCMX
      IF (XC.LT.XB+XBCMN) XC=XB+XBCMN
      XBC=XC-XB
      IF (MCP.LT.0) WRITE (6,109) ITLE,N4
      IF (MCP.GT.0) WRITE (6,109) ITLE,N5
57    C(2)=XBC*WBP
      C(3)=HALF*XBC*XBC*WBPP
      IF (MCP.LT.0) C(4)=FOUR*WCB-THR*C(2)-TWO*C(3)
      IF (MCP.LT.0) C(5)=-THR*WCB+TWO*C(2)+C(3)
      IF (MCP.GT.0) C(4)=TEN*WCB-SIX*C(2)-THR*C(3)
      IF (MCP.GT.0) C(5)=-FFTN*WCB+EIT*C(2)+THR*C(3)
      IF (MCP.GT.0) C(6)=SIX*WCB-THR*C(2)-C(3)
      IF (LC.LT.0) C(5)=ZRO
      IF (LC.LE.0) C(6)=ZRO
      XC=XB+XBC
      GO TO 63
C
C     LENGTH OF DOWNSTREAM MACH NO. DISTRIBUTION, RADIAL FLOW
58    CALL CONIC (BMACH,D)
      XB=D(1)
      BMP=D(2)
      SMPP=D(3)
      SMPPP=D(4)
      CBM=CMACH-BMACH
      C(1)=BMACH
      BMPP=SMPP*IP/TEN
      IF (LC.NE.0) GO TO 59
      IF (MCP.LT.0) WRITE (6,108) ITLE,N3
      IF (MCP.LT.0) XBCN=THR*CBM/BMP
      IF (MCP.LT.0) XBCM=-TWO*BMP/BMPP
      IF (MCP.GT.0) WRITE (6,108) ITLE,N4
      IF (MCP.GT.0) XBCN=FOUR*CBM/BMP
      IF (MCP.GT.0) XBCM=-THR*BMP/BMPP
      ABCM=ONE-XBCN/XBCM
      IF (ABCM.LT.ZRO) GO TO 88
      XBC=XBCN/(DSQRT(ABCM)+ONE)
      XC=XB+XBC
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      GO TO 62                                                          AXI  507
59    IF (LC.NE.1) GO TO 61                                             AXI  508
      DO 60 K=1,ND                                                      AXI  509
      READ (9) AX(K),AXM(K),AXMP(K)                                     AXI  510
      IF (K.EQ.1) DX=XB-AX(1)                                           AXI  511
60    AXIS(1,K)=AX(K)+DX                                                AXI  512
      IF (AXMP(2).EQ.ZRO) CALL SCOND (AX,AXM,AXMP,ND)                   AXI  513
      AXM(1)=BMACH                                                      AXI  514
      AXMP(1)=BMP                                                       AXI  515
      XC=AXIS(1,ND)                                                     AXI  516
      XBC=XC-XB                                                         AXI  517
      WRITE (6,111) ITLE                                                AXI  518
      GO TO 63                                                          AXI  519
61    IF (MCP.GT.0) XBCMN=CUBIC(SMPPP/THR,THR*BMPP,TLV*BMP,-TWO*TEN*CBM)AXI  520
      IF (MCP.LT.0) XBCMN=CUBIC(SMPPP/SIX,BMPP,THR*BMP,-FOUR*CBM)       AXI  521
      XBCMX=FIV*CBM/(DSQRT(BMP**2+IP*CBM*SMPP/EIT)+BMP)                 AXI  522
      IF (XC.GT.XB+XBCMX) XC=XB+XBCMX                                   AXI  523
      IF (XC.LT.XB+XBCMN) XC=XB+XBCMN                                   AXI  524
      XBC=XC-XB                                                         AXI  525
      IF (MCP.LT.0) WRITE (6,108) ITLE,N4                               AXI  526
      IF (MCP.GT.0) WRITE (6,108) ITLE,N5                               AXI  527
62    C(2)=XBC*BMP                                                      AXI  528
      C(3)=HALF*XBC*XBC*BMPP                                            AXI  529
      IF (MCP.LT.0) C(4)=FOUR*CBM-THR*C(2)-TWO*C(3)                     AXI  530
      IF (MCP.LT.0) C(5)=-THR*CBM+TWO*C(2)+C(3)                         AXI  531
      IF (MCP.GT.0) C(4)=TEN*CBM-SIX*C(2)-THR*C(3)                      AXI  532
      IF (MCP.GT.0) C(5)=-FFTN*CBM+EIT*C(2)+THR*C(3)                    AXI  533
      IF (MCP.GT.0) C(6)=SIX*CBM-THR*C(2)-C(3)                          AXI  534
      IF (LC.LE.0) C(6)=ZRO                                             AXI  535
63    CPP=ZRO                                                           AXI  536
      CMP=ZRO                                                           AXI  537
      IF (MCP.LT.0) CPP=(TWO*C(3)+SIX*C(4)+TLV*C(5))/XBC**2             AXI  538
      BPPP=SIX*C(4)/XBC/XBC/XBC                                         AXI  539
      CPPP=SIX*(C(4)+FOUR*C(5)+TEN*C(6))/XBC/XBC/XBC                    AXI  540
      XD=XC+TYE*CBET                                                    AXI  541
      WRITE (6,100) M,N,NP,GAM,ETAD,RC,SF                               AXI  542
      IF (IP) 64,67,65                                                  AXI  543
64    WRITE (6,116) WB,WBP,WBPP,BPPP,WSPP,WC,WCP,CPP,CPPP,WSPPP         AXI  544
      GO TO 66                                                          AXI  545
65    WRITE (6,117) BMACH,BMP,BMPP,BPPP,SMPP,CMACH,CMP,CPP,CPPP,SMPPP   AXI  546
66    WRITE (6,94) C(1),C(2),C(3),C(4),C(5),C(6)                        AXI  547
      WRITE (6,118) AMACH,XA,XB,XBC,XC,XD                               AXI  548
      XAIN=SF*XA+FRIP                                                   AXI  549
      YAIN=SF*XA*DTAN(ETA)                                              AXI  550
      XBIN=SF*XB+FRIP                                                   AXI  551
      XCIN=SF*XC+FRIP                                                   AXI  552
      XDIN=SF*XD+FRIP                                                   AXI  553
      TYIN=SF*TYE                                                       AXI  554
      WRITE (6,120) XAIN,YAIN,XBIN,XCIN,XDIN,TYIN                       AXI  555
67    IF (N) 87,4,68                                                    AXI  556
68    IF (MQ.LT.0) GO TO 69                                             AXI  557
C                                                                       AXI  558
C     CALCULATE AXIAL DISTRIBUTION                                      AXI  559
      WRITE (6,103) IAXIS                                               AXI  560
69    FN=N-1                                                            AXI  561
      L=(N+40)/41                                                       AXI  562
```

```
      IF (IP.NE.0) XIE=XBC
      IF (IP.NE.0) XI=XB
      Q=ZRO
      DO 84 K=1,N
      IF (ISE.EQ.1.AND.LC.EQ.1) GO TO 72
      IF (IP.NE.0) GO TO 70
      IF (NX.EQ.0) Q=((N-K)/FN)**2
      IF (NX.NE.0) Q=((N-K)/FN)**(NX*1.D-1)
      GO TO 71
   70 IF (LC.EQ.1) GO TO 72
      Q=(K-1)/FN
   71 AXIS(1,K)=XIE*Q+XI
   72 RMACH=ONE
      IF (ISE.EQ.1) GO TO 75
      IF (AXIS(1,K).LT.ONE+1.D-9) GO TO 74
      AB=AXIS(1,K)**(RGA/QT)
      IF (AB.LT.TWO) SM=((ONE+DSQRT(AB*GM-GM))**GA)**2
      IF (AB.GE.TWO) SM=(AB/G5)**G7
   73 CM=SM**G5
      FQ=SM*(G6+G5*SM-CM*AB)/(SM-ONE)/G5/G6
      SM=SM-FQ
      IF (DABS(FQ).GT.1.D-9) GO TO 73
      RMACH=DSQRT(SM)
   74 IF (IP.LT.1) GO TO 78
   75 IF (LC.EQ.1) GO TO 76
      XM=C(1)+Q*(C(2)+Q*(C(3)+Q*(C(4)+Q*(C(5)+Q*C(6)))))
      IF (ISE.EQ.1.OR.K.EQ.1) GO TO 77
      IF (RMACH.LT.XM) WRITE (6,124) K,RMACH,XM
      GO TO 77
   76 XM=AXM(K)
   77 XMP=(C(2)+Q*(TWO*C(3)+Q*(THR*C(4)+Q*(FOUR*C(5)+Q*FIV*C(6)))))/XIE
      IF (LC.EQ.1) XMP=AXMP(K)
      XMPP=TWO*(C(3)+Q*(THR*C(4)+Q*(SIX*C(5)+Q*TEN*C(6))))/XIE/XIE
      XMPPP=SIX*(C(4)+Q*(FOUR*C(5)+TEN*Q*C(6)))/XIE/XIE/XIE
      GMM=XM*XM+G9
      GQ=DSQRT(GMM)
      W=G2*XM/GQ
      WM=G9*G2/GQ/GMM
      WP=WM*XMP
      WPP=WM*(XMPP-THR*XM*XMP*XMP/GMM)
      GMP=FIV*XM*XM*XMP*XMP/GMM-THR*XM*XMPP-XMP*XMP
      WPPP=WM*(XMPPP+THR*XMP*GMP/GMM)
      IF (MQ.LT.0) GO TO 83
      IF (MOD(K-1,L).NE.0) GO TO 83
      GO TO 82
   78 W=C(1)+Q*(C(2)+Q*(C(3)+Q*(C(4)+Q*(C(5)+Q*C(6)))))
      WP=(C(2)+Q*(TWO*C(3)+Q*(THR*C(4)+Q*(FOUR*C(5)+Q*FIV*C(6)))))/XIE
      WPP=TWO*(C(3)+Q*(THR*C(4)+Q*(SIX*C(5)+Q*TEN*C(6))))/XIE/XIE
      WPPP=SIX*(C(4)+Q*(FOUR*C(5)+TEN*Q*C(6)))/XIE/XIE/XIE
      GWW=G7-W*W*G8
      IF (GWW.GT.ZRO) GO TO 80
   79 WRITE (6,119)
      GO TO 4
   80 GW=DSQRT(GWW)
      XM=W/GW
      IF (K.EQ.1.OR.K.EQ.N) GO TO 81
```

```
      IF (IP.EQ.0.AND.RMACH.GT.XM) WRITE (6,124) K,RMACH,XM
      IF (IP.NE.0.AND.RMACH.LT.XM) WRITE (6,124) K,RMACH,XM
81    XMW=G7/GW/GWW
      XMP=XMW*WP
      XMPP=XMW*(WPP+THR*G8*W*WP*WP/GWW)
      GWP=FIV*W*W*WP*WP*G8/GWW+THR*W*WPP+WP*WP
      XMPPP=XMW*(WPPP+THR*WP*G8*GWP/GWW)
      IF (MQ.LT.0) GO TO 83
      IF (MOD(K-1,L).NE.0) GO TO 83
82    XINCH=SF*AXIS(1,K)+FRIP
      WRITE (6,97) K,AXIS(1,K),XINCH,XM,XMP,XMPP,XMPPP,W,WP,WPP,WPPP
      IF (MOD(K+L-1,10*L).EQ.0) WRITE (6,115)
83    AXIS(3,K)=XM
      AXIS(2,K)=ZRO
      AXIS(5,K)=IE*HALF*(XM-ONE/XM)*WP/W
      XBET=DSQRT(XM**2-ONE)
84    AXIS(4,K)=G2*DATAN(G4*XBET)-DATAN(XBET)
      IF (IQ.EQ.0.AND.IP.EQ.0.AND.M.LE.0) GO TO 50
      IF (M) 87,4,85
85    IF (IP.NE.0) RETURN
      DO 86 K=1,N
      DO 86 J=1,5
86    TAXI(J,K)=AXIS(J,K)
      RETURN
87    LV=-1
      RETURN
88    WRITE (6,114)
      GO TO 4
89    WRITE (6,112)
      GO TO 4
90    WRITE (6,121) NOCON
      GO TO 4
91    STOP
C
92    FORMAT (16I5)
93    FORMAT (8E10.0)
94    FORMAT (1H0,9X,3HC1=F11.7,3X,3HC2=F12.8,3X,3HC3=1PE15.7,3X,3HC4=,
     1E15.7,3X,3HC5=,E15.7,3X,3HC6=,E15.7)
95    FORMAT (1H0,9X,4HXOI=F12.8,3X,3HXI=F12.8,3X,3HXO=F12.8,3X,3HYO=F12
     1.8,3X,4HXIE=F12.8,3X,3HXE=F12.8,I5,11H ITERATIONS/)
96    FORMAT (1H ,4X,26HCURVE FROM MACH 1,    XIE=F12.8,6H   C2=F12.8,6H
     1   C3=1PE15.7,6H   C4=E15.7,6H   X1=0PF12.8 /)
97    FORMAT (1H ,I3,2F10.5,F10.6,1P3E14.6,0PF10.6,1P3E14.6 )
98    FORMAT (1H0,9X,3HWE=F12.8,4X,4HWEP=F12.8,4X,5HWEPP=,1PE15.7,4X,6HW
     1EPPP=,E15.7,4X,6HWRPPP=,E15.7)
99    FORMAT (1H ,4X,31HNO. OF POINTS ON 1ST CHAR. (M)=I3,5X,26HNO. OF P
     1OINTS ON AXIS (N)=I3,5X,9HEPSI/ETA=F8.5,4X,6HBMACH=F9.5,4X,6HCMACH
     2=F9.5//5X,6HGAMMA=F7.4,5X,22HINFLECTION ANG. (ETA)=F8.4,2X,7HDEGRE
     3ES,5X,19HRAD. OF CURV. (RC)=F11.6,5X,18HSCALE FACTOR (SF)=F13.8)
100   FORMAT (1H ,4X,31HNO. OF POINTS ON 1ST CHAR. (M)=I3,5X,26HNO. OF P
     1OINTS ON AXIS (N)=I3,5X,33HNO. OF POINTS ON LAST CHAR. (NP)=I3//5X
     2,6HGAMMA=F7.4,5X,22HINFLECTION ANG. (ETA)=F8.4,2X,7HDEGREES,5X,19H
     3RAD. OF CURV. (RC)=F13.8,5X,18HSCALE FACTOR (SF)=F11.6)
101   FORMAT (1H0,9X,3HWI=F12.8,4X,4HWIP=F12.8,4X,5HWIPP=,1PE15.7,4X,6HW
     1IPPP=,E15.7,4X,6HWOPPP=,E15.7)
102   FORMAT (1H0,4X,3HY*=F10.8,4X,6HRMASS=F10.8,4X,4HWWO=F10.7,4X,5HWWO
```

```
     1P=,F11.8,4X,6HEMACH=,F8.5,4X,6HFMACH=F10.7,4X,A4,2HH=F9.5)
 103  FORMAT (1H ,1X,A4/6H POINT,4X,1HX,7X,5HX(IN),3X,8HMACH NO.,4X,5HDM
     1/DX,8X,7HD2M/DX2,7X,7HD3M/DX3,7X,6HW=Q/A*,5X,5HDW/DX,8X,7HD2W/DX2,
     27X,7HD3W/DX3/)
 104  FORMAT (1H0,//)
 105  FORMAT (1H1)
 106  FORMAT (1H1,3A4,16H THROAT CONTOUR,,A4,49H-DEG AXIAL VELOCITY DIST
     1RIBUTION FROM SONIC POINT/)
 107  FORMAT (1H1,3A4,18H INVISCID CONTOUR,,A4,A4,68H AXIAL MACH NUMBER
     1DISTRIBUTION FROM THROAT CHARACTERISTIC WHICH HAS,I4,7H POINTS /)
 108  FORMAT (1H ,3A4,20H DOWNSTREAM CONTOUR,,A4,35H-DEG AXIAL MACH NUMB
     1ER DISTRIBUTION/)
 109  FORMAT (1H ,3A4,20H DOWNSTREAM CONTOUR,,A4,32H-DEG AXIAL VELOCITY
     1DISTRIBUTION/)
 110  FORMAT (1H1,3A4,16H THROAT CONTOUR,,A4,69H-DEG AXIAL VELOCITY DIST
     1RIBUTION FROM THROAT CHARACTERISTIC WHICH HAS,I4,7H POINTS /)
 111  FORMAT (1H ,3A4,19H DOWNSTREAM CONTOUR/)
 112  FORMAT (1H0,38HSOLUTION TO CUBIC EQUATION IS NEGATIVE)
 113  FORMAT (1H0,35HRC IS TOO LARGE TO ALLOW A SOLUTION)
 114  FORMAT (1H0,38HBMACH IS TOO SMALL TO ALLOW A SOLUTION)
 115  FORMAT (1H )
 116  FORMAT (1H0,9X,3HWB=F12.8,4X,4HWBP=F12.8,4X,5HWBPP=,1PE15.7,4X,6HW
     1BPPP=,E15.7,5X,5HWSPP=,E15.7//10X,3HWC=0PF12.8,4X,4HWCP=F12.8,4X,
     25HWCPP=,1PE15.7,4X,6HWCPPP=,E15.7,4X,6HWSPPP=,E15.7 )
 117  FORMAT (1H0,9X,6HBMACH=F9.5,4X,4HBMP=F12.8,4X,5HBMPP=,1PE15.7,4X,
     16HBMPPP=,E15.7,5X,5HSMPP=,E15.7//10X,6HCMACH=0PF9.5,4X,4HCMP=,F12.
     28,4X,5HCMPP=,1PE15.7,4X,6HCMPPP=,E15.7,4X,6HSMPPP=,E15.7)
 118  FORMAT (1H0,9X,6HAMACH=F11.7,4X,3HXA=,F11.7,4X,3HXB=,F11.7,4X,
     14HXBC=,F11.7,4X,3HXC=,F12.7,4X,3HXD=,F12.7/)
 119  FORMAT (1H0,47HVELOCITY GREATER THAN THEORETICAL MAXIMUM VALUE)
 120  FORMAT (1H ,9X,7HXA(IN)=,F11.7,9H, YA(IN)=,F11.7,9H, XB(IN)=,F12.7
     1,9H, XC(IN)=,F12.7,9H, XD(IN)=,F12.7,9H, YD(IN)=,F11.7 /)
 121  FORMAT (1H1,'NO CONVERGENCE IN',I4,' ITERATIONS' )
 122  FORMAT (1H1,3A4,18H INVISCID CONTOUR,,A4,A4,48H AXIAL MACH NUMBER
     1DISTRIBUTION FROM SONIC POINT /)
 123  FORMAT (1H0,9X,3HWI=F12.8,4X,4HWIP=F12.8,4X,5HWIPP=1PE15.7,4X,3HMI
     1=0PF12.8,4X,4HMIP=F12.8,4X,5HMIPP=1PE15.7 )
 124  FORMAT (1H ,I3,8H  RMACH=,2F12.8 )
 125  FORMAT (1H ,9X,4HMACH,F11.8,3H AT,F11.7,17H IN.,   MACH 1 AT,F11.7
     1,12H IN.,   MACH,F11.8,3H AT,F11.7,4H IN. /)
      END
      SUBROUTINE BOUND
C
C     TO OBTAIN THE CORRECTION DUE TO THE TURBULENT BOUNDARY LAYER
C
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /GG/ GAM,GM,G1,G2,G3,G4,G5,G6,G7,G8,G9,GA,RGA,QT
      COMMON /CORR/ DLA(200),RCO(200),DAX(200),DRX(200),SL(200),DR2
      COMMON /COORD/ S(200),FS(200),WALTAN(200),SD(200),WMN(200),TTR(200
     1),DMDX(200),SPR(200),BTA(200),SREF(200),XBIN,XCIN,GMA,GMB,GMC,GMD
      COMMON /PROP/ AR,ZO,RO,VISC,VISM,SFOA,SBL,CONV
      COMMON /PARAM/ ETAD,RC,AMACH,BMACH,CMACH,EMACH,GMACH,FRC,SF,WWO,WW
     1OP,QM,WE,CBET,XE,ETA,EPSI,BPSI,XO,YO,RRC,SDO,XB,XC,AH,PP,SE,TYE,XA
      COMMON /HTTR/ HAIR,TAW,TWQ,TW,TWAT,QFUN,QFUNW,IPQ,IJ,IV,IW
      COMMON /CONTR/ ITLE(3),IE,LR,IT,JB,JQ,JX,KAT,KBL,KING,KO,LV,NOCON,
     1IN,MC,MCP
```

```
      DIMENSION Z(16), D(16), SCV(200), SK(200), COS(200), RW(200)      BOU
      DATA ZRO/0.0D+0/,ONE/1.D+0/,TWO/2.D+0/,SIX/6.D+0/,HALF/5.D-1/     BOU
      DATA THR/3.D+0/,FOUR/4.D+0/,TEN/1.D+1/,TLV/1.2D+1/                BOU
      DATA CF1/3.865D-2/,CF2/4.561D+0/,CF3/5.46D-1/,FSI/3.1789797D+0/   BOU
      DATA LY/4H   Y/,LS/4H   S/,DD/8HD2Y/DX2 /,DK/8H CURV.  /          BOU
      DATA Z(1)/.0529953250D-1/,Z(4)/.1222977958D+0/,Z(7)/.3591982246D+0/BOU
      DATA Z(2)/.2771248850D-1/,Z(5)/.1910618778D+0/,Z(8)/.4524937451D+0/BOU
      DATA Z(3)/.6718439880D-1/,Z(6)/.2709916112D+0/                    BOU
      DATA D(1)/.1357622970D-1/,D(2)/.3112676200-1/,D(3)/.4757925580D-1/ BOU
      DATA D(4)/.6231448560D-1/,D(5)/.7479799440D-1/,D(6)/.8457825970D-1/ BOU
      DATA D(7)/.9130170750D-1/,D(8)/.9472530520D-1/                    BOU
      DO 1 J=9,16                                                       BOU
      D(J)=D(17-J)                                                      BOU
    1 Z(J)=ONE-Z(17-J)                                                  BOU
      DO 2 J=1,KAT                                                      BOU
    2 SREF(J)=S(J)                                                      BOU
      SBIN=XBIN                                                         BOU
      SCIN=XCIN                                                         BOU
      TRPI=CONV/90.D+0                                                  BOU
      FCC=2.05D+0+DLOG(.41D+0)                                          BOU
      CHAIR=GAM*G1*AR/RO/RO/777.64885D+0                                BOU
      IF (IT.EQ.0) XBL=SBL                                              BOU
C                                                                       BOU
    3 READ (5,66,END=65) PPQ,TO,TWT,TWAT,QFUN,ALPH,IHT,IR,LO,LV         BOU
C                                                                       BOU
      PPS=PPQ                                                           BOU
      RHO=144.D+0*PPS/ZO/AR/TO                                          BOU
      ID=IABS(LD)                                                       BOU
      KOR=KO                                                            BOU
      IF (IABS(IN).EQ.10) KOR=1                                         BOU
      IF (MCP.LT.0) KOR=KING                                            BOU
      ROY=ONE                                                           BOU
      IF (IE.EQ.0) HW=AH                                                BOU
      IF ((ID.EQ.0).OR.(IE.EQ.1)) HW=ZRO                                BOU
      IF (HW.EQ.ZRO) YOH=ZRO                                            BOU
      IF (HW.EQ.ZRO) YOHA=ZRO                                           BOU
      ALF=DABS(ALPH)                                                    BOU
      ARC=FRC                                                           BOU
      IF (IHT.LT.0) ARC=FRC**(IE+1)                                     BOU
      IPQ=0                                                             BOU
      IW=1                                                              BOU
      IF (LV.NE.0) IW=IABS(LV)                                          BOU
      DO 4 J=1,KAT                                                      BOU
      S(J)=SREF(J)                                                      BOU
      SL(J)=S(J)                                                        BOU
      RW(J)=FS(J)                                                       BOU
      RCO(J)=FS(J)                                                      BOU
      SCW=DSQRT(ONE+WALTAN(J)**2)                                       BOU
      SK(J)=SD(J)/SCW**3                                                BOU
      IF (KAT.EQ.KING) GO TO 4                                          BOU
      IF (S(J).LT.SBL) KBL=J+2                                          BOU
    4 DRX(J)=WALTAN(J)                                                  BOU
      IF (KBL.GT.KAT) KBL=KAT+4                                         BOU
      DO 58 IV=1,IW                                                     BOU
      IF ((IV.GT.1).AND.(IV.LT.IW)) GO TO 15                            BOU
      IF (LD.GE.0) WRITE (6,80) ITLE,PPS,TO                             BOU
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```
5       IF (ALPH.GT.ZRO) GO TO 6
        ALPHA=ZRO
        IF (LD.GE.0.OR.PPQ.EQ.ZRO) WRITE (6,71)
        GO TO 7
6       ALPHA=ALPH
        IF (LD.GE.0.OR.PPQ.EQ.ZRO) WRITE (6,70)
7       IF (IR.EQ.2) GO TO 13
        IF (ALF.EQ.ONE) GO TO 8
        IF (LD.GE.0.OR.PPQ.EQ.ZRO) WRITE (6,75)
        GO TO 9
8       IF (LD.GE.0.OR.PPQ.EQ.ZRO) WRITE (6,72)
9       IF (IR) 10,11,12
10      IF (LD.GE.0.OR.PPQ.EQ.ZRO) WRITE (6,74)
        GO TO 14
11      IF (LD.GE.0.OR.PPQ.EQ.ZRO) WRITE (6,73)
        GO TO 14
12      IF (LD.GE.0.OR.PPQ.EQ.ZRO) WRITE (6,76)
        GO TO 14
13      IF (LD.GE.0.OR.PPQ.EQ.ZRO) WRITE (6,77)
14      IF (PPQ.EQ.ZRO) GO TO 60
15      CAPI=.55D+0
        IPP=0
        IJ=1
        DO 56 J=1,KAT
        BET=TTR(J)-ONE
        STR=ONE/TTR(J)
        TE=TO*STR
        RAJ=WMN(J)*(G7*STR)**GA
        IF (IHT.GE.0) RAJ=RAJ**QT
        SCW=DSQRT(ONE+DRX(J)**2)
        EMU=VISC*TE*DSQRT(TE)/(TE+VISM)
        IF (TE.LT.VISM) EMU=HALF*VISC*TE/DSQRT(VISM)
        IF (VISM.LE.ONE) EMU=VISC*TE**VISM
        TAW=TE*(ONE+RO*BET)
        RHOE=RHO*STR**G1
        VE=WMN(J)*DSQRT(GAM*AR*TE)
        REO=RHOE*VE/EMU/TLV
        IF (HW.GT.ZRO) YOH=FS(J)/HW
        IF (IE.EQ.0.AND.HW.GT.ZRO) ROY=(HW/FS(J)+ONE)*TRPI
        K=J
        IF (J.EQ.1) GO TO 19
        IF (J.GT.KOR) K=J-KOR+1
        IF (K-3) 16,17,18
16      DS=S(J)-S(J-1)
        SMD=HALF*DS
        GO TO 19
17      DT=S(J)-S(J-1)
        DST=DS+DT
        SMA=DST*(TWO-DT/DS)/SIX
        SMC=DST*(TWO-DS/DT)/SIX
        SMB=DST-SMA-SMC
        HB=H
        IF (IV.GT.1) GO TO 19
        BMA=TWO/DS/DST
        BMB=-TWO/DS/DT
        BMC=TWO/DT/DST
```

```
      GO TO 19
18    DU=S(J)-S(J-1)
      DT=S(J-1)-S(J-2)
      DS=S(J-2)-S(J-3)
      DST=DS+DT
      DSTU=DST+DU
      DTU=DT+DU
      DUT=DU-DT
      DTS=DS-DT
      DTUS=DT+TWO*(DU-DS)
      DTSU=DT+TWO*(DS-DU)
      DSTTU=TWO*(DST+DTU)
      HA=HB
      HB=H
      QMA=HALF*DS*(ONE-DS*(THR*(DTU+DU)/DST)/DSTU/SIX)
      QMB=HALF*DS*(ONE+DS*(TWO*(DST+DT)/DTU)/DT/SIX)
      QMC=-DS**3*(ONE+(DTU+DU)/DST)/DT/DU/TLV
      QMD=DS**3*(DST+DT)/DU/DTU/DSTU/TLV
      SMA=HALF*DS+(DUT*DTU**3/DS-DS*DS*(DS+DSTTU))/DST/DSTU/TLV
      SMB=HALF*DST+(DS*DS*(DSTTU-DS)/DT+DT*DT*DTUS/DS-DU**3*(DSTU+DST)/D
     1S/DT)/DTU/TLV
      SMC=HALF*DTU+(DT*DT*DTSU/DU+DU*DU*(DSTTU-DU)/DT-DS**3*(DSTU+DTU)/D
     1T/DU)/DST/TLV
      SMD=HALF*DU+(DTS*DST**3/DU-DU*DU*(DU+DSTTU))/DTU/DSTU/TLV
19    IF (TWT.NE.ZRO) GO TO 20
      TW=TAW
      GO TO 21
20    TWD=(ARC*RAJ-ONE)*(TWT-TWAT)/(ARC-ONE)
      IF (TWD.LT.ZRO) TWD=ZRO
      TW=TWD+TWAT
21    WMU=VISC*TW*DSQRT(TW)/(TW+VISM)
      IF (VISM.LE.ONE) WMU=VISC*TW**VISM
      DL=TW/TE
      DM=ALPHA*(TAW-TW)/TE
      DN=ONE-DL-DM
      DA=ALF*(TAW-TW)
      DB=DA+TW-TE
      IF (DB) 22,23,24
22    DG=DSQRT(-DB*TE)
      DH=DSQRT(-DB*TW)
      DI=(TWO*(DG+TE-TW)-DA)/(TWO*DH+DA)
      DJ=DLOG(DI)
      TP=-DB/DJ/DJ
      GO TO 25
23    TP=(DSQRT(TE)+DSQRT(TW))**2/FOUR
      GO TO 25
24    DC=DSQRT(DA*DA+FOUR*TW*DB)
      DF=DARSIN((DB+TW-TE)/DC)
      DE=DARSIN(DA/DC)
      TP=DB/(DF+DE)/(DF+DE)
25    IF (IR) 26,27,28
26    FRD=TW*EMU/WMU/TP
      GO TO 29
27    FRD=EMU/WMU
      GO TO 29
28    FRD=TE*EMU/WMU/DSQRT(TP*TW)
```

```
29    IF (IPP.GT.0) GO TO 31
      RTHI=1.D-2*REO*FS(1)
      RTII=RTHI
      RDLI=TEN*RTHI
      IF (IR.EQ.1) GO TO 32
30    RTHG=DLOG10(RTHI)
      CFI=CF1/(RTHG+CF2)/(RTHG-CF3)
31    IF (IR.NE.2) GO TO 33
      SCFI=DSQRT(CFI)
      TC=TW+17.2D+0*SCFI*DA-305.D+0*CFI*DB
      CMU=VISC*TC*DSQRT(TC)/(TC+VISM)
      IF (VISM.LE.ONE) CMU=VISC*TC**VISM
      TP=TW*CMU/WMU
      FRD=EMU/CMU
      GO TO 33
32    RDLG=DLOG10(RDLI)
      CFI=0.0444D+0/(RDLG+4.6221D+0)/(RDLG-1.4402D+0)
33    CF=CFI*TE/TP
      CFS=CF*SCW
      RTIG=DLOG10(RTII)
      XCF=.41D+0*DSQRT((RTIG+CF2)*(RTIG-CF3)/CF1)
34    C3=TWO+CAPI*(FSI+1.5D+0*CAPI)
      C2=ONE+CAPI
      C1=C2-C3/XCF
      FXCF=XCF+DLOG(C1/RTII)-FCC-TWO*CAPI
      FPCP=(XCF-FSI-THR*CAPI)/XCF/C1-TWO
      CAPI=CAPI-FXCF/FPCP
      IF (DABS(FXCF).GT.1.D-8) GO TO 34
      DOTI=XCF/C1
      XN=HALF*(DOTI+DSQRT(DOTI*(DOTI-SIX)+ONE)-THR)
      HI=ONE+TWO/XN
      SUMA=ZRO
      SUMB=ZRO
      SUMC=ZRO
      SUMD=ZRO
      DO 35 L=1,16
      UN=Z(L)**XN
      TR=DL+Z(L)*(DM+Z(L)*DN)
      ADD=D(L)*XN*UN/TR
      BDD=ADD*Z(L)
      CDD=ADD*UN
      DDD=BDD*UN
      SUMA=SUMA+ADD
      SUMB=SUMB+BDD
      SUMC=SUMC+CDD
35    SUMD=SUMD+DDD
      DOT=ONE/(SUMA-SUMB)
      DSOD=ONE-SUMA
      DSM=HALF-SUMC
      THM=SUMC-SUMD
      HU=DSOD*DOT
      IF (IPP.GT.0) GO TO 36
      H=HU
      DOTR=DOT
36    FMY=(H+TWO-G9*BET)*DMDX(J)*STR/WMN(J)+ID*DRX(J)/(RW(J)+HW)
      IF (J.EQ.1) TH=CFS/FMY
```

```
      IF (K.EQ.2) TH=(THA+SMD*(DTHA+CFS))/(ONE+SMD*FMY)
      IF (K.EQ.3) TH=(THA+SMA*DTHA+SMB*DTHB+SMC*CFS)/(ONE+SMC*FMY)
      IF (K.GT.3) TH=(THA+SMA*DTHA+SMB*DTHB+SMC*DTHC+SMD*CFS)/(ONE+SMD*F
     1MY)
      DELST=H*TH
      ASEC=DELST+DSQRT(ID*DELST**2+(FS(J)*SCW*ROY)**2)
      DOR=ID*DOTR*TH/ASEC
      DSROD=DSOD-DOR*DSM
      IPP=1
      DOTR=ONE/(ONE/DOT-THM*DOR)
      HR=DSROD*DOTR
      IF (DABS(H-HR).LT.5.D-7) GO TO 37
      H=HR
      GO TO 36
   37 DELTA=DOTR*TH
      THU=DELTA/DOT
      DSU=DELTA*DSOD
      RDEL=REO*DELTA
      RTII=RDEL/DOTI
      RDLX=FRD*RDEL
      RTHX=RDLX/DOT
      IF (RTHX.LT.100.D+0) GO TO 38
      IF (IR.EQ.1) GO TO 39
      IF (DABS(ONE-RTHX/RTHI).LT.1.D-6) GO TO 41
      RTHI=RTHX
      GO TO 30
   38 WRITE (6,88) RTHX,REO,FRD,TH,DELTA,DOT
      RETURN
   39 IF (DABS(ONE-RDLX/RDLI).LT.1.D-6) GO TO 40
      RDLI=RDLX
      GO TO 32
   40 RTHG=HALF*(DSQRT((CF2+CF3)**2+FOUR*CF1/CF1)-CF2+CF3)
      RTHX=TEN**RTHG
   41 IF (J.GT.1) GO TO 42
      DTH=ZRO
      HAIR=RHOE*VE*CF*CHAIR
      TAIR=HAIR
      IF (TWAT.EQ.TWT.OR.QFUN.EQ.ZRO) GO TO 46
      TWQ=(HAIR*TAW+QFUN*(TWAT-15.D+0))/(HAIR+QFUN)
      CALL HEAT
      IF (IPQ.GT.100) GO TO 65
      IF (DABS(TW-TWQ).LT.1.D-2.AND.DABS(QFUN-QFUNW).LT.1.D-5) GO TO 46
      TWT=TWAT+(TWQ-TWAT)*(ARC-ONE)/(ARC*RAJ-ONE)
      QFUN=QFUNW
      GO TO 20
   42 DTH=CFS-TH*FMY
      IF (DTH.LT.ZRO) DTH=ZRO
      IF (J.EQ.KOR) GO TO 46
      IF (K-3) 43,45,44
   43 DTHB=DTH
      GO TO 47
   44 THA=THA+QMA*DTHA+QMB*DTHB+QMC*DTHC+QMD*DTH
      DTHA=DTHB
      DTHB=DTHC
      IF (K.GT.5) GO TO 45
      SCU=DSQRT(ONE+DRX(J-2)**2)
```

```
      DELA=HA*THA
      IF ((IE.EQ.1).OR.(ID.EQ.0)) YSEC=FS(J-2)*SCU
      IF (IE.EQ.0.AND.HW.GT.ZRO) YSEC=SCU*(FS(J-2)+HW)*TRPI
      IF (HW.GT.ZRO) YOHA=FS(J-2)/HW
      ASCA=DELA+DSQRT(ID*DELA**2+YSEC**2)
      RW(J-2)=ASCA/SCU
      DLA(J-2)=SCU*(ASCA-YSEC)*(ONE+YOHA)
      RCO(J-2)=FS(J-2)+DLA(J-2)
   45 DTHC=DTH
      GO TO 47
   46 THA=TH
      DTHA=DTH
      IF ((IV.GT.1).AND.(IV.LT.IW)) GO TO 47
      IF (J.EQ.1.AND.LD.GE.0) WRITE (6,82)
   47 CDS(J)=ASEC-SCW*FS(J)*ROY
      DLA(J)=SCW*CDS(J)*(ONE+YOH)
      RCO(J)=FS(J)+DLA(J)
      RW(J)=ASEC/SCW
      IF (IV.LT.IW) GO TO 48
      BTA(J)=-DMDX(J)*DSU/WMN(J)/TTR(J)/SCW/CFI
      IF (J.EQ.1.OR.J.GT.KO.OR.IHT.EQ.0) GO TO 48
      IF (MOD(J,IHT).NE.1) GO TO 48
      IJ=J
      HAIR=RHOE*VE*CF*CHAIR
      CALL HEAT
   48 IF (LD.LT.0) GO TO 56
      IF ((IV.GT.1).AND.(IV.LT.IW)) GO TO 56
      CFIK=2000.D+0*CFI
      CFK=2000.D+0*CF
      CFSK=2000.D+0*CFS
      DTHK=1000.D+0*DTH
      CTH=TWO*TH/(ONE+DSQRT(ONE-TWO*TH*ID/ASEC))
      CH=CDS(J)/CTH
      IEO=REO+HALF
      ITHX=RTHX+HALF
      WRITE (6,83) J,TW,TE,TAW,TP,IEO,ITHX,FRD,CFIK,CFK,CFSK,H,HI,FMY,DT
     1HK,TH,DELTA,DELST
      IF (J.LT.KBL-3) GO TO 54
      IF (J-KBL+2) 49,50,51
   49 CTHA=CTH
      XNA=XN
      DLTA=DELTA
      REOA=REO
      GO TO 55
   50 CTHB=CTH
      XNB=XN
      DLTB=DELTA
      REOB=REO
      GO TO 55
   51 IF (J-KBL) 52,53,54
   52 CTHC=CTH
      XNC=XN
      DLTC=DELTA
      REOC=REO
      GO TO 55
   53 IF (IT.GT.0) GO TO 55
```

```
      DLST=GMA*CDS(J-3)+GMB*CDS(J-2)+GMC*CDS(J-1)+GMD*CDS(J)
      THBL=GMA*CTHA+GMB*CTHB+GMC*CTHC+GMD*CTH
      HBL=DLST/THBL
      DLTBL=GMA*DLTA+GMB*DLTB+GMC*DLTC+GMD*DELTA
      REOBL=GMA*REOA+GMB*REOB+GMC*REOC+GMD*REO
      REOFT=TLV*REOBL
      RETH=THBL*REOBL
      REDL=DLTBL*REOBL
      RETHG=DLOG10(RETH)
      REDLG=DLOG10(REDL)
      XNBL=GMA*XNA+GMB*XNB+GMC*XNC+GMD*XN
      GO TO 55
   54 IF ((J.GT.3).AND.(MOD(J,10).NE.0)) GO TO 56
   55 WRITE (6,86) S(J),DSU,THU,CTH,HU,H,CH,XN
   56 CONTINUE
      RW(1)=RCO(1)
      CALL SCOND (S,DLA,DAX,KAT)
      DO 57 J=1,KAT
   57 DRX(J)=WALTAN(J)+DAX(J)
      IF ((IT.GT.0).OR.(LD.LT.0)) GO TO 58
      IF ((IV.GT.1).AND.(IV.LT.IW)) GO TO 58
      IF (KBL.LE.KAT) WRITE (6,85) XBL,DLST,THBL,HBL,XNBL,DLTBL,REOFT,RE
     1TH,RETHG,REDL,REDLG
      IF (KBL.LE.KAT) GO TO 58
      HBL=CDS(KAT)/CTH
      REOFT=TLV*REO
      RETH=CTH*REO
      REDL=DELTA*REO
      RETHG=DLOG10(RETH)
      REDLG=DLOG10(REDL)
      IF (KBL.GT.KAT) WRITE (6,85) S(KAT),CDS(KAT),CTH,HBL,XN,DELTA,REOF
     1T,RETH,RETHG,REDL,REDLG
   58 CONTINUE
      DD2=BMA*DLA(1)+BMB*DLA(2)+BMC*DLA(3)
      DR2=SD(1)+DD2
      DXS=DAX(1)/DR2
      XST=S(1)-DXS
      YST=RCO(1)-HALF*DAX(1)**2/DR2
      SCW=DSQRT(ONE+DAX(1)**2)
      DR2=DR2/SCW**3
      RCV=ONE/DR2/YST
      IF (IT.GT.0) XBIN=SBIN-XST
      IF (IT.GT.0) XCIN=SCIN-XST
      WRITE (6,78) ITLE,XBIN,XCIN,SF
      PPQ=ZRO
      WRITE (6,67) RC,ETAD,AMACH,BMACH,CMACH,EMACH,MC,AH
      IF (TWT.NE.ZRO) GO TO 59
      WRITE (6,81) PPS,TO
      GO TO 5
   59 WRITE (6,79) PPS,TO,TWT,TWAT,TAIR
      GO TO 5
   60 IF (IT.EQ.0) GO TO 63
      DO 61 K=1,KAT
      S(K)=SREF(K)-XST
   61 SCV(K)=DSQRT(ONE+DRX(K)**2)
      SCV(1)=ONE
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```
      SL(1)=ZRO
      IM=(KAT-1)/2
      DO 62 I=1,IM
      J=2*I
      SS=S(J)-S(J-1)
      IF (I.EQ.1) SS=S(2)
      TT=S(J+1)-S(J)
      ST=SS+TT
      S1=(TWO-TT/SS)*ST/SIX
      S3=(TWO-SS/TT)*ST/SIX
      S2=ST-S1-S3
      SA=(TWO+TT/ST)*SS/SIX
      SB=(TWO+ST/TT)*SS/SIX
      SC=SS-SA-SB
      SL(J)=SL(J-1)+SA*SCV(J-1)+SB*SCV(J)+SC*SCV(J+1)
   62 SL(J+1)=SL(J-1)+S1*SCV(J-1)+S2*SCV(J)+S3*SCV(J+1)
      XST=ZRO
      WRITE (6,68) LS,DK
      WRITE (6,69) (K,S(K),SL(K),DLA(K),RCO(K),WALTAN(K),SK(K),DAX(K),DR
     1X(K),WMN(K),DMDX(K),SPR(K),BTA(K),K=1,KAT)
      IF (KBL.GT.KAT) GO TO 64
      CALL TWIXT (SL,GMA,GMB,GMC,GMD,SBL,KAT,KBL)
      XBL=GMA*S(KBL-3)+GMB*S(KBL-2)+GMC*S(KBL-1)+GMD*S(KBL)
      DLAB=GMA*DLA(KBL-3)+GMB*DLA(KBL-2)+GMC*DLA(KBL-1)+GMD*DLA(KBL)
      RCOB=GMA*RCO(KBL-3)+GMB*RCO(KBL-2)+GMC*RCO(KBL-1)+GMD*RCO(KBL)
      WRITE (6,89) XBL,SBL,DLAB,RCOB,GMA,GMB,GMC,GMD
      GO TO 64
   63 WRITE (6,68) LY,DD
      WRITE (6,69) (K,S(K),FS(K),DLA(K),RCO(K),WALTAN(K),SD(K),DAX(K),DR
     1X(K),WMN(K),DMDX(K),SPR(K),BTA(K),K=1,KAT)
      IF (KBL.GT.KAT) GO TO 64
      CALL TWIXT (S,GMA,GMB,GMC,GMD,XBL,KAT,KBL)
      DLAB=GMA*DLA(KBL-3)+GMB*DLA(KBL-2)+GMC*DLA(KBL-1)+GMD*DLA(KBL)
      RCOB=GMA*RCO(KBL-3)+GMB*RCO(KBL-2)+GMC*RCO(KBL-1)+GMD*RCO(KBL)
      YBL=RCOB-DLAB
      WRITE (6,84) XBL,YBL,DLAB,RCOB,GMA,GMB,GMC,GMD
   64 WRITE (6,87) XST,YST,DD2,DR2,RCV
      S(1)=XST
      RCO(1)=YST
      DRX(1)=ZRO
      IF (SBL.EQ.1.D+3) RETURN
      IF (LV.GT.0) GO TO 3
   65 CONTINUE
      IF (J.EQ.1) WRITE (6,90) IPQ,QFUNW,TWT
      RETURN
C
   66 FORMAT (6E10.0,4I5)
   67 FORMAT (1H ,4H RC=,F11.6,3X,5HETAD=F8.4,4H DEG,3X,6HAMACH=F10.7,3X
     1,6HBMACH=F10.7,3X,6HCMACH=F10.7,3X,6HEMACH=F10.7,3X,A4,2HH=F11.7/)
   68 FORMAT (1H ,7X,9HSTA(IN)  ,A4,40H(IN)     DELR(IN)      R(IN)     DY
     1/DX     ,A8,50H    DA/DX      DR/DX     MACH NO.     DM/DX      PE/PO,7
     2X,4HBETA /)
   69 FORMAT (10(I4,0P2F11.6,2F11.7,4F10.7,F11.7,F10.7,1P2E12.4/))
   70 FORMAT (1H+,5X,34HQUADRATIC TEMPERATURE DISTRIBUTION)
   71 FORMAT (1H+,5X,34HPARABOLIC TEMPERATURE DISTRIBUTION)
   72 FORMAT (1H+,44X,34HSPALDING-CHI REFERENCE TEMPERATURE)
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73    FORMAT (1H+,83X,36HVAN DRIEST REFERENCE REYNOLDS NUMBER /)
74    FORMAT (1H+,83X,35HCOLES LAW REFERENCE REYNOLDS NUMBER /)
75    FORMAT (1H+,44X,34HMODIF. SPALDING-CHI REFERENCE TEMP)
76    FORMAT (1H+,83X,40HREFERENCE REYNOLDS NUMBER BASED ON DELTA /)
77    FORMAT (1H+,44X,29HMODIFIED COLES TRANSFORMATION /)
78    FORMAT (1H1,3A4,39HNOZZLE CONTOUR, RADIAL FLOW ENDS AT STA,F12.7,2
     15H, TEST CONE BEGINS AT STA,F1 .7,16H, SCALE FACTOR =,F13.8/)
79    FORMAT (1H ,1X,15HSTAG. PRESSURE=F5.0,24H PSI, STAG. TEMPERATURE=,
     1F5.0,21H DEG R, THROAT TEMP.=F5.0,19H DEG R, WALL TEMP.=F4.0,24H D
     2EG R, THROAT HT COEF.=F8.5//)
80    FORMAT (1H1,3A4,49HBOUNDARY LAYER CALCULATIONS, STAGNATION PRESSUR
     1E=F5.0,28HPSI, STAGNATION TEMPERATURE=,F5.0,27H DEG R, N BASED ON
     2RE,DELTA //)
81    FORMAT (1H ,5X,15HSTAG. PRESSURE=F5.0,24H PSI  STAG. TEMPERATURE=,
     1F5.0,34H DEG R  ADIABATIC WALL TEMPERATURE//)
82    FORMAT  (1H ,5X,38HTW     TE     TAW     TP      RE/IN   RTHI,
     14X,3HFRD,5X,4HKCFI,4X,3HKCF,5X,4HKCFS,5X,1HH,6X,2HHI,5X,38HFMY
     2 KTHP  THETA-1  DELTA  DELTA*-1 /)
83    FORMAT (1H ,I3,2F6.1,F7.1,F6.1,I9,I7,4F8.5,F8.4,F7.4,2F8.5,F9.6 ,
     1F7.4,F9.6  )
84    FORMAT (1H ,3HSTA,2F11.6,2F11.7,7X,27HINTERPOLATION COEFFICIENTS,,
     1  F12.8,1H,,F11.8,1H,,F11.8,1H,,F12.8/)
85    FORMAT (1H0,5H   X=,F7.3,11H,    DELTA*=,F10.7,10H,   THETA=,F9.7,6
     1H,   H=,F10.6,6H,   N=,F10.7,10H,   DELTA=,F11.7,10H,   RE/FT=,F11
     2.0//35X,9HRE,THETA=,F9.0,8H,   LOG=,F8.5,1H,,16X,9HRE,DELTA=,F11.0
     3,8H,   LOG=,F8.5)
86    FORMAT (1H ,3X,2HX=,F7.3,8H,   DSU=,F8.5,8H,   THU=,F9.7,8H,   CTH
     1=,F9.7,7H,   HU=,F10.6,6H,   H=,F10.6,7H,   CH=,F10.6,6H,   N=,F8.
     25)
87    FORMAT (1H ,3HSTA,F11.6,9H,     Y*=,F11.7,14H,     D2A/DX2=,F12.9,
     114H,     D2R/DX2=,F12.9,16H,     VISCID RC=,F14.8 )
88    FORMAT (1H ,'RTHX=',1PE12.5,', REO=',E12.5,', FRO=',0PF8.5,', TH='
     1,F8.5,', DELTA=',F8.5,', DOT=',F9.5 )
89    FORMAT (1H ,3HSTA,2F11.6,2F11.7,7X,27HINTERPOLATION COEFFICIENTS,,
     1F12.8,1H,,F11.8,1H,,F11.8,1H,,F12.8 /)
90    FORMAT (1H0,' ITERATION',I4,',    QFUN =',F8.5,',    THROAT TEMP =
     1',F6.1 / )
      END
      SUBROUTINE CONIC (XM,B)
C     TO OBTAIN MACH NUMBER DERIVATIVES IN RADIAL FLOW
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /GG/ GAM,GM,G1,G2,G3,G4,G5,G6,G7,G8,G9,GA,RGA,QT
      DATA ONE 1.D+0/,TWO/2.D+0/,THR/3.D+0/,FOUR/4.D+0/
      DIMENSION B(4)
      XMM=XM*XM
      XMM1=XMM-ONE
      XMM2=XMM1**2
      BMM=ONE+G8*XMM
      AREA=(G6+G5*XMM)**GA/XM
      B(1)=AREA**QT
      B(2)=XM*BMM/QT/XMM1/B(1)
      C2=TWO-(ONE+THR*G8)/QT
      C4=G8/QT-ONE
      CMM=XMM*(C2+XMM*C4)-ONE-ONE/QT
      B(3)=B(2)*CMM/XMM2/B(1)
      DMM=(FOUR*C4*XMM+TWO*C2)/CMM-FOUR/XMM1
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      B(4)=B(3)*(B(3)/B(2)+XM*B(2)*DMM-ONE/B(1))
      RETURN
      END
      FUNCTION CUBIC (EA,EB,EC,ED)
      IMPLICIT REAL*8(A-H,O-Z)
C     TO OBTAIN POSITIVE REAL ROOT OF CUBIC EQUATION
      DATA ZRO/0.0D+0/,ONE/1.D+0/,TWO/2.D+0/,THR/3.D+0/
      E3=EB/THR
      Q1=EA*EC/THR-E3**2
      R1=EA*(E3*EC-EA*ED)/TWO-E3**3
      QR=Q1**3+R1**2
      RQ=DSQRT(DABS(QR))
      Q=DSQRT(DABS(Q1))
      B=DSIGN(ONE,R1)
      CBB=-ONE
      CBC=-ONE
      CBT1=ZRO
      CBT2=ZRO
      A=ZRO
      IF (QR.GT.ZRO) GO TO 1
      IF (QR.NE.ZRO) A=DARSIN(-RQ/Q1/Q)/THR
      CSA=DCOS(A)
      CSNA=DSQRT(THR)*DSIN(A)
      CBA=(TWO*B*Q*CSA-E3)/EA
      CBB=-(B*Q*(CSA+CSNA)+E3)/EA
      CBC=-(B*Q*(CSA-CSNA)+E3)/EA
      GO TO 2
1     IF (R1+RQ.NE.ZRO) CBT1=DSIGN(DEXP(DLOG(DABS(R1+RQ))/THR),R1+RQ)
      IF (R1-RQ.NE.ZRO) CBT2=DSIGN(DEXP(DLOG(DABS(R1-RQ))/THR),R1-RQ)
      CBA=(CBT1+CBT2-E3)/EA
2     IA=DSIGN(ONE,CBA)
      IB=DSIGN(ONE,CBB)
      IC=DSIGN(ONE,CBC)
      IF (IA+IB+IC+1) 11,3,7
3     IF (IA.EQ.1) GO TO 5
      IF (IB.EQ.1) GO TO 6
4     CUBIC=CBC
      RETURN
5     CUBIC=CBA
      RETURN
6     CUBIC=CBB
      RETURN
7     IF (IA+2*IB+3*IC-2) 8,9,10
8     IF (CBA.GT.CBB) GO TO 6
      GO TO 5
9     IF (CBA.GT.CBC) GO TO 4
      GO TO 5
10    IF (CBB.GT.CBC) GO TO 4
      GO TO 6
11    AA=A*9.D+1/DARSIN(ONE)
      WRITE (6,12) EA,EB,EC,ED,Q1,R1,QR,RQ,Q,AA,CBA,CBB,CBC
      CUBIC=-ONE
      RETURN
C
12    FORMAT (1H0,3HEA=E14.7,5H  EB=E14.7,5H  EC=E14.7,5H  ED=E14.7,
     15H  Q1=E14.7,5H  R1=E14.7,5H  QR=E14.7/5H  RQ=E14.7,5H  Q=E14.7,
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```
     2', AA=',E14.7,',CBA=',E14.7,',CBB=',E14.7,',CBC=',E14.7 / )
      END
      FUNCTION FMV (PMA)
C     TO OBTAIN MACH NUMBER FROM PRANDTL MEYER ANGLE
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /GG/ GAM,GM,G1,G2,G3,G4,G5,G6,G7,G8,G9,GA,RGA,QT
      ONE=1.D+0
      THIRD=ONE/3.D+0
      VM=(DARSIN(ONE)*(PMA/(G2-ONE))**2)**THIRD
      Z=ONE+.895D+0*((G7*(G2-ONE))**2)**THIRD*DTAN(VM)
      DO 1 I=1,100
      ZBET=DSQRT(Z*Z-ONE)
      ANG=G2*DATAN(ZBET/G2)-DATAN(ZBET)
      REM=(ANG-PMA)*Z*(Z*Z+G9)/G9/ZBET
      IF (DABS(REM).LT.1.D-10) GO TO 2
1     Z=Z-REM
2     FMV=Z-REM
      RETURN
      END
      SUBROUTINE FVDGE (X,Y,DS,DY)
C
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION X(5), Y(5)
      DATA H/0.5D+0/,TWO/2.0D+0/
C
      X1=X(1)
      X2=X(2)
      X3=X(3)
      X4=X(4)
      X5=X(5)
C
      Y1=Y(1)
      Y2=Y(2)
      Y3=Y(3)
      Y4=Y(4)
      Y5=Y(5)
C
C     FIND DELTA-Y.
      F1=(X3-X1)*(X3-X2)
      F1=TWO/F1
C
      F2=(X4-X3)*(X3-X2)
      F2=-TWO/F2
C
      F3=(X5-X3)*(X4-X3)
      F3=TWO/F3
C
      Z13=X1+X2+X2-X4-X4-X5
      A1=(X2+X3-X4-X5)/Z13
      A3=(X1+X2-X3-X4)/Z13
C
      YP21=(Y2-Y1)/(X2-X1)
      YP32=(Y3-Y2)/(X3-X2)
      YP43=(Y4-Y3)/(X4-X3)
      YP54=(Y5-Y4)/(X5-X4)
C
```

```
      X21=H*(X2+X1)
      X32=H*(X3+X2)
      X43=H*(X4+X3)
      X54=H*(X5+X4)
C
      YPP1=(YP32-YP21)/(X32-X21)
      YPP2=(YP43-YP32)/(X43-X32)
      YPP3=(YP54-YP43)/(X54-X43)
      DS=A1*YPP1+A3*YPP3-YPP2
      FX=F2-A1*F1-A3*F3
      DY=DS/FX
C
      RETURN
      END
      SUBROUTINE HEAT
C     DUMMY TO BE MODIFIED FOR SPECIAL CALCULATIONS OF HEAT TRANSFER
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /HTTR/ HAIR,TAW,TWQ,TWT,TWAT,QFUN,QFUNW,IPQ,IJ,IV,IW
      QFUNW=QFUN
      RETURN
      END
      SUBROUTINE NEO
C
C     SMOOTH BY LINEAR SECOND DERIVATIVE
C
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /WORK/ E(400),Z(400),X(400),Y(400),YST(400),WTN(250),WALL(5
     1,200),WAX(200),WAY(200),WAN(200)
      COMMON /CONTR/ ITLE(3),IE,LR,IT,JB,JQ,JX,KAT,KBL,KING,KO,LV,NOCON,
     1IN,MC,MCP,IP,IQ,ISE,JC,M,MP,MQ,N,NP,NR,NUT,NF
      DATA ZERO/0.0D+0/,ONE/1.D+0/,TWO/ .D+0/
      DATA J0/4H  UP/,J1/4HDOWN/
C
      CONV=90.D+0/DARSIN(ONE)
      TNI=DTAN(WALL(5,1))
C
      IF (JQ.EQ.0.OR.IQ.LT.0) READ (5,14,END=13) NOUP,NPCT,NODO
C     IF (JQ.EQ.0.OR.IQ.LT.0) READ (5,14,END=13)NOUP,NPCT,NODO
      IF (JQ.GT.0) GO TO 2
      JN=J0
      LIM=NUT
      NOTM=NOUP
      DO 1 J=1,LIM
      X(J+1)=WAX(J)
      Y(J+1)=WAY(J)
    1 YST(J+1)=Y(J+1)
      X(1)=TWO*X(2)-X(3)
      Y(1)=Y(3)
      X(LIM+2)=TWO*X(LIM+1)-X(LIM)
      Y(LIM+2)=Y(LIM+1)+TNI*(X(LIM+2)-X(LIM+1))
      GO TO 4
    2 LIM=N+NP-1
      NOTM=NODO
      JN=J1
      DO 3 J=1,LIM
      X(J+1)=WALL(1,J)
```

```
      Y(J+1)=WALL(2,J)
3     YST(J+1)=Y(J+1)
      X(1)=TWO*X(2)-X(3)
      Y(1)=Y(2)-TNI*(X(2)-X(1))
      X(LIM+2)=TWO*X(LIM+1)-X(LIM)
      Y(LIM+2)=Y(LIM+1)
4     LUS=1+(LIM-3)/6
      IF (NOTM.EQ.0) RETURN
      YST(1)=Y(1)
      YST(LIM+2)=Y(LIM+2)
      SMP=1.D-2*NPCT
      WRITE (6,16) ITLE,JN,NOTM,SMP
C
      DO 8 M=1,NOTM
      CALL OREZ (E,800)
C
      DO 5 K=3,LIM
      CALL FVDGE (X(K-2),Y(K-2),E(K),Z(K))
5     CONTINUE
      E(1)=ZERO
      E(2)=ZERO
      E(LIM+1)=ZERO
      E(LIM+2)=ZERO
C     SEARCH ARRAY AND FIND MAX ERR
      DO 7 LU=1,LUS
      EMAX=ZERO
      DO 6 K=[illegible],LIM
      TEST=DABS(E(K))
      IF (EMAX.GT.TEST) GO TO 6
      J=K
      EMAX=TEST
6     CONTINUE
C     APPLY CORRECTION
      E(J)=ZERO
      E(J+1)=ZERO
      E(J+2)=ZERO
      E(J-1)=ZERO
      E(J-2)=ZERO
      Y(J)=Y(J)+SMP*Z(J)
7     CONTINUE
8     CONTINUE
C
      ERR=ZERO
      DO 9 J=1,LIM
      K=J+1
      E(K)=Y(K)-YST(K)
      IF (ERR.LT.DABS(E(K))) MAX=J
      IF (ERR.LT.DABS(E(K))) ERR=DABS(E(K))
      WRITE (6,15) J,X(K),Y(K),YST(K),E(K),J
9     IF (MOD(J,10).EQ.0) WRITE (6,17)
      WRITE (6,19) ERR,MAX
C
      LM=LIM-1
      CALL SCOND (X,Y,WTN,LIM+2)
      IF (JQ.EQ.1) GO TO 11
      DO 10 J=2,LM
```

```
      WAY(J)=Y(J+1)
10    WAN(J)=CONV*DATAN(WTN(J+1))
      RETURN
C
11    DO 12 J=2,LM
      WALL(2,J)=Y(J+1)
12    WALL(5,J)=DATAN(WTN(J+1))
      RETURN
C
13    WRITE (6,18)
      STOP
C
14    FORMAT (16I5)
15    FORMAT (1H ,20X,I5,2X,0P4F13.7,I8 )
16    FORMAT (1H1,3A4,2X,A4,24HSTREAM CONTOUR, SMOOTHED,I5,19H TIMES WIT
     1H FACTOR=,F4.2
     2//34X,1HX,11X,6HY-CALC,7X,4HY-IN,10X,4HDIFF /)
17    FORMAT (1H )
18    FORMAT (1H0,10X,34HCARD NOT AVAILABLE FOR NEGATIVE NF )
19    FORMAT (1H0,26X,21HMAX. ABSOLUTE ERROR =,1PG15.6,10H  AT POINT,I5)
      END
      SUBROUTINE OFELD (A,B,C,NOCON)
C     TO OBTAIN POINTS IN CHARACTERISTIC NETWORK
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /CONTR/ ITLE(3),IE
      DATA ZRO/0.0D+0/,ONE/1.D+0/,TWO/2.D+0/,HALF/5.D-1/
      DIMENSION A(5), B(5), C(5)
      A1=DARSIN(ONE/A(3))
      A2=DARSIN(ONE/B(3))
      T1=A(5)
      T2=B(5)
      IF (IE.EQ.0) GO TO 8
      IF (A(2).EQ.ZRO) GO TO 5
      FSY1=DSIN(A(5))/A(2)/A(3)
      GO TO 6
5     T1=ZRO
      FSY1=A(5)
6     IF (B(2).EQ.ZRO) GO TO 7
      FSY2=DSIN(B(5))/B(2)/B(3)
      GO TO 8
7     T2=ZRO
      FSY2=B(5)
8     TN1=DTAN(T1-A1)
      IF (B(3).NE.ONE) TN2=DTAN(T2+A2)
      I=-1
      HDPSI=HALF*(A(4)-B(4))
      HT3=HALF*(T1+T2)+HDPSI
      T3=HT3-HALF*IE*HDPSI
      HPSI3=HALF*(A(4)+B(4)+T1-T2)
      PSI3=HPSI3+HALF*IE*(T1-T2)
      C(3)=FMV(PSI3)
      TOLD=T3
1     I=I+1
      FM3=C(3)
      A3=DARSIN(ONE/C(3))
      TNA=HALF*(TN1+DTAN(T3-A3))
```

```
      IF (B(3).NE.ONE) TNB=HALF*(DTAN(T3+A3)+TN2)
      IF (B(3).EQ.ONE) TNB=TWO*DTAN(T3+A3)
      DTN=TNB-TNA
      X3=(B(1)*TNB-A(1)*TNA+A(2)-B(2))/DTN
      Y3=(A(2)*TNB-B(2)*TNA+(B(1)-A(1))*TNA*TNB)/DTN
      IF (IE.EQ.0.OR.DABS(Y3).LT.1.D-9) GO TO 4
      FSY3=DSIN(T3)/Y3/FM3
      P1=HALF*(FSY1+FSY3)*(X3-A(1))*DSQRT(ONE+TNA**2)
      P2=HALF*(FSY2+FSY3)*(X3-B(1))*DSQRT(ONE+TNB**2)
      T3=HT3+HALF*(P1-P2)
      PSI3=HPSI3+HALF*(P1+P2)
      C(3)=FMV(PSI3)
      IF (DABS(T3-TOLD).GT.1.D-9) GO TO 2
      IF (DABS(C(3)-FM3).LT.1.D-9) GO TO 4
    2 IF (I.EQ.40) GO TO 3
      TEMP=T3
      T3=(T3+TOLD)*HALF
      TOLD=TEMP
      GO TO 1
    3 NOCON=1
    4 C(1)=X3
      C(2)=Y3
      C(4)=PSI3
      C(5)=T3
      RETURN
      END
      SUBROUTINE OREZ (A,NA)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(1)
      DO 1 K=1,NA
    1 A(K)=0.0D+0
      RETURN
      END
      SUBROUTINE PERFC
C
C     TO OBTAIN THE INVISCID CONTOUR OF THE NOZZLE
C
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /GG/ GAM,GM,G1,G2,G3,G4,G5,G6,G7,G8,G9,GA,RGA,QT
      COMMON /CLINE/ AXIS(5,150),TAXI(5,150),WIP,X1,FRIP,ZONK,SEO,CSE
      COMMON /COORD/ S(200),FS(200),WALTAN(200),SD(200),WMN(200),TTR(200
     1),DMDX(200),SPR(200),DPX(200),SECO(200),XBIN,XCIN,GMA,GMB,GMC,GMD
      COMMON /WORK/ A(5,150),B(5,150),FINAL(5,150),WALL(5,200),WAX(200),
     1WAY(200),WAN(200)
      COMMON /PROP/ AR,ZO,RO,VISC,VISM,SFOA,XBL,CONV
      COMMON /PARAM/ ETAD,RC,AMACH,BMACH,CMACH,EMACH,GMACH,FRC,SF,WWO,WW
     1OP,QM,WE,CBET,XE,ETA,EPSI,BPSI,XO,YO,RRC,SDO,XB,XC,AH,PP,SE,TYE,XA
      COMMON /TROAT/ FC(6,51)
      COMMON /CONTR/ ITLE(3),IE,LR,IT,JB,JQ,JX,KAT,KBL,KING,KO,LV,NOCON,
     1IN,MC,MCP,IP,IQ,ISE,JC,M,MP,MQ,N,NP,NF,NUT
      DIMENSION CHAR(6,150), SU(150), WDX(200), WTAN(200), SCDF(200), YI
     1(100)
      DATA ZRO/0.0D+0/,ONE/1.D+0/,TWO/2.D+0/,SIX/6.D+0/,HALF/5.D-1/
      DATA IFR/4HFIRS/,IWL/4HWALL/,LST/4HLAST/,IBL/4H    /,THR/3.D+0/
      CALL OREZ (A,4*750+250)
      CPSI=G2*DATAN(G4*CBET)-DATAN(CBET)
```

```
      IF (JQ.GT.0) GO TO 6
      IF (LR.EQ.0) GO TO 4
C
C     THROAT CHARACTERISTIC VALUES
      SUMAX=(SE/SEO)**(IE+1)
      IF (QM.EQ.ONE) SUMAX=ONE
      LQ=ZONK*(LR-1)+1
      NL=N+LQ-1
      DO 3 J=1,LQ
      IF (QM.NE.ONE) GO TO 1
      FC(1,J)=FC(1,J)*SE+XO
      FC(2,J)=FC(2,J)*SE
    1 FINAL(1,J)=FC(1,J)
      FINAL(2,J)=FC(2,J)
      FINAL(3,J)=FC(3,J)
      FINAL(4,J)=FC(4,J)
      FINAL(5,J)=FC(5,J)
      IF (MQ.LT.0) GO TO 3
      IF (J.GT.1) GO TO 2
      WRITE (6,93) ITLE
      WRITE (6,99) IBL
    2 XMU=CONV*DARSIN(ONE/FINAL(3,J))
      PSI=CONV*FINAL(4,J)
      AN=CONV*FINAL(5,J)
      XINCH=SF*FINAL(1,J)+FRIP
      YINCH=SF*FINAL(2,J)
      WRITE (6,103) J,(FINAL(K,J),K=1,3),XMU,PSI,AN,XINCH,YINCH
      IF (MOD(J,10).EQ.0) WRITE (6,98)
    3 SU(J)=FC(6,J)/SUMAX
    4 IF (ISE.EQ.0) GO TO 8
C
C     INITIAL CHARACTERISTIC VALUES IF NON-RADIAL FLOW
      DO 5 K=1,M
      A(2,K)=(K-1)*TYE/(M-1)
      A(1,K)=A(2,K)*CBET+XE
      A(3,K)=CMACH
      A(4,K)=CPSI
    5 A(5,K)=ZRO
      GO TO 10
C
C     FINAL CHARACTERISTIC VALUES IF RADIAL FLOW
    6 NL=N+NP-1
      FN=NP-1
      DO 7 JJ=1,NP
      IF (IE.EQ.0) F=(JJ-1)/FN
      IF (IE.EQ.1) F=TWO*DSIN(HALF*ETA*(JJ-1)/FN)/SE
      FINAL(2,JJ)=F*TYE
      FINAL(1,JJ)=FINAL(2,JJ)*CBET+XC
      FINAL(3,JJ)=CMACH
      FINAL(4,JJ)=CPSI
      FINAL(5,JJ)=ZRO
    7 SU(JJ)=F**(IE+1)
C
C     INITIAL CHARACTERISTIC VALUES IF RADIAL FLOW
    8 EM=ETA/(M-1)
      DO 9 K=1,M
```

```
      T=(K-1)*EM
      IF (IP.EQ.0) XM=FMV(EPSI+T/QT)
      IF (IP.NE.0) XM=FMV(BPSI-T/QT)
      R=((G6+G5*XM**2)**GA/XM)**QT
      XBET=DSQRT(XM**2-ONE)
      A(1,K)=R*DCOS(T)
      A(2,K)=R*DSIN(T)
      A(3,K)=XM
      A(4,K)=G2*DATAN(G4*XBET)-DATAN(XBET)
9     A(5,K)=T
      IF (IE.EQ.1.AND.IP.EQ.0) A(5,1)=TAXI(5,1)
      IF (IE.EQ.1.AND.IP.NE.0) A(5,1)=AXIS(5,1)
10    DO 11 J=1,5
11    WALL(J,1)=A(J,M)
      LINE=1
      IF (MQ.LT.0) GO TO 14
      IF (ISE.EQ.1) GO TO 12
      IF (JQ.EQ.0) WRITE (6,91) ITLE
      IF (JQ.EQ.1) WRITE (6,94) ITLE
      GO TO 13
12    WRITE (6,102) ITLE
13    WRITE (6,106) LINE
14    SU(1)=ZRO
      IF (IE.EQ.0) BX=ONE/SE
      NN=1
      DO 15 K=1,M
      DO 15 J=1,5
15    B(J,K)=A(J,K)
      LAST=M-1
      GO TO 20
16    LAST=M
      LINE=2
      IF (IP.NE.0) GO TO 38
17    DO 18 J=1,5
18    B(J,1)=TAXI(J,LINE)
      DO 19 J=1,LAST
      K=J
      CALL OFELD (A(1,K),B(1,K),B(1,K+1),NOCON)
      IF (NOCON.NE.0) GO TO 83
19    CONTINUE
20    LASTP=LAST+1
      IF (LINE.LT.LASTP) LP=LINE
      NK=1+LP/52
      LA=CONV*DARSIN(ONE/B(3,NN))
      IPRNT=0
      ICHAR=0
      IF (JC.EQ.0) GO TO 21
      KC=IABS(JC)
      IF (JC.GT.0.AND.JQ.NE.0) GO TO 21
      IF (JC.LT.0.AND.JQ.EQ.0) GO TO 21
      ICHAR=1
      IF (KC.GT.100.AND.KC.LT.101+LINE) IPRNT=1
      IF (NN.EQ.1.AND.MOD(LINE-1,KC).EQ.0) IPRNT=1
      IF (NN.GT.1.AND.MOD(NN-1,KC).EQ.0) IPRNT=1
21    DO 27 J=NN,LASTP
      IF (IE.EQ.1) BX=TWO*B(2,J)/SE**2
```

```
      XM=B(3,J)
      XMUR=DARSIN(ONE/XM)
      XMU=CONV*XMUR
      PSI=B(4,J)*CONV
      AN=B(5,J)*CONV
      IF (B(2,J).EQ.ZRO) AN=ZRO
      IF (IP.EQ.0.OR.LA.GT.45) GO TO 22
      S(J)=B(1,NN)-B(1,J)
C     MASS INTEGRATION WITH RESPECT TO X
      DSX=ONE/DCOS(B(5,J)-XMUR)
      IF (B(2,J).EQ.ZRO) DSX=XM/DSQRT(XM**2-ONE)
      GO TO 23
22    S(J)=B(2,J)-B(2,NN)
C     MASS INTEGRATION WITH RESPECT TO Y
      IF (IP.EQ.0) DSX=ONE/DSIN(XMUR+B(5,J))
      IF (IP.NE.0) DSX=ONE/DSIN(XMUR-B(5,J))
      IF (B(2,J).EQ.ZRO) DSX=XM
23    IF (ICHAR.EQ.0.OR.J.NE.LINE) GO TO 24
      CHAR(1,J)=B(1,J)
      CHAR(2,J)=B(2,J)
      CHAR(3,J)=XM
      CHAR(4,J)=XMU
      CHAR(5,J)=PSI
      CHAR(6,J)=AN
24    FS(J)=DSX*BX/(G6+G5*XM**2)**GA
      IF (MQ.GE.0.AND.LINE.EQ.1) GO TO 25
      IF (IPRNT.EQ.0) GO TO 27
      IF (J.GT.NN) GO TO 25
      IF (IP.EQ.0) WRITE (6,104) ITLE
      IF (IP.NE.0) WRITE (6,105) ITLE
      WRITE (6,106) LINE
25    IF ((NK.GT.1).AND.(MOD(J,NK).EQ.0)) GO TO 26
      XINCH=SF*B(1,J)+FRIP
      YINCH=SF*B(2,J)
      WRITE (6,103) J,B(1,J),B(2,J),XM,XMU,PSI,AN,XINCH,YINCH
26    IF (MOD(J,10*NK).EQ.0) WRITE (6,98)
27    CONTINUE
C
C     INTEGRATION AND INTERPOLATION FOF MASS FLOW
      SA=ZRO
      SB=ZRO
      SC=ZRO
      SUM=SU(NN)
      KAN=(LASTP-NN)/2
      DO 28 J=1,KAN
      K=NN+2*J
      KT=K
      AS=S(K-1)-S(K-2)
      BS=S(K)-S(K-1)
      CS=AS+BS
      S1=(TWO-BS/AS)*CS/SIX
      S3=(TWO-AS/BS)*CS/SIX
      S2=CS-S1-S3
      ADD=S1*FS(K-2)+S2*FS(K-1)+S3*FS(K)
      SUM=ADD+SUM
      IF (LINE.EQ.1) GO TO 28
```

```
      DEL=ONE-SUM
      IF (DEL) 30,29,28
28    CONTINUE
      IF (LINE.EQ.1) WRITE (6,96) SUM
      IF (LINE.EQ.1) GO TO 16
      BS=S(K+1)-S(K)
      KT=K+1
      DN=TWO*DEL/BS
      SC=DN/(FS(K)+DSQRT(FS(K)**2+(FS(KT)-FS(K))*DN))
      SB=ONE-SC
      GO TO 34
29    SC=ONE
      GO TO 34
30    S2=BS*(TWO+CS/AS)/SIX
      S3=BS*(TWO+AS/CS)/SIX
      S1=BS-S2-S3
      BDD=S1*FS(K-2)+S2*FS(K-1)+S3*FS(K)
      IF (BDD+DEL) 31,32,33
31    DN=TWO*(ADD+DEL)/AS
      SB=DN/(FS(K-2)+DSQRT(FS(K-2)**2+(FS(K-1)-FS(K-2))*DN))
      SA=ONE-SB
      GO TO 34
32    SB=ONE
      GO TO 34
33    DN=TWO*DEL/BS
      SC=ONE+DN/(FS(K)+DSQRT(FS(K)**2+(FS(K)-FS(K-1))*DN))
      SB=ONE-SC
34    DO 35 J=1,5
35    WALL(J,LINE)=B(J,KT-2)*SA+B(J,KT-1)*SB+B(J,KT)*SC
      IF (IPRNT.EQ.1) WRITE (6,107) (WALL(J,LINE),J=1,5)
      LAST=KT
      IF (N-LINE) 42,41,36
36    LINE=LINE+1
      DO 37 K=1,5
      DO 37 L=1,150
37    A(K,L)=B(K,L)
      IF (IP.EQ.0) GO TO 17
38    DO 39 J=1,5
39    B(J,1)=AXIS(J,LINE)
      DO 40 J=1,LAST
      K=J
      CALL OFELD (B(1,K),A(1,K),B(1,K+1),NOCON)
      IF (NOCON.NE.0) GO TO 83
40    CONTINUE
      GO TO 20
41    IF (IP.NE.0) GO TO 42
      IF (LR.EQ.0.OR.IT.NE.0) GO TO 49
42    IF (LINE.EQ.NL-1) GO TO 48
      NN=NN+1
      LINE=LINE+1
      DO 43 K=1,5
      DO 43 L=1,150
43    A(K,L)=B(K,L)
      DO 44 K=1,5
      DO 44 L=1,150
44    B(K,L)=FINAL(K,L)
```

```
      IF ((LR.NE.0).AND.(JQ.EQ.0)) GO TO 46
      DO 45 J=NN,LAST
      K=J
      CALL OFELD (B(1,K),A(1,K),B(1,K+1),NOCON)
      IF (NOCON.NE.0) GO TO 83
45    CONTINUE
      GO TO 20
46    DO 47 J=NN,LAST
      K=J
      CALL OFELD (A(1,K),B(1,K),B(1,K+1),NOCON)
      IF (NOCON.NE.0) GO TO 83
47    CONTINUE
      GO TO 20
48    IF (IP.NE.0) GO TO 64
C
C     INTEGRATION OF SLOPES
49    IB=1
      IF (IABS(JB).GT.1) IB=2
      LT=0
      IF (IT.NE.0) LT=IB
      NUT=(LINE-1)/IB+2-LT
      WALL(1,LINE+1)=XO
      WALL(5,LINE+1)=ZRO
      YI(NUT)=WALL(2,1)
      Y=YI(NUT)
      LIN=2*((LINE-LT)/2)
      DO 50 J=2,LIN,2
      I=NUT-J
      SS=WALL(1,J)-WALL(1,J-1)
      TT=WALL(1,J+1)-WALL(1,J)
      ST=SS+TT
      S1=SS*(TWO+TT/ST)/SIX
      S2=SS*(TWO+ST/TT)/SIX
      S3=SS-S1-S2
      T3=TT*(TWO+SS/ST)/SIX
      T2=TT*(TWO+ST/SS)/SIX
      T1=TT-T2-T3
      Y=Y+S1*DTAN(WALL(5,J-1))+S2*DTAN(WALL(5,J))+S3*DTAN(WALL(5,J+1))
      IF (IB.EQ.1) YI(I+1)=Y
      Y=Y+T1*DTAN(WALL(5,J-1))+T2*DTAN(WALL(5,J))+T3*DTAN(WALL(5,J+1))
      IF (IB.EQ.1) YI(I)=Y
      IF (IB.EQ.2) YI(I+J/2)=Y
50    CONTINUE
      IF (LR.NE.0.AND.LINE.EQ.LIN) GO TO 51
      X=WALL(1,LINE-LT)-XO
      YI(1)=YI(2)-X*(DTAN(WALL(5,LINE-LT))+HALF*X*SDO)/THR
51    DO 52 L=2,NUT
      JJ=1+IB*(NUT-L)
      WAX(L)=WALL(1,JJ)
      WAY(L)=WALL(2,JJ)
      WMN(L)=WALL(3,JJ)
      WAN(L)=CONV*WALL(5,JJ)
52    WALTAN(L)=DTAN(WALL(5,JJ))
      WAX(1)=XO
      WAY(1)=YO
      WAN(1)=ZRO
```

```
      WMN(1)=WWO/DSQRT(G7-G8*WWO**2)
      WALTAN(1)=ZRO
      IF (NF.GE.0) GO TO 54
C
C     SMOOTH UPSTREAM CONTOUR IF DESIRED
      CALL NEO
      DO 53 J=1,NUT
53    WALTAN(J)=DTAN(WAN(J)/CONV)
54    CALL SCOND (WAX,WALTAN,SECD,NUT)
      SECD(1)=SDO
      SECD(NUT)=ZRO
      KO=NUT+MP
      IF (MP.EQ.0) GO TO 56
C
C     RADIAL FLOW SECTION COORDINATES
      SNE=DSIN(ETA)
      TNE=DTAN(ETA)
      DM=(AMACH-GMACH)/MP
      DO 55 L=1,MP
      LL=NUT+L
      WMN(LL)=GMACH+L*DM
      RL=((G5*WMN(LL)**2+G6)**GA/WMN(LL))**QT
      WAX(LL)=RL*CSE
      WAY(LL)=RL*SNE
      WAN(LL)=ETAD
      WALTAN(LL)=TNE
55    SECD(LL)=ZRO
56    IF (MQ.LT.0) GO TO 60
      IF (JC.LE.0) GO TO 58
      WRITE (6,105) ITLE
      WRITE (6,99) LST
      DO 57 K=1,LP,NK
      I=(K-1)/NK+1
      XINCH=SF*CHAR(1,K)+FRIP
      YINCH=SF*CHAR(2,K)
      WRITE (6,103) K,(CHAR(J,K),J=1,6),XINCH,YINCH
57    IF (MOD(I,10).EQ.0) WRITE (6,98)
58    IF (ISE.EQ.0) WRITE (6,91) ITLE
      IF (ISE.EQ.1) WRITE (6,102) ITLE
      WRITE (6,84) RC,ETAD,AMACH,BMACH,CMACH,EMACH,MC,AH
      IF (NOCON.NE.0) GO TO 59
      WRITE (6,100) IWL
      WRITE (6,85) (K,WAX(K),WAY(K),WMN(K),WAN(K),WALTAN(K),SECD(K),K=1,
     1NUT)
      IF ((LR.EQ.0).AND.(N.LT.42)) GO TO 59
      IF ((LR.NE.0).AND.(N+LR.LT.27)) GO TO 59
      NOCON=1
      GO TO 58
59    WRITE (6,87)
      NOCON=0
C
C     COMPARISON OF CONTOUR WITH PARABOLA AND HYPERBOLA
60    DO 62 J=1,NUT
      XS=(WAX(J)-XO)/YO
      XS2=XS**2
      XS3=XS**3
```

```
      YS=WAY(J)/YO
      YE=YI(J)/YO
      PS=ONE+HALF*XS2*RRC
      DHP=ONE+XS2*RRC
      HS=DSQRT(DHP)
      IF (J.GT.1) GO TO 61
      IF (MQ.LT.0) GO TO 62
      WRITE (6,88) J,XS,YS,YE,PS,HS
      GO TO 62
   61 YPX=WALTAN(J)/XS
      CY=(PS-YS)/XS3
      CI=(PS-YE)/XS3
      IF (J.EQ.2) ICY=1.D+6*(DABS(CY)-DABS(CI))
      IF (MQ.LT.0) GO TO 63
      CYP=(RRC-YPX)/XS/THR
      WRITE (6,88) J,XS,YS,YE,PS,HS,CY,CI,CYP
   62 IF (MOD(J,10).EQ.0) WRITE (6,98)
   63 WRITE (6,97) ICY
      IF (IQ.GT.0) GO TO 70
      JQ=1
      RETURN
   64 LINE=NL
      DO 65 J=1,5
   65 WALL(J,NL)=FINAL(J,NP)
C
C     SMOOTH DOWNSTREAM CONTOUR IF DESIRED
      IF (NF.LT.0) CALL NEO
      DO 66 J=1,NL
      WDX(J)=WALL(1,J)
   66 WTAN(J)=DTAN(WALL(5,J))
      CALL SCOND (WDX,WTAN,SCDF,NL)
      SCDF(1)=ZRO
      SCDF(NL)=ZRO
      IF (JC.GE.0) GO TO 68
      WRITE (6,104) ITLE
      WRITE (6,99) IFR
      DO 67 K=1,LP,NK
      I=(K-1)/NK+1
      XINCH=SF*CHAR(1,K)+FRIP
      YINCH=SF*CHAR(2,K)
      WRITE (6,103) K,(CHAR(J,K),J=1,6),XINCH,YINCH
   67 IF (MOD(I,10).EQ.0) WRITE (6,98)
   68 IF (IQ.LT.0) KO=1
      NAG=KO-1
      KING=LINE+NAG
      DO 69 L=1,LINE
      WAX(NAG+L)=WALL(1,L)
      WAY(NAG+L)=WALL(2,L)
      WMN(NAG+L)=WALL(3,L)
      WAN(NAG+L)=CONV*WALL(5,L)
      WALTAN(NAG+L)=WTAN(L)
   69 SECD(NAG+L)=SCDF(L)
      IF (MQ.LT.0) GO TO 71
      WRITE (6,94) ITLE
      WRITE (6,84) RC,ETAD,AMACH,BMACH,CMACH,EMACH,MC,AH
      WRITE (6,100) IWL
```

```
      WRITE (6,85) (K,WAX(K),WAY(K),WMN(K),WAN(K),WALTAN(K),SECD(K),K=KOPER  416
     1,KING)                                                            PER  417
      GO TO 71                                                          PER  418
   70 KING=KO                                                           PER  419
C                                                                       PER  420
C     APPLICATION OF SCALE FACTOR TO NON-DIMENSIONAL COORDINATES        PER  421
   71 DO 72 K=1,KING                                                    PER  422
      S(K)=SF*WAX(K)+FRIP                                               PER  423
      FS(K)=SF*WAY(K)                                                   PER  424
      TTR(K)=ONE+G8*WMN(K)**2                                           PER  425
      SPR(K)=ONE/TTR(K)**(ONE+G1)                                       PER  426
   72 SD(K)=SECD(K)/SF                                                  PER  427
      IF (ISE.EQ.1) XBIN=ZRO                                            PER  428
      IF (ISE.EQ.0) XBIN=XB*SF+FRIP                                     PER  429
      XCIN=XC*SF+FRIP                                                   PER  430
      CALL SCOND (S,WMN,DMDX,KING)                                      PER  431
      DMDX(1)=G7*WWOP*WMN(1)**3/WWO**3/SF                               PER  432
      IF (MP.EQ.0.OR.IQ.LT.0) GO TO 74                                  PER  433
      DO 73 K=NUT,KO                                                    PER  434
   73 DMDX(K)=WMN(K)*TTR(K)/(WMN(K)**2-ONE)/QT/SF/WAX(K)                PER  435
      GO TO 75                                                          PER  436
   74 IF (ISE.EQ.0) DMDX(KO)=AMACH*TTR(KO)/(AMACH**2-ONE)/QT/SF/XA      PER  437
   75 IF (IQ.LT.1.OR.ISE.EQ.1) DMDX(KING)=ZRO                           PER  438
      DO 76 K=1,KING                                                    PER  439
   76 DPX(K)=-GAM*WMN(K)*DMDX(K)*SPR(K)/TTR(K)                          PER  440
      JQ=0                                                              PER  441
      KAT=KING                                                          PER  442
      IF (IABS(MQ).LT.2) GO TO 78                                       PER  443
C                                                                       PER  444
C     EXTENSION OF PARALLEL-FLOW CONTOUR                                PER  445
      KIT=KING+1                                                        PER  446
      KAT=KING+IABS(MQ)                                                 PER  447
      KUT=S(KING)+HALF                                                  PER  448
      INC=S(KING)-S(KING-1)                                             PER  449
      IF (INC.LT.1) INC=1                                               PER  450
      DO 77 K=KIT,KAT                                                   PER  451
      S(K)=KUT+(K-KING)*INC                                             PER  452
      FS(K)=FS(KING)                                                    PER  453
      WMN(K)=WMN(KING)                                                  PER  454
      TTR(K)=TTR(KING)                                                  PER  455
      SPR(K)=SPR(KING)                                                  PER  456
      WAN(K)=ZRO                                                        PER  457
      WALTAN(K)=ZRO                                                     PER  458
      DMDX(K)=ZRO                                                       PER  459
      DPX(K)=ZRO                                                        PER  460
   77 SD(K)=ZRO                                                         PER  461
   78 IF (XBL.EQ.ZRO) GO TO 79                                          PER  462
      IF (S(KING-1).LT.XBL) GO TO 79                                    PER  463
C                                                                       PER  464
C     INTERPOLATE FOR VALUES AT SPECIFIED STATION                       PER  465
      CALL TWIXT (S,GMA,GMB,GMC,GMD,XBL,KING,KBL)                       PER  466
      GO TO 80                                                          PER  467
   79 KBL=KAT+4                                                         PER  468
   80 IF (JB.GT.0) RETURN                                               PER  469
      IF (ISE.EQ.0) GO TO 81                                            PER  470
      WRITE (6,102) ITLE                                                PER  471
```

```
      WRITE (6,92) RC,SE,XCIN
      GO TO 82
81    IF (IQ.GT.0) WRITE (6,91) ITLE
      IF (IQ.LE.0) WRITE (6,95) ITLE,XBIN,XCIN,SF
      WRITE (6,84) RC,ETAD,AMACH,BMACH,CMACH,EMACH,MC,AH
82    WRITE (6,89)
      WRITE (6,90) (K,S(K),FS(K),WALTAN(K),SD(K),WMN(K),DMDX(K),SPR(K),D
     1PX(K),K=1,KING)
      IF (KBL.GT.KAT) RETURN
      J=KBL-1
      FSX=GMA*FS(J-2)+GMB*FS(J-1)+GMC*FS(J)+GMD*FS(J+1)
      WMNX=GMA*WMN(J-2)+GMB*WMN(J-1)+GMC*WMN(J)+GMD*WMN(J+1)
      DMXX=GMA*DMDX(J-2)+GMB*DMDX(J-1)+GMC*DMDX(J)+GMD*DMDX(J+1)
      DYDX=GMA*WALTAN(J-2)+GMB*WALTAN(J-1)+GMC*WALTAN(J)+GMD*WALTAN(J+1)
      SDX=GMA*SD(J-2)+GMB*SD(J-1)+GMC*SD(J)+GMD*SD(J+1)
      SPRX=GMA*SPR(J-2)+GMB*SPR(J-1)+GMC*SPR(J)+GMD*SPR(J+1)
      DPXX=GMA*DPX(J-2)+GMB*DPX(J-1)+GMC*DPX(J)+GMD*DPX(J+1)
      WRITE (6,101) XBL,FSX,DYDX,SDX,WMNX,DMXX,SPRX,DPXX
      RETURN
83    WRITE (6,86) IP,NN,LINE,J
      RETURN
C
84    FORMAT (1H ,4H RC=,F11.6,3X,5HETAD=F8.4,4H DEG,3X,6HAMACH=F10.7,3X
     1,6HBMACH=F10.7,3X,6HCMAC =F10.7,3X,6HEMACH=F10.7,3X,A4,2HH=F11.7/)
85    FORMAT (10(8X,I3,2X,1P6E15.7/))
86    FORMAT (1H0,9HOFELO IP=,I3,5H, NN=,I3,7H, LINE=,I3,8H, POINT=,I3 )
87    FORMAT (1H ,9X,'POINT      X/YO',8X,'Y/YO',7X,'INT.Y/YO',7X,'PAR/YO
     1',7X,'HYP/YO        C(Y)',11X,'C(YI)',10X,'C(YP)' /)
88    FORMAT (1H ,9X,I3,5F13.7,1P3E15.6 )
89    FORMAT (1H ,9X,5HPOINT,7X,5HX(IN),9X,5HY(IN),9X,5HDY/DX,8X,7HD2Y/D
     1X2,7X,8HMACH NO.,7X,5HDM/DX,9X,5HPE/PO,11X,6HDPR/DX/)
90    FORMAT (10(10X,I3,2X,0P6F14.7,1P2E16.5/))
91    FORMAT (1H1,3A4,17H UPSTREAM CONTOUR/)
92    FORMAT (1H ,' RC=',F11.7,',      STREAMLINE RATIO=',F11.8,',     TEST
     1 CONE BEGINS AT',F12.7,' IN.' / )
93    FORMAT (1H1,3A4,22H THROAT CHARACTERISTIC )
94    FORMAT (1H1,3A4,19H DOWNSTREAM CONTOUR/)
95    FORMAT (1H1,3A4,45H INVISCID NOZZLE CONTOUR, RADIAL FLOW ENDS ATF1
     11.6,25H IN., TEST CONE BEGINS ATF11.6,19H IN., SCALE FACTOR=F9.4/)
96    FORMAT (1H0,8X,6HMASS =,F13.10)
97    FORMAT (1H0,9X,5HICY =,I13 / )
98    FORMAT (1H )
99    FORMAT (1H ,8X,A4/8X,5HPOINT,8X,1HX,14X,1HY,10X,68HMACH NO.      M
     1ACH ANG.(D)      PSI (D)       FLOW ANG.(D)        X(IN),9X,5HY(IN)/)
100   FORMAT (1H ,8X,A4/8X,5HPOINT,8X,1HX,14X,1HY,10X,37HMACH NO.      F
     1LOW ANG.(D)      WALTAN,9X,6HSECDIF/)
101   FORMAT (1H0,14X,6F14.7,1P2E16.5)
102   FORMAT (1H1,3A4,17H INVISCID CONTOUR/)
103   FORMAT (1H ,I10,2X,1P6E15.7,0P2F14.7)
104   FORMAT (1H1,3A4,33H INTERMEDIATE LEFT CHARACTERISTIC /)
105   FORMAT (1H1,3A4,34H INTERMEDIATE RIGHT CHARACTERISTIC /)
106   FORMAT (1H ,8H CHARACT,I4/8X,5HPOINT,8X,1HX,14X,1HY,10X,68HMACH NO
     1.        MACH ANG.(D)      PSI (D)       FLOW ANG.(D)        X(IN),9X,5
     2HY(IN) /)
107   FORMAT (1H0,12H    CONTOUR   ,1P3E15.7 )
      END
```

```
      SUBROUTINE PLATE
C     DUMMY TO BE MODIFIED FOR SPECIAL CALCULATIONS FOR FLEXIBLE PLATE
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /JACK/ SJ(30),XJ(30),YJ(30),AJ(30)
      RETURN
      END
      SUBROUTINE SCOND (A,B,C,KING)
C     TO OBTAIN PARABOLIC DERIVATIVE OF CURVE (UNEQUALLY SPACED POINTS)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(300), B(300), C(300)
      N=KING-1
      DO 1 K=2,N
      S=A(K)-A(K-1)
      T=A(K+1)-A(K)
    1 C(K)=((B(K+1)-B(K))*S*S+(B(K)-B(K-1))*T*T)/(S*S*T+S*T*T)
      SO=A(2)-A(1)
      TO=A(3)-A(2)
      QO=SO+TO
      C(1)=(-TO*(QO+SO)*B(1)+QO*QO*B(2)-SO*SO*B(3))/QO/SO/TO
      SF=A(KING-1)-A(KING-2)
      TF=A(KING)-A(KING-1)
      QF=SF+TF
      QST=QF*SF*TF
      C(KING)=(SF*(QF+TF)*B(KING)-QF*QF*B(KING-1)+TF*TF*B(KING-2))/QST
      RETURN
      END
      SUBROUTINE SORCE (W,B)
C     TO OBTAIN VELOCITY DERIVATIVES IN RADIAL FLOW
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /GG/ GAM,GM,G1,G2,G3,G4,G5,G6,G7,G8,G9,GA,RGA,QT
      DATA ONE/1.D+0/,TWO/2.D+0/,THR/3.D+0/,FOUR/4.D+0/
      DIMENSION B(4)
      WW=W*W
      AL=G7*G9
      AWW=AL-WW
      WW1=WW-ONE
      AREA=(((AL-ONE)/AWW)**G1)/W
      B(1)=AREA**QT
      AXW=AL*WW1*B(1)
      B(2)=W*AWW/AXW/QT
      C2=THR/QT+AL*(TWO-ONE/QT)
      C4=AL+ONE/QT
      CWW=WW*(C2-WW*C4)-AL*(ONE+ONE/QT)
      B(3)=B(2)*CWW/AXW/WW1
      DWW=(TWO*C2-FOUR*C4*WW)/CWW-FOUR/WW1
      B(4)=B(3)*(B(3)/B(2)+W*B(2)*DWW-ONE/B(1))
      RETURN
      END
      SUBROUTINE SPLIND (X,Y,TNZ,TNL,L)
C     COMPUTE CUBIC COEFFICIENTS FOR A CURVE X-Y
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /COEF/ E(5,200),NE
      COMMON /WORK/ A(300),B(300),C(300),D(300),G(300),SB(300),XM(300),D
     1X(300),DY(300)
      DIMENSION X(1), Y(1)
      DATA ZERO/0.0D+0/,ONE/1.D+0/,THR/3.D+0/,SIX/6.D+0/
```

```
      CALL OREZ (E,5*200)
      CALL OREZ (A,9*300)
      DX(1)=ZERO
      DY(1)=ZERO
      N=L-1
      DO 1 K=2,L
      DX(K)=X(K)-X(K-1)
    1 DY(K)=Y(K)-Y(K-1)
C
      B(1)=DX(2)/THR
      C(1)=DX(2)/SIX
      D(1)=DY(2)/DX(2)-TNZ
      A(L)=DX(L)/SIX
      B(L)=DX(L)/THR
      D(L)=TNL-DY(L)/DX(L)
      A(1)=ZERO
      DO 2 K=2,N
      A(K)=DX(K)/SIX
      B(K)=(DX(K)+DX(K+1))/THR
      D(K)=DY(K+1)/DX(K+1)-DY(K)/DX(K)
    2 C(K)=DX(K+1)/SIX
      SW=ONE/B(1)
      SB(1)=SW*C(1)
      G(1)=SW*D(1)
      DO 3 K=2,L
      SW=ONE/(B(K)-A(K)*SB(K-1))
      SB(K)=SW*C(K)
    3 G(K)=SW*(D(K)-A(K)*G(K-1))
      XM(L)=G(L)
      DO 4 K=1,N
      J=L-K
    4 XM(J)=G(J)-SB(J)*XM(J+1)
      DO 5 K=2,L
      DXR=ONE/DX(K)
      Q=DXR/SIX
      P=-XM(K-1)*Q
      Q=Q*XM(K)
      R=DX(K)*XM(K-1)/SIX-DXR*Y(K-1)
      S=Y(K)*DXR-DX(K)*XM(K)/SIX
      XK=X(K)
      PX=XK*P
      PXX=PX*XK
      PXXX=PXX*XK
      XJ=X(K-1)
      QX=XJ*Q
      QXX=QX*XJ
      QXXX=QXX*XJ
      E(2,K)=P+Q
      E(3,K)=-THR*(PX+QX)
      E(4,K)=THR*(PXX+QXX)+R+S
      E(5,K)=-PXXX-QXXX-R*XK-S*XJ
    5 CONTINUE
      DO 6 K=2,L
      E(1,K)=X(K)
    6 CONTINUE
      E(1,1)=X(1)
```

```
      NE=L
      RETURN
      END
      FUNCTION TORIC (WIP.SE)
C     TO OBTAIN THROAT RADIUS OF CURVATURE FROM VELOCITY GRADIENT
      IMPLICIT REAL*8(A-H.O-Z)
      COMMON /FG/ GC.GD.GE.GF.GH.GI.HA.HB.HC.HE
      COMMON /GG/ GAM.GM.G1.G2.G3.G4.G5.G6.G7.G8.G9.GA.RGA.QT
      DATA ONE/1.D+0/.THR/3.D+0/.FIV/5.D+0/
      IE=ONE/QT-ONE
      FW=WIP*SE*DSQRT(QT*(GAM+ONE))
      TRR=FW*(ONE+(GC+(THR*GC**2-GD)*FW**2)*FW**2)
1     TR2=TRR**2
      TK=(ONE-G7*(ONE+(GE+GF*TR2)*TR2)*TR2**2/(45.D+0+3*IE))**QT
      FF=FW/TK-TRR*(ONE-TR2*(GC-GD*TR2))
      FP=ONE-TR2*(THR*GC-FIV*GD*TR2)
      TRR=TRR+FF/FP
      IF (DABS(FF).GT.1.D-11) GO TO 1
      TORIC=ONE/TRR**2
      RETURN
      END
      SUBROUTINE TRANS (RTO.TK.WO.AMN.AMP.AMPP.W.AWP.AWPP.CWOPPP.AXN)
C     TO DETERMINE THROAT CHARACTERISTIC
      IMPLICIT REAL*8(A-H.O-Z)
      COMMON /GG/ GAM.GM.G1.G2.G3.G4.G5.G6.G7.G8.G9.GA.RGA.QT
      COMMON /CONTR/ ITLE(3).IE.LR
      COMMON /TROAT/ FC(6.51)
      DATA ZRO/0.0D+0/.ONE/1.D+0/.TWO/2.D+0/.SIX/6.D+0/.HALF/5.D-1/
      DATA TRHV/1.5D+0/.THR/3.D+0/.FOUR/4.D+0/.EIT/8.D+0/.TLV/1.2D+1/
      NN=IABS(LR)
      JJ=240/(NN-1)
      IF (MOD(JJ.2).NE.0) JJ=JJ+1
      IF (JJ.LT.10) JJ=10
      KK=JJ*NN-JJ
      GB=IE/EIT
      GK=(GAM*(GAM+2.25D+0*IE-16.5D+0)+2.25D+0*(2+IE))/TLV
      GU=ONE-GAM/TRHV
      GV=(HALF*(5+3*IE)*GAM+IE)/(9-IE)
      GZ=DSQRT(QT*(GAM+ONE))
      U22=GB+GAM/THR/(3-IE)
      U42=(GAM+(4-IE)*TRHV)/SIX/(3-IE)
      IF (IE.EQ.0) GO TO 1
      GT=(GAM*(GAM*92.D+0+180.D+0)-9.D+0)/1152.D+0
      U23=(GAM*(304.D+0*GAM+255.D+0)-54.D+0)/1728.D+0
      U43=(GAM*(388.D+0*GAM+777.D+0)+153.D+0)/2304.D+0
      U63=(GAM*(556.D+0*GAM+1737.D+0)+3069.D+0)/10368.D+0
      UP0=(GAM*(52.D+0*GAM+75.D+0)-9.D+0)/192.D+0
      UP2=(GAM*(52.D+0*GAM+51.D+0)+327.D+0)/384.D+0
      V02=(28.D+0*GAM-15.D+0)/288.D+0
      V22=(20.D+0*GAM+27.D+0)/96.D+0
      V42=(GAM/THR+ONE)/THR
      V03=(GAM*(7100.D+0*GAM+2151.D+0)+2169.D+0)/82944.D+0
      V23=(GAM*(3424.D+0*GAM+4071.D+0)-972.D+0)/13824.D+0
      V43=(GAM*(3380.D+0*GAM+7551.D+0)+3771.D+0)/13824.D+0
      V63=(GAM*(6836.D+0*GAM+23031.D+0)+30627.D+0)/82944.D+0
      GO TO 2
```

```
1     GT=(GAM*(GAM*134.D+0+429.D+0)+123.D+0)/4320.D+0
      U23=(GAM*(854.D+0*GAM+807.D+0)+279.D+0)/12960.D+0
      U43=(GAM*(194.D+0*GAM+549.D+0)-63.D+0)/2592.D+0
      U63=(GAM*(362.D+0*GAM+1449.D+0)+3177.D+0)/12960.D+0
      UP0=(GAM*(26.D+0*GAM+51.D+0)-27.D+0)/144.D+0
      UP2=(GAM*(26.D+0*GAM+27.D+0)+237.D+0)/288.D+0
      V02=(34.D+0*GAM-75.D+0)/1080.D+0
      V22=(10.D+0*GAM+15.D+0)/108.D+0
      V42=(22.D+0*GAM+75.D+0)/360.D+0
      V03=(GAM*(7570.D+0*GAM+3087.D+0)+23157.D+0)/544320.D+0
      V23=(GAM*(5026.D+0*GAM+7551.D+0)-4923.D+0)/77760.D+0
      V43=(GAM*(2254.D+0*GAM+6153.D+0)+2979.D+0)/25920.D+0
      V63=(GAM*(6574.D+0*GAM+26481.D+0)+40059.D+0)/181440.D+0
2     WWO=WO+(HALF+(U42-U22+(U63-U43+U23)/RTO)/RTO)/RTO
      WOP=(ONE-(GB-GT/RTO)/RTO)/DSQRT(RTO)
      WOPP=(GU-GV/RTO)/RTO
      HOPPP=GK/RTO/DSQRT(RTO)
      HVPPP=(3*IE-(10-3*IE)*GAM)/FOUR/RTO/DSQRT(RTO)
      AMN=WWO/DSQRT(G7-G8*WWO**2)
      BET=DSQRT(AMN**2-ONE)
      PSI1=G2*DATAN(BET/G2)-DATAN(BET)
      P1=ZRO
      T1=ZRO
      X1=ZRO
      Y1=ONE
      FSY1=ZRO
      TN2=-ONE/BET
      FC(1,NN)=X1
      FC(2,NN)=Y1
      FC(3,NN)=AMN
      FC(4,NN)=PSI1
      FC(5,NN)=ZRO
      FC(6,NN)=ZRO
      BX=ONE
      SUM=ZRO
      FSA=(IE+1)*AMN/(G6+G5*AMN**2)**GA
      DO 8 J=1,KK
      Y=DFLOAT(KK-J)/KK
      IF (IE.EQ.1) BX=Y+Y
      YY=Y*Y
      TN1=TN2
      VO=(((YY*(YY*(YY*V63-V43)+V23)-V03)/RTO+YY*(YY*V42-V22)+V02)/RTO+H
     1ALF*(YY-ONE)/(3-IE))/RTO
      VP=(ONE+((YY*(TWO*GAM+3*(4-IE))-TWO*GAM-TRHV*IE)/(3-IE)/THR+(YY*(S
     1IX*U63*YY-FOUR*U43)+TWO*U23)/RTO)/RTO)/DSQRT(RTO)
      VPP=TWO*(ONE+(TWO*UP2*YY-UP0)/RTO)/RTO
C     ITERATE FOR X AND MACH NUMBER FROM CHARACTERISTIC EQUATIONS
      DO 4 I=1,10
      TNA=HALF*(TN1+TN2)
      X=X1+(Y-Y1)/TNA
      DXI=DSQRT((Y-Y1)**2+(X-X1)**2)
      XOT=X/GZ
      VY=GZ*(VO+XOT*(VP+XOT*(HALF*VPP+XOT*HVPPP/THR)))/DSQRT(RTO)
      W=AMN/DSQRT(G6+G5*AMN**2)
      T=DARSIN(VY*Y/W)
      FSY=IE*VY/W/AMN
```

```
      P1=HALF*(FSY1+FSY)*DXI
 3    PSI=P1+PSI1+T1-T
      FMA=FMV(PSI)
      IF (DABS(AMN-FMA).LT.1.D-10) GO TO 5
      FMU=DARSIN(ONE/FMA)
      TN2=DTAN(T-FMU)
      AMN=FMA
 4    CONTINUE
C     ITERATION COMPLETE
 5    IF (MOD(J,2).EQ.0) GO TO 6
      AS=Y1-Y
      FSB=RX/DSIN(FMU-T)/(G6+G5*FMA**2)**GA
      GO TO 7
 6    BS=Y1-Y
      CS=AS+BS
      S1=(TWO-BS/AS)*CS/SIX
      S3=(TWO-AS/BS)*CS/SIX
      S2=CS-S1-S3
      FSC=RX/DSIN(FMU-T)/(G6+G5*FMA**2)**GA
      ADD=S1*FSA+S2*FSB+S3*FSC
      SUM=ADD+SUM
      FSA=FSC
 7    X1=X
      Y1=Y
      T1=T
      FSY1=FSY
      PSI1=PSI
      IF (MOD(J,JJ).NE.0) GO TO 8
      K=NN-J/JJ
      FC(1,K)=X
      FC(2,K)=Y
      FC(3,K)=FMA
      FC(4,K)=PSI
      FC(5,K)=T
      FC(6,K)=SUM
 8    CONTINUE
      DO 9 J=1,NN
      FC(1,J)=FC(1,J)/TK
      FC(2,J)=FC(2,J)/TK
 9    FC(6,J)=ONE-FC(6,J)/SUM
      AXN=FC(1,1)
      AWOP=WOP*TK/GZ
      AWOPP=WOPP*(TK/GZ)**2
      AWOPPP=TWO*WOPPP*(TK/GZ)**3
      CWOPPP=SIX*(W-WO-AXN*(AWOP+AXN*AWOPP/TWO))/AXN**3
      IF (CWOPPP.LT.AWOPPP) CWOPPP=AWOPPP
      AWP=AWOP+AXN*(AWOPP+AXN*CWOPPP/TWO)
      AWPP=AWOPP+AXN*CWOPPP
      AMP=AWP*G7*(AMN/W)**3
      AMPP=AMP*(AWPP/AWP+THR*G5*AMP*W*W/AMN)
      IF (ER.GT.0) RETURN
      LR=NN
      RC=RTO-ONE
      WRITE (6,12) ITLE,RC,AWOP,AWOPP,AWOPPP
      DO 10 J=1,NN
      Y=DFLOAT(J-1)/(NN-1)
```

```
      YY=Y*Y
      Y4=YY**2
      Y6=YY**3
      DUY=(HALF*YY+(U42*Y4-U22*YY+(U63*Y6-U43*Y4+U23*YY)/RTO)/RTO)/RTO
      UY=WO+DUY
      VO=(((YY*(YY*(YY*V63-V43)+V23)-V03)/RTO+YY*(YY*V42-V22)+V02)/RTO+H
     1ALF*(YY-ONE)/(3-IE))/RTO
      VY=GZ*VO*Y/DSQRT(RTO)
      WY=DSQRT(UY**2+VY**2)
      YM=WY/DSQRT(G7-G8*WY**2)
      WRITE (6,13) Y,UY,VY,WY,YM
   10 IF (MOD(J,10).EQ.0) WRIT  (6,14)
      XX1=CUBIC(CWOPPP/SIX,AWOPP/TWO,AWOP,WO-ONE)
      XXI=CUBIC(AWOPPP/SIX,AWOPP/TWO,AWOP,WO-W)
      WRITE (6,15) XX1,XXI,W,CWOPPP,TK
      WRITE (6,16)
      PX=AXN+1.D-1
      DO 11 J=1,11
      X=.1D+0*(J-1)
      XW=WO+X*(AWOP+X*(AWOPP/TWO+X*CWOPPP/SIX))
      XWP=AWOP+X*(AWOPP+X*CWOPPP/TWO)
      XWPP=AWOPP+X*CWOPPP
      XM=XW/DSQRT(G7-G8*XW**2)
      XMP=XWP*G7*(XM/XW)**3
      XMPP=XMP*(XWPP/XWP+THR*G5*XMP*XW*XW/XM)
      IF (X.LT.AXN.OR.X.GT.PX) GO TO 11
      WRITE (6,18) AXN,W,AWP,AWPP,AMN,AMP,AMPP
   11 WRITE (6,17) X,XW,XWP,XWPP,XM,XMP,XMPP
      RETURN
C
   12 FORMAT (1H1,8X,3A4,39H THROAT VELOCITY DISTRIBUTION, X=0, RC=,F10.
     16//10X,44HDERIVATIVES TAKEN WITH RESPECT TO X/Y*, WOP=,F11.8//10X,
     25HWOPP=,1PE15.7,5X,6HWOPPP=,E15.7//10X,4HY/YO,7X,4HU/A*,10X,4HV/A*
     3,11X,1HW,11X,8HMACH NO. /)
   13 FORMAT (1H ,F14.4,4F14.8 )
   14 FORMAT (1H )
   15 FORMAT (1H0,9X,18HFROM CUBIC, X/Y* =,F11.8,11H FOR W= 1.0 //22X,6H
     1X/Y* =,F11.8,7H FOR W=,F11.8 //10X,16HCORRECTED WOPPP=,1PE15.7 //
     210X,15HRMASS = Y*/YO =,0PF13.10 //)
   16 FORMAT (1H0,9X,32HAXIAL VELOCITY DISTRIBUTION, Y=0 //10X,4HX/Y*,9X
     1,1HW,17X,2HWP,16X,3HWPP,15X,1HM,17X,2HMP,16X,3HMPP /)
   17 FORMAT (1H ,F13.3,1P6E18.7 )
   18 FORMAT (1H ,F16.8,1PE15.7,5E18.7 )
      END
      SUBROUTINE TWIXT (S,GMA,GMB,GMC,GMD,XBL,KAT,KBL)
C     TO DETERMINE INTERPOLATION COEFFICIENTS
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION S(200)
      DO 1 L=1,KAT
      IF (S(KAT-L).LT.XBL) GO TO 2
    1 CONTINUE
    2 J=KAT-L+1
      XBB=S(J)-XBL
      KBL=J+1
      DU=S(J+1)-S(J)
      DT=S(J)-S(J-1)
```

```
      DS=S(J-1)-S(J-2)
      DST=DS+DT
      DSTU=DST+DU
      DTU=DT+DU
      GMA=-XBB*(DT-XBB)*(DU+XBB)/DS/DST/DSTU
      GMB=XBB*(DST-XBB)*(DU+XBB)/DS/DT/DTU
      GMC=(DST-XBB)*(DT-XBB)*(DU+XBB)/DST/DT/DU
      GMD=-XBB*(DST-XBB)*(DT-XBB)/DSTU/DTU/DU
      RETURN
      END
      SUBROUTINE XYZ (XX,YY,YYP,YYPP)
C     COMPUTE  Y,Y',Y" FOR A CURVE DESCRIBED BY CUBIC'S A(5,*)
C     WHERE (1) = X-MAX (2)= HIGH ORDER COEFFICIENT.
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /COEF/ A(5,200),NA
      DATA ZERO/0.0D+0/
      X=XX
      IF (X.GE.A(1,1)) GO TO 2
1     Y=ZERO
      YP=ZERO
      YPP=ZERO
      GO TO 5
2     DO 3 K=2,200
      IF (X.LE.A(1,K)) GO TO 4
3     CONTINUE
      GO TO 1
4     A3=A(2,K)
      A2=A(3,K)
      A1=A(4,K)
      AZ=A(5,K)
      T=A2+A2
      S=A3*3.0D+0
      R=S+S
      Y=AZ+X*(A1+X*(A2+X*A3))
      YP=A1+X*(T+X*S)
      YPP=T+R*X
5     YY=Y
      YYP=YP
      YYPP=YPP
      RETURN
      END
```

```
SEV00469(09-01-1977)       VKF07600 TUESDAY JUN 06,1978  11:35.34

1     M A C H 4                                                              1
2      1.4      1716.563    1.       0.896   2.26968E-8  198.72         1000.      2
3       8.67      6.                 3.        4.       -12.25    60.             3
4       41   21          10         41   49  -61            1        10      -21   13   4
5       50   85   50                                                              5
6      200.      1638.     900.      540.      .38                          1    5   6
7      1000.      46.      172.      2.                                           7

      |.........|.........|.........|.........|.........|.........|.........|.........|
      1        10        20        30        40        50        60        70        80
*************************************************END OF INPUT DATA *************************************************
```

M A C H 4   THROAT VELOCITY DISTRIBUTION, X=0, RC= 6.000000

DERIVATIVES TAKEN WITH RESPECT TO X/Y*, WOP= 0.34136118

WOPP= 2.8328436D-03   WOPPP= -7.6881686D-02

Y/YO	U/A*	V/A*	W	MACH NO.
0.0	0.96385164	0.0	0.96385164	0.95708127
0.0500	0.96401577	-0.00071638	0.96401603	0.95727442
0.1000	0.96450872	-0.00142453	0.96450977	0.95785464
0.1500	0.96533218	-0.00211614	0.96533450	0.95882420
0.2000	0.96648905	-0.00278269	0.96649305	0.96018698
0.2500	0.96798341	-0.00341543	0.96798943	0.96194847
0.3000	0.96982065	-0.00400516	0.96982892	0.96411593
0.3500	0.97200756	-0.00454220	0.97201817	0.96669850
0.4000	0.97455242	-0.00501616	0.97456533	0.96970739
0.4500	0.97746515	-0.00541581	0.97748016	0.97315605
0.5000	0.98075749	-0.00572885	0.98077422	0.97706044
0.5500	0.98444311	-0.00594164	0.98446104	0.98143928
0.6000	0.98853789	-0.00603898	0.98855634	0.98631439
0.6500	0.99306008	-0.00600372	0.99307823	0.99171105
0.7000	0.99803057	-0.00581642	0.99804752	0.99765839
0.7500	1.00347313	-0.00545488	1.00348795	1.00418993
0.8000	1.00941470	-0.00489374	1.00942656	1.01134407
0.8500	1.01588572	-0.00410381	1.01589400	1.01916472
0.9000	1.02292039	-0.00305157	1.02292494	1.02770206
0.9500	1.03055708	-0.00169844	1.03055848	1.03701332
1.0000	1.03883866	-0.00000000	1.03883866	1.04716380

FROM CUBIC, X/Y* = 0.10589172 FOR W= 1.0

X/Y* = 0.30916451 FOR W= 1.06914514

CORRECTED WOPPP= -7.5023201D-02

RMASS = Y*/YO = 0.9997135747

AXIAL VELOCITY DISTRIBUTION, Y=0

X/Y*	W	WP	WPP	M	MP	MPP
0.0	9.6385164D-01	3.4136118D-01	2.8328436D-03	9.5708127D-01	4.0106175D-01	8.1394664D-02
0.100	9.9798942D-01	3.4126935D-01	-4.6694765D-03	9.9758876D-01	4.0903018D-01	7.7921558D-02
0.200	1.0320805D 00	3.4042728D-01	-1.2171797D-02	1.0388752D 00	4.1663426D-01	7.4093984D-02
0.300	1.0660499D 00	3.3883499D-01	-1.9674117D-02	1.0809022D 00	4.2383427D-01	6.9825012D-02
0.30913748	1.0691451D 00	3.3865208D-01	-2.0359640D-02	1.0847778D 00	4.2447041D-01	6.9409656D-02
0.400	1.0998225D 00	3.3649246D-01	-2.7176437D-02	1.1236269D 00	4.3058135D-01	6.5018363D-02
0.500	1.1333234D 00	3.3339970D-01	-3.4678757D-02	1.1670014D 00	4.3681650D-01	5.9567934D-02
0.600	1.1664774D 00	3.2955671D-01	-4.2181077D-02	1.2109708D 00	4.4246962D-01	5.3357501D-02
0.700	1.1992097D 00	3.2496349D-01	-4.9683397D-02	1.2554732D 00	4.4745846D-01	4.6260683D-02
0.800	1.2314451D 00	3.1962003D-01	-5.7185717D-02	1.3004372D 00	4.5168768D-01	3.8141263D-02
0.900	1.2631087D 00	3.1352634D-01	-6.4688038D-02	1.3457817D 00	4.5504780D-01	2.8854013D-02
1.000	1.2941254D 00	3.0668242D-01	-7.2190358D-02	1.3914137D 00	4.5741446D-01	1.8246177D-02

M A C H 4 THROAT CONTOUR, 3RD-DEG AXIAL VELOCITY DISTRIBUTION FROM THROAT CHARACTERISTIC WHICH HAS 21 POINTS

NO. OF POINTS ON 1ST CHAR. (M)= 41 NO. OF POINTS ON AXIS (N)= 21 EPSI/ETA= 1.91896 BMACH= 3.08215 CMACH= 4.00000

GAMMA= 1.4000 INFLECTION ANG. (ETA)= 8.6700 DEGREES RAD. OF CURV. (RC)= 6.000000 SCALE FACTOR (SF)= 24.75038624

Y*=0.15117572 RMASS=0.99971357 WWO= 1.0388387 WWOP= 2.59666557 EMACH= 1.66015 FMACH= 3.0821543 GMACH= 2.28784

WI= 1.06914514 WIP= 2.24012223 WIPP= -8.9085294D-01 MI= 1.08477784 MIP= 2.80779489 MIPP= 3.0370771D 00

WI= 1.06914514 WIP= 2.24012223 WIPP= -8.9085294D-01 WIPPP= -3.0009603D 01 WOPPP= -2.1714482D 01

WE= 1.46016505 WEP= 1.45785766 WEPP= -6.9097416D 00 WEPPP= -3.0009603D 01 WRPPP= 7.0885236D 01

C1= 1.0691451 C2= 0.44929096 C3= -1.7917934D-02 C4= -4.0353099D-02 C5= 0.0 C6= 0.0

XOI= 0.04673408 XI= 0.94011759 XO= 0.89338351 YO= 0.15121903 XIE= 0.20056538 XE= 1.14068296 44 ITERATIONS

MACH 0.95708127 AT 46.0758555 IN., MACH 1 AT 46.4720875 IN., MACH 1.08477784 AT 47.2325420 IN.

AXIS POINT	X	X(IN)	MACH NO.	DM/DX	D2M/DX2	D3M/DX3	W=Q/A*	DW/DX	D2W/DX2	D3W/DX3
1	1.14068	52.19661	1.660154	2.571198D 00	-7.941402D 00	-9.736933D 01	1.460165	1.457858D 00	-6.909740D 00	-3.000960D 01
2	1.12775	51.87640	1.626258	2.665954D 00	-6.719118D 00	-9.151293D 01	1.440736	1.544743D 00	-6.521482D 00	-3.000960D 01
3	1.11501	51.56120	1.591793	2.744263D 00	-5.592033D 00	-8.545953D 01	1.420545	1.625361D 00	-6.139308D 00	-3.000960D 01
4	1.10249	51.25121	1.557012	2.807756D 00	-4.559660D 00	-7.939040D 01	1.399717	1.699899D 00	-5.763454D 00	-3.000960D 01
5	1.09018	50.94665	1.522140	2.858004D 00	-3.619389D 00	-7.344595D 01	1.378372	1.768548D 00	-5.394177D 00	-3.000960D 01
6	1.07810	50.64775	1.487383	2.896498D 00	-2.767086D 00	-6.773052D 01	1.356629	1.831503D 00	-5.031764D 00	-3.000960D 01
7	1.06627	50.35478	1.452920	2.924635D 00	-1.997592D 00	-6.231762D 01	1.334605	1.888963D 00	-4.676531D 00	-3.000960D 01
8	1.05468	50.06801	1.418917	2.943712D 00	-1.305143D 00	-5.725539D 01	1.312413	1.941131D 00	-4.328835D 00	-3.000960D 01
9	1.04336	49.78780	1.385519	2.954920D 00	-6.836916D-01	-5.257154D 01	1.290166	1.988218D 00	-3.989077D 00	-3.000960D 01
10	1.03232	49.51451	1.352861	2.959353D 00	-1.271681D-01	-4.827793D 01	1.267976	2.030435D 00	-3.657716D 00	-3.000960D 01
11	1.02157	49.24858	1.321067	2.958009D 00	3.703329D-01	-4.437445D 01	1.245956	2.068003D 00	-3.335281D 00	-3.000960D 01
12	1.01115	48.99052	1.290254	2.951801D 00	8.144091D-01	-4.085234D 01	1.224218	2.101147D 00	-3.022388D 00	-3.000960D 01
13	1.00106	48.74094	1.260536	2.941566D 00	1.210247D 00	-3.769686D 01	1.202882	2.130099D 00	-2.719771D 00	-3.000960D 01
14	0.99135	48.50056	1.232030	2.928079D 00	1.562546D 00	-3.488958D 01	1.182070	2.155098D 00	-2.428316D 00	-3.000960D 01
15	0.98205	48.27030	1.204861	2.912069D 00	1.875449D 00	-3.241018D 01	1.161919	2.176391D 00	-2.149123D 00	-3.000960D 01
16	0.97320	48.05131	1.179173	2.894235D 00	2.152472D 00	-3.023811D 01	1.142582	2.194231D 00	-1.883599D 00	-3.000960D 01
17	0.96487	47.84514	1.155142	2.875278D 00	2.396397D 00	-2.835415D 01	1.124242	2.208880D 00	-1.633624D 00	-3.000960D 01
18	0.95715	47.65400	1.133010	2.855943D 00	2.609062D 00	-2.674250D 01	1.107137	2.220601D 00	-1.401869D 00	-3.000960D 01
19	0.95017	47.48133	1.113151	2.837101D 00	2.790867D 00	-2.539460D 01	1.091613	2.229651D 00	-1.192512D 00	-3.000960D 01
20	0.94420	47.33358	1.096265	2.819995D 00	2.939221D 00	-2.431998D 01	1.078282	2.236235D 00	-1.013365D 00	-3.000960D 01
21	0.94012	47.23254	1.084778	2.807795D 00	3.037077D 00	-2.362573D 01	1.069145	2.240122D 00	-8.908529D-01	-3.000960D 01

M A C H 4   THROAT CHARACTERISTIC

POINT	X	Y	MACH NO.	MACH ANG.(D)	PSI (D)	FLOW ANG.(D)	X(IN)	Y(IN)
1	9.4011759D-01	0.0	1.0847778D 00	6.7197722D 01	1.0529074D 00	0.0	47.2325420	0.0
2	9.3701840D-01	7.5609515D-03	1.0763292D 00	6.8292446D 01	9.0424997D-01	7.2383284D-02	47.1558360	0.1871365
3	9.3407248D-01	1.5121903D-02	1.0688059D 00	6.9329122D 01	7.7756238D-01	1.3030526D-01	47.0829233	0.3742729
4	9.3127055D-01	2.2682855D-02	1.0621631D 00	7.0300762D 01	6.7051186D-01	1.7551318D-01	47.0135744	0.5614094
5	9.2860242D-01	3.0243806D-02	1.0563575D 00	7.1199985D 01	5.8093009D-01	2.0961900D-01	46.9475371	0.7485459
6	9.2605695D-01	3.7804758D-02	1.0513476D 00	7.2019228D 01	5.0681641D-01	2.3409749D-01	46.8845358	0.9356823
7	9.2362206D-01	4.5365709D-02	1.0470926D 00	7.2751043D 01	4.4634349D-01	2.5028227D-01	46.8242714	1.1228188
8	9.2128479D-01	5.2926661D-02	1.0435525D 00	7.3388485D 01	3.9786423D-01	2.5936047D-01	46.7664229	1.3099553
9	9.1903136D-01	6.0487612D-02	1.0406880D 00	7.3925570D 01	3.5991872D-01	2.6236744D-01	46.7106498	1.4970918
10	9.1684740D-01	6.8048564D-02	1.0384604D 00	7.4357744D 01	3.3123977D-01	2.6018255D-01	46.6565958	1.6842282
11	9.1471809D-01	7.5609515D-02	1.0368325D 00	7.4682308D 01	3.1075561D-01	2.5352757D-01	46.6038946	1.8713647
12	9.1262847D-01	8.3170467D-02	1.0357685D 00	7.4898702D 01	2.9758870D-01	2.4296849D-01	46.5521759	2.0585012
13	9.1056374D-01	9.0731418D-02	1.0352346D 00	7.5008590D 01	2.9105011D-01	2.2892116D-01	46.5010728	2.2456376
14	9.0850946D-01	9.8292370D-02	1.0352002D 00	7.5015712D 01	2.9062972D-01	2.1166043D-01	46.4502286	2.4327741
15	9.0645188D-01	1.0585332D-01	1.0356377D 00	7.4925531D 01	2.9598320D-01	1.9133212D-01	46.3993029	2.6199106
16	9.0437811D-01	1.1341427D-01	1.0365238D 00	7.4744736D 01	3.0691718D-01	1.6796608D-01	46.3479762	2.8070470
17	9.0227620D-01	1.2097522D-01	1.0378392D 00	7.4480709D 01	3.2337420D-01	1.4148933D-01	46.2959531	2.9941835
18	9.0013522D-01	1.2853618D-01	1.0395689D 00	7.4141015D 01	3.4541889D-01	1.1173767D-01	46.2429631	3.1813200
19	8.9794528D-01	1.3609713D-01	1.0417028D 00	7.3732991D 01	3.7322646D-01	7.8465045D-02	46.1887611	3.3684565
20	8.9569740D-01	1.4365808D-01	1.0442348D 00	7.3263452D 01	4.0707408D-01	4.1350138D-02	46.1331253	3.5555929
21	8.9338351D-01	1.5121903D-01	1.0471638D 00	7.2738506D 01	4.4733546D-01	0.0	46.0758555	3.7427294

M A C H 4 UPSTREAM CONTOUR

CHARACT 1

POINT	X	Y	MACH NO.	MACH ANG.(D)	PSI (D)	FLOW ANG.(D)	X(IN)	Y(IN)
1	1.1406830D 00	0.0	1.6601538D 00	3.7038665D 01	1.6637379D 01	0.0	52.1966126	0.0
2	1.1464740D 00	4.3370327D-03	1.6748667D 00	3.6659798D 01	1.7070879D 01	2.1675000D-01	52.3392858	0.1073432
3	1.1523046D 00	8.7185055D-03	1.6896010D 00	3.6288807D 01	1.7504379D 01	4.3350000D-01	52.4842521	0.2157864
4	1.1582552D 00	1.3145607D-02	1.7043594D 00	3.5925352D 01	1.7937879D 01	6.5025000D-01	52.6315327	0.3253588
5	1.1643003D 00	1.7619542D-02	1.7191446D 00	3.5569117D 01	1.8371379D 01	8.6700000D-01	52.7811500	0.4360905
6	1.1704407D 00	2.2141533D-02	1.7339594D 00	3.5219807D 01	1.8804879D 01	1.0837500D 00	52.9331274	0.5480115
7	1.1766774D 00	2.6712820D-02	1.7488062D 00	3.4877142D 01	1.9238379D 01	1.3005000D 00	53.0874894	0.6611526
8	1.1830116D 00	3.1334663D-02	1.7636876D 00	3.4540862D 01	1.9671879D 01	1.5172500D 00	53.2442616	0.7755450
9	1.1894441D 00	3.6008343D-02	1.7786058D 00	3.4210721D 01	2.0105379D 01	1.7340000D 00	53.4034705	0.8912204
10	1.1959763D 00	4.0735158D-02	1.7935633D 00	3.3886486D 01	2.0538879D 01	1.9507500D 00	53.5651437	1.0082109
11	1.2026092D 00	4.5516434D-02	1.8085623D 00	3.3567940D 01	2.0972379D 01	2.1675000D 00	53.7293100	1.1265493
12	1.2093440D 00	5.0353514D-02	1.8236050D 00	3.3254875D 01	2.1405879D 01	2.3842500D 00	53.8959990	1.2462689
13	1.2161819D 00	5.5247769D-02	1.8386936D 00	3.2947095D 01	2.1839379D 01	2.6010000D 00	54.0652414	1.3674036
14	1.2231244D 00	6.0200592D-02	1.8538302D 00	3.2644418D 01	2.2272879D 01	2.8177500D 00	54.2370690	1.4899879
15	1.2301726D 00	6.5213404D-02	1.8690170D 00	3.2346665D 01	2.2706379D 01	3.0345000D 00	54.4115145	1.6140569
16	1.2373279D 00	7.0287651D-02	1.8842560D 00	3.2053673D 01	2.3139879D 01	3.2512500D 00	54.5886119	1.7396465
17	1.2445918D 00	7.5424807D-02	1.8995492D 00	3.1765281D 01	2.3573379D 01	3.4680000D 00	54.7683961	1.8667931
18	1.2519657D 00	8.0626375D-02	1.9148986D 00	3.1481341D 01	2.4006879D 01	3.6847500D 00	54.9509029	1.9955339
19	1.2594511D 00	8.5893887D-02	1.9303062D 00	3.1201710D 01	2.4440379D 01	3.9015000D 00	55.1361696	2.1259069
20	1.2670495D 00	9.1228907D-02	1.9457739D 00	3.0926250D 01	2.4873879D 01	4.1182500D 00	55.3242341	2.2579507
21	1.2747626D 00	9.6633030D-02	1.9613037D 00	3.0654834D 01	2.5307379D 01	4.3350000D 00	55.5151358	2.3917048
22	1.2825920D 00	1.0210788D-01	1.9768975D 00	3.0387336D 01	2.5740879D 01	4.5517500D 00	55.7089151	2.5272095
23	1.2905392D 00	1.0765513D-01	1.9925573D 00	3.0123639D 01	2.6174379D 01	4.7685000D 00	55.9056134	2.6645060
24	1.2986062D 00	1.1327646D-01	2.0082848D 00	2.9863630D 01	2.6607879D 01	4.9852500D 00	56.1052734	2.8036361
25	1.3067946D 00	1.1897362D-01	2.0240820D 00	2.9607200D 01	2.7041379D 01	5.2020000D 00	56.3079389	2.9446429
26	1.3151062D 00	1.2474836D-01	2.0399508D 00	2.9354248D 01	2.7474879D 01	5.4187500D 00	56.5136549	3.0875702
27	1.3235429D 00	1.3060251D-01	2.0558930D 00	2.9104673D 01	2.7908379D 01	5.6355000D 00	56.7224677	3.2324626
28	1.3321067D 00	1.3653791D-01	2.0719104D 00	2.8858382D 01	2.8341879D 01	5.8522500D 00	56.9344247	3.3793660
29	1.3407995D 00	1.4255645D-01	2.0880051D 00	2.8615283D 01	2.8775379D 01	6.0690000D 00	57.1495747	3.5283271
30	1.3496233D 00	1.4866006D-01	2.1041788D 00	2.8375289D 01	2.9208879D 01	6.2857500D 00	57.3679677	3.6793939
31	1.3585803D 00	1.5485072D-01	2.1204334D 00	2.8138317D 01	2.9642379D 01	6.5025000D 00	57.5896549	3.8326151
32	1.3676724D 00	1.6113045D-01	2.1367708D 00	2.7904286D 01	3.0075879D 01	6.7192500D 00	57.8146890	3.9880408
33	1.3769020D 00	1.6750132D-01	2.1531928D 00	2.7673119D 01	3.0509379D 01	6.9360000D 00	58.0431242	4.1457223
34	1.3862712D 00	1.7396544D-01	2.1697013D 00	2.7444742D 01	3.0942879D 01	7.1527500D 00	58.2750157	4.3057118
35	1.3957823D 00	1.8052498D-01	2.1862983D 00	2.7219083D 01	3.1376379D 01	7.3695000D 00	58.5104205	4.4680630
36	1.4054378D 00	1.8718216D-01	2.2029855D 00	2.6996074D 01	3.1809879D 01	7.5862500D 00	58.7493969	4.6328309
37	1.4152400D 00	1.9393925D-01	2.2197650D 00	2.6775648D 01	3.2243379D 01	7.8030000D 00	58.9920046	4.8000714
38	1.4251914D 00	2.0079858D-01	2.2366387D 00	2.6557742D 01	3.2676879D 01	8.0197500D 00	59.2383050	4.9698423
39	1.4352945D 00	2.0776251D-01	2.2536083D 00	2.6342294D 01	3.3110379D 01	8.2365000D 00	59.4883611	5.1422024
40	1.4455519D 00	2.1483350D-01	2.2706760D 00	2.6129244D 01	3.3543879D 01	8.4532500D 00	59.7422374	5.3172121
41	1.4559664D 00	2.2201404D-01	2.2878437D 00	2.5918536D 01	3.3977379D 01	8.6700000D 00	60.0000000	5.4949332

MASS = 1.0000000381

M A C H 4 INTERMEDIATE LEFT CHARACTERISTIC

CHARACT 11

POINT	X	Y	MACH NO.	MACH ANG.(D)	PSI (D)	FLOW ANG.(D)	X(IN)	Y(IN)
1	1.0215724D 00	0.0	1.3210673D 00	4.9197253D 01	6.7509438D 00	0.0	49.2485811	0.0
2	1.0268511D 00	6.0554298D-03	1.3368776D 00	4.8418434D 01	7.1918213D 00	2.2266495D-01	49.3792293	0.1498742
3	1.0320925D 00	1.1954396D-02	1.3529441D 00	4.7657258D 01	7.6438354D 00	4.5512827D-01	49.5089554	0.2958759
4	1.0372900D 00	1.7699220D-02	1.3692059D 00	4.6915771D 01	8.1050114D 00	6.9604949D-01	49.6375964	0.4380625
5	1.0424389D 00	2.3294023D-02	1.3856029D 00	4.6195634D 01	8.5733505D 00	9.4401004D-01	49.7650329	0.5765361
6	1.0475359D 00	2.8744351D-02	1.4020756D 00	4.5498190D 01	9.0468319D 00	1.1975112D 00	49.8911859	0.7114338
7	1.0525794D 00	3.4056976D-02	1.4185644D 00	4.4824540D 01	9.5234100D 00	1.4549711D 00	50.0160153	0.8429233
8	1.0575695D 00	3.9239798D-02	1.4350095D 00	4.4175579D 01	1.0001020D 01	1.7147277D 00	50.1395211	0.9712002
9	1.0625077D 00	4.4301840D-02	1.4513510D 00	4.3552044D 01	1.0477581D 01	1.9750382D 00	50.2617444	1.0964877
10	1.0673976D 00	4.9253293D-02	1.4675284D 00	4.2954537D 01	1.0951003D 01	2.2340817D 00	50.3827712	1.2190380
11	1.0722446D 00	5.4105606D-02	1.4834805D 00	4.2383557D 01	1.1419191D 01	2.4899576D 00	50.5027359	1.3391346
12	1.0765189D 00	5.8341751D-02	1.4974120D 00	4.1898947D 01	1.1828998D 01	2.7130431D 00	50.6085268	1.4439809
13	1.0808722D 00	6.2617781D-02	1.5114323D 00	4.1423853D 01	1.2242133D 01	2.9368256D 00	50.7162740	1.5498143
14	1.0853057D 00	6.6935190D-02	1.5255217D 00	4.0958596D 01	1.2657888D 01	3.1608768D 00	50.8260034	1.6566718
15	1.0898199D 00	7.1295186D-02	1.5396676D 00	4.0503225D 01	1.3075769D 01	3.3849605D 00	50.9377333	1.7645834
16	1.0944157D 00	7.5698866D-02	1.5538617D 00	4.0057640D 01	1.3495408D 01	3.6089397D 00	51.0514789	1.8735762
17	1.0990934D 00	8.0147282D-02	1.5680984D 00	3.9621650D 01	1.3916522D 01	3.8327349D 00	51.1672544	1.9836762
18	1.1038537D 00	8.4641474D-02	1.5823741D 00	3.9195011D 01	1.4338888D 01	4.0563007D 00	51.2850733	2.0949092
19	1.1086971D 00	8.9182484D-02	1.5966864D 00	3.8777452D 01	1.4762330D 01	4.2796137D 00	51.4049497	2.2073009
20	1.1136242D 00	9.3771365D-02	1.6110340D 00	3.8368686D 01	1.5186702D 01	4.5026636D 00	51.5268977	2.3208775
21	1.1186356D 00	9.8409188D-02	1.6254163D 00	3.7968417D 01	1.5611886D 01	4.7254490D 00	51.6509323	2.4356654
22	1.1237320D 00	1.0309704D-01	1.6398332D 00	3.7576353D 01	1.6037782D 01	4.9479737D 00	51.7770691	2.5516916
23	1.1289139D 00	1.0783604D-01	1.6542850D 00	3.7192205D 01	1.6466307D 01	5.1702450D 00	51.9053245	2.6689836
24	1.1341822D 00	1.1262731D-01	1.6687725D 00	3.6815691D 01	1.6891391D 01	5.3922722D 00	52.0357158	2.7875693
25	1.1395375D 00	1.1747201D-01	1.6832964D 00	3.6446537D 01	1.7318974D 01	5.6140656D 00	52.1682609	2.9074775
26	1.1449805D 00	1.2237132D-01	1.6978579D 00	3.6084479D 01	1.7747003D 01	5.8356361D 00	52.3029789	3.0287375
27	1.1505122D 00	1.2732645D-01	1.7124581D 00	3.5729263D 01	1.8175434D 01	6.0569948D 00	52.4398896	3.1513789
28	1.1561333D 00	1.3233864D-01	1.7270984D 00	3.5380647D 01	1.8604228D 01	6.2781524D 00	52.5790137	3.2754324
29	1.1618447D 00	1.3740913D-01	1.7417801D 00	3.5038398D 01	1.9033351D 01	6.4991195D 00	52.7203729	3.4009291
30	1.1676473D 00	1.4253922D-01	1.7565049D 00	3.4702291D 01	1.9462774D 01	6.7199063D 00	52.8639897	3.5279008
31	1.1735420D 00	1.4773022D-01	1.7712741D 00	3.4372115D 01	1.9892469D 01	6.9405224D 00	53.0098876	3.6563799
32	1.1795300D 00	1.5298346D-01	1.7860893D 00	3.4047666D 01	2.0322414D 01	7.1609771D 00	53.1580910	3.7863997
33	1.1856121D 00	1.5830031D-01	1.8009522D 00	3.3728750D 01	2.0752588D 01	7.3812790D 00	53.3086250	3.9179939
34	1.1917894D 00	1.6368218D-01	1.8158643D 00	3.3415182D 01	2.1182972D 01	7.6014363D 00	53.4615161	4.0511971
35	1.1980630D 00	1.6913048D-01	1.8308274D 00	3.3106784D 01	2.1613549D 01	7.8214568D 00	53.6167912	4.1860447
36	1.2044341D 00	1.7464668D-01	1.8458429D 00	3.2803388D 01	2.2044305D 01	8.0413476D 00	53.7744785	4.3225728
37	1.2109039D 00	1.8023227D-01	1.8609127D 00	3.2504831D 01	2.2475227D 01	8.2611156D 00	53.9346070	4.4608182
38	1.2174734D 00	1.8588875D-01	1.8760383D 00	3.2210961D 01	2.2906301D 01	8.4807671D 00	54.0972066	4.6008185
39	1.2241441D 00	1.9161770D-01	1.8912215D 00	3.1921629D 01	2.3337518D 01	8.7003082D 00	54.2623083	4.7426121
40	1.2309172D 00	1.9742070D-01	1.9064640D 00	3.1636695D 01	2.3768868D 01	8.9197445D 00	54.4299439	4.8862385
CONTOUR	1.2173753D 00	1.8580425D-01	1.8758124D 00					

M A C H 4 INTERMEDIATE LEFT CHARACTERISTIC

CHARACT 21

POINT	X	Y	MACH NO.	MACH ANG.(D)	PSI (D)	FLOW ANG.(D)	X(IN)	Y(IN)
1	9.4011759D-01	0.0	1.0847778D 00	6.7197722D 01	1.0529074D 00	0.0	47.2325420	0.0
2	9.4212238D-01	4.6946459D-03	1.0905075D 00	6.6491982D 01	1.1573065D 00	5.3009134D-02	47.2821613	0.1161943
3	9.4493824D-01	1.1049675D-02	1.0988787D 00	6.5507920D 01	1.3146987D 00	1.3560221D-01	47.3518550	0.2734837
4	9.4808475D-01	1.7847363D-02	1.1086461D 00	6.4422365D 01	1.5051524D 00	2.3899145D-01	47.4297324	0.4417291
5	9.5141846D-01	2.4733173D-02	1.1194327D 00	6.3292125D 01	1.7233478D 00	3.6109650D-01	47.5122430	0.6121556
6	9.5486697D-01	3.1548019D-02	1.1310294D 00	6.2147143D 01	1.9663934D 00	5.0074527D-01	47.5975949	0.7808257
7	9.5838729D-01	3.8214498D-02	1.1432954D 00	6.1005303D 01	2.2322159D 00	6.5698840D-01	47.6847242	0.9458236
8	9.6195123D-01	4.4695078D-02	1.1561254D 00	5.9877919D 01	2.5190656D 00	8.2891323D-01	47.7729330	1.1062204
9	9.6553893D-01	5.0973234D-02	1.1694342D 00	5.8772370D 01	2.8253199D 00	1.0155778D 00	47.8617301	1.2616072
10	9.6913571D-01	5.7044031D-02	1.1831495D 00	5.7693554D 01	3.1493948D 00	1.2159851D 00	47.9507518	1.4118618
11	9.7273033D-01	6.2909139D-02	1.1972071D 00	5.6644735D 01	3.4897026D 00	1.4290723D 00	48.0397199	1.5570255
12	9.7631404D-01	6.8574104D-02	1.2115481D 00	5.5628075D 01	3.8446317D 00	1.6537065D 00	48.1284183	1.6972356
13	9.7988011D-01	7.4046827D-02	1.2261177D 00	5.4644985D 01	4.2125368D 00	1.8886814D 00	48.2166797	1.8326876
14	9.8342344D-01	7.9336723D-02	1.2408634D 00	5.3696343D 01	4.5917389D 00	2.1327199D 00	48.3043787	1.9636145
15	9.8694052D-01	8.4454275D-02	1.2557343D 00	5.2782652D 01	4.9805251D 00	2.3844715D 00	48.3914278	2.0902759
16	9.9042931D-01	8.9410827D-02	1.2706808D 00	5.1904149D 01	5.3771548D 00	2.6425156D 00	48.4777766	2.2129525
17	9.9388928D-01	9.4218525D-02	1.2856542D 00	5.1060870D 01	5.7798662D 00	2.9053620D 00	48.5634121	2.3319449
18	9.9732146D-01	9.8890353D-02	1.3006064D 00	5.0252712D 01	6.1868830D 00	3.1714519D 00	48.6483600	2.4475744
19	1.0007286D 00	1.0344023D-01	1.3154898D 00	4.9479464D 01	6.5964232D 00	3.4391599D 00	48.7326871	2.5601856
20	1.0041151D 00	1.0788315D-01	1.3302571D 00	4.8740840D 01	7.0067077D 00	3.7067953D 00	48.8165045	2.6701496
21	1.0074874D 00	1.1223536D-01	1.3448616D 00	4.8036500D 01	7.4159665D 00	3.9726023D 00	48.8999711	2.7778684
22	1.0104769D 00	1.1603809D-01	1.3576597D 00	4.7439335D 01	7.7772045D 00	4.2057291D 00	48.9739616	2.8719875
23	1.0135379D 00	1.1988226D-01	1.3705828D 00	4.6854265D 01	8.1442146D 00	4.4408653D 00	49.0497224	2.9671322
24	1.0166720D 00	1.2377030D-01	1.3836113D 00	4.6281692D 01	8.5162983D 00	4.6774038D 00	49.1272938	3.0633628
25	1.0198803D 00	1.2770381D-01	1.3967306D 00	4.5721739D 01	8.8928936D 00	4.9149073D 00	49.2066996	3.1607185
26	1.0231633D 00	1.3168392D-01	1.4099297D 00	4.5174352D 01	9.2735319D 00	5.1530474D 00	49.2879551	3.2592280
27	1.0265214D 00	1.3571158D-01	1.4231997D 00	4.4639364D 01	9.6578149D 00	5.3915729D 00	49.3710703	3.3589140
28	1.0299550D 00	1.3978754D-01	1.4365340D 00	4.4116531D 01	1.0045399D 01	5.6302890D 00	49.4560528	3.4597957
29	1.0334643D 00	1.4391252D-01	1.4499272D 00	4.3605560D 01	1.0435986D 01	5.8690437D 00	49.5429083	3.5618906
30	1.0370494D 00	1.4808719D-01	1.4633750D 00	4.3106126D 01	1.0829314D 01	6.1077187D 00	49.6316417	3.6652151
31	1.0407106D 00	1.5231219D-01	1.4768742D 00	4.2617886D 01	1.1225152D 01	6.3462212D 00	49.7222577	3.7697855
32	1.0444480D 00	1.5658818D-01	1.4904223D 00	4.2140488D 01	1.1623294D 01	6.5844792D 00	49.8147608	3.8756179
33	1.0482619D 00	1.6091583D-01	1.5040174D 00	4.1673576D 01	1.2023557D 01	6.8224369D 00	49.9091562	3.9827290
34	1.0521525D 00	1.6529583D-01	1.5176580D 00	4.1216796D 01	1.2425778D 01	7.0600517D 00	50.0054492	4.0911356
35	1.0561200D 00	1.6972889D-01	1.5313431D 00	4.0769801D 01	1.2829810D 01	7.2972913D 00	50.1036461	4.2008556
36	1.0601647D 00	1.7421576D-01	1.5450721D 00	4.0332252D 01	1.3235519D 01	7.5341321D 00	50.2037536	4.3119073
CONTOUR	1.0496494D 00	1.6247788D-01	1.5088820D 00					

M A C H 4   INTERMEDIATE LEFT CHARACTERISTIC

CHARACT 31

POINT	X	Y	MACH NO.	MACH ANG.(D)	PSI (D)	FLOW ANG.(D)	X(IN)	Y(IN)
11	9.14718090-01	7.56095150-02	1.03683250 00	7.46823080 01	3.10755610-01	2.53527570-01	46.6038946	1.8713647
12	9.15711220-01	7.91859510-02	1.04192150 00	7.36918210 01	3.76114380-01	3.06001260-01	46.6284751	1.9598829
13	9.17162560-01	8.40518470-02	1.04938900 00	7.23517030 01	4.78689270-01	3.87991910-01	46.6643962	2.0803157
14	9.18853930-01	8.92881310-02	1.05813020 00	7.09200330 01	6.07873660-01	4.90781660-01	46.7062582	2.2099157
15	9.20714500-01	9.46217330-02	1.06781060 00	6.94711340 01	7.61227310-01	6.12346590-01	46.7523082	2.3419244
16	9.22702420-01	9.99262960-02	1.07824340 00	6.80383530 01	9.37357630-01	7.51554850-01	46.8015100	2.4732144
17	9.24788370-01	1.05137480-01	1.08930190 00	6.66381920 01	1.13510870 00	9.07491690-01	46.8531380	2.6021932
18	9.26950050-01	1.10221810-01	1.10089080 00	6.52790510 01	1.35335030 00	1.07927670 00	46.9066404	2.7280323
19	9.29169780-01	1.15162560-01	1.11293260 00	6.39651230 01	1.59090910 00	1.26599980 00	46.9615796	2.8503177
20	9.31433170-01	1.19952640-01	1.12536110 00	6.26983010 01	1.84654810 00	1.46669700 00	47.0175993	2.9688742
21	9.33728400-01	1.24590810-01	1.13811770 00	6.14791890 01	2.11896060 00	1.68034090 00	47.0744071	3.0836706
22	9.36045780-01	1.29079520-01	1.15114850 00	6.03076520 01	2.40677370 00	1.90583670 00	47.1317633	3.1947680
23	9.38377500-01	1.33423740-01	1.16440300 00	5.91831400 01	2.70855290 00	2.14202100 00	47.1894742	3.3022891
24	9.40717440-01	1.37630250-01	1.17783350 00	5.81048550 01	3.02281170 00	2.38766490 00	47.2473887	3.4064020
25	9.43061140-01	1.41707310-01	1.19139370 00	5.70718740 01	3.34801830 00	2.64147270 00	47.3053961	3.5073107
26	9.45405730-01	1.45664420-01	1.20503890 00	5.60832050 01	3.68260680 00	2.90208590 00	47.3634256	3.6052506
27	9.47749990-01	1.49512320-01	1.21872540 00	5.51378230 01	4.02498770 00	3.16808560 00	47.4214470	3.7004876
28	9.50094390-01	1.53262980-01	1.23241050 00	5.42346980 01	4.37355740 00	3.43799390 00	47.4794717	3.7933180
29	9.52441160-01	1.56929740-01	1.24605260 00	5.33728030 01	4.72670930 00	3.71027690 00	47.5375552	3.8840716
30	9.54794400-01	1.60527350-01	1.25961050 00	5.25511210 01	5.08284540 00	3.98334740 00	47.5957989	3.9731140
31	9.57160230-01	1.64072230-01	1.27304450 00	5.17686560 01	5.44038350 00	4.25556470 00	47.6543542	4.0608510
CONTOUR	9.49893690-01	1.52941900-01	1.23123900 00					

M A C H 4   UPSTREAM CONTOUR, SMOOTHED   50 TIMES WITH FACTOR=0.85

	X	Y-CALC	Y-IN	DIFF	
1	0.8933835	0.1512190	0.1512190	0.0	1
2	0.8981780	0.1512317	0.1512316	0.0000001	2
3	0.9031363	0.1512714	0.1512712	0.0000002	3
4	0.9082511	0.1513406	0.1513403	0.0000002	4
5	0.9135380	0.1514422	0.1514422	0.0000000	5
6	0.9189965	0.1515789	0.1515787	0.0000003	6
7	0.9246596	0.1517547	0.1517539	0.0000009	7
8	0.9305367	0.1519731	0.1519726	0.0000005	8
9	0.9366783	0.1522399	0.1522387	0.0000012	9
10	0.9431175	0.1525609	0.1525592	0.0000017	10
11	0.9498937	0.1529430	0.1529419	0.0000011	11
12	0.9570730	0.1533955	0.1533942	0.0000014	12
13	0.9647004	0.1539274	0.1539264	0.0000009	13
14	0.9728364	0.1545491	0.1545491	0.0	14
15	0.9815448	0.1552720	0.1552734	-0.0000014	15
16	0.9908919	0.1561084	0.1561105	-0.0000022	16
17	1.0009363	0.1570703	0.1570737	-0.0000035	17
18	1.0117627	0.1581731	0.1581767	-0.0000036	18
19	1.0234319	0.1594306	0.1594343	-0.0000037	19
20	1.0360337	0.1608591	0.1608628	-0.0000036	20
21	1.0496494	0.1624749	0.1624779	-0.0000030	21
22	1.0586537	0.1635797	0.1635826	-0.0000029	22
23	1.0715645	0.1652082	0.1652117	-0.0000036	23
24	1.0863627	0.1671320	0.1671360	-0.0000040	24
25	1.1024792	0.1692874	0.1692926	-0.0000052	25
26	1.1196438	0.1716423	0.1716478	-0.0000054	26
27	1.1376982	0.1741740	0.1741802	-0.0000061	27
28	1.1565561	0.1768682	0.1768733	-0.0000051	28
29	1.1761470	0.1797114	0.1797158	-0.0000044	29
30	1.1964348	0.1826928	0.1826961	-0.0000032	30
31	1.2173753	0.1858020	0.1858043	-0.0000022	31
32	1.2389456	0.1890300	0.1890304	-0.0000004	32
33	1.2611122	0.1923669	0.1923672	-0.0000004	33
34	1.2838486	0.1958053	0.1958053	0.0	34
35	1.3071231	0.1993364	0.1993364	0.0	35
36	1.3309005	0.2029516	0.2029521	-0.0000005	36
37	1.3551440	0.2066430	0.2066430	0.0	37
38	1.3798149	0.2104028	0.2104028	0.0	38
39	1.4048689	0.2142226	0.2142226	0.0	39
40	1.4302636	0.2180949	0.2180949	0.0	40
41	1.4559664	0.2220140	0.2220140	0.0	41

MAX. ABSOLUTE ERROR =   6.126897D-06   AT POINT   27

M A C H 4   INTERMEDIATE RIGHT CHARACTERISTIC

LAST POINT	X	Y	MACH NO.	MACH ANG.(D)	PSI (D)	FLOW ANG.(D)	X(IN)	Y(IN)
1	1.1406830D 00	0.0	1.6601538D 00	3.7038665D 01	1.6637379D 01	0.0	52.1966126	0.0
2	1.1341318D 00	4.9613543D-03	1.6431841D 00	3.7486504D 01	1.6136718D 01	2.5022628D-01	52.0344692	0.1227954
3	1.1275127D 00	1.0011767D-02	1.6258503D 00	3.7956481D 01	1.5624713D 01	5.0524583D-01	51.8706443	0.2477951
4	1.1208237D 00	1.5157130D-02	1.6082341D 00	3.8447702D 01	1.5103900D 01	7.6301523D-01	51.7050870	0.3751448
5	1.1140644D 00	2.0402261D-02	1.5904149D 00	3.8959195D 01	1.4576790D 01	1.0215567D 00	51.5377939	0.5049638
6	1.1072367D 00	2.5750960D-02	1.5724705D 00	3.9489885D 01	1.4045870D 01	1.2789887D 00	51.3688057	0.6373462
7	1.1003439D 00	3.1206016D-02	1.5544769D 00	4.0038577D 01	1.3513601D 01	1.5335178D 00	51.1982044	0.7723609
8	1.0933908D 00	3.6769168D-02	1.5365084D 00	4.0603927D 01	1.2982411D 01	1.7834439D 00	51.0261121	0.9100511
9	1.0863840D 00	4.2440986D-02	1.5186381D 00	4.1184413D 01	1.2454700D 01	2.0271575D 00	50.8526913	1.0504308
10	1.0793318D 00	4.8220652D-02	1.5009381D 00	4.1778292D 01	1.1932841D 01	2.2631387D 00	50.6781476	1.1934798
11	1.0722446D 00	5.4105606D-02	1.4834805D 00	4.2383557D 01	1.1419191D 01	2.4899576D 00	50.5027359	1.3391346
12	1.0651350D 00	6.0090970D-02	1.4663377D 00	4.2997869D 01	1.0916107D 01	2.7062691D 00	50.3267714	1.4872747
13	1.0580190D 00	6.6168647D-02	1.4495844D 00	4.3618467D 01	1.0425974D 01	2.9108096D 00	50.1506482	1.6376996
14	1.0509170D 00	7.2325891D-02	1.4332992D 00	4.4242048D 01	9.9512498D 00	3.1023900D 00	49.9748707	1.7900937
15	1.0438559D 00	7.8542967D-02	1.4175682D 00	4.4864571D 01	9.4945492D 00	3.2798849D 00	49.8001059	1.9439688
16	1.0368730D 00	8.4789186D-02	1.4024901D 00	4.5480961D 01	9.0587823D 00	3.4422132D 00	49.6272753	2.0985651
17	1.0300224D 00	9.1015793D-02	1.3881863D 00	4.6084575D 01	8.6474172D 00	3.5883009D 00	49.4577215	2.2526760
18	1.0233888D 00	9.7142147D-02	1.3748202D 00	4.6666182D 01	8.2650122D 00	3.7169967D 00	49.2935376	2.4043057
19	1.0171168D 00	1.0302534D-01	1.3626422D 00	4.7211679D 01	7.9184507D 00	3.8268534D 00	49.1383024	2.5499170
20	1.0114948D 00	1.0837595D-01	1.3521227D 00	4.7695466D 01	7.6206355D 00	3.9153593D 00	48.9991555	2.6823466
21	1.0074874D 00	1.1223536D-01	1.3448616D 00	4.8036500D 01	7.4159665D 00	3.9726023D 00	48.8999711	2.7778684
22	1.0012857D 00	1.1828424D-01	1.3340277D 00	4.8556572D 01	7.1120522D 00	4.0514822D 00	48.7464767	2.9275806
23	9.9538551D-01	1.2412624D-01	1.3241927D 00	4.9040845D 01	6.8377692D 00	4.1154037D 00	48.6004446	3.0721723
24	9.8977348D-01	1.2976290D-01	1.3152829D 00	4.9490008D 01	6.5907029D 00	4.1659900D 00	48.4615445	3.2116818
25	9.8443513D-01	1.3519767D-01	1.3072261D 00	4.9905087D 01	6.3685182D 00	4.2047418D 00	48.3294183	3.3461946
26	9.7935466D-01	1.4043627D-01	1.2999520D 00	5.0287409D 01	6.1689727D 00	4.2330288D 00	48.2036747	3.4758520
27	9.7451475D-01	1.4548697D-01	1.2933924D 00	5.0638560D 01	5.9899283D 00	4.2520837D 00	48.0838852	3.6008587
28	9.6989649D-01	1.5036081D-01	1.2874818D 00	5.0960326D 01	5.8293626D 00	4.2629967D 00	47.9695814	3.7214882
29	9.6547939D-01	1.5507163D-01	1.2821582D 00	5.1254622D 01	5.6853846D 00	4.2667108D 00	47.8602565	3.8380827

M A C H 4 UPSTREAM CONTOUR

RC= 6.000000 ETAD= 8.6700 DEG AMACH= 2.2878437 BMACH= 3.0821543 CMACH= 4.0000000 EMACH= 1.6601538 GMACH= 2.2878437

WALL POINT	X	Y	MACH NO.	FLOW ANG.(D)	WALTAN	SECDIF
1	8.9338351D-01	1.5121903D-01	1.0471638D 00	0.0	0.0	1.1021541D 00
2	8.9817803D-01	1.5123170D-01	1.0626027D 00	3.0245925D-01	5.2789588D-03	1.0996321D 00
3	9.0313629D-01	1.5127139D-01	1.0786293D 00	6.1441645D-01	1.0724001D-02	1.0968392D 00
4	9.0825111D-01	1.5134059D-01	1.0952300D 00	9.3538991D-01	1.6327084D-02	1.0926953D 00
5	9.1353801D-01	1.5144220D-01	1.1124932D 00	1.2653979D 00	2.2088951D-02	1.0855826D 00
6	9.1899646D-01	1.5157894D-01	1.1303552D 00	1.6033225D 00	2.7990563D-02	1.0751564D 00
7	9.2465957D-01	1.5175473D-01	1.1489592D 00	1.9498158D 00	3.4043849D-02	1.0607205D 00
8	9.3053668D-01	1.5197313D-01	1.1682305D 00	2.3036495D 00	4.0227947D-02	1.0426474D 00
9	9.3667828D-01	1.5223987D-01	1.1883589D 00	2.6663346D 00	4.6569941D-02	1.0191646D 00
10	9.4311748D-01	1.5256093D-01	1.2093556D 00	3.0362174D 00	5.3041650D-02	9.8791142D-01
11	9.4989369D-01	1.5294304D-01	1.2312390D 00	3.4115784D 00	5.9613744D-02	9.4952199D-01
12	9.5707300D-01	1.5339554D-01	1.2541190D 00	3.7917793D 00	6.6275817D-02	9.0305903D-01
13	9.6470038D-01	1.5392737D-01	1.2779433D 00	4.1730231D 00	7.2962051D-02	8.4722246D-01
14	9.7283636D-01	1.5454907D-01	1.3026785D 00	4.5511485D 00	7.9600009D-02	7.8409951D-01
15	9.8154483D-01	1.5527196D-01	1.3283469D 00	4.9228566D 00	8.6132110D-02	7.1749170D-01
16	9.9089189D-01	1.5610837D-01	1.3550399D 00	5.2854769D 00	9.2511544D-02	6.5053418D-01
17	1.0009363D 00	1.5707028D-01	1.3829205D 00	5.6368754D 00	9.8700684D-02	5.8644040D-01
18	1.0117627D 00	1.5817310D-01	1.4120873D 00	5.9772441D 00	1.0470270D-01	5.2474031D-01
19	1.0234319D 00	1.5943060D-01	1.4427244D 00	6.3029481D 00	1.1045311D-01	4.6410130D-01
20	1.0360337D 00	1.6085912D-01	1.4749409D 00	6.6117213D 00	1.1591127D-01	4.0788671D-01
21	1.0496494D 00	1.6247489D-01	1.5088820D 00	6.9045359D 00	1.2109362D-01	3.5309811D-01
22	1.0586537D 00	1.6357969D-01	1.5308817D 00	7.0747554D 00	1.2410917D-01	3.1909219D-01
23	1.0715645D 00	1.6520817D-01	1.5618623D 00	7.2906021D 00	1.2793624D-01	2.7973569D-01
24	1.0863627D 00	1.6713198D-01	1.5966017D 00	7.5078996D 00	1.3179276D-01	2.4342529D-01
25	1.1024792D 00	1.6928744D-01	1.6335898D 00	7.7117619D 00	1.3541435D-01	2.0780700D-01
26	1.1196438D 00	1.7164233D-01	1.6720611D 00	7.8949827D 00	1.3867221D-01	1.7414320D-01
27	1.1376982D 00	1.7417403D-01	1.7116110D 00	8.0549464D 00	1.4151890D-01	1.4430635D-01
28	1.1565561D 00	1.7686825D-01	1.7519140D 00	8.1929694D 00	1.4397695D-01	1.1771595D-01
29	1.1761470D 00	1.7971142D-01	1.7928312D 00	8.3079571D 00	1.4602606D-01	9.3849670D-02
30	1.1964348D 00	1.8269284D-01	1.8341515D 00	8.4020831D 00	1.4770430D-01	7.3736928D-02
31	1.2173753D 00	1.8580201D-01	1.8758124D 00	8.4777598D 00	1.4905419D-01	5.6290407D-02
32	1.2389456D 00	1.8903000D-01	1.9176407D 00	8.5356298D 00	1.5008681D-01	4.1891545D-02
33	1.2611122D 00	1.9236687D-01	1.9595949D 00	8.5800232D 00	1.5087917D-01	3.0945147D-02
34	1.2838486D 00	1.9580533D-01	2.0015440D 00	8.6131638D 00	1.5147080D-01	2.1778656D-02
35	1.3071231D 00	1.9933644D-01	2.0434024D 00	8.6358918D 00	1.5187660D-01	1.4512271D-02
36	1.3309005D 00	2.0295157D-01	2.0850968D 00	8.6512393D 00	1.5215065D-01	9.4814587D-03
37	1.3551440D 00	2.0664295D-01	2.1265044D 00	8.6612814D 00	1.5232998D-01	5.7476131D-03
38	1.3798149D 00	2.1040276D-01	2.1675528D 00	8.6669028D 00	1.5243037D-01	2.9135948D-03
39	1.4048689D 00	2.1422257D-01	2.2081710D 00	8.6693439D 00	1.5247397D-01	1.0425217D-03
40	1.4302636D 00	2.1809487D-01	2.2482849D 00	8.6698209D 00	1.5248249D-01	2.3058018D-04
41	1.4559664D 00	2.2201404D-01	2.2878437D 00	8.6700000D 00	1.5248569D-01	0.0

M A C H 4   UPSTREAM CONTOUR

RC= 6.000000   ETAD= 8.6700 DEG   AMACH= 2.2878437   BMACH= 3.0821543   CMACH= 4.0000000   EMACH= 1.6601538   GMACH= 2.2878437

POINT	X/YO	Y/YO	INT.Y/YO	PAR/YO	HYP/YO	C(Y)	C(YI)	C(YP)
1	0.0	1.0000000	1.0000088	1.0000000	1.0000000			
2	0.0317058	1.0000838	1.0000929	1.0000838	1.0000838	-9.027028D-04	-2.852807D-01	1.771458D-03
3	0.0644944	1.0003463	1.0003562	1.0003466	1.0003466	1.335669D-03	-3.549911D-02	2.008653D-03
4	0.0983183	1.0008039	1.0008144	1.0008055	1.0008052	1.755874D-03	-9.341050D-03	2.045023D-03
5	0.1332802	1.0014758	1.0014864	1.0014803	1.0014792	1.894462D-03	-2.575465D-03	2.334730D-03
6	0.1693765	1.0023801	1.0023903	1.0023907	1.0023878	2.183707D-03	8.706624D-05	2.775271D-03
7	0.2068262	1.0035425	1.0035516	1.0035648	1.0035584	2.514029D-03	1.483045D-03	3.328814D-03
8	0.2456911	1.0049868	1.0049947	1.0050303	1.0050178	2.936302D-03	2.401355D-03	3.979032D-03
9	0.2863051	1.0067508	1.0067572	1.0068309	1.0068077	3.414329D-03	3.140626D-03	4.666592D-03
10	0.3288870	1.0088739	1.0088791	1.0090139	1.0089736	3.935851D-03	3.788562D-03	5.463341D-03
11	0.3736976	1.0114008	1.0114059	1.0116375	1.0115706	4.536391D-03	4.438139D-03	6.371137D-03
12	0.4211738	1.0143931	1.0143998	1.0147823	1.0146746	5.208751D-03	5.118797D-03	7.365824D-03
13	0.4716131	1.0179100	1.0179204	1.0185349	1.0183662	5.957219D-03	5.858147D-03	8.452715D-03
14	0.5254157	1.0220213	1.0220373	1.0230051	1.0227464	6.782668D-03	6.672634D-03	9.622585D-03
15	0.5830041	1.0268017	1.0268248	1.0283245	1.0279343	7.684559D-03	7.568188D-03	1.082225D-02
16	0.6448156	1.0323328	1.0323620	1.0346489	1.0340686	8.638715D-03	8.530062D-03	1.199149D-02
17	0.7112386	1.0386939	1.0387293	1.0421550	1.0413021	9.620060D-03	9.521659D-03	1.307283D-02
18	0.7828325	1.0459867	1.0460258	1.0510689	1.0498275	1.059354D-02	1.051204D-02	1.401668D-02
19	0.8600004	1.0543025	1.0543411	1.0616334	1.0598428	1.152555D-02	1.146479D-02	1.481894D-02
20	0.9433346	1.0637492	1.0637853	1.0741567	1.0715938	1.239789D-02	1.235492D-02	1.547443D-02
21	1.0333747	1.0744341	1.0744669	1.0889886	1.0853466	1.318935D-02	1.315968D-02	1.596194D-02
22	1.0929194	1.0817401	1.0817717	1.0995394	1.0950246	1.363447D-02	1.361026D-02	1.619796D-02
23	1.1782974	1.0925091	1.0925435	1.1156987	1.1096835	1.417519D-02	1.415420D-02	1.643316D-02
24	1.2761568	1.1052311	1.1052701	1.1357147	1.1275768	1.466742D-02	1.464866D-02	1.655844D-02
25	1.3827342	1.1194850	1.1195301	1.1593295	1.1483288	1.507135D-02	1.505430D-02	1.656967D-02
26	1.4962419	1.1350577	1.1351040	1.1865616	1.1718034	1.537570D-02	1.536189D-02	1.648270D-02
27	1.6156349	1.1517997	1.1518474	1.2175230	1.1979341	1.558439D-02	1.557308D-02	1.631418D-02
28	1.7403406	1.1696163	1.1696609	1.2523988	1.2267019	1.570491D-02	1.569645D-02	1.607683D-02
29	1.8698934	1.1884180	1.1884549	1.2913751	1.2580740	1.574729D-02	1.574165D-02	1.578939D-02
30	2.0040550	1.2081339	1.2081635	1.3346864	1.2920421	1.572322D-02	1.571955D-02	1.546264D-02
31	2.1425332	1.2286946	1.2287147	1.3825374	1.3285612	1.564207D-02	1.564003D-02	1.510634D-02
32	2.2851759	1.2500411	1.2500531	1.4351691	1.3676031	1.551362D-02	1.551261D-02	1.473092D-02
33	2.4317621	1.2721076	1.2721171	1.4927889	1.4091053	1.534625D-02	1.534559D-02	1.434097D-02
34	2.5821161	1.2948458	1.2948518	1.5556103	1.4530040	1.514681D-02	1.514646D-02	1.394272D-02
35	2.7360289	1.3181968	1.3182015	1.6238212	1.4992139	1.492196D-02	1.492173D-02	1.354235D-02
36	2.8932668	1.3421034	1.3421088	1.6975827	1.5476322	1.467739D-02	1.467717D-02	1.314302D-02
37	3.0535872	1.3665142	1.3665203	1.7770329	1.5981445	1.441790D-02	1.441769D-02	1.274797D-02
38	3.2167339	1.3913775	1.3913815	1.8622814	1.6506250	1.414773D-02	1.414761D-02	1.236036D-02
39	3.3824143	1.4166376	1.4166393	1.9533938	1.7049304	1.387065D-02	1.387060D-02	1.198239D-02
40	3.5503471	1.4422449	1.4422444	2.0504137	1.7609166	1.358976D-02	1.358977D-02	1.161558D-02
41	3.7203183	1.4681620	1.4681620	2.1533973	1.8184594	1.330759D-02	1.330759D-02	1.126063D-02

ICY = -284377

M A C H 4 DOWNSTREAM CONTOUR, 4TH-DEG AXIAL MACH NUMBER DISTRIBUTION

NO. OF POINTS ON 1ST CHAR. (M)= 41 NO. OF POINTS ON AXIS (N)= 49 NO. OF POINTS ON LAST CHAR. (NP)= 61

GAMMA= 1.4000 INFLECTION ANG. (ETA)= 8.6700 DEGREES RAD. OF CURV. (RC)= 6.00000000 SCALE FACTOR (SF)= 24.750386

BMACH= 3.08215 BMP= 0.98284937 BMPP= -4.3579323D-01 BMPPP= -3.9863251D-01 SMPP= -4.3579323D-01

CMACH= 4.00000 CMP= 0.0 CMPP= 0.0 CMPPP= 7.8811750D-01 SMPPP= 5.3283530D-01

C1= 3.0821543 C2= 2.19941261 C3= -1.0911639D 00 C4= -7.4452744D-01 C5= 5.5412437D-01 C6= 0.0

AMACH= 2.2878437 XA= 1.4559664 XB= 2.1398501 XBC= 2.2377922 XC= 4.3776423 XD= 6.2945435

XA(IN)= 60.0000000, YA(IN)= 5.4949332, XB(IN)= 76.9263852, XC(IN)= 132.3126057, XD(IN)= 179.7566517, YD(IN)= 12.2500000

AXIS POINT	X	X(IN)	MACH NO.	DM/DX	D2M/DX2	D3M/DX3	W=Q/A*	DW/DX	D2W/DX2	D3W/DX3
1	2.13985	76.92639	3.082154	9.828494D-01	-4.357932D-01	-3.986325D-01	1.982672	2.180194D-01	-2.333161D-01	1.925083D-01
3	2.23309	79.23414	3.171850	9.405542D-01	-4.706570D-01	-3.491846D-01	2.002012	1.970900D-01	-2.157468D-01	1.839255D-01
5	2.32633	81.54190	3.257457	8.952233D-01	-5.009101D-01	-2.997367D-01	2.019476	1.777583D-01	-1.990784D-01	1.733650D-01
7	2.41957	83.84966	3.338713	8.472865D-01	-5.265527D-01	-2.502888D-01	2.035208	1.599330D-01	-1.834491D-01	1.617701D-01
9	2.51282	86.15742	3.415394	7.971736D-01	-5.475846D-01	-2.008408D-01	2.049344	1.435139D-01	-1.689213D-01	1.498375D-01
11	2.60606	88.46518	3.487317	7.453147D-01	-5.640060D-01	-1.513929D-01	2.062011	1.283976D-01	-1.555017D-01	1.380698D-01
13	2.69930	90.77294	3.554341	6.921396D-01	-5.758168D-01	-1.019450D-01	2.073325	1.144821D-01	-1.431575D-01	1.268202D-01
15	2.79254	93.08070	3.616362	6.380782D-01	-5.830170D-01	-5.249709D-02	2.083394	1.016696D-01	-1.318283D-01	1.163301D-01
17	2.88578	95.38846	3.673317	5.835603D-01	-5.856066D-01	-3.049173D-03	2.092316	8.986926D-02	-1.214353D-01	1.067592D-01
19	2.97902	97.69622	3.725185	5.290160D-01	-5.835856D-01	4.639874D-02	2.100182	7.899777D-02	-1.118878D-01	9.820936D-02
21	3.07226	100.00398	3.771982	4.748750D-01	-5.769540D-01	9.584666D-02	2.107075	6.898090D-02	-1.030873D-01	9.074235D-02
23	3.16550	102.31174	3.813767	4.215673D-01	-5.657119D-01	1.452946D-01	2.113070	5.975375D-02	-9.493112D-02	8.439370D-02
25	3.25875	104.61950	3.850637	3.695228D-01	-5.498591D-01	1.947425D-01	2.118240	5.126114D-02	-8.731398D-02	7.918227D-02
27	3.35199	106.92725	3.882729	3.191714D-01	-5.293958D-01	2.441904D-01	2.122651	4.345776D-02	-8.012937D-02	7.511689D-02
29	3.44523	109.23501	3.910222	2.709430D-01	-5.043218D-01	2.936383D-01	2.126365	3.630828D-02	-7.327027D-02	7.220029D-02
31	3.53847	111.54277	3.933335	2.252675D-01	-4.746373D-01	3.430862D-01	2.129441	2.978733D-02	-6.662961D-02	7.043084D-02
33	3.63171	113.85053	3.952324	1.825747D-01	-4.403422D-01	3.925342D-01	2.131939	2.387954D-02	-6.010067D-02	6.980227D-02
35	3.72495	116.15829	3.967488	1.432946D-01	-4.014365D-01	4.419821D-01	2.133913	1.857942D-02	-5.357763D-02	7.030152D-02
37	3.81819	118.46605	3.979165	1.078570D-01	-3.579202D-01	4.914300D-01	2.135422	1.389130D-02	-4.695632D-02	7.190485D-02
39	3.91144	120.77381	3.987734	7.669195D-02	-3.097933D-01	5.408779D-01	2.136523	9.829082D-03	-4.013552D-02	7.457224D-02
41	4.00468	123.08157	3.993613	5.022924D-02	-2.570558D-01	5.903258D-01	2.137276	6.415922D-03	-3.301876D-02	7.824013D-02
43	4.09792	125.38933	3.997260	2.889880D-02	-1.997077D-01	6.397737D-01	2.137741	3.683634D-03	-2.551694D-02	8.281264D-02
45	4.19116	127.69709	3.999175	1.313051D-02	-1.377491D-01	6.892217D-01	2.137985	1.671872D-03	-1.755176D-02	8.815168D-02
47	4.28440	130.00485	3.999895	3.354276D-03	-7.117984D-02	7.386696D-01	2.138077	4.269151D-04	-9.060223D-03	9.406618D-02
49	4.37764	132.31261	4.000000	-4.167444D-15	-6.030310D-15	7.881175D-01	2.138090	-5.303792D-16	-7.674610D-16	1.003016D-01

M A C H 4 DOWNSTREAM CONTOUR

CHARACT 1

POINT	X	Y	MACH NO.	MACH ANG.(D)	PSI (D)	FLOW ANG.(D)	X(IN)	Y(IN)
1	2.1398501D 00	0.0	3.0821543D 00	1.8932159D 01	5.1317379D 01	0.0	76.9263852	0.0
2	2.1164620D 00	8.0066165D-03	3.0590621D 00	1.9080579D 01	5.0883879D 01	2.1675000D-01	76.3475216	0.1981669
3	2.0934923D 00	1.5839670D-02	3.0361744D 00	1.9230047D 01	5.0450379D 01	4.3350000D-01	75.7790116	0.3920379
4	2.0709313D 00	2.3504015D-02	3.0134877D 00	1.9380580D 01	5.0016879D 01	6.5025000D-01	75.2206173	0.5817335
5	2.0487696D 00	3.1004358D-02	2.9909983D 00	1.9532198D 01	4.9583379D 01	8.6700000D-01	74.6721080	0.7673698
6	2.0269983D 00	3.8345258D-02	2.9687030D 00	1.9684919D 01	4.9149879D 01	1.0837500D 00	74.1332594	0.9490599
7	2.0056085D 00	4.5531135D-02	2.9465982D 00	1.9838764D 01	4.8716379D 01	1.3005000D 00	73.6038537	1.1269132
8	1.9845917D 00	5.2566276D-02	2.9246807D 00	1.9993751D 01	4.8282879D 01	1.5172500D 00	73.0836792	1.3010356
9	1.9639395D 00	5.9454836D-02	2.9029473D 00	2.0149903D 01	4.7849379D 01	1.7340000D 00	72.5725301	1.4715302
10	1.9436439D 00	6.6200847D-02	2.8813946D 00	2.0307240D 01	4.7415879D 01	1.9507500D 00	72.0702063	1.6384965
11	1.9236970D 00	7.2808217D-02	2.8600196D 00	2.0465784D 01	4.6982379D 01	2.1675000D 00	71.5765135	1.8020315
12	1.9040913D 00	7.9280741D-02	2.8388193D 00	2.0625556D 01	4.6548879D 01	2.3842500D 00	71.0912626	1.9622290
13	1.8848191D 00	8.5622099D-02	2.8177905D 00	2.0786580D 01	4.6115379D 01	2.6010000D 00	70.6142697	2.1191800
14	1.8658734D 00	9.1835865D-02	2.7969303D 00	2.0948879D 01	4.5681879D 01	2.8177500D 00	70.1453561	2.2729731
15	1.8472471D 00	9.7925507D-02	2.7762358D 00	2.1112476D 01	4.5248379D 01	3.0345000D 00	69.6843478	2.4236941
16	1.8289334D 00	1.0389439D-01	2.7557042D 00	2.1277397D 01	4.4814879D 01	3.2512500D 00	69.2310756	2.5714263
17	1.8109255D 00	1.0974579D-01	2.7353325D 00	2.1443667D 01	4.4381379D 01	3.4680000D 00	68.7853750	2.7162507
18	1.7932172D 00	1.1548288D-01	2.7151182D 00	2.1611311D 01	4.3947879D 01	3.6847500D 00	68.3470857	2.8582458
19	1.7758019D 00	1.2110874D-01	2.6950584D 00	2.1780356D 01	4.3514379D 01	3.9015000D 00	67.9160519	2.9974880
20	1.7586737D 00	1.2662637D-01	2.6751504D 00	2.1950830D 01	4.3080879D 01	4.1182500D 00	67.4921219	3.1340515
21	1.7418265D 00	1.3203868D-01	2.6553917D 00	2.2122760D 01	4.2647379D 01	4.3350000D 00	67.0751479	3.2680083
22	1.7252546D 00	1.3734851D-01	2.6357796D 00	2.2296175D 01	4.2213879D 01	4.5517500D 00	66.6649862	3.3994286
23	1.7089522D 00	1.4255860D-01	2.6163117D 00	2.2471105D 01	4.1780379D 01	4.7685000D 00	66.2614968	3.5283805
24	1.6929140D 00	1.4767164D-01	2.5969853D 00	2.2647581D 01	4.1346879D 01	4.9852500D 00	65.8645434	3.6549301
25	1.6771344D 00	1.5269022D-01	2.5777981D 00	2.2825633D 01	4.0913379D 01	5.2020000D 00	65.4739932	3.7791418
26	1.6616083D 00	1.5761687D-01	2.5587476D 00	2.3005295D 01	4.0479879D 01	5.4187500D 00	65.0897170	3.9010784
27	1.6463307D 00	1.6245406D-01	2.5398314D 00	2.3186599D 01	4.0046379D 01	5.6355000D 00	64.7115887	4.0208006
28	1.6312964D 00	1.6720417D-01	2.5210472D 00	2.3369580D 01	3.9612879D 01	5.8522500D 00	64.3394858	4.1383679
29	1.6165008D 00	1.7186955D-01	2.5023926D 00	2.3554272D 01	3.9179379D 01	6.0690000D 00	63.9732887	4.2538379
30	1.6019391D 00	1.7645246D-01	2.4838653D 00	2.3740713D 01	3.8745879D 01	6.2857500D 00	63.6128808	4.3672666
31	1.5876067D 00	1.8095511D-01	2.4654632D 00	2.3928939D 01	3.8312379D 01	6.5025000D 00	63.2581489	4.4787089
32	1.5734992D 00	1.8537965D-01	2.4471838D 00	2.4118989D 01	3.7878879D 01	6.7192500D 00	62.9089822	4.5882180
33	1.5596122D 00	1.8972817D-01	2.4290252D 00	2.4310903D 01	3.7445379D 01	6.9360000D 00	62.5652729	4.6958456
34	1.5459414D 00	1.9400272D-01	2.4109850D 00	2.4504722D 01	3.7011879D 01	7.1527500D 00	62.2269161	4.8016422
35	1.5324828D 00	1.9820528D-01	2.3930611D 00	2.4700489D 01	3.6578379D 01	7.3695000D 00	61.8938093	4.9056572
36	1.5192322D 00	2.0233779D-01	2.3752515D 00	2.4898246D 01	3.6144879D 01	7.5862500D 00	61.5658527	5.0079384
37	1.5061858D 00	2.0640213D-01	2.3575539D 00	2.5098040D 01	3.5711379D 01	7.8030000D 00	61.2429489	5.1085325
38	1.4933397D 00	2.1040016D-01	2.3399664D 00	2.5299917D 01	3.5277879D 01	8.0197500D 00	60.9250032	5.2074852
39	1.4806902D 00	2.1433366D-01	2.3224869D 00	2.5503925D 01	3.4844379D 01	8.2365000D 00	60.6119228	5.3048408
40	1.4682336D 00	2.1820438D-01	2.3051134D 00	2.5710114D 01	3.4410879D 01	8.4532500D 00	60.3036178	5.4006428
41	1.4559664D 00	2.2201404D-01	2.2878437D 00	2.5918536D 01	3.3977379D 01	8.6700000D 00	60.0000000	5.4949332

MASS = 0.9999999136

M A C H 4 DOWNSTREAM CONTOUR, SMOOTHED 50 TIMES WITH FACTOR=0.85

	X	Y-CALC	Y-IN	DIFF	
1	1.4559664	0.2220140	0.2220140	0.0	1
2	1.4783065	0.2254207	0.2254211	-0.0000004	2
3	1.5005471	0.2288121	0.2288122	-0.0000002	3
4	1.5227029	0.2321903	0.2321902	0.0000001	4
5	1.5447888	0.2355573	0.2355570	0.0000004	5
6	1.5668216	0.2389156	0.2389150	0.0000007	6
7	1.5888196	0.2422675	0.2422666	0.0000009	7
8	1.6108018	0.2456153	0.2456146	0.0000007	8
9	1.6327838	0.2489607	0.2489617	-0.0000010	9
10	1.6547950	0.2523073	0.2523073	-0.0000000	10
11	1.6768523	0.2556568	0.2556564	0.0000004	11
12	1.6989763	0.2590114	0.2590116	-0.0000002	12
13	1.7211884	0.2623733	0.2623733	-0.0000000	13
14	1.7435111	0.2657447	0.2657437	0.0000010	14
15	1.7659655	0.2691277	0.2691271	0.0000006	15
16	1.7885670	0.2725233	0.2725249	-0.0000016	16
17	1.8113487	0.2759349	0.2759349	0.0000000	17
18	1.8343264	0.2793635	0.2793639	-0.0000004	18
19	1.8575201	0.2828101	0.2828102	-0.0000001	19
20	1.8809524	0.2862765	0.2862751	0.0000014	20
21	1.9046426	0.2897636	0.2897639	-0.0000003	21
22	1.9286045	0.2932714	0.2932721	-0.0000007	22
23	1.9528712	0.2968028	0.2968031	-0.0000003	23
24	1.9774540	0.3003574	0.3003592	-0.0000018	24
25	2.0023732	0.3039357	0.3039348	0.0000009	25
26	2.0276463	0.3075379	0.3075385	-0.0000006	26
27	2.0532825	0.3111628	0.3111637	-0.0000009	27
28	2.0793143	0.3148122	0.3148121	0.0000001	28
29	2.1057480	0.3184841	0.3184853	-0.0000012	29
30	2.1326005	0.3221780	0.3221758	0.0000022	30
31	2.1598844	0.3258924	0.3258930	-0.0000006	31
32	2.1876038	0.3296247	0.3296246	0.0000002	32
33	2.2157874	0.3333758	0.3333762	-0.0000004	33
34	2.2444348	0.3371422	0.3371430	-0.0000008	34
35	2.2735572	0.3409220	0.3409208	0.0000012	35
36	2.3031506	0.3447114	0.3447171	-0.0000057	36
37	2.3332387	0.3485098	0.3485106	-0.0000008	37
38	2.3638162	0.3523132	0.3523172	-0.0000039	38
39	2.3948832	0.3561181	0.3561184	-0.0000003	39
40	2.4264414	0.3599210	0.3599209	0.0000000	40
41	2.4584751	0.3637164	0.3637192	-0.0000028	41
42	2.4910016	0.3675029	0.3675020	0.0000009	42
43	2.5240006	0.3712742	0.3712773	-0.0000030	43
44	2.5574640	0.3750262	0.3750226	0.0000036	44
45	2.5913777	0.3787536	0.3787554	-0.0000018	45
46	2.6257145	0.3824508	0.3824499	0.0000009	46
47	2.6604786	0.3861155	0.3861174	-0.0000018	47
48	2.6956345	0.3897415	0.3897411	0.0000005	48
49	2.7311606	0.3933244	0.3933235	0.0000010	49
50	2.7804383	0.3981596	0.3981670	-0.0000074	50
51	2.8303081	0.4028951	0.4028965	-0.0000014	51
52	2.8807504	0.4075249	0.4075214	0.0000035	52

53	2.9317139	0.4120413	0.4120429	-0.0000017	53
54	2.9831884	0.4164406	0.4164456	-0.0000050	54
55	3.0351722	0.4207206	0.4207173	0.0000033	55
56	3.0876232	0.4248761	0.4248761	0.0	56
57	3.1405382	0.4289056	0.4289149	-0.0000092	57
58	3.1939216	0.4328084	0.4328062	0.0000022	58
59	3.2477348	0.4365807	0.4365807	0.0000000	59
60	3.3019779	0.4402224	0.4402325	-0.0000102	60
61	3.3566594	0.4437334	0.4437302	0.0000032	61
62	3.4117403	0.4471112	0.4471113	-0.0000001	62
63	3.4672234	0.4503561	0.4503640	-0.0000079	63
64	3.5231177	0.4534689	0.4534660	0.0000029	64
65	3.5793863	0.4564483	0.4564488	-0.0000005	65
66	3.6360322	0.4592957	0.4593053	-0.0000097	66
67	3.6930612	0.4620126	0.4620117	0.0000008	67
68	3.7504417	0.4645990	0.4645983	0.0000007	68
69	3.8081853	0.4670572	0.4670598	-0.0000026	69
70	3.8662636	0.4693873	0.4693890	-0.0000017	70
71	3.9246796	0.4715916	0.4715896	0.0000020	71
72	3.9834323	0.4736721	0.4736688	0.0000033	72
73	4.0424953	0.4756301	0.4756315	-0.0000014	73
74	4.1018677	0.4774685	0.4774722	-0.0000037	74
75	4.1615486	0.4791899	0.4791889	0.0000010	75
76	4.2215140	0.4807971	0.4807957	0.0000014	76
77	4.2817672	0.4822935	0.4822915	0.0000020	77
78	4.3422861	0.4836819	0.4836815	0.0000003	78
79	4.4030717	0.4849655	0.4849659	-0.0000004	79
80	4.4641037	0.4861472	0.4861492	-0.0000020	80
81	4.5253768	0.4872307	0.4872314	-0.0000008	81
82	4.5868848	0.4882197	0.4882193	0.0000004	82
83	4.6486081	0.4891185	0.4891186	-0.0000001	83
84	4.7105436	0.4899314	0.4899311	0.0000003	84
85	4.7726727	0.4906627	0.4906628	-0.0000002	85
86	4.8349909	0.4913166	0.4913163	0.0000003	86
87	4.8974804	0.4918974	0.4918974	0.0	87
88	4.9601354	0.4924095	0.4924092	0.0000003	88
89	5.0229390	0.4928577	0.4928577	0.0	89
90	5.0858844	0.4932465	0.4932463	0.0000002	90
91	5.1489555	0.4935803	0.4935809	-0.0000006	91
92	5.2121447	0.4938637	0.4938637	0.0	92
93	5.2754384	0.4941018	0.4941011	0.0000006	93
94	5.3388238	0.4942989	0.4942984	0.0000005	94
95	5.4022929	0.4944599	0.4944593	0.0000006	95
96	5.4658324	0.4945892	0.4945890	0.0000002	96
97	5.5294342	0.4946909	0.4946906	0.0000003	97
98	5.5930872	0.4947690	0.4947681	0.0000009	98
99	5.6567813	0.4948275	0.4948264	0.0000010	99
100	5.7205095	0.4948696	0.4948687	0.0000009	100
101	5.7842631	0.4948988	0.4948979	0.0000010	101
102	5.8480345	0.4949182	0.4949172	0.0000010	102
103	5.9118183	0.4949301	0.4949293	0.0000008	103
104	5.9756089	0.4949369	0.4949362	0.0000007	104
105	6.0394017	0.4949403	0.4949397	0.0000007	105
106	6.1031937	0.4949417	0.4949412	0.0000005	106
107	6.1669822	0.4949420	0.4949417	0.0000004	107
108	6.2307657	0.4949419	0.4949418	0.0000001	108

109	6.2945435	0.4949418	0.4949418	0.0	109

MAX. ABSOLUTE ERROR = 1.0154520-05 AT POINT 60

M A C H 4   DOWNSTREAM CONTOUR

RC= 6.000000   ETAD= 8.6700 DEG   AMACH= 2.2878437   BMACH= 3.0821543   CMACH= 4.0000000   EMACH= 1.6601538   GMACH= 2.2878437

WALL POINT	X	Y	MACH NO.	FLOW ANG.(D)	WALTAN	SECDIF
41	1.4559664D 00	2.2201404D-01	2.2878437D 00	8.6700000D 00	1.5248569D-01	0.0
42	1.4783065D 00	2.2542068D-01	2.3214084D 00	8.6701296D 00	1.5248800D-01	-1.2304520D-04
43	1.5005471D 00	2.2881206D-01	2.3541235D 00	8.6696954D 00	1.5248025D-01	-5.3040854D-04
44	1.5227029D 00	2.3219025D-01	2.3860447D 00	8.6688128D 00	1.5246448D-01	-9.4818702D-04
45	1.5447888D 00	2.3555734D-01	2.4172256D 00	8.6673483D 00	1.5243833D-01	-1.5513350D-03
46	1.5668216D 00	2.3891564D-01	2.4477161D 00	8.6649825D 00	1.5239608D-01	-2.3928483D-03
47	1.5888196D 00	2.4226748D-01	2.4775625D 00	8.6614505D 00	1.5233300D-01	-3.5086915D-03
48	1.6108018D 00	2.4561528D-01	2.5068080D 00	8.6563427D 00	1.5224179D-01	-4.9722566D-03
49	1.6327838D 00	2.4896066D-01	2.5354718D 00	8.6492093D 00	1.5211440D-01	-6.6615979D-03
50	1.6547950D 00	2.5230727D-01	2.5635910D 00	8.6399281D 00	1.5194867D-01	-8.4624544D-03
51	1.6768523D 00	2.5565679D-01	2.5912185D 00	8.6283194D 00	1.5174139D-01	-1.0377058D-02
52	1.6989763D 00	2.5901139D-01	2.6183867D 00	8.6142433D 00	1.5149007D-01	-1.2367249D-02
53	1.7211884D 00	2.6237326D-01	2.6450950D 00	8.5975978D 00	1.5119290D-01	-1.4433931D-02
54	1.7435111D 00	2.6574470D-01	2.6713791D 00	8.5782226D 00	1.5084702D-01	-1.6588975D-02
55	1.7659655D 00	2.6912769D-01	2.6972864D 00	8.5559686D 00	1.5044980D-01	-1.8864302D-02
56	1.7885670D 00	2.7252328D-01	2.7228104D 00	8.5305823D 00	1.4999673D-01	-2.1277555D-02
57	1.8113487D 00	2.7593495D-01	2.7479725D 00	8.5018332D 00	1.4948371D-01	-2.3770103D-02
58	1.8343264D 00	2.7936346D-01	2.7728239D 00	8.4695954D 00	1.4890853D-01	-2.6297425D-02
59	1.8575201D 00	2.8281013D-01	2.7973472D 00	8.4337430D 00	1.4826897D-01	-2.8805629D-02
60	1.8809524D 00	2.8627650D-01	2.8215632D 00	8.3942634D 00	1.4756485D-01	-3.1242249D-02
61	1.9046426D 00	2.8976357D-01	2.8455195D 00	8.3511536D 00	1.4679614D-01	-3.3618118D-02
62	1.9286045D 00	2.9327141D-01	2.8691629D 00	8.3043766D 00	1.4596224D-01	-3.5915916D-02
63	1.9528712D 00	2.9680285D-01	2.8925668D 00	8.2539385D 00	1.4506329D-01	-3.8130491D-02
64	1.9774540D 00	3.0035739D-01	2.9157299D 00	8.1998141D 00	1.4409889D-01	-4.0297114D-02
65	2.0023732D 00	3.0393571D-01	2.9386209D 00	8.1419288D 00	1.4306777D-01	-4.2435677D-02
66	2.0276463D 00	3.0753791D-01	2.9613088D 00	8.0801817D 00	1.4196819D-01	-4.4568599D-02
67	2.0532825D 00	3.1116280D-01	2.9837327D 00	8.0144508D 00	1.4079804D-01	-4.6681025D-02
68	2.0793143D 00	3.1481219D-01	3.0059512D 00	7.9446277D 00	1.3955545D-01	-4.8729155D-02
69	2.1057480D 00	3.1848412D-01	3.0279603D 00	7.8707202D 00	1.3824063D-01	-5.0659241D-02
70	2.1326005D 00	3.2217795D-01	3.0497246D 00	7.7928164D 00	1.3685523D-01	-5.2458321D-02
71	2.1598844D 00	3.2589236D-01	3.0713107D 00	7.7109535D 00	1.3539998D-01	-5.4125471D-02
72	2.1876038D 00	3.2962475D-01	3.0926338D 00	7.6252729D 00	1.3387746D-01	-5.5612612D-02
73	2.2157874D 00	3.3337579D-01	3.1137755D 00	7.5359249D 00	1.3229042D-01	-5.6965224D-02
74	2.2444348D 00	3.3714218D-01	3.1346955D 00	7.4429389D 00	1.3063946D-01	-5.8230148D-02
75	2.2735572D 00	3.4092201D-01	3.1553882D 00	7.3463854D 00	1.2892590D-01	-5.9356792D-02
76	2.3031506D 00	3.4471136D-01	3.1758845D 00	7.2464884D 00	1.2715379D-01	-6.0361665D-02
77	2.3332387D 00	3.4850985D-01	3.1961171D 00	7.1432346D 00	1.2537295D-01	-6.1275719D-02
78	2.3638162D 00	3.5231324D-01	3.2161669D 00	7.0367696D 00	1.2343604D-01	-6.2079966D-02
79	2.3948832D 00	3.5611805D-01	3.2359485D 00	6.9272392D 00	1.2149570D-01	-6.2818104D-02
80	2.4264414D 00	3.5992096D-01	3.2555157D 00	6.8146258D 00	1.1950169D-01	-6.3530558D-02
81	2.4584751D 00	3.6371644D-01	3.2748313D 00	6.6990017D 00	1.1746534D-01	-6.4197346D-02
82	2.4910016D 00	3.6750288D-01	3.2938948D 00	6.5803707D 00	1.1535678D-01	-6.4768539D-02
83	2.5240006D 00	3.7127425D-01	3.3127386D 00	6.4590178D 00	1.1321111D-01	-6.5208966D-02
84	2.5574640D 00	3.7502616D-01	3.3312761D 00	6.3351856D 00	1.1102266D-01	-6.5476517D-02
85	2.5913777D 00	3.7875364D-01	3.3496037D 00	6.2093238D 00	1.0879942D-01	-6.5497518D-02
86	2.6257145D 00	3.8245083D-01	3.3676009D 00	6.0820586D 00	1.0655247D-01	-6.5331377D-02
87	2.6604786D 00	3.8611554D-01	3.3853741D 00	5.9535733D 00	1.0428506D-01	-6.5078085D-02
88	2.6956345D 00	3.8974154D-01	3.4028437D 00	5.8241595D 00	1.0200233D-01	-6.4757058D-02
89	2.7311606D 00	3.9332442D-01	3.4200450D 00	5.6940295D 00	9.9708027D-02	-6.4389214D-02
90	2.7804383D 00	3.9815961D-01	3.4432004D 00	5.5147090D 00	9.6548156D-02	-6.3827866D-02

91	2.8303081D 00	4.0289506D-01	3.4657596D 00	5.3348098D 00	9.3380004D-02	-6.3185466D-02
92	2.8807504D 00	4.0752494D-01	3.4878170D 00	5.1547160D 00	9.0210285D-02	-6.2421121D-02
93	2.9317139D 00	4.1204125D-01	3.5093670D 00	4.9750894D 00	8.7050580D-02	-6.1528767D-02
94	2.9831884D 00	4.1644061D-01	3.5303869D 00	4.7963326D 00	8.3907888D-02	-6.0550794D-02
95	3.0351722D 00	4.2072063D-01	3.5508706D 00	4.6187013D 00	8.0786611D-02	-5.9494730D-02
96	3.0876232D 00	4.2487610D-01	3.5708751D 00	4.4426751D 00	7.7695080D-02	-5.8376896D-02
97	3.1405382D 00	4.2890561D-01	3.5904045D 00	4.2684252D 00	7.4636200D-02	-5.7243990D-02
98	3.1939216D 00	4.3280838D-01	3.6093807D 00	4.0959967D 00	7.1610663D-02	-5.6091470D-02
99	3.2477348D 00	4.3658074D-01	3.6279067D 00	3.9257046D 00	6.8623890D-02	-5.4908102D-02
100	3.3019779D 00	4.4022235D-01	3.6459872D 00	3.7576760D 00	6.5678011D-02	-5.3728363D-02
101	3.3566594D 00	4.4373341D-01	3.6635161D 00	3.5918613D 00	6.2772060D-02	-5.2558932D-02
102	3.4117403D 00	4.4711121D-01	3.6806240D 00	3.4284630D 00	5.9909488D-02	-5.1369517D-02
103	3.4672234D 00	4.5035610D-01	3.6972824D 00	3.2676363D 00	5.7092924D-02	-5.0143112D-02
104	3.5231177D 00	4.5346892D-01	3.7134107D 00	3.1095475D 00	5.4325190D-02	-4.8869392D-02
105	3.5793863D 00	4.5644834D-01	3.7291180D 00	2.9545328D 00	5.1612080D-02	-4.7542522D-02
106	3.6360322D 00	4.5929566D-01	3.7443916D 00	2.8028181D 00	4.8957462D-02	-4.6188222D-02
107	3.6930612D 00	4.6201258D-01	3.7591219D 00	2.6544550D 00	4.6362155D-02	-4.4850522D-02
108	3.7504417D 00	4.6459903D-01	3.7734273D 00	2.5094733D 00	4.3826600D-02	-4.3549610D-02
109	3.8081853D 00	4.6705716D-01	3.7873119D 00	2.3677751D 00	4.1349012D-02	-4.2272603D-02
110	3.8662636D 00	4.6938733D-01	3.8006914D 00	2.2294523D 00	3.8930933D-02	-4.0979383D-02
111	3.9246796D 00	4.7159159D-01	3.8135937D 00	2.0946933D 00	3.6575592D-02	-3.9660340D-02
112	3.9834323D 00	4.7367206D-01	3.8260686D 00	1.9635839D 00	3.4284427D-02	-3.8328669D-02
113	4.0424953D 00	4.7563013D-01	3.8381050D 00	1.8362902D 00	3.2060288D-02	-3.6971480D-02
114	4.1018677D 00	4.7746846D-01	3.8496669D 00	1.7129839D 00	2.9906120D-02	-3.5574673D-02
115	4.1615486D 00	4.7918990D-01	3.8607359D 00	1.5938692D 00	2.7825443D-02	-3.4146872D-02
116	4.2215140D 00	4.8079709D-01	3.8713637D 00	1.4791046D 00	2.5820981D-02	-3.2736117D-02
117	4.2817672D 00	4.8229350D-01	3.8815507D 00	1.3685560D 00	2.3890352D-02	-3.1383344D-02
118	4.3422861D 00	4.8368187D-01	3.8912901D 00	1.2620849D 00	2.2031101D-02	-3.0084064D-02
119	4.4030717D 00	4.8496548D-01	3.9005824D 00	1.1595862D 00	2.0241361D-02	-2.8791888D-02
120	4.4641037D 00	4.8614720D-01	3.9094140D 00	1.0612293D 00	1.8524064D-02	-2.7461591D-02
121	4.5253768D 00	4.8723067D-01	3.9177645D 00	9.6723242D-01	1.6882994D-02	-2.6081144D-02
122	4.5868848D 00	4.8821973D-01	3.9256728D 00	8.7782419D-01	1.5322121D-02	-2.4660755D-02
123	4.6486081D 00	4.8911850D-01	3.9331370D 00	7.9317076D-01	1.3844326D-02	-2.3239759D-02
124	4.7105436D 00	4.8993140D-01	3.9401601D 00	7.1321654D-01	1.2448620D-02	-2.1856195D-02
125	4.7726727D 00	4.9066267D-01	3.9467425D 00	6.3784807D-01	1.1133009D-02	-2.0525218D-02
126	4.8349909D 00	4.9131663D-01	3.9528889D 00	5.6689794D-01	9.8945585D-03	-1.9217913D-02
127	4.8974804D 00	4.9189739D-01	3.9586023D 00	5.0044818D-01	8.7346907D-03	-1.7890123D-02
128	4.9601354D 00	4.9240955D-01	3.9638895D 00	4.3864390D-01	7.6559298D-03	-1.6563433D-02
129	5.0229390D 00	4.9285773D-01	3.9687563D 00	3.8140434D-01	6.6568598D-03	-1.5279647D-02
130	5.0858844D 00	4.9324650D-01	3.9732116D 00	3.2857094D-01	5.7347076D-03	-1.4026820D-02
131	5.1489555D 00	4.9358029D-01	3.9772645D 00	2.8014011D-01	4.8894062D-03	-1.2762646D-02
132	5.2121447D 00	4.9386375D-01	3.9809020D 00	2.3625454D-01	4.1234429D-03	-1.1492904D-02
133	5.2754384D 00	4.9410176D-01	3.9841501D 00	1.9686079D-01	3.4358824D-03	-1.0259409D-02
134	5.3388238D 00	4.9429894D-01	3.9870320D 00	1.6179720D-01	2.8239014D-03	-9.0661286D-03
135	5.4022929D 00	4.9445994D-01	3.9895641D 00	1.3097227D-01	2.2859012D-03	-7.9291229D-03
136	5.4658324D 00	4.9458923D-01	3.9917639D 00	1.0410128D-01	1.8169121D-03	-6.8660237D-03
137	5.5294342D 00	4.9469091D-01	3.9936403D 00	8.0959473D-02	1.4130103D-03	-5.8515327D-03
138	5.5930872D 00	4.9476903D-01	3.9951934D 00	6.1439804D-02	1.0723273D-03	-4.8965890D-03
139	5.6567813D 00	4.9482746D-01	3.9964793D 00	4.5233950D-02	7.8948152D-04	-4.0206540D-03
140	5.7205095D 00	4.9486962D-01	3.9975219D 00	3.2087632D-02	5.6003489D-04	-3.2039977D-03
141	5.7842631D 00	4.9489885D-01	3.9983248D 00	2.1832565D-02	3.8105016D-04	-2.4698163D-03
142	5.8480345D 00	4.9491821D-01	3.9989255D 00	1.4042261D-02	2.4508369D-04	-1.8409896D-03
143	5.9118183D 00	4.9493011D-01	3.9993651D 00	8.3783417D-03	1.4622965D-04	-1.2924731D-03
144	5.9756089D 00	4.9493686D-01	3.9996582D 00	4.5951557D-03	8.0200596D-05	-8.4893356D-04
145	6.0394017D 00	4.9494034D-01	3.9998381D 00	2.1726944D-03	3.7920671D-05	-5.2468866D-04

146	6.1031937D 00	4.9494170D-01	3.9999408D 00	7.5963470D-04	1.3258127D-05	-2.8422970D-04
147	6.1669822D 00	4.9494203D-01	3.9999845D 00	9.4983970D-05	1.6577830D-06	-1.1988355D-04
148	6.2307657D 00	4.9494191D-01	3.9999980D 00	-1.1667088D-04	-2.0362910D-06	-1.2991921D-05
149	6.2945435D 00	4.9494177D-01	4.0000000D 00	0.0	0.0	0.0

M A C H 4 BOUNDARY LAYER CALCULATIONS, STAGNATION PRESSURE= 200.PSI, STAGNATION TEMPERATURE=1638. DEG R, N BASED ON RE.DELTA

PARABOLIC TEMPERATURE DISTRIBUTION MODIF. SPALDING-CHI REFERENCE TEMP VAN DRIEST REFERENCE REYNOLDS NUMBER

	TW	TE	TAW	TP	RE/IN	RTHI	FRD	KCFI	KCF	KCFS	H	HI	FMY	KTHP	THETA-1	DELTA	DELTA*-1
1	866.0	1343.4	1607.4	1011.2	1349924	19679	1.33396	2.32911	3.09435	3.09435	0.5083	1.3172	0.14257	0.0	0.010852	0.0909	0.005516
X= 46.076,	DSU= 0.00555,	THU=0.0109284,	CTH=0.0108678,	HU= 0.507469,	H= 0.508254,	CH= 0.507892,	N= 6.30583										
2	865.7	1336.2	1606.6	1008.9	1352630	19660	1.32983	2.32948	3.08522	3.08526	0.5155	1.3171	0.14015	.02158	0.010853	0.0910	0.005595
X= 46.195,	DSU= 0.00563,	THU=0.0109299,	CTH=0.0108691,	HU= 0.514745,	H= 0.515535,	CH= 0.515172,	N= 6.30774										
3	865.3	1328.8	1605.8	1006.5	1354981	19640	1.32561	2.32987	3.07587	3.07605	0.5231	1.3170	0.13668	0.05401	0.010858	0.0912	0.005679
X= 46.317,	DSU= 0.00571,	THU=0.0109345,	CTH=0.0108735,	HU= 0.522260,	H= 0.523055,	CH= 0.522693,	N= 6.30970										
4	864.7	1321.1	1605.0	1004.0	1356933	19621	1.32129	2.33025	3.06627	3.06668	0.5308	1.3169	0.13330	0.08485	0.010867	0.0915	0.005768
5	864.1	1313.0	1604.2	1001.2	1358454	19601	1.31686	2.33064	3.05641	3.05716	0.5388	1.3168	0.12971	0.11731	0.010880	0.0918	0.005862
6	863.3	1304.6	1603.3	998.3	1359497	19582	1.31234	2.33101	3.04631	3.04750	0.5471	1.3167	0.12594	0.15122	0.010898	0.0921	0.005962
7	862.4	1295.9	1602.4	995.1	1360023	19563	1.30770	2.33138	3.03590	3.03765	0.5556	1.3165	0.12188	0.18770	0.010922	0.0925	0.006069
8	861.4	1286.8	1601.5	991.8	1359983	19546	1.30297	2.33172	3.02520	3.02764	0.5645	1.3164	0.11755	0.22645	0.010952	0.0929	0.006182
9	860.2	1277.3	1600.5	988.2	1359327	19531	1.29810	2.33202	3.01411	3.01737	0.5736	1.3163	0.11302	0.26663	0.010989	0.0934	0.006304
10	858.8	1267.3	1599.4	984.4	1357994	19519	1.29309	2.33226	3.00261	3.00683	0.5831	1.3162	0.10805	0.31100	0.011035	0.0940	0.006435
X= 47.307,	DSU= 0.00647,	THU=0.0111153,	CTH=0.0110514,	HU= 0.582300,	H= 0.583139,	CH= 0.582784,	N= 6.32598										
11	857.2	1256.9	1598.4	980.3	1355928	19511	1.28795	2.33241	2.99066	2.99597	0.5930	1.3160	0.10277	0.35807	0.011091	0.0947	0.006577
12	855.5	1246.0	1597.2	975.9	1353056	19509	1.28265	2.33244	2.97817	2.98470	0.6033	1.3158	0.09716	0.40807	0.011159	0.0956	0.006732
13	853.5	1234.7	1596.1	971.2	1349327	19517	1.27722	2.33230	2.96513	2.97301	0.6139	1.3157	0.09122	0.46109	0.011242	0.0965	0.006901
14	851.3	1222.9	1594.8	966.2	1344694	19535	1.27167	2.33193	2.95149	2.96082	0.6249	1.3155	0.08517	0.51455	0.011340	0.0976	0.007086
15	848.9	1210.7	1593.6	961.0	1339108	19568	1.26598	2.33130	2.93722	2.94810	0.6363	1.3153	0.07931	0.56541	0.011456	0.0989	0.007289
16	846.3	1198.0	1592.2	955.4	1332502	19614	1.26016	2.33040	2.92228	2.93476	0.6480	1.3150	0.07382	0.61157	0.011593	0.1004	0.007512
17	843.4	1184.8	1590.9	949.5	1324786	19672	1.25417	2.32924	2.90663	2.92075	0.6602	1.3147	0.06863	0.65396	0.011750	0.1020	0.007758
18	840.2	1171.0	1589.4	943.1	1315877	19744	1.24799	2.32784	2.89023	2.90603	0.6730	1.3144	0.06370	0.69299	0.011931	0.1039	0.008029
19	836.7	1156.5	1587.9	936.4	1305663	19828	1.24159	2.32621	2.87304	2.89052	0.6863	1.3141	0.05900	0.72927	0.012136	0.1061	0.008329
20	832.9	1141.4	1586.4	929.2	1294046	19924	1.23495	2.32437	2.85505	2.87417	0.7003	1.3138	0.05442	0.76395	0.012369	0.1085	0.008663
X= 49.607,	DSU= 0.00872,	THU=0.0124676,	CTH=0.0123883,	HU= 0.699364,	H= 0.700334,	CH= 0.700009,	N= 6.37371										
21	828.7	1125.5	1584.7	921.6	1280919	20032	1.22805	2.32231	2.83622	2.85694	0.7151	1.3134	0.04998	.79715	0.012632	0.1112	0.009033
22	825.9	1115.3	1583.6	916.6	1271961	20104	1.22362	2.32093	2.82410	2.84577	0.7246	1.3132	0.04726	0.81738	0.012812	0.1131	0.009284
23	821.9	1100.9	1582.1	909.4	1258800	20208	1.21745	2.31896	2.80715	2.83003	0.7380	1.3129	0.04362	0.84455	0.013078	0.1158	0.009652
24	817.2	1084.9	1580.5	901.4	1243347	20328	1.21060	2.31670	2.78832	2.81244	0.7531	1.3125	0.03980	0.87319	0.013392	0.1191	0.010086
25	812.2	1068.0	1578.7	892.8	1226175	20458	1.20339	2.31428	2.76849	2.79376	0.7692	1.3121	0.03600	0.90202	0.013747	0.1227	0.010574
26	806.8	1050.6	1576.9	883.8	1207626	20595	1.19597	2.31175	2.74811	2.77441	0.7859	1.3117	0.03230	0.93056	0.014136	0.1267	0.011110
27	801.1	1032.8	1575.1	874.4	1187927	20736	1.18842	2.30916	2.72742	2.75460	0.8032	1.3112	0.02875	0.95868	0.014558	0.1311	0.011693
28	795.3	1015.0	1573.2	865.0	1167300	20880	1.18078	2.30654	2.70659	2.73450	0.8208	1.3108	0.02539	0.98611	0.015012	0.1358	0.012322
29	789.3	997.0	1571.3	855.3	1145891	21025	1.17309	2.30392	2.68573	2.71421	0.8388	1.3104	0.02221	1.01299	0.015497	0.1408	0.012999
30	783.2	979.2	1569.5	845.6	1123888	21171	1.16538	2.30131	2.66491	2.69382	0.8571	1.3099	0.01922	1.03912	0.016012	0.1461	0.013724
X= 53.576,	DSU= 0.01383,	THU=0.0161641,	CTH=0.0160401,	HU= 0.855869,	H= 0.857100,	CH= 0.856885,	N= 6.45346										
31	776.9	961.4	1567.6	835.8	1101410	21316	1.15765	2.29873	2.64420	2.67341	0.8756	1.3095	0.01644	1.06450	0.016557	0.1518	0.014498
32	770.7	943.8	1565.8	826.0	1078631	21461	1.14993	2.29619	2.62365	2.65303	0.8944	1.3090	0.01386	1.08898	0.017132	0.1578	0.015323
33	764.3	926.5	1564.0	816.3	1055651	21603	1.14222	2.29371	2.60329	2.63275	0.9133	1.3086	0.01149	1.11260	0.017736	0.1641	0.016199
34	758.0	909.4	1562.2	806.6	1032618	21743	1.13453	2.29129	2.58317	2.61263	0.9324	1.3082	0.00933	1.13494	0.018369	0.1707	0.017127
35	751.7	892.6	1560.5	797.1	1009643	21880	1.12689	2.28894	2.56332	2.59272	0.9516	1.3077	0.00736	1.15630	0.019029	0.1777	0.018108
36	745.4	876.2	1558.8	787.6	986827	22013	1.11929	2.28668	2.54378	2.57306	0.9709	1.3073	0.00559	1.17632	0.019715	0.1849	0.019142
37	739.3	860.1	1557.1	778.3	964289	22142	1.11175	2.28450	2.52458	2.55370	0.9903	1.3069	0.00402	1.19480	0.020427	0.1925	0.020228
38	733.2	844.5	1555.5	769.2	942112	22267	1.10429	2.28241	2.50575	2.53470	1.0097	1.3065	0.00261	1.21204	0.021161	0.2003	0.021366
39	727.2	829.3	1553.9	760.3	920368	22386	1.09691	2.28043	2.48732	2.51607	1.0290	1.3061	0.00137	1.22795	0.021918	0.2084	0.022554
40	721.3	814.5	1552.4	751.6	899125	22499	1.08962	2.27855	2.46930	2.49785	1.0484	1.3057	0.00029	1.24242	0.022695	0.2167	0.023792
X= 59.364,	DSU= 0.02404,	THU=0.0229654,	CTH=0.0227417,	HU= 1.046707,	H= 1.048362,	CH= 1.048468,	N= 6.54185										
41	715.6	800.3	1550.9	743.2	878429	22607	1.08243	2.27678	2.45172	2.48006	1.0676	1.3053	-0.00065	1.25527	0.023489	0.2253	0.025078
42	710.7	788.3	1549.6	736.1	861085	22695	1.07633	2.27535	2.43694	2.46511	1.0841	1.3050	-0.00137	1.26571	0.024186	0.2329	0.026221
43	706.1	776.9	1548.4	729.2	844383	22777	1.07039	2.27402	2.42266	2.45066	1.1004	1.3047	-0.00201	1.27533	0.024885	0.2405	0.027383
44	701.6	765.9	1547.3	722.6	828292	22853	1.06458	2.27278	2.40884	2.43668	1.1164	1.3044	-0.00257	1.28408	0.025587	0.2481	0.028565
45	697.2	755.3	1546.2	716.3	812778	22924	1.05890	2.27163	2.39546	2.42313	1.1321	1.3041	-0.00306	1.29201	0.026291	0.2558	0.029765

46	693.0	745.1	1545.1	710.1	797810	22991	1.05335	2.27056	2.38248	2.40999	1.1477	1.3039	-0.00349	1.29915	0.026998	0.2636 0.030985
47	688.9	735.3	1544.1	704.2	783356	23052	1.04791	2.26957	2.36987	2.39721	1.1630	1.3036	-0.00386	1.30554	0.027707	0.2715 0.032224
48	685.0	725.8	1543.1	698.4	769389	23110	1.04257	2.26865	2.35761	2.38477	1.1782	1.3034	-0.00417	1.31098	0.028419	0.2793 0.033484
49	681.1	716.6	1542.2	692.8	755892	23163	1.03734	2.26780	2.34567	2.37265	1.1932	1.3031	-0.00443	1.31532	0.029133	0.2873 0.034763
50	677.4	707.7	1541.3	687.4	742838	23213	1.03220	2.26701	2.33403	2.36083	1.2081	1.3029	-0.00465	1.31911	0.029851	0.2953 0.036062
X= 64.921,	DSU= 0.03651,	THU=0.0302746,	CTH=0.0299214,	HU= 1.205995,	H= 1.208070,	CH= 1.208665,	N= 6.60376									
51	673.8	699.1	1540.4	682.2	730196	23260	1.02715	2.26627	2.32268	2.34927	1.2228	1.3026	-0.00484	1.32262	0.030572	0.3034 0.037383
52	670.2	690.8	1539.5	677.0	717942	23303	1.02217	2.26559	2.31158	2.33795	1.2374	1.3024	-0.00499	1.32500	0.031297	0.3115 0.038726
53	666.8	682.7	1538.6	672.1	706070	23344	1.01728	2.26494	2.30073	2.32687	1.2518	1.3022	-0.00509	1.32634	0.032026	0.3198 0.040090
54	663.5	674.8	1537.8	667.2	694556	23383	1.01246	2.26434	2.29010	2.31601	1.2662	1.3019	-0.00518	1.32755	0.032759	0.3281 0.041478
55	660.2	667.2	1537.0	662.5	683372	23419	1.00771	2.26377	2.27968	2.30534	1.2804	1.3017	-0.00524	1.32816	0.033497	0.3364 0.042890
56	657.0	659.8	1536.3	657.9	672514	23453	1.00302	2.26324	2.26947	2.29485	1.2945	1.3015	-0.00526	1.32754	0.034240	0.3449 0.044325
57	653.9	652.5	1535.5	653.5	661967	23485	0.99840	2.26273	2.25943	2.28454	1.3086	1.3013	-0.00528	1.32684	0.034988	0.3535 0.045786
58	650.9	645.5	1534.8	649.1	651702	23516	0.99383	2.26225	2.24957	2.27437	1.3226	1.3011	-0.00527	1.32572	0.035742	0.3621 0.047273
59	648.0	638.6	1534.1	644.8	641721	23546	0.98932	2.26178	2.23987	2.26435	1.3365	1.3009	-0.00524	1.32351	0.036503	0.3709 0.048786
60	645.1	631.9	1533.4	640.7	632009	23575	0.98486	2.26133	2.23032	2.25447	1.3503	1.3007	-0.00521	1.32158	0.037270	0.3797 0.050327
X= 70.519,	DSU= 0.05105,	THU=0.0378746,	CTH=0.0373667,	HU= 1.347848,	H= 1.350328,	CH= 1.351562,	N= 6.65118									
61	642.3	625.3	1532.7	636.6	622542	23602	0.98045	2.26091	2.22090	2.24471	1.3641	1.3005	-0.00516	1.31874	0.038044	0.3887 0.051896
62	639.5	618.9	1532.0	632.6	613335	23630	0.97609	2.26048	2.21163	2.23507	1.3778	1.3003	-0.00509	1.31524	0.038825	0.3978 0.053494
63	636.8	612.7	1531.4	628.7	604355	23657	0.97178	2.26007	2.20248	2.22553	1.3915	1.3001	-0.00504	1.31233	0.039614	0.4070 0.055122
64	634.2	606.6	1530.7	624.9	595596	23683	0.96751	2.25966	2.19344	2.21610	1.4051	1.2999	-0.00495	1.30815	0.040411	0.4163 0.056782
65	631.6	600.6	1530.1	621.2	587066	23710	0.96328	2.25924	2.18452	2.20676	1.4187	1.2997	-0.00487	1.30408	0.041217	0.4257 0.058472
66	629.1	594.8	1529.5	617.5	578734	23736	0.95910	2.25884	2.17570	2.19751	1.4322	1.2995	-0.00478	1.29985	0.042031	0.4353 0.060196
67	626.6	589.1	1528.9	614.0	570618	23763	0.95496	2.25842	2.16698	2.18836	1.4456	1.2993	-0.00468	1.29492	0.042855	0.4450 0.061952
68	624.2	583.5	1528.3	610.4	562693	23791	0.95086	2.25800	2.15836	2.17927	1.4591	1.2992	-0.00460	1.29073	0.043687	0.4549 0.063743
69	621.8	578.0	1527.8	607.0	554955	23819	0.94679	2.25757	2.14982	2.17027	1.4724	1.2990	-0.00450	1.28556	0.044530	0.4649 0.065568
70	619.5	572.7	1527.2	603.6	547413	23848	0.94277	2.25712	2.14138	2.16134	1.4858	1.2988	-0.00441	1.28082	0.045383	0.4750 0.067429
X= 76.747,	DSU= 0.06852,	THU=0.0462088,	CTH=0.0455107,	HU= 1.482872,	H= 1.485767,	CH= 1.487807,	N= 6.69383									
71	617.2	567.5	1526.7	600.3	540039	23877	0.93879	2.25667	2.13301	2.15247	1.4991	1.2986	-0.00431	1.27577	0.046246	0.4853 0.069326
72	615.0	562.3	1526.1	597.1	532858	23909	0.93485	2.25619	2.12473	2.14368	1.5123	1.2984	-0.00421	1.27038	0.047120	0.4958 0.071259
73	612.8	557.3	1525.6	594.0	525840	23941	0.93095	2.25569	2.11652	2.13496	1.5255	1.2982	-0.00413	1.26585	0.048004	0.5064 0.073229
74	610.7	552.4	1525.1	590.9	518992	23975	0.92708	2.25517	2.10839	2.12631	1.5386	1.2980	-0.00404	1.26048	0.048900	0.5172 0.075238
75	608.6	547.6	1524.6	587.8	512313	24011	0.92326	2.25463	2.10034	2.11772	1.5517	1.2978	-0.00396	1.25595	0.049807	0.5281 0.077284
76	606.5	542.9	1524.1	584.8	505790	24048	0.91948	2.25406	2.09235	2.10920	1.5647	1.2976	-0.00387	1.25072	0.050725	0.5392 0.079369
77	604.5	538.3	1523.6	581.9	499439	24088	0.91575	2.25346	2.08445	2.10075	1.5776	1.2975	-0.00378	1.24583	0.051654	0.5505 0.081492
78	602.5	533.8	1523.2	579.1	493232	24129	0.91205	2.25284	2.07661	2.09237	1.5905	1.2973	-0.00371	1.24140	0.052596	0.5620 0.083654
79	600.6	529.4	1522.7	576.3	487191	24173	0.90840	2.25217	2.06884	2.08405	1.6033	1.2971	-0.00363	1.23653	0.053548	0.5736 0.085854
80	598.7	525.1	1522.3	573.5	481295	24219	0.90479	2.25148	2.06115	2.07581	1.6160	1.2969	-0.00357	1.23268	0.054512	0.5854 0.088094
X= 84.020,	DSU= 0.08969,	THU=0.0556160,	CTH=0.0546774,	HU= 1.612690,	H= 1.616030,	CH= 1.619064,	N= 6.73669									
81	596.9	520.8	1521.8	570.9	475553	24268	0.90124	2.25075	2.05353	2.06764	1.6287	1.2967	-0.00350	1.22828	0.055488	0.5973 0.090371
82	595.1	516.7	1521.4	568.2	469961	24319	0.89772	2.24998	2.04598	2.05955	1.6412	1.2965	-0.00346	1.22503	0.056475	0.6094 0.092687
83	593.4	512.7	1521.0	565.7	464506	24373	0.89426	2.24918	2.03850	2.05152	1.6536	1.2963	-0.00340	1.22126	0.057475	0.6217 0.095042
84	591.6	508.8	1520.6	563.2	459209	24430	0.89084	2.24832	2.03110	2.04357	1.6659	1.2961	-0.00336	1.21826	0.058485	0.6342 0.097433
85	590.0	504.9	1520.2	560.7	454038	24490	0.88747	2.24744	2.02376	2.03571	1.6782	1.2959	-0.00332	1.21551	0.059506	0.6469 0.099862
86	588.3	501.2	1519.8	558.4	449025	24553	0.88417	2.24651	2.01652	2.02793	1.6903	1.2957	-0.00328	1.21279	0.060538	0.6597 0.102325
87	586.7	497.5	1519.4	556.0	444136	24618	0.88090	2.24554	2.00934	2.02024	1.7022	1.2955	-0.00327	1.21128	0.061581	0.6726 0.104825
88	585.2	494.0	1519.0	553.8	439389	24687	0.87769	2.24453	2.00225	2.01263	1.7141	1.2953	-0.00324	1.20941	0.062634	0.6857 0.107359
89	583.7	490.5	1518.7	551.5	434772	24759	0.87454	2.24348	1.99523	2.00512	1.7258	1.2951	-0.00324	1.20910	0.063697	0.6990 0.109927
90	581.7	485.9	1518.2	548.6	428644	24862	0.87029	2.24198	1.98574	1.99497	1.7416	1.2948	-0.00323	1.20786	0.065171	0.7175 0.113504
X= 92.781,	DSU= 0.11582,	THU=0.0666456,	CTH=0.0653847,	HU= 1.737778,	H= 1.741632,	CH= 1.745897,	N= 6.78392									
91	579.7	481.4	1517.7	545.7	422769	24971	0.86616	2.24039	1.97641	1.98501	1.7572	1.2945	-0.00322	1.20701	0.066661	0.7362 0.117135
92	577.8	477.1	1517.3	543.0	417115	25085	0.86213	2.23874	1.96723	1.97522	1.7724	1.2943	-0.00324	1.20823	0.068169	0.7552 0.120825
93	576.0	473.0	1516.8	540.3	411676	25205	0.85819	2.23703	1.95820	1.96561	1.7875	1.2940	-0.00325	1.20918	0.069693	0.7745 0.124574
94	574.3	469.0	1516.4	537.8	406449	25331	0.85436	2.23524	1.94932	1.95617	1.8022	1.2937	-0.00325	1.20934	0.071234	0.7940 0.128377
95	572.6	465.1	1516.0	535.3	401431	25462	0.85062	2.23338	1.94060	1.94692	1.8166	1.2934	-0.00326	1.21048	0.072791	0.8138 0.132232
96	571.0	461.4	1515.6	532.9	396599	25599	0.84698	2.23146	1.93201	1.93784	1.8308	1.2931	-0.00328	1.21284	0.074363	0.8338 0.136143
97	569.4	457.8	1515.3	530.6	391948	25740	0.84343	2.22948	1.92357	1.92892	1.8447	1.2928	-0.00328	1.21333	0.075953	0.8541 0.140108
98	567.9	454.3	1514.9	528.3	387490	25889	0.83998	2.22742	1.91528	1.92018	1.8582	1.2925	-0.00328	1.21414	0.077556	0.8747 0.144118
99	566.4	450.9	1514.5	526.2	383196	26042	0.83662	2.22531	1.90712	1.91161	1.8716	1.2923	-0.00330	1.21708	0.079175	0.8955 0.148180
100	565.0	447.7	1514.2	524.1	379059	26200	0.83334	2.22315	1.89910	1.90319	1.8846	1.2920	-0.00329	1.21745	0.080810	0.9166 0.152294
X=105.689,	DSU= 0.15593,	THU=0.0829414,	CTH=0.0811067,	HU= 1.879957,	H= 1.884602,	CH= 1.890793,	N= 6.85020									

101	563.7	444.6	1513.9	522.1	375099	26365	0.83017	2.22091	1.89123	1.89495	1.8973	1.2917	-0.00328	1.21809	0.082458	0.9379	0.156447
102	562.4	441.6	1513.6	520.2	371282	26535	0.82707	2.21862	1.88348	1.88686	1.9098	1.2914	-0.00330	1.22079	0.084120	0.9594	0.160649
103	561.1	438.7	1513.3	518.3	367609	26710	0.82407	2.21628	1.87587	1.87892	1.9219	1.2911	-0.00328	1.22064	0.085797	0.9812	0.164896
104	559.9	435.9	1513.0	516.5	364094	26892	0.82116	2.21388	1.86840	1.87115	1.9338	1.2908	-0.00326	1.22077	0.087485	1.0032	0.169176
105	558.7	433.2	1512.7	514.7	360710	27078	0.81833	2.21143	1.86106	1.86353	1.9453	1.2905	-0.00326	1.22282	0.089186	1.0254	0.173498
106	557.6	430.6	1512.4	513.1	357455	27270	0.81558	2.20893	1.85384	1.85606	1.9566	1.2902	-0.00323	1.22155	0.090901	1.0478	0.177859
107	556.5	428.1	1512.2	511.5	354349	27469	0.81293	2.20637	1.84678	1.84876	1.9676	1.2899	-0.00319	1.22003	0.092624	1.0704	0.182242
108	555.5	425.7	1511.9	509.9	351364	27672	0.81037	2.20377	1.83984	1.84161	1.9782	1.2896	-0.00318	1.22095	0.094356	1.0932	0.186656
109	554.5	423.4	1511.7	508.4	348496	27881	0.80788	2.20113	1.83303	1.83460	1.9886	1.2893	-0.00315	1.21958	0.096101	1.1162	0.191103
110	553.5	421.2	1511.5	507.0	345759	28096	0.80548	2.19843	1.82636	1.82774	1.9986	1.2891	-0.00309	1.21643	0.097852	1.1393	0.195565

X=119.656, DSU= 0.20106, THU=0.1008818, CTH=0.0982603, HU= 1.993003, H= 1.998580, CH= 2.007013, N= 6.91913

111	552.6	419.1	1511.2	505.6	343144	28317	0.80317	2.19569	1.81983	1.82105	2.0083	1.2888	-0.00305	1.21452	0.099609	1.1626	0.200041
112	551.7	417.0	1511.0	504.3	340639	28543	0.80095	2.19291	1.81343	1.81449	2.0176	1.2885	-0.00302	1.21311	0.101374	1.1860	0.204537
113	550.8	415.1	1510.8	503.0	338242	28774	0.79880	2.19009	1.80715	1.80808	2.0267	1.2882	-0.00297	1.21005	0.103146	1.2096	0.209048
114	550.0	413.2	1510.6	501.8	335959	29011	0.79674	2.18723	1.80101	1.80182	2.0355	1.2879	-0.00290	1.20495	0.104920	1.2332	0.213561
115	549.3	411.4	1510.4	500.7	333792	29255	0.79477	2.18433	1.79502	1.79571	2.0438	1.2876	-0.00283	1.20003	0.106696	1.2569	0.218071
116	548.5	409.8	1510.3	499.6	331726	29503	0.79288	2.18140	1.78916	1.78975	2.0519	1.2873	-0.00277	1.19577	0.108474	1.2807	0.222579
117	547.8	408.1	1510.1	498.5	329761	29757	0.79107	2.17844	1.78342	1.78393	2.0596	1.2870	-0.00271	1.19068	0.110254	1.3045	0.227084
118	547.2	406.6	1509.9	497.6	327896	30016	0.78934	2.17544	1.77783	1.77826	2.0671	1.2867	-0.00264	1.18475	0.112033	1.3284	0.231578
119	546.5	405.2	1509.8	496.6	326128	30281	0.78769	2.17242	1.77236	1.77272	2.0741	1.2865	-0.00256	1.17779	0.113810	1.3522	0.236057
120	546.0	403.8	1509.6	495.7	324458	30551	0.78612	2.16937	1.76703	1.76734	2.0809	1.2862	-0.00247	1.16921	0.115583	1.3761	0.240512

X=134.453, DSU= 0.24845, THU=0.1197765, CTH=0.1161323, HU= 2.074240, H= 2.080862, CH= 2.091713, N= 6.98852

121	545.4	402.5	1509.5	494.9	322890	30826	0.78465	2.16629	1.76185	1.76210	2.0872	1.2859	-0.00238	1.16026	0.117349	1.3999	0.244935
122	544.9	401.3	1509.4	494.1	321412	31107	0.78325	2.16319	1.75680	1.75701	2.0933	1.2856	-0.00229	1.15149	0.119109	1.4236	0.249326
123	544.4	400.1	1509.3	493.3	320026	31392	0.78193	2.16007	1.75189	1.75206	2.0989	1.2853	-0.00220	1.14185	0.120861	1.4473	0.253681
124	543.9	399.0	1509.1	492.6	318728	31683	0.78069	2.15694	1.74711	1.74725	2.1043	1.2851	-0.00210	1.13137	0.122603	1.4709	0.257994
125	543.5	398.0	1509.0	492.0	317517	31978	0.77952	2.15379	1.74247	1.74258	2.1093	1.2848	-0.00200	1.12012	0.124334	1.4943	0.262260
126	543.1	397.1	1508.9	491.4	316392	32277	0.77844	2.15062	1.73796	1.73805	2.1140	1.2845	-0.00190	1.10815	0.126053	1.5176	0.266475
127	542.7	396.2	1508.9	490.8	315350	32582	0.77743	2.14745	1.73360	1.73366	2.1183	1.2843	-0.00179	1.09550	0.127757	1.5408	0.270631
128	542.3	395.4	1508.8	490.3	314390	32890	0.77650	2.14427	1.72936	1.72941	2.1223	1.2840	-0.00168	1.08219	0.129446	1.5637	0.274726
129	542.0	394.7	1508.7	489.8	313509	33203	0.77564	2.14108	1.72526	1.72530	2.1260	1.2837	-0.00157	1.06830	0.131117	1.5864	0.278755
130	541.7	394.0	1508.6	489.4	312705	33520	0.77486	2.13789	1.72129	1.72132	2.1294	1.2835	-0.00146	1.05392	0.132770	1.6089	0.282715

X=149.842, DSU= 0.29351, THU=0.1383385, CTH=0.1334834, HU= 2.121666, H= 2.129352, CH= 2.142498, N= 7.05535

131	541.5	393.4	1508.6	489.0	311977	33840	0.77415	2.13470	1.71746	1.71748	2.1324	1.2832	-0.00134	1.03838	0.134404	1.6311	0.286600
132	541.2	392.9	1508.5	488.6	311324	34164	0.77351	2.13152	1.71376	1.71377	2.1351	1.2830	-0.00121	1.02213	0.136015	1.6530	0.290404
133	541.0	392.4	1508.5	488.3	310743	34492	0.77294	2.12834	1.71019	1.71020	2.1375	1.2827	-0.00110	1.00629	0.137604	1.6747	0.294125
134	540.8	391.9	1508.4	488.0	310229	34822	0.77243	2.12517	1.70674	1.70675	2.1396	1.2825	-0.00099	0.99059	0.139170	1.6960	0.297766
135	540.7	391.6	1508.4	487.8	309778	35155	0.77199	2.12201	1.70342	1.70342	2.1414	1.2822	-0.00088	0.97488	0.140714	1.7170	0.301325
136	540.5	391.2	1508.3	487.6	309386	35490	0.77160	2.11886	1.70021	1.70022	2.1430	1.2820	-0.00077	0.95899	0.142234	1.7378	0.304804
137	540.4	390.9	1508.3	487.4	309053	35828	0.77127	2.11573	1.69712	1.69712	2.1443	1.2817	-0.00065	0.94240	0.143731	1.7581	0.308198
138	540.3	390.7	1508.3	487.2	308778	36168	0.77100	2.11262	1.69415	1.69415	2.1453	1.2815	-0.00055	0.92663	0.145203	1.7782	0.311506
139	540.2	390.5	1508.3	487.1	308550	36509	0.77077	2.10953	1.69127	1.69127	2.1461	1.2813	-0.00046	0.91257	0.146653	1.7979	0.314737
140	540.2	390.4	1508.2	487.0	308365	36852	0.77059	2.10646	1.68849	1.68849	2.1468	1.2810	-0.00037	0.89858	0.148081	1.8174	0.317897

X=165.549, DSU= 0.33159, THU=0.1550857, CTH=0.1489637, HU= 2.138136, H= 2.146777, CH= 2.161746, N= 7.11626

141	540.1	390.2	1508.2	486.9	308223	37196	0.77045	2.10342	1.68581	1.68581	2.1472	1.2808	-0.00028	0.88515	0.149488	1.8366	0.320985
142	540.1	390.2	1508.2	486.9	308117	37541	0.77034	2.10040	1.68321	1.68321	2.1475	1.2806	-0.00021	0.87366	0.150876	1.8555	0.324007
143	540.0	390.1	1508.2	486.8	308039	37886	0.77026	2.09742	1.68068	1.68068	2.1477	1.2804	-0.00015	0.86345	0.152247	1.8742	0.326975
144	540.0	390.1	1508.2	486.8	307987	38233	0.77021	2.09446	1.67822	1.67822	2.1477	1.2802	-0.00010	0.85434	0.153603	1.8926	0.329894
145	540.0	390.0	1508.2	486.8	307956	38579	0.77018	2.09153	1.67582	1.67582	2.1477	1.2800	-0.00006	0.84721	0.154946	1.9110	0.332770
146	540.0	390.0	1508.2	486.8	307937	38925	0.77016	2.08864	1.67347	1.67347	2.1475	1.2797	-0.00003	0.84168	0.156279	1.9291	0.335617
147	540.0	390.0	1508.2	486.8	307930	39272	0.77016	2.08578	1.67116	1.67116	2.1474	1.2795	-0.00001	0.83757	0.157604	1.9473	0.338439
148	540.0	390.0	1508.2	486.8	307927	39618	0.77015	2.08295	1.66889	1.66889	2.1472	1.2793	-0.00000	0.83502	0.158924	1.9653	0.341246
149	540.0	390.0	1508.2	486.8	307927	39965	0.77015	2.08015	1.66664	1.66664	2.1470	1.2791	0.0	0.83332	0.160241	1.9833	0.344044

X=179.757, DELTA*= 0.3488741, THETA=0.1612733, H= 2.163248, N= 7.1651556, DELTA= 1.9833418, RE/FT= 3695124.

RE,THETA= 49660., LOG= 4.69601, RE,DELTA= 610725., LOG= 5.78585

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M A C H 4  BOUNDARY LAYER CALCULATIONS, STAGNATION PRESSURE= 200.PSI, STAGNATION TEMPERATURE=1638. DEG R, N BASED ON RE,DELTA
    PARABOLIC TEMPERATURE DISTRIBUTION     MODIF. SPALDING-CHI REFERENCE TEMP     VAN DRIEST REFERENCE REYNOLDS NUMBER
    TW    TE    TAW    TP     RE/IN   RTHI    FRD     KCFI    KCF     KCFS     H      HI     FMY     KTHP  THETA-1  DELTA  DELTA*-1

 1 866.01343.4 1607.41011.2  1349924  19656 1.33392 2.32956 3.09486 3.09486  0.5083 1.3172 0.14276 0.0      0.010840 0.0908 0.005510
  X= 46.076,   DSU= 0.00554,   THU=0.0109159,   CTH=0.0108554,   HU=  0.507560,   H=  0.508344,   CH=  0.507981,   N= 6.30523
 2 865.71336.2 1606.61009.0  1352630  19637 1.32979 2.32993 3.08573 3.08579  0.5156 1.3171 0.14033 0.02154 0.010841 0.0909 0.005590
  X= 46.195,   DSU= 0.00562,   THU=0.0109173,   CTH=0.0108567,   HU=  0.514836,   H=  0.515625,   CH=  0.515263,   N= 6.30714
 3 865.31328.8 1605.81006.6  1354981  19617 1.32556 2.33033 3.07638 3.07658  0.5231 1.3170 0.13687 0.05391 0.010845 0.0911 0.005674
  X= 46.317,   DSU= 0.00571,   THU=0.0109220,   CTH=0.0108611,   HU=  0.522351,   H=  0.523146,   CH=  0.522784,   N= 6.30910
 4 864.81321.1 1605.01004.0  1356933  19598 1.32124 2.33070 3.06678 3.06723  0.5309 1.3169 0.13349 0.08469 0.010854 0.0914 0.005762
 5 864.11313.0 1604.21001.2  1358454  19578 1.31682 2.33109 3.05692 3.05771  0.5389 1.3168 0.12991 0.11708 0.010867 0.0917 0.005857
 6 863.41304.6 1603.3 998.3  1359497  19559 1.31230 2.33147 3.04682 3.04808  0.5472 1.3167 0.12614 0.15092 0.010886 0.0920 0.005956
 7 862.51295.9 1602.4 995.2  1360023  19540 1.30766 2.33184 3.03640 3.03824  0.5557 1.3166 0.12208 0.18732 0.010909 0.0924 0.006063
 8 861.41286.8 1601.5 991.8  1359983  19523 1.30293 2.33217 3.02570 3.02825  0.5645 1.3165 0.11775 0.22601 0.010939 0.0928 0.006176
 9 860.21277.3 1600.5 988.2  1359327  19508 1.29806 2.33248 3.01461 3.01799  0.5737 1.3163 0.11323 0.26611 0.010977 0.0933 0.006298
10 858.81267.3 1599.4 984.4  1357994  19495 1.29305 2.33272 3.00311 3.00747  0.5832 1.3162 0.10826 0.31039 0.011023 0.0939 0.006429
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11 857.31256.9 1598.4 980.3  1355928  19487 1.28791 2.33288 2.99116 2.99663  0.5931 1.3160 0.10299 0.35738 0.011079 0.0946 0.006571
12 855.51246.0 1597.2 975.9  1353056  19486 1.28261 2.33291 2.97867 2.98539  0.6034 1.3159 0.09738 0.40729 0.011147 0.0954 0.006725
13 853.61234.7 1596.1 971.2  1349327  19493 1.27718 2.33277 2.96563 2.97372  0.6140 1.3157 0.09143 0.46022 0.011228 0.0964 0.006894
14 851.41222.9 1594.8 966.3  1344694  19512 1.27163 2.33240 2.95200 2.96156  0.6250 1.3155 0.08539 0.51360 0.011327 0.0975 0.007079
15 849.01210.7 1593.6 961.0  1339108  19544 1.26594 2.33177 2.93773 2.94885  0.6363 1.3153 0.07953 0.56438 0.011443 0.0988 0.007282
16 846.31198.0 1592.2 955.4  1332502  19589 1.26012 2.33087 2.92279 2.93554  0.6481 1.3150 0.07404 0.61046 0.011579 0.1002 0.007504
17 843.41184.8 1590.9 949.5  1324786  19648 1.25413 2.32972 2.90714 2.92156  0.6603 1.3148 0.06885 0.65277 0.011736 0.1019 0.007750
18 840.21171.0 1589.4 943.2  1315877  19720 1.24795 2.32832 2.89074 2.90686  0.6731 1.3145 0.06392 0.69172 0.011916 0.1038 0.008021
19 836.71156.5 1587.9 936.4  1305663  19803 1.24155 2.32670 2.87356 2.89138  0.6864 1.3142 0.05922 0.72791 0.012121 0.1059 0.008320
20 832.91141.4 1586.4 929.3  1294046  19899 1.23491 2.32485 2.85557 2.87506  0.7004 1.3138 0.05464 0.76251 0.012354 0.1084 0.008653
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21 828.71125.5 1584.7 921.6  1280919  20006 1.22801 2.32280 2.83675 2.85786  0.7152 1.3135 0.05020 0.79561 0.012617 0.1111 0.009023
22 825.91115.3 1583.6 916.6  1271961  20078 1.22359 2.32143 2.82463 2.84670  0.7247 1.3132 0.04748 0.81578 0.012796 0.1129 0.009274
23 821.91100.9 1582.1 909.5  1258800  20182 1.21741 2.31946 2.80768 2.83099  0.7381 1.3129 0.04384 0.84285 0.013061 0.1157 0.009641
24 817.31084.9 1580.5 901.4  1243347  20301 1.21057 2.31721 2.78886 2.81342  0.7532 1.3125 0.04002 0.87139 0.013375 0.1189 0.010074
25 812.21068.0 1578.7 892.8  1226175  20430 1.20336 2.31479 2.76903 2.79478  0.7693 1.3121 0.03622 0.90010 0.013729 0.1226 0.010561
26 806.81050.6 1576.9 883.8  1207626  20566 1.19594 2.31227 2.74866 2.77545  0.7860 1.3117 0.03253 0.92851 0.014117 0.1266 0.011096
27 801.21032.8 1575.1 874.5  1187927  20707 1.18838 2.30969 2.72798 2.75568  0.8033 1.3113 0.02898 0.95648 0.014538 0.1309 0.011678
28 795.31015.0 1573.2 865.0  1167300  20850 1.18075 2.30708 2.70716 2.73561  0.8209 1.3108 0.02562 0.98376 0.014991 0.1356 0.012307
29 789.3 997.0 1571.3 855.3  1145891  20994 1.17306 2.30447 2.68630 2.71536  0.8389 1.3104 0.02244 1.01047 0.015475 0.1406 0.012982
30 783.2 979.2 1569.5 845.6  1123888  21139 1.16535 2.30187 2.66550 2.69500  0.8572 1.3099 0.01946 1.03642 0.015989 0.1459 0.013706
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33 764.4 926.5 1564.0 816.3  1055651  21568 1.14219 2.29432 2.60392 2.63404  0.9134 1.3086 0.01173 1.10930 0.017708 0.1638 0.016175
34 758.0 909.4 1562.2 806.6  1032618  21707 1.13450 2.29192 2.58382 2.61395  0.9325 1.3082 0.00957 1.13143 0.018339 0.1704 0.017101
35 751.7 892.6 1560.5 797.1  1009643  21842 1.12686 2.28959 2.56399 2.59407  0.9517 1.3078 0.00761 1.15256 0.018997 0.1774 0.018079
36 745.5 876.2 1558.8 787.6   986827  21974 1.11926 2.28735 2.54447 2.57445  0.9710 1.3074 0.00584 1.17236 0.019681 0.1846 0.019110
37 739.3 860.1 1557.1 778.3   964289  22101 1.11172 2.28519 2.52529 2.55513  0.9904 1.3070 0.00426 1.19060 0.020390 0.1921 0.020194
38 733.2 844.5 1555.5 769.2   942112  22224 1.10426 2.28313 2.50648 2.53616  1.0098 1.3066 0.00286 1.20760 0.021122 0.1999 0.021328
39 727.2 829.3 1553.9 760.3   920368  22341 1.09688 2.28117 2.48807 2.51757  1.0291 1.3062 0.00162 1.22328 0.021876 0.2080 0.022513
40 721.3 814.5 1552.4 751.6   899125  22453 1.08959 2.27931 2.47008 2.49938  1.0485 1.3058 0.00054 1.23751 0.022649 0.2163 0.023747
  X= 59.364,   DSU= 0.02399,   THU=0.0229189,   CTH=0.0226962,   HU=  1.046817,   H=  1.048468,   CH=  1.048574,   N= 6.54074
41 715.6 800.3 1550.9 743.2   878429  22559 1.08241 2.27757 2.45252 2.48164  1.0677 1.3054-0.00040 1.25011 0.023441 0.2248 0.025028
42 710.8 788.3 1549.6 736.1   861085  22645 1.07631 2.27616 2.43776 2.46672  1.0842 1.3051-0.00112 1.26035 0.024135 0.2323 0.026168
43 706.1 776.9 1548.4 729.2   844383  22726 1.07036 2.27485 2.42350 2.45230  1.1005 1.3048-0.00176 1.26977 0.024831 0.2399 0.027326
44 701.6 765.9 1547.3 722.7   828292  22801 1.06456 2.27363 2.40970 2.43835  1.1165 1.3045-0.00232 1.27831 0.025530 0.2475 0.028503
45 697.2 755.3 1546.2 716.3   812778  22870 1.05888 2.27250 2.39634 2.42484  1.1322 1.3042-0.00281 1.28605 0.026231 0.2552 0.029699
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46	693.0	745.1	1545.1	710.1	797810	22935	1.05333	2.27146	2.38338	2.41172	1.1478	1.3039	-0.00324	1.29300	0.026934	0.2630	0.030915
47	688.9	735.3	1544.1	704.2	783356	22995	1.04789	2.27049	2.37079	2.39897	1.1632	1.3037	-0.00361	1.29919	0.027640	0.2707	0.032149
48	685.0	725.8	1543.1	698.4	769389	23051	1.04255	2.26960	2.35854	2.38656	1.1783	1.3034	-0.00392	1.30445	0.028348	0.2786	0.033403
49	681.1	716.6	1542.2	692.8	755892	23103	1.03732	2.26877	2.34663	2.37447	1.1933	1.3032	-0.00418	1.30861	0.029059	0.2865	0.034677
50	677.4	707.7	1541.3	687.4	742838	23151	1.03218	2.26800	2.33501	2.36268	1.2082	1.3029	-0.00440	1.31223	0.029773	0.2945	0.035971

X= 64.921, DSU= 0.03642, THU=0.0301939, CTH=0.0298428, HU= 1.206115, H= 1.208184, CH= 1.208778, N= 6.60228

51	673.8	699.1	1540.4	682.2	730196	23196	1.02713	2.26728	2.32368	2.35114	1.2229	1.3027	-0.00459	1.31557	0.030490	0.3025	0.037286
52	670.3	690.8	1539.5	677.1	717942	23238	1.02216	2.26662	2.31260	2.33985	1.2375	1.3025	-0.00474	1.31780	0.031211	0.3106	0.038623
53	666.8	682.7	1538.6	672.1	706070	23277	1.01726	2.26600	2.30176	2.32880	1.2519	1.3022	-0.00484	1.31899	0.031936	0.3188	0.039982
54	663.5	674.8	1537.8	667.3	694556	23314	1.01244	2.26542	2.29116	2.31796	1.2663	1.3020	-0.00493	1.32005	0.032665	0.3270	0.041363
55	660.2	667.2	1537.0	662.5	683372	23348	1.00769	2.26488	2.28076	2.30731	1.2805	1.3018	-0.00500	1.32053	0.033399	0.3354	0.042768
56	657.1	659.8	1536.3	658.0	672514	23381	1.00301	2.26437	2.27056	2.29685	1.2947	1.3016	-0.00502	1.31978	0.034137	0.3438	0.044196
57	654.0	652.5	1535.5	653.5	661967	23412	0.99838	2.26388	2.26055	2.28655	1.3087	1.3014	-0.00504	1.31895	0.034881	0.3523	0.045650
58	650.9	645.5	1534.8	649.1	651702	23441	0.99381	2.26342	2.25070	2.27641	1.3227	1.3012	-0.00504	1.31771	0.035631	0.3609	0.047129
59	648.0	638.6	1534.1	644.8	641721	23469	0.98930	2.26298	2.24102	2.26640	1.3366	1.3010	-0.00501	1.31540	0.036387	0.3696	0.048635
60	645.1	631.9	1533.4	640.7	632009	23496	0.98485	2.26255	2.23149	2.25654	1.3505	1.3008	-0.00498	1.31336	0.037149	0.3784	0.050168

X= 70.519, DSU= 0.05089, THU=0.0377495, CTH=0.0372452, HU= 1.347979, H= 1.350451, CH= 1.351681, N= 6.64934

61	642.3	625.3	1532.7	636.6	622542	23522	0.98043	2.26215	2.22209	2.24679	1.3642	1.3006	-0.00493	1.31042	0.037918	0.3873	0.051730
62	639.5	618.9	1532.0	632.6	613335	23548	0.97608	2.26174	2.21284	2.23717	1.3779	1.3004	-0.00486	1.30683	0.038694	0.3963	0.053319
63	636.8	612.7	1531.4	628.7	604355	23574	0.97176	2.26135	2.20371	2.22765	1.3916	1.3002	-0.00481	1.30382	0.039478	0.4055	0.054938
64	634.2	606.6	1530.7	624.9	595596	23598	0.96749	2.26097	2.19469	2.21822	1.4052	1.3000	-0.00473	1.29956	0.040270	0.4147	0.056589
65	631.6	600.6	1530.1	621.2	587066	23624	0.96327	2.26058	2.18578	2.20890	1.4188	1.2998	-0.00465	1.29540	0.041071	0.4241	0.058270
66	629.1	594.8	1529.5	617.5	578734	23648	0.95908	2.26019	2.17698	2.19966	1.4323	1.2996	-0.00457	1.29108	0.041880	0.4336	0.059984
67	626.6	589.1	1528.9	614.0	570618	23674	0.95495	2.25980	2.16828	2.19052	1.4458	1.2994	-0.00447	1.28608	0.042697	0.4433	0.061730
68	624.2	583.5	1528.3	610.5	562693	23700	0.95084	2.25940	2.15967	2.18144	1.4592	1.2993	-0.00439	1.28181	0.043524	0.4531	0.063510
69	621.8	578.0	1527.8	607.0	554955	23726	0.94678	2.25899	2.15115	2.17244	1.4726	1.2991	-0.00429	1.27656	0.044361	0.4630	0.065326
70	619.5	572.7	1527.2	603.7	547413	23754	0.94276	2.25857	2.14272	2.16352	1.4859	1.2989	-0.00420	1.27174	0.045208	0.4731	0.067175

X= 76.747, DSU= 0.06826, THU=0.0460270, CTH=0.0453348, HU= 1.483015, H= 1.485898, CH= 1.487931, N= 6.69162

71	617.2	567.5	1526.7	600.4	540039	23782	0.93878	2.25814	2.13437	2.15467	1.4992	1.2987	-0.00411	1.26662	0.046065	0.4833	0.069061
72	615.0	562.3	1526.1	597.1	532858	23811	0.93484	2.25768	2.12611	2.14589	1.5124	1.2985	-0.00401	1.26115	0.046932	0.4937	0.070982
73	612.8	557.3	1525.6	594.0	525840	23842	0.93094	2.25721	2.11792	2.13717	1.5256	1.2983	-0.00393	1.25654	0.047810	0.5042	0.072940
74	610.7	552.4	1525.1	590.9	518992	23874	0.92707	2.25671	2.10981	2.12852	1.5387	1.2981	-0.00384	1.25109	0.048700	0.5149	0.074936
75	608.6	547.6	1524.6	587.8	512313	23909	0.92326	2.25619	2.10177	2.11994	1.5518	1.2979	-0.00376	1.24647	0.049600	0.5258	0.076969
76	606.5	542.9	1524.1	584.8	505790	23944	0.91947	2.25565	2.09380	2.11142	1.5648	1.2978	-0.00367	1.24115	0.050511	0.5368	0.079041
77	604.5	538.3	1523.6	581.9	499439	23982	0.91574	2.25507	2.08591	2.10298	1.5778	1.2976	-0.00359	1.23617	0.051433	0.5480	0.081149
78	602.6	533.8	1523.2	579.1	493232	24022	0.91204	2.25447	2.07809	2.09460	1.5907	1.2974	-0.00352	1.23164	0.052367	0.5593	0.083298
79	600.6	529.4	1522.7	576.3	487191	24064	0.90839	2.25382	2.07034	2.08629	1.6034	1.2972	-0.00344	1.22667	0.053312	0.5708	0.085483
80	598.8	525.1	1522.3	573.5	481295	24108	0.90479	2.25315	2.06266	2.07805	1.6162	1.2970	-0.00338	1.22269	0.054268	0.5825	0.087707

X= 84.020, DSU= 0.08929, THU=0.0553614, CTH=0.0544319, HU= 1.612848, H= 1.616172, CH= 1.619192, N= 6.73410

81	596.9	520.8	1521.8	570.9	475553	24155	0.90123	2.25245	2.05506	2.06988	1.6288	1.2968	-0.00332	1.21818	0.055236	0.5944	0.089969
82	595.1	516.7	1521.4	568.3	469961	24205	0.89772	2.25170	2.04753	2.06179	1.6413	1.2966	-0.00327	1.21480	0.056215	0.6064	0.092268
83	593.4	512.7	1521.0	565.7	464506	24256	0.89425	2.25092	2.04006	2.05376	1.6538	1.2964	-0.00322	1.21089	0.057206	0.6186	0.094606
84	591.7	508.8	1520.6	563.2	459209	24312	0.89084	2.25009	2.03268	2.04582	1.6661	1.2962	-0.00318	1.20773	0.058207	0.6310	0.096979
85	590.0	504.9	1520.2	560.7	454038	24369	0.88747	2.24924	2.02537	2.03796	1.6783	1.2960	-0.00314	1.20482	0.059220	0.6435	0.099391
86	588.3	501.2	1519.8	558.4	449025	24430	0.88416	2.24833	2.01814	2.03019	1.6904	1.2958	-0.00310	1.20194	0.060243	0.6562	0.101835
87	586.8	497.5	1519.4	556.0	444136	24493	0.88089	2.24739	2.01098	2.02250	1.7024	1.2956	-0.00308	1.20023	0.061276	0.6690	0.104316
88	585.2	494.0	1519.0	553.8	439389	24560	0.87769	2.24640	2.00390	2.01490	1.7142	1.2954	-0.00306	1.19816	0.062320	0.6820	0.106830
89	583.7	490.5	1518.7	551.5	434772	24630	0.87453	2.24538	1.99690	2.00739	1.7259	1.2952	-0.00306	1.19762	0.063373	0.6952	0.109377
90	581.7	485.9	1518.2	548.6	428644	24729	0.87029	2.24391	1.98744	1.99725	1.7418	1.2949	-0.00305	1.19606	0.064833	0.7135	0.112925

X= 92.781, DSU= 0.11521, THU=0.0662907, CTH=0.0650438, HU= 1.737954, H= 1.741787, CH= 1.746030, N= 6.78089

91	579.7	481.4	1517.7	545.7	422769	24835	0.86616	2.24237	1.97814	1.98729	1.7573	1.2947	-0.00303	1.19488	0.066308	0.7320	0.116524
92	577.8	477.1	1517.3	543.0	417115	24946	0.86212	2.24076	1.96899	1.97751	1.7726	1.2944	-0.00305	1.19572	0.067800	0.7508	0.120182
93	576.0	473.0	1516.8	540.3	411676	25062	0.85819	2.23908	1.95998	1.96791	1.7876	1.2941	-0.00306	1.19627	0.069309	0.7699	0.123897
94	574.3	469.0	1516.4	537.8	406449	25184	0.85435	2.23733	1.95114	1.95849	1.8023	1.2938	-0.00306	1.19604	0.070833	0.7892	0.127665
95	572.6	465.1	1516.0	535.3	401431	25311	0.85062	2.23551	1.94244	1.94925	1.8168	1.2935	-0.00307	1.19677	0.072372	0.8087	0.131483
96	571.0	461.4	1515.6	532.9	396599	25444	0.84697	2.23363	1.93389	1.94018	1.8309	1.2933	-0.00309	1.19866	0.073927	0.8285	0.135355
97	569.4	457.8	1515.3	530.6	391948	25582	0.84342	2.23170	1.92548	1.93127	1.8448	1.2930	-0.00309	1.19872	0.075497	0.8486	0.139280
98	567.9	454.3	1514.9	528.3	387490	25725	0.83997	2.22968	1.91722	1.92255	1.8584	1.2927	-0.00309	1.19908	0.077081	0.8689	0.143248
99	566.4	450.9	1514.5	526.2	383196	25874	0.83661	2.22762	1.90910	1.91399	1.8717	1.2924	-0.00311	1.20151	0.078679	0.8895	0.147266
100	565.0	447.7	1514.2	524.1	379059	26027	0.83334	2.22550	1.90111	1.90559	1.8848	1.2921	-0.00310	1.20142	0.080293	0.9103	0.151334

X=105.689, DSU= 0.15492, THU=0.0823957, CTH=0.0805858, HU= 1.880166, H= 1.884781, CH= 1.890933, N= 6.84641

101	563.7	444.6	1513.9	522.1	375099	26188	0.83016	2.22331	1.89327	1.89737	1.8975	1.2918	-0.00309	1.20157	0.081918	0.9313	0.155439
102	562.4	441.6	1513.6	520.2	371282	26352	0.82707	2.22108	1.88556	1.88930	1.9099	1.2916	-0.00310	1.20374	0.083558	0.9525	0.159591
103	561.1	438.7	1513.3	518.3	367609	26522	0.82406	2.21879	1.87798	1.88138	1.9221	1.2913	-0.00308	1.20309	0.085211	0.9740	0.163786
104	559.9	435.9	1513.0	516.5	364094	26698	0.82116	2.21644	1.87055	1.87363	1.9340	1.2910	-0.00306	1.20272	0.086875	0.9956	0.168013
105	558.7	433.2	1512.7	514.7	360710	26879	0.81833	2.21404	1.86325	1.86604	1.9455	1.2907	-0.00306	1.20422	0.088550	1.0175	0.172278
106	557.6	430.6	1512.4	513.1	357455	27065	0.81558	2.21160	1.85608	1.85859	1.9568	1.2904	-0.00303	1.20246	0.090238	1.0396	0.176581
107	556.5	428.1	1512.2	511.5	354349	27258	0.81293	2.20909	1.84905	1.85131	1.9678	1.2901	-0.00299	1.20046	0.091934	1.0618	0.180904
108	555.5	425.7	1511.9	509.9	351364	27455	0.81036	2.20655	1.84216	1.84418	1.9784	1.2898	-0.00298	1.20083	0.093639	1.0842	0.185255
109	554.5	423.4	1511.7	508.4	348496	27657	0.80788	2.20396	1.83538	1.83720	1.9888	1.2895	-0.00294	1.19895	0.095354	1.1068	0.189638
110	553.5	421.2	1511.5	507.0	345759	27865	0.80548	2.20132	1.82876	1.83037	1.9988	1.2893	-0.00289	1.19534	0.097075	1.1295	0.194033

X=119.656, DSU= 0.19943, THU=0.1000546, CTH=0.0974769, HU= 1.993259, H= 1.998791, CH= 2.007159, N= 6.91436

111	552.6	419.1	1511.2	505.6	343144	28079	0.80317	2.19864	1.82227	1.82370	2.0085	1.2890	-0.00284	1.19294	0.098801	1.1524	0.198440
112	551.7	417.0	1511.0	504.3	340639	28298	0.80094	2.19592	1.81591	1.81718	2.0179	1.2887	-0.00281	1.19101	0.100535	1.1754	0.202865
113	550.8	415.1	1510.8	503.0	338242	28522	0.79880	2.19316	1.80968	1.81079	2.0269	1.2884	-0.00276	1.18749	0.102273	1.1985	0.207303
114	550.0	413.2	1510.6	501.8	335959	28752	0.79674	2.19036	1.80358	1.80456	2.0357	1.2881	-0.00269	1.18197	0.104015	1.2216	0.211741
115	549.3	411.4	1510.4	500.7	333792	28988	0.79477	2.18752	1.79763	1.79849	2.0441	1.2878	-0.00262	1.17665	0.105756	1.2449	0.216174
116	548.5	409.8	1510.3	499.6	331726	29228	0.79287	2.18465	1.79181	1.79256	2.0521	1.2875	-0.00256	1.17197	0.107499	1.2681	0.220603
117	547.8	408.1	1510.1	498.5	329761	29474	0.79106	2.18174	1.78613	1.78677	2.0599	1.2873	-0.00250	1.16648	0.109243	1.2915	0.225028
118	547.2	406.6	1509.9	497.6	327896	29725	0.78934	2.17881	1.78057	1.78113	2.0673	1.2870	-0.00243	1.16019	0.110986	1.3148	0.229440
119	546.5	405.2	1509.8	496.6	326128	29981	0.78769	2.17584	1.77515	1.77563	2.0744	1.2867	-0.00235	1.15291	0.112726	1.3382	0.233835
120	546.0	403.8	1509.6	495.7	324458	30243	0.78612	2.17285	1.76987	1.77028	2.0811	1.2864	-0.00226	1.14407	0.114461	1.3615	0.238205

X=134.453, DSU= 0.24598, THU=0.1185693, CTH=0.1149995, HU= 2.074552, H= 2.081109, CH= 2.091857, N= 6.98261

121	545.4	402.5	1509.5	494.9	322890	30510	0.78464	2.16983	1.76473	1.76507	2.0875	1.2861	-0.00217	1.13490	0.116189	1.3848	0.242542
122	544.9	401.3	1509.4	494.1	321412	30781	0.78325	2.16679	1.75972	1.76002	2.0935	1.2859	-0.00209	1.12591	0.117910	1.4080	0.246845
123	544.4	400.1	1509.3	493.3	320026	31058	0.78193	2.16373	1.75485	1.75510	2.0992	1.2856	-0.00199	1.11610	0.119622	1.4311	0.251112
124	543.9	399.0	1509.1	492.6	318728	31339	0.78069	2.16065	1.75012	1.75032	2.1046	1.2853	-0.00190	1.10550	0.121325	1.4542	0.255337
125	543.5	398.0	1509.0	492.0	317517	31625	0.77952	2.15756	1.74552	1.74569	2.1096	1.2851	-0.00180	1.09417	0.123017	1.4770	0.259513
126	543.1	397.1	1508.9	491.4	316392	31915	0.77844	2.15445	1.74106	1.74119	2.1143	1.2848	-0.00170	1.08218	0.124695	1.4998	0.263637
127	542.7	396.2	1508.9	490.8	315350	32210	0.77743	2.15133	1.73673	1.73684	2.1186	1.2845	-0.00159	1.06955	0.126359	1.5223	0.267704
128	542.3	395.4	1508.8	490.3	314390	32509	0.77650	2.14820	1.73253	1.73262	2.1226	1.2843	-0.00148	1.05632	0.128008	1.5447	0.271709
129	542.0	394.7	1508.7	489.8	313509	32813	0.77564	2.14506	1.72847	1.72855	2.1263	1.2840	-0.00138	1.04256	0.129639	1.5668	0.275648
130	541.7	394.0	1508.6	489.4	312705	33120	0.77486	2.14193	1.72454	1.72460	2.1296	1.2838	-0.00127	1.02835	0.131252	1.5887	0.279518

X=149.842, DSU= 0.29005, THU=0.1366870, CTH=0.1319490, HU= 2.122034, H= 2.129630, CH= 2.142629, N= 7.04826

131	541.5	393.4	1508.6	489.0	311977	33430	0.77415	2.13879	1.72074	1.72079	2.1327	1.2835	-0.00115	1.01305	0.132846	1.6104	0.283315
132	541.2	392.9	1508.5	488.6	311324	33745	0.77351	2.13565	1.71708	1.71712	2.1354	1.2833	-0.00103	0.99711	0.134418	1.6318	0.287031
133	541.0	392.4	1508.5	488.3	310743	34063	0.77294	2.13251	1.71354	1.71357	2.1378	1.2830	-0.00092	0.98159	0.135967	1.6528	0.290666
134	540.8	391.9	1508.4	488.0	310229	34383	0.77243	2.12938	1.71013	1.71015	2.1399	1.2828	-0.00081	0.96624	0.137495	1.6736	0.294222
135	540.7	391.6	1508.4	487.8	309778	34707	0.77199	2.12626	1.70684	1.70686	2.1417	1.2825	-0.00070	0.95091	0.139001	1.6941	0.297698
136	540.5	391.2	1508.3	487.6	309386	35033	0.77160	2.12316	1.70366	1.70368	2.1433	1.2823	-0.00060	0.93543	0.140484	1.7143	0.301094
137	540.4	390.9	1508.3	487.4	309053	35361	0.77127	2.12007	1.70060	1.70061	2.1446	1.2820	-0.00049	0.91930	0.141944	1.7341	0.304408
138	540.3	390.7	1508.3	487.2	308778	35692	0.77100	2.11699	1.69765	1.69766	2.1456	1.2818	-0.00038	0.90400	0.143380	1.7536	0.307637
139	540.2	390.5	1508.3	487.1	308550	36024	0.77077	2.11393	1.69480	1.69481	2.1464	1.2816	-0.00030	0.89035	0.144794	1.7729	0.310792
140	540.2	390.4	1508.2	487.0	308365	36357	0.77059	2.11090	1.69205	1.69205	2.1471	1.2814	-0.00021	0.87678	0.146188	1.7918	0.313877

X=165.549, DSU= 0.32721, THU=0.1530049, CTH=0.1470484, HU= 2.138547, H= 2.147074, CH= 2.161857, N= 7.10823

141	540.1	390.2	1508.2	486.9	308223	36692	0.77045	2.10789	1.68938	1.68939	2.1475	1.2811	-0.00013	.86376	0.147561	1.8105	0.316891
142	540.1	390.2	1508.2	486.9	308117	37028	0.77034	2.10490	1.68681	1.68681	2.1478	1.2809	-0.00006	0.85261	0.148915	1.8289	0.319841
143	540.0	390.1	1508.2	486.8	308039	37365	0.77026	2.10194	1.68430	1.68430	2.1480	1.2807	-0.00000	0.84269	0.150253	1.8471	0.322739
144	540.0	390.1	1508.2	486.8	307987	37702	0.77021	2.09901	1.68186	1.68186	2.1480	1.2805	0.00005	0.83382	0.151577	1.8651	0.325588
145	540.0	390.0	1508.2	486.8	307956	38040	0.77018	2.09610	1.67948	1.67948	2.1480	1.2803	0.00008	0.82686	0.152887	1.8829	0.328396
146	540.0	390.0	1508.2	486.8	307937	38377	0.77016	2.09323	1.67715	1.67715	2.1479	1.2801	0.00011	0.82141	0.154189	1.9007	0.331174
147	540.0	390.0	1508.2	486.8	307930	38715	0.77016	2.09039	1.67486	1.67486	2.1477	1.2799	0.00013	0.81732	0.155482	1.9183	0.333928
148	540.0	390.0	1508.2	486.8	307927	39053	0.77015	2.08759	1.67261	1.67261	2.1475	1.2797	0.00014	0.81471	0.156770	1.9359	0.336667
149	540.0	390.0	1508.2	486.8	307927	39390	0.77015	2.08481	1.67038	1.67038	2.1473	1.2795	0.00014	0.81292	0.158055	1.9534	0.339397

X=179.757, DFLTA*= 0.3440982, THETA=0.1590590, H= 2.163337, N= 7.1564820, DELTA= 1.9534113, RE/FT= 3695124.

RE.THETA= 48979., LOG= 4.69001, RE.DELTA= 601508., LOG= 5.77924

M A C H 4 NOZZLE CONTOUR, RADIAL FLOW ENDS AT STA 76.9263852, TEST CONE BEGINS AT STA 132.3126057, SCALE FACTOR = 24.75038624

RC= 6.000000 ETAD= 8.6700 DEG AMACH= 2.2878437 BMACH= 3.0821543 CMACH= 4.0000000 EMACH= 1.6601538 GMACH= 2.2878437

STAG. PRESSURE= 200. PSI, STAG. TEMPERATURE=1638. DEG R, THROAT TEMP.= 866. DEG R, WALL TEMP.=540. DEG R, THROAT HT COEF.= 0.17482

PARABOLIC TEMPERATURE DISTRIBUTION MODIF. SPALDING-CHI REFERENCE TEMP VAN DRIEST REFERENCE REYNOLDS NUMBER

	STA(IN)	Y(IN)	DELR(IN)	R(IN)	DY/DX	D2Y/DX2	DA/DX	DR/DX	MACH NO.	DM/DX	PE/PO	BETA
1	46.075855	3.742729	0.0055143	3.7482437	0.0	0.0445308	0.0006641	0.0006641	1.0471638	0.1289481	4.9957D-01	-4.8038D-01
2	46.194522	3.743043	0.0055941	3.7486371	0.0052790	0.0444289	0.0006795	0.0059585	1.0626027	0.1303456	4.9034D-01	-4.8279D-01
3	46.317241	3.744025	0.0056784	3.7497038	0.0107240	0.0443160	0.0006964	0.0114204	1.0786293	0.1308606	4.8085D-01	-4.8187D-01
4	46.443834	3.745738	0.0057677	3.7515058	0.0163271	0.0441486	0.0007156	0.0170426	1.0952300	0.1315243	4.7113D-01	-4.8152D-01
5	46.574687	3.748253	0.0058627	3.7541157	0.0220890	0.0438612	0.0007355	0.0228245	1.1124932	0.1320693	4.6113D-01	-4.8071D-01
6	46.709786	3.751637	0.0059634	3.7576009	0.0279906	0.0434400	0.0007567	0.0287473	1.1303552	0.1324678	4.5091D-01	-4.7940D-01
7	46.849950	3.755988	0.0060711	3.7620592	0.0340438	0.0428567	0.0007789	0.0348227	1.1489592	0.1326094	4.4041D-01	-4.7720D-01
8	46.995411	3.761394	0.0061860	3.7675796	0.0402279	0.0421265	0.0008019	0.0410298	1.1682305	0.1324519	4.2969D-01	-4.7401D-01
9	47.147418	3.767996	0.0063098	3.7743055	0.0465699	0.0411777	0.0008264	0.0473963	1.1883589	0.1320898	4.1867D-01	-4.7018D-01
10	47.306791	3.775942	0.0064435	3.7823854	0.0530416	0.0399150	0.0008511	0.0538927	1.2093556	0.1311293	4.0736D-01	-4.6439D-01
11	47.474504	3.785399	0.0065884	3.7919877	0.0596137	0.0383639	0.0008766	0.0604903	1.2312390	0.1296467	3.9580D-01	-4.5698D-01
12	47.652195	3.796599	0.0067465	3.8033455	0.0662758	0.0364867	0.0009022	0.0671780	1.2541190	0.1275207	3.8394D-01	-4.4760D-01
13	47.840976	3.809762	0.0069193	3.8166811	0.0729621	0.0342307	0.0009269	0.0738890	1.2779433	0.1245724	3.7186D-01	-4.3572D-01
14	48.042344	3.825149	0.0071085	3.8322578	0.0796000	0.0316803	0.0009509	0.0805509	1.3026785	0.1210265	3.5960D-01	-4.2222D-01
15	48.257882	3.843041	0.0073161	3.8503570	0.0861321	0.0289891	0.0009744	0.0871065	1.3283469	0.1173018	3.4719D-01	-4.0859D-01
16	48.489226	3.863742	0.0075443	3.8712867	0.0925115	0.0262838	0.0009986	0.0935101	1.3550399	0.1138238	3.3462D-01	-3.9631D-01
17	48.737829	3.887550	0.0077958	3.8953458	0.0987007	0.0236942	0.0010235	0.0997242	1.3829205	0.1105609	3.2187D-01	-3.8522D-01
18	49.005786	3.914845	0.0080735	3.9229188	0.1047027	0.0212013	0.0010497	0.1057524	1.4120873	0.1075151	3.0893D-01	-3.7530D-01
19	49.294604	3.945969	0.0083808	3.9543497	0.1104531	0.0187513	0.0010777	0.1115309	1.4427244	0.1047381	2.9578D-01	-3.6670D-01
20	49.606502	3.981325	0.0087215	3.9900470	0.1159113	0.0164800	0.0011075	0.1170188	1.4749409	0.1020542	2.8244D-01	-3.5881D-01
21	49.943497	4.021316	0.0091002	4.0304164	0.1210936	0.0142664	0.0011397	0.1222334	1.5088820	0.0995120	2.6892D-01	-3.5180D-01
22	50.166357	4.048660	0.0093566	4.0580171	0.1241092	0.0128924	0.0011610	0.1252702	1.5308817	0.0979907	2.6044D-01	-3.4783D-01
23	50.485904	4.088966	0.0097325	4.0986985	0.1279362	0.0113023	0.0011917	0.1291280	1.5618623	0.0959719	2.4889D-01	-3.4283D-01
24	50.852165	4.136581	0.0101754	4.1467564	0.1317928	0.0098352	0.0012271	0.1330199	1.5966017	0.0938333	2.3646D-01	-3.3786D-01
25	51.251055	4.189929	0.0106726	4.2006021	0.1354143	0.0083961	0.0012656	0.1366800	1.6335898	0.0916764	2.2381D-01	-3.3318D-01
26	51.675884	4.248214	0.0112190	4.2594329	0.1386722	0.0070360	0.0013068	0.1399790	1.6720611	0.0895581	2.1129D-01	-3.2891D-01
27	52.122740	4.310875	0.0118127	4.3226873	0.1415189	0.0058305	0.0013501	0.1428690	1.7116110	0.0874521	1.9907D-01	-3.2493D-01
28	52.589479	4.377557	0.0124533	4.3900108	0.1439769	0.0047561	0.0013955	0.1453724	1.7519140	0.0853867	1.8728D-01	-3.2129D-01
29	53.074361	4.447927	0.0131415	4.4610685	0.1460261	0.0037918	0.0014426	0.1474687	1.7928312	0.0833563	1.7596D-01	-3.1793D-01
30	53.576491	4.521718	0.0138780	4.5355964	0.1477043	0.0029792	0.0014914	0.1491957	1.8341515	0.0813511	1.6517D-01	-3.1479D-01
31	54.094777	4.598672	0.0146642	4.6133357	0.1490542	0.0022743	0.0015416	0.1505958	1.8758124	0.0793805	1.5491D-01	-3.1186D-01
32	54.628651	4.678566	0.0155008	4.6940663	0.1500868	0.0016926	0.0015929	0.1516797	1.9176407	0.0774225	1.4522D-01	-3.0904D-01
33	55.177283	4.761154	0.0163893	4.7775437	0.1508792	0.0012503	0.0016456	0.1525247	1.9595949	0.0755200	1.3608D-01	-3.0646D-01
34	55.740017	4.846257	0.0173303	4.8635878	0.1514708	0.0008799	0.0016987	0.1531694	2.0015440	0.0736156	1.2750D-01	-3.0387D-01
35	56.316071	4.933654	0.0183244	4.9519784	0.1518766	0.0005863	0.0017525	0.1536291	2.0434024	0.0717661	1.1945D-01	-3.0146D-01
36	56.904570	5.023130	0.0193719	5.0425017	0.1521507	0.0003831	0.0018065	0.1539571	2.0850968	0.0699376	1.1193D-01	-2.9907D-01
37	57.504606	5.114493	0.0204721	5.1349650	0.1523300	0.0002322	0.0018601	0.1541901	2.1265044	0.0681244	1.0492D-01	-2.9665D-01
38	58.115220	5.207549	0.0216244	5.2291739	0.1524304	0.0001177	0.0019137	0.1543441	2.1675528	0.0663705	9.8393D-02	-2.9435D-01
39	58.735317	5.302091	0.0228279	5.3249191	0.1524740	0.0000421	0.0019671	0.1544410	2.2081710	0.0646682	9.2333D-02	-2.9214D-01
40	59.363844	5.397932	0.0240810	5.4220133	0.1524825	0.0000093	0.0020197	0.1545022	2.2482849	0.0630080	8.6714D-02	-2.8994D-01
41	60.000000	5.494933	0.0253825	5.5203158	0.1524857	0.0	0.0020715	0.1545572	2.2878437	0.0613810	8.1508D-02	-2.8771D-01
42	60.552926	5.579249	0.0265402	5.6057892	0.1524880	-0.0000050	0.0021158	0.1546038	2.3214084	0.0600664	7.7339D-02	-2.8602D-01
43	61.103390	5.663187	0.0277170	5.6909039	0.1524802	-0.0000214	0.0021595	0.1546398	2.3541235	0.0588206	7.3482D-02	-2.8446D-01
44	61.651753	5.746798	0.0289130	5.7757114	0.1524645	-0.0000383	0.0022022	0.1546666	2.3860447	0.0576257	6.9906D-02	-2.8295D-01

45	62.198387	5.830135	0.0301283	5.8602635	0.1524383	-0.0000627	0.0022437	0.1546820	2.4172256	0.0564765	6.6585D-02	-2.8147D-01
46	62.743709	5.913254	0.0313630	5.9446174	0.1523961	-0.0000967	0.0022841	0.1546802	2.4477161	0.0553653	6.3492D-02	-2.8000D-01
47	63.288168	5.996214	0.0326174	6.0288310	0.1523330	-0.0001418	0.0023232	0.1546562	2.4775625	0.0542857	6.0608D-02	-2.7852D-01
48	63.832236	6.079073	0.0338918	6.1129649	0.1522418	-0.0002009	0.0023606	0.1546024	2.5068080	0.0532190	5.7911D-02	-2.7693D-01
49	64.376299	6.161873	0.0351860	6.1970586	0.1521144	-0.0002692	0.0023959	0.1545103	2.5354718	0.0521503	5.5388D-02	-2.7517D-01
50	64.921084	6.244702	0.0365006	6.2812030	0.1519487	-0.0003419	0.0024301	0.1543788	2.5635910	0.0511115	5.3023D-02	-2.7341D-01
51	65.467010	6.327604	0.0378366	6.3654410	0.1517414	-0.0004193	0.0024636	0.1542049	2.5912185	0.0501117	5.0801D-02	-2.7170D-01
52	66.014590	6.410632	0.0391946	6.4498266	0.1514901	-0.0004997	0.0024948	0.1539849	2.6183867	0.0490995	4.8710D-02	-2.6978D-01
53	66.564347	6.493840	0.0405743	6.5344139	0.1511929	-0.0005832	0.0025239	0.1537168	2.6450950	0.0480789	4.6741D-02	-2.6767D-01
54	67.116843	6.577284	0.0419766	6.6192606	0.1508470	-0.0006703	0.0025522	0.1533993	2.6713791	0.0470964	4.4885D-02	-2.6562D-01
55	67.672596	6.661014	0.0434029	6.7044173	0.1504498	-0.0007622	0.0025792	0.1530290	2.6972864	0.0461238	4.3130D-02	-2.6350D-01
56	68.231992	6.745056	0.0448529	6.7899094	0.1499967	-0.0008597	0.0026035	0.1526003	2.7228104	0.0451284	4.1471D-02	-2.6111D-01
57	68.795850	6.829497	0.0463275	6.8758240	0.1494837	-0.0009604	0.0026270	0.1521107	2.7479725	0.0441636	3.9900D-02	-2.5877D-01
58	69.364555	6.914354	0.0478283	6.9621818	0.1489085	-0.0010625	0.0026493	0.1515578	2.7728239	0.0432111	3.8411D-02	-2.5637D-01
59	69.938609	6.999660	0.0493551	7.0490151	0.1482690	-0.0011638	0.0026692	0.1509382	2.7973472	0.0422396	3.6998D-02	-2.5373D-01
60	70.518568	7.085454	0.0509087	7.1363625	0.1475648	-0.0012623	0.0026888	0.1502536	2.8215632	0.0413084	3.5656D-02	-2.5122D-01
61	71.104909	7.171760	0.0524911	7.2242513	0.1467961	-0.0013583	0.0027064	0.1495025	2.8455195	0.0403647	3.4379D-02	-2.4850D-01
62	71.697974	7.258581	0.0541007	7.3126815	0.1459622	-0.0014511	0.0027222	0.1486844	2.8691629	0.0394195	3.3166D-02	-2.4566D-01
63	72.298584	7.345985	0.0557407	7.4017258	0.1450633	-0.0015406	0.0027382	0.1478015	2.8925668	0.0385213	3.2010D-02	-2.4300D-01
64	72.907018	7.433961	0.0574114	7.4913728	0.1440989	-0.0016281	0.0027518	0.1468507	2.9157299	0.0375957	3.0907D-02	-2.4005D-01
65	73.523780	7.522526	0.0591122	7.5816383	0.1430678	-0.0017145	0.0027645	0.1458323	2.9386209	0.0366957	2.9857D-02	-2.3715D-01
66	74.149298	7.611682	0.0608458	7.6725280	0.1419682	-0.0018007	0.0027764	0.1447446	2.9613088	0.0358090	2.8853D-02	-2.3422D-01
67	74.783805	7.701399	0.0626106	7.7640100	0.1407980	-0.0018861	0.0027866	0.1435846	2.9837327	0.0349161	2.7897D-02	-2.3114D-01
68	75.428101	7.791723	0.0644094	7.8561328	0.1395555	-0.0019688	0.0027970	0.1423525	3.0059512	0.0340659	2.6982D-02	-2.2824D-01
69	76.082345	7.882605	0.0662428	7.9488479	0.1382406	-0.0020468	0.0028056	0.1410463	3.0279603	0.0331975	2.6107D-02	-2.2511D-01
70	76.746956	7.974029	0.0681098	8.0421385	0.1368552	-0.0021195	0.0028139	0.1396691	3.0497246	0.0323598	2.5272D-02	-2.2208D-01
71	77.422242	8.065962	0.0700133	8.1359750	0.1354000	-0.0021869	0.0028212	0.1382212	3.0713107	0.0315266	2.4471D-02	-2.1898D-01
72	78.108309	8.158340	0.0719505	8.2302903	0.1338775	-0.0022469	0.0028274	0.1367049	3.0926338	0.0306975	2.3707D-02	-2.1580D-01
73	78.805862	8.251179	0.0739254	8.3251049	0.1322904	-0.0023016	0.0028343	0.1351247	3.1137755	0.0299100	2.2974D-02	-2.1281D-01
74	79.514896	8.344399	0.0759373	8.4203364	0.1306395	-0.0023527	0.0028397	0.1334791	3.1346955	0.0291099	2.2273D-02	-2.0963D-01
75	80.235689	8.437951	0.0779857	8.5159371	0.1289259	-0.0023982	0.0028453	0.1317712	3.1553882	0.0283486	2.1602D-02	-2.0664D-01
76	80.968136	8.531739	0.0800723	8.6118115	0.1271538	-0.0024388	0.0028497	0.1300035	3.1758845	0.0275796	2.0959D-02	-2.0348D-01
77	81.712829	8.625753	0.0821951	8.7079484	0.1253229	-0.0024757	0.0028538	0.1281767	3.1961171	0.0268336	2.0344D-02	-2.0039D-01
78	82.469634	8.719889	0.0843573	8.8042461	0.1234360	-0.0025082	0.0028583	0.1262943	3.2161669	0.0261126	1.9753D-02	-1.9739D-01
79	83.238552	8.814059	0.0865560	8.9006154	0.1214957	-0.0025381	0.0028617	0.1243574	3.2359485	0.0253917	1.9189D-02	-1.9430D-01
80	84.019630	8.908183	0.0887931	8.9969758	0.1195017	-0.0025669	0.0028661	0.1223678	3.2555157	0.0247095	1.8647D-02	-1.9140D-01
81	84.812477	9.002122	0.0910671	9.0931894	0.1174553	-0.0025938	0.0028697	0.1203250	3.2748313	0.0240239	1.8129D-02	-1.8838D-01
82	85.617520	9.095838	0.0933785	9.1892167	0.1153568	-0.0026169	0.0028743	0.1182310	3.2938948	0.0233783	1.7633D-02	-1.8559D-01
83	86.434259	9.189181	0.0957286	9.2849096	0.1132111	-0.0026347	0.0028781	0.1160892	3.3127386	0.0227294	1.7156D-02	-1.8267D-01
84	87.262491	9.282042	0.0981129	9.3801551	0.1110227	-0.0026455	0.0028826	0.1139052	3.3312761	0.0221102	1.6701D-02	-1.7989D-01
85	88.101869	9.374299	0.1005357	9.4748345	0.1087994	-0.0026463	0.0028875	0.1116869	3.3496037	0.0215079	1.6264D-02	-1.7717D-01
86	88.951717	9.465806	0.1029906	9.5687962	0.1065525	-0.0026396	0.0028924	0.1094449	3.3676009	0.0209182	1.5847D-02	-1.7445D-01
87	89.812142	9.556509	0.1054826	9.6619914	0.1042851	-0.0026294	0.0028991	0.1071842	3.3853741	0.0203684	1.5446D-02	-1.7198D-01
88	90.682263	9.646254	0.1080077	9.7542614	0.1020023	-0.0026164	0.0029058	0.1049081	3.4028437	0.0198214	1.5063D-02	-1.6945D-01
89	91.561549	9.734931	0.1105661	9.8454975	0.0997080	-0.0026015	0.0029145	0.1026225	3.4200450	0.0193209	1.4696D-02	-1.6722D-01
90	92.781191	9.854604	0.1141289	9.9687331	0.0965482	-0.0025789	0.0029252	0.0994733	3.4432004	0.0186333	1.4216D-02	-1.6403D-01
91	94.015488	9.971808	0.1177444	10.0895528	0.0933800	-0.0025529	0.0029361	0.0963161	3.4657596	0.0179740	1.3766D-02	-1.6093D-01
92	95.263954	10.086400	0.1214187	10.2078184	0.0902103	-0.0025220	0.0029509	0.0931612	3.4878170	0.0173776	1.3340D-02	-1.5825D-01
93	96.525320	10.198180	0.1251509	10.3233311	0.0870506	-0.0024860	0.0029651	0.0900157	3.5093670	0.0167933	1.2938D-02	-1.5553D-01
94	97.799333	10.307066	0.1289366	10.4360026	0.0839079	-0.0024465	0.0029770	0.0868849	3.5303869	0.0162112	1.2558D-02	-1.5269D-01
95	99.085954	10.412998	0.1327748	10.5457720	0.0807866	-0.0024038	0.0029904	0.0837770	3.5508706	0.0156662	1.2200D-02	-1.5006D-01
96	100.384135	10.515847	0.1366663	10.6525138	0.0776951	-0.0023586	0.0030057	0.0807008	3.5708751	0.0151618	1.1860D-02	-1.4769D-01
97	101.693801	10.615580	0.1406126	10.7561922	0.0746362	-0.0023129	0.0030171	0.0776533	3.5904045	0.0146382	1.1539D-02	-1.4499D-01
98	103.015063	10.712175	0.1446040	10.8567787	0.0716107	-0.0022663	0.0030281	0.0746388	3.6093807	0.0141368	1.1236D-02	-1.4239D-01
99	104.346959	10.805542	0.1486469	10.9541888	0.0686239	-0.0022185	0.0030428	0.0716667	3.6279067	0.0136893	1.0948D-02	-1.4019D-01
100	105.689498	10.895673	0.1527419	11.0484151	0.0656780	-0.0021708	0.0030524	0.0687304	3.6459872	0.0132107	1.0675D-02	-1.3755D-01

101	107.042885	10.982573	0.1568759	11.1394492	0.0627721	-0.0021236	0.0030610	0.0658331	3.6635161	0.0127512	1.0418D-02 -1.3498D-01
102	108.406158	11.066175	0.1610578	11.2272328	0.0599095	-0.0020755	0.0030732	0.0629826	3.6806240	0.0123407	1.0173D-02 -1.3281D-01
103	109.779387	11.146487	0.1652857	11.3117732	0.0570929	-0.0020260	0.0030795	0.0601724	3.6972824	0.0118955	9.9403D-03 -1.3014D-01
104	111.162793	11.223531	0.1695469	11.3930778	0.0543252	-0.0019745	0.0030848	0.0574100	3.7134107	0.0114691	9.7207D-03 -1.2754D-01
105	112.555461	11.297273	0.1738494	11.4711222	0.0516121	-0.0019209	0.0030932	0.0547053	3.7291180	0.0110870	9.5120D-03 -1.2531D-01
106	113.957469	11.367745	0.1781915	11.5459365	0.0489575	-0.0018662	0.0030945	0.0520520	3.7443916	0.0106658	9.3137D-03 -1.2253D-01
107	115.368960	11.434990	0.1825558	11.6175455	0.0463622	-0.0018121	0.0030935	0.0494556	3.7591219	0.0102550	9.1267D-03 -1.1972D-01
108	116.789148	11.499005	0.1869513	11.6859567	0.0438266	-0.0017596	0.0030969	0.0469235	3.7734273	0.0098946	8.9490D-03 -1.1738D-01
109	118.218325	11.559845	0.1913802	11.7512254	0.0413490	-0.0017080	0.0030953	0.0444443	3.7873119	0.0095120	8.7802D-03 -1.1466D-01
110	119.655785	11.617518	0.1958242	11.8133419	0.0389309	-0.0016557	0.0030877	0.0420186	3.8006914	0.0091164	8.6208D-03 -1.1166D-01
111	121.101604	11.672074	0.2002828	11.8723568	0.0365756	-0.0016024	0.0030820	0.0396576	3.8135937	0.0087518	8.4701D-03 -1.0890D-01
112	122.555756	11.723567	0.2047620	11.9283285	0.0342844	-0.0015486	0.0030772	0.0373616	3.8260686	0.0084067	8.3271D-03 -1.0626D-01
113	124.017588	11.772029	0.2092558	11.9812853	0.0320603	-0.0014938	0.0030673	0.0351276	3.8381050	0.0080513	8.1916D-03 -1.0337D-01
114	125.487078	11.817529	0.2137532	12.0312820	0.0299061	-0.0014373	0.0030514	0.0329575	3.8496669	0.0076813	8.0638D-03 -1.0015D-01
115	126.964204	11.860135	0.2182468	12.0783820	0.0278254	-0.0013797	0.0030347	0.0308601	3.8607359	0.0073276	7.9434D-03 -9.7024D-02
116	128.448371	11.899914	0.2227397	12.1226533	0.0258210	-0.0013227	0.0030191	0.0288401	3.8713637	0.0069963	7.8297D-03 -9.4061D-02
117	129.939660	11.936950	0.2272299	12.1641803	0.0238904	-0.0012680	0.0030011	0.0268914	3.8815507	0.0066670	7.7223D-03 -9.1001D-02
118	131.437526	11.971313	0.2317102	12.2030234	0.0220311	-0.0012155	0.0029797	0.0250108	3.8912901	0.0063397	7.6212D-03 -8.7844D-02
119	132.941993	12.003083	0.2361758	12.2392588	0.0202414	-0.0011633	0.0029545	0.0231958	3.9005824	0.0060118	7.5261D-03 -8.4550D-02
120	134.452558	12.032331	0.2406179	12.2729487	0.0185241	-0.0011095	0.0029244	0.0214485	3.9094140	0.0056768	7.4369D-03 -8.1024D-02
121	135.969093	12.059147	0.2450280	12.3041751	0.0168830	-0.0010538	0.0028923	0.0197753	3.9177645	0.0053509	7.3537D-03 -7.7495D-02
122	137.491440	12.083627	0.2494072	12.3330342	0.0153221	-0.0009964	0.0028601	0.0181822	3.9256728	0.0050407	7.2757D-03 -7.4066D-02
123	139.019115	12.105872	0.2537512	12.3596230	0.0138443	-0.0009390	0.0028253	0.0166697	3.9331370	0.0047340	7.2030D-03 -7.0561D-02
124	140.552042	12.125991	0.2580543	12.3840457	0.0124486	-0.0008831	0.0027876	0.0152362	3.9401601	0.0044313	7.1353D-03 -6.6990D-02
125	142.089762	12.144091	0.2623106	12.4064013	0.0111330	-0.0008293	0.0027472	0.0138802	3.9467425	0.0041330	7.0725D-03 -6.3360D-02
126	143.632160	12.160276	0.2665156	12.4267920	0.0098946	-0.0007765	0.0027043	0.0125988	3.9528889	0.0038397	7.0144D-03 -5.9682D-02
127	145.178800	12.174650	0.2706641	12.4453143	0.0087347	-0.0007228	0.0026591	0.0113938	3.9586023	0.0035520	6.9609D-03 -5.5967D-02
128	146.729536	12.187326	0.2747517	12.4620781	0.0076559	-0.0006692	0.0026118	0.0102677	3.9638895	0.0032704	6.9117D-03 -5.2227D-02
129	148.283950	12.198419	0.2787739	12.4771932	0.0066569	-0.0006173	0.0025626	0.0092195	3.9687563	0.0029955	6.8668D-03 -4.8477D-02
130	149.841872	12.208041	0.2827273	12.4907688	0.0057347	-0.0005667	0.0025116	0.0082463	3.9732116	0.0027282	6.8260D-03 -4.4731D-02
131	151.402906	12.216303	0.2866074	12.5029103	0.0048894	-0.0005157	0.0024575	0.0073469	3.9772645	0.0024612	6.7891D-03 -4.0876D-02
132	152.966864	12.223318	0.2904067	12.5137252	0.0041234	-0.0004644	0.0024013	0.0065248	3.9809020	0.0021997	6.7562D-03 -3.7001D-02
133	154.533406	12.229209	0.2941247	12.5233341	0.0034359	-0.0004145	0.0023462	0.0057821	3.9841501	0.0019553	6.7269D-03 -3.3302D-02
134	156.102220	12.234090	0.2977629	12.5318526	0.0028239	-0.0003663	0.0022921	0.0051160	3.9870320	0.0017245	6.7011D-03 -2.9734D-02
135	157.673105	12.238074	0.3013211	12.5393955	0.0022859	-0.0003204	0.0022382	0.0045241	3.9895641	0.0015054	6.6784D-03 -2.6271D-02
136	159.245731	12.241275	0.3047986	12.5460732	0.0018169	-0.0002774	0.0021839	0.0040008	3.9917639	0.0012955	6.6589D-03 -2.2878D-02
137	160.819901	12.243791	0.3081933	12.5519845	0.0014130	-0.0002364	0.0021285	0.0035415	3.9936403	0.0010889	6.6422D-03 -1.9456D-02
138	162.395337	12.245725	0.3115025	12.5572270	0.0010723	-0.0001978	0.0020758	0.0031481	3.9951934	0.0009008	6.6284D-03 -1.6280D-02
139	163.971791	12.247171	0.3147358	12.5619065	0.0007895	-0.0001624	0.0020281	0.0028176	3.9964793	0.0007384	6.6171D-03 -1.3496D-02
140	165.549089	12.248214	0.3178987	12.5661128	0.0005600	-0.0001295	0.0019822	0.0025422	3.9975219	0.0005849	6.6079D-03 -1.0811D-02
141	167.127015	12.248938	0.3209899	12.5699276	0.0003811	-0.0000998	0.0019384	0.0023195	3.9983248	0.0004447	6.6008D-03 -8.3096D-03
142	168.705380	12.249417	0.3240170	12.5734338	0.0002451	-0.0000744	0.0019006	0.0021457	3.9989255	0.0003295	6.5955D-03 -6.2232D-03
143	170.284056	12.249711	0.3269903	12.5767017	0.0001462	-0.0000522	0.0018677	0.0020140	3.9993651	0.0002321	6.5917D-03 -4.4294D-03
144	171.862898	12.249878	0.3299144	12.5797929	0.0000802	-0.0000343	0.0018390	0.0019192	3.9996582	0.0001498	6.5891D-03 -2.8891D-03
145	173.441792	12.249965	0.3327975	12.5827620	0.0000379	-0.0000212	0.0018164	0.0018544	3.9998381	0.0000895	6.5875D-03 -1.7442D-03
146	175.020669	12.249998	0.3356503	12.5856485	0.0000133	-0.0000115	0.0017994	0.0018127	3.9999408	0.0000464	6.5866D-03 -9.1300D-04
147	176.599460	12.250006	0.3384795	12.5884859	0.0000017	-0.0000048	0.0017872	0.0017889	3.9999845	0.0000181	6.5862D-03 -3.6011D-04
148	178.178127	12.250003	0.3412934	12.5912968	-0.0000020	-0.0000005	0.0017798	0.0017778	3.9999980	0.0000049	6.5861D-03 -9.8402D-05
149	179.756652	12.250000	0.3440987	12.5940987	0.0	0.0	0.0017746	0.0017746	4.0000000	0.0	6.5861D-03 0.0

STA 46.060986, Y*= 3.7482388, D2A/DX2= 0.000130108, D2R/DX2= 0.044660860, VISCID RC= 5.97373108

M A C H 4   COORDINATES AND DERIVATIVES, LENGTH = 133.6956656

X(IN)	Y(IN)	DY/DX	ANGLE	D2Y/DX2
46.060986	3.748239	0.0	0.0	4.46608599D-02
48.000000	3.828872	7.92875276D-02	4.53335690D 00	3.23312112D-02
50.000000	4.037350	1.23108050D-01	7.01825859D 00	1.38626975D-02
52.000000	4.305187	1.42210129D-01	8.09376932D 00	6.17761254D-03
54.000000	4.599067	1.50433872D-01	8.55507609D 00	2.44455973D-03
56.000000	4.903448	1.53426554D-01	8.72267533D 00	7.89588375D-04
58.000000	5.211391	1.54331457D-01	8.77332320D 00	2.04430906D-04
60.000000	5.520316	1.54556026D-01	8.78589030D 00	1.17939093D-04
62.000000	5.829576	1.54680272D-01	8.79284286D 00	2.74083513D-05
64.000000	6.138901	1.54584890D-01	8.78750550D 00	-1.55627214D-04
66.000000	6.447580	1.53999203D-01	8.75472838D 00	-4.40629780D-04
68.000000	6.754483	1.52794847D-01	8.68731028D 00	-7.75590079D-04
70.000000	7.058280	1.50877708D-01	8.57994161D 00	-1.14501259D-03
72.000000	7.357525	1.48256053D-01	8.43301867D 00	-1.46882223D-03
74.000000	7.650897	1.45019495D-01	8.25148123D 00	-1.76461079D-03
76.000000	7.937226	1.41222264D-01	8.03828318D 00	-2.03338859D-03
78.000000	8.215470	1.36952466D-01	7.79828497D 00	-2.22815556D-03
80.000000	8.484813	1.32337785D-01	7.53859168D 00	-2.37552527D-03
82.000000	8.744656	1.27470439D-01	7.26434180D 00	-2.48224443D-03
84.000000	8.994573	1.22422184D-01	6.97954482D 00	-2.56156775D-03
86.000000	9.234248	1.17233577D-01	6.68646837D 00	-2.62281232D-03
88.000000	9.463443	1.11956199D-01	6.38801679D 00	-2.65025211D-03
90.000000	9.682080	1.06689586D-01	6.08982658D 00	-2.62306385D-03
92.000000	9.890242	1.01484659D-01	5.79480316D 00	-2.58632039D-03
94.000000	10.088061	9.63488288D-02	5.50339369D 00	-2.54268685D-03
96.000000	10.275706	9.13129511D-02	5.21737789D 00	-2.49121487D-03
98.000000	10.453387	8.63868433D-02	4.93734392D 00	-2.43336403D-03
100.000000	10.621344	8.15952732D-02	4.66473083D 00	-2.35869491D-03
102.000000	10.779858	7.69378839D-02	4.39954874D 00	-2.29791347D-03
104.000000	10.929194	7.24243454D-02	4.14237678D 00	-2.21733826D-03
106.000000	11.069648	6.80479113D-02	3.89285688D 00	-2.15809312D-03
108.000000	11.201485	6.38149983D-02	3.65137887D 00	-2.07936728D-03
110.000000	11.324996	5.97142239D-02	3.41731505D 00	-2.02025440D-03
112.000000	11.440445	5.57634984D-02	3.19170757D 00	-1.93494923D-03
114.000000	11.548148	5.19599653D-02	2.97441183D 00	-1.87107466D-03
116.000000	11.648387	4.83081119D-02	2.76570085D 00	-1.78371679D-03
118.000000	11.741483	4.48088022D-02	2.56563905D 00	-1.72205955D-03
120.000000	11.827702	4.14352247D-02	2.37270623D 00	-1.64819876D-03
122.000000	11.907330	3.82180757D-02	2.18866925D 00	-1.57234891D-03
124.000000	11.980667	3.51418009D-02	2.01264865D 00	-1.50387224D-03
126.000000	12.047989	3.22038563D-02	1.84450759D 00	-1.43033342D-03
128.000000	12.109594	2.94278241D-02	1.68560366D 00	-1.34894234D-03
130.000000	12.165800	2.68014979D-02	1.53524519D 00	-1.27846302D-03
132.000000	12.216891	2.43117279D-02	1.39268506D 00	-1.21232845D-03
134.000000	12.263132	2.19507955D-02	1.25748600D 00	-1.14751593D-03
136.000000	12.304785	1.97275401D-02	1.13015819D 00	-1.07428230D-03
138.000000	12.342143	1.76551796D-02	1.01146219D 00	-9.99015303D-04
140.000000	12.375503	1.57288423D-02	9.01121971D-01	-9.27206162D-04
142.000000	12.405153	1.39441444D-02	7.98888848D-01	-8.58380327D-04
144.000000	12.431367	1.22912949D-02	7.04203858D-01	-7.93686046D-04
146.000000	12.454409	1.07735381D-02	6.17254381D-01	-7.24275824D-04

M A C H 4 COORDINATES AND DERIVATIVES, LENGTH = 133.6956656

X(IN)	Y(IN)	DY/DX	ANGLE	D2Y/DX2
148.000000	12.474553	9.39216534D-03	5.38115612D-01	-6.58091366D-04
150.000000	12.492063	8.13953236D-03	4.66350553D-01	-5.95039869D-04
152.000000	12.507192	7.00930971D-03	4.01597287D-01	-5.32529461D-04
154.000000	12.520192	6.01328645D-03	3.44531782D-01	-4.65704477D-04
156.000000	12.531329	5.14437478D-03	2.94748363D-01	-4.03224707D-04
158.000000	12.540852	4.39881668D-03	2.52032005D-01	-3.43757846D-04
160.000000	12.548996	3.76222227D-03	2.15558441D-01	-2.93142352D-04
162.000000	12.555969	3.22901915D-03	1.85008526D-01	-2.37784049D-04
164.000000	12.561986	2.80338138D-03	1.60621501D-01	-1.90196057D-04
166.000000	12.567239	2.46407018D-03	1.41180536D-01	-1.48366223D-04
168.000000	12.571900	2.21052027D-03	1.26653276D-01	-1.07725817D-04
170.000000	12.576128	2.02839844D-03	1.16218510D-01	-7.52059936D-05
172.000000	12.580055	1.90785138D-03	1.09311699D-01	-4.62866371D-05

NOMENCLATURE

A	Area
A_C	Exit area, inviscid contour
$A*$	Sonic area
$a*$	Sonic speed
C	Factor in logarithmic skin friction law, Eq. (77)
$C_{1,2,3,4,5,6}$	Coefficients, Eq. (35)
C_D	Ratio of actual mass flow to that if R were infinite
C_f	Skin friction coefficient, compressible
C_{f_i}	Skin friction coefficient, incompressible
C_p	Specific heat at constant pressure
$D_{1,2,3,4,5,6}$	Coefficients, Eq. (37)
F_c	Ratio, C_{f_i}/C_f
F_n	Multiplying factors, Eq. (97)
F_{R_δ}	Ratio, $R_{\theta_i}/R_{\theta_c}$
G_n	Multiplying factors, Eqs. (94) and (96)

H	Ratio, δ^*/θ
h_a	Heat-transfer coefficient
K	Streamline curvature
ln	Natural logarithm (base e)
log	Common logarithm (Base 10)
M	Mach number
m	Exponent in Eq. (90)
N	Velocity profile exponent
n	Distance normal to streamline
$P_{1,2}$	Factors in axisymmetric characteristics equations
P_n	Coefficient of θ at nth point on contour
Pr	Prandtl number
Q	Factor related to heat transfer, Eq. (91)
Q_n	Coefficient in momentum equation
q	Velocity along streamline or, in boundary-layer equations, velocity within boundary layer
q_e	Velocity at edge of boundary layer

R	Ratio of throat radius of curvature to throat radius (half height, $\sigma = 0$)
R_g	Gas constant, ft^2/sec^2R
R_δ	Reynolds number based on δ, compressible
R_{δ_i}	Incompressible Reynolds number
R_{θ_c}	Reynolds number based on θ_c, compressible
R_{θ_i}	Incompressible Reynolds number
r	Distance from source
r_1	Distance from source where $M = 1$, used to non-dimensionalize distances for inviscid calculations
r_w	Radius of viscid contour
S	$R + 1$
s,t,u	Cubic integration increments, Appendix B
T	Temperature within boundary layer
T_{aw}	Adiabatic wall temperature
T_c	Reference temperature, Eq. (87)
T_e	Free-stream temperature at edge of inviscid contour

T_w	Wall temperature
T_{w_D}	Wall temperature at nozzle exit
T_{w_T}	Wall temperature at nozzle throat
u	Axial component of velocity, normalized by a*
v	Normal component of velocity, normalized by a*
W	Velocity along streamline, normalized by a*
X	Ratio in Eq. (36) or (38)
x	Axial distance, normalized by y_o in transonic equations, normalized by r_1 in inviscid calculations, not normalized in boundary-layer calculations
y	Normal distance, normalized same as x
y_o	Throat half height, used to normalize x and y in transonic calculations
y*	Theoretical throat height if R is infinite
z	Function of x in transonic equations, or distance normal to contour in boundary-layer calculations

α	Mean angle of right-running characteristic, or factor in temperature distribution in boundary layer
β	Mean angle of left-running characteristic
Δ	Prefix to indicate increment in value
γ	Specific heat ratio
δ	Boundary-layer thickness
δ^*	Displacement thickness in boundary layer
δ^*_a	Displacement thickness when boundary layer is large relative to r_w
δ^*_i	Incompressible displacement thickness in boundary layer
ζ	Distance along left-running characteristic
η	Inflection angle, radians
θ	Momentum thickness in boundary layer
θ_a	Momentum thickness when boundary layer is large relative to r_w
θ_c	Compressible θ for flat plate
θ_i	Incompressible value of θ
θ_k	Kinematic momentum thickness

θ_n	Value of θ at nth point on contour
κ	Constant in logarithmic skin-friction law
λ	$\left[\frac{1+\sigma}{(\gamma+1)S}\right]^{\frac{1}{2}}$
μ	Mach angle, $\sin^{-1}(1/M)$
μ_c	Viscosity at value of T_c
μ_e	Viscosity at value of T_e
μ_w	Viscosity at value of T_w
ξ	Distance along right-running characteristic
Π	Wake variable in logarithmic skin-friction law
ρ	Density within boundary layer
ρ_e	Density at edge of boundary layer
σ	Zero for planar flow, 1 for axisymmetric flow
ϕ	Flow angle
ϕ_w	Flow angle of viscid contour
ψ	Prandtl-Meyer angle

SUBSCRIPTS

1	Values at point 1 on right-running characteristic
2	Values at point 2 on left-running characteristic
3	Values at intersection of characteristics
A,B,C,D,E, F,G,I,J,T	Variables evaluated at points on Figs. 1 through 4
a,b,c	With u and v, values corresponding to first-, second-, and third-order approximations, respectively

OTHER NOTATION

′	d/dx

OUTPUT NOMENCLATURE

BETA	Pressure gradient parameter $\dfrac{2\delta^* \, dP_E/dx}{\gamma M^2 \, P_E C_{f_i}}$
C(Y)	Coefficient of third-degree term if throat contour is a cubic
C(YI)	Coefficient of third-degree term if integrated throat contour is a cubic

C(YP)	Coefficient of third-degree term determined from slope of contour
D2A/DX2	Second derivative of boundary-layer correction evaluated at the throat
D2R/DX2	Second derivative of corrected contour evaluated at the throat
DA/DX	Slope of boundary-layer correction
DELR(IN)	Boundary-layer correction to inviscid contour
DELTA*	δ^*_a from Eq. (66)
DELTA* - 1	δ^* from Eq. (63)
FMY	Bracketed term in Eq. (61)
HYP/YO	Value of hyperbola with same throat curvature ratio
ICY	$10^6 \left[C(YI) - C(Y)\right]$ for Point 2
INT.Y/YO	Value of Y/YO obtained by integrating contour slopes starting at inflection point
KCF	$1000\ C_f$
KCFI	$1000\ C_{f_i}$
KCFS	KCF sec ϕ_w

KTHP	1000 $d\theta/dx$
MASS	Result of mass integration along characteristic EG or AB (measure of accuracy of numerical integration)
PAR/YO	Value of parabola with same throat curvature ratio
PE/PO	Ratio of static to stagnation pressure
R(IN)	Ordinate of viscid contour
RMASS	$C_D^{1/(1+\sigma)}$
RTHI	Incompressible Reynolds number based on momentum thickness
SMPP	Second derivative of Mach number in source flow evaluated for BMACH
SMPPP	Third derivative of Mach number in source flow evaluated for BMACH
THETA - 1	θ from Eq. (62) used in Eq. (61)
WE	Velocity ratio at Point E (Fig. 3)
WI	Velocity ratio at Point I (Fig. 3)
WO	Velocity ratio on axis at throat
WOPPP	Third derivative of throat velocity distribution

WRPPP	Third derivative of velocity ratio in source flow evaluated at WE
WWO	Velocity ratio on wall at throat