NASA CONTRACTOR REPORT

NASA CR-2498

NASA CR-2498

A THEORETICAL METHOD FOR THE ANALYSIS AND DESIGN OF AXISYMMETRIC BODIES

T. D. Beatty

Prepared by
MCDONNELL DOUGLAS AIRCRAFT CORPORATION
Long Beach, Calif. 90801
for Langley Research Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • MARCH 1975

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-2498		

4. Title and Subtitle	5. Report Date
A THEORETICAL METHOD FOR THE ANALYSIS AND DESIGN OF AXISYMMETRIC BODIES	MARCH 1975
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
T. D. BEATTY	
	10. Work Unit No. 501-06-01-01-00
9. Performing Organization Name and Address MCDONNELL DOUGLAS AIRCRAFT CORP. LONG BEACH, CALIF.	11. Contract or Grant No. NAS1-12986
	13. Type of Report and Period Covered CONTRACTOR REPORT
12. Sponsoring Agency Name and Address NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WASHINGTON, D.C. 20546	14. Sponsoring Agency Code

15. Supplementary Notes

FINAL REPORT.

16. Abstract

A THEORETICAL METHOD IS PRESENTED FOR THE COMPUTATION OF THE FLOW FIELD ABOUT AN AXISYMMETRIC BODY OPERATING IN A VISCOUS, INCOMPRESSIBLE FLUID. A POTENTIAL FLOW METHOD IS USED TO DETERMINE THE INVISCID FLOW FIELD. THESE RESULTS YIELD THE BOUNDARY CONDITIONS FOR THE BOUNDARY LAYER SOLUTIONS. BOUNDARY LAYER EFFECTS IN THE FORCES OF DISPLACEMENT THICKNESS AND EMPIRICALLY MODELED SEPARATION STREAMLINES ARE ACCOUNTED FOR IN SUBSEQUENT POTENTIAL FLOW SOLUTIONS. THIS PROCEDURE IS REPEATED UNTIL THE SOLUTIONS CONVERGE. AN EMPIRICAL METHOD IS USED TO DETERMINE BASE DRAG ALLOWING CONFIGURATION DRAG TO BE COMPUTED.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
AXISYMMETRIC BODY POTENTIAL FLOW AXISYMMETRIC BODY BOUNDARY LAYER FLOW COUPLED VISCOUS/INVISCOUS FLOW SOLUTIONS FLOW SEPARATION ON AXISYMMETRIC BODIES	UNCLASSIFIED - UNLIMITED STAR CATEGORY 34

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
UNCLASSIFIED	UNCLASSIFIED	279	$8.75

*For sale by the National Technical Information Service, Springfield, Virginia 22151

SUMMARY

A theoretical method is presented for the computation of the flow field about an axisymmetric body operating in a viscous incompressible fluid. This approach combines a smoothing routine, a potential flow method based on a surface source distribution, and a finite-difference boundary-layer method to accomplish the analysis. An empirical method used for modeling separated flow is shown to work reasonably well for cases of extreme flow separation. Results obtained by this method are presented which show very good agreement with experimental data. Suggestions are made for extending this method both to include a better model for separated flow and to calculate the "viscous" flow about axisymmetric bodies at angle of attack. A detailed instruction manual for inputing data to the computer program is given in Appendix A. Appendix B contains the necessary information to place this program on to a computer. This appendix also contains a complete description of output parameters from the computer program, as well as basic flow charts of some of the major subroutines. Appendix C contains a complete listing of the computer program for operation on either a CDC or an IBM computer.

TABLE OF CONTENTS

A THEORETICAL METHOD FOR THE ANALYSIS AND DESIGN OF AXISYMMETRIC BODIES

by T. D. Beatty
McDonnell Douglas Aircraft Corporation

One of the ultimate goals in aerodynamics is the achievement of the ability to obtain the real fluid flow field about an arbitrary three-dimensional configuration by theoretical calculation rather than by resorting to expensive and time consuming wind tunnel tests. The exact treatment of this problem requires the solution of the full Navier-Stokes equations, which is currently not practical. However, a good approximation to this real flow can be obtained by displacing the surface boundaries of the original body to account for viscosity as shown by Thwaites in Reference (1).

This technique of displacing the boundary surface to obtain a viscous solution has been used in two-dimensional flows quite successfully, as shown in References 2, 3, and 4. The extension of this approach to three-dimensional flow requires that appropriate computational routines be available to calculate the potential and viscous flow parameters. A potential flow routine which can calculate the flow about arbitrary three-dimensional bodies is available (Reference 5), although the comparable three-dimensional boundary layer method is not currently in the state of the art. At the present time, the general three-dimensional problem cannot be solved. However, both an axisymmetric potential flow method and an axisymmetric boundary layer method which can calculate the inviscid and viscous flow field about a body of revolution at zero degrees angle of attack are currently available.

Because of its simple nature and its common appearance in fluid dynamics, it was decided that a body of revolution would be a good starting point for the development of a three-dimensional method for calculating inviscid and viscous flow fields.

The axisymmetric potential flow routine (References 6 & 7), used in the present method was developed at the Douglas Aircraft Company under the guidance of A. M. O. Smith and has proven over the years to be an extremely versatile and accurate method, as well as the only purely axisymmetric potential flow method, generally available in industry today. This method has been well disseminated throughout industry; only a brief discussion will, therefore, be presented in a following section.

The boundary layer method presented in this report (Reference 8) is a finite difference technique which uses an eddy-viscosity concept to replace the Reynolds shear stress term. Since this method is relatively new and has been modified extensively since Reference 8 was reported, a detailed description will be presented.

The capability of the present method to determine the viscous flow about axisymmetric bodies is shown by correlations between the calculated results and experimental data.

Recommendations are presented for extending the present method to the calculation of the flow field about axisymmetric bodies at angle of attack.

DEFINITION OF SYMBOLS

A	Damping length or frontal area, wherever applicable
A^+	Damping constants
C_F	Total skin friction coefficient
C_P	Pressure coefficient
c	Chord
c_f	Local skin friction coefficient $\tau_w/(\frac{1}{2})\rho u_e^2$
D	Maximum diameter
f	Dimensionless stream function
G	Spot formation parameter
H	Shape factor, θ/δ
K_1	Mixing-length constant
k	Power to determine 2-D or axisymmetric flow
L	Reference body length
ℓ	Mixing length
P^+	Pressure gradient parameter
R_c	Chord Reynolds number, $u_\infty c/\nu$
R_D	Diameter Reynolds number, $u_\infty D/\nu$
R_x	Local Reynolds number. $u_e x/\nu$
R_θ	Momentum thickness Reynolds number, $U_e\theta/\nu$
r	Radial distance from axis of revolution
r_o	Local radius of body of revolution
T	Absolute temperature, °K or °R.
t	Transverse curvature term
U_∞	Free stream velocity
u_τ	Friction velocity, $\sqrt{\tau_w/\rho}$
u	x component of velocity

u_e Velocity at edge of boundary layer

v y-component of velocity

x Distance along surface measured from leading edge or from stagnation point

y Distance normal to the surface of the body

α Angle between normal to the surface y and the radius r

$\propto$ Constant in outer eddy viscosity equation

β Dimensionless velocity - gradient term, $\beta = (2\xi/u_e)(du_e/d\xi)$

γ_{Tr} Transitional parameter

δ Boundary layer thickness

δ^* Boundary layer displacement thickness

ε Eddy viscosity

ε^+ Ratio of eddy viscosity to kinematic viscosity, ε/ν

η Transformed y-coordinate

θ Momentum Thickness

μ Dynamic viscosity

ν Kinematic viscosity

ξ Transformed x-coordinate

ρ Density

τ Shear stress

SUBSCRIPTS

c Switching point between the inner and outer eddy viscosity formulas

e Outer edge of boundary layer

i Inner region

ℓ Laminar

o	Outer Region
t	Turbulent
Tr	Transition
w	Wall
∞	Free-stream conditions

Primes denote differentiation with respect to η.

TECHNICAL DISCUSSION

Geometry Definition

The geometry input to the Douglas Neumann Potential Flow Program must satisfy two primary requirements: the coordinates must be distributed properly and the surface curvature must be smooth. These requirements are easily achieved on an analytical body shape, since the input coordinates may be calculated exactly for any prescribed distribution. However, some method of determining accurate input coordinates for an arbitrary axisymmetric body is necessary, since the body may not always be amenable to exact analytical definition. The approach adopted in the following method is to assume that the coordinates are input in the proper distribution about the body, but that they are not necessarily smooth. These two requirements will be discussed in some detail in the following sections.

<u>Point distribution</u>. - In order to obtain a high degree of accuracy in defining a pressure distribution when using the Douglas Neumann Potential Flow program, surface coordinates should be concentrated in regions of high surface curvature where rapid changes in the surface pressures would be expected. Since the total number of points per body is fixed, the distribution of these points about the body contour becomes extremely important. The Neumann program uses the input coordinates to create linear segments between points, thus approximating the body by a series of Frustums of Cones. The basis distribution required is then quite simple: more points and thus smaller segment sizes in regions of high curvature and less points and thus larger segment sizes in the other areas of the body. The basic guidelines to follow to insure proper point distribution are simply that the surface lengths of adjacent elements should not change by more than twenty to thirty percent and the maximum length of any segment should not exceed either five percent of the body chord or fifty percent of the local body thickness.

<u>Smoothness of input coordinates</u>. - The Douglas Neumann program, or any similar potential flow method, is sensitive to the derivative of the surface slopes, or the curvature of the surface. The surface defined by the input coordinates must therefore have smooth first and second derivatives. The approach used in the

present method to smooth these coordinates, is a five point smoothing routine, which assumes that the input coordinates are smooth and continuous to graphical accuracy, i.e., points are chosen from a small graph (approximately a 10 inch chord). The output points from this routine will be moved very slightly to smooth the derivatives, but this movement will be negligible as far as the body shape is concerned. The equations used to accomplish this smoothing are as follows:

$$\bar{x}_j = \frac{1}{16}\left\{- x_{j-2} + 4x_{j-1} + 10x_j + 4x_{j+1} - x_{j+2}\right\} \quad (1a)$$

$$\bar{y}_j = \frac{1}{16}\left\{- y_{j-2} + 4y_{j-1} + 10y_j + 4y_{j+1} - y_{j+2}\right\} \quad (1b)$$

where x_j and y_j are the unsmoothed input coordinates

and $\bar{x}_j$ and $\bar{y}_j$ are the smoothed coordinates.

Potential Flow Method

The Douglas Neumann method, (References 6 and 7) is very general in that it can calculate the potential flow about virtually any body. There is no restriction, for example, to slender bodies; in fact, the "body" in question need not be a single body but may be an ensemble of bodies. In principle, the calculated solution may be made as accurate as desired by suitably refining the numerical procedure; accordingly, the so-called Neumann method is designated an exact method in this sense.

The Neumann method is based on the use of a distribution of source density over the body surface. Applying the condition of zero normal velocity on the body surface yields an integral equation for the source distribution. Specifically, the equation is a Fredholm integral equation of the second kind over the body surface. Once this has been solved for the source distribution, all flow quantities of interest, i.e., velocity, pressure, etc., can be calculated by rapid straightforward procedures. To implement this method on a computer, the body surface is approximated by a large number of small surface segments, over each of which the source density is assumed constant. The integral equation is replaced by a set of linear algebraic equations for the values of the source density on the segments. Input to the computer program consists of the coordinates of a set of points defining the body surface; these points are then used to determine the surface segments for approximating the body. There is no assumption made that the body can be analytically represented.

The usefulness of potential flow with its neglect of viscosity and compressibility is due to the fact that it is a good approximation to real flow under a wide variety of circumstances. With regard to viscosity, the program obtains useful results except in regions of catastrophic separation. To verify the usefulness of potential flow as a predictor of real flow, results calculated by the Neumann program have been compared with experimental data. Several collections of comparisons have been made. Reference 9 was a very complete collection but is now rather old. Reference 10 is a more recent collection that shows a smaller number of comparisons. In the calculation of the viscous flow about axisymmetric bodies it is necessary to add the boundary layer displacement thickness to the body as will be shown in a subsequent section. This results in an "open" trailing edge body. This "open" body can be evaluated by the Neumann program without any difficulty even though the boundary surface does not close. Reference 11 presents an explanation of this phenomenon which proceeds as follows: for a closed body the integral of the source density over the body is zero; for an "open trailing edge body, this integral is not zero, and a streamtube leaves the trailing edge of the open body which proceeds downstream and approaches infinity parallel to $\vec{u}_\infty$ as a constant cross section streamtube. Thus, the flow that is calculated may be thought of as that about a semi-infinite body consisting of the open body and an extension defined by this streamtube. The shape of the extension is unknown but is presumably unique, having both zero normal velocity and zero source density.

The potential flow program has many useful options available which do not pertain directly to the present development. The details of these options are described in References 12 through 17.

Boundary Layer Method

Basic boundary layer equations. - The calculation of the viscous flow over an axisymmetric body involves the solution of the laminar and turbulent flow equations. For laminar flows, the problem is strictly mathematical because the governing differential equations can be written exactly. For turbulent flows on the other hand, an exact solution of the governing equations is not possible. Consequently, in order to proceed at all, one must rely on a certain degree of empiricism. In the past, most of the work in this area has concentrated on so-called momentum and/or energy integral methods as a means of evaluating the viscous flow parameters. Thus, the exact mathematical solution to the problems of the turbulent flow was bypassed, leading to fast and simple methods with varying degrees of accuracy. These methods usually rely quite heavily on empirical correlations and generally are restricted to a limited range of flow conditions.

The Douglas Boundary-Layer Method (Reference 8), eliminates many of the disadvantages of the integral methods by proceeding to solve the full partial-differential equations governing the flow, thereby, being classified as a differential method. For two-dimensional and axisymmetric incompressible flows, turbulent boundary-layer equations contain terms involving time means of fluctuating velocity components known as Reynolds stress terms. At present the exact relationship between these terms and the mean velocity distribution in the boundary layer still remains unknown. In the present method, a relation based on the eddy-viscosity concept is used giving highly satisfactory results for a variety of flow conditions.

If the normal-stress terms are neglected, the incompressible turbulent boundary-layer equations for two-dimensional and axisymmetric flows can be written as in Reference 8:

Continuity

$$\frac{\partial}{\partial x}\left[r^k u\right] + \frac{\partial}{\partial y}\left[r^k v\right] = 0 \qquad (2)$$

Momentum

$$u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = u_e \frac{du_e}{dx} + \frac{1}{\rho_\infty} \frac{1}{r^k} \frac{\partial}{\partial y} \left(r^k \tau \right) \tag{3}$$

where

$$\tau = \tau_\ell + \tau_t$$

with

$$\tau_\ell = \mu_\infty \frac{\partial u}{\partial y} \qquad \text{(For laminar flow only)} \tag{4}$$

$$\tau_t = - \rho_\infty \overline{u'v'} \qquad \text{(Additional term due to turbulent flow)}$$

and

$\overline{u'v'}$ = Reynolds shear stress term

$k = 0$ for two-dimensional flow

$k = 1$ for axisymmetric flow

The basic notation and coordinate scheme are shown in Figure 1, where U_∞ is a reference velocity and $u_e(x)$ is the velocity just outside the boundary layer. The coordinate system is a curvilinear one in which x is the distance along the surface measured from the stagnation point or leading edge, and y is measured normal to the surface. Within the boundary layer, the velocity components in the x- and y-directions are u and v, respectively. The body radius is r_o.

The boundary conditions for equation (3) are

$$u(x,0) = 0 \tag{5a}$$

$$v(x,0) = 0 \tag{5b}$$

$$\lim_{y \to \infty} u(x,y) = u_e(x) \tag{5c}$$

Before equations (2) and (3) can be solved, they must be transformed to a coordinate system which removes the singularity at $x = 0$ and stretches the coordinate normal to the flow direction. First, these equations are placed in an almost two-dimensional form by the Probstein-Elliott transformation (Reference 18):

$$d\overline{x} = \left[\frac{r_o(x)}{L}\right]^{2k} dx \tag{6}$$

$$d\overline{y} = \left[\frac{r(x,y)}{L}\right]^{k} dy \tag{7}$$

where $r_o(x)$ is the body radius and $r(x,y)$ is a radius which accounts for the transverse curvature effect which will be subsequently discussed. A stream function Ψ is defined that satisfies the continuity equation (2):

$$\frac{\partial \Psi}{\partial y} = r^k u \qquad \frac{\partial \Psi}{\partial x} = - r^k v \quad , \quad \overline{\Psi} = \frac{\Psi}{L} \tag{8}$$

The resulting equations are transformed by the Levy-Lees transformation (Reference 19) in order to remove the singularity at $\overline{x} = 0$ and stretch the coordinates in the $\overline{x}$ and $\overline{y}$ directions. The Levy-Lees transformations are:

$$d\xi = \rho_\infty \mu_\infty u_e \, d\overline{x} \tag{9a}$$

$$d\eta = \frac{\rho_\infty u_\infty}{(2\xi)^{\frac{1}{2}}} \, d\overline{y} \tag{9b}$$

A dimensionless stream function, f, is introduced which is related to $\overline{\Psi}$ as follows:

$$\overline{\Psi} = (2\xi)^{\frac{1}{2}} f(\xi,\eta) \tag{10}$$

Combining the Levy-Lees and the Probstein-Elliott transformations given above we have

$$d\xi = \rho_\infty \mu_\infty u_e \left[\frac{r_o(x)}{L}\right]^{2k} dx \tag{11a}$$

$$d\eta = \frac{\rho_\infty u_e}{(2\xi)^{\frac{1}{2}}} \left[\frac{r(x,y)}{L}\right]^{k} dy \tag{11b}$$

Introducing an eddy viscosity term to account for the Reynolds shear stress terms,

$$\varepsilon \equiv - \frac{\overline{u'v'}}{\frac{\partial u}{\partial y}} \quad , \quad \varepsilon^+ \equiv \frac{\varepsilon}{U} \tag{12}$$

and a transverse curvature term t along with a pressure parameter term

$$\beta = \frac{2\xi}{u_e} \frac{du_e}{d\xi} \tag{13}$$

The momentum equation (3) then becomes, with $f' = u/u_e$,

$$\left[(1+t)^{2k} (1+\varepsilon^+) f''\right]' + ff'' + \beta\left[1-(f')^2\right] = 2\xi\left[f' \frac{\partial f'}{\partial \xi} - f'' \frac{\partial f}{\partial \xi}\right] \tag{14}$$

The boundary conditions given by equation (5) become

$$f(\xi,0) = f_w = 0 \tag{15a}$$

$$f'(\xi,0) = 0 \tag{15b}$$

$$\lim_{\eta \to \infty} f'(\xi,\eta) = 1 \tag{15c}$$

The momentum equation is then solved by a very efficient numerical scheme developed by Keller, (Reference 20) and applied to boundary layer calculations by Cebeci and Keller, (References 21 and 22).

Eddy viscosity equations. - The eddy viscosity concept is used to relate the time-mean fluctuating velocities to a mean velocity distribution as given in equation (12)

$$\varepsilon \equiv - \frac{\overline{u'v'}}{\frac{\partial u}{\partial y}} \tag{12}$$

A two-layer model of the eddy viscosity within the boundary layer will be used as shown in figure 2.

In the inner region of the boundary layer an eddy viscosity model, based on Prandtl's mixing-length theory, is used:

$$\varepsilon_i = \ell^2 \left|\frac{\partial u}{\partial y}\right| \tag{16}$$

where ℓ, the mixing length is given by

$$\ell = K_1 Y \tag{17}$$

A modified expression for ℓ has been developed by Van Driest (Reference 23) to account for the viscous sublayer close to the wall. This modification is

$$\ell = K_1 Y \left[1 - e^{-(Y/A)}\right] \tag{18}$$

where A is given by

$$A = A^+ \frac{\nu_\infty}{N} \left[\frac{\tau_w}{\rho_\infty}\right]^{-\frac{1}{2}} \tag{19}$$

and

$$A^+ = 26.0 \tag{20}$$

$$N = \left[1 - 11.8\ P^+\right]^{-\frac{1}{2}} \tag{21}$$

$$P^+ = \frac{\nu_\infty u_e}{u_\tau^3} \frac{du_e}{d\xi} \rho_\infty \mu_\infty u_e \left(\frac{r_o}{L}\right)^{2k} \tag{22}$$

$$u_\tau = \left(\frac{\tau_w}{\rho_\infty}\right) \tag{23}$$

Now for axisymmetric flows the value of ℓ is replaced by

$$\ell = .4r_o \ln\left(\frac{r}{r_o}\right) \left[1 - e^{-\frac{r_o}{A} \ln\left(\frac{r}{r_o}\right)}\right] \tag{24}$$

which is developed in reference 24. If transverse curvature effects are desired then

$$\frac{r}{r_o} = \frac{r_o + Y \cos\alpha}{r_o} = 1 + \frac{Y}{r_o} \cos\alpha$$

$$= 1 + t \tag{25}$$

$$\text{where } t = \frac{Y}{r_o} \cos\alpha$$

then ℓ becomes

$$\ell = .4r_o \ln(1+t) \left[1 - e^{-\frac{r_o}{A} \ln(1+t)}\right] \tag{26}$$

The eddy viscosity in the outer region of the boundary layer is given by

$$\varepsilon_o = \alpha\, u_e\, \delta_k^* \tag{27}$$

where δ_k^* is the boundary layer displacement thickness defined by

$$\delta^* = \int_0^{n_\infty} \left[1 - \left(\frac{u}{u_e}\right)\right] dn \tag{28}$$

which in the transformed plane becomes

$$\delta_k^* = \left[\frac{L}{r_o}\right]^k \frac{(2\xi)^{\frac{1}{2}}}{\rho_\infty u_e} \int_0^{n_\infty} (1-f')(1+t)^{-k} dn \tag{29}$$

where

$$1+t = \left[1 + \frac{2L \cos \alpha}{r_o^2} \frac{(2\xi)^{\frac{1}{2}}}{\rho_\infty u_e} \int_0^{n_\infty} dn\right]^{\frac{1}{2}}. \tag{30}$$

This relationship for ϵ_o is the same for two-dimensional or axisymmetric flows as shown in Reference 24.

<u>Low Reynolds number effects</u>. - The calculation of turbulent boundary layers about two-dimensional and axisymmetric bodies must often be done at low Reynolds number, i.e., momentum thickness Reynolds number, R_θ, less than 6000. Most of the boundary layer methods including the one presented above are based on empirical data which were obtained at high Reynolds numbers. A correction term to account for low Reynolds numbers which was developed by Cebeci (Reference 25) based on prior work by Coles (Reference 26) is, therefore, applied to the outer eddy viscosity by varying the α in equation (27) with R_θ in the following manner.

if $R_\theta < 425$ then $\alpha = (.0168)(1.55)$ (31a)

if $R_\theta > 6000$ then $\alpha = .0168$ (31b)

if $425 < R_\theta < 6000$ then $\alpha = .0168 \left[\frac{1.55}{1+\Pi}\right]$ where

$$\Pi = .55 \left[1 - e^{-.243\sqrt{\gamma} - .298\,\gamma}\right] \text{ and } \gamma = \left(r_\theta/425\right) - 1 \tag{31c}$$

<u>Transverse curvature</u>. - In developing the axisymmetric boundary layer equations a radius term is introduced as shown in equations (2) and (3). If the assumption is made that the body radius is very large compared to the boundary layer thickness then the radii in equations (2) and (3) reduce to the local body radius r_o and the effect of the transverse (i.e.,

circumferential) curvature in the momentum equation is neglected. If, however, the body radius is small compared to the boundary layer thickness then the effect of the transverse curvature cannot be ignored and r must be a function of the distance into the boundary layer, y. The relationship between y, r_o, and r is given by:

$$r = r_o + y \cos \alpha \tag{32}$$

As observed in figure 3, α is simply the surface slope in the longitudinal direction. i.e.,

$$\tan \alpha = \frac{dr}{dx} \tag{33}$$

For slender cylinders where $\alpha = 0°$,

$$r = r_o + Y \tag{34}$$

The inclusion of the transverse curvature terms in the boundary layer equations is shown in References 24 and 27 to substantially improve the accuracy of the calculation of the local skin friction as well as the other viscous parameters.

Transition region effect. - The boundary layer method has the capability of calculating transition from laminar flow to turbulent flow in two different ways. The first approach is to use the transition point as a switching point between laminar and turbulent boundary layer calculations. At the transition point the turbulent boundary layer calculations are started by activating the eddy viscosity coefficient. In general, especially at low Reynolds numbers this approach can lead to errors as shown by Cebeci in Reference 28. The second approach which is available uses the intermittancy factor given by Chen and Thyson (Reference 29) to modify the eddy viscosity equations to account for a region of transition. This modification was developed from the point of view of intermittent production of turbulent spots and is a further extension of Emmons' spot theory (Reference 30). The modification to be used is to multiply the inner and outer eddy viscosities equations (16) and (27) by the following parameter:

$$\gamma_{Tr} = 1 - e^{-Gr_o\left(x_{Tr}\right)\left[\int_{x_{Tr}}^{x} \frac{dx}{r_o}\right]\left[\int_{x_{Tr}}^{x} \frac{dx}{u_e}\right]} \tag{35}$$

$$G = \left(\frac{3}{3600}\right)\left(\frac{u_e^{\,3}}{\nu_\infty^{\,2}}\right) Re_{Tr}^{\;-1.34}$$

$$\text{where} \qquad Re_{Tr} = \frac{u_e x_{Tr}}{\nu_\infty}$$

The effect of this transition region correction can be seen in figure 4 which compares experimental data to theoretical calculations for local skin friction with and without the above correction on a two-dimensional ellipse. This transitional effect will be assumed to be the same for axisymmetric bodies.

Boundary layer transition location. - The location of boundary layer transition from laminar to turbulent flow can be either input to the boundary layer method or calculated internally within the program. The approach used to calculate the transition location is one developed for two-dimensional flow by Michel (Reference 31) and later verified by Smith (Reference 32). This method correlates the local momentum thickness Reynolds number, R_θ and the local distance Reynolds number, R_x, as shown in figure 5 which comes from Reference 32. The procedure used is to calculate the values of R_x and R_θ at each station and to compare them to the curve in figure 5. If the value of R_θ is less than the value of $R_{\theta_{TR}}$ than transition has not been reached but if the value of R_θ is greater than $R_{\theta_{TR}}$ then transition has occurred.

The above method was extended to axisymmetric flow by the use of Mangler's transformation. The parameters R_θ and R_x are calculated by the axisymmetric boundary layer routine and they are then transformed to two-dimensional values by the following relationships:

$$\theta_{2-D} = \left(\frac{r_o}{L}\right) \theta_{AXISYMMETRIC} \tag{36a}$$

$$X_{2-D} = \int_0^{x_{LOCAL}} \left(\frac{r_o}{L}\right)^2 (dX)_{AXISYMMETRIC} \tag{36b}$$

These values of θ_{2-D} and X_{2-D} are used to determine values of R_θ and R_x which can be used in conjunction with figure 5.

A study of transition location calculation for axisymmetric bodies was recently completed by Kaups (Reference 33). In this study empirical methods due to Granville, Hall and Gibbons, and the method of Michel presented above were compared to the stability analysis technique of Smith (Reference 32). It was determined that for flows where transition occurred in an adverse pressure gradient all of the above techniques predicted transition fairly accurately. For flows where transition occurred in favorable pressure gradients, only the method of Smith (Reference 32) gave satisfactory results as shown in figure 6 which is taken from Reference 33. The method of Smith, however, requires extremely lengthy computer calculation times which makes it undesirable for the iterative type of calculation presented in this report. Therefore, based on the results of Reference 33, the method of predicting transition in the present program should not be used for flows with very large Reynolds numbers where the transition location might occur in a favorable gradient, but rather the transition point should be input to the program.

Calculation Procedure

The viscous flow field about an axisymmetric body is simulated by calculating the inviscid flow about an equivalent "viscous" body which is formed by adding the boundary layer displacement thickness to the original body surface. This technique of defining the inviscid body has been used quite successfully for two-dimensional flows as shown in Reference 2 and has also been used for axisymmetric flows as presented in Reference 34. This equivalent body is formed by combining the previously discussed geometry routine, potential flow method, and boundary layer method under control of the axisymmetric design and analysis method computer program known as ADAM.

Given the desired axisymmetric configuration and flow conditions, the ADAM program utilizes these sections, as shown in figure 7, in the following iterative manner:

1. Precise geometry definition for input into the potential flow program.

2. Calculation of the exact nonlinear potential flow for specified geometry and flow conditions.

3. Calculation of the viscous flow characteristics based on the results of the potential flow program.

4. Addition of boundary-layer displacement thickness to the basic geometry for each element.

5. Recalculation of the pressure distribution utilizing the potential flow program, based on the redefined geometry.

6. Recalculation of viscous flow field based on recalculated pressure distribution from redefined geometry, if desired.

7. Possible iteration of the above scheme; the degree to which this is required is presented in the subsequent discussion on correlations with experimental data.

The above technique must be modified when the boundary layer separates or when the local body radius approaches zero at the trailing edge of the body. When the dimension of the local body radius approaches zero at the trailing edge, the boundary layer equations become invalid since the $1/r$ term in equation (3) approaches infinity. When this occurs, the boundary layer results are ignored from this point downstream to the trailing edge. The assumption is then made that the boundary layer displacement area at the point where

$$\delta^* \cos \alpha = r_o \tag{37}$$

is defined by

$$\mathrm{DAREA} = \pi \left\{ \left(r_{o_p} + \delta^* \cos \alpha_p \right)^2 - r_{o_p}^{\,2} \right\} \tag{38}$$

where p refers to the point where equation (37) is first satisfied. This displacement area is then considered to remain constant from the point p to the trailing edge. The new "viscous" body coordinates in this region are then defined by

$$y_{new} = \left\{ \frac{\pi r_o^{\,2} + \mathrm{DAREA}}{\pi} \right\}^{1/2} \tag{39}$$

The second problem area occurs when the boundary layer separates from the body creating a separation bubble. This bubble must be accounted for in the creation of a "viscous" body if the flow about this configuration is to be predicted accurately. The simplest technique of modeling this separation bubble is to assume that the flow leaves the surface parallel to the free-stream direction, producing a cylindrical wake shape as shown in figure 8. This approach, however, gives decelerations in the flow at the junction of the body with the cylinder as shown in figure 9, which do not exist in the real flow field. To minimize this problem, a circular arc is used to fair the body into the separated cylinder.

This circular arc is defined by passing a circle through the last three "viscous" body coordinates defined prior to the separation point. The radius of this circle is then used to create a circular arc which is tangent to the "viscous" body at the point of separation. The center of this arc is then defined according to whether the surface slope of the body at separation is positive or negative.

If the surface slope is positive then the center is taken as the center of the circle passed through the three points as defined above. This center is defined by

$$x_c = x_{sep} + R \sin \left[\tan^{-1} \left| \frac{dy}{dx} \right| \right] \tag{40a}$$

$$y_c = y_{sep} - R \cos \left[\tan^{-1} \left| \frac{dy}{dx} \right| \right] \tag{40b}$$

where R = Radius of the circle

$\frac{dy}{dx}$ = Surface slope at separation

This arc is then used from the point of separation to either the end of the body or to the maximum point on the arc, where $dy/dx = 0$, as shown in figure 10a. If the maximum point of the arc occurs before the trailing edge of the body is reached then a cylinder is defined which extends from the maximum point of the arc to the trailing edge.

If the surface slope is negative then the circular arc is defined such that the center is located above the body. The center is then defined by

$$x_c = x_{sep} + R \left[\sin \tan^{-1} \left|\frac{\partial y}{\partial x}\right|\right] \tag{41a}$$

$$y_c = y_{sep} + R \left[\cos \tan^{-1} \left|\frac{\partial y}{\partial x}\right|\right] \tag{41b}$$

This arc is then used from the point of separation to either the end of the body or to the minimum point on the arc, where $dy/dx = 0$, as shown in figure 10b. If the minimum point of the arc occurs before the trailing edge of the body then a cylinder is defined which extends from the minimum point of the arc to the trailing edge of the body.

The above separated wake model has been derived from intuitive considerations rather than from first principals. It does, however, provide reasonable results, as will be shown in the subsequent discussion.

The base drag coefficient for blunt axisymmetric bodies is calculated using the method of Hoerner, reference 35. This approach is based on the assumption that the flow field behind a blunt base is basically a jet pump, in that, air flowing around the body leaves the trailing edge forming a cylindrical jet which attempts to pump away the stagnated air in the base region. However, since there is no air to replace this stagnated air, the pumping mechanism can only reduce the static pressure acting on the base. The effectiveness of this jet pump mechanism is controlled by the boundary layer thickness at the base since this region of lower momentum flow acts as a buffer between the stagnated air behind the base and the flow in the jet. Since the boundary layer thickness is directly related to the skin friction on the body, C_f, Hoerner used C_f to correlate with the base drag to develop an empirical approach to determine base drag. Figure 11 shows the correlation obtained by Hoerner for bodies whose base area is the same as the maximum area. This curve is represented by

$$C_{D_{BASE}} = .029/\sqrt{C_{f_{Forebody}}} \tag{42}$$

where the coefficients are based on the base area. Thus, once the skin friction on the forebody has been calculated in the boundary layer programs, then the base drag can be determined by equation 42.

This equation must be modified for boat-tailed bodies, that is, bodies whose base area is less than their maximum area. The mechanics of the base drag for these configurations do not change, but the calculation must take into account the reduced base area. This effect is taken into account by the following relationship:

$$C_{D_{BASE}} = C_{D_{BASE}} \cdot \left(\frac{d_{BASE}}{D_{MAX}}\right)^2 \qquad (42a)$$

and

$$\underset{\text{(BOAT TAIL)}}{C_{f_B}} = C_{f_B} \cdot \left(\frac{D_{MAX}}{d_{BASE}}\right)^2 \qquad (43b)$$

so

$$\underset{\text{BOAT TAIL}}{C_{D_{BASE}}} = \frac{.029}{\sqrt{C_{f_B}}} \cdot \left(\frac{d_{BASE}}{D_{MAX}}\right)^3 \qquad (43c)$$

A comparison of results calculated by the above method in ADAM with experimental force data from reference 35 is presented in figure 12. One of these cases is for a boat-tailed body and the other for a body whose base area is also the maximum area.

The experimental data used for this comparison as well as the configuration used for the analytical calculations are both subject to some discussion. The experimental base drag, taken from Figure 4 of Reference 35, originally came from an old German report which is not readily available. These base drag values were obtained from both force measurements and pressure measurements which unfortunately do not agree. Therefore, since it was felt that the force measurements were the more accurate, they were used in the comparison shown in Figure 12. In addition, no good definition of the configuration tested was available, therefore, the geometry used in the ADAM analysis was taken from the schematics shown in Reference 35. In light of these uncertainties the comparison presented in Figure 12 is fairly good in that even though the levels are different, the trends are the same. It should be noted that this comparison was used only because there is a singular lack of experimental data for blunt based axisymmetric bodies at low subsonic Mach numbers.

EXPERIMENTAL CORRELATIONS

Experimental results from three different configurations were selected to establish the extent of validity of the method presented in this report. These geometries consisted of a high fineness ratio body of revolution, and a sphere in both subcritical and supercritical flow regimes. These correlations, while limited to some extent by the scope of the present effort, do represent a wide range of axisymmetric flow conditions.

The body of revolution chosen was tested in the low speed wind tunnel at the Douglas Aircraft Company, (Reference 36), and is shown in figure 13. This model was composed of three sections; an elliptical nose section, a cylindrical control section, and a parabolic afterbody. The calculation done for this configuration used the wind tunnel flow properties, namely, $U_\infty = 71.628$ M/Sec (235 Ft/Sec), $T_\infty = 288.3°K$ (519.0°R) and $R_L = 10.05 \times 10^6$. Boundary layer transition was fixed on the model and in the calculation at .03048 meters (1.2 inches) from the nose. This model was relatively large for the wind tunnel in which it was tested; wall effects, not accounted for in the original data reduction, were present. To correct for this, the model was run in the potential flow program in the presence of the wind tunnel walls as shown in figure 14. The effect of including the walls in the calculation is shown in the inviscid pressure distributions of figure 15. The final results for this configuration are shown in figure 16 where the calculated "viscous" results are compared to experimental data. The inviscid distribution is also shown for reference. In this particular case no separation occurred and so only one iteration, that is, two potential flow solutions and two boundary layer solutions, was necessary. The calculated "viscous" results agree very well with the experimental values except in the region of the nose. This discrepancy is not due to the calculation method, but rather is due to the model being too long for the wind tunnel test section resulting in the nose being in a different static pressure field than the rest of the body. The overall effect of viscosity on this configuration is seen to be small except in the region of the trailing edge. The body is so slender in this region that the boundary layer equations are no longer valid so the technique described in the calculation procedure was used to modify the viscous body. The results show a pressure osciliation in this modified region which is due to an unsmooth curvature distribution. However, the level of these pressures agree quite well with the experimental values.

The second case considered was that of a sphere in the supercritical flow regime, i.e., $R_D = 1 \times 10^6$. Since the boundary layer transition was forced to occur at an $X/D = .65$, there were regions of both laminar and turbulent flow present. The experimental data for this case were taken from references 37 and 38. The freestream velocity assumed for this case was 47.85 M/Sec (157 Ft/Sec). Figure 17 shows the sphere with the "viscous" body superimposed and figure 18 presents a comparison between the calculated "viscous" solution and experimental data. Note that while the calculated pressure distribution is in reasonably good agreement with the experimental values, the calculated separation point is .07 diameters further downstream than the experimentally measured value. The inviscid and "viscous" solutions for the local skin friction coefficient, C_f, are presented in figure 19. The "viscious" solution shown is the fourth iteration, i.e., the fifth potential flow solution, and appears to be the best solution possible for this configuration with the technique being used in the present method to simulate flow separation.

The last correlation to be presented is for the flow about a sphere in the subcritical regime, i.e., $R_D = 1 \times 10^5$, which is a purely laminar case. The experimental data is again taken from Reference 37. The freesteam velocity for this case was assumed to be 4.785 M/Sec (15.7 Ft/Sec). The calculated "viscous" body is shown in figure 20 while a comparison of the "viscous" pressure distribution to experimental data is shown in figure 21. The calculated "viscous" pressures are in close agreement with the experimental values with some slight over-prediction in the separated region. The calculated separation point is only .03 diameters further downstream than the experimental value which is excellent considering the large effect that viscosity has on this configuration. Figure 22 presents the inviscid and "viscous" solutions for the local skin friction coefficient for this case.

CONCLUDING REMARKS

A method has been presented for the computation of the viscous flow field about axisymmetric bodies at zero angle of attack in incompressible flow. This computing program requires only the specified body geometry and desired flow conditions as input. The appropriate theory has been discussed and correlations between theoretical and experimental results presented.

The flow field about axisymmetric bodies at zero angle of attack with no flow separation is well defined and can be computed accurately by the present method. When flow separation occurs, the flow field is no longer amenable to analytical treatment. Currently, methods do not exist to calculate the flow field within a separated region; it is therefore necessary to resort to empirical methods to account for flow separation. Since there is almost a complete lack of experimental data concerning the behavior of separated regions, any empirical methods must necessarily be somewhat crude. The most sophisticated model for separation currently available is due to Jacob (References 39 and 40) and is strictly for two-dimensional airfoils. An unsuccessful attempt was made in Reference 41 to adapt Jacob's approach to axisymmetric configurations. The conclusions of Reference 41 indicated that the assumed boundary conditions needed to be modified if this approach was to be used for axisymmetric flow. It is proposed that the Douglas-Neumann program be used to pursue this approach at modeling separation. This potential flow program is ideal for attempting to use Jacob's technique since it already has the ability to specify a non-uniform flow distribution over all or part of a configuration; therefore, only suitable boundary conditions would have to be added to the program. It is felt that this approach can be successful in modeling separation if care is taken in developing the distribution of non-uniform velocity as well as specifying the proper boundary considerations.

The further extension of this model to the calculation of flow about axisymmetric bodies at angle of attack is also possible. The potential flow routine contained in the present method has the capability of predicting the flow field about non-lifting bodies at angle of attack by combining the streamflow and the crossflow solutions. The boundary layer analysis would require the replacement of the routine in the present method by a three-dimensional technique, which is currently not available. However, it is felt that a good approximation to the boundary layer calculations can be made by the small crossflow program of Reference 42.

One area of primary concern in extending the method to include an angle of attack capability is the determination of the separation line about the body. The present method of predicting separation for two-dimensional bodies and for axisymmetric bodies at zero angle of attack is to find the location where the skin friction goes to zero. It has been shown in several studies, including those reported in References 43 and 44, that this condition does not apply in three-dimensional flows because the skin friction along a separation line is not necessarily zero. Therefore, some method of determining the separation line for axisymmetric bodies at angle of attack must be developed. It is proposed that the present method could be extended to calculate the "viscous" flow about axisymmetric bodies at angle of attack when no flow separation is present. This method could then be used to assist in the development of a procedure for determining the separation line location. Once the location of the separation line is known then a model could be developed for analyzing the viscous flow about the separated body. The development of such procedures is not a simple task and considerable effort would have to be expended; but the reward for accomplishing this task is an advance in the ability to calculate the real flow about arbitrary three-dimensional bodies which is our ultimate goal.

APPENDIX A

INPUT INFORMATION FOR ADAM COMPUTER PROGRAM

This part of the report contains the necessary information to input data to the ADAM computer program. The input data is broken into three sections: smoothing, potential flow, and viscous flow. These sections can be used together in the iterative fashion described in the main text, or the potential flow and viscous flow sections may be used independently. A detailed card-by-card description of all input quantities is given followed by a set of input forms which can be used to facilitate the loading of the input data into the program.

Input Instructions

The Adam program requires one system control card followed by the required sets of data cards for each program option to be executed. The sets of data furnished must be in the same order as the options are specified on the system control card. If an iteration is desired the system control card is repeated along with the necessary other data cards.

The general scheme used in describing the input data is shown below:

Column	Code	Routine Format	Explanation

Column - Column indicates the starting position on the card for each data field.

Code - The "code" gives the FORTRAN name used in the read statement by the program.

Routine - "Routine" indicates the subroutine where the data is read.

Format - The parameter "FORMAT" which is given right under the routine name, indicates the FORTRAN format of the data read statement field. The parameter I5 would indicate that the parameter is an integer in a field that is 5 columns wide. Integers should be punched on the right side of the field (right justified). The parameter F10.0 would indicate a fixed point number punched with a decimal point (i.e., -12.354). The number may be punched anywhere in the field indicated irrespective of the decimal point location indicatied by the format. The parameter E12.6 would indicate a floating point number punched with a decimal point (i.e., 5.0×10^6). The number must be punched to the right of the field in the manner 5.0E+06.

Explanation - The description of the input data is given under "explanation".

SUSTEM CONTROL DATA CARD (This card must be the first card in the data deck)

Column	Code	Routine Format	Explanation
4	IGEOM	MAIN I1	Smoothing option flag =0 no smoothing is desired =1 smoothing is desired
8	INEUM	MAIN I1	Potential flow option flag =0 No potential flow solution is desired =1 Potential flow solution is desired
12	IBOUND	MAIN I1	Boundary layer option flag =0 No boundary layer solution is desired =1 Boundary layer solution is desired
16	ITER	MAIN I1	"Viscous" body formation flag =0 No "viscous" body is formed =1 "Viscous" body is formed
17-20	IFINSH	MAIN I4	Termination Flag =0 Another case expected =9999 Program will stop after exercising all options specified above

SMOOTHING SECTION

These cards required if IGEOM = 1 on system control card. This section is used to smooth body geometry data before it is input to the potential flow program.

Smoothing Control Card

Column	Code	Routine Format	Explanation
2	NPTS	SMOOTH I3	Number of input data points for this configuration. NPTS must be ≤ 100
8	ITAPE	SMOOTH I1	Data source flag =0 Data input on unit 5 (card input) ≠0 Data input on unit 1. This is used for a case where a "viscous" body generated by the iteration procedure is being read.

Geometry Data Input Cards

These cards are input only if ITAPE = 0.

Column	Code	Routine Format	Explanation
x-coordinate cards			
1-10 11-20 21-30 etc.	x(1) x(2) x(3)	SMOOTH 6F10.0	x-coordinates starting at the leading edge and proceeding along the upper surface to the trailing edge. Input 6 x-values on each card. The numbers of x-values must be equal to NPTS.
y-coordinate cards			
1-10 11-20 21-30 etc.	y(1) y(2) y(3)	SMOOTH 6F10.0	y-coordinates to correspond to the above x-locations. y-values must be positive. Input 6 values per card.

POTENTIAL FLOW SECTION

These cards required if INEUM = 1 on system control card. The input geometry for this program may be obtained from the geometry storage unit (10) as generated by the smoothing section, or it may be input directly on unit 5. Thus, this program may be operated as a separate entry if so desired. The program saves the geometry data element midpoints with the corresponding pressure coefficients on unit 3 for input to the boundary layer routine and it saves the basic non-dimentional input Neumann coordinates on unit 1 for use if a "visous' body is desired.

Title Card

Column	Code	Routine Format	Explanation
1	HEDR	PART1 10A6	Title of case. May be any characters input in the first 60 columns of card.
63	CASE	PART1 I6	Case number
77	PSF	PART1 I6	Additional identifier for this case.

Flag Card

Card columns 1-30 when punched with any non-zero integer, activate flags that indicate the following:

Column	Code	Routine Format	Explanation
1	NB	PART1 I1	The number of bodies input. Normally set equal to 1. $1 \leq NB \leq 5$
2	NNU	PART1 I1	The number of non-uniform onset flows. Normally set equal to 0.
3	FLG03	PART1 I1	Axisymmetric flow flag. =0 No axisymmetric stream-flow solution calculated. =1 Axisymmetric streamflow solution is calculated Normally set equal to 1

Flag Card (Continued)

Column	Code	Routine Format	Explanation
4	FLG04	PART1 I1	Cross flow flag. =0 No cross flow solution is calculated =1 Cross flow solution is calculated Normally set equal to 0
5	FLG05	PART1 I1	Off-body point flag =0 No off body points input =1 Off body points are input This flag allows the velocity at points off the body surface to be determined.
6	FLG06	PART1 I1	Basic data formation flag =0 A full case will be done =1 The basic data, i.e., midpoints, normals, etc. will be formed and printed. No velocities will be calculated.
7	FLG07	PART1 I1	Ellipse generator option =0 Body coordinates will be input =1 An ellipse is generated using data input later. No body coordinates are input
8	FLG08	PART1 I1	Matrix print flag =0 Coefficient matrices are not printed. =1 Coefficient matrices will be printed. Normally set equal to 0
11	FLG11	PART1 I1	Perturbation velocity flag =0 Normal case =1 No onset flow used. Only perturbation velocities are calculated.
12	FLG12	PART1 I1	Potential matrix solution * =0 Normal case =1 A potential matrix is solved

Flag Card (Continued)

Column	Code	Routine Format	Explanation
13	FLG13	PART1 I1	Matrix solution flag =0 No matrix solution done =1 Matrix solution performed Normally set equal to 1.
14	FLG14	PART1 I1	Prescribed tangential velocity flag * =0 Normal case =1 Tangential velocities are specified
15	FLG15	PART1 I1	Strip ring vorticity flag * =0 Normal case =1 A vorticity distribution is formulated.
16	FLG16	PART1 I1	Axisymmetric uniform flow flag =0 Normal case =1 Axisymmetric uniform flow solution is omitted Normally set equal to 0.
17	FLG17	PART1 I1	Crossflow uniform flow flag =0 Normal case =1 Crossflow uniform flow solution is omitted. Since FLG04 is normally = 0 then so is FLG17 normally set equal to 0.
18	FLG18	PART1 I1	Surface vorticity flag * =0 Normal case =1 Surface vorticity is generated.
19	FLG19	PART1 I1	Prescribed vorticity Flag * =0 Normal case =1 A prescribed vorticity is input
20	FLG20	PART1 I1	Total vorticity flag * =0 Normal case =1 Total vorticity calculated

Flag Card (Continued)

Column	Code	Routine Format	Explanation
21	FLG21	PART1 I1	Extra crossflow flag * =0 Normal case =1 Extra crossflow option used
22	FLG22	PART1 I1	Generated boundary condition flag * =0 Normal case =1 Boundary conditions generated
23	FLG23	PART1 I1	Ring wing option flag * =0 Normal case =1 Ring wing option used
28-29	NIN	PART1 I2	Tape input flag =0, 10 Data input on unit 10 from smoothing program =5 Data input from unit 5 (card input)
30	ITER	PART1 I1	Iteration tape flag =0 x/c, y/c transformed data saved on unit 15 =1 x/c, y/c transformed data not saved. This flag is necessary because for a "viscous" body to be formed, the coordinates of the original unmodified body must be saved. Therefore, for the first case set ITER = 0. For subsequent iterations we do not want to use the modified bodies to form new bodies so set ITER = 1.

* These flags are for special options which are discussed in the main text. They are never used for a normal axisymmetric calculation. Therefore, set them equal to zero.

Chord Card

Column	Code	Routine Format	Explanation
1	CHORD	PART1 F10.0	Reference chord length used to non-dimensionalize x and y coordinates
11	MN	PART1 F10.0	Mach number (MN < 1.0) use to approximate effect of compressibility (Gothert's rule)
21	TCNST	PART1 F10.0	This is a constant which is used for the value of the tangential velocity if this option is desired.

Body Transformation Card

Column	Code	Routine Format	Explanation
8	NN	BASIC1 I3	The number of input points on this body. NN ≤ 100
11	MX	BASIC1 F10.0	A factor used to multiply all x-coordinates. MX is assumed equal to 1 if no value is input.
21	MY	BASIC1 F10.0	A factor used to multiply all y-coordinates. MY is assumed equal to 1 if no value is input.
31	THETA	BASIC1 F10.0	An angle (in degrees) through which all points of a body are to be rotated about the origin in the clockwise direction.
41	ADDX	BASIC1 F10.0	A constant to be added to all x-coordinates
51	ADDY	BASIC1 F10.0	A constant to be added to all y-coordinates

Body Control Card

Column	Code	Routine Format	Explanation
10	BDN	BASIC1 I1	Body sequence number. This program will handle up to 5 bodies.
20	SUBKS	BASIC1 I1	Subcase Flag. =0 Normal case =1 Use unmodified coordinates of the previous case.
30	NLF	BASIC1 I1	Non-lifting flag =0 Body is non-lifting (normal case) =1 Body is lifting (this is used in special option)
31	XE	BASIC1 F10.0	Value of major semi-axis for use by ellipse generation option.
41	YE	BASIC1 F10.0	Value of minor semi-axis for use by ellipse generation option Note: if XE = YE a sphere will be formed.

Geometry Data Cards

The body geometry data cards are included only if the input parameters NIN = 5 and FLG07 = 0 on the flag card. If NIN = 0 or 10 then the data is read from unit 10. If NIN = 5 and BDN = 0, then the following cards contain the x-y coordinates of off-body points instead of x-y geometry data. The number of either geometry data point or off-body points must be equal to NN.

x-Coordinate cards (six values per card)

Column	Code	Routine Format	Explanation
1	TX1(1)	BASIC1 6F10.0	x-coordinates of body input from leading to trailing edge.
11	TX1(2)		
21	TX1(3)		

y-Coordinate cards (six values per card)

Column	Code	Routine Format	Explanation
1	TY1(1)	BASIC1 6F10.0	y-Coordinates of body which correspond to the x-values above. y values must be positive.
11	TY1(2)		
21	TY1(3)		
etc.			

NOTE: Each body input, including the off body points, requires the body transformation card, the body control card, and may also require the geometry data cards depending on the input flags. This is the stopping place for a normal axisymmetric case. The following cards are input only if one of the special options is required.

Tangential Velocity Data (six values per card)

These cards are input only if FLG14 ≠ 0 and TCNST = 0.0

Column	Code	Routine Format	Explanation
1	TG(1)	BASIC1 6F10.0	Specified tangential velocities at element midpoints.
11	TG(2)		
21	TG(3)		
etc.			

Non-uniform Flow Cards (six values per card)

These cards are input only if NNU ≠ 0.

Column	Code	Routine Format	Explanation
6	NUM	BASIC2 I5	Non-uniform flow identification number.

Non-uniform Flow Cards (Continued)

Column	Code	Routine Format	Explanation
19	MSF	BASIC2 I2	If MSF = 0 the flow velocities N_o, T_o will be used for the axisymmetric case only. If MSF = 1 the flow velocities N_o, T_o will be used for the cross flow case only. If MSF > 1 the flow velocities will be used for both axisymmetric and cross flow cases.
21	TYPE	BASIC2 F10.0	Flag which specifies the type of input flow velocities at each mid-point. If TYPE > 0.0, the velocities are input as x & y components. If TYPE = 0.0 the velocities are input as normal & tangential components. If TYPE < 0.0 the automatic generation of the flow due to a rotating body is used.
31	FG	BASIC2 F10.0	Constant used by the flow generator. Type must be less than 0.0.

The following cards are input only if NNU ≠ 0 and TYPE ≠ -1.0.

Normal velocity cards (six values per card)

Column	Code	Routine Format	Explanation
1	NO(1)	BASIC2	This is either the x or normal velocity component depending on the value of type above. These values must be in sequence with the coordinate data. If the x component is input it is defined as positive to the right. If the normal velocity is input it is positive if it is to the interior of the body. NN-1 values are input.

Tangential Velocity Cards (six values per card)

Column	Code	Routine Format	Explanation
1	TO(1)	BASIC2 6F10.0	This is either the y or tangential velocity component depending on the value of type above. These values must correspon to the NO values above. If the y component is input it is defined as positive if it is orientated upwards. If the tangential velocity is input it is positive if the flow field is to the left of the vector representing the tangential velocity.

VISCOUS FLOW SECTION

These cards required if IBOUND = 1.

BOUNDARY LAYER PROGRAM

The geometry and pressure distribution data required by this program may be input directly on cards (Unit 5), or read from the data save unit (Unit 3) as generated by the Neumann program.

HEADER CARD

This card is supplied purely for description purposes.

Column	Code	Routine Format	Explanation
1-60	TITLE	INPT 15A4	Description of input
61	CASE	INPT A4	Case number

Flag Control Card

This card contains flags which control the type of flow to be considered and the form of the input.

Column	Code	Routine Format	Explanation
1	NXT	INPT I4	The number of the x-station where the flow goes turbulent measured from the stagnation point (i.e., the leading edge for axisymmetric bodies at zero angle of attack) if transition is to be calculated by the program set NXT to be one greater than the number of points input.
5	LG16	INPT I1	Transition flag =0 Boundary layer transition point is input =1 Boundary layer transition point is computed. Set NXT to be greater than number of points input.

Flag Control Card (Continued)

Column	Code	Routine Format	Explanation
6	LG17	INPT I1	Transition control flag =0 Transition is instantaneous =1 Transition is gradual (transitional region used)
7	LG18	INPT I1	Transverse curvature flag =0 No transverse curvature correction used. =1 Transverse curvature corrections applied.
8	LG32	INPT I1	Print control flag =0 Print using long format (with velocity profiles) =1 Use short printout (no velocity profiles)
9	LG26	INPT I1	Velocity input control flag =2 Velocity ratio (U_e/U_∞) is input =3 Pressure coefficient (c_p) is input.
10	LG40	INPT I1	Unit input flag for geometry and velocity data. =0 Data read from unit 3 as generated by the potential flow program. ≠0 Data read from cards (unit 5)
11	LG41	INPT I1	System of units FLAG =0 English system of units =1 Internation system of units

Flow Condition Card

Column	Code	Routine Format	Explanation
1	TI	INPT F10.0	Reference static temperature used to compute the reference fluid properties. If TI is input as zero then TI is set equal to either 288.33°K or 519°R depending on FLAG LG41

Flow Condition Card (Continued)

Column	Code	Routine Format	Explanation
11	RMI	INPT F10.0	Reference or free-stream Mach number. =0.0 UI is input next ≠0.0 UI is computed from RMI.
21	UI	INPT F10.0	Reference or free-stream velocity =0.0 M_∞ is input above ≠0.0 M_∞ input as zero above.
31	FK	INPT F10.0	Flow index =0.0 2-D flow assumed =1.0 Axisymmetric flow assumed
41	RL	INPT F10.0	Chord or reference length
51	RI	INPT E12.0	Reynolds number/foot $R_c/\ell = \frac{U_\infty}{\nu}$ If CHORD = 1.0 then RI must be Reynolds number based on CHORD. NOTE: The input of either Mach number or freestream velocity is for convenience only. This program is entirely incompressible.

Radius card

Column	Code	Routine Format	Explanation
1	ROMAX	INPT F10.0	Maximum radius of body. This is used to obtain frontal area for skin friction calculation.
11	DETA1	INPT F10.0	Initial step size of boundary layer velocity profile grid. For a case which contains turbulent flow set DETA1 = .005.

Radius card (continued)

Column	Code	Routine Format	Explanation
21	VGP	INPUT F10.0	VGP is the growth factor for the boundary layer velocity profile grid; for cases with turbulent flow set equal to 1.14. NOTE: For laminar cases the boundary layer velocity profile grid may be made constant if VGP = 1.0 is input. However, if this is done the minimum value of DETA1 that can be input is approximately .10. This can be calculated if the value of the transformed boundary layer thickness, ETAINF, in known. Then DETA1 becomes $\text{DETA1} = \frac{\text{ETAINF}}{100}$

Geometry-Pressure Distribution Cards

These cards input only if LG40 ≠ 0.

Point Number Card

Column	Code	Routine Format	Explanation
1	NXM	INPT I4	Number of data points to be input. Maximum of 100 points allowed.

x-Coordinate Data Cards

Column	Code	Routine Format	Explanation
1	XS(1)	INPT 6F10.0	x-coordinate points input from leading to trailing edge input 6 points per card. Number of points = NXM
11	XS(2)		
21	XS(3)		
etc.			

y-Coordinate Data Cards

Column	Code	Routine Format	Explanation
1	YS(1)	INPT 6F10.0	y-coordinate points corresponding to x-coordinates above input 6 points per card.

y-Coordinate Data Cards (continued)

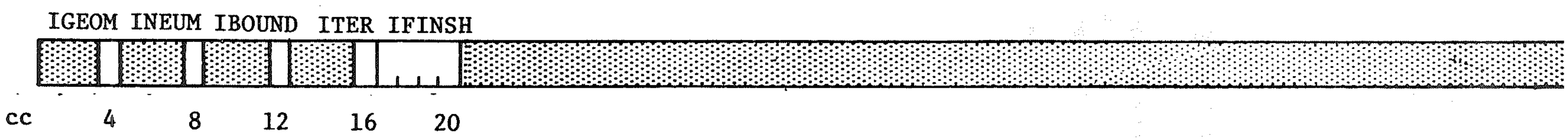
Column	Code	Routine Format	Explanation
11	YS(2)		
21	YS(3)		
etc.			

Pressure Distribution Cards

Column	Code	Routine Format	Explanation
1	UE(1)	INPT 6F10.0	Velocity-pressure-distribution points corresponding to x-points input above input 6 points per card.
11	UE(2)		If LG26 = 2 u_e/U_∞ input
21	UE(3)		LG26 = 3 c_p input
etc.			

A D A M

AXISYMMETRIC DESIGN AND ANALYSIS METHOD



SYSTEM CONTROL DATA CARD

cc 4	IGEOM	=	0	NO SMOOTHING REQUIRED	=	1	FIVE-POINT SMOOTHING USED
cc 8	INEUM	=	0	NO POTENTIAL FLOW	=	1	NEUMANN ROUTINE USED
cc 12	IBOUND	=	0	NO BOUNDARY LAYER SOLUTION DESIRED	=	1	BOUNDARY LAYER SOLUTION WILL BE DONE
cc 16	ITER	=	0	NO "VISCOUS" SOLUTION IS DESIRED	=	1	A "VISCOUS" BODY WILL BE CREATED
cc 17	IFINSH	=	0000	ANOTHER CASE IS EXPECTED	=	9999	THIS IS THE LAST CASE

Instructions to Keypunch:
Do not punch blank columns

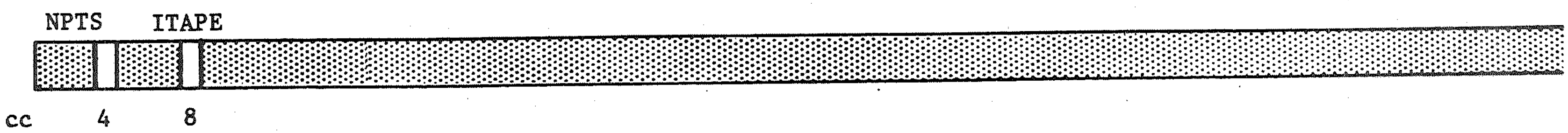
ENGINEER ____________________ PHONE __________

DATE ________________________ PAGE ___ OF ______

A D A M

SMOOTHING PROGRAM

SMOOTHING CONTROL CARD



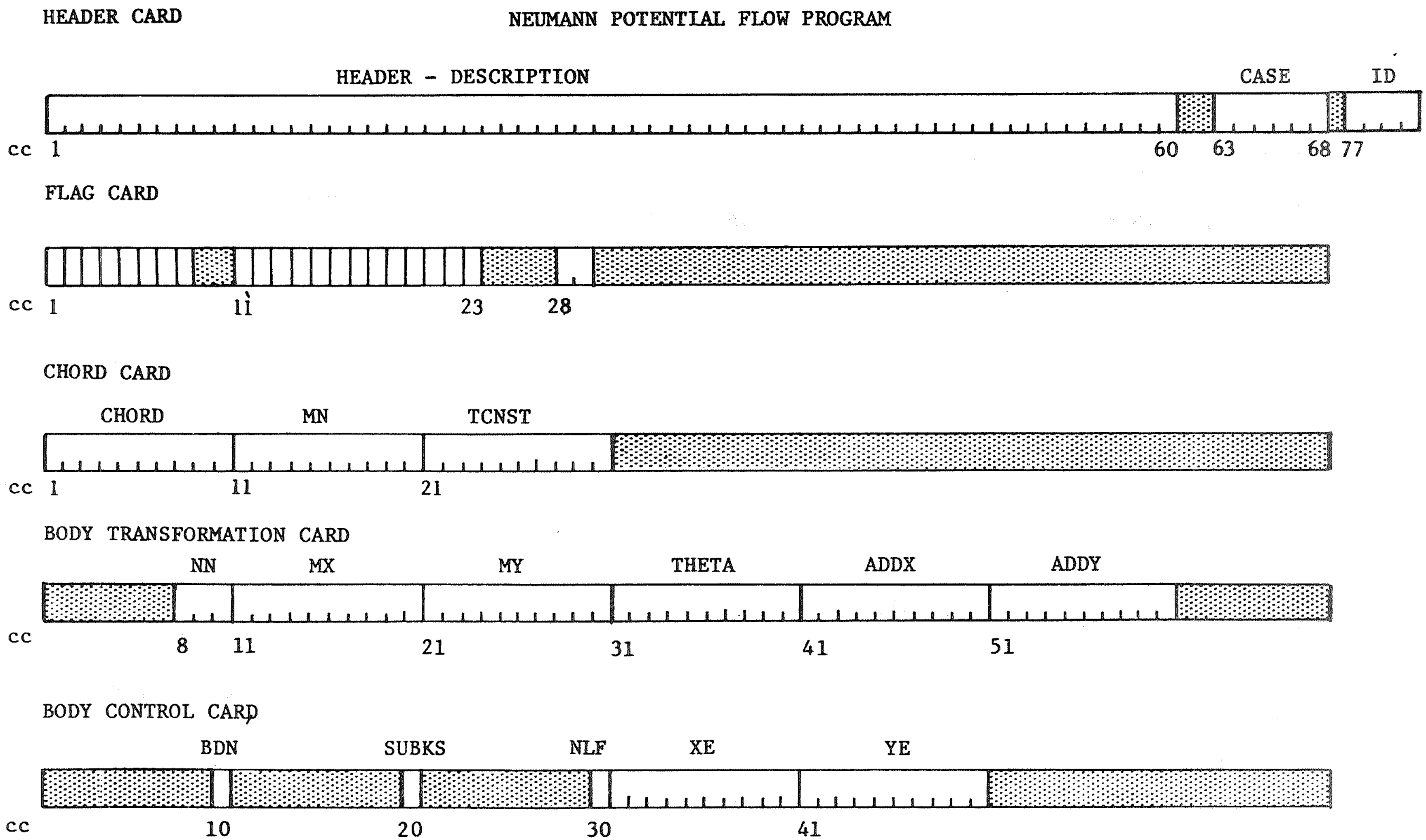
Instructions to Keypunch
Do not punch blank columns

ENGINEER____________________ PHONE__________

DATE________________________ PAGE_____ OF_____

A D A M

NEUMANN POTENTIAL FLOW PROGRAM



Instructions to Keypunch
Do not punch blank columns

ENGINEER ____________________ PHONE __________

DATE ____________________ PAGE ____ OF ____

A D A M

BOUNDARY LAYER PROGRAM

TITLE | CASE

cc 1 | 61

FLAG CONTROL CARD

N

cc 2

TI | RMI | UI | FK | RL | RI

E

cc 1 | 11 | 21 | 31 | 41 | 51

RADIUS CARD

ROMAX | DETA1 | VGP

cc 1 | 11 | 21

ENGINEER ______________ PHONE ______________

DATE ______________ PAGE ____ OF ____

Instructions to Keypunch
Do not punch blank columns

Instructions to Keypunch
Do not punch blank columns

ENGINEER ____________ PHONE ____________

DATE ____________ PAGE ______ OF ______

COORDINATE DATA OR VELOCITY CARDS

	X(I) Y(I) CP(I)	X(I) Y(I) CP(I)	X(I) Y(I) CP(I)	X(I) Y(I) CP(I)	X(I) Y(I) CP(I)	X(I) Y(I) CP(I)
cc	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60

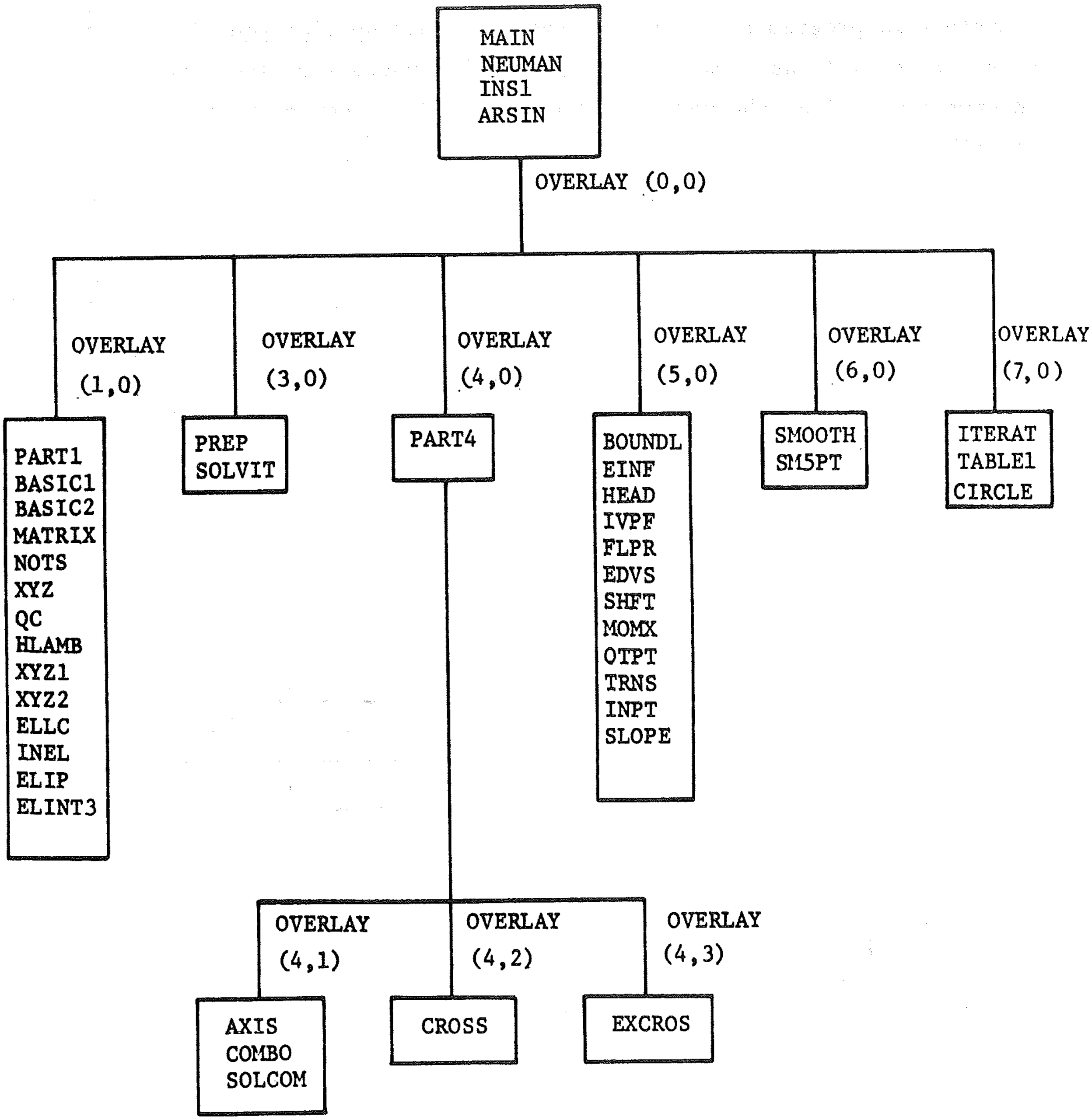
THIS INPUT FORM IS THE SAME FOR GEOMETRY DATA INPUT TO THE SMOOTHING ROUTINE, THE POTENTIAL FLOW PROGRAM, AND THE BOUNDARY LAYER ROUTINE. THIS FORM IS ALSO USED FOR VELOCITY DATA INPUT TO THE BOUNDARY LAYER PROGRAM AND FOR THE NON-UNIFORM VELOCITY DATA WHICH CAN BE INPUT TO THE POTENTIAL FLOW ROUTINE.

APPENDIX B

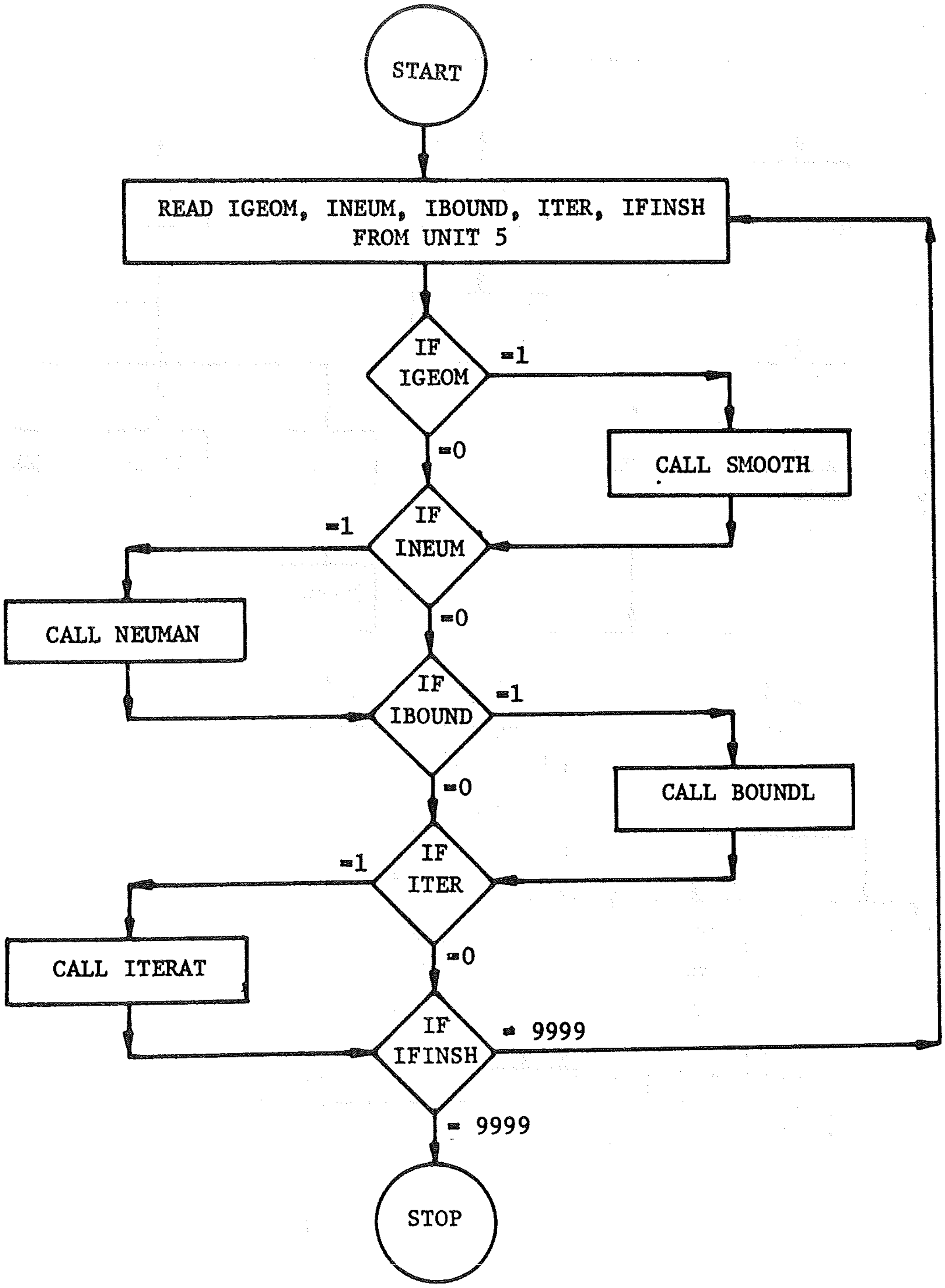
CONTROL INFORMATION FOR ADAM COMPUTER PROGRAM

This part of the report contains the necessary control information to operate this program on a computer system. This section contains the overlay structure as well as flow charts of the main subroutines including input flow information. Also, the various data sets used between main programs are described.

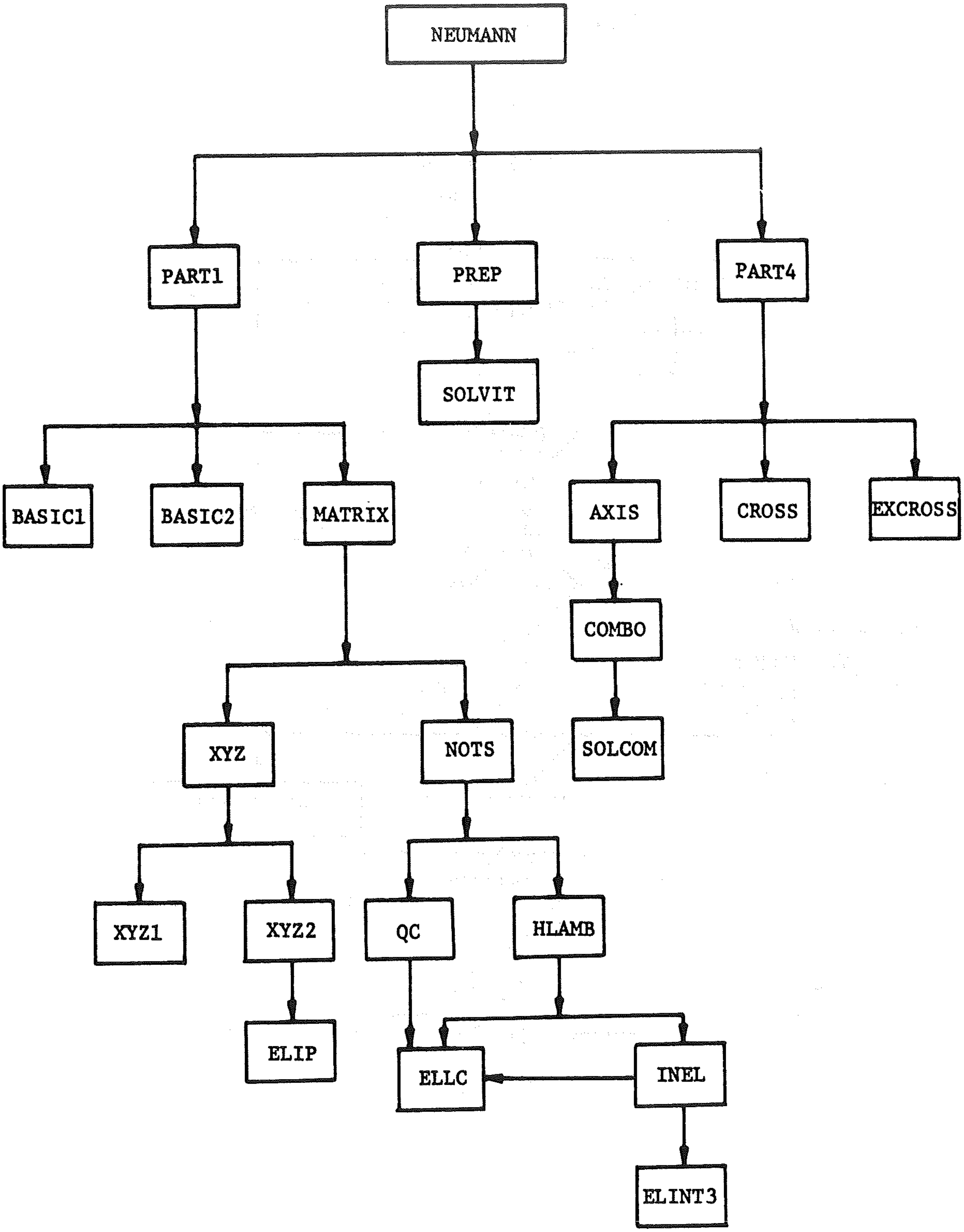
OVERLAY STRUCTURE OF ADAM



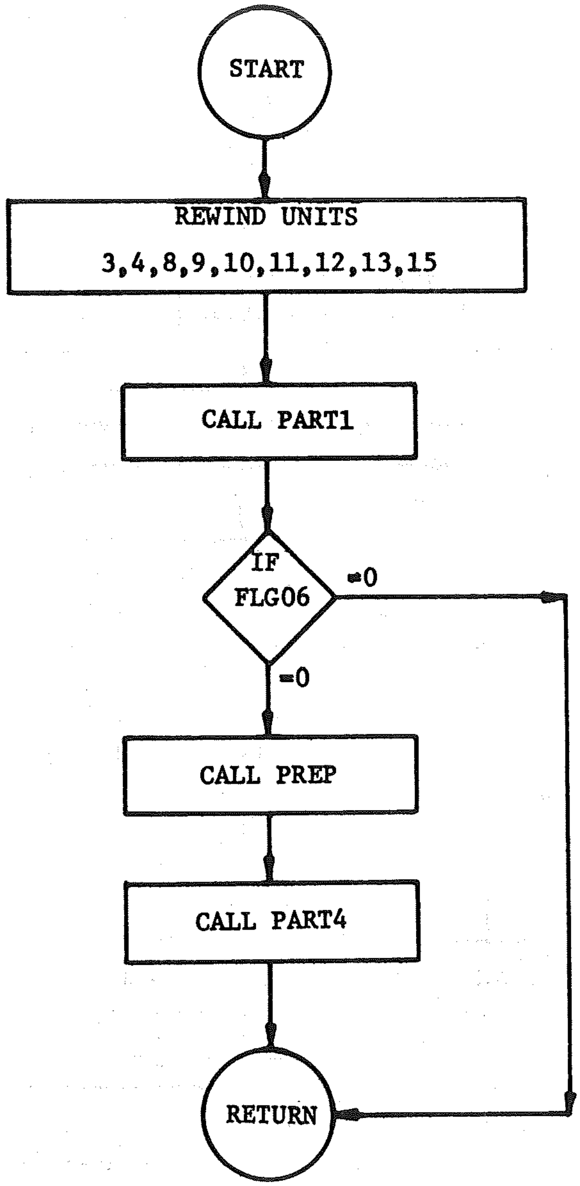
MAIN PROGRAM



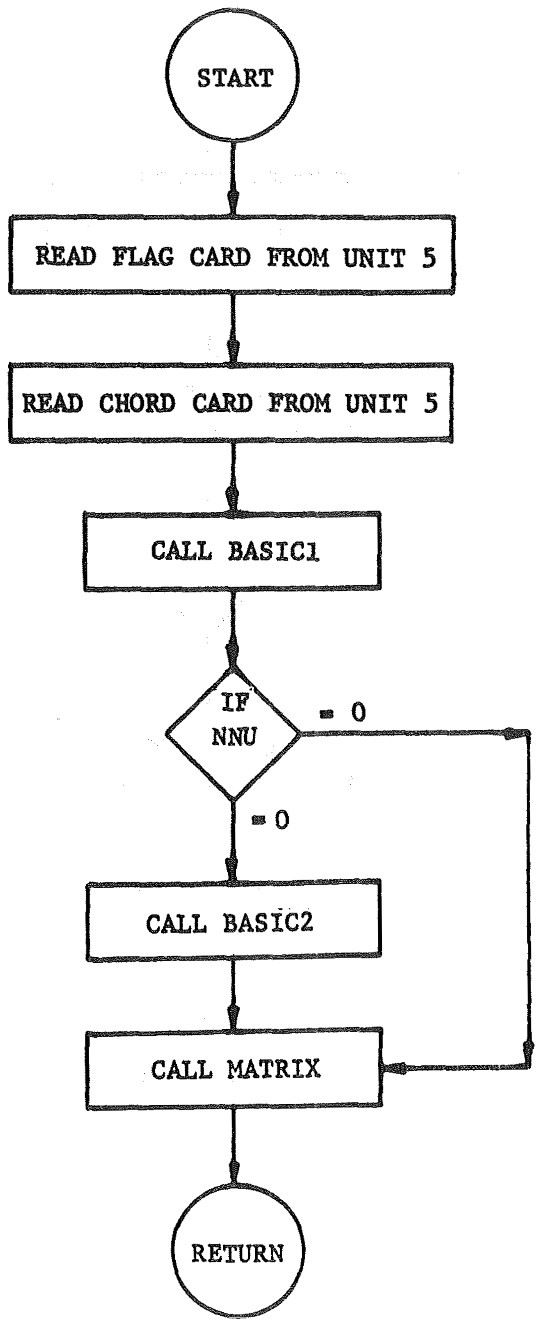
FUNCTIONAL ORGANIZATION OF NEUMANN PROGRAM



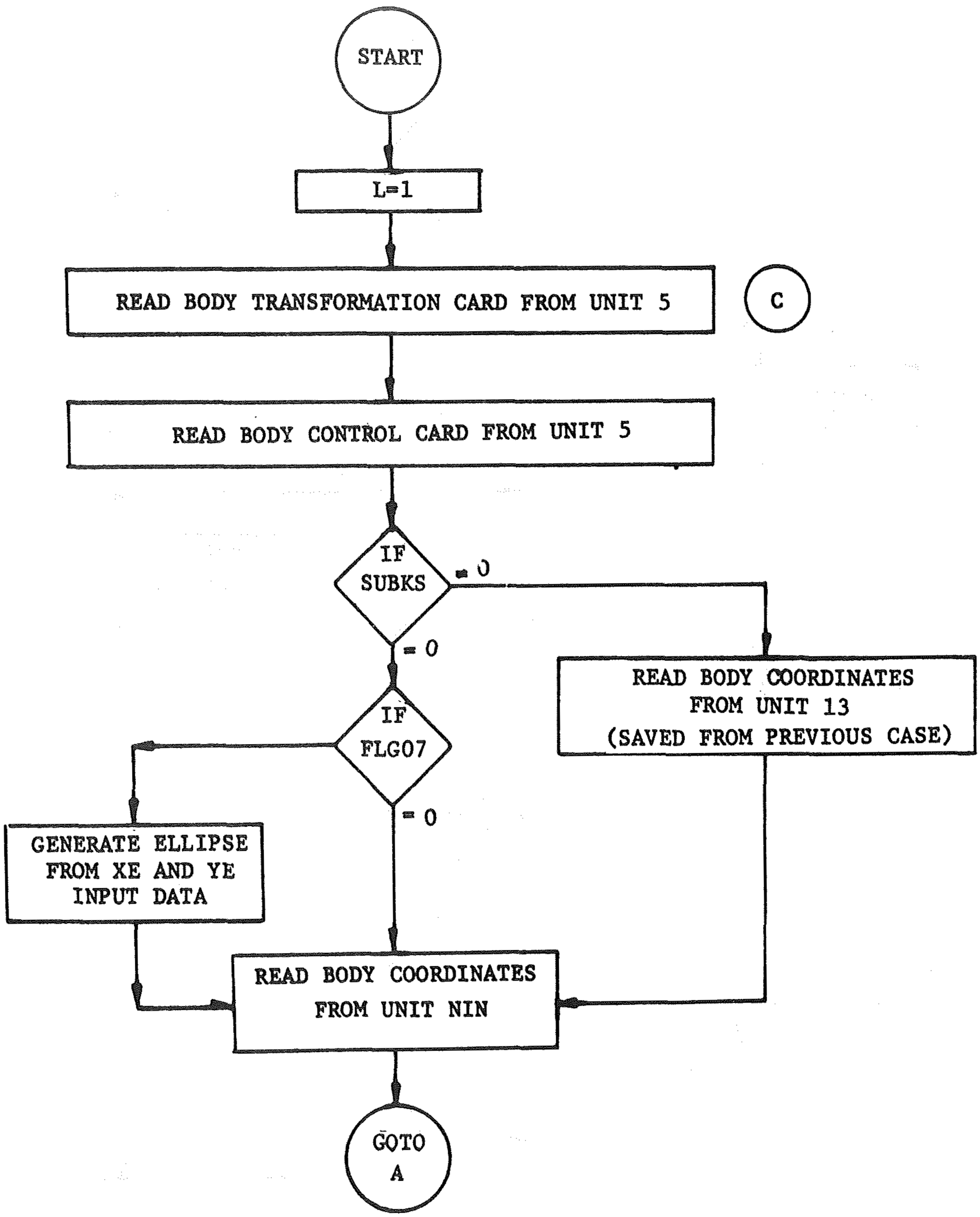
BASIC FLOW CHART FOR SUBROUTINE NEUMANN



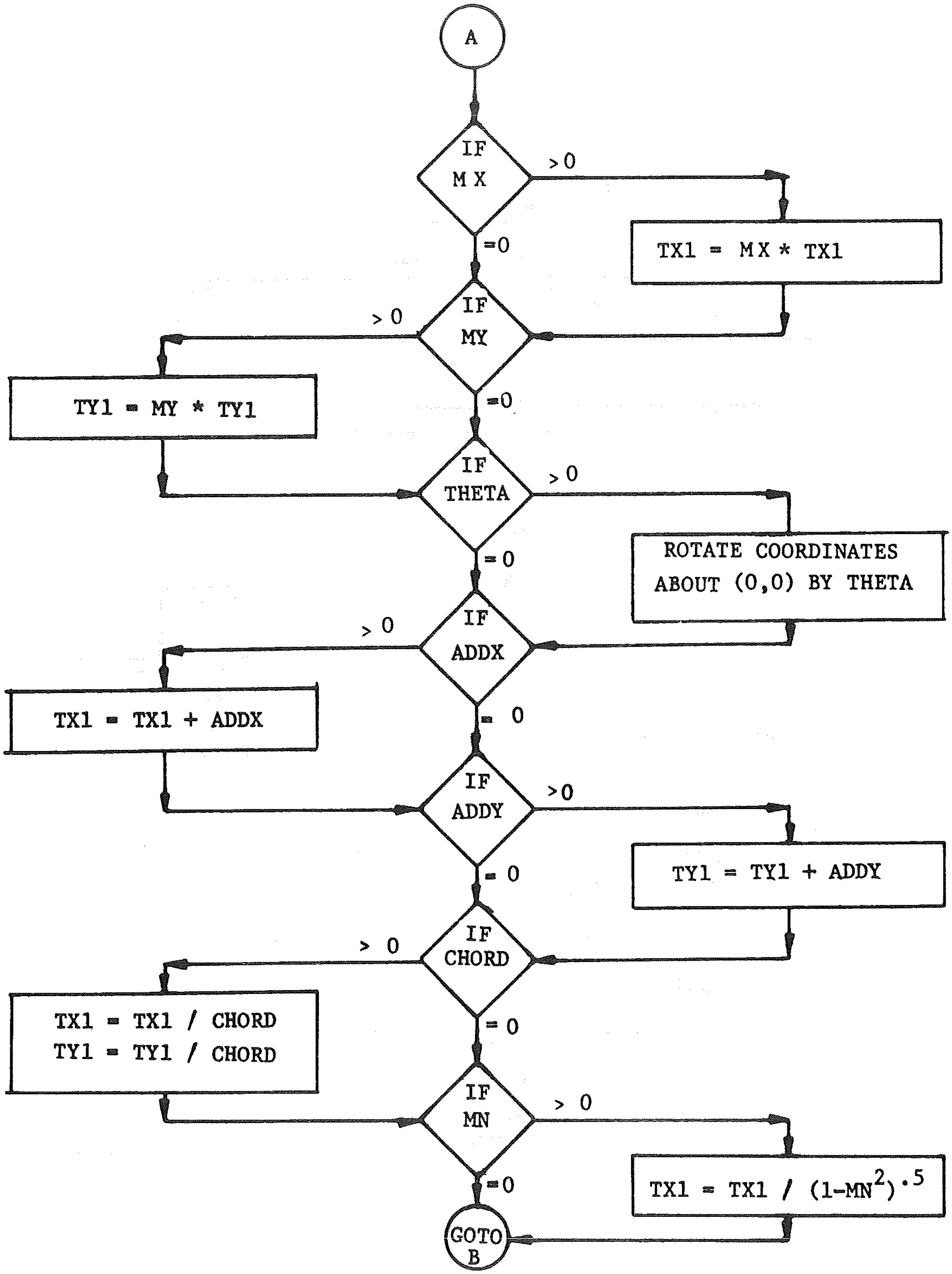
BASIC FLOW CHART FOR SUBROUTINE PART1

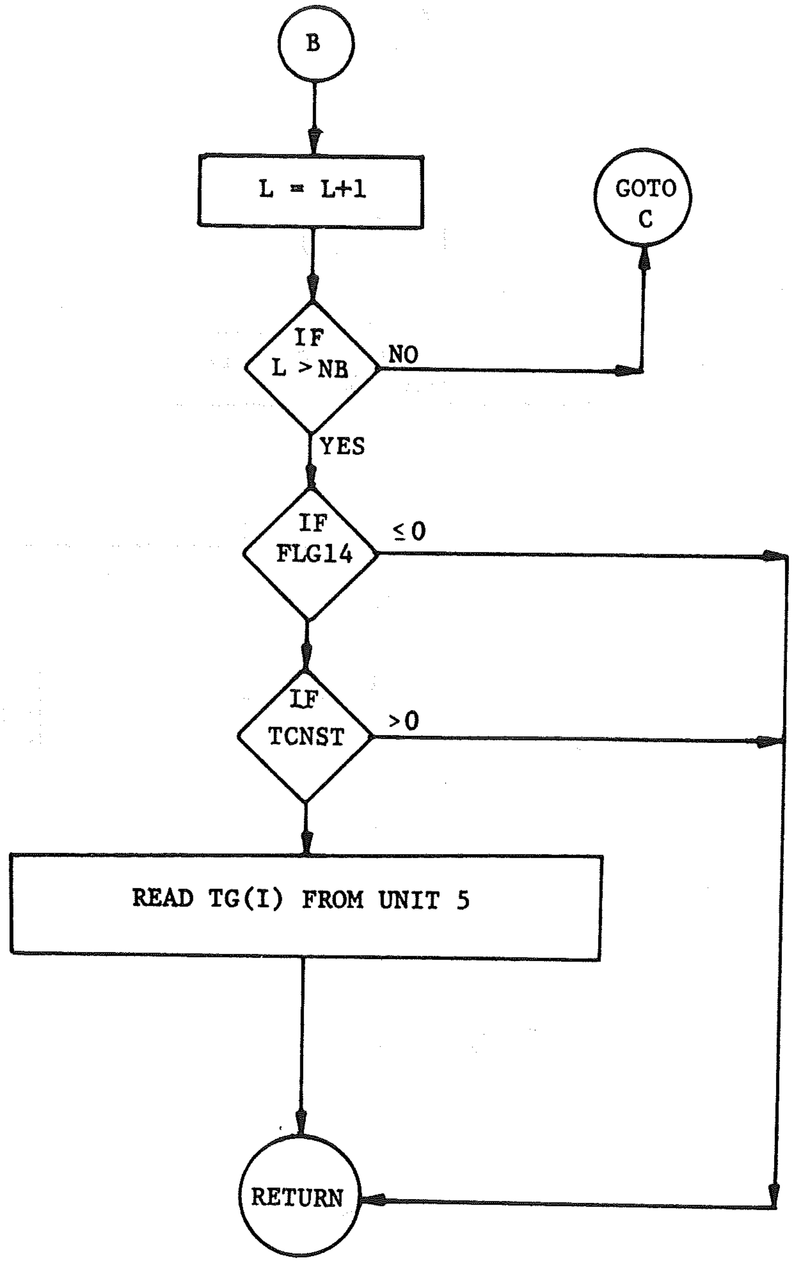


BASIC FLOW CHART FOR SUBROUTINE BASIC1

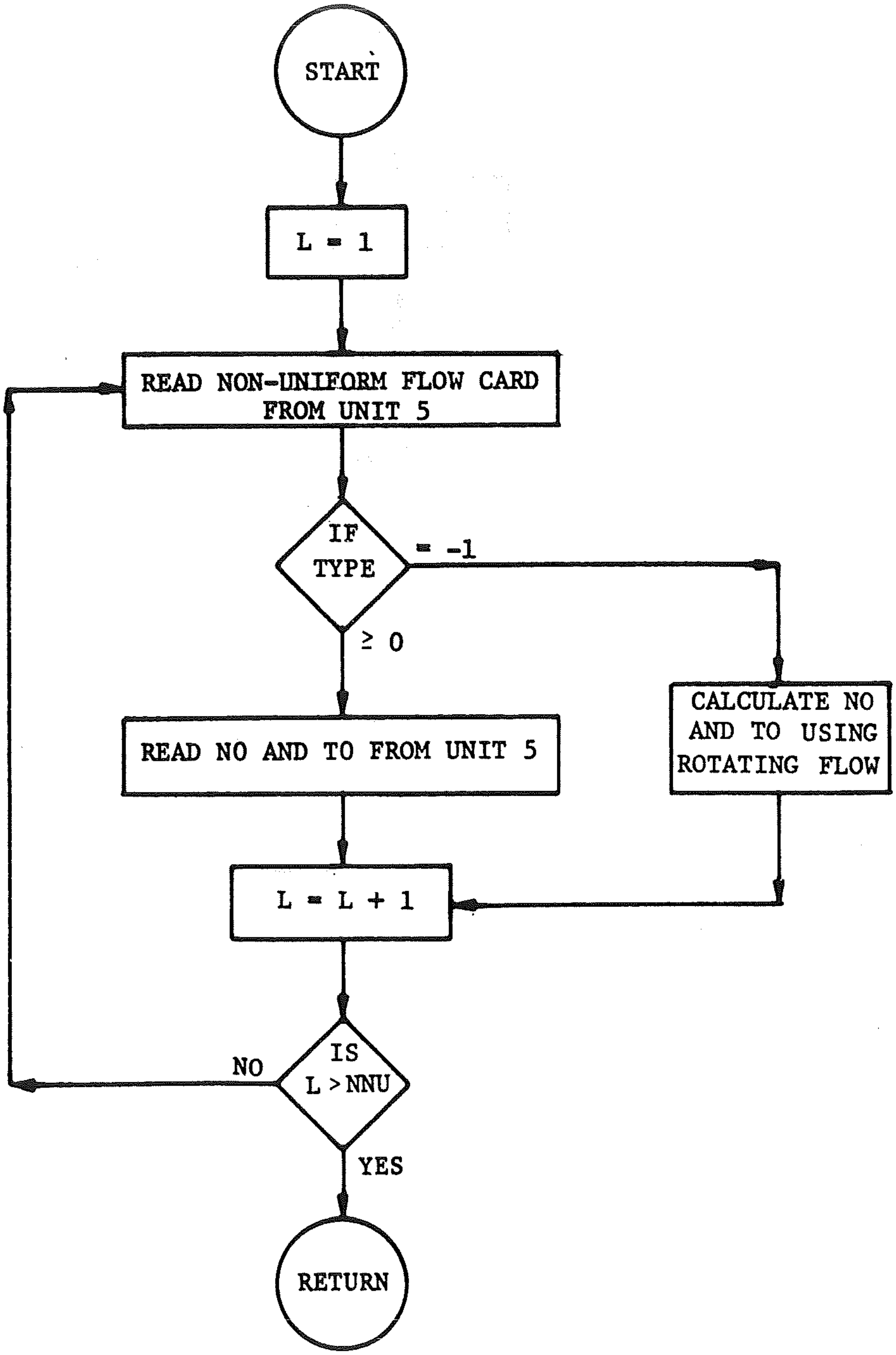


BASIC FLOW CHART FOR SUBROUTINE BASIC1 (CONTINUED)

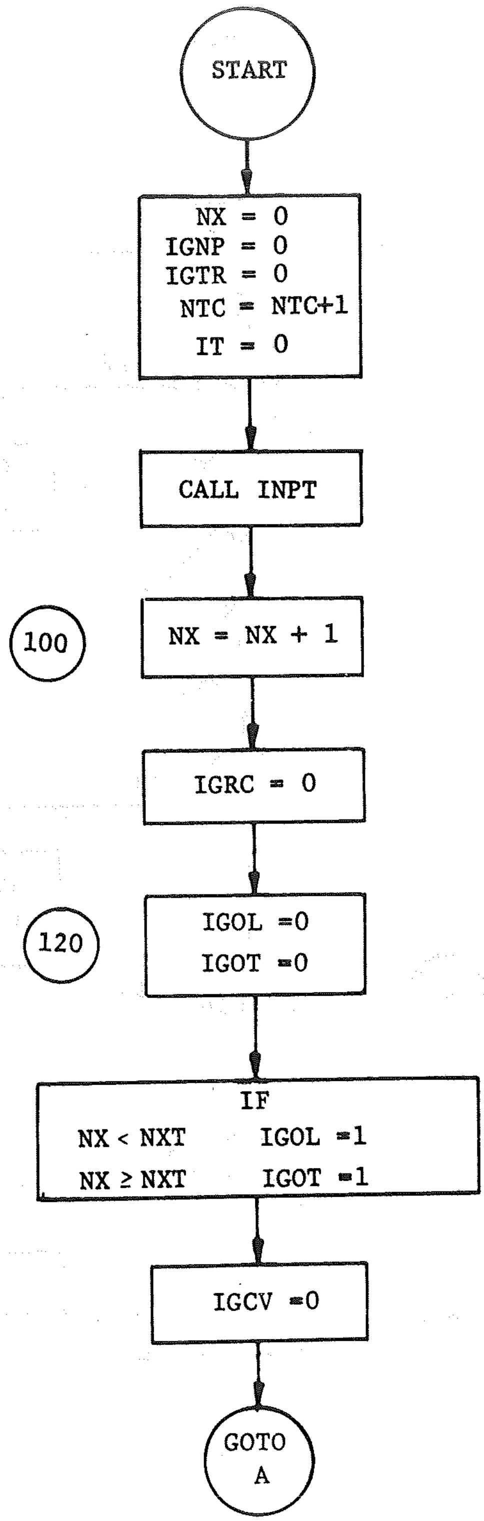


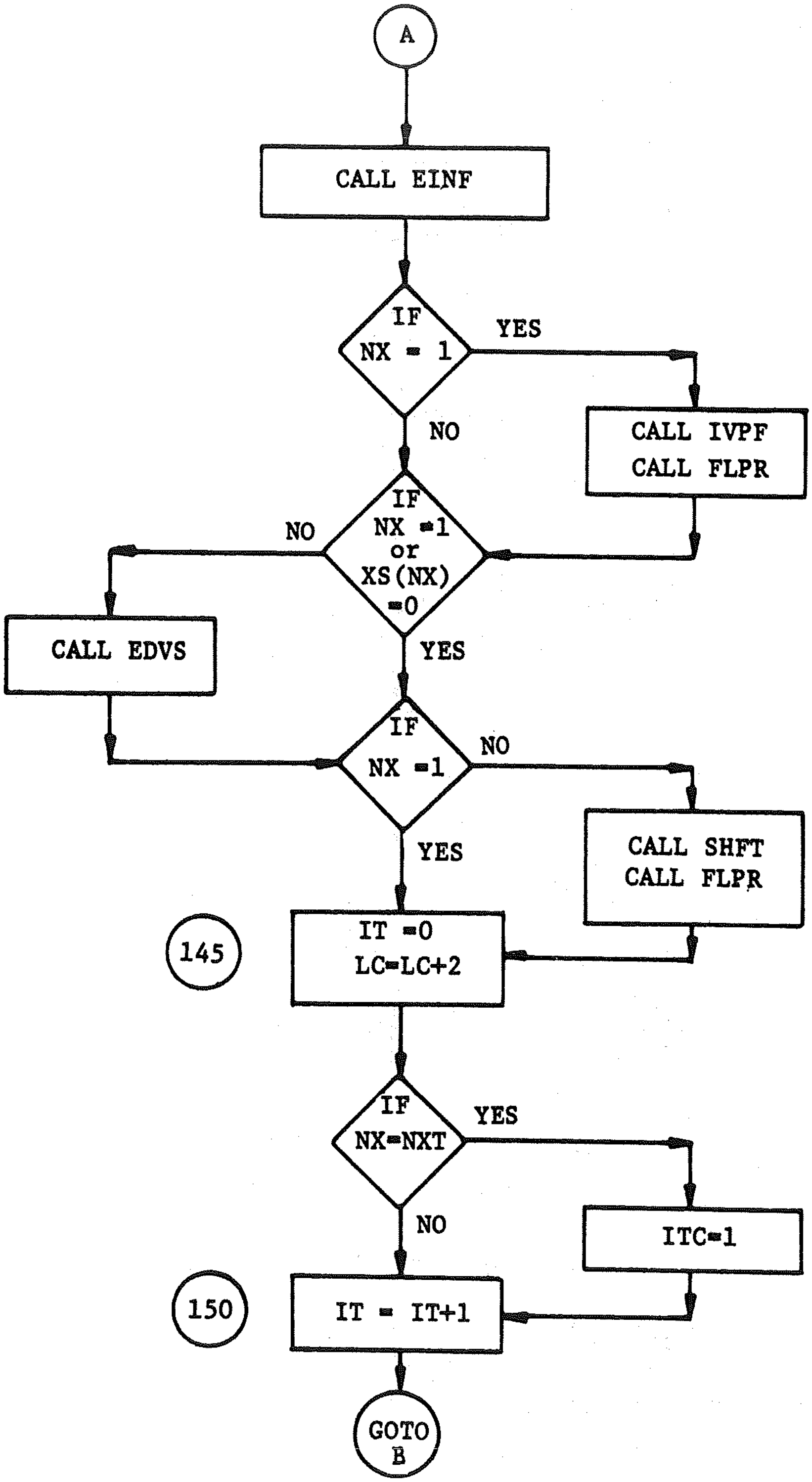

B
L = L+1
GOTO
C
IF
L > NB
NO
YES
IF
FLG14
≤ 0
IF
TCNST
> 0
READ TG(I) FROM UNIT 5
RETURN

BASIC FLOW CHART FOR SUBROUTINE BASIC2

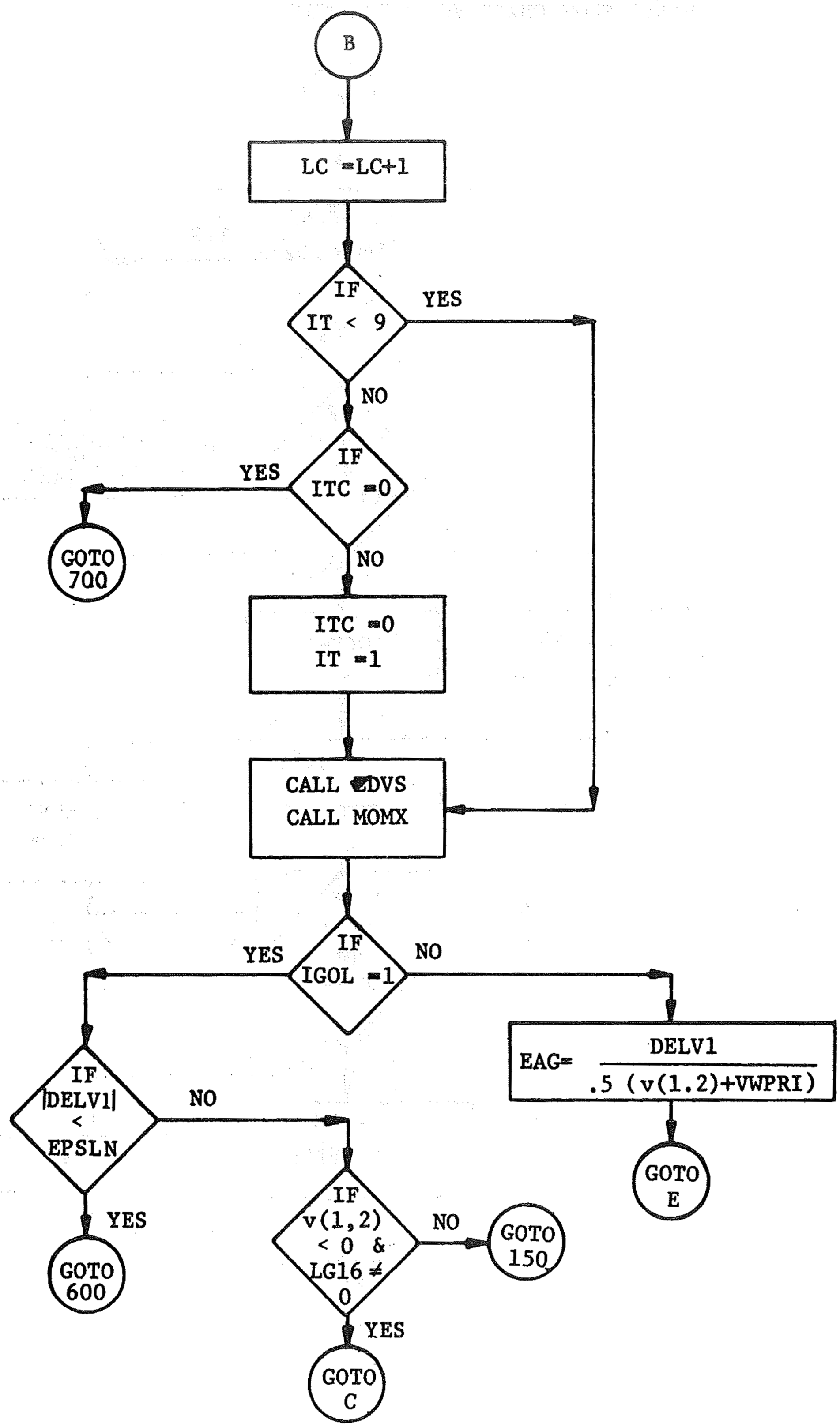


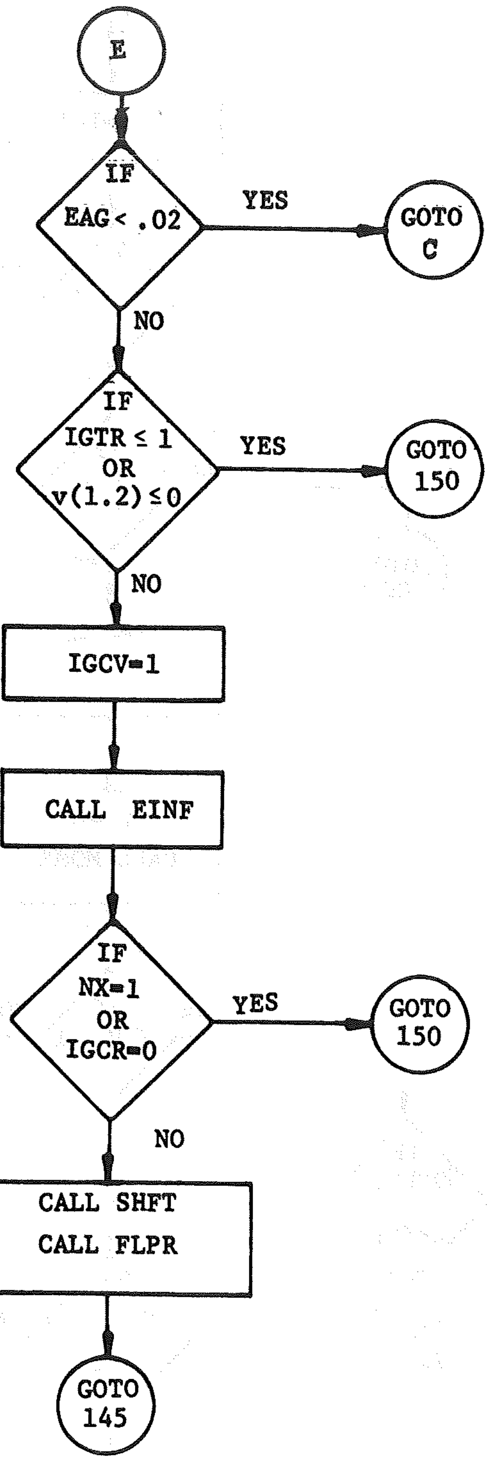
BASIC FLOW CHART FOR SUBROUTINE BOUNDL

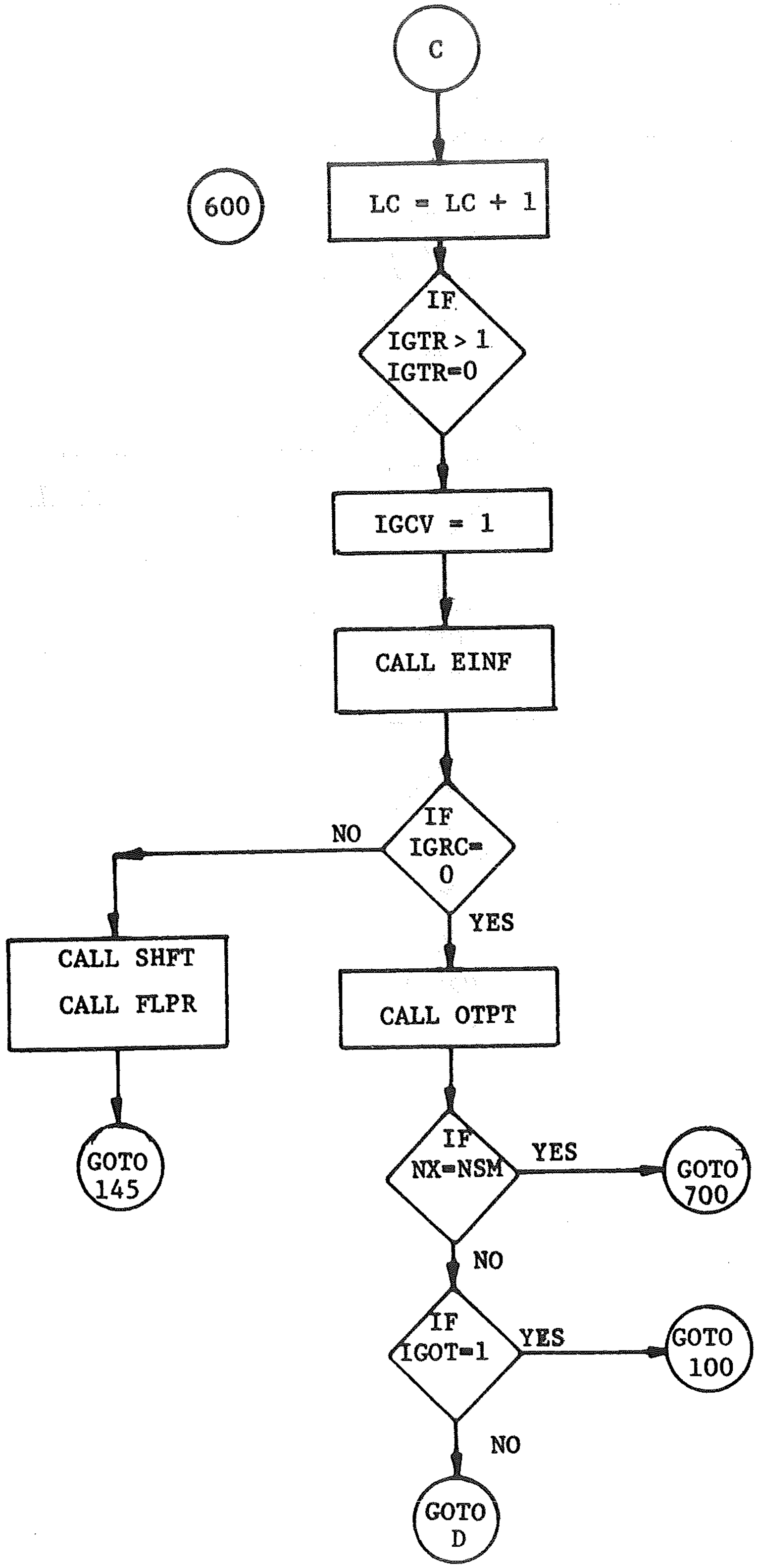



A
CALL EINF
IF NX = 1
YES
NO
CALL IVPF
CALL FLPR
IF NX =1 or XS(NX) =0
NO
YES
CALL EDVS
IF NX =1
NO
YES
CALL SHFT
CALL FLPR
145
IT =0
LC=LC+2
IF NX=NXT
YES
NO
ITC=1
150
IT = IT+1
GOTO B

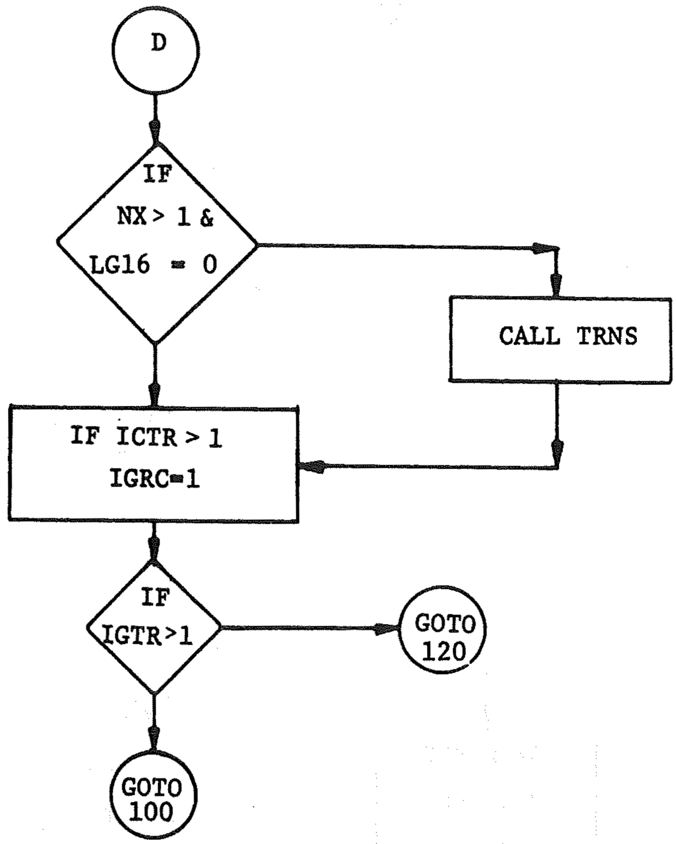
BASIC FLOW CHART FOR SUBROUTINE BOUNDL (CONTINUED)



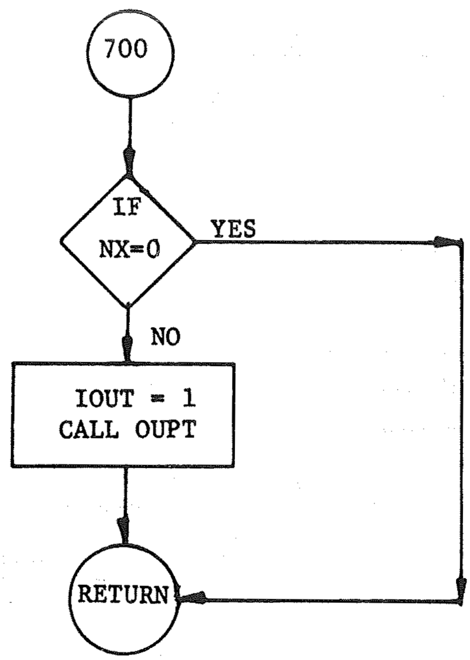

E
IF
EAG < .02
YES
GOTO
C
NO
IF
IGTR ≤ 1
OR
v(1.2) ≤ 0
YES
GOTO
150
NO
IGCV=1
CALL EINF
IF
NX=1
OR
IGCR=0
YES
GOTO
150
NO
CALL SHFT
CALL FLPR
GOTO
145


C
600
LC = LC + 1
IF
IGTR > 1
IGTR=0
IGCV = 1
CALL EINF
IF
IGRC=
0
NO
YES
CALL SHFT
CALL FLPR
GOTO
145
CALL OTPT
IF
NX=NSM
YES
GOTO
700
NO
IF
IGOT=1
YES
GOTO
100
NO
GOTO
D

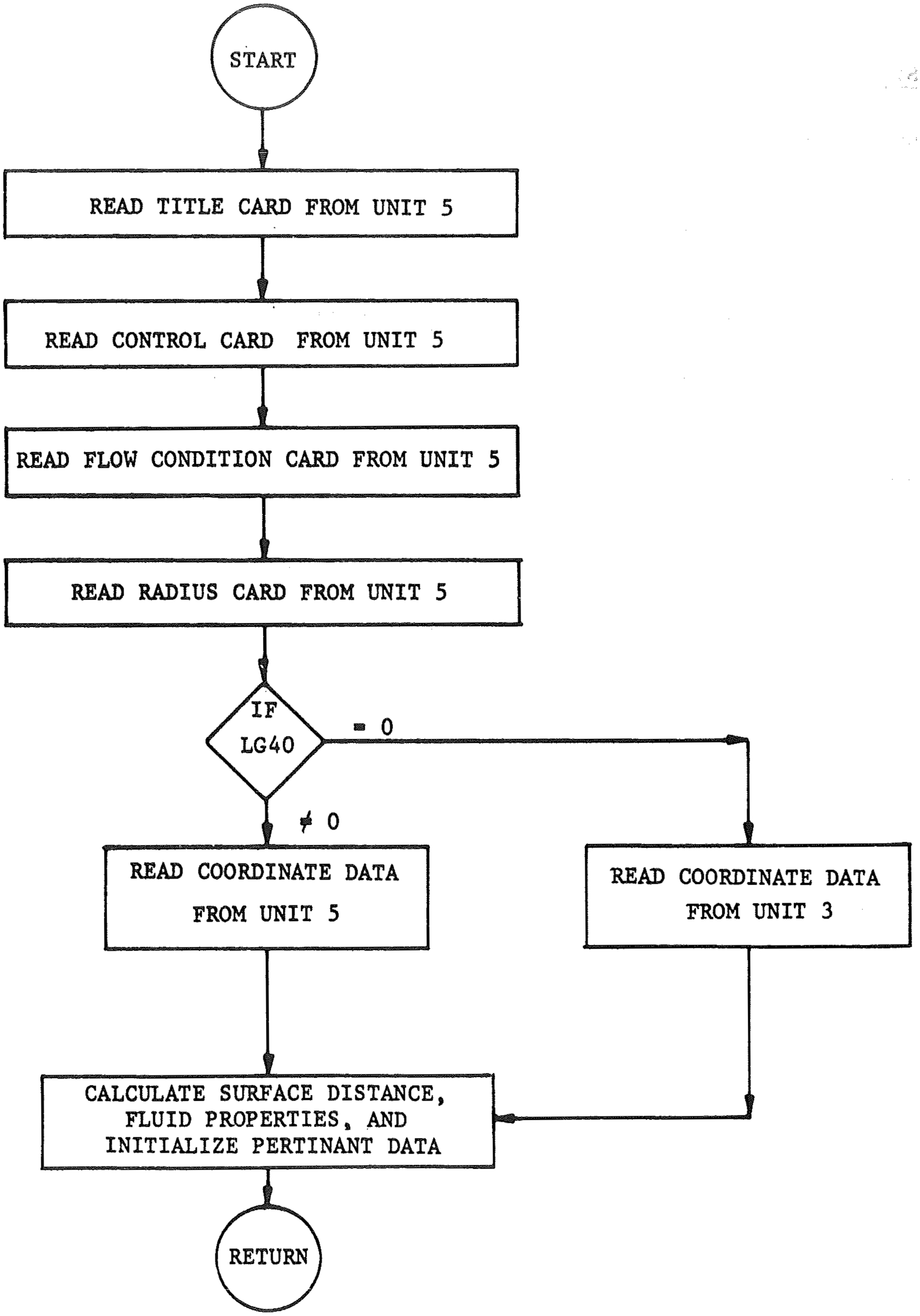
BASIC FLOW CHART FOR SUBROUTINE BOUNDL (CONTINUED)



BASIC FLOW CHART FOR SUBROUTINE BOUNDL (CONTINUED)



BASIC FLOW CHART FOR SUBROUTINE INPT



The following is a description of the output symbols from the various sections of the ADAM computer program:

NEUMANN POTENTIAL FLOW SUBPROGRAM

SYMBOL	DESCRIPTION
ADDED MASS	$\Sigma 2\pi \cdot \text{Phi} \cdot V_n \cdot ds$
AJK	Influence coefficients W_{jk} resolved parallel to the outward normal of the element. Output only if FLG08 = 1.
ADDX	Constant which is added to all X-coordinates of a particular body. Value printed out for each body.
ADDY	Constant which is added to all Y-coordinates of a particular body. Value printed out for each body.
BJK	Influence coefficient W_{jk} resolved parallel to the tangent direction of the element.
BODIES	Number of bodies in system, same as NB input on flag card.
BODY NO.	Number of this particular body. This parameter input on body control card.
CHORD	The reference chord for the system.
COSA	The cosine of DALPHA
CP	The pressure coefficient on a body element.
DALPHA	The change in angle between consecutive elements of a body. (degrees)
DELTAS	The length of a body element.
MACH NO.	Mach number used in Gothert's transformation.
MX	The factor by which all X-coordinates are multiplied for one body. Input on body transformation card.
MY	The factor by which all Y-coordinates are multiplied for one body. Input on body transformation card.

SYMBOL	DESCRIPTION
N	Velocity normal to a surface element, this is a measure of how well the boundary condition of zero normal velocity is satisfied.
NN	The number of geometry data points for a given body. This is input on the body transformation card.
NNU	The number of non-uniform onset flows to be considered.
PHI	Value of potential on each surface element.
PSF NO.	Identification for this case..
SIGMA	Source density on each surface element.
SINA	Sin of DALPHA
SUM(T) DELTA(S)	This is the summation of T multiplied by Deltas up to each element midpoint.
SUMDS	Summation of Deltas, surface distance around the body.
TCNST	Constant value of tangential velocity used in special option.
THETA	The angle through which a body is to be rotated about the origin in a clockwise direction.
TI	The velocity at each midpoint.
VOLUME	The volume of the body being analyzed. (calculated by Neumann)
X	The input X-coordinate defining the body surface, or off-body X-coordinates.
XE	The value of semi-major axis used in ellipse generation option.
Y	The input Y-coordinates defining the body surface, or off-body Y-coordinates.
YE	The value of semi-minor axis used in ellipse generation option.

OUTPUT DATA SYMBOLS

Finite Difference Boundary Layer Subprogram

Output of this routine consists of CASE DATA and STATION DATA inputs as well as the computed STATION DATA. Body geometry data, flags and counters, and reference quantities are printed out under the heading of CASE DATA. Values of parameters at the outer edge of the boundary layer as well as the boundary condition inputs are printed out under the heading of STATION DATA. These are followed by iteration results, velocity profiles for each x-station (if FLG32 = 0), and a summary of the computed boundary-layer parameters as functions of streamwise or x-distance.

Error messages generated by the program are printed out at the end of the STATION DATA printout if they are generated by input errors. Other error messages are issued at different locations in the profile printout if errors are detected during the computations.

SYMBOL	DESCRIPTION
ALPH1	Local body slope dy/dx.
ALPH2	Not used in this program.
BETA	$\beta = (2\xi/u_e)(du_e/d\xi)$
C	CHORD
CDBASE	Base drag coefficient.
CF	$c_f = \tau_w/(1/2\ u_e^2)$, value of local skin friction coefficient.
CFA	Total integrated skin friction to each point.
C_P	Pressure coefficient
DELS	Boundary layer displacement thickness.
DELVW	Delta V(1,2) used in iteration for V(1,2).
EPS	ε^+, eddy viscosity parameter for outer region.
EPS1	ε_1, eddy viscosity parameter for inner region.
ETA	η, non-dimensionalized boundary layer thickness to each point in the boundary layer.

SYMBOL	DESCRIPTION
ETAE	η_∞ value of η which corresponds to δ.
ETAINF	Non-dimensional boundary layer thickness used as maximum. value in forming numerical solution grid.
F,FP,FPP	f,f',f", respectively.
FPPW	f" at the wall.
FPW	$f' = U/U_e$ at the wall.
FW	f_w, this is the transformed stream function at the wall. $$f_w = -\frac{1}{(2\xi)^{1/2}} \int_0^\xi \frac{V_w}{\mu_e u_e} d\xi$$
GW	Not used in this method.
GPW	Not used in this method.
H	Boundary layer form factor, $H = \delta^*/\theta$
HE	Enthalpy
H1	Initial step size, same as DETA1 in input.
IMAX	Number of points taken through the boundary layer.
K	Initial step size of the variable grid system.
KK	Variable grid parameter chosen internally.
ME	Local Mach number.
MUE	Local dynamic viscosity, μ_e, at edge of boundary layer.
MREF	Free stream Mach number.
MUREF	Free stream dynamic viscosity, μ_∞.
PE	Pressure at edge of boundary layer, P_e.
PRO	Laminar Prandtl number.
QW	Not used in this program.
REY	Reynolds number based on reference conditions (see input)

SYMBOL	DESCRIPTION
RHOREF	Freestream reference density.
R_o/C	R_o/L axisymmetric radius.
RR	Not used by this program.
RTHETA	Momentum thickness Reynolds number, R_θ.
R_x	Reynolds number based on local conditions. $$R_x = \frac{u_e x}{\nu}$$
S	Surface distance.
S/C	Nondimensionalized surface distance.
SHORTP	Flag which tells program to print velocity profiles. Same as FLG32 in input.
SQUIG	Transformed x-coordinate, ξ $$\xi = \int_0^x \rho_e \mu_e u_e \left(\frac{r_o}{L}\right)^{2k} dx$$
ST	Not used in this program.
SWEEP	Not used in this program.
TE	Temperature through boundary layer. Not needed for this program.
THETA	Momentum thickness, θ.
TREF	Reference temperature, T_∞.
TRFLAG	Flag which determines transition (input).
TRINT	Flag which determines instantaneous transition or use of transitional region option (input).
TW	Temperature at the wall. Not used in this program.
TVC	Transverse curvature flag (input).
UE	Velocity at edge of boundary layer.
UPLUS	Non-dimensionlized velocity in the boundary layer.

SYMBOL	DESCRIPTION
X	X-coordinate
X/C	Non-dimensionalized x-coordinate
XI	Transformed x-coordinate - same as SQUIG
Y	Y-coordinate
Y/C	Non-dimensionalized y-coordinate
YPLUS	Non-dimensionalized y-coordinate in boundary layer.
VREF	Reference velocity (input)

Iteration Subprogram

XNEW and YNEW These are the coordinates of the equivalent viscous body. The original coordinates modified by the addition of the boundary layer displacement thickness δ^*.

DESCRIPTION OF STORAGE UNITS

The following is a description of all disk storage units used in ADAM:

TAPE	DESCRIPTION
TAPE1	This unit used in subroutine SOLVIT as a scratch unit and also used to transfer the "viscous" coordinates from subroutine iterat to subroutine smooth or subroutine BASIC1.
TAPE2	This unit used in subroutine SOLVIT as a scratch unit and also used to transfer the boundary layer displacement thickness's from subroutine OTPT to subroutine ITERAT.
TAPE3	This unit used to store source densities in subroutine SOLVIT and used to transfer body geometry and pressures from subroutine AXIS to subroutine INPT.
TAPE4	sin α, cos α, TCNST, TG(I), cos R^2, 2|(sin α) (cos α)|, N_o, T_o, V_N, T_T, A(J), B(J), etc. Used exclusively in Neumann subprogram to store and transfer data.
TAPE5	This tape used for card input.
TAPE6	This tape used for printed output.
TAPE8	This tape used to store extra cross flow matrices, EC , ECY, ECZ, in subroutine MATRIX.
TAPE9	This tape used to store axisymmetric flow matrices AS, AY, AZ, in subroutine MATRIX.
TAPE10	This tape used to store cross flow matrices CX, CY, CZ in subroutine matrix and also used to transfer smoothed

TAPE	DESCRIPTION
TAPE10 (Continued)	coordinate data from subroutine smooth to subroutine BASIC1.
TAPE11	This tape used as a scratch unit in subroutine SOLVIT.
TAPE12	This tape used to store transformed parameters X1, Y1, X2, Y2, and ΔS_i.
TAPE13	This tape used to store untransformed coordinates (TX1, TY1) for use in SUBCASE option.
TAPE15	This tape used to store transformed coordinates, (X1, Y1) for use in subroutine ITERAT.

APPENDIX C

PROGRAM LISTINGS

This part of the report contains the source card listings for the axisymmetric design and analysis method (ADAM) computer program. This program may be run either on a CDC or an IBM computer. The listing as presented here is for the CDC version of the program. This program has been run on the CDC 6600 computer. The program is written in FORTRAN for the CDC run compiler and has been run under the scope 3.1 and 3.4 operating systems. In this listing all cards that are peculiar to the CDC version of FORTRAN are identified by a C in card column 80. All cards that are peculiar to the IBM FORTRAN IV compiler are identified by an I in card column 80 and a C in card column 1. In other words, the code for both CDC and IBM machines is in the deck but the IBM cards are made inactive by converting them to comment statements (C in card column 1). Since all of the machine dependent cards are identified by an I or C in card column 80 it is a simple matter to convert the deck from one version to the other with a small conversion program. When converting from CDC to IBM code this conversion program reads and copies each card to a storage unit. If a card has a C in card oolumn 80, then a C is written into card column 1 to make the CDC peculiar card inactive. If a card has an I in card bolumn 80, then the C is removed from card column 1 and the card image written to the storage unit as an active FORTRAN statement. The conversion from IBM back to CDC is made in a similar manner. The conversion program to convert the deck from CDC to IBM FORTRAN is listed below (for use on an IBM machine):

```
      DIMENSION DATA(22)
      DATA CB,CC,CI/1H, 1HC,1HI/
      REWIND 19
      DO 100 I=1,20000
        READ (5,20,END=300) DATA
 20       FORMAT (1A1,19A4,1A2,1A1)
      IF (DATA(22) .EQ. CI) DATA(1) = CB
      IF (DATA(22) .EQ. CC) DATA(1) = CC
      WRITE (19,20) DATA
100   CONTINUE
300   STOP
      END
```

This program places the new deck with IBM cards made active, and CDC cards inactive, on to unit 19. The references to unit 19 above can be changed to unit 7 to punch the deck out.

```
      OVERLAY(AXSY,0,0)                                                 MAIN  001C
      PROGRAM MAIN(INPUT=201,OUTPUT,          TAPE5=INPUT,TAPE6=OUTPUT, MAIN  002C
     1              TAPE1=201,TAPE2=201,TAPE3=201,TAPE4=201,TAPE8=201,  MAIN  003C
     2 TAPE9=201,TAPE10=201,TAPE11=201,TAPE12=201,TAPE13=201,TAPE15=201) MAIN  004C
C     B8AC MAIN PROGRAM                                                 MAIN  005
C                                                                       MAIN  006
C     THIS IS THE AXISYMMETRIC DESIGN AND ANALYSIS METHOD ,ADAM,        MAIN  007
C     COMPUTER PROGRAM.  THIS COMPUTER PROGRAM WILL CALCULATE THE       MAIN  008
C     AERODYNAMIC FORCES ACTING ON AN AXISYMMETRIC BODY OPERATING       MAIN  009
C     IN A VISCOUS INCOMPRESSIBLE FLOW FIELD                            MAIN  010
C                                                                       MAIN  011
    1 FORMAT(5I4)                                                       MAIN  012
C                                                                       MAIN  013
    2 READ(5,1) IGEOM,INEUM,IBOUND,ITER,IFINSH                          MAIN  014
C                                                                       MAIN  015
C     THESE FOUR FLAGS DETERMINE WHICH ROUTINES WILL BE USED            MAIN  016
C                                                                       MAIN  017
C     IGEOM CONTROLS THE GEOMETRY DEFINITION                            MAIN  018
C     IF  IGEOM = 0  NO SMOOTHING IS USED                               MAIN  019
C     IF  IGEOM = 1     SMOOTHING IS USED                               MAIN  020
C                                                                       MAIN  021
C     INEUM INDICATES WHETHER OR NOT A POTENTIAL FLOW SOLUTION WILL     MAIN  022
C     BE GENERATED                                                      MAIN  023
C     IF  INEUM = 0  NO POTENTIAL FLOW SOLUTION IS USED                 MAIN  024
C     IF  INEUM = 1  A  POTENTIAL FLOW SOLUTION IS USED                 MAIN  025
C                                                                       MAIN  026
C     IBOUND INDICATES WHETHER OR NOT A BOUNDARY LAYER SOLUTION IS      MAIN  027
C     DESIRED                                                           MAIN  028
C     IF IBOUND = 0  NO BOUNDARY LAYER SOLUTION IS NEEDED               MAIN  029
C     IF IBOUND = 1  A BOUNDARY LAYER SOLUTION IS NEEDED                MAIN  030
C                                                                       MAIN  031
C     ITER CONTROLS THE ITERATION CYCLE                                 MAIN  032
C     IF ITER = 0  NO ITERATION IS NEEDED                               MAIN  033
C     IF ITER = 1  AN ITERATION IS NEEDED                               MAIN  034
C                                                                       MAIN  035
```

```
      IGEOM = IGEOM + 1                                    MAIN  036
      INFUM = INFUM + 1                                    MAIN  037
      IBOUND = IBOUND + 1                                  MAIN  038
      ITER = ITER + 1                                      MAIN  039
C                                                          MAIN  040
      GO TO (30,20), IGEOM                                 MAIN  041
C                                                          MAIN  042
C  20 CALL SMOOTH                                          MAIN  043I
   20 CALL OVERLAY(4HAXSY,6,0,6HRECALL)                    MAIN  044C
C                                                          MAIN  045
   30 GO TO (60,50),INEUM                                  MAIN  046
C                                                          MAIN  047
   50 CALL NEUMAN                                          MAIN  048
C                                                          MAIN  049
   60 GO TO (90,80), IBOUND                                MAIN  050
C                                                          MAIN  051
C  80 CALL BOUNDL                                          MAIN  052I
   80 CALL OVERLAY(4HAXSY,5,0,6HRECALL)                    MAIN  053C
C                                                          MAIN  054
   90 GO TO (120,110), ITER                                MAIN  055
C                                                          MAIN  056
C 110 CALL ITERAT                                          MAIN  057I
  110 CALL OVERLAY(4HAXSY,7,0,6HRECALL)                    MAIN  058C
C                                                          MAIN  059
  120 IF (IFINSH .NE. 9999) GO TO 2                        MAIN  060
C                                                          MAIN  061
C     STOP                                                 MAIN  062I
  200 CONTINUE                                             MAIN  063C
      END                                                  MAIN  064
```

```
      SUBROUTINE NEUMAN                                                  NEUM 001
C*              ** DOUGLAS NEUMANN POTENTIAL FLOW PROGRAM **             NEUM 002
C                                                                        NEUM 003
C                * CALCULATION OF POTENTIAL FLOW ABOUT BODIES OF         NEUM 004
C                  REVOLUTION HAVING FLOWS PARALLEL AND PERPENDICULAR    NEUM 005
C                  TO THE AXIS OF REVOLUTION.                            NEUM 006
C                                                                        NEUM 007
C                * MAIN PROGRAM                                          NEUM 008
C                                                                        NEUM 009
      COMMON /IPSF/ PSF                                                  NEUM 010
       COMMON / NBSAVE / NBOLD, NIN                                      NEUM 011
      COMMON       HEDR(10)  ,CASE      ,NB        ,NNU                  NEUM 012
     1            ,FLG03     ,FLG04     ,FLG05     ,FLG06     ,FLG07     NEUM 013
     2            ,FLG08     ,FLG09     ,FLG10     ,FLG11     ,FLG12     NEUM 014
     3            ,FLG13     ,FLG14     ,FLG15     ,FLG16     ,FLG17     NEUM 015
     4            ,FLG18     ,FLG19     ,FLG20     ,FLG21     ,FLG22     NEUM 016
     5            ,FLG23     ,FLG24     ,FLG25     ,FLG26     ,FLG27     NEUM 017
      COMMON   NT,        ND(11),    MN,        NUNA(5),   TYPEA(5),     NEUM 018
     1         NER1,      NER2,      NMA,       NSIGA,     NSIGC,        NEUM 019
     2         NUNC(5),   TYPEC(5),  NLF(11),   IFC,       NSIGEC,       NEUM 020
     3         TYPFEC(5),NUNEC(5)                                        NEUM 021
      COMMON/ITERF/ ITER                                                 NEUM 022
C     DOUBLE PRECISION  HEDR, CASE                                       NEUM 023I
      INTEGER      FLG03     ,FLG04     ,FLG05     ,FLG06     ,FLG07     NEUM 024
     1            ,FLG08     ,FLG09     ,FLG10     ,FLG11     ,FLG12     NEUM 025
     2            ,FLG13     ,FLG14     ,FLG15     ,FLG16     ,FLG17     NEUM 026
     3            ,FLG18     ,FLG19     ,FLG20     ,FLG21     ,FLG22     NEUM 027
     4            ,FLG23     ,FLG24     ,FLG25     ,FLG26     ,FLG27     NEUM 028
      REAL         MN                                                    NEUM 029
       NBOLD = 0                                                         NEUM 030
C                                                                        NEUM 031
      REWIND 3                                                           NEUM 032
      REWIND 4                                                           NEUM 033
      REWIND 8                                                           NEUM 034
      REWIND 9                                                           NEUM 035
```

```
      REWIND 10                                   NEUM   036
      REWIND 11                                   NEUM   037
   10 REWIND 12                                   NEUM   038
      REWIND 13                                   NEUM   039
      REWIND 15                                   NEUM   040
C     CALL PART1                                  NEUM   041I
      CALL OVERLAY (4HAXSY,1,0,6HRECALL )         NEUM   042C
      IF(FLG06 .NE. 0) GO TO 50                   NEUM   043
C  30 CALL PREP                                   NEUM   044I
   30 CALL OVERLAY (4HAXSY,3,0,6HRECALL )         NEUM   045C
C  40 CALL PART4                                  NEUM   046I
   40 CALL OVERLAY (4HAXSY,4,0,6HRECALL )         NEUM   047C
   50 RETURN                                      NEUM   048
      END                                         NEUM   049
```

```
      SUBROUTINE INS1 ( ARG, TABLE, OTPT  , NLQ, NFR )
C     INS1 - SINGLE LINEAR OR QUADRATIC INTERPOLATION
C            ONE OR TWO FUNCTIONS OF ONE VARIABLE
C
C     THIS SUBROUTINE WILL INTERPOLATE FOR EITHER
C         1)    F(X) FROM A TABLE OF X VRS F(X), OR
C         2)    F(X) AND G(X) FROM A TABLE OF X VRS F(X),G(X).
C         THE TABLE MAY HAVE UNEQUAL SPACING IN X.  EITHER LINEAR
C         OR QUADRATIC LAGRANGE INTERPOLATION MAY BE USED.
C
C
C         ARG     = INPUT  = X ARGUMENT
C
C         TABLE   = INPUT  = IS A LINEAR ARRAY.  THE FIRST WORD IS AN
C                            INTEGER CODE (EITHER INTEGER FORM OR REAL*4
C                            FORM).  IF THIS CODE IS POSITIVE, THE CODE
C                            SPECIFIES THE NUMBER OF X,F(X) PAIRS
C                            IMMEDIATELY FOLLOWING THE CODE IN SUCCESSIVE
C                            WORDS.  IF THE CODE IS NEGATIVE,
C                            ABSOLUTE VALUE OF THE CODE SPECIFIES THE
C                            NUMBER OF X,F(X),G(X) TRIPLES IMMEDIATELY
C                            FOLLOWING THE CODE IN SUCCESSIVE WORDS.
C                            THE X-VALUES MUST BE IN ASCENDING ORDER.
C                            EXCEPT FOR THE CODE, THE INPUT TABLE VALUES
C                            MUST BE IN REAL*4 FORM
C
C         OTPT    = OTPT   = INTERPOLATED VALUE OF F(X) IF TABLE(1) IS
C                                    POSITIVE
C                          = A TWO WORD ARRAY (IF TABLE(1) IS NEGATIVE)
C                                    CONTAING THE INTERPOLATED VALUES
C                                    FOR F(X) AND G(X)
C
C         NLQ     = INPUT  = INTERPOLATION FLAG (INTEGER)
C                          = 1  FOR LINEAR INTERPOLATION
C                          = 2  FOR QUADRATIC INTERPOLATION
```

```
C
C          NER      = OUTPUT = ERROR CODE (INTEGER)
C                            = 1  INTERPOLATION SUCCESSFUL
C                            = 2  BELOW TABLE, MINIMUM VALUE FURNISHED
C                            = 3  ABOVE TABLE, MAXIMUM VALUE FURNISHED
C                            = 4  NOT ENOUGH ENTRIES = NO ANSWER
C                            = 5  X=VALUES NOT IN ASCENDING ORDER = NO
C                                 ANSWERS
C
      DIMENSION OTPT(2), TABLE(1)
C
      EQUIVALENCE  ( NOENTR, A )
C
      A = ABS( TABLE(1) )
      M = 2
      IF  ( TABLE(1) .LT. 0.0 )  M = 3
      MM1 = M - 1
      MP1 = M + 1
      IF  ( A .GT. 0.99E0 )  NOENTR = A + 0.5E0
      J = 3
C
C     CHECK FOR NUMBER OF ENTRIES
C
      IF  ( NLQ .NE. 1 )  GO TO 20
      IF  ( NOENTR .GE. 2 )  GO TO 30
   10 NER = 4
      GO TO 140
   20 IF  ( NOENTR .LT. 3 )  GO TO 10
C
C     CHECK FOR ARGUMENT LESS THAN OR EQUAL TO LOW LIMIT
C
   30 IF  ( ARG - TABLE(2) )40,50,60
   40 NER = 2
      GO TO 130
   50 NER = 1
```

```
      GO TO 130
C
C     SEARCH FOR ENTRY WITHIN TABLE
C
   60 NOS = M * NOFNTR
      IST = 2 + M
      DO  90  I = IST, NOS, M
      J = I + 1
      IF  ( TABLE(I) - TABLE(I-M) )70,70,80
   70 NER = 5
      GO TO 140
   80 IF  ( TABLE(I) - ARG )90,50,100
   90 CONTINUE
      NER = 3
      GO TO 130
C
C     SEARCH SUCCESSFUL, TEST INTERPOLATION TYPE
C
  100 IF  ( NLQ .GT. 1)  GO TO 110
C
C     USE LINEAR INTERPOLATION
C
      NER = 1
      OTPT  (1) = TABLE(I+1) * ( ARG - TABLE(I-M) ) / ( TABLE(I) -
     1            TABLE(I-M) ) + TABLE(I-MM1) * ( ARG - TABLE(I) ) /
     2            ( TABLE(I-M) - TABLE(I) )
      IF  ( M .NE. 3 )  GO TO 140
      OTPT  (2) = TABLE(I+2) * ( ARG - TABLE(I-7) ) / ( TABLE(I) -
     1            TABLE(I-7) ) + TABLE(I-1) * ( ARG - TABLF(I) ) /
     2            ( TABLE(I-M) - TABLE(I) )
      GO TO 140
C
C     USE QUADRATIC INTERPOLATION
C
  110 I = I - M
```

```
      IF  ( I .GE. 2*M )  GO TO 120
      I = I + M
  120 XA1 = ARG - TABLE(I)
      XA0 = ARG - TABLE(I-M)
      XA2 = ARG - TABLE(I+M)
      X01 = TABLE(I-M) - TABLE(I)
      X02 = TABLE(I-M) - TABLE(I+M)
      X12 = TABLE(I)   - TABLE(I+M)
      NER = 1
      OTPT  (1) = TABLE(I-MM1) * ( XA1 / X01 ) * ( XA2 / X02 ) -
     1            TABLE(I+1)   *  ( XA0 / X01 ) * ( XA2 / X12 ) +
     2            TABLF(I+MP1) * ( XA0 / X02 ) * ( XA1 / X12 )
      IF  ( M .NE. 3 )  GO TO 140
      OTPT  (2) = TABLE(I-1) * ( XA1 / X01 ) * ( XA2 / X02) -
     1            TABLE(I+2) * ( XA0 / X01 ) * ( XA2 / X12 ) +
     2            TABLE(I+5) * ( XA0 / X02 ) * ( XA1 / X12 )
      GO TO 140
C
C     ERROR EXIT  -  SET OUTPUT VALUE
C
  130 OTPT  (1) = TABLE(J)
      IF  ( M .EQ. 3 )  OTPT  (2) = TABLE(J+1)
C
C     NORMAL EXIT
C
  140 RETURN
      END
```

```
      FUNCTION ARSIN(X)                                                 ARSN  001C
C     THIS ROUTINE IS REQUIRED BECAUSE OF DIFFERENCES BETWEEN CDC AND IBM ARSN  002
C     FORTRAN.                                                          ARSN  003
      ARSIN = ASIN(X)                                                   ARSN  004C
      RETURN                                                            ARSN  005C
      END                                                               ARSN  006C
```

```
      OVERLAY(AXSY,1,0)                                                 PAR1  001C
      PROGRAM PART1                                                     PAR1  002C
C     SUBROUTINE PART1                                                  PAR1  003I
C                                                                       PAR1  004
C              * CONTROL FOR BASIC DATA AND FORM MATRIX                 PAR1  005
C                                                                       PAR1  006
       COMMON / NBSAVE /  NBOLD, NIN                                    PAR1  007
      COMMON  /RNGWNG/ VA(100,2),  VR(100,2),VAN(100), VAT(100)         PAR1  008
      COMMON /ECF/ ECX(100), ECY(100), ECZ(100)                         PAR1  009
      COMMON  /D/ D1, D3, XMXJ, YMYJ, XMXJP1, YMYJP1, S                 PAR1  010
      COMMON       HEDR(10)  ,CASE       ,NB        ,NNU                PAR1  011
     1            ,FLG03     ,FLG04      ,FLG05     ,FLG06     ,FLG07   PAR1  012
     2            ,FLG08     ,FLG09      ,FLG10     ,FLG11     ,FLG12   PAR1  013
     3            ,FLG13     ,FLG14      ,FLG15     ,FLG16     ,FLG17   PAR1  014
     4            ,FLG18     ,FLG19      ,FLG20     ,FLG21     ,FLG22   PAR1  015
     5            ,FLG23     ,FLG24      ,FLG25     ,FLG26     ,FLG27   PAR1  016
      COMMON   NT,       ND(11),    MN,       NUNA(5),  TYPEA(5),       PAR1  017
     1         NER1,     NER2,      NMA,      NSIGA,    NSIGC,          PAR1  018
     2         NUNC(5),  TYPEC(5),  NLF(11),  IFC,      NSIGEC,         PAR1  019
     3         TYPEEC(5),NUNEC(5)                                       PAR1  020
C     DOUBLE PRECISION  HEDR, CASE                                      PAR1  021I
      INTEGER      FLG03     ,FLG04      ,FLG05     ,FLG06     ,FLG07   PAR1  022
     1            ,FLG08     ,FLG09      ,FLG10     ,FLG11     ,FLG12   PAR1  023
     2            ,FLG13     ,FLG14      ,FLG15     ,FLG16     ,FLG17   PAR1  024
     3            ,FLG18     ,FLG19      ,FLG20     ,FLG21     ,FLG22   PAR1  025
     4            ,FLG23     ,FLG24      ,FLG25     ,FLG26     ,FLG27   PAR1  026
      COMMON /IPSF/ PSF                                                 PAR1  027
      REAL         MN                                                   PAR1  028
C                                                                       PAR1  029
      COMMON /CL/   X1(100),  Y1(100),  X2(100),  Y2(100),  DELS(100),  PAR1  030
     1              SINA(100),COSA(100),XP(100),  YP(100)               PAR1  031
     2             ,XWAKE(11),YWAKE(11)                                 PAR1  032
      COMMON /TL/   TX1(100), TY1(100), NG(100),  TG(100),  ALFA(100),  PAR1  033
     1  RSDS(100),DALF(100),CHORD,TCNST,DUMMY(1315)                     PAR1  034
      COMMON/ITERF/ ITER                                                PAR1  035
```

```
      INTFGER      BDN        ,SUBKS
      REAL         MX         ,MY          ,NG
C
C                 * START
C                 * RFAD INPUT DATA
  100 READ (5,4) HEDR, CASE, PSF , NB, NNU, FLG03, FLG04, FLG05, FLG06,
     1           FLG07, FLG08, FLG09, FLG10, FLG11, FLG12, FLG13, FLG14,
     2           FLG15, FLG16, FLG17, FLG18, FLG19, FLG20, FLG21, FLG22,
     3           FLG23, FLG24, FLG25, FLG26, FLG27,          NIN,ITER
C*** ***TRIANGULARIZATION OF THE MATRIX (SOLVIT) IS THE DEFAULT SOLUTION
      IF(FLG09.EQ.0.AND.FLG10.EQ.0)FLG13=1
C***   ***FLG22 IS GENERATED (RESEP) BOUNDARY CONDITIONS
C***   ***FLG21 IS EXTRA CROSS FLOW
    1 IF (FLG22.LE.0)GO TO 5
      FLG21 = 1
      FLG03 = 1
      FLG04 = 1
C***   ***IF FLAG 18 IS NOT EQUAL TO FLAG 14 YOU MUST USE DIRECT MATRIX
    5 IF (FLG18.NE.FLG14)GO TO 2
      IF (FLG21.LE.0)GO TO 3
      FLG12 = 1
    2 FLG13 = 1
      FLG09 = 0
      FLG10 = 0
    3 CONTINUE
        IF( NBOLD .EQ. 0 )        NBOLD = NB
C*** ***CARDS (UNIT 5) ARE THE DEFAULT METHOD OF INPUT
        IF( NIN .EQ. 0 )        NIN = 10
    4 FORMAT ( 10A6, 2X A6, 8X A4/ 27I1, I2,I1)
      READ (5,8) CHORD, MN, TCNST
    8 FORMAT ( 3F10.0 )
C*** ***THE DEFAULT CHORD LENGTH IS 1.0
      IF(CHORD.GT.-1.0E-5.AND.CHORD.LT.1.0E-5)CHORD=1.0
      WRITE (6,12) HEDR, CASE, NB, NNU, CHORD, MN, TCNST, PSF
   12 FORMAT ( 1H1 25X, 26HDOUGLAS  AIRCRAFT COMPANY /
```

```
      1        28X, 21HLONG  BEACH  DIVISION ///                       PAR1  071
      2         6X, 43HPROGRAM EODA -- AXISYMMETRIC AND CROSSFLOW //   PAR1  072
      3        11X, 29H***** CASE CONTROL DATA ***** ///               PAR1  073
      4         6X, 10A6, 4X, 10HCASE NO.  A6 //                       PAR1  074
      5         6X  9HBODIES  =I3/ 6X 9HNNU     =I3/ 6X 9HCHORD   =F12.7/ PAR1  075
      6         6X  9HMACH NO.=F12.8/ 6X 9HTCNST   =F12.7/             PAR1  076
      7         6X  9HPSF NO. = A4///)                                 PAR1  077
      IF (FLG03.GT.0) WRITE (6,16)                                     PAR1  078
   16 FORMAT (13X 21HSURFACE OF REVOLUTION )                           PAR1  079
      IF (FLG04.GT.0) WRITE (6,20)                                     PAR1  080
   20 FORMAT (13X  9HCROSSFLOW)                                        PAR1  081
      IF (FLG05.GT.0) WRITE (6,24)                                     PAR1  082
   24 FORMAT (13X 15HOFF-BODY POINTS )                                 PAR1  083
      IF (FLG06.GT.0) WRITE (6,28)                                     PAR1  084
   28 FORMAT (13X 15HBASIC DATA ONLY )                                 PAR1  085
      IF (FLG07.GT.0) WRITE (6,32)                                     PAR1  086
   32 FORMAT (13X 17HELLIPSE GENERATOR )                               PAR1  087
      IF (FLG08.GT.0) WRITE (6,36)                                     PAR1  088
   36 FORMAT (13X 14HPRINT MATRICES )                                  PAR1  089
      IF (FLG09.GT.0) WRITE (6,40)                                     PAR1  090
   40 FORMAT (13X 10HOLD SEIDEL )                                      PAR1  091
      IF (FLG10.GT.0) WRITE (6,44)                                     PAR1  092
   44 FORMAT(13X,31HMODIFIED SEIDEL MATRIX SOLUTION)                   PAR1  093
      IF (FLG11.GT.0) WRITE (6,48)                                     PAR1  094
   48 FORMAT (13X 18HPERTURBATIONS ONLY )                              PAR1  095
      IF (FLG12.GT.0) WRITE (6,52)                                     PAR1  096
   52 FORMAT (13X 22HSOLVE POTENTIAL MATRIX )                          PAR1  097
      IF (FLG13.GT.0) WRITE (6,56)                                     PAR1  098
   56 FORMAT (13X 47HMATRIX SOLUTION BY TRIANGULARIZATION   (SOLVIT))  PAR1  099
      IF (FLG14.GT.0) WRITE (6,53)                                     PAR1  100
   53 FORMAT ( 13X 30HPRESCRIBED TANGENTIAL VELOCITY )                 PAR1  101
      IF (FLG18.GT.0) WRITE (6,69)                                     PAR1  102
   69 FORMAT ( 15X 22HWITH SURFACE VORTICITY )                         PAR1  103
      IF (FLG15.GT.0) WRITE (6,54)                                     PAR1  104
   54 FORMAT (13X 12HSTRIP VORTEX )                                    PAR1  105
```

```
      IF (FLG16.GT.0) WRITE (6,64)
   64 FORMAT (13X 40HOMIT AXI-SYMMETRIC UNIFORM FLOW SOLUTION )
      IF (FLG17.GT.0) WRITE (6,68)
   68 FORMAT (13X 36HOMIT CROSSFLOW UNIFORM FLOW SOLUTION )
      IF (FLG19.GT.0) WRITE (6,72)
   72 FORMAT (13X 20HPRESCRIBED VORTICITY)
      IF (FLG20 .GT. 0)WRITE(6,74)
   74 FORMAT(13X 15HTOTAL VORTICITY  )
      IF (FLG21 .GT. 0)WRITE(6,76)
   76 FORMAT ( 13X  16HEXTRA CROSS FLOW )
      IF (FLG22 .GT. 0)WRITE(6,78)
   78 FORMAT(13X 82HGENERATED BOUNDARY CONDITIONS FOR 3 AXISYMMETRIC, 1
     1CROSS, AND 1 EXTRA CROSS FLOW.  )
      IF (FLG23 .LE. 0)GO TO 81
      WRITE(6,79)
   79 FORMAT(13X 16HRING WING OPTION )
      FLG03 = 1
      FLG13 = 1
      FLG15 = 1
      FLG19 = 1
   81 IF (FLG19 .GT. 0)FLG18 = 1
      IF (FLG22.GT.0.AND.NB.NE.2) GO TO 82
      GO TO 84
   82 WRITE(6,83)
   83 FORMAT (128H0 WHEN GENERATED RESEP BOUNDARY CONDITIONS ARE USED,NU
     1MBER OF BODIES MUST BE EXACTLY TWO.   YOU GOOFED.   EXECUTION TERM
     2INATING.)
      STOP
   84 IF (FLG22.GT.0.AND.NNU.GT.0)GO TO 86
      GO TO 88
   86 WRITE (6,87)
   87 FORMAT (98H0 GENERATED RESEP BOUNDARY CONDITIONS CANNOT HAVE NON-U
     1NIFORM FLOW INPUT.   EXECUTION TERMINATING.)
   88 CONTINUE
       WRITE ( 6,75 )  NIN
```

```
      IF (FLG18.LE.0.OR.FLG14.GT.0) GO TO 125
   75  FORMAT( 13X,58HINPUT TAPE NO. FOR COORDINATES AND NON-UNIFORM FLO
     1W ONLY = ,  I5    )
      WRITE (6,70)
   70 FORMAT (1H0//63H FLG14 MUST BE USED WITH FLG18 OR FLG19,  EXECUTIO
     1N TERMINATED. )
      STOP
  125 IF (NNU.LE.0.OR.FLG14.LE.0) GO TO 130
      WRITE (6,60)
   60 FORMAT (1H0// 49H COLUMNS 2 AND 14 OF FLAG CARD ARE BOTH NON-ZERO,
     A            / 43H ILLEGAL COMBINATION. EXECUTION TERMINATED. )
      STOP
C                 * READ DATA AND SETUP FOR UNIFORM FLOW
  130 CALL BASIC1
C*** ***NSIGA AND NSIGC ULTIMATELY BECOME THE NUMBER OR RIGHT HAND SIDES
C*** ***IN AXISYMMETRIC FLOW AND CROSS FLOW RESPECTIVELY
  133 NSIGA=0
      IF (FLG03.GT.0.AND.FLG16.LE.0) NSIGA=1
      NSIGC=0
      IF (FLG04.GT.0.AND.FLG17.LE.0) NSIGC=1
      IF (FLG22.GT.0) GO TO 136
      DO 135 I = 1,5
      NUNA(I) = 123456
  135 TYPEA(I) = 100.
      IF(FLG23 .GT. 0)GO TO 141
      GO TO 138
C***   ***PREPARE NUNA AND TYPEA FOR NON-UNIFORM AXISYMMETRIC FLOW,GENER
C***   ***(RESEP) BOUNDARY CONDITIONS
  136 DO 137 I = 1,3
      NUNA(I) = I
  137 TYPEA(I) = 100.0
      GO TO 138
C
C
C   ***   RING WING OPTION
```

```
C   ***   STRIP VORTEX FLOWS ALREADY HAVE NUNA(I) = 123456.
C   ***   MAKE PRESCRIBED VORTICITY FLOWS NUNA(J) = TO THEIR FLOW NO. J
C
  141 ICNT = 0
      DO 142 I = 1,NB
      IF(NLF(I) .GT. 0) GO TO 142
      ICNT = ICNT + 1
  142 CONTINUE
C
C   ***   ICNT IS THE NUMBER OF LIFTING BODIES
C   ***   NUMBER OF FLOWS IS 2 * ICNT  + 1
C
      NFLOWS = 2 * ICNT + 1
      ICNTP2 = ICNT + 2
      DO 143 I = ICNTP2,NFLOWS
  143 NUNA(I) = I
  138 CONTINUE
C*** ***IF FLG02 (NON-UNIFORM FLOW) IS NOT CHECKED INITIALLY, THE FLOW
C*** ***OF CONTROL WILL NEVER REACH BASIC2
      IF (NNU) 140,150,140
C               * READ DATA AND SETUP FOR NON-UNIFORM FLOW
  140 CALL BASIC2
  150 CONTINUE
  160 REWIND 4
      IF (NSIGA .LE. 5 )GO TO 180
  170 WRITE(6,172)
  172 FORMAT (1H1 75HAXI-SYMMETRIC OR CROSSFLOW NON-UNIFORM FLOWS EXCEED
     A 5. EXECUTION TERMINATED  )
      STOP
  180 IF (NSIGC .GT. 5)GO TO 170
      IF (FLG15.LE.0.OR.FLG03.GT.0) GO TO 200
      WRITE (6,190)
  190 FORMAT (64H1STRIP RING VORTEX OPTION MUST USE SURFACE OF REVOLUTIO
     1N OPTION. / 22H EXECUTION TERMINATED. )
      STOP
```

```
 200 IF (FLG15.LE.0) GO TO 230
     J = 0
     DO 210 I = 1, NB
 210 IF (NLF(I).LE.0) J=J+1
     IF (NSIGA + J  .LE.  5 )GO TO 230
     WRITE (6,220)
 220 FORMAT (68H1GENERATED STRIP VORTEX ONSET FLOWS (ONE FOR EACH LIFTI
    1NG BODY) PLUS / 34H INPUT NON-UNIFORM FLOWS EXCEED 5. /
    2 22H0EXECUTION TERMINATED. )
     STOP
 230 IF (FLG06.NE.0) GO TO 235
     CALL MATRIX
C 235 RETURN
 235 CONTINUE
     END
```

```
      SUBROUTINE BASIC1
C
C              * READ DATA AND SETUP FOR UNIFORM FLOW
C
       COMMON / NBSAVE / NBOLD, NIN
      COMMON      HEDR(10)  ,CASE       ,NB         ,NNU
     1           ,FLG03     ,FLG04      ,FLG05      ,FLG06      ,FLG07
     2           ,FLG08     ,FLG09      ,FLG10      ,FLG11      ,FLG12
     3           ,FLG13     ,FLG14      ,FLG15      ,FLG16      ,FLG17
     4           ,FLG18     ,FLG19      ,FLG20      ,FLG21      ,FLG22
     5           ,FLG23     ,FLG24      ,FLG25      ,FLG26      ,FLG27
      COMMON    NT,         ND(11),     MN,         NUNA(5),   TYPEA(5),
     1          NER1,       NER2,       NMA,        NSIGA,     NSIGC,
     2          NUNC(5),    TYPFC(5),   NLF(11),    IEC,       NSIGEC,
     3          TYPEEC(5),NUNEC(5)
C     DOUBLE PRECISION  HEDR, CASE
      INTEGER     FLG03     ,FLG04      ,FLG05      ,FLG06      ,FLG07
     1           ,FLG08     ,FLG09      ,FLG10      ,FLG11      ,FLG12
     2           ,FLG13     ,FLG14      ,FLG15      ,FLG16      ,FLG17
     3           ,FLG18     ,FLG19      ,FLG20      ,FLG21      ,FLG22
     4           ,FLG23     ,FLG24      ,FLG25      ,FLG26      ,FLG27
      DIMENSION COSSQR(100), RHS(100)
      REAL        MN
C
      COMMON /CL/    X1(100),   Y1(100),   X2(100),   Y2(100),   DELS(100),
     1               SINA(100),COSA(100),XP(100),   YP(100)
     2              ,XWAKE(11),YWAKE(11)
      COMMON /TL/    TX1(100),  TY1(100),  NG(100),   TG(100),   ALFA(100),
     1  RSDS(100),DALF(100),CHORD,TCNST,DUMMY(1315)
      INTEGER     BDN       ,SUBKS
      REAL        MX        ,MY         ,NG
C
C              * START
      NT=0
      K=0
```

```
      K2=NB
       IF( NIN .EQ. 0 )        NIN = 10
      IF (FLG05.NE.0) K2=NB+1
C              * MAJOR LOOP * NO. OF BODIES + OFF BODY POINTS
      LCNT = 0
      DO 1000 L=1,K2
      READ (5,15) NN, MX, MY, THETA, ADDX, ADDY
   15 FORMAT ( 5X I5, 5F10.0)
      READ (5,16) BDN,SUBKS,NLF(L),XF,YE
   16 FORMAT (3(5X,I5),2F10.0)
C*** ***ND(L) IS THE NUMBER OF POINTS ON BODY L, OR THE NUMBER OF OFF
C*** ***BODY POINTS FOR L = NB + 1
      ND(L)=NN
      M=NN-1
      IF (SUBKS) 140,150,140
 140   IF( L .NE. K2 )          GO TO 148
       NTIMES = NBOLD - NB
       IF( NTIMES .LE. 0 )           GO TO 148
       DO 145 NSKIPS = 1, NTIMES
 145   READ(13) ( TX1(I),I=1,NN), (TY1(I),I=1,NN )
 148   READ(13) ( TX1(I),I=1,NN), (TY1(I),I=1,NN )
      GO TO 220
  150 IF (BDN.EQ.0) GO TO 200
      IF (FLG07) 160,200,160
C              * ELLIPSE GENERATOR FOR X1 AND Y1
  160 IF (XE.EQ.0.0) XE=1.
      IF (YE.EQ.0.0) YE=1.
      EN=M
      DGAM=3.141593  /EN
      GAM=3.141593
      DO 170 I=1,NN
      TX1(I)=XE*COS(GAM)
      TY1(I)=YE*SIN(GAM)
  170 GAM=GAM-DGAM
      GO TO 210
```

```
C                * READ X1 AND Y1 FROM INPUT CARDS                            BAS1  071
  200 DO 204 I=1,NN,6                                                         BAS1  072
      READ(NIN,20)TX1(I),TX1(I+1),TX1(I+2),TX1(I+3),TX1(I+4),TX1(I+5)         BAS1  073
   20 FORMAT ( 6F10.0)                                                        BAS1  074
  204 CONTINUE                                                                BAS1  075
      DO 206 I=1,NN,6                                                         BAS1  076
      READ(NIN,20)TY1(I),TY1(I+1),TY1(I+2),TY1(I+3),TY1(I+4),TY1(I+5)         BAS1  077
  206 CONTINUE                                                                BAS1  078
C                                                                             BAS1  079
C*** *  NB - FLG14 + 1  TO  NB  ARE PRESCRIBED VORTICITY BODIES                BAS1  080
C                                                                             BAS1  081
      IF ( FLG23 .LE. 0  .OR.  (L.LE.NB-FLG14  .OR. L .GT. NB))GO TO 210      BAS1  082
C                                                                             BAS1  083
C*** *  IF CONTROL REACHES THIS POINT, RING WING OPTION IS IN EFFECT AND      BAS1  084
C*** *L IS A PRESCRIBED VORTICITY BODY                                        BAS1  085
C   ***   LCNT IS THE RELATIVE NUMBER OF THE WAKE BODY STARTING WITH 1        BAS1  086
C                                                                             BAS1  087
      LCNT = LCNT + 1                                                         BAS1  088
      XWAKE(LCNT) = TX1(NN)                                                   BAS1  089
      YWAKE(LCNT) = TY1(NN)                                                   BAS1  090
C                * SAVE X1 AND Y1 FOR SUBCASE                                 BAS1  091
  210 WRITE (13) (TX1(I),I=1,NN),(TY1(I),I=1,NN)                              BAS1  092
C                * BASIC DATA CALC. AND PRINT (UNTRANSFORMED COORDINATES)     BAS1  093
  220 WRITE (6,24) HEDR, NN, MX, MY, THETA, ADDX, ADDY, XE, YE                BAS1  094
   24 FORMAT ( 1H1 25X 26HDOUGLAS  AIRCRAFT  COMPANY /                        BAS1  095
     1           28X 21HLONG  BEACH  DIVISION /// 5X 10A6 //                  BAS1  096
     2            8X 4HNN = I4, 15X 4HMX = F13.7, 4X 4HMY = F13.7 /           BAS1  097
     3            5X 7HTHETA = F13.7, 4X 6HADDX = F13.7, 2X 6HADDY =F13.7/    BAS1  098
     4            8X 4HXE = F13.7, 6X 4HYE = F13.7 )                          BAS1  099
      IF (BDN) 240,230,240                                                    BAS1  100
  230 WRITE (6,28) (I, TX1(I), TY1(I), I=1,NN)                                BAS1  101
   28 FORMAT ( 1H0 4X 36HOFF-BODY COORDINATES (UNTRANSFORMED) //              BAS1  102
     1           10X 5HX-OFF  9X 5HY-OFF // (1H  I3, 2F14.7))                 BAS1  103
      GO TO 270                                                               BAS1  104
  240 SUMS=0.0                                                                BAS1  105
```

```
      DO 250 I=1,M
      T1=TX1(I+1)-TX1(I)
      T2=TY1(I+1)-TY1(I)
      X2(I)=(TX1(I+1)+TX1(I))/2.
      Y2(I)=(TY1(I+1)+TY1(I))/2.
      DELS(I)=SQRT(T1*T1+T2*T2)
      SUMS=SUMS+DELS(I)
      RSDS(I)=SUMS
  250 ALFA(I) = ATAN2( T2, T1 )
      MA=M-1
      DO 260 I=1,MA
  260 DALF(I) = ( ALFA(I+1)-ALFA(I) ) * 57.29578
      WRITE (6,36) BDN,TX1(1),TY1(1),X2(1),Y2(1),DELS(1),RSDS(1)
   36 FORMAT ( 1H0 4X 35HON-BODY COORDINATES (UNTRANSFORMED) /
     1         9H BODY NO. I3// 11X 2H X 13X 1HY 11X 7HDELTA S 7X
     2         5HSUMDS 8X 7HD ALPHA //  1H 3H  1,2F14.7 / 4X 4F14.7)
      WRITE (6,40) (I, TX1(I), TY1(I), DALF(I-1), X2(I), Y2(I),
     1          DELS(I), RSDS(I), I=2,M) , NN, TX1(NN), TY1(NN)
   40 FORMAT ( 1H  I3, 2F14.7, 28X F14.7 / 4X 4F14.7)
C              * ADJUST COORDINATES (TRANSFORMED)
  270 IF (MX) 280,300,280
  280 DO 290 I=1,NN
  290 TX1(I)=TX1(I)*MX
  300 IF (MY) 310,330,310
  310 DO 320 I=1,NN
  320 TY1(I)=TY1(I)*MY
  330 IF (THETA) 340,360,340
  340 THETA = THETA / 57.29578
      CSTHT = COS(THETA)
      SNTHT = SIN(THETA)
      DO 350 I=1,NN
      T1=TX1(I)
      TX1(I)=T1*CSTHT+TY1(I)*SNTHT
  350 TY1(I)=TY1(I)*CSTHT-T1*SNTHT
  360 IF (ADDX) 370,390,370
```

```
  370 DO 380 I=1,NN
  380 TX1(I)=TX1(I)+ADDX
  390 IF (ADDY) 400,420,400
  400 DO 410 I=1,NN
  410 TY1(I)=TY1(I)+ADDY
  420 IF (CHORD .EQ. 1.0 .OR. CHORD .EQ. 0.0 )GO TO 450
  430 DO 440 I=1,NN
      TX1(I)=TX1(I)/CHORD
  440 TY1(I)=TY1(I)/CHORD
  450 IF (MN) 460,475,460
  460 SRM=SQRT(1.-MN*MN)
      DO 470 I=1,NN
  470 TX1(I)=TX1(I)/SRM
C                * SHIFT X1 AND Y1 TO COMMON /CL/
C*** ***IF BDN = 0.0, OFF BODY POINTS ARE BEING OPERATED ON
  475 IF (BDN) 500,480,500
  480 DO 490 I=1,NN
      XP(I)=TX1(I)
  490 YP(I)=TY1(I)
      WRITE (12) (XP(I),I=1,NN),(YP(I),I=1,NN)
      GO TO 1000
  500 DO 510 I=1,NN
      K=K+1
      X1(K)=TX1(I)
  510 Y1(K)=TY1(I)
      NT=NT+M
 1000 CONTINUE
      REWIND 13
      IF (FLG14.LE.0) GO TO 2000
      IF (FLG14.LE.NB) GO TO 1050
      WRITE (6,1025)
 1025 FORMAT (45H1VALUE OF FLG14 EXCEEDS NO. OF BODIES.  STOP. )
      STOP
 1050 IF (FLG14.NE.NB) GO TO 1075
      NMA=0
```

```
      GO TO 1150
 1075 L = NB-FLG14
      NMA = -L
      DO 1100 I = 1, L
C*** ***NMA BECOMES THE NUMBER OF ELEMENTS ON THE 1ST L BODIES (IE THOSE
C*** ***NOT HAVING AN INPUT VORTICITY OR VELOCITY)
 1100 NMA = NMA + ND(I)
C*** ***NR BECOMES THE NUMBER OF ELEMENTS RECEIVING AN INPUT VORTICITY
C*** ***OR VELOCITY
 1150 NR = NT-NMA
      IF (TCNST.GT.0.)GO TO 2000
      DO 1200 I = 1,NR,6
      READ (5,20) TG(I),TG(I+1),TG(I+2),TG(I+3),TG(I+4),TG(I+5)
 1200 CONTINUE
C               * CALC. PARAMETERS WITH TRANSFORMED COORDINATES AND
C                 MACH NO. ADJUSTMENT
 2000 N1=0
      J1=0
      DO 2500 K=1,NB
      M1=N1+1
      N1=N1+ND(K)-1
      DO 2400 J=M1,N1
      J1=J1+1
      T1=X1(J1+1)-X1(J1)
      T2=Y1(J1+1)-Y1(J1)
      X2(J)=(X1(J1+1)+X1(J1))/2.
      Y2(J)=(Y1(J1+1)+Y1(J1))/2.
      DELS(J)=SQRT(T1*T1+T2*T2)
      COSA(J)=T1/DELS(J)
 2400 SINA(J)=T2/DELS(J)
 2500 J1=J1+1
C               * SAVE PARAMETERS
      WRITE (12) (X1(I),I=1,J1),(Y1(I),I=1,J1),(X2(I),I=1,NT)
     1          ,(Y2(I),I=1,NT),(DELS(I),I=1,NT)
      REWIND 12
```

```
C                 * SAVE SINA AND COSA ON TAPE 4 FOR CALC. OF MATRIX
C                   SOLUTION (RIGHT HAND MATRIX)
      WRITE (4)   (SINA(I),I=1,NT),(COSA(I),I=1,NT)
      IF ( FLG14) 2600,2600,2550
 2550 IF (TCNST.GT.0.0) WRITE(4) (TCNST,I=1,NR)
      IF (TCNST.LE.0.) WRITE(4) (TG(I), I=1,NR)
 2600 IF (FLG22.LE.0) RETURN
      NPB1 = ND(1) - 1
      DO 2700 I = 1,NPB1
      COSSQR(I) = COSA(I)**2
 2700 RHS(I) = 2.0 * ABS( SINA(I) * COSA(I) )
      WRITE(4) ( COSSQR(I),I=1,NPB1), (RHS(I),I = 1,NPB1)
      RETURN
      END
```

```
      SUBROUTINE BASIC2
C
C               * READ DATA AND SETUP FOR NON-UNIFORM FLOWS
C
       COMMON / NBSAVE / NBOLD, NIN
      COMMON        HEDR(10)  ,CASE        ,NB         ,NNU
     1             ,FLG03     ,FLG04       ,FLG05      ,FLG06      ,FLG07
     2             ,FLG08     ,FLG09       ,FLG10      ,FLG11      ,FLG12
     3             ,FLG13     ,FLG14       ,FLG15      ,FLG16      ,FLG17
     4             ,FLG18     ,FLG19       ,FLG20      ,FLG21      ,FLG22
     5             ,FLG23     ,FLG24       ,FLG25      ,FLG26      ,FLG27
      COMMON   NT,        ND(11),    MN,       NUNA(5),  TYPEA(5),
     1         NER1,      NER2,      NMA,      NSIGA,    NSIGC,
     2         NUNC(5),   TYPEC(5),  NLF(11),  IEC,      NSIGEC,
     3         TYPFEC(5),NUNEC(5)
C     DOUBLE PRECISION  HEDR, CASE
      INTEGER       FLG03     ,FLG04       ,FLG05      ,FLG06      ,FLG07
     1             ,FLG08     ,FLG09       ,FLG10      ,FLG11      ,FLG12
     2             ,FLG13     ,FLG14       ,FLG15      ,FLG16      ,FLG17
     3             ,FLG18     ,FLG19       ,FLG20      ,FLG21      ,FLG22
     4             ,FLG23     ,FLG24       ,FLG25      ,FLG26      ,FLG27
      REAL          MN
C
      COMMON /CL/     X1(100),  Y1(100),  X2(100),  Y2(100),  DELS(100),
     1                SINA(100),COSA(100),XP(100),  YP(100)
     2               ,XWAKE(11),YWAKE(11)
      COMMON /TL/     TX1(100), TY1(100), NG(100),  TG(100),  ALFA(100),
     1  RSDS(100),DALF(100),CHORD,TCNST,DUMMY(1315)
      INTEGER       BDN
      REAL          MX        ,MY          ,NG
C
C              * START
C              * SETS OF NON-UNIFORM FLOW LOOP
      NSIGEC = 0
      KA=0
```

```
      KC=0                                                              BAS2 036
      KEC = 0                                                           BAS2 037
      DO 1000 L=1,NNU                                                   BAS2 038
      READ (5,20) NUN,MSF,TYPE,FG                                       BAS2 039
   20 FORMAT ( 2(5X I5), 2F10.0)                                        BAS2 040
      IF (MSF.EQ.1.OR.MSF.EQ.2.OR.MSF.EQ.5) GO TO 30                    BAS2 041
      KA=KA+1                                                           BAS2 042
      NSTGA=NSIGA+1                                                     BAS2 043
      NUNA(KA)=NUN                                                      BAS2 044
      TYPEA(KA)=TYPE                                                    BAS2 045
   30 IF (MSF.FQ.0.OR.MSF.EQ.2.OR.MSF.EQ.4) GO TO 35                    BAS2 046
      KC=KC+1                                                           BAS2 047
      NSIGC=NSIGC+1                                                     BAS2 048
      NUNC(KC)=NUN                                                      BAS2 049
      TYPEC(KC)=TYPE                                                    BAS2 050
   35 IF (MSF.LT.2.OR.MSF.EQ.3) GO TO 40                                BAS2 051
      KEC = KEC + 1                                                     BAS2 052
      NSIGFC = NSIGEC + 1                                               BAS2 053
      NUNEC(KEC) = NUN                                                  BAS2 054
      TYPEFC(KEC) = TYPE                                                BAS2 055
   40 IF (TYPE) 50,70,70                                                BAS2 056
C                * COMPUTED TYPE                                        BAS2 057
   50 DO 60 I=1,NT                                                      BAS2 058
      NG(I)=Y2(I)                                                       BAS2 059
   60 TG(I)=FG-X2(I)                                                    BAS2 060
      GO TO 110                                                         BAS2 061
C                * (X,Y) OR (N,T) TYPE * READ INPUT                     BAS2 062
   70 DO 90 I=1,NT,6                                                    BAS2 063
      READ( 5 ,80)NG(I),NG(I+1),NG(I+2),NG(I+3),NG(I+4),NG(I+5)         BAS2 064
   80 FORMAT ( 6F10.0)                                                  BAS2 065
   90 CONTINUE                                                          BAS2 066
      DO 100 I=1,NT,6                                                   BAS2 067
      READ( 5 ,80)TG(I),TG(I+1),TG(I+2),TG(I+3),TG(I+4),TG(I+5)         BAS2 068
  100 CONTINUE                                                          BAS2 069
  110 IF (TYPE) 120,140,120                                             BAS2 070
```


BAS2

```
120 DO 130 I = 1, NT
    T1=NG(I)
    NG(I)= T1*SINA(I)-TG(I)*COSA(I)
130 TG(I)= T1*COSA(I)+TG(I)*SINA(I)
C              * WRITE BASIC DATA OUTPUT
140 WRITE (6,150) HEDR,MSF,TYPE,FG,NUN,(NG(I),I=1,NT)
150 FORMAT ( 1H1 25X 26HDOUGLAS  AIRCRAFT  COMPANY /
   1          28X, 21HLONG  BEACH  DIVISION /// 5X 10A6 //
   2          6X 5HMSF = I4, 10X 6HTYPE = F10.4, 10X 4HFG = F13.7 /
   3           1H0, 4X, 20HNON-UNIFORM FLOW NO.I6 /
   4           1H0, 4X, 10HLIST OF NG// (1H 6F14.7))
    WRITE (6,160) (TG(I), I = 1, NT)
160 FORMAT (1H0 4X 10HLIST OF TG // (1H 6F14.7))
    WRITE (4) MSF,(NG(I),I=1,NT),(TG(I),I=1,NT)
1000 CONTINUE
    RETURN
    END
```

```
      SUBROUTINE MATRIX                                                 MATX 001
C                                                                       MATX 002
C              * COMPUTE MATRIX A,B,Z OR X,Y,Z                          MATX 003
C                                                                       MATX 004
      COMMON      HEDR(10)  ,CASE      ,NB        ,NNU                  MATX 005
     1           ,FLG03     ,FLG04     ,FLG05     ,FLG06     ,FLG07     MATX 006
     2           ,FLG08     ,FLG09     ,FLG10     ,FLG11     ,FLG12     MATX 007
     3           ,FLG13     ,FLG14     ,FLG15     ,FLG16     ,FLG17     MATX 008
     4           ,FLG18     ,FLG19     ,FLG20     ,FLG21     ,FLG22     MATX 009
     5           ,FLG23     ,FLG24     ,FLG25     ,FLG26     ,FLG27     MATX 010
      COMMON   NT,        ND(11),    MN,        NUNA(5),   TYPEA(5),    MATX 011
     1         NER1,      NER2,      NMA,       NSIGA,     NSIGC,       MATX 012
     2         NUNC(5),   TYPEC(5),  NLF(11),   IEC,       NSIGEC,      MATX 013
     3         TYPEEC(5),NUNEC(5)                                       MATX 014
C     DOUBLE PRECISION  HEDR, CASE                                      MATX 015I
      INTEGER     FLG03     ,FLG04     ,FLG05     ,FLG06     ,FLG07     MATX 016
     1           ,FLG08     ,FLG09     ,FLG10     ,FLG11     ,FLG12     MATX 017
     2           ,FLG13     ,FLG14     ,FLG15     ,FLG16     ,FLG17     MATX 018
     3           ,FLG18     ,FLG19     ,FLG20     ,FLG21     ,FLG22     MATX 019
     4           ,FLG23     ,FLG24     ,FLG25     ,FLG26     ,FLG27     MATX 020
      REAL        MN                                                    MATX 021
      LOGICAL  PF                                                       MATX 022
C                                                                       MATX 023
      COMMON /FCF/ ECX(100), ECY(100), ECZ(100)                         MATX 024
      COMMON  /RNGWNG/ VA(100,2),  VR(100,2),VAN(100), VAT(100)         MATX 025
      COMMON /CL/   X1(100),  Y1(100),  X2(100),  Y2(100),  DELS(100),  MATX 026
     1              SINA(100),COSA(100),XP(100),  YP(100)               MATX 027
     2             ,XWAKE(11),YWAKE(11)                                 MATX 028
      COMMON /TL/   A(100),   B(100),   AX(100),  AY(100),  AZ(100),    MATX 029
     1              CX(100),  CY(100),  CZ(100),  AXV(100),AYV(100),    MATX 030
     2              VN(100,5),VT(100,5),BON,           IAC,             MATX 031
     3              I,        J,        J1,       SJ,       DS,         MATX 032
     4              DX,       DY,       NI,       XJ,       YJ,         MATX 033
     5              XK,       EEK,      EKK,      K,        PF          MATX 034
C                                                                       MATX 035
```

```
C                    * START                                                         MATX  036
C                    * INITIALIZE                                                    MATX  037
      L1=NT                                                                          MATX  038
      BON=0.0                                                                        MATX  039
      YZERO=0.0                                                                      MATX  040
C***   ***TEST TYPE OF FLOW AND SET INDICATORS IAC AND IEC                           MATX  041
C***   ***CROSS FLOW ONLY                          IAC = -1  IEC = -1               MATX  042
C***   ***AXISYMMETRIC FLOW ONLY                   IAC = +1  IEC = -1               MATX  043
C***   ***EXTRA CROSS FLOW ONLY                    IAC =  0  IEC =  0               MATX  044
C***   ***CROSS FLOW AND AXISYMMETRIC FLOW         IAC =  0  IEC = -1               MATX  045
C***   ***CROSS FLOW AND EXTRA CROSS FLOWW         IAC = -1  IEC = +1               MATX  046
C***   ***AXISYMMETRIC AND EXTRA CROSS FLOW        IAC = +1  IEC = +1               MATX  047
C***   ***AXISYMMETRIC, CROSS, AND EXTRA CROSS   IAC=0 IEC = +1                     MATX  048
      IF(FLG03)30,10,30                                                              MATX  049
   10 IF(FLG04)25,15,25                                                              MATX  050
   15 IAC = 0                                                                        MATX  051
      IEC = 0                                                                        MATX  052
      GO TO 55                                                                       MATX  053
   25 IAC = -1                                                                       MATX  054
      GO TO 45                                                                       MATX  055
   30 IF(FLG04)35,40,35                                                              MATX  056
   35 IAC = 0                                                                        MATX  057
      GO TO 45                                                                       MATX  058
   40 IAC = 1                                                                        MATX  059
   45 IF(FLG21)50,53,50                                                              MATX  060
   50 IEC = +1                                                                       MATX  061
      GO TO 55                                                                       MATX  062
   53 IEC = -1                                                                       MATX  063
   55 ASSIGN 110 TO K1                                                               MATX  064
      IF (FLG15.GT.0) ASSIGN 102 TO K1                                               MATX  065
   60 DO 70 I=1,L1                                                                   MATX  066
      DO 65 J = 1,5                                                                  MATX  067
      VN(I,J) = 0.                                                                   MATX  068
   65 VT(I,J) = 0.                                                                   MATX  069
      VAN(I)=0.0                                                                     MATX  070
```

```
   70 VAT(I)=0.0                                                     MATX  071
C                *  I MIDPOINT LOOP                                  MATX  072
      DO 400 I=1,L1                                                  MATX  073
C                *  J ELEMENT LOOP                                   MATX  074
C                   J1 IS THE COORDINATE COUNTFR                     MATX  075
C                   J IS THE ELEMENT COUNTER                         MATX  076
      J1=0                                                           MATX  077
      N1=0                                                           MATX  078
      IF (FLG23 .GT. 0)CALL NOTS                                     MATX  079
      DO 110 K=1,NB                                                  MATX  080
      M1=N1+1                                                        MATX  081
      N1=N1+ND(K)-1                                                  MATX  082
      DO 100 J=M1,N1                                                 MATX  083
      J1=J1+1                                                        MATX  084
      PF = FLG18.GT.0.AND.J.GT.NMA.OR.FLG20.GT.0                     MATX  085
C                * COMPUTE X,Y,Z MATRICES                            MATX  086
      CALL XYZ                                                       MATX  087
  100 CONTINUE                                                       MATX  088
      GO TO K1, (102,110)                                            MATX  089
  102 IF (NLF(K).GT.0) GO TO 110                                     MATX  090
      IF (BON.EQ.0.) GO TO 105                                       MATX  091
      DO 103 J = M1, N1                                              MATX  092
      VN(I,K) = VN(I,K)+AXV(J)                                       MATX  093
  103 VT(I,K) = VT(I,K)+AYV(J)                                       MATX  094
      GO TO 110                                                      MATX  095
  105 DO 106 J = M1, N1                                              MATX  096
      VN(I,K) = VN(I,K) +AXV(J)*SINA(I) - AYV(J)*COSA(I)             MATX  097
  106 VT(I,K) = VT(I,K) +AXV(J)*COSA(I) + AYV(J)*SINA(I)             MATX  098
  110 J1=J1+1                                                        MATX  099
      IF( FLG08 .LE.0  .OR.  FLG15 .LE. 0 )GO TO 118                 MATX  100
C                                                                    MATX  101
C*** *  PRINT STRIP VORTEX MATRICES                                  MATX  102
C                                                                    MATX  103
      IF( I .EQ. 1  .AND.  BON .EQ. 0. )WRITE(6,111)                 MATX  104
      IF( I .EQ. 1  .AND.  BON .EQ. 1. )WRITE(6,112)                 MATX  105
```

```
  111 FORMAT(1H1,31H STRIP VORTEX MATRICES  ON BODY //)
  112 FORMAT(1H1,31H STRIP VORTEX MATRICES OFF BODY //)
      WRITF(6,114)I,( AXV(J),J=1,NT)
      WRITE(6,115)  ( AYV(J),J=1,NT)
  114 FORMAT(1H0,5H ROW,I4/9H X MATRIX / (6E20.7) )
  115 FORMAT(9H Y MATRIX / (6E20.7) )
  118 IF (BON)120,210,120
C               * SAVE X,Y,Z ON TAPE *OFF BODY POINTS
C***    ***SAVE X,Y,Z ON TAPE   *   OFF BODY POINTS
C***    ***AXISYMMETRIC FLOW   *   TAPE 9
C***    ***CROSS FLOW   *   TAPE 10
C***    ***EXTRA CROSS FLOW   *   TAPE 8
  120 IF(IEC.EQ.-1)GO TO 125
  122 WRITF(8) (ECX(J),J=1,NT), (ECY(J),J=1,NT), (FCZ(J),J=1,NT)
      IF (IEC) 125,400,125
  125 IF(IAC) 140,130,130
  130 WRITE (9) (AX(J),J=1,NT),(AY(J),J=1,NT),(AZ(J),J=1,NT)
      IF (IAC) 400,140,400
  140 WRITE (10)(CX(J),J=1,NT),(CY(J),J=1,NT),(CZ(J),J=1,NT)
      GO TO 400
C***    ***SAVE ON TAPE   *   ON BODY
C***    ***AXISYMMETRIC FLOW   *   TAPE 9
C***    ***CROSS FLOW   *   TAPE 10
C***    ***EXTRA CROSS FLOW   *   TAPE 8
C***    ***IEC = -1 MEANS NO EXTRA CROSS FLOW
  210 IF (IEC.EQ.-1) GO TO 240
  220 DO 230 J = 1,NT
      A(J) = -ECX(J) * SINA(I) + ECY(J) * COSA(I)
  230 B(J) = FCX(J) * COSA(I) + ECY(J) * SINA(I)
      WRITE (8) (A(J),J=1,NT), (B(J),J=1,NT), (ECZ(J),J=1,NT)
      IF ( IEC ) 240,400,240
  240 IF (IAC) 310,250,250
  250 DO 260 J=1,NT
      A(J)=-AX(J)*SINA(I)+AY(J)*COSA(I)
  260 B(J)=AX(J)*COSA(I)+AY(J)*SINA(I)
```

```
      WRITE (9) (A(J),J=1,NT),(B(J),J=1,NT),(AZ(J),J=1,NT)
  270 IF (IAC) 400,310,400
  310 DO 320 J=1,NT
      A(J)=-CX(J)*SINA(I)+CY(J)*COSA(I)
  320 B(J)=CX(J)*COSA(I)+CY(J)*SINA(I)
      WRITE (10) (A(J),J=1,NT),(B(J),J=1,NT),(CZ(J),J=1,NT)
  400 CONTINUE
      IF (FLG15.LE.0) GO TO 1400
      IF (BON.NE.0.) GO TO 1200
C*** ***ON BODY
      READ (4)
C
C*** *  IF FLG23 .GT. 0 INPUT NNU MUST BE NONE, HENCE NNU = 0 HERE
C
      IF (NNU.LE.0) GO TO 600
      DO 500 I = 1, NNU
      READ (4) MSF,(A(J),J=1,NT),(B(J),J=1,NT)
  500 WRITE (3) MSF,(A(J),J=1,NT),(B(J),J=1,NT)
      REWIND 3
      REWIND 4
      READ (4)
  600 N=NSIGA-1
      IF (FLG16.GT.1) N=NSIGA
C*** ***N = 0 MEANS 1 RHS ONLY  NO NON-UNIFORM FLOW
C*** *  IF FLG23 .GT. 0 INPUT NNU MUST BE NONE, HENCE N = 0  HERE
C
      IF (N.EQ.0) GO TO 800
      DO 700 I = 1, N
      READ (3) MSF,(A(J),J=1,NT),(B(J),J=1,NT)
  700 WRITE(4) MSF,(A(J),J=1,NT),(B(J),J=1,NT)
  800 M=0
C*** *  SKIP PRESCRIBED VORTEX INPUTS ON 4 Sn THAT STRIP VORTEX
C*** *  SUMMATIONS CAN GO BEHIND IT
C
      IF(FLG23 .GT. 0)READ(4)
```

```
      DO 900 J = 1, NB                                                  MATX
      IF (NLF(J).GT.0) GO TO 900                                        MATX
      NSIGA=NSIGA+1                                                     MATX
      NNU=NNU+1                                                         MATX
      WRITE (4) M,(VN(I,J),I=1,NT),(VT(I,J),I=1,NT)                     MATX
  900 CONTINUE                                                          MATX
C                                                                       MATX
C*** *  SINCE NO NNU IS INPUT WITH FLG23 GT 0, NSIGC IS MAX OF 1 AND M   MATX
C*** *  SHOLD BE 0 IF FLG17 LE 0.  DONT USE FLG17 WITH FLG23            MATX
C                                                                       MATX
      IF (FLG23 .LE. 0)GO TO 975                                        MATX
C                                                                       MATX
C*** *  RING WING OPTION - FORM COLUMN (PARTLY) FOR PRESCRIBED VORTICIY  MATX
C*** *RHS                                                               MATX
C                                                                       MATX
      IBOD = 0                                                          MATX
      DO 950 J=1,NB                                                     MATX
      IF( NLF(J) .GT. 0)GO TO 950                                       MATX
      IBOD = IBOD + 1                                                   MATX
C                                                                       MATX
C*** *  CONVERT (ON BODY) X,Y  TO NORMAL, TANGENTIAL                     MATX
C                                                                       MATX
      DO 925 I=1,NT                                                     MATX
      VAN(I) = VAN(I) + VA(I,IBOD)*SINA(I)  - VR(I,IBOD)*COSA(I)        MATX
  925 VAT(I) = VAT(I) + VA(I,IBOD)*COSA(I)  + VR(I,IBOD)*SINA(I)        MATX
      WRITE(4)(VAN(I),I=1,NT),(VAT(I),I=1,NT)                           MATX
  950 CONTINUE                                                          MATX
  975 M = NSIGC - 1                                                     MATX
      IF (FLG17.GT.0) M=NSIGC                                           MATX
      IF (M.LE.0) GO TO 1100                                            MATX
      DO 1000 I = 1, M                                                  MATX
      READ (3) MSF,(A(J),J=1,NT),(B(J),J=1,NT)                          MATX
 1000 WRITE (4) MSF,(A(J),J=1,NT),(B(J),J=1,NT)                         MATX
 1100 REWIND 3                                                          MATX
      GO TO 1400                                                        MATX
```

```
C*** ***OFF BODY
 1200 DO 1300 J = 1, NB
      IF (NLF(J).GT.0) GO TO 1300
      WRITE(4)  (VN(I,J), I = 1,L1), (VT(I,J),I = 1,L1)
 1300 CONTINUE
      IF(FLG23 .LE. 0)GO TO 1400
      IBOD = 0
      DO 1350 J=1,NB
      IF( NLF(J) .GT. 0)GO TO 1350
      IBOD = IBOD + 1
      WRITE(4) ( VA(I,IBOD),I=1,L1 ), ( VR(I,IBOD),I=1,L1)
 1350 CONTINUE
C              * TEST IF OFF BODY COMPLETED
C              * TEST IF OFF BODY
 1400 IF (FLG05.EQ.0.OR.BON.NE.0.) GO TO 1600
C              * INITIAL FOR OFF BODY * THEN RE-ENTER I,J LOOPS
      BON=1.
      L1=ND(NB+1)
      DO 1500 I = 1, L1
      X2(I) = XP(I)
 1500 Y2(I) = YP(I)
      GO TO 60
 1600 REWIND 9
      REWIND 8
      REWIND 10
      REWIND 4
      RETURN
      END
```

```
      SUBROUTINE XYZ
C
C              * CONTROL FOR X,Y,Z MATRICES COMPUTATION
C
      COMMON  /D/ D1, D3, XMXJ, YMYJ, XMXJP1, YMYJP1, S
      COMMON       HEDR(10)  ,CASE       ,NØ        ,NNU
     1            ,FLG03     ,FLG04      ,FLG05     ,FLG06     ,FLG07
     2            ,FLG08     ,FLG09      ,FLG10     ,FLG11     ,FLG12
     3            ,FLG13     ,FLG14      ,FLG15     ,FLG16     ,FLG17
     4            ,FLG18     ,FLG19      ,FLG20     ,FLG21     ,FLG22
     5            ,FLG23     ,FLG24      ,FLG25     ,FLG26     ,FLG27
      COMMON    NT,         ND(11),     MN,        NUNA(5),  TYPEA(5),
     1          NER1,       NER2,       NMA,       NSIGA,    NSIGC,
     2          NUNC(5),    TYPEC(5),   NLF(11),   IEC,      NSIGEC,
     3          TYPFEC(5),NUNEC(5)
C     DOUBLE PRECISION  HEDR, CASE
      INTEGER      FLG03     ,FLG04      ,FLG05     ,FLG06     ,FLG07
     1            ,FLG08     ,FLG09      ,FLG10     ,FLG11     ,FLG12
     2            ,FLG13     ,FLG14      ,FLG15     ,FLG16     ,FLG17
     3            ,FLG18     ,FLG19      ,FLG20     ,FLG21     ,FLG22
     4            ,FLG23     ,FLG24      ,FLG25     ,FLG26     ,FLG27
      REAL         MN
      LOGICAL PF
C
      COMMON  /RNGWNG/ VA(100,2),  VR(100,2),VAN(100), VAT(100)
      COMMON /CL/    X1(100),  Y1(100),  X2(100),  Y2(100),  DELS(100),
     1               SINA(100),COSA(100),XP(100),  YP(100)
     2              ,XWAKE(11),YWAKE(11)
      COMMON /TL/    A(100),   B(100),   AX(100),  AY(100),  AZ(100),
     1               CX(100),  CY(100),  CZ(100),  AXV(100),AYV(100),
     2               VN(100,5),VT(100,5),BON,                IAC,
     3               I,        J,        J1,       SJ,       DS,
     4               DX,       DY,       NI,       XJ,       YJ,
     5               XK,       EEK,      EKK,      K,        PF
C
```

```
C                * START                                              XYZ
      IF (BON) 100,10,100                                             XYZ
   10 IF (J-I) 110,20,110                                             XYZ
C                * J EQUAL I PATH                                     XYZ
   20 T1=.5*DELS(J)                                                   XYZ
      SJ=T1/Y2(J)                                                     XYZ
      IF (SJ-.08) 30,30,40                                            XYZ
   30 CALL XYZ1                                                       XYZ
      GO TO 1000                                                      XYZ
   40 SJ=.08                                                          XYZ
      CALL XYZ1                                                       XYZ
      NI=33                                                           XYZ
      T2=.08*Y2(J)                                                    XYZ
      DS=(T1-T2)/32.                                                  XYZ
      DX=DS*COSA(J)                                                   XYZ
      DY=DS*SINA(J)                                                   XYZ
      XJ=X2(J)+T2*COSA(J)-DX                                          XYZ
      YJ=Y2(J)+T2*SINA(J)-DY                                          XYZ
      CALL XYZ2                                                       XYZ
      GO TO 300                                                       XYZ
C                * INITIAL Y COORDINATE MID-POINT FOR ZERO TEST       XYZ
  100 YZERO=Y2(I)-.000001                                             XYZ
C                * J NOT EQUAL I PATH                                 XYZ
C                * COMPUTE MINIMUM DISTANCE TO I MIDPOINT             XYZ
  110 J1P1 = J1 + 1                                                   XYZ
      XMXJ = X2(I) - X1(J1)                                           XYZ
      YMYJ = Y2(I) - Y1(J1)                                           XYZ
      XMXJP1 = X2(I) - X1(J1P1)                                       XYZ
      YMYJP1 = Y2(I) - Y1(J1P1)                                       XYZ
      D1 = XMXJ**2 + YMYJ**2                                          XYZ
      D2=(X2(I)-X2(J))**2+(Y2(I)-Y2(J))**2                            XYZ
      D3 = XMXJP1**2 + YMYJP1**2                                      XYZ
      S = SQRT( (X1(J1P1) - X1(J1) )**2  +   ( Y1(J1P1) - Y1(J1) )**2 )  XYZ
      IF (D1-D2) 130,130,120                                          XYZ
  120 IF (D2-D3) 150,150,140                                          XYZ
```

```
  130 IF (D1-D3) 160,160,140
  140 DM=SQRT(D3)
      GO TO 170
  150 DM=SQRT(D2)
      GO TO 170
  160 DM=SQRT(D1)
C                * COMPUTE NO. OF INTERVALS(NI) AND DELTA S (DS)
C                  FOR SIMPSON RULE INTEGRATION
  170 IF (DM.EQ.0.0) GO TO 200
      NI=8.*DELS(J)/DM+0.9
      IF (NI) 180,180,190
  180 NI=3
      DS=DELS(J)/2.
      GO TO 220
  190 NI=NI+NI
      IF (NI-128) 210,200,200
  200 NI=129
      DS=DELS(J)/128.
      GO TO 220
  210 XNI=NI
      DS=DELS(J)/XNI
      NI=NI+1
  220 DX=DS*COSA(J)
      DY=DS*SINA(J)
  300 XJ=X1(J1)-DX
      YJ=Y1(J1)-DY
      CALL XYZ2
 1000 RETURN
      END
```

```
      SUBROUTINE XYZ1                                                   XYZ1  001
C                                                                       XYZ1  002
C            * COMPUTE X,Y,Z MATRICES FOR SJ LESS THAN OR EQUAL  .08    XYZ1  003
C                                                                       XYZ1  004
      COMMON        HEDR(10)   ,CASE      ,NB        ,NNU               XYZ1  005
     1             ,FLG03     ,FLG04     ,FLG05     ,FLG06     ,FLG07    XYZ1  006
     2             ,FLG08     ,FLG09     ,FLG10     ,FLG11     ,FLG12    XYZ1  007
     3             ,FLG13     ,FLG14     ,FLG15     ,FLG16     ,FLG17    XYZ1  008
     4             ,FLG18     ,FLG19     ,FLG20     ,FLG21     ,FLG22    XYZ1  009
     5             ,FLG23     ,FLG24     ,FLG25     ,FLG26     ,FLG27    XYZ1  010
      COMMON   NT,        ND(11),    MN,        NUNA(5),   TYPEA(5),    XYZ1  011
     1         NER1,      NER2,      NMA,       NSIGA,     NSIGC,       XYZ1  012
     2         NUNC(5),   TYPEC(5),  NLF(11),   IEC,       NSIGEC,      XYZ1  013
     3         TYPEEC(5),NUNEC(5)                                       XYZ1  014
C     DOUBLE PRECISION  HEDR, CASE                                      XYZ1  015I
      INTEGER       FLG03     ,FLG04     ,FLG05     ,FLG06     ,FLG07    XYZ1  016
     1             ,FLG08     ,FLG09     ,FLG10     ,FLG11     ,FLG12    XYZ1  017
     2             ,FLG13     ,FLG14     ,FLG15     ,FLG16     ,FLG17    XYZ1  018
     3             ,FLG18     ,FLG19     ,FLG20     ,FLG21     ,FLG22    XYZ1  019
     4             ,FLG23     ,FLG24     ,FLG25     ,FLG26     ,FLG27    XYZ1  020
      COMMON   /RNGWNG/ VA(100,2),  VR(100,2),VAN(100), VAT(100)        XYZ1  021
      COMMON /ECF/ ECX(100), ECY(100), ECZ(100)                         XYZ1  022
      REAL          MN                                                  XYZ1  023
      LOGICAL PF                                                        XYZ1  024
C                                                                       XYZ1  025
      COMMON /CL/   X1(100),  Y1(100),  X2(100),  Y2(100),  DELS(100),  XYZ1  026
     1              SINA(100),COSA(100),XP(100),  YP(100)               XYZ1  027
     2             ,XWAKE(11),YWAKF(11)                                 XYZ1  028
      COMMON /TL/   A(100),   B(100),   AX(100),  AY(100),  AZ(100),    XYZ1  029
     1              CX(100),  CY(100),  CZ(100),  AXV(100),AYV(100),    XYZ1  030
     2              VN(100,5),VT(100,5),BON,                IAC,        XYZ1  031
     3              I,        J,        J1,       SJ,       DS,         XYZ1  032
     4              DX,       DY,       NI,       XJ,       YJ,         XYZ1  033
     5              XK,       FEK,      EKK,      K,        PF          XYZ1  034
C                                                                       XYZ1  035
```

```
C                 * START
C                 * INITIALIZE
      T1=SJ*SJ
      T2=ALOG(SJ/8.)
      T3=SINA(J)*SINA(J)
      T4=T2+T3
      T5=.6666667   *T3
      T6=T5*T3
      T7=SJ+SJ
      T8=T7+T7
       T9=6.283185 *COSA(J)
      T10=6.283185 *SINA(J)
      T11=T1*SJ
      T14 = .3333333 * (16.0 + 6.0 * T3) + 2.0 * T2
      IF (IEC.EQ.-1) GO TO 15
C***   ***EXTRA CROSS FLOW   1ST TERM OF X(I,I), Y(I,I), Z(I,I)
   10 ECX(J) = 6.283185 * SINA(J) + 2.0 * SINA(J) * COSA(J) * SJ
      ECY(J) =-6.283185 * COSA(J) + SJ * T14
      ECZ(J) = -8.0 * (1.666667 + T2) * SJ
      IF (IEC) 15,1000,15
   15 IF(PF) GO TO 25
      IF (IAC) 30,20,20
C                 * AXIS FLOW
   20 AX(J)=T10+SINA(J)*COSA(J)*(T7+(T4+2.166667   )*T11/12.)
      AY(J)=T7*T4-T9-(1.+T2-T3-T6)*T11/8.
      T12=T1+T1
      AZ(J)=Y2(J)*T8*(1.-T2+T1*(2.-T12+3.*T2*(1.+T12))/144.)
   25 IF (IAC) 30,30,100
C                 * CROSS FLOW
   30 T13=T1/16.
      CX(J)=T10+2.*SINA(J)*SJ*COSA(J)*(1.-T13*(3.-T5+T2+T2))
      CY(J)=-T9+T7*(2.+T4+T13*(1.-4.777778   *T3+T6+T2*(3.-2.666667   *
     1                T3)))
      CZ(J)=-T8*(1.+T2-T13*(1.111111   *T3+T2*(T5-1.)))
  100 IF (PF) GO TO 200
```

```
      IF (FLG15.LE.0.OR.NLF(K).GT.0) GO TO 1000
  200 AXV(J) = T9+T7*(T2-T3)+T11*(T2*(12.*T3-9.)
     1          -9. + 23.*T3 - 6.*T3*T3) / 72.
      AYV(J) = T10 + 2.*COSA(J)*SINA(J)*(SJ-T11*(6.*T2+9.-2.*T3)/48. )
      IF (.NOT.PF) GO TO 1000
      AX(J) = AXV(J)
      AY(J) = AYV(J)
C
C*** *  RING WING OPTION PV EFFECTS ON ITSELF NEGLECTS 2*PI TERMS
C
      IF(FLG23 .LE. 0)GO TO 1000
      AX(J) = AX(J) - T9
      AY(J) = AY(J) - T10
      AYV(J)=AY(J)
      AXV(J)=AX(J)
 1000 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE XYZ2
C
C              * COMPUTE X,Y,Z MATRICES USING SIMPSON RULE INTEGRATION
C
      REAL LIJ2D
      COMMON /D/ R1SQR, R2SQR, XMXJ, YMYJ, XMXJP1, YMYJP1, S
      COMMON      HEDR(10)  ,CASE       ,NB         ,NNU
     1            ,FLG03     ,FLG04      ,FLG05      ,FLG06      ,FLG07
     2            ,FLG08     ,FLG09      ,FLG10      ,FLG11      ,FLG12
     3            ,FLG13     ,FLG14      ,FLG15      ,FLG16      ,FLG17
     4            ,FLG18     ,FLG19      ,FLG20      ,FLG21      ,FLG22
     5            ,FLG23     ,FLG24      ,FLG25      ,FLG26      ,FLG27
      COMMON   NT,        ND(11),    MN,        NUNA(5),  TYPEA(5),
     1         NER1,      NER2,      NMA,       NSIGA,    NSIGC,
     2         NUNC(5),   TYPEC(5),  NLF(11),   IEC,      NSIGEC,
     3         TYPEEC(5),NUNEC(5)
C     DOUBLE PRECISION  HEDR, CASE
      INTEGER     FLG03     ,FLG04      ,FLG05      ,FLG06      ,FLG07
     1            ,FLG08     ,FLG09      ,FLG10      ,FLG11      ,FLG12
     2            ,FLG13     ,FLG14      ,FLG15      ,FLG16      ,FLG17
     3            ,FLG18     ,FLG19      ,FLG20      ,FLG21      ,FLG22
     4            ,FLG23     ,FLG24      ,FLG25      ,FLG26      ,FLG27
      COMMON /ECF/ ECX(100), ECY(100), ECZ(100)
      COMMON  /RNGWNG/ VA(100,2),  VR(100,2),VAN(100), VAT(100)
      DATA NSW /1/
C***   ***RSMALL WILL BE TRUE IF IS .LT. EPS      AND THEREFORE SMALL EL
      LOGICAL RSMALL
      REAL        MN
      LOGICAL PF
C
      COMMON /CL/   X1(100),  Y1(100),  X2(100),  Y2(100),  DELS(100),
     1              SINA(100),COSA(100),XP(100),  YP(100)
     2             ,XWAKE(11),YWAKE(11)
      COMMON /TL/   A(100),   B(100),   AX(100),  AY(100),  AZ(100),
     1              CX(100),  CY(100),  CZ(100),  AXV(100),AYV(100),
```

```
     2              VN(100,5),VT(100,5),BON,              IAC,                     XYZ2  036
     3              I,        J,        J1,        SJ,        DS,                 XYZ2  037
     4              DX,       DY,       NI,        XJ,        YJ,                 XYZ2  038
     5              XK,       EEK,      EKK,       K,         PF                  XYZ2  039
C                                                                                 XYZ2  040
C               * START                                                           XYZ2  041
C               * INITIALIZE                                                      XYZ2  042
      EPS = 0.0                                                                   XYZ2  043
      ASSIGN 570 TO K1                                                            XYZ2  044
C*** ***K5 = 80 FOR NON-SMALL ELEMENT AXISYMMETRIC                                 XYZ2  045
      ASSIGN 80 TO K5                                                             XYZ2  046
C***   ***K6 = 295 FOR NON SMALL ELEMENT   CROSS FLOW                             XYZ2  047
      ASSIGN 295 TO K6                                                            XYZ2  048
      IF (FLG15.LE.0.OR.NLF(K).GT.0) GO TO 15                                     XYZ2  049
   10 ASSIGN 420 TO K1                                                            XYZ2  050
   15 S2=.6666667  *DS                                                            XYZ2  051
      S1 = .3333333 * DS                                                          XYZ2  052
      S3 = 8.0/3.0 * S1                                                           XYZ2  053
      S5 = .3333333 * S1                                                          XYZ2  054
      S4 = S2+S2                                                                  XYZ2  055
      T1=Y2(I)*Y2(I)                                                              XYZ2  056
      ASSIGN 28 TO K2                                                             XYZ2  057
      ASSIGN 410 TO K3                                                            XYZ2  058
      ASSIGN 570 TO K4                                                            XYZ2  059
      IF( .NOT. PF  ) GO TO 12                                                    XYZ2  060
      ASSIGN 110 TO K2                                                            XYZ2  061
      ASSIGN 420 TO K3                                                            XYZ2  062
      ASSIGN 560 TO K4                                                            XYZ2  063
   12 IF ( (I .NE. J) .OR. (BON .NE. 0.0) ) GO TO 16                              XYZ2  064
C*** ***I = J ** ON BODY                                                           XYZ2  065
      R = DELS(I) / 2.0                                                           XYZ2  066
      RSMALL = ( R / Y2(I) ) .LT. EPS                                             XYZ2  067
      NSW = 2                                                                     XYZ2  068
      GO TO 17                                                                    XYZ2  069
   16 R = SQRT( AMAX1(R1SQR,R2SQR) )                                              XYZ2  070
```

```
      IF( ABS(Y2(I) ) .LT. 10E-30)GO TO 13
      RSMALL = ( R / Y2(I) ) .LT. EPS
      GO TO 17
   13 RSMALL = .FALSE.
   17 IF( .NOT. RSMALL) GO TO 19
C*** ***SMALL ELEMENT -- FORM XIJ2D, YIJ2D, LIJ
C
C*** ***K5 = 105 FOR SMALL ELEMENT AXISYMMETRIC
      ASSIGN 105 TO K5
C***   ***K6 = 320 FOR SMALL ELEMENT   CROSS FLOW
      ASSIGN 320 TO K6
C*** ***NSW = 1  FOR I NE J
C*** ***NSW = 2  FOR I EQ J 1ST TIME THROUGH
C*** ***NSW = 3  FOR I EQ J 2ND TIME THROUGH
      GO TO (14, 21, 22), NSW
C
C*** ***I = J  1ST TIME THROUGH
   21 XLEFT = XJ + DX
      YLEFT = YJ + DY
      J1P1  = J + 1
      XRIGHT = X1(J1P1)
      YRIGHT = Y1(J1P1)
C*** ***GET NSW READY FOR I = J  2ND TIME THROUGH
      NSW = 3
      GO TO 23
C*** ***I = J   2ND TIME THROUGH
   22 XLEFT = X1(J1)
      YLEFT = Y1(J1)
      XRIGHT = XLEFT + 32.0 * DX
      YRIGHT = YLEFT + 32.0 * DY
      NSW = 1
C*** ***CALCULATE QUANTITIES WHICH HAVE NOT YET BEEN CALCULATED FOR I=4
   23 XMXJ = X2(I) - XLEFT
      YMYJ = Y2(I) - YLEFT
      XMXJP1 = X2(I) - XRIGHT
```

```
      YMYJP1 = Y2(I) - YRIGHT
      RLFFT = R
      RRIGHT = R
      S = SQRT( (XLEFT - XRIGHT)**2  + (YLEFT - YRIGHT)**2 )
      GO TO 11
C*** ***I NE J  SMALL FLEMENT
   14 RLEFT = R1SQR
      RRIGHT = R2SQR
C*** ***NOW FORM XIJ2D, YIJ2D, LIJ
   11 H = (-XMXJ * SINA(J) ) + ( YMYJ * COSA(J) )
      FL1 = (XMXJ * COSA(J) )+ ( YMYJ * SINA(J) )
      EL2 = (XMXJP1 * COSA(J) ) + (YMYJP1 * SINA(J) )
      DPHIDX =-ALOG (RLEFT / RRIGHT)
      IF(ABS(H/EL1) .LT. 10.0E-10)GO TO 7
      DPHIDY = -2.0 * ( ATAN(EL1/H) - ATAN(EL2/H) )
      GO TO 8
    7 DPHIDY = 0.0
      IF( (EL1 * EL2) .LT. 0.0) DPHIDY = -6.283186
    8 XIJ2D = (COSA(J)*DPHIDX) - (SINA(J)*DPHIDY)
      YIJ2D = (SINA(J)*DPHIDX) + (COSA(J)*DPHIDY)
      LIJ2D = ( (-(EL1 + EL2) / 4.0 ) * DPHIDX )
     1      + ( (S/4.0) * ALOG( (RLEFT *RRIGHT) / ( 4096.0 * T1**2) ) )
     2         -S  - ( (H/2.0) * DPHIDY )
C                * NO. OF INTERVAL LOOP
   19 DO 1000 IS=1,NI
      XJ=XJ+DX
      YJ=YJ+DY
      T2=YJ*YJ
      T3=X2(I)-XJ
      T4=T3*T3
      T5=(Y2(I)+YJ)**2
      T6=T4+T5
      T7=SQRT(T6)
      T8=T2+T4
      T9A = Y2(I) - YJ
```

```
      T9 = T9A**2
      T10=T9+T4
      T10A = SQRT(T10)
C
C   ***   IF DENOM  (T8)   IS ZERO THEN MAKE T21 FAIL ALL TESTS
C
      IF( ABS(T8) .LT. 10.0E-30)GO TO 29
      T21 = SQRT( T1 / T8 )
      GO TO 27
   29 T21 = 0.10
C                 * COMPUTE ELLIPIC INTEGRAL
   27 IF(RSMALL  .AND.  FLG21 .EQ. 0)GO TO 18
      XK=4.*YJ*Y2(I)/T6
      CALL ELIP
      IF ( IEC ) 18,575,18
   18 IF (IAC) 200,20,20
C                 * AXIS FLOW
   20 IF (RSMALL)GO TO 25
      T11 = YJ/T7
      IF ( T21.LT.0.01) GO TO 24
      T12 = YJ/Y2(I)
      FV2 = (EKK+EEK*(T1-T8)/T10)/T7
      FV3 = Y2(I)/T10 * T3/T7 * EEK
      F1 = FV3*T12
      F2 = FV2*T12
      FV4 = FV2*T3/Y2(I)
      F3=T11*EKK
      GO TO 26
   24 FV2 = 0.
      FV3 = 0.
      FV4 = 0.
C***   ***SMALL Y FORMULAS AXISYMMETRIC FLOW
      T23 = T1 / T8**2
      T24 = 2.0 * T4 - T2
      F1 = ( (   1.570796  * YJ * T3 ) / ( T8**1.5      ) ) *
```

```
     1  ( 1.0 + ( .75 * ( 3.0 * T2 - 2.0 * T4 ) * T23 ) )
      F2 = (    1.570796   * YJ * Y2(I) ) * ( T24 / (T8**2.5          ) )
      F3 = 1.570796 * YJ * ( 1.0 + (.25 * T23 * (-T24) ) ) / SQRT(T8 )
      GO TO 26
   25 T32 = T3 / T10A
      T33 = T9A / T10A
      T34 = T33**2
      T35A = T10A / (8.0 * Y2(I) )
      T35 = ALOG(T35A)
      T36 = T9A/Y2(I)
      T40  = T10A / Y2(I)
      T37 = (T40**2)*0.125
      T38 = 0.250*T36*T35
      T39 = 0.125*T36
      T34A = 2.0*T34
      T34B = T34A + 3.0
      F1 = ( -2.0 * T32 * ( (-T35A * T35) - (0.5 * T33)
     1     -( (T40/16.0) * T34B ) ) ) / Y2(I)
      F2 =-( (0.25 * T36 * T35) -T34 -1.0 - (T39 * T34B) ) / Y2(I)
      F3 = ( T35 * ( T36 + (0.25 * T36**2) + T37 ) ) -T36 +T37
   26 GO TO K2, (28,110)
C                 * SIMPSON RULE INTEGRATION
   28 IF (IS-1) 30,30,40
C                 * FIRST PASS
   30 AXS=F1
      AYS=F2
      AZS=F3
      IA=0
      GO TO 110
   40 IF(IS.EQ.NI)GO TO 75
   50 IF (IA) 70,60,70
C                 * EVEN PASS
   60 AXS=AXS+4.*F1
      AYS=AYS+4.*F2
      AZS=AZS+4.*F3
```

```
      IA=1
      GO TO 110
C                * ODD PASS
   70 AXS=AXS+F1+F1
      AYS=AYS+F2+F2
      AZS=AZS+F3+F3
      IA=0
      GO TO 110
   75 GO TO K5, (80,105)
C                * LAST PASS
   80 IF (J-I) 100,90,100
   90 IF (BON.NE.0.0) GO TO 100
      AX(J)=AX(J)-S4*(AXS+F1)
      AY(J)=AY(J)-S2*(AYS+F2)
      AZ(J)=AZ(J)+S4*(AZS+F3)
      GO TO 110
  100 AX(J)=-S4*(AXS+F1)
      AY(J)=-S2*(AYS+F2)
      AZ(J)=S4*(AZS+F3)
      GO TO 110
C*** ***LAST PASS  *  SMALL ELEMENT
  105 IF( (J .NE.I) .OR. (BON .NE. 0.0) )GO TO 107
C*** ***I = J   ON BODY
      AX(J) = AX(J) + XIJ2D + (AXS + F1) * S1
      AY(J) = AY(J) + YIJ2D + (LIJ2D / Y2(I) ) + (AYS + F2) * S1
      AZ(J) = AZ(J) -(2.0 * LIJ2D) + (AZS + F3) * S1
      GO TO 110
C*** ***I NE J   ON OR OFF BODY
  107 AX(J) = XIJ2D  + (AXS + F1) * S1
      AY(J) = YIJ2D + (LIJ2D / Y2(I) ) + (AYS + F2) * S1
      AZ(J) = -2.0 * LIJ2D + (AZS + F3)  * S1
  110 IF (IAC) 200,200,400
C                * CROSS FLOW
  200 IF (RSMALL)GO TO 223
      IF (T21 .LT. 0.04)GO TO 220
```

```
      T12 = T1 + T8
      F1=T3/Y2(I)*(EKK-EEK*T12/T10)/T7
      F2=(EEK*(T8*T8+T1*(T4-T2))/T10-EKK*T8)/T1/T7
      F3=T7*(EKK*T12/T6-EEK)/T1
      GO TO 230
C***   ***SMALL Y FORMULAS   *   CROSS FLOW
  220 T23 = T1 / T8**2
      T29 = ( 1.570796 * T2 ) / ( T8**1.5      )
      T26 = 4.0 * T4 - T2
      T31 = T26 * T23
      F1 = ( (-4.712389) * T2 * T3 * Y2(I) ) / ( T8**2.5        )
      F2 = T29 * ( 1.0 - (1.125 * T31 ) )
      F3 = T29 * ( 1.0 - (.375 * T31) )
      GO TO 230
C*** ***IAC LT 0 MEANS NO AXISYMMETRIC FLOW
  223 IF(IAC)225,227,227
C*** ***CALCULATE SMALL ELEMENT QUANTITIES THAT DID NOT GET CALCULATED
C*** ***BECAUSE THERE WAS NO AXISYMMETRIC FLOW
  225 T32 = T3 / T10A
      T33 = T9A / T10A
      T34 = T33**2
      T35A = T10A / (8.0 * Y2(I) )
      T35 = ALOG(T35A)
      T36 = T9A/Y2(I)
      T40  = T10A / Y2(I)
      T37 = (T40**2)*0.125
      T38 = 0.250*T36*T35
C*** ***CALCULATE SMALL ELEMENT F1,F2,F3  CROSS FLOW
  227 T38A = -5.0 * T38
      T40A = T40**2
      T36A = T36**2
      F1 = (T32 / Y2(I)) * ( (-0.75 * T40 * T35) + T33
     1   +(0.125 * T40 * (2.0 * T34 -5.0) ) )
      F2 = ( T38A + T34 + 3.0 + (0.25 * T36 * (T34 - 6.50) ) ) / Y2(I)
      F3 = ( ( T36 - (0.375 * T40A) - (0.25 * T36A) ) * T35 -4.0 +T36
```

```
      1      =(0.50 * T36A) - T37 ) / Y2(I)
C                  * SIMPSON RULE INTEGRATION
  230 IF (IS-1) 240,240,250
C                  * FIRST PASS
  240 CXS=F1
      CYS=F2
      CZS=F3
      IC=0
      GO TO 400
  250 IF (IS-NI) 260,290,260
  260 IF (IC) 280,270,280
C                  * EVEN PASS
  270 CXS=CXS+4.*F1
      CYS=CYS+4.*F2
      CZS=CZS+4.*F3
      IC=1
      GO TO 400
C                  * ODD PASS
  280 CXS=CXS+F1+F1
      CYS=CYS+F2+F2
      CZS=CZS+F3+F3
      IC=0
      GO TO 400
  290 GO TO K6,(295,320)
C                  * LAST PASS
  295 IF(J .NE. I)GO TO 310
  300 IF (RON.NE.0.0) GO TO 310
      CX(J)=CX(J)+S2*(CXS+F1)
      CY(J)=CY(J)+S2*(CYS+F2)
      CZ(J)=CZ(J)+S2*(CZS+F3)
      GO TO 400
  310 CX(J)=S2*(CXS+F1)
      CY(J)=S2*(CYS+F2)
      CZ(J)=S2*(CZS+F3)
      GO TO 400
```

```
  320 IF ( (I.NE.J) .OR. (BON .NE. 0.0) ) GO TO 340
C*** ***LAST PASS   SMALL ELEMENT   I=J  ON BODY
      CX(J) = CX(J) + XIJ2D + (CXS + F1) * S1
      CY(J) = CY(J) + YIJ2D + (LIJ2D / Y2(I)) + (CYS + F2) * S1
      CZ(J) = CZ(J) -(2.0 * LIJ2D / Y2(I) )    + (CZS + F3) * S1
      GO TO 400
C*** ***I NE J OR ANY OFF BODY
  340 CX(J) = XIJ2D + (CXS + F1) * S1
      CY(J) = YIJ2D + (LIJ2D/Y2(I)) +(CYS + F2) * S1
      CZ(J) = -(2.0 * LIJ2D / Y2(I) ) + (CZS + F3) * S1
C*** ***K3 = 420 FOR SURFACE VORTICITY   PF TRUE
  400 GO TO K3,(410,420)
C*** ***K1 = 420 FOR STRIP VORTEX
  410 GO TO K1, (570,420)
C*** ***FLOW OF CONTROL REACHES HERE FOR (PF=TRUE) OR ( (FLG15 GT 0 AND
C*** ***NLF LE 0 (LIFTING BODY)) AND (I NE J ON BODY OR ANY OFF BODY) )
  420 IF (RSMALL)GO TO 542
      FV1 = (T2-T1) / T7  * EEK / T10
      IF (IS.GT.1) GO TO 440
C              * FIRST PASS
      AX1 = FV1
      AX2 = FV2
      AY1 = FV3
      AY2 = FV4
      IV=0
      GO TO 570
  440 IF (IS.EQ.NI) GO TO 500
      IF (IV) 460,450,460
C              * EVEN PASS
  450 AX1 = AX1+4.*FV1
      AX2 = AX2+4.*FV2
      AY1 = AY1+4.*FV3
      AY2 = AY2+4.*FV4
      IV=1
      GO TO 570
```

```
C                 * ODD PASS
  460 AX1 = AX1+FV1+FV1
      AX2 = AX2+FV2+FV2
      AY1 = AY1+FV3+FV3
      AY2 = AY2+FV4+FV4
      IV = 0
      GO TO 570
C                 * LAST PASS
  500 IF (J-I) 540,520,540
  520 IF (BON.NE.0.) GO TO 540
      AXV(J) = AXV(J) - S4*(AX1+FV1) - S2*(AX2+FV2)
      AYV(J) = AYV(J) - S4*(AY1+FV3) + S2*(AY2+FV4)
      GO TO 550
  540 AXV(J) = -S4*(AX1+FV1) -S2*(AX2+FV2)
      AYV(J) = -S4*(AY1+FV3) +S2*(AY2+FV4)
      GO TO 550
  542 T34C = T34B - 8.0
      FV1 = ( T38 + (T32**2) - (T39 * T34C) ) / Y2(I)
      FV2 = ( T32 / Y2(I) ) * ( (-0.75 * T40 * T35) +T33
     1      +(0.125 * T40 * T34C) )
      IF (IS .GT.1)GO TO 544
C*** ***FIRST PASS  SMALL ELEMENT
      AX1 = FV1
      AY1 = FV2
      IV = 0
      GO TO 570
  544 IF(IS .EQ. NI)GO TO 548
      IF(IV .NE. 0 )GO TO 546
C*** ***EVEN PASS   SMALL ELEMENT
      AX1 = AX1 + 4.0* FV1
      AY1 = AY1 + 4.0* FV2
      IV = 1
      GO TO 570
C*** ***ODD PASS    SMALL ELEMENT
  546 AX1 = AX1 + FV1 + FV1
```

```
      AY1 = AY1 + FV2 + FV2
      IV = 0
      GO TO 570
C*** ***LAST PASS   SMALL ELEMENT
  548 IF ( (I .NE. J) .OR. (BON .NE. 0.0) )GO TO 549
C*** ***I = J   ON  BODY
      AXV(J) = AXV(J) - YIJ2D + (LIJ2D / Y2(I) ) + (AX1 + FV1)*S1
      AYV(J) = AYV(J) + XIJ2D + (AY1 + FV2)*S1
      GO TO 550
C*** ***I NE J  OR  ANY OFF BODY
  549 AXV(J) = -YIJ2D  + (LIJ2D / Y2(I) ) + (AX1 + FV1)*S1
      AYV(J) = XIJ2D +(AY1 + FV2)*S1
C*** ***K4 = 560 FOR SURFACE VORTICITY   PF TRUE
  550 GO TO K4,(560,570)
C*** ***FLOW OF CONTROL REACHES HERE IF PF IS TRUE
  560 AX(J) = AXV(J)
      AY(J) = AYV(J)
  570 IF (IEC.EQ.-1) GO TO 1000
  575 IF (T21.LT.0.08)GO TO 595
  580 T20 = SQRT( T2 / (T1 + T4) )
      IF (T20.LT.0.01) GO TO 590
      T13 = YJ * Y2(I)**3
      T14 = T1 + T8
      T15 = T2 * T1
      T16 = T14 * T14
      T17 = T1 * YJ
      T18 = T1 * T1
      T19 = T8 * T8
      F3 = ( T7/T13 ) * ( (-T14) * EFK + ( ( (T16 - T15) * EKK) / T6 ) )
      F1 =(T3 / (T17 *T7) ) * ( (EFK / T10 ) * (T16 - 3.0 * T15) -
     1  (T14 * EKK) )
      TEMP1 =((-8.0*T8**3) - (12.0*T1*T19) + (26.0*T15*T8)
     1    + (2.0*T18*(2.0*T1 -5.0*T2) ))* EFK/T10
      TEMP2 = EKK * ( (8.0*T19) + (4.0*T1*T8) - (2.0*T15) - (4.0*T18) )
      F2 = (TEMP1 + TEMP2) / ( T13 * T7)
```

```
      GO TO 630
C***   ***SMALL YJ FORMULAS    *    FXTRA CROSS FLOW
  590 T25 = YJ**3
      T30 = T4 + T1
      T27 = T30**3.5
      T28 = T25 * Y2(I)
      F1 = (    2.945243   * T25 * T3 * T1) / T27
      F2 =    7.068584   * T28 * ( 3.0 * T1   -  2.0 * T4 ) / T27
      F3 = 1.767146 * T28 /(T30**2.5      )
      GO TO 630
C***   ***SMALL Y FORMULAS    *    EXTRA CROSS FLOW
  595 T25 =  YJ**3
      F1 = (    2.945243   * T25 * T3 * T1 ) / ( T8**3.5         )
      F2 = ( (-14.13717) * T25 * Y2(I) ) / (T8**2.5)
      F3 = -F2 / 8.0
C***   ***SIMPSON*S RULE
  630 IF (IS - 1) 640,640,650
C***   ***FIRST PASS
  640 ECXS = F1
      ECYS = F2
      ECZS = F3
      IE = 0
      GO TO 1000
  650 IF (IS - NI) 660,690,660
  660 IF ( IE ) 680,670,680
C***   ***FVEN PASS
  670 ECXS = ECXS + 4.0 * F1
      ECYS = ECYS + 4.0 * F2
      ECZS = ECZS + 4.0 * F3
      IE = 1
      GO TO 1000
C***   ***ODD PASS
  680 ECXS = ECXS + F1 + F1
      ECYS = ECYS + F2 + F2
      ECZS = ECZS + F3 + F3
```

```
      IE = 0
      GO TO 1000
C***   ***LAST PASS
  690 IF(J - I) 710,700,710
C***   ***I=J      *       ELEMENTS ON MAIN DIAGONAL
  700 IF (BON.NE.0.0) GO TO 710
      ECX(J) = ECX(J) -S4 * ( ECXS + F1 )
      ECY(J) = ECY(J) -S5 * ( ECYS + F2 )
      ECZ(J) = ECZ(J) +S3 * ( ECZS + F3 )
      GO TO 1000
C***   ***OFF MAIN DIAGONAL OR OFF BODY POINTS
  710 ECX(J) = -S4 * ( ECXS + F1 )
      ECY(J) = -S5 * ( ECYS + F2 )
      ECZ(J) =  S3 * ( ECZS + F3 )
 1000 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ELIP                                                   ELIP 001
C                                                                       ELIP 002
C               * HASTINGS APPROXIMATION FOR FLLIPTIC INTERGALS         ELIP 003
C                                                                       ELIP 004
      COMMON      HEDR(10)  ,CASE      ,NB        ,NNU                  ELIP 005
     1           ,FLG03    ,FLG04     ,FLG05     ,FLG06     ,FLG07      ELIP 006
     2           ,FLG08    ,FLG09     ,FLG10     ,FLG11     ,FLG12      ELIP 007
     3           ,FLG13    ,FLG14     ,FLG15     ,FLG16     ,FLG17      ELIP 008
     4           ,FLG18    ,FLG19     ,FLG20     ,FLG21     ,FLG22      ELIP 009
     5           ,FLG23    ,FLG24     ,FLG25     ,FLG26     ,FLG27      ELIP 010
      COMMON    NT,        ND(11),    MN,       NUNA(5),  TYPEA(5),     ELIP 011
     1          NER1,      NER2,      NMA,      NSIGA,    NSIGC,        ELIP 012
     2          NUNC(5),   TYPEC(5),  NLF(11),  IEC,      NSIGEC,       ELIP 013
     3          TYPEEC(5),NUNEC(5)                                      ELIP 014
C     DOUBLE PRECISION  HEDR, CASE                                      ELIP 015I
      INTEGER     FLG03    ,FLG04     ,FLG05     ,FLG06     ,FLG07      ELIP 016
     1           ,FLG08    ,FLG09     ,FLG10     ,FLG11     ,FLG12      ELIP 017
     2           ,FLG13    ,FLG14     ,FLG15     ,FLG16     ,FLG17      ELIP 018
     3           ,FLG18    ,FLG19     ,FLG20     ,FLG21     ,FLG22      ELIP 019
     4           ,FLG23    ,FLG24     ,FLG25     ,FLG26     ,FLG27      ELIP 020
      REAL        MN                                                    ELIP 021
      LOGICAL PF                                                        ELIP 022
C                                                                       ELIP 023
      COMMON /CL/   X1(100),  Y1(100),  X2(100),  Y2(100),  DELS(100),  ELIP 024
     1              SINA(100),COSA(100),XP(100),  YP(100)               ELIP 025
     2              XWAKE(11),YWAKE(11)                                 ELIP 026
      COMMON /TL/   A(100),   B(100),   AX(100),  AY(100),  AZ(100),    ELIP 027
     1              CX(100),  CY(100),  CZ(100),  AXV(100),AYV(100),    ELIP 028
     2              VN(100,5),VT(100,5),BUN,          IAC,              ELIP 029
     3              I,        J,        J1,       SJ,       DS,         ELIP 030
     4              DX,       DY,       NI,       XJ,       YJ,         ELIP 031
     5              XK,       EEK,      EKK,      K,        PF          ELIP 032
C                                                                       ELIP 033
C               * START                                                 ELIP 034
      FTA = 1. - XK                                                     ELIP 035
```

```
      IF (FTA) 20,20,40
   20 WRITF (6,30) ETA
   30 FORMAT ( 1H0 36H *** ERROR IN SUBROUTINE ELIP * ETA= F15.8 )
       WRITF(6,800) I,XJ,DX,YJ,DY,X2(I),Y2(I),XK
  800  FORMAT(1H ,I5,7F15.6)
       FTA = 0.000005
   40 ELN=ALOG(ETA)
      FKK = 1.386294F0       + FTA * (.9666344E-1    + ETA *
     1      (.3590092E-1     + ETA * (.3742564E-1    + ETA *
     2      .1451196F-1   ))) - FLN * (.5 + ETA * (.1249859E0      +
     3      FTA * (.6880249E-1     + ETA * (.3328355E-1     + ETA *
     4      .4417870E-2  ))))
      FEK = 1. + FTA * (.4432514F0      + ETA * (.6260601E-1    + FTA *
     1      (.4757384E-1     + ETA * .1736506F-1    ))) - ELN * (ETA *
     2      (.2499837E0     + ETA * (.9200180F-1     + ETA *
     3      (.4069698E-1     + ETA * .5264496F-2  ))))
      RETURN
      FND
```

```
      SUBROUTINE NOTS
      COMMON      HEDR(10)   ,CASE      ,NB        ,NNU
     1           ,FLG03     ,FLG04     ,FLG05     ,FLG06     ,FLG07
     2           ,FLG08     ,FLG09     ,FLG10     ,FLG11     ,FLG12
     3           ,FLG13     ,FLG14     ,FLG15     ,FLG16     ,FLG17
     4           ,FLG18     ,FLG19     ,FLG20     ,FLG21     ,FLG22
     5           ,FLG23     ,FLG24     ,FLG25     ,FLG26     ,FLG27
C
      COMMON   NT,        ND(11),    MN,        NUNA(5),   TYPEA(5),
     1         NER1,      NER2,      NMA,       NSIGA,     NSIGC,
     2         NUNC(5),   TYPEC(5),  NLF(11),   IEC,       NSIGEC,
     3         TYPEEC(5),NUNEC(5)
C     DOUBLE PRECISION HEDR,CASE
C
      COMMON  /RNGWNG/ VA(100,2),  VR(100,2),VAN(100), VAT(100)
C
      INTEGER     FLG03     ,FLG04     ,FLG05     ,FLG06     ,FLG07
     1           ,FLG08     ,FLG09     ,FLG10     ,FLG11     ,FLG12
     2           ,FLG13     ,FLG14     ,FLG15     ,FLG16     ,FLG17
     3           ,FLG18     ,FLG19     ,FLG20     ,FLG21     ,FLG22
     4           ,FLG23     ,FLG24     ,FLG25     ,FLG26     ,FLG27
C
      COMMON /CL/   X1(100),  Y1(100),  X2(100),  Y2(100),  DELS(100),
     1              SINA(100),COSA(100),XP(100),  YP(100)
     2             ,XWAKE(11),YWAKE(11)
C
      COMMON /TL/   A(100),   B(100),   AX(100),  AY(100),  AZ(100),
     1              CX(100),  CY(100),  CZ(100),  AXV(100),AYV(100),
     2              VN(100,5),VT(100,5),BUN,                IAC,
     3              I,        J,        J1,       SJ,       DS,
     4              DX,       DY,       NI,       XJ,       YJ,
     5              XK,       EEK,      EKK,      K,        PF
C
      REAL  MN,KAY
      LOGICAL PF
```

```
C
C*** *  FOLLOWING ARE 3 ARITHMETIC FUNCTIONS
C
      OMEG(Z,SMALLR,BIGR) = 1.0 + ( ( Z**2 + (SMALLR-BIGR)**2) /
     1                      (2.0*SMALLR * BIGR) )
      BETAF(Z,SMALLR,BIGR)= ARSIN( Z / ( SQRT(Z**2 + (SMALLR-BIGR)**2)))
C
C
      AKAYF(Z,SMALLR,BIGR)= SQRT( (4.0 * SMALLR * BIGR) /
     1                      ( Z**2 + (SMALLR + BIGR)**2 ) )
C
      DO 100 IBOD =1,FLG14
      Z = X2(I) - XWAKE(IBOD)
      OMEGA = OMEG( Z, Y2(I), YWAKE(IBOD) )
      BETA  =BETAF( Z, Y2(I), YWAKE(IBOD) )
      KAY   =AKAYF( Z, Y2(I), YWAKE(IBOD) )
      CALL QC(OMEGA,QM,Q)
C
C   ***   SMALLR IS Y2(I)
C   ***   BIGR IS YWAKE(IBOD)
      IF( Y2(I) .LE. YWAKE(IBOD) ) GO TO 30
C
C   ***   SMALLR GT BIGR
C
      BIGK = ( Z / ( SQRT( Y2(I) * YWAKE(IBOD) )*2.0 ) ) * QM -
     1        ( 1.570796 * HLAMB(BETA,KAY) )
      GO TO 40
C
C*** *  SMALLR LE BIGR
C
   30 BIGK = 3.141593 + ( Z / ( SQRT( Y2(I) * YWAKE(IBOD) )*2.0) ) *QM +
     1       ( 1.570796 * HLAMB(BETA,KAY) )
C
C*** *  NOTE THAT VA AND VR WILL NOT YET BE MULTIPLIED BY  DGAMMA/DZ
C*** *  WHICH IS REALLY THE INPUT PRESCRIBED VORTICITY
```

```
C
   40 VA(I,IBOD) = BIGK / 6.283185
  100 VR(I,IBOD) = -(Q * (SQRT(YWAKE(IBOD) / Y2(I) ) ) )  /  6.283185
      RETURN
      END
```

```
      FUNCTION HLAMB (BETA,K)
C   THIS SUBROUTINE CALCULATES THE HEUMAN≠S LAMBDA FUNCTION OF BETA AND K
C     DOUBLE PRECISION A,F,E
      REAL K
      DATA TWOP/0.6366197724/
      CALL INEL (FI,EI,PI,BETA,BETA,1.0-K**2          ,0,1,1)
      A = 1.0 - K  **2
      CALL ELLC (A             ,F,E,1)
      CALL ELLC (A             ,F,E,2)
      HLAMB = TWOP*(F*EI +(E-F)*FI)
      RETURN
      END
```

```
      SUBROUTINE QC(OMEG,QM,Q)
C  THIS SUBROUTINE CALCULATES THE LEGENDRE FUNCTIONS OF THE SECOND KIND
C  AND HALF ORDER. THE ARGUMENTS ARE=
C        OMEG    ARGUMENT FOR WHICH LEGENDRE FUNCTIONS WILL BE FOUND
C        QM      VALUE OF LEGENDRE FUNCTION OF MINUS ONE HALF ORDER
C        Q       VALUE OF LEGENDRE FUNCTION OF PLUS ONE HALF ORDER
C     DOUBLE PRECISION OMEGD,ARG,A,F,E,QMD,QD
      OMEGD=OMEG
      ARG=2.0/(OMEGD+1.0)
      A=1.0-ARG
      CALL ELLC (A,F,E,1)
      CALL ELLC (A,F,E,2)
      QMD=F*ARG**0.5
      QD=-E*(2.0*(OMEGD+1.0))**0.5+OMEGD*QMD
      QM=QMD
      Q=QD
      RETURN
      END
```

```
      SUBROUTINE ELLC (A,K,E,I)
C     THIS SUBROUTINE CALCULATES THE ASSOCIATED COMPLETE ELLIPTIC INTEGRALS
C     OF THE FIRST OR SECOND KIND
C     THE ARGUMENTS ARE≠
C          A    ARGUMENT (K SQUARED) FOR WHICH E≠ OR K≠ WILL BE FOUND
C          K    VALUE OF ASSOCIATED COMPLETE ELLIPTIC INTEGRAL OF FIRST KIND
C          E    VALUE OF ASSOCIATED COMPLETE ELLIPTIC INTEGRAL OF SECOND KIN
C          I    IF EQ 1, COMPUTE K ; IF EQ 2, COMPUTE E
C     DOUBLE PRECISION K,E,CON(32),A,LN4,CF(29),CL(3),DLOG
      DOUBLE PRECISION CON(32),CF(29),CL(3)
      EQUIVALENCE (CON,CF),(CON(30),CL)
      DATA CF  /9.6573590797589018D-2,3.0885573486752694D-2,1.4978988178
     17046290-2,9.6587579861753113D-3,1.1208918554644092D-2,1.3855601247
     215656D-2,6.6905509906897936D-3,6.4998443329390180-4,1.249999999411
     37923D-1,7.0312426464627361D-2,4.8818058565403952D-2,3.706839893415
     45422D-2,2.7189861116788250-2,1.4105380776158048D-2,3.1831309927862
     5886D-3,1.5049181783601883D-4,4.4314718112155806D-1,5.6805657874695
     6358D-2,2.1876220647186198D-2,1.2510592410844644D-2,1.3034146073731
     7432D-2,1.5377102528552019D-2,7.3356164974290365D-3,7.0980964089987
     8229D-4,2.4999999993617622D-1,9.3749920249680113D-2,5.8582839536559
     9024D-2,4.2382807456947 9D-2,3.0302747728412848D-2 /
      DATA CL  / 1.5525129948040721D-2,3.4838679435896492D-3,1.642721079
     17048025D-4 /
      LN4 = 1.3862943611198900
      IF (A.EQ.0.0) GO TO 4
      GO TO (1,2),I
    1 K = LN4 + (((((((CON(8)*A+CON(7))*A+CON(6))*A+CON(5))*A+CON(4))*A
     1+ CON(3))*A+CON(2))*A+CON(1))*A - DLOG(A)*(0.5+(((((((CON(16)*A+
     2CON(15))*A+CON(14))*A+CON(13))*A+CON(12))*A+CON(11))*A+CON(10))*A
     3+ CON(9))*A)
      GO TO 3
    2 E = 1.0D0+(((((((CON(24)*A+CON(23))*A+CON(22))*A+CON(21))*A+CON(20
     1))*A+CON(19))*A+CON(18))*A+CON(17))*A - DLOG(A)*((((((((CON(32)*A
     2+ CON(31))*A+CON(30))*A+CON(29))*A+CON(28))*A+CON(27))*A+CON(26))*
     3A+CON(25))*A)
```

```
      3 RETURN                                                          ELLC  036
C     4 K = 0.99999999D30                                               ELLC  037I
      4 K = 0.99999999F30                                               ELLC  038C
C       F = 1.0D0                                                       ELLC  039I
        F = 1.0E0                                                       ELLC  040C
        RETURN                                                          ELLC  041
        END                                                             ELLC  042
```

```
      SUBROUTINE ELINT3(XKSQ,XN,PHI,PIE)
C  THIS SUBROUTINE CALCULATES THE INCOMPLETE ELLIPTIC INTEGRAL OF THE
C  THIRD KIND, THE ARGUMENTS ARE*
C       XKSQ   VALUE OF K SQUARED
C       XN     VALUE OF MINUS ALPHA SQUARED
C       PHI    VALUE OF PHI
C       PIE    VALUE OF INCOMPLETE ELLIPTIC INTEGRAL OF THIRD KIND
  101 FORMAT (7E16.8)
      DATA HP /1.570796/
      DATA ROUND /.0000050/
      SK=XKSQ
      FN=XN
      P=PHI
      IF (FN.EQ.-1.0.AND.SK.EQ.1.0) GO TO 50
      IF(SK.GT.1.) GO TO 48
      IF(FN.LT.(-1.)) GO TO 48
      IF(P)1,48,2
C     NORMALIZE PHI
 1    A=-1.
      P=-P
      GOTO3
 2    A=1.
 3    B=1.
      BB=1.
      IF (ABS(P-1.570796   ).LE.10.0**(-7)) GO TO 10
      IF(P-HP)11,10,4
 4    J=P/(2.*HP)
      XX=2*J
      P1=P-XX*HP
      P=HP
      B=-1.
      GOTO10
 5    D=SUM
      B=0.
      IF(P1-HP)6,7,8
```


ELNT

```
 6    P=P1
      XXX=1.
      GOTO11
 7    PIE=(XX+1.)*A*D
      GOTO47
 8    XXX=-1.
      XX=XX+2.
      P=2.*HP-P1
      GOTO11
 9    PIE=A*(XX*D+XXX*SUM)
      GOTO47
10    IF(SK.EQ.1.) GOTO48
      IF(FN.EQ.(-1.)) GO TO 48
11    IF(P.GT.10.E-4)GOTO13
      IF(FN.GT.0.)GOTO12
      SUM=P
      GOTO45
12    RRT=SQRT(FN)
      SUM=ATAN(P*RRT)/RRT
      GOTO45
13    S=SIN(P)
      S2=S**2
      C=COS(P)
      IF(SK.GT.0.64)GOTO20
      IF(ABS(FN).GE.0.6)GOTO15
C     POWER SERIES IN N AND K SQUARED
      SA=1.
      SB=SK/2.
      CB=S*C
      CA=P
      FM=0.
      SUM=P
      X=SUM*1.E-8
14    SA=SB-SA*FN
      CA=(-CB/(2.*(FM+1.)))+(1.-.5/(FM+1.))*CA
```

```
      Y=SA*CA
      SUM=SUM+Y
      IF((SB*CA).GT.X) GO TO 141
      IF(ABS(Y) .LT.X) GO TO 45
  141 FM=FM+1.
      CB=CB*S2
      SB=(1.-.5/(FM+1.))*SK*SB
      GOTO14
C     POWER SERIES IN K SQUARED
   15 PK=SK
      RT=SQRT(1.+FN)
      IF(RT.NE.0.) GO TO 16
      G=S/C
      GOTO18
   16 IF(C.GT.4.E-3)GOTO17
      G=(HP-(C/(RT*S)))/RT
      GOTO18
   17 G=ATAN(RT*S/C)/RT
   18 G1=G*1.E-8
      E=P
      F=S*C
      H=1.
      SUM=G
      FM=0.
   19 G=(E-G)/FN
      H=H*(1.-0.5/(FM+1.))
      G2=H*G*PK
      SUM=SUM+G2
      IF(G2.LE.G1)GOTO45
      FM=FM+1.
      E=-F/(2.*FM)+(1.-0.5/FM)*E
      F=F*S2
      PK=PK*SK
      GOTO19
   20 SKP=1.-SK
```

```
      IF(S.LT.C) GO TO 32
C     ADDITION FORMULA
   21 ZP=SQRT(1.-SK*S2)
      RT1=SQRT(ABS(FN*(FN+1.)*(FN+SK)))
      SST=(1.-ZP)/(SK*(C+1.))
      XP=(SST*S*RT1)/(1.+FN*S2-FN*SST*C*ZP)
      IF(FN)22,29,25
   22 IF(RT1.NE.0.) GO TO 24
      R=S/(C+1.)
      IF(FN.NE.(-1.)) GO TO 23
      CF=(2.*R-SK*SST*S-(S/C)*ZP)/SKP
      GOTO30
   23 CF=(SST*(S-(2./R))+S*C/ZP)*(SK/SKP)
      GOTO30
   24 IF(FN*(FN+SK) .LT.0.) GO TO 26
   25 CF=(FN/RT1)*ATAN(XP)
      GOTO30
   26 IF(ABS(XP).GE.0.1)GOTO27
      YX=XP**2
      YX=2.*XP*(1.+YX*(1./3.+YX*(.2+YX/7.)))
      GOTO28
   27 YX=ALOG((1.+XP)/(1.-XP))
   28 CF=(FN*YX)/(2.*RT1)
      GOTO30
   29 CF=0.
   30 BB=-1.
      S=SQRT(SST)
      C=SQRT(1.-SST)
      GOTO32
   31 SUM=2.*SUM-CF
      GOTO45
   32 U=S/C
      V=1./C
      T=U*V
      W=U**2
```

```
      IF(S.GT.0.1)GOTO33
      R=S*(1.+S2*(1./3.+S2*(.2+S2/7.)))
      GOTO34
   33 R=ALOG(U+V)
   34 D=1.+FN
      IF(D.GT.SKP) GOTO37
C     POWER SERIFS IN 1+N AND 1 - (K SQUARED)
   35 CA=1.
      CB=-0.5*SKP
      AL=(T+R)/2.
      BE=U*V**3
      FM=0.
      SUM=AL
      T1=SUM*1.E-8
   36 CA=-D*CA+CB
      AL=(BE-(2.*FM+1.)*AL)/(2.*(FM+2.))
      X=CA*AL
      SUM=SUM+X
      IF(ABS(X).LT.T1)GOTO44
      FM=FM+1.
      CB=-((2.*FM+1.)/(2.*(FM+1.)))*CB*SKP
      IF(ABS(BE).LT.10.E-30) BE=0.
      BE=BE*W
      GOTO36
C     POWER SERIES IN 1 - (K SQUARED)
   37 RT=SQRT(ABS(FN))
      IF(FN)38,39,40
   38 Q=ALOG((1.+RT*S)/(1.-RT*S))/(2.*RT)
      GOTO41
   39 Q=S
      GOTO41
   40 Q=ATAN(RT*S)/RT
   41 SUM=FN*Q+R
      PKP=SKP
      AP=-0.5
```

```
      FM=1.                                                             ELNT 176
      T1=SUM*1.E-8                                                      ELNT 177
   42 Q=(R-Q)/D                                                         ELNT 178
      R=T/(2.*FM)-(1.-.5/FM)*R                                          ELNT 179
      X=AP*(FN*Q+R)*PKP                                                 ELNT 180
      SUM=SUM+X                                                         ELNT 181
      IF(ABS(X).LT.T1)GOTO43                                            ELNT 182
      T=T*W                                                             ELNT 183
      PKP=PKP*SKP                                                       ELNT 184
      FM=FM+1.                                                          ELNT 185
      AP=-AP*(1.-.5/FM)                                                 ELNT 186
      GOTO42                                                            ELNT 187
   43 SUM=SUM/D                                                         ELNT 188
   44 IF(BB.LT.0.)GOTO31                                                ELNT 189
   45 IF(B)5,9,46                                                       ELNT 190
   46 PIF=A*SUM                                                         ELNT 191
   47 PIF=PIE+PIE*ROUND                                                 ELNT 192
      RETURN                                                            ELNT 193
C     ERROR RETURN                                                      ELNT 194
   48 PIF=0.                                                            ELNT 195
      GOTO47                                                            ELNT 196
C   CASE OF PI(1,1,PHI)                                                 ELNT 197
   50 PIE = 0.5*(TAN(P )/ COS(P )+ALOG(TAN((HP+P )/2.0)))               ELNT 198
      GO TO 47                                                          ELNT 199
      END                                                               ELNT 200
```

```
      SUBROUTINE INEL (F,E,PI,A,PHI,SKI,K3,K2,K1)
C  THIS SUBROUTINE CALCULATES THE INCOMPLETE ELLIPTIC INTEGRALS OF THE
C  FIRST, SECOND AND THIRD KINDS. THE ARGUMENTS ARE=
C       F      VALUE OF INCOMPLETE ELLIPTIC INTEGRAL OF THE FIRST KIND
C       F      VALUF OF INCOMPLFTF ELLIPTIC INTFGRAL OF THE SECOND KIND
C       PI     VALUF OF INCOMPLETF ELLIPTIC INTEGRAL OF THE THIRD KIND
C       A      VALUE OF ALPHA SQUARED
C       PHI    VALUE OF PHI
C       SKI    VALUE OF K SQUARED
C       K3     IF EQ 0, DO NOT COMPUTE PI ; IF NE 0, COMPUTE PI
C       K2     IF EQ 0, DO NOT COMPUTE E  ; IF NE 0, COMPUTE E
C       K1     IF EQ 0, DO NOT COMPUTE F  ; IF NE 0, COMPUTE F
C     DOUBLE PRECISION ARG,FD,ED
      DATA PIT/1.57079633/
      F=0.0
      F=0.0
      IF (K3.EQ.0) GO TO 220
      CALL ELINT3 (SKI,-A,PHI,PI)
  220 IF (K1.EQ.0) GO TO 240
      IF (ABS(PHI-PIT).GT.10.0**(-7)) GO TO 230
      ARG=1.0-SKI
      CALL ELLC (ARG,FD,ED,1)
      F=FD
      GO TO 240
  230 CALL ELINT3 (SKI,0.0,PHI,F)
  240 IF (K2.EQ.0) GO TO 260
      IF (ABS(PHI-PIT).GT.10.0**(-7)) GO TO 250
      ARG=1.0-SKI
      CALL ELLC (ARG,FD,ED,2)
      E=ED
      GO TO 260
  250 CALL ELINT3 (SKI,-SKI,PHI,E)
      E=(1.0-SKI)*F+0.5*SKI*SIN(2.0*PHI)/SQRT(1.0-SKI*SIN(PHI)**2)
  260 RETURN
      END
```

```
      OVERLAY(AXSY,3,0)                                                  PREP  001C
      PROGRAM PREP                                                       PREP  002C
C     SUBROUTINE  PREP                                                   PREP  003I
C **          * PREPARE TAPES 3 AND 11 FOR USE BY LINK 5 (MATSOL)        PREP  004
      COMMON/SPACER/WKAREA(5000)                                         PREP  005
      DIMENSION TEMP(105), Y2(100)                                       PREP  006
      COMMON      HEDR(10)  ,CASE      ,NB       ,NNU                    PREP  007
     1            ,FLG03    ,FLG04     ,FLG05    ,FLG06     ,FLG07       PREP  008
     2            ,FLG08    ,FLG09     ,FLG10    ,FLG11     ,FLG12       PREP  009
     3            ,FLG13    ,FLG14     ,FLG15    ,FLG16     ,FLG17       PREP  010
     4            ,FLG18    ,FLG19     ,FLG20    ,FLG21     ,FLG22       PREP  011
     5            ,FLG23    ,FLG24     ,FLG25    ,FLG26     ,FLG27       PREP  012
      COMMON   NT,       ND(11),   MN,      NUNA(5),  TYPEA(5),          PREP  013
     1         NER1,     NER2,     NMA,     NSIGA,    NSIGC,             PREP  014
     2         NUNC(5),  TYPEC(5), NLF(11), IEC,      NSIGEC,            PREP  015
     3         TYPEEC(5),NUNEC(5)                                        PREP  016
C     DOUBLE PRECISION  HEDR, CASE                                       PREP  017I
      INTEGER     FLG03     ,FLG04     ,FLG05    ,FLG06     ,FLG07       PREP  018
     1            ,FLG08    ,FLG09     ,FLG10    ,FLG11     ,FLG12       PREP  019
     2            ,FLG13    ,FLG14     ,FLG15    ,FLG16     ,FLG17       PREP  020
     3            ,FLG18    ,FLG19     ,FLG20    ,FLG21     ,FLG22       PREP  021
     4            ,FLG23    ,FLG24     ,FLG25    ,FLG26     ,FLG27       PREP  022
      REAL        MN                                                     PREP  023
      DIMENSION COSSQR(100), RHS(100)                                    PREP  024
      DIMENSION     A(105),   R(100,5),  FF(100),  T(100)                PREP  025
      DATA  FOURPI/12.5663706/                                           PREP  026
C***   ***AXISYMMETRIC FLOW ONLY                       MS = 0            PREP  027
C***   ***CROSS FLOW ONLY                              MS = 1            PREP  028
C***   ***EXTRA CROSS FLOW ONLY                        MS = 2            PREP  029
C***   ***AXISYMMETRIC AND CROSS FLOW                  MS = 3            PREP  030
C***   ***AXISYMMETRIC AND EXTRA CROSS FLOW            MS = 4            PREP  031
C***   ***CROSS AND EXTRA CROSS FLOW                   MS = 5            PREP  032
C***   ***AXISYMMETRIC,CROSS, AND EXTRA CROSS FLOW  MS = 6               PREP  033
      NCK1=0                                                             PREP  034
      NCK2=0                                                             PREP  035
```

```
      NCK3=0                                                            PREP 036
      NCK4=0                                                            PREP 037
      NCK5=0                                                            PREP 038
      NCK6=0                                                            PREP 039
      IF(FLG12.EQ.0.OR.(FLG04.EQ.0.AND.FLG21.EQ.0) ) GO TO 3            PREP 040
      IF (FLG05.EQ.0) GO TO 4                                           PREP 041
C***   ***SKIP OFF BODY COORDINATES                                     PREP 042
      READ(12)                                                          PREP 043
    4 NI=NT+NB                                                          PREP 044
      READ(12) (TEMP(I),I = 1,NI),(TEMP(I),I = 1,NI),                   PREP 045
     1   (TEMP(I),I = 1,NT), (Y2(I),I = 1,NT)                           PREP 046
      REWIND 12                                                         PREP 047
    3 REWIND 3                                                          PREP 048
      IF (FLG03) 5,800,5                                                PREP 049
C **           * PREPARE AXISYMMETRIC MATRIX TAPE (3)                   PREP 050
    5 IF (FLG19.GT.0) GO TO 2000                                        PREP 051
      IF ( FLG22.GT.0) GO TO 255                                        PREP 052
      K = 0                                                             PREP 053
      L = NT+NSIGA                                                      PREP 054
      READ (4) (A(I),I=1,NT),(FF(I),I=1,NT)                             PREP 055
      IF (FLG16.NE.0) GO TO 20                                          PREP 056
      K = K+1                                                           PREP 057
      DO 10 I = 1, NT                                                   PREP 058
   10 R(I,K) = A(I)                                                     PREP 059
   20 IF (NNU) 60,60,30                                                 PREP 060
   30 DO 50 J = 1, NNU                                                  PREP 061
      READ (4) MS,(A(I),I=1,NT)                                         PREP 062
      IF (MS.EQ.1.OR.MS.EQ.2.OR.MS.EQ.5) GO TO 50                       PREP 063
      K = K+1                                                           PREP 064
      DO 40 I = 1, NT                                                   PREP 065
   40 R(I,K) = A(I)                                                     PREP 066
   50 CONTINUE                                                          PREP 067
   60 IF (FLG14.LE.0) GO TO 290                                         PREP 068
      NR= NMA+1                                                         PREP 069
      READ (4) (R(I,1), I=NR,NT)                                        PREP 070
```

```
      REWIND 4
      DΠ 220 I = NR, NT
  220 R(I,1) = R(I,1)-FF(I)
      IF (FLG14,EQ,NB) GO TO 245
      DO 240 I = 1, NMA
      READ (9) (A(J),J=1,NT)
      A(NT+1) =  R(I,1)
  240 WRITE (3) (A(J),J=1,L)
  245 DO 250 I = NR, NT
      READ (9) (A(J),J=1,NT),(A(J),J=1,NT)
      A(NT+1) =  R(I,1)
  250 WRITE (3) (A(J),J=1,L)
C  PRESCRIBED TANGENTIAL VELOCITY       INPUT TO SOLVIT ON TAPE 3
C                                       OUTPUT FROM SOLVIT ON TAPE 3
C  TAPES 1 AND 2 ARE SCRATCH TAPES
      CALL SOLVIT(WKAREA,NT,NSIGA,5000,3,1,2,3,NCK1)
      IF(NCK1 ,EQ, 1) GO TO 9010
  251 REWIND 9
      GO TO 800
C***   ***AXISYMMETRIC FLOW   *   GENERATED (RESEP) BOUNDARY CONDITIONS
C***   ***NPB1 = THE NUMBER OF ELEMENTS ON BODY 1
C***   ***NPB2 = THE NUMBER OF ELEMENTS ON BODY 2
  255 NPB1 = ND(1) - 1
      NPB2 = ND(2) - 1
      NSIGA = 3
      NSIGC = 1
      NSIGFC = 1
      L = NT + NSIGA
C***   ***L IS THE TOTAL  WIDTH OF THE MATRIX FOR AXISYMMETRIC FLOW INCL
C***   ***RIGHT HAND SIDES
      READ (4)
      READ(4) ( COSSQR(I),I = 1,NPB1), (RHS(I),I = 1,NPB1 )
      REWIND 4
      DO 260 I = 1,NPB1
      R(T,1) = 0.0
```

```
      R(I,2) = 1.0
  260 R(I,3) = COSSQR(I)
      NBEGIN = NPB1 + 1
      NEND = NPB1 + NPB2
      DO 265 I = NBEGIN,NEND
      R(I,1) = 1.0
      R(I,2) = 0.0
  265 R(I,3) = 0.0
  290 REWIND 4
      ASSIGN 400 TO M
      IF (FLG12.NE.0) ASSIGN 300 TO M
      DO 700 I = 1, NT
      GO TO M, (300,400)
  300 READ (9) (A(J),J=1,NT),(A(J),J=1,NT),(A(J),J=1,NT)
      GO TO 500
  400 READ (9) (A(J),J=1,NT)
  500 DO 600 J = 1, NSIGA
      K = NT+J
  600 A(K)=  R(I,J)
  700 WRITE (3) (A(J),J=1,L)
C  AXISYMMETRIC FLOW         INPUT TO SOLVIT ON TAPE 3
C                            OUTPUT FROM SOLVIT ON TAPE 3
C  TAPES 1 AND 2 ARE SCRATCH TAPES
      CALL SOLVIT(WKAREA,NT,NSIGA,5000,3,1,2,3,NCK2)
      IF(NCK2 .EQ. 1) GO TO 9020
  701 REWIND 9
C **            * PREPARE CROSSFLOW MATRIX TAPE (11)
C **            * SKIP SINA * READ COSA
  800 IF (FLG04.EQ.0) GO TO 1610
      K = 0
      L = NT+NSIGC
      IF (FLG22.GT.0) GO TO 910
      READ (4) (A(I),I=1,NT),(A(I),I=1,NT)
      IF (FLG17.NE.0) GO TO 820
      K = K+1
```

```
      DO 810 I = 1, NT
  810 R(I,K) = A(I)
  820 IF (NNU) 900,900,830
  830 DO 850 J = 1, NNU
      READ (4) MS,(A(I),I=1,NT)
      IF ( MS.EQ.0.OR.MS.EQ.2.OR.MS.EQ.4) GO TO 850
      K = K+1
      DO 840 I = 1, NT
  840 R(I,K) = -A(I)
  850 CONTINUE
  900 REWIND 4
      GO TO 1000
C***   ***CROSS FLOW    *    GENERATED (RESEP) BOUNDARY CONDITIONS
  910 DO 920 I = 1,NPB1
  920 R(I,1) = -RHS(I)
      DO 930 I = NBEGIN,NEND
  930 R(I,1) = 0.0
 1000 ASSIGN 1300 TO M
      IF (FLG12.NE.0) ASSIGN 1200 TO M
      DO 1600 I = 1, NT
      GO TO M, (1200,1300)
 1200 READ (10) (A(J),J=1,NT),(A(J),J=1,NT),(A(J),J=1,NT)
C***   ***FORM PHI MATRIX FROM THETA (CROSS FLOW) MATRIX
      DO 1250 J = 1,NT
 1250 A(J) = Y2(I) * A(J)
      GO TO 1400
 1300 READ (10) (A(J),J=1,NT)
 1400 DO 1500 J = 1, NSIGC
      K = NT+J
 1500 A(K) =-R(I,J)
 1600 WRITE (11) (A(J),J=1,L)
C  CROSS FLOW        INPUT TO SOLVIT ON TAPE 11
C                    OUTPUT FROM SOLVIT ON TAPF 3
C  TAPES 1 AND 2 ARE SCRATCH TAPES
      CALL SOLVIT(WKAREA,NT,NSIGC,5000,11,1,2,3,NCK3)
```

```
      IF(NCK3 .EQ. 1) GO TO 9030
 1605 REWIND 10
 1610 CONTINUE
C***   ***FXTRA CROSS FLOW
      REWIND 11
      IF (FLG21.EQ.0.AND.FLG22.EQ.0)RETURN
      K = 0
      L = NT + NSIGEC
      IF (FLG22.GT.0) GO TO 1800
C***   ***EXTRA CROSS FLOW    *   NON-UNIFORM FLOW ONLY
C***   ***SKIP RECORD WITH SINES AND COSINES
      READ (4)
      DO 1650 J=1,NNU
      READ(4) MS, (A(I),I=1,NT)
      IF (MS.LT.2.OR.MS.EQ.3) GO TO 1650
      K = K+ 1
      DO 1640 I = 1,NT
 1640 R(I,K) = A(I)
 1650 CONTINUE
      GO TO 1900
C***   ***EXTRA CROSS FLOW    *   GENERATED (RESEP) BOUNDARY CONDITIONS
 1800 DO 1820 I = 1,NPB1
 1820 R(T,1) = COSSQR(I)
      DO 1840 I = NBEGIN,NEND
 1840 R(I,1) = 0.0
 1900 REWIND 4
C***   ***M IS 1920    *   SOLVE A MATRIX
      ASSIGN 1920 TO M
C***   ***M IS 1940    *   SOLVE POTENTIAL MATRIX
      IF (FLG12.NE.0)ASSIGN 1940 TO M
      DO 1980 I = 1,NT
      GO TO M, (1920,1940)
C***   ***SOLVF A MATRIX
 1920 READ (8) (A(J),J =1,NT)
      GO TO 1960
```

```
 1940 READ (8) (A(J),J=1,NT),(A(J),J=1,NT),(A(J),J=1,NT)
C***   ***FORM PHI MATRIX FROM THETA (EXTRA CROSS FLOW) MATRIX
      DO 1950 J = 1,NT
 1950 A(J) = Y2(I) * A(J) / 2.0
 1960 DO 1970 J = 1,NSIGEC
      K = NT + J
 1970 A(K) = R(I,J)
 1980 WRITE (11) (A(J),J=1,L)
C***   ***EXTRA CROSS FLOW   INPUT TO SOLVIT ON TAPE 11
C***   ***OUTPUT FROM SOLVIT ON TAPE 3
C***   ***TAPES 1 AND 2 ARE SCRATCH TAPES
      CALL SOLVIT (WKAREA,NT,NSIGEC,5000,11,1,2,3,NCK4)
      IF(NCK4 .EQ. 1) GO TO 9040
 1985 REWIND 8
      REWIND 11
C     RETURN
      GO TO 9070
 2000 IF(FLG23 .GT. 0)GO TO 3000
      NR = NT - NMA
      L = NMA+1
      READ (4) (R(I,1),I=1,NMA)
      READ (4) (FF(I),I=1,NR)
      DO 2100 I = 1, NR
 2100 FF(I) = FF(I)/FOURPI
      BACKSPACE 4
      WRITE (4) (FF(I),I=1,NR)
      REWIND 4
      DO 2300 I = 1, NMA
      READ (9) (A(J),J=1,NMA),(T(J),J=1,NR)
      DO 2200 J = 1, NR
 2200 R(I,1) = R(I,1)- T(J)*FF(J)
      A(L) =  R(I,1)
 2300 WRITE (3) (A(J),J=1,L)
C  PRESCRIBED VORTICITY       INPUT FOR SOLVIT ON TAPE 3
C                             OUTPUT FROM SOLVIT ON TAPE 3
```

```
C  TAPFS 1 AND 2 ARE SCRATCH TAPES
      CALL SOLVIT(WKAREA,NMA,L - NMA,5000,3,1,2,3,NCK5)
      IF(NCK5 .EQ. 1) GO TO 9000
 2500 REWIND 9
      GO TO 800
 3000 NR = NT - NMA
      NMAP1 = NMA + 1
C*** *  CALCULATE THE NUMBER OF RHS
C
      LL = 0
      DO 3100 I=1,NB
      IF( NLF(I) .GT. 0 )GO TO 3100
      LL = LL + 2
 3100 CONTINUE
      L = NMAP1 + LL
C
C*** *  READ SINS FOR STREAMFLOW RHS
C
      READ(4)( R(I,1),I=1,NMA )
C
C*** *  READ  INPUT PRESCRIBED VORTICITIES
C
      READ(4)( FF(I),I=NMAP1,NT )
      WRITE(6,8001) (FF(I),I=NMAP1,NT)
 8001 FORMAT(1H1,* THE INPUT PV ARE */(6E20.7))
      DO 3125 I = NMAP1,NT
 3125 FF(I) = FF(I) / (-FOURPI)
C
C*** *  READ STRIP VORTEX RHS
C
      LLD2P1 = LL/2 + 1
      DO 3150 J=2,LLD2P1
 3150 READ(4)MS,( R(I,J),I=1,NMA )
C
C*** *  IPV IS BODY NUMBER OF 1ST PRESCRIBED VORTICITY BODY
```

```
C
      IPV = NB - FLG14 + 1
      JBOD = LLD2P1
      NN = NMA
C
      DO 3300 KCNT = IPV,NB
      JBOD = JBOD + 1
      NN = NN + ND(KCNT) - 1
C
C*** *  READ COLUMN OF RHS CALCULATED BY NOTS FORMULA
C
      READ(4) (R(ICNT,JBOD),ICNT = 1,NMA)
C
C*** *  MULTIPLY NOTS COLUMN BY LAST PRESCRIBED VORTICITY ON THAT BODY
C
      DO 3300 ICNT =1,NMA
 3300 R(ICNT,JBOD) = R(ICNT,JBOD) * FF(NN) *(-FOURPI)
C
      REWIND 4
      DO 3400 I=1,NMA
      NEND = NMA
      JBOD = LLD2P1
      READ(9) ( A(J),J=1,NMA),( T(J),J=NMAP1,NT )
C
      DO 3350 KCNT=IPV,NB
      JBOD = JBOD + 1
      NBEG = NEND + 1
      NEND = NEND + ND(KCNT) -1
C
C*** *  SUM PV VORTEX ELEMENTS * INPUT PV AND ADD TO NOTS RHS
C
      DO 3350 NCNT=NBEG,NEND
C
C    ***   WHEN COMING OFF UNIT 9, THE VORTEX ELEMENTS( T(J) ) ARE STILL
C    ***   WHILE NOTS COLUMNS COMING OFF UNIT 4 ARE RHS.   THE TWO SHOULD
```

```
C   ***   ADDED TO FORM A COMPLETE RHS, BUT THEY ARE SUBTRACTED SINCE TH
C   ***   OF T(J)  MUST BE CHANGED
C
 3350 R(I,JBOD) = R(I,JBOD) - T(NCNT) * FF(NCNT)
C
C*** *  ATTACH ALL RHS FOR ROW NUMBER I
C
      LRHS = 0
      DO 3375  ICNT=NMAP1,L
      LRHS = LRHS + 1
 3375 A(ICNT) = R(I,LRHS)
C
 3400 WRITE(3)(A(J),J=1,L)
C*** *  RING WING OPTION        INPUT FOR SOLVIT ON TAPE 3
C*** *                          OUTPUT FOR SOLVIT ON TAPE 3
C
      CALL SOLVIT(WKAREA,NMA,L-NMA,5000,3,1,2,3,NCK6)
      IF(NCK6 .EQ. 1) GO TO 9050
 3500 REWIND 9
      GO TO 800
 9000 WRITE(6,9001)
 9001 FORMAT(61H NOT ENOUGH SPACE RESERVED IN SOLVIT FOR PRESCRIBED VORT
     1ICITY)
      GO TO 9080
 9010 WRITE(6,9011)
 9011 FORMAT(71H NOT ENOUGH SPACE RESERVED IN SOLVIT FOR PRESCRIBED TANG
     1ENTIAL VELOCITY)
      GO TO 9080
 9020 WRITE (6,9021)
 9021 FORMAT(58H NOT ENOUGH SPACE RESERVED IN SOLVIT FOR AXISYMMETRIC FL
     1OW)
      GO TO 9080
 9030 WRITE(6,9031)
 9031 FORMAT(51H NOT ENOUGH SPACE RESERVED IN SOLVIT FOR CROSS FLOW)
      GO TO 9080
```

```
9040 WRITE (6,9041)                                                       PREP  351
9041 FORMAT (57H NOT ENOUGH SPACE RESERVED IN SOLVIT FOR EXTRA CROSS FL   PREP  352
    1OW)                                                                  PREP  353
     GO TO 9080                                                           PREP  354
9050 WRITE(6,9051)                                                        PREP  355
9051 FORMAT(51H NOT ENOUGH SPACF RESERVED IN SOLVIT FOR RING WING )       PREP  356
9070 CONTINUE                                                             PREP  357C
9080 STOP                                                                 PREP  358
     END                                                                  PREP  359
```

PREP

```
      SUBROUTINE  SOLVIT (A, ND, MD, KD, NI, MM, NO, NW, NCK)            SOLV  001
C                                                                        SOLV  002
C                                                                        SOLV  003
C          ****   ***/  *******  *****  *     ***/      *                SOLV  004
C          *   *  *  /*    *     *      *     *  /*   ******             SOLV  005
C     **** ****   * / *    *     ***    *     * / * ****  * *            SOLV  006
C          *      */  *    *     *      *     */  *        ***           SOLV  007
C          *      /***     *     *      ***** /***        *  *           SOLV  008
C                                                                        SOLV  009
C           D I R E C T   M A T R I X   S O L U T I O N                  SOLV  010
C                                                                        SOLV  011
C     WRITTEN BY J. L. HESS * PROGRAMMED BY T. M. RIDDELL                SOLV  012
C                                                                        SOLV  013
      DIMENSION  A ( KD )                                                SOLV  014
C                                                                        SOLV  015
      LOGICAL  LAST                                                      SOLV  016
C                                                                        SOLV  017
C     CALL TIMEV(AA1)                                                    SOLV  018I
      NCK=0                                                              SOLV  019
      N = ND                                                             SOLV  020
      M = MD                                                             SOLV  021
      KORE = KD                                                          SOLV  022
      NPM = N + M                                                        SOLV  023
      IF (MAX0(3 * NPM, M * N) .GT. KORE)  NCK= 1                        SOLV  024
      MT = MM                                                            SOLV  025
      REWIND MT                                                          SOLV  026
      NIN = NI                                                           SOLV  027
      REWIND NIN                                                         SOLV  028
      NOUT = NO                                                          SOLV  029
      REWIND NOUT                                                        SOLV  030
      MP1 = M + 1                                                        SOLV  031
      NN = N                                                             SOLV  032
      NEL = NPM                                                          SOLV  033
C                                                                        SOLV  034
C - - CALCULATE THE MAXIMUM NO. OF ROWS, =K=                             SOLV  035
```


SOLV

```
C
   10 K = (KORE - NEL) / NEL
C
C - - TEST TO SEE IF THE REST OF THE MATRIX WILL FIT IN CORE
C
      LAST = K .GE. NN
      IF (LAST) K = NN
C
C - - READ *K* ROWS OF THE AUGMENTED *A* MATRIX
C
   30 NT = 0
      DO 40 IB = 1, K
      NS = NT + 1
      NT = NT + NEL
   40 READ (NIN) (A(IO), IO = NS, NT)
C
C - - CHECK TO SEE IF WE WERE UNLUCKY ENOUGH TO END UP WITH ONLY ONE ROW
C
      IF (K .EQ. 1) GO TO 90
C
C - - *K* IS GREATER THAN *1* SO WE CAN START THE TRIANGULARIZATION
C
      NELP1 = NEL + 1
      NS = - NEL
      NELP2 = NELP1 + 1
C
C - - FORM THE *TRAPEZOIDAL* ARRAY  (8)
C
      DO 50 IB = 2, K
      NP = NELP2 - IB
      NS = NS + NELP1
      NT = NS
      DO 50 IO = IB, K
      NT = NT + NEL
      MN = NT
```

```
      NB = NS
      A(NT) = (-A(NT)) / A(NS)
      DO 50 NF = 2, NP
      MN = MN + 1
      NB = NB + 1
   50 A(MN) = A(MN) + A(NT) * A(NB)
      IF (LAST) GO TO 90
C
C - - WRITE THE ≠TRAPEZOIDAL≠ MATRIX ON TAPE
C
      NT = 0
      NP = NEL
      NS = - NEL
      DO 60 IO = 1, K
      NS = NS + NELP1
      NT = NT + NEL
      WRITE (MT) NP, (A(IB), IB = NS, NT)
   60 NP = NP - 1
      NP = NP - M
      NS = KORE - NEL + 1
C
C - - READ ANOTHER ROW
C
      DO 80 IO = 1, NP
      READ (NIN) (A(IB), IB = NS, KORE)
C
C - - MODIFY THIS ROW BY THE ≠TRAPEZOIDAL≠ ARRAY
C
      NT = 1
      MN = NS
      DO 70 IB = 1, K
      NB = NT
      NF = MN + 1
      A(MN) = (-A(MN)) / A(NT)
      DO 65 NN = NF, KORE
```

```
      NB = NB + 1                                                       SOLV 106
   65 A(NN) = A(NN) + A(MN) * A(NB)                                     SOLV 107
      MN = NF                                                           SOLV 108
   70 NT = NT + NELP1                                                   SOLV 109
C                                                                       SOLV 110
C - - WRITF THE MODIFIED ROW ON TAPE                                    SOLV 111
C                                                                       SOLV 112
   80 WRITF (NOUT)      (A(NT), NT = MN, KURE)                          SOLV 113
      REWIND NOUT                                                       SOLV 114
      REWIND NIN                                                        SOLV 115
C                                                                       SOLV 116
C - - SWITCH THE TAPFS                                                  SOLV 117
C                                                                       SOLV 118
      NT = NIN                                                          SOLV 119
      NIN = NOUT                                                        SOLV 120
      NOUT = NT                                                         SOLV 121
C                                                                       SOLV 122
C - - RE-CALCULATE ROW LENGTH AND LOOP BACK                             SOLV 123
C                                                                       SOLV 124
      NEL = NEL - K                                                     SOLV 125
      NN = NEL - M                                                      SOLV 126
      GO TO 10                                                          SOLV 127
C                                                                       SOLV 128
C - - REWIND ALL TAPES                                                  SOLV 129
C                                                                       SOLV 130
   90 REWIND MT                                                         SOLV 131
      REWIND NIN                                                        SOLV 132
      REWIND NOUT                                                       SOLV 133
C                                                                       SOLV 134
C - - CONDFNSE THE MATRIX                                               SOLV 135
C                                                                       SOLV 136
      NN = NEL                                                          SOLV 137
      NL = NFL + 1                                                      SOLV 138
      IF (K .EQ. 1) GO TO 105                                           SOLV 139
      NS = 1                                                            SOLV 140
```

```
      NT = NFL
      DO 100 IB = 2, K
      NS = NS + NELP1
      NT = NT + NEL
      DO 100 IO = NS, NT
      A(NL) = A(IO)
  100 NL = NL + 1
  105 N1 = KORF - K * M + 1
C
C - - THERE, NOW WE CAN START THE BACK-SOLUTION
C * * NOTE..THE FIRST AVAILABLE LOCATION FOR THE SOLUTIONS IS A(N1)
C
      NREM = N
      NEL = NPM
      LAST = K .EQ. N
      NPASS = 0
C
C - - SOLVE FOR THE ANSWERS CORRESPONDING TO *K* ROWS
C
  110 KM1 = K - 1
      KP1 = K + 1
      NS = NL - MP1
      NPASS = NPASS + 1
      DO 130 MN = 1, M
      NF = NS + MN
      A(NF) = A(NF) / A(NS)
      NT = NS
      IF (KM1 .EQ. 0) GO  TO 130
      DO 125 IB = 1, KM1
      NF = NF - IB - M
      NT = NT - MP1 - IB
      SUM = 0.0
      NP = NF
      N2 = MP1 + IB
      DO 120 IO = 1, IB
```

```
      NN = NT + IO
      NP = NP + N2 - IO
  120 SUM = SUM + A(NN) * A(NP)
  125 A(NF) = (A(NF) - SUM) / A(NT)
  130 CONTINUE
C
C - - MOVE THE SOLUTIONS TO CONTIGUOUS LOCATIONS STARTING AT A(N1)
C
      N1 = KORE + 1
      DO 140 NN = 1, K
      DO 135 MN = 1, M
      NL = NL - 1
      N1 = N1 - 1
  135 A(N1) = A(NL)
  140 NL = NL - NN
C
C - - WRITE THE SOLUTIONS ON TAPE
C
      WRITE (NIN) K
      NS = N1 - 1
      DO 145 MN = 1, M
      NT = NS + MN
  145 WRITE ( NIN ) (A(IO), IO = NT, KORE, M)
C
C - - TEST IF THIS IS THE LAST PASS
C
      IF (LAST) GO TO 200
C
C - - WE MUST NOW MODIFY THE TRIANGULAR MATRIX TO REFLECT THE EFFECT OF
C     THE SOLUTIONS OBTAINED SO FAR  (EQ 21)
C * * NOTE..LOCATIONS A(1) TO A(N1-1) ARE NOW FREE TO USE
C
C - - CALCULATE THE NEXT VALUES OF 'NEL' AND 'NREM'
C
      NELOLD = NEL
```

```
      KOLD = K
      NEL = NEL - K
      NREM = NREM - K
C
C - - NOW APPLY THE INCREDIBLE FORMULA FOR THE NEW *K*
C
      K = (-4 * M - 1) / 2 + IFIX(SQRT(0.25 + FLOAT((4 * M + 2) * M +
     1 2 * (KORE - NELOLD))))
      NROW = NREM - K + 1
      IF (K .LT. NREM) GO TO 150
      LAST = .TRUE.
      NROW = 1
      K = NREM
  150 NS = 1
      NT = NELOLD + 1
C
C - - READ IN THE ROWS TO BE MODIFIED
C
      DO 190 IB = 1, NREM
      NT = NT - 1
      IF (IB .LE. NROW) GO TO 160
      NS = NS + NN
      NT = NT + NN
  160 READ ( MT ) NN, (A(IO), IO = NS, NT)
      NP = N1 - 1
      NF = NT - M - KM1
      NN = NN - KOLD
      DO 170 MN = 1, M
      N2 = NF
      NA = NP + MN
      NB = NA
      SUM = 0.0
      DO 165 IO = 1, KOLD
      SUM = SUM + A(N2) * A(NA)
      N2 = N2 + 1
```

```
  165 NA = NA + M
      N2 = N2 + MN - 1
  170 A(N2) = A(N2) - SUM
C
C - - WRITF THE MODIFIED ROW ON TAPE OR CONDFNSE THE ROW
C
      NL = NT - M + 1
      IF (IB .GE. NROW) GO TO 175
      NF = NL - KP1
      WRITF (NOUT) NN, (A(IO), IO = NS, NF), (A(IO), IO = NL, NT)
      GO TO 190
  175 NF = NL - KOLD
      DO 180 MN = NL, NT
      A(NF) = A(MN)
  180 NF = NF + 1
  190 CONTINUE
      REWIND MT
      REWIND NOUT
C
C - - SWITCH THE TAPES
C
      NT = MT
      MT = NOUT
      NOUT = NT
C
C - - LOOP BACK THRU THE SOLUTION
C
      NL = NF
      GO TO 110
C
C - - START TO WRAP IT UP
C
  200 REWIND NIN
      N2 = N
C
```

```
C * * NOTE.. AT THIS POINT ALL LOCATIONS A(1) THRU A(KORE) ARE FREE        SOLV  281
C                                                                          SOLV  282
      DO 220 IH = 1, NPASS                                                 SOLV  283
      READ (NIN) K                                                         SOLV  284
      N1 = N2 - K + 1                                                      SOLV  285
      NS = N1                                                              SOLV  286
      NT = N2                                                              SOLV  287
C                                                                          SOLV  288
C - - READ IN THE SOLUTIONS                                                SOLV  289
C                                                                          SOLV  290
      DO 210 IO = 1, M                                                     SOLV  291
      READ (NIN) (A(NN), NN = NS, NT)                                      SOLV  292
      NT = NT + N                                                          SOLV  293
  210 NS = NS + N                                                          SOLV  294
  220 N2 = N1 - 1                                                          SOLV  295
C                                                                          SOLV  296
C  ---  REWIND ALL INPUT TAPES                                             SOLV  297
      REWIND NIN                                                           SOLV  298
      REWIND MT                                                            SOLV  299
      REWIND NOUT                                                          SOLV  300
C - - WRITE THE SOLUTIONS ON TAPE                                          SOLV  301
C                                                                          SOLV  302
      NT = 0                                                               SOLV  303
      DO 230 IO = 1, M                                                     SOLV  304
      NS = NT + 1                                                          SOLV  305
      NT = NT + N                                                          SOLV  306
  230 WRITE (NW) (A(NN), NN = NS, NT)                                      SOLV  307
C                                                                          SOLV  308
C     CALL TIMEV(AA2)                                                      SOLV  309I
C     BB = (AA2 - AA1) / 60.                                               SOLV  310I
C     WRITE (6, 300) N, N, M, BB                                           SOLV  311I
C 300 FORMAT (4HOTHE I5, 2H X I5, 12H MATRIX WITH I4, 35H RIGHT SIDES WA   SOLV  312I
C    1S SOLVED DIRECTLY IN F8.3, 9H MINUTES. )                             SOLV  313I
      RETURN                                                               SOLV  314
      END                                                                  SOLV  315
```

```
      OVERLAY(AXSY,4,0)                                                          PAR4  001C
      PROGRAM PART4                                                              PAR4  002C
C     SUBROUTINE PART4                                                           PAR4  003I
C                                                                                PAR4  004
C              * COMPUTE VELOCITY COMPONENTS AND PRINT                           PAR4  005
C                                                                                PAR4  006
      COMMON /IPSF/ PSF                                                          PAR4  007
      COMMON       HEDR(10)   ,CASE       ,NB         ,NNU                       PAR4  008
     1            ,FLG03      ,FLG04      ,FLG05      ,FLG06      ,FLG07         PAR4  009
     2            ,FLG08      ,FLG09      ,FLG10      ,FLG11      ,FLG12         PAR4  010
     3            ,FLG13      ,FLG14      ,FLG15      ,FLG16      ,FLG17         PAR4  011
     4            ,FLG18      ,FLG19      ,FLG20      ,FLG21      ,FLG22         PAR4  012
     5            ,FLG23      ,FLG24      ,FLG25      ,FLG26      ,FLG27         PAR4  013
      COMMON    NT,        ND(11),    MN,        NUNA(5),  TYPEA(5),             PAR4  014
     1          NER1,      NER2,      NMA,       NSIGA,    NSIGC,                PAR4  015
     2          NUNC(5),   TYPEC(5),  NLF(11),   IEC,      NSIGEC,               PAR4  016
     3          TYPEEC(5),NUNEC(5)                                               PAR4  017
C     DOUBLE PRECISION  HEDR, CASE                                               PAR4  018I
      COMMON /COMBIN/CHAY(2)                                                     PAR4  019
      INTEGER      FLG03      ,FLG04      ,FLG05      ,FLG06      ,FLG07         PAR4  020
     1            ,FLG08      ,FLG09      ,FLG10      ,FLG11      ,FLG12         PAR4  021
     2            ,FLG13      ,FLG14      ,FLG15      ,FLG16      ,FLG17         PAR4  022
     3            ,FLG18      ,FLG19      ,FLG20      ,FLG21      ,FLG22         PAR4  023
     4            ,FLG23      ,FLG24      ,FLG25      ,FLG26      ,FLG27         PAR4  024
      REAL         MN                                                            PAR4  025
C                                                                                PAR4  026
      COMMON /C4/   X1(100),  Y1(100),  X2(100),  Y2(100),  DELS(100),           PAR4  027
     1              SINA(100),COSA(100),XP(100),  YP(100)                        PAR4  028
      COMMON /TC/   RB(100,10),         SIG(100,5),    A(100),   B(100),         PAR4  029
     1              Z(100),             PHI(100,5),    XN(100,5),T(100,5),       PAR4  030
     2              T3(100,5),          NSIG,          NP,       NI,             PAR4  031
     3              SUMV,               SUMM(5)                                  PAR4  032
C                                                                                PAR4  033
C              * START                                                           PAR4  034
      DO 20 J = 1,10                                                             PAR4  035
```

```
      DO 20 I = 1,500
   20 RB(I,J) = 0.0
      REWIND 3
      IF (FLG05.EQ.0) GO TO 30
C                * READ OFF-BODY XP,YP
      NP=ND(NB+1)
      READ (12) (XP(I),I=1,NP),(YP(I),I=1,NP)
C                * READ X1,Y1,X2,Y2,DELS WITH MACH NO. ADJUSTMENT IF ANY
   30 NI=NT+NB
      READ (12)   (X1(I),I=1,NI),(Y1(I),I=1,NT),(X2(I),I=1,NT)
     1            ,(Y2(I),I=1,NT),(DELS(I),I=1,NT)
C                * READ SINA,COSA,NO,TO..
      READ (4) (A(I),I=1,NT),(B(I),I=1,NT)
      NMAP1 = NMA + 1
      IF(FLG23 .GT. 0)READ(4)(Z(I),I=NMAP1,NT)
      SUMV = 0.0
      DO 100 I = 1, NT
      SINA(I) = A(I)
      COSA(I) = B(I)
  100 SUMV = SUMV + B(I)*DELS(I)*Y2(I)**2
      SUMV = SUMV*3.141593
      IF (FLG03.LE.0) GO TO 1000
      L = 1
      LS = 0
      IF (FLG16.NE.0) GO TO 200
      DO 150 I = 1, NT
      RB(I,L) = A(I)
  150 RB(I,L+1) = B(I)
  200 IF (NNU) 600,600,300
  300 DO 500 J = 1, NNU
      READ (4) MS,(A(I),I=1,NT),(B(I),I=1,NT)
      IF (MS.EQ.1.OR.MS.EQ.2.OR.MS.EQ.5) GO TO 500
      L = L+2
      LS = LS+1
      IF (LS.EQ.1.AND.FLG16.GT.0) L=L-2
```

```
      DO 400 I = 1, NT
      RB(I,L) = A(I)
  400 RB(I,L+1) = B(I)
  500 CONTINUE
      IF(FLG23 .LE. 0)GO TO 600
      IPV = NB - FLG14 + 1
      NN = NMA
      DO 550 KCNT = IPV,NB
      L = L + 2
      NN = NN + ND(KCNT) - 1
C    ***   READ NOTS COLUMNS OF RHS
      READ(4)(RB(I,L),I=1,NT),(RB(I,L+1),I=1,NT)
C    ***   MULTIPLY NOTS COLUMN BY LAST INPUT PV ON THAT BODY
      DO 550 I=1,NT
      RB(I,L) = RB(I,L) * Z(NN)
  550 RB(I,L+1) = RB(I,L+1) * Z(NN)
  600 REWIND 4
      NSIG = NSIGA
      IF(FLG23 .GT. 0)NSIG = 2.0 * NSIG - 1
C     CALL AXIS
      CALL OVERLAY (4HAXSY,4,1,6HRECALL )
 1000 IF (FLG04.LE.0) GO TO 2000
      IF (FLG03.LE.0) GO TO 1050
      READ (4) (A(I),I=1,NT),(B(I),I=1,NT)
 1050 L = 1
      LS=0
      IF (FLG17.NE.0) GO TO 1200
      DO 1100 I = 1, NT
      RB(I,L) = A(I)
 1100 RB(I,L+1) = B(I)
 1200 IF (NNU) 1600,1600,1300
 1300 DO 1500 J = 1, NNU
      READ (4) MS,(A(I),I=1,NT),(B(I),I=1,NT)
      IF ( MS.EQ.0.OR.MS.EQ.2.OR.MS.FQ.4) GO TO 1500
      L = L+2
```

```
      LS=LS+1
      IF (LS.EQ.1.AND.FLG17.GT.0) L=L-2
      DO 1400 I = 1, NT
      RB(I,L) = A(I)
 1400 RB(I,L+1) = B(I)
 1500 CONTINUE
 1600 REWIND 4
      NSIG = NSIGC
C     CALL CROSS
      CALL OVERLAY (4HAXSY,4,2,6HRECALL )
C2000 IF (FLG21.LE.0) RETURN
 2000 IF (FLG21.LE.0)  GO TO 2500
 2050 REWIND 4
      IF(FLG22.GT.0) GO TO 2400
      L = 0
C***   ***IF CONTROL REACHES THIS POINT, THERE IS AT LEAST 1 NNU
C***   ***SKIP RECORD WITH SIN AND COS
      READ (4)
      DO 2200 J = 1,NNU
      READ(4) MS, ( A(I),I=1,NT ), ( B(I),I=1,NT )
      L = L + 1
      DO 2200 I = 1,NT
      RB(I,L) = A(I)
 2200 RB(I,L+1) = B(I)
 2400 REWIND 4
      NSIG = NSIGEC
C***   ***CALL TO EXCROS FOR GENERATED (RESEP) BOUNDARY CONDITIONS
C     CALL EXCROS
      CALL OVERLAY (4HAXSY,4,3,6HRECALL )
C     RETURN
 2500 CONTINUE
      END
```

```
      OVERLAY(AXSY,4,1)                                                  AXIS 001C
      PROGRAM AXIS                                                       AXIS 002C
C     SUBROUTINE AXIS                                                    AXIS 003I
C                                                                        AXIS 004
C           * COMPUTE AXISYMMETRIC VELOCITY COMPONENTS AND PRINT         AXIS 005
C                                                                        AXIS 006
      COMMON /COMBIN/CHAY(2)                                             AXIS 007
      COMMON /IPSF/ PSF                                                  AXIS 008
      COMMON      HEDR(10)  ,CASE      ,NB       ,NNU                    AXIS 009
     1            ,FLG03    ,FLG04     ,FLG05    ,FLG06     ,FLG07       AXIS 010
     2            ,FLG08    ,FLG09     ,FLG10    ,FLG11     ,FLG12       AXIS 011
     3            ,FLG13    ,FLG14     ,FLG15    ,FLG16     ,FLG17       AXIS 012
     4            ,FLG18    ,FLG19     ,FLG20    ,FLG21     ,FLG22       AXIS 013
     5            ,FLG23    ,FLG24     ,FLG25    ,FLG26     ,FLG27       AXIS 014
      COMMON   NT,        ND(11),    MN,        NUNA(5),  TYPEA(5),      AXIS 015
     1         NER1,      NER2,      NMA,       NSIGA,    NSIGC,         AXIS 016
     2         NUNC(5),   TYPEC(5),  NLF(11),   IFC,      NSIGEC,        AXIS 017
     3         TYPFEC(5),NUNEC(5)                                        AXIS 018
C     DOUBLE PRECISION  HEDR, CASE                                       AXIS 019I
      INTFGER     FLG03     ,FLG04     ,FLG05    ,FLG06     ,FLG07       AXIS 020
     1            ,FLG08    ,FLG09     ,FLG10    ,FLG11     ,FLG12       AXIS 021
     2            ,FLG13    ,FLG14     ,FLG15    ,FLG16     ,FLG17       AXIS 022
     3            ,FLG18    ,FLG19     ,FLG20    ,FLG21     ,FLG22       AXIS 023
     4            ,FLG23    ,FLG24     ,FLG25    ,FLG26     ,FLG27       AXIS 024
      REAL        MN                                                     AXIS 025
C                                                                        AXIS 026
      COMMON /C4/    X1(100),  Y1(100),  X2(100),   Y2(100),  DELS(100), AXIS 027
     1               SINA(100),COSA(100),XP(100),   YP(100)              AXIS 028
      COMMON /TC/    RB(100,10),    SIG(100,5),     A(100),   B(100),    AXIS 029
     1               Z(100),        PHI(100,5),     XN(100,5),T(100,5),  AXIS 030
     2               T3(100,5),     NSIG,           NP,       NI,        AXIS 031
     3               SUMV,          SUMM(5)                              AXIS 032
      COMMON/ITERF/ ITER                                                 AXIS 033
C                                                                        AXIS 034
      DIMENSION UB(100),YB(100),XB(100)                                  AXIS 035
```

```
      DIMENSION      VX(100,5),      VY(100,5),      VT(100,5),
     1               TH(100,5),      CP(100,5),      SUMTDS(5)
C
      DATA FOURPI /12.5663706/
      EQUIVALENCE  ( VX(1,1) , XN(1,1) ) , (VY(1,1),T(1,1) ) ,
     1  ( VT(1,1), T3(1,1) ), ( TH(1,1),SIG(1,1) ), (CP(1,1),T3(1,1) )
C
C              * START
      NC=NT
      IF (FLG19.GT.0) NC=NMA
      IF (FLG08.EQ.0) GO TO 10
C              * TITLE FOR MATRIX PRINT
      WRITE(6,150)HEDR,CASE,PSF
      WRITE (6,8)
    8 FORMAT (1H 43H MATRICES A,B,Z BY ROWS * AXISYMMETRIC FLOW //)
C              * READ AXIS SIGMAS
   10 DO 20 N=1,NSIG
      SUMM(N)=0.0
      SUMTDS(N)=0.0
   20 READ (3) (SIG(I,N),I=1,NC)
      IF (FLG19.LE.0) GO TO 25
      READ (4)
      NR = NMA+1
      IF(FLG23 .GT. 0)GO TO 21
      READ (4) (SIG(I,1),I=NR,NT)
      REWIND 4
      GO TO 25
C
C
C*** *  RING WING
C
   21 LIFBOD = 0
      DO 22 K = 1,NB
      IF( NLF(K) .GT. 0)GO TO 22
      LIFBOD = LIFBOD + 1
```

```
   22 CONTINUE
      LBP1 = LIFBOD + 1
      DO 23 N=1,LBP1
      DO 23 I=NR,NT
   23 SIG(I,N) = 0.0
      LBP2 = LBP1 + 1
      DO 24 N = LBP2,NSIG
   24 READ(4) (SIG(I,N),I=NR,NT)
C    ***   SIGMAS HERE HAVE BECOME THE INPUT PV
      DO 26 N = LBP2,NSIG
      DO 26 I=NR,NT
   26 SIG(I,N) = SIG(I,N) /(-FOURPI)
      REWIND 4
C                 * NO. OF MIDPOINTS LOOP
   25 DO 100 I=1,NT
C                 * READ MATRICES A,B,Z
      READ (9) (A(J),J=1,NT),(B(J),J=1,NT),(Z(J),J=1,NT)
C                 * NO. OF FLOWS LOOP
      N1=0
      DO 70 N=1,NSIG
      N1=N1+2
      SN=0.0
      ST=0.0
      SP=0.0
C                 * NO. OF ELEMENTS LOOP
      DO 30 J=1,NT
      SN=SN+A(J)*SIG(J,N)
      ST=ST+B(J)*SIG(J,N)
      IF(FLG23 .GT. 0)Z(J) = 0.0
   30 SP=SP+Z(J)*SIG(J,N)
      IF(FLG22.GT.0) GO TO 68
      IF (FLG12.EQ.0) GO TO 40
      XN(I,N)=SN
      PHI(I,N)=SP-RB(I,N1-1)
      GO TO 50
```

```
   40 XN(I,N)=SN-RB(I,N1-1)
      PHI(I,N)=SP
   50 IF (FLG11.EQ.0) GO TO 60
      T(I,N)=ST
      GO TO 65
   60 T(I,N)=ST+RB(I,N1)
   65 SUMM(N)=SUMM(N)+PHI(I,N)*Y2(I)*RB(I,N1-1)*DELS(I)
      CP(I,N)=1.-T(I,N)**2
      GO TO 70
   68 XN(I,N) = SN
      PHI(I,N) = SP
      T(I,N) = ST
      CP(I,N) = 1.0 - T(I,N)**2
   70 CONTINUE
      IF(FLG08.EQ.0) GO TO 100
      WRITE (6,80) I,(A(J),J=1,NT)
   80 FORMAT (1H0 13H MATRIX A ROW I6/ (1H 10F10.5))
      WRITE (6,85) I,(B(J),J=1,NT)
   85 FORMAT (1H0 13H MATRIX B ROW I6/ (1H 10F10.5))
      WRITE (6,90) I,(Z(J),J=1,NT)
   90 FORMAT (1H0 13H MATRIX Z ROW I6/ (1H 10F10.5))
  100 CONTINUE
      IF (MN.EQ.0.0) GO TO 130
C                * MACH NO. ADJUSTMENT
      D1=MN*MN
      D2=1.-D1
      D3=SQRT(D2)
      D4=.7*D1
      D5=.2*D1
      DO 120 N=1,NSIG
      DO 120 I=1,NT
      TX=(T(I,N)*COSA(I)-1.)/D2+1.
      TY = ( T(I,N) * SINA(I) ) / D3
      T(I,N)=SQRT(TX*TX+TY*TY)
  120 CP(I,N)=((1.+D5*(1.-T(I,N)**2))**3.5-1.)/D4
```

```
C                 * ELIMINATE MACH NO EFFECT FOR PRINTOUT
      DO 122 I=1,NT
  122 X1(I)=X1(I)*D3
      N=0
      J1=0
      DO 126 K=1,NB
      M=N+1
      N=N+ND(K)-1
      DO 124 J=M,N
      J1=J1+1
      T1=X1(J1+1)-X1(J1)
      T2=Y1(J1+1)-Y1(J1)
      X2(J)=(X1(J1+1)+X1(J1))/2.
      DELS(J)=SQRT(T1*T1+T2*T2)
      COSA(J)=T1/DELS(J)
  124 SINA(J)=T2/DELS(J)
  126 J1=J1+1
C                 * PRINT AXIS FLOW (ON-BODY) OUTPUT
  130 DO 250 L=1,NSIG
      KA = L
      IF (FLG16.LE.0) KA=L-1
      IF(FLG22 .GT. 0    .OR. FLG23 .GT. 0 )KA = L
      IF(FLG22.GT.0)GO TO 136
      SUMM(L)=-6.2831853*SUMM(L)
      DO 135 J = 1, NT
  135 SUMTDS(L) = SUMTDS(L) + T(J,L)*DELS(J)
  136 I = 1
      J=1
      REWIND 1
      REWIND 3
      M=1
      N=ND(M)
      NSM=N-1
      XB(1)=X1(1)
      UB(1)=.9999999
```

```
      YB(1)=Y1(1)
      DO 138 KK=1,NSM
      XB(KK+1)=X2(KK)
      YB(KK+1)=Y2(KK)
  138 UB(KK+1)=CP(KK,L)
      WRITE(3) N
      WRITF(3) (XB(K),K=1,N)
      WRTTF(3) (YB(K),K=1,N)
      WRITE(3) (UB(K),K=1,N)
      IF(ITER .GE. 1) GO TO 139
      WRITE(15) N
      WRITE(15) (X1(K),K=1,N)
      WRITE(15) (Y1(K),K=1,N)
  139 CONTINUE
      LCTR=22
  140 WRITE(6,150)HEDR,CASE,PSF
  150 FORMAT (1H1 25X, 26HDOUGLAS  AIRCRAFT  COMPANY /
     1        28X, 21HLONG  BEACH  DIVISION ///
     2  6X,10A6,4X,10HCASE NO.  A6,10H    PSF = ,A4  //)
      IF (FLG22.GT.0) GO TO 178
      IF (L.GT.1.OR.FLG16.NE.0) GO TO 170
      WRITE (6,160)
  160 FORMAT (1H 34H ON-BODY UNIFORM AXISYMMETRIC FLOW )
      GO TO 190
  170 IF (TYPEA(KA).GE.0.0) GO TO 175
      WRITE (6,172)
  172 FORMAT (1H 44H FLOW GENERATOR * ROTATING BODY * TYPE ERROR )
  175 IF (NUNA(KA).EQ.123456) WRITE (6,177)
  177 FORMAT (27H  ON-BODY STRIP VORTEX FLOW)
  178 IF (NUNA(KA).NE.123456) WRITE(6,180)NUNA(KA)
  180 FORMAT (1H 42H ON-BODY NON-UNIFORM AXISYMMETRIC FLOW NO. I8)
  190 WRITE (6,200)
  200 FORMAT (1H 5X 24H TRANSFORMED COORDINATES //
     1         12X 1HX 13X 1HY 13X          2HT1 12X 2HCP  9X 5HSIN A
     2         6X 5HCOS A 7X 5HSIGMA 11X 1HN 13X 3HPHI //)
```

```
210 WRITF (6,220) I,X1(I),Y1(I),X2(J),Y2(J),          T(J,L),CP(J,L),     AXIS  211
   1             STNA(J),COSA(J),SIG(J,L),XN(J,L),PHI(J,L)                AXIS  212
220 FORMAT (1H I3,2F14.7/ 4X 4F14.7,2F11.5,3F14.7)                        AXIS  213
    I=I+1                                                                 AXIS  214
    J=J+1                                                                 AXIS  215
    IF (I.EQ.N) GO TO 230                                                 AXIS  216
    IF (I.LE.LCTR) GO TO 210                                              AXIS  217
    LCTR=LCTR+22                                                          AXIS  218
    GO TO 140                                                             AXIS  219
230 M=M+1                                                                 AXIS  220
    N=N+ND(M)                                                             AXIS  221
    WRITE (6,240) I,X1(I),Y1(I)                                           AXIS  222
240 FORMAT (1H I3, 2F14.7 //)                                             AXIS  223
    I=I+1                                                                 AXIS  224
    IF ( J - NT ) 210, 242, 242                                           AXIS  225
242 IF(FLG22.GT.0) GO TO 250                                              AXIS  226
    WRITE(6,244) SUMM(L), SUMV, SUMTDS(L)                                 AXIS  227
244 FORMAT (1H0 10X 13H ADDED MASS =F12.7, 4X 9H VOLUME = F12.7,          AXIS  228
   A          5X 18HSUM (T)(DELTA S) = F12.7 )                            AXIS  229
250 CONTINUE                                                              AXIS  230
252 LL = 1                                                                AXIS  231
    IF(FLG23 .GT. 0)CALL COMBO(LL)                                        AXIS  232
C   IF(FLG05 .EQ. 0)RETURN                                                AXIS  233I
    IF(FLG05 .EQ. 0) GO TO 700                                            AXIS  234C
C               * OFF-BODY POINT                                          AXIS  235
253 IF (FLG15.LE.0) GO TO 258                                             AXIS  236
    M = 0                                                                 AXIS  237
    DO 254 I = 1, NB                                                      AXIS  238
254 IF (NLF(I) .LE. 0) M = M + 1                                          AXIS  239
    IF ( M .EQ. 0 ) GO TO 258                                             AXIS  240
    MM = NNU + 1                                                          AXIS  241
    IF(FLG23 .GT. 0)MM = MM + NNU                                         AXIS  242
    DO 255 I = 1, MM                                                      AXIS  243
255 READ (4)                                                              AXIS  244
    IF (FLG22.GT.0)READ(4)                                                AXIS  245
```

```
      DO 256 J = 1, M
  256 READ(4) (RB(I,J),I = 1,NP), (T3(I,J),I = 1,NP)
      REWIND 4
  258 DO 300 I = 1, NP
      L=0
C                 * READ MATRICES X,Y,Z
      READ (9) (A(J),J=1,NT),(B(J),J=1,NT),(7(J),J=1,NT)
C                 * NO. OF FLOW
      DO 300 N=1,NSIG
      KA=N
      IF (FLG16.LE.0) KA=N-1
      SX=0.0
      SY=0.0
      SP=0.0
C                 * NO. OF ELEMENTS LOOP
      DO 260 J=1,NT
      SX=SX+A(J)*SIG(J,N)
      SY=SY+B(J)*SIG(J,N)
      IF(FLG23 .GT. 0)Z(J) = 0.0
  260 SP=SP+Z(J)*SIG(J,N)
      PHI(I,N)=SP
      IF (FLG22.GT.0) GO TO 270
      IF (FLG11.GT.0) GO TO 270
      IF (N.NE.1.OR.FLG16.GT.0) GO TO 262
      VX(I,N) = SX+1.
      GO TO 280
  262 IF (NUNA(KA).NE.123456) GO TO 270
      L=L+1
      VX(I,N)=SX+RB(I,L)
      VY(I,N)=SY+T3(I,L)
      GO TO 300
  270 VX(I,N) = SX
  280 VY(I,N) = SY
  300 CONTINUE
      IF (MN.EQ.0.0) GO TO 330
```

```
C                  * MACH NO. ADJUSTMENT
      DO 320 N=1,NSIG
      DO 320 I=1,NP
      VY(I,N)=VY(I,N)/D3
  320 VX(I,N)=(VX(I,N)-1.)/D2+1.
      DO 322 I = 1, NP
  322 XP(I)=XP(I)*D3
C                  * COMPUTE VT AND THETA
  330 DO 335 N=1,NSIG
      DO 335 I=1,NP
      VT(I,N)=SQRT(VX(I,N)**2+VY(I,N)**2)
  335 TH(I,N)=ATAN2(VY(I,N),VX(I,N)) * 57.29578
C                  * PRINT AXIS FLOW (OFF-BODY) OUTPUT
      DO 450 L=1,NSIG
      KA = L
      IF(FLG16 .LE. 0)KA = L - 1
      IF(FLG22 .GT. 0    .OR.     FLG23 .GT. 0) KA = L
      I=1
      LCTR=45
  340 WRITE(6,150)HEDR,CASE,PSF
      IF (L.GT.1.OR.FLG16.NE.0) GO TO 370
      IF(FLG22.GT.0) GO TO 378
      WRITE (6,360)
  360 FORMAT (1H 35H OFF-BODY UNIFORM AXISYMMETRIC FLOW )
      GO TO 390
  370 IF (TYPEA(KA).GE.0.) GO TO 375
      WRITE (6,172)
  375 IF (NUNA(KA).EQ.123456) WRITE (6,377)
  377 FORMAT (28H  OFF-BODY STRIP VORTEX FLOW)
  378 IF (NUNA(KA).NE.123456) WRITE (6,380) NUNA(KA)
  380 FORMAT (1H 43H OFF-BODY NON-UNIFORM AXISYMMETRIC FLOW NO. I8)
  390 WRITE (6,400)
  400 FORMAT (1H 5X, 24H TRANSFORMED COORDINATES //
     1          12X 1HX 13X 1HY 13X          2HVX 12X 2HVY 12X 2HVT 10X
     2          5HTHETA 11X 3HPHI //)
```

```
410 WRITE (6,420) I,XP(I),YP(I),          VX(I,L),VY(I,L),VT(I,L),      AXIS  316
   1 TH(I,L), PHI(I,L)                                                   AXIS  317
420 FORMAT (1H I3, 7F14.7)                                               AXIS  318
    I=I+1                                                                AXIS  319
    IF (I.GT.NP) GO TO 450                                               AXIS  320
    IF (I.LE.LCTR) GO TO 410                                             AXIS  321
    LCTR=LCTR+45                                                         AXIS  322
    GO TO 340                                                            AXIS  323
450 CONTINUE                                                             AXIS  324
500 LL = 0                                                               AXIS  325
    IF(FLG23 .GT. 0)CALL COMBU(LL)                                       AXIS  326
C   RETURN                                                               AXIS  327I
700 CONTINUE                                                             AXIS  328C
    END                                                                  AXIS  329
```

```
      SUBROUTINE COMBO(LL)
C
      COMMON / IPSF /   PSF
      COMMON /COMBIN/CHAY(2)
      COMMON        HEDR(10)  ,CASE       ,NB         ,NNU
     1             ,FLG03     ,FLG04      ,FLG05      ,FLG06      ,FLG07
     2             ,FLG08     ,FLG09      ,FLG10      ,FLG11      ,FLG12
     3             ,FLG13     ,FLG14      ,FLG15      ,FLG16      ,FLG17
     4             ,FLG18     ,FLG19      ,FLG20      ,FLG21      ,FLG22
     5             ,FLG23     ,FLG24      ,FLG25      ,FLG26      ,FLG27
      COMMON   NT,        ND(11),   MN,       NUNA(5),  TYPEA(5),
     1         NER1,      NER2,     NMA,      NSIGA,    NSIGC,
     2         NUNC(5),   TYPFC(5), NLF(11),  IEC,      NSIGEC,
     3         TYPFEC(5),NUNFC(5)
C     DOUBLE PRECISION  HEDR, CASE
      INTEGER       FLG03     ,FLG04      ,FLG05      ,FLG06      ,FLG07
     1             ,FLG08     ,FLG09      ,FLG10      ,FLG11      ,FLG12
     2             ,FLG13     ,FLG14      ,FLG15      ,FLG16      ,FLG17
     3             ,FLG18     ,FLG19      ,FLG20      ,FLG21      ,FLG22
     4             ,FLG23     ,FLG24      ,FLG25      ,FLG26      ,FLG27
      REAL          MN
C
      COMMON /C4/   X1(100),  Y1(100),  X2(100),  Y2(100),  DELS(100),
     1              SINA(100),COSA(100),XP(100),  YP(100)
      COMMON /TC/   RB(100,10),    SIG(100,5),    A(100),   B(100),
     1              Z(100),        PHI(100,5),    XN(100,5),T(100,5),
     2              T3(100,5),     NSIG,          NP,       NI,
     3              SUMV,          SUMM(5)
      DIMENSION C(2,2), DV(2),          TFIRST(2,5),TLAST(2,5),TSUM(2,5)
      DIMENSION  CP(100)
      EQUIVALENCE ( CP(1),A(1) )
      EQUIVALENCE (  DV(1),CHAY(1)   )
      DIMENSION VX(100,5),VY(100,5),VT(100,5)
      EQUIVALENCE   (VX(1,1),XN(1,1)),(VY(1,1),T(1,1)),
     1   (VT(1,1),T3(1,1))
```

```
C
C  **    ICNT WILL BE THE NUMBER OF LIFTING BODIES
C  *    NFLOW WILL BE THE NUMBER OF FLOWS
C
      ICNT = 0
      DO 10 K=1,NB
   10 IF( NLF(K) .LE. 0)ICNT=ICNT+1
      NFLOW = 1 + 2*ICNT
      IF(LL .EQ. 0)GO TO 1000
      READ(5,4)( DV(I),I=1,ICNT )
    4 FORMAT (6F10.0)
      WRITE(6,6) (DV(I),I=1,ICNT)
    6 FORMAT(1H1,42H THE INPUT DV FOR COMBINATION SOLUTION ARE /
     1  (2X,6F10.4)  )
C
C   ***    IPTCNT WILL BE THE LAST MIDPOINT ON BODY K
C
      IPTCNT = 0
C  *    ILIFT WILL BE THE LIFTING BODY NUMBER
      ILIFT = 0
      DO 100 K=1,NB
      IPTCNT = IPTCNT + ND(K) - 1
      IFIRST = IPTCNT - ND(K) + 2
      IF ( NLF(K) .GT. 0 )GO TO 100
      ILIFT = ILIFT + 1
C
      DO 50 J=1,NFLOW
      TFIRST(ILIFT,J) = T(IFIRST,J)
      TLAST(ILIFT,J) = T(IPTCNT,J)
   50 TSUM(ILIFT,J)  = TFIRST(ILIFT,J) + TLAST(ILIFT,J)
  100 CONTINUE
C
C  **    IPVBOD WILL BE 1ST PRESCRIBED VORTICITY FLOW
C  *    LASTSV WILL BE LAST STRIP VORTEX FLOW
C
```

```
      IPVBOD = 2+ICNT
      LASTSV = IPVBOD - 1
      DO 300 I=1,ICNT
      JCNT = 0
      DV(I)= DV(I) - TSUM(I,1)
C
      DO 200 J=IPVBOD,NFLOW
  200 DV(I) = DV(I) - TSUM(I,J)
C
      DO 250 J=2,LASTSV
      JCNT = JCNT + 1
  250 C(I,JCNT) = TSUM(I,J)
  300 CONTINUE
C
C
      CALL SOLCOM( DV, C, ICNT )
      DO 500 I = 1,NT
C    ***   ADD PV FLOWS TO AXIS FLOW FOR COMBINATION SOLUTION   ON BODY
      JCNT = 0
      DO 350 J=IPVBOD,NFLOW
      XN(I,1) = XN(I,1) + XN(I,J)
  350 T(I,1) = T(I,1) + T(I,J)
C    ***   ADD K * STRIP VORTEX BODY VELOCITY FOR COMBINATION SOLUTION
      DO 400 J = 2,LASTSV
      JCNT = JCNT + 1
      XN(I,1) = XN(I,1) + CHAY(JCNT)* XN(I,J)
  400 T(I,1) = T(I,1) + CHAY(JCNT)*T(I,J)
      CP(I) = 1.0  - T(I,1)**2
  500 CONTINUE
      I=1
      J=1
      M=1
      N=ND(M)
      LCTR = 22
  540 WRITE(6,550)HEDR,CASE,PSF
```

```
550 FORMAT(1H1,25X, 26HDOUGLAS  AIRCRAFT  COMPANY /                   COMB
    1       28X, 21HLONG  BEACH  DIVISION ///                         COMB
    2 6X,10A6, 4X,10HCASE NO.  A6, 9H   PSF = ,A4  // )               COMB
      WRITE(6,560)                                                    COMB
560 FORMAT( 1H ,21H COMBINATION SOLUTION  )                           COMB
      WRITF(6,700)                                                    COMB
700 FORMAT(1H 5X 24H TRANSFORMED COORDINATES //                       COMB
    1 12X,1HX 13X 1HY 13X 2HT1 12X 2HCP 9X 5HSIN A 6X 5HCOS A 11X 1HN  COMB
    2 // )                                                            COMB
710 WRITF(6,720)I,X1(I),Y1(I),X2(J),Y2(J),T(J,1),CP(J),SINA(J),COSA(J) COMB
    2          ,XN(J,1)                                               COMB
720 FORMAT(1H I3,2F14.7 / 4X 4F14.7,2F11.5,F14.7 )                    COMB
      I=I+1                                                           COMB
      J=J+1                                                           COMB
      IF( I  .EQ. N) GO TO 730                                        COMB
      IF( I  .LE. LCTR ) GO TO 710                                    COMB
      LCTR = LCTR + 22                                                COMB
      GO TO 540                                                       COMB
730 M=M+1                                                             COMB
      N=N+ND(M)                                                       COMB
      WRITE(6,740)I,X1(I),Y1(I)                                       COMB
740 FORMAT( 1H ,I3, 2F14.7 // )                                       COMB
      I=I+1                                                           COMB
      IF( J .LT. NT)GO TO 710                                         COMB
      M1 = 0                                                          COMB
      N1 = 0                                                          COMB
      DO 800 K = 1,NB                                                 COMB
      M1 = N1 + 1                                                     COMB
      N1 = N1 + ND(K) - 1                                             COMB
      CIRC = 0.0                                                      COMB
      THRUST = 0.0                                                    COMB
      DO 790 I = M1,N1                                                COMB
      CIRC = CIRC + ( T(I,1) * DELS(I) )                              COMB
790 THRUST = THRUST + ( Y2(I) * CP(I) * SINA(I) * DELS(I) )           COMB
      THRUST = -6.283186 * THRUST                                     COMB
```

```
      WRITE(6,795)K,CIRC,THRUST
  795 FORMAT(///13H    BODY NO. ,I4,5X,14HCIRCULATION = ,F14.7,5X,
     1       9HTHRUST = ,F14.7)
  800 CONTINUE
      RETURN
C    ***   OFF BODY COMBINATION SOLUTION
 1000 IPVBOD = 2 + ICNT
      LASTSV = IPVBOD - 1
      DO 1500 I=1,NP
      JCNT = 0
C    ***   ADD PV FLOWS TO AXIS FLOW FOR COMBINATION SOLUTION   OFF BODY
      DO 1350 J = IPVBOD,NFLOW
      VX(I,1) = VX(I,1) + VX(I,J)
 1350 VY(I,1) = VY(I,1) + VY(I,J)
C    ***   ADD K * STRIP VORTEX OFF BODY VELOCITY
      DO 1400 J=2,LASTSV
      JCNT = JCNT + 1
      VX(I,1) = VX(I,1) + CHAY(JCNT) * VX(I,J)
 1400 VY(I,1) = VY(I,1) + CHAY(JCNT) * VY(I,J)
      VT(I,1) = SQRT( VX(I,1)**2 + VY(I,1)**2 )
 1500 CONTINUE
      I = 1
      LCTR = 45
 1540 WRITE(6,550)HEDR,CASE,PSF
      WRITE(6,1560)
 1560 FORMAT(1H ,31H COMBINATION SOLUTION  OFF BODY  )
      WRITE(6,1700)
 1700 FORMAT(1H ,5X,24H TRANSFORMED COORDINATES //
     1    12X,1HX,13X,1HY,13X,2HVX,12X,2HVY,12X,2HVT //)
 1710 WRITE(6,1720)I,XP(I),YP(I),VX(I,1),VY(I,1),VT(I,1)
 1720 FORMAT(1H ,I3,5F14.7)
      I = I + 1
      IF(I .GT. NP)GO TO 1750
      IF(I .LE. LCTR )GO TO 1710
      LCTR = LCTR + 45
```

```
      GO TO 1540                                                        COMB  176
 1750 CONTINUE                                                          COMB  177
      RETURN                                                            COMB  178
      END                                                               COMB  179
```

```
      SUBROUTINE SOLCOM( DV,  A    , ICNT)
C
C  **   NOTE THAT THIS SUBROUTINE SOLVES ONLY A 1X1 OR 2X2 MATRIX
C  **   IT IS SEPARATED SO THAT IF PROGRAM IS EVER INLARGED, THIS
C  **   IS WHERE THE MATRIX 'SOLUTION FOR THE COMBINATION PART OF
C  **   THE PROGRAM WILL GO.  THE MATRICES HAVE BEEN FORMED GENERALLY
C  **   IN SUBROUTINE COMBO.
C
      DIMENSION DV(2), A(2,2)
      IF(ICNT .EQ. 2) GO TO 20
      DV(1) = DV(1) / A(1,1)
      RETURN
   20 DV(1) = (DV(1) - (A(1,2)/A(2,2) ) * DV(2)   ) /
     1        (  A(1,1)   -  A(1,2)*A(2,1) / A(2,2)   )
      DV(2) =( DV(2) - A(2,1)*DV(1) ) / A(2,2)
      RETURN
      END
```

```
      OVERLAY(AXSY,4,2)
      PROGRAM CROSS
C     SUBROUTINE CROSS
C
C              * COMPUTE CROSS FLOW VELOCITY COMPONENTS AND PRINT
C
      COMMON /IPSF/ PSF
      COMMON       HEDR(10)  ,CASE       ,NB         ,NNU
     1            ,FLG03     ,FLG04      ,FLG05      ,FLG06      ,FLG07
     2            ,FLG08     ,FLG09      ,FLG10      ,FLG11      ,FLG12
     3            ,FLG13     ,FLG14      ,FLG15      ,FLG16      ,FLG17
     4            ,FLG18     ,FLG19      ,FLG20      ,FLG21      ,FLG22
     5            ,FLG23     ,FLG24      ,FLG25      ,FLG26      ,FLG27
      COMMON    NT,        ND(11),    MN,        NUNA(5),  TYPEA(5),
     1          NER1,      NER2,      NMA,       NSIGA,    NSIGC,
     2          NUNC(5),   TYPEC(5),  NLF(11),   IEC,      NSIGEC,
     3          TYPEEC(5),NUNEC(5)
C     DOUBLE PRECISION  HEDR, CASE
      INTEGER      FLG03     ,FLG04      ,FLG05      ,FLG06      ,FLG07
     1            ,FLG08     ,FLG09      ,FLG10      ,FLG11      ,FLG12
     2            ,FLG13     ,FLG14      ,FLG15      ,FLG16      ,FLG17
     3            ,FLG18     ,FLG19      ,FLG20      ,FLG21      ,FLG22
     4            ,FLG23     ,FLG24      ,FLG25      ,FLG26      ,FLG27
      REAL         MN
C
      COMMON /C4/    X1(100),  Y1(100),  X2(100),  Y2(100),  DELS(100),
     1               SINA(100),COSA(100),XP(100),  YP(100)
      COMMON /TC/    RB(100,10),    SIG(100,5),    A(100),   B(100),
     1               Z(100),        PHI(100,5),    XN(100,5),T(100,5),
     2               T3(100,5),     NSIG,          NP,       NI,
     3               SUMV,          SUMM(5)
C
      DIMENSION VX(100,5),VY(100,5),VZ(100,5),T2(100,5)
C
      EQUIVALENCE ( VX(1,1), XN(1,1) ), ( VY(1,1), T(1,1) ),
```

```
      1    (VZ(1,1), T3(1,1) ),  (T2(1,1), T(1,1) )
C
C                   * START
      IF (FLG08.EQ.0) GO TO 10
C                   * TITLE FOR MATRIX PRINT
      WRITE(6,150)HEDR,CASE,PSF
      WRITE (6,8)
    8 FORMAT (1H 36H MATRICES A,B,Z BY ROWS * CROSS FLOW //)
C                   * READ CROSS SIGMAS
   10 DO 20 N=1,NSIG
      SUMM(N)=0.0
   20 READ (3) (SIG(I,N),I=1,NT)
C                   * NO. OF MIDPOINTS LOOP
      DO 100 I=1,NT
C                   * READ MATRICES A,B,Z
      READ (10) (A(J),J=1,NT),(B(J),J=1,NT),(Z(J),J=1,NT)
C                   * NO. OF FLOWS LOOP
      M=0
      DO 70 N=1,NSIG
      M=M+2
      SA=0.0
      SB=0.0
      SZ=0.0
C                   * NO. OF ELEMENTS LOOP
      DO 30 J=1,NT
      SA=SA+A(J)*SIG(J,N)
      SB=SB+B(J)*SIG(J,N)
   30 SZ=SZ+Z(J)*SIG(J,N)
C                   * INITIALIZE UNIFORM OR NON-UNIFORM PARAMETERS
      IF (FLG21.GT.0) GO TO 38
      IF (N.EQ.1.AND.FLG17.LE.0) GO TO 35
      C1=RB(I,M)
      C2 = -RB(I,M-1)
      C3=0.0
      GO TO 40
```

```
   35 C1=SINA(I)                                                  CROS  071
      C2=COSA(I)                                                  CROS  072
      C3=1.                                                       CROS  073
      GO TO 40                                                    CROS  074
   38 C1 = 0.0                                                    CROS  075
      C2 = 0.0                                                    CROS  076
      C3 = 0.0                                                    CROS  077
   40 IF (FLG12.EQ.0) GO TO 45                                    CROS  078
C                  * OPTION FOR Z (PHI) MATRIX SOLUTION           CROS  079
      XN(I,N) = SA                                                CROS  080
      PHI(I,N) = Y2(I) * SZ                                       CROS  081
      GO TO 50                                                    CROS  082
C                  * REGULAR A MATRIX SOLUTION                    CROS  083
   45 PHI(I,N)=Y2(I)*SZ                                           CROS  084
      XN(I,N)=SA+C2                                               CROS  085
   50 IF (FLG11.EQ.0) GO TO 55                                    CROS  086
C                  * OPTION PERTURBATIONS                         CROS  087
      T2(I,N)=SB                                                  CROS  088
      T3(I,N)=SZ                                                  CROS  089
      GO TO 60                                                    CROS  090
   55 T2(I,N)=SB+C1                                               CROS  091
      T3(I,N)=SZ+C3                                               CROS  092
   60 IF(FLG21.GT.0) GO TO 70                                     CROS  093
      SUMM(N) = SUMM(N) + PHI(I,N) * Y2(I) * C2 * DELS(I)         CROS  094
   70 CONTINUE                                                    CROS  095
      IF (FLG08.EQ.0) GO TO 100                                   CROS  096
      WRITE (6,80) I,(A(J),J=1,NT)                                CROS  097
   80 FORMAT (1H0 13H MATRIX A ROW I6/  (1H 10F10.5))             CROS  098
      WRITE (6,85) I,(B(J),J=1,NT)                                CROS  099
   85 FORMAT (1H0 13H MATRIX B ROW I6/ (1H 10F10.5))              CROS  100
      WRITE (6,90) I,(Z(J),J=1,NT)                                CROS  101
   90 FORMAT (1H0 13H MATRIX Z ROW I6/ (1H 10F10.5))              CROS  102
  100 CONTINUE                                                    CROS  103
C                  * PRINT CROSS FLOW (ON-BODY) OUTPUT            CROS  104
  130 DO 250 L=1,NSIG                                             CROS  105
```

```
      KC = L                                                            CROS 106
      IF (FLG17.LE.0) KC=L-1                                            CROS 107
      IF(FLG21.GT.0) GO TO 138                                          CROS 108
      SUMM(L) = 3.141593  *SUMM(L)                                      CROS 109
  138 I = 1                                                             CROS 110
      J=1                                                               CROS 111
      M=1                                                               CROS 112
      N=ND(M)                                                           CROS 113
      LCTR=22                                                           CROS 114
  140 WRITE(6,150)HEDR,CASE,PSF                                         CROS 115
  150 FORMAT (1H1 25X, 26HDOUGLAS  AIRCRAFT  COMPANY /                  CROS 116
     1        28X, 21HLONG  BEACH  DIVISION ///                         CROS 117
     2  6X,10A6,4X,10HCASE NO.  A6,10H    PSF = ,A4  //)                CROS 118
      IF (FLG22.GT.0) GO TO 175                                         CROS 119
      IF (L.GT.1.OR.FLG17.NE.0) GO TO 170                               CROS 120
      WRITE (6,160)                                                     CROS 121
  160 FORMAT (1H 27H ON-BODY UNIFORM CROSS FLOW )                       CROS 122
      GO TO 190                                                         CROS 123
  170 IF (TYPEC(KC).GE.0.) GO TU 175                                    CROS 124
      WRITE (6,172)                                                     CROS 125
  172 FORMAT (1H 31H FLOW GENERATOR * ROTATING BODY )                   CROS 126
  175 WRITE (6,180) NUNC(KC)                                            CROS 127
  180 FORMAT (1H 35H ON-BODY NON-UNIFORM CROSS FLOW NO. I8)             CROS 128
  190 WRITE (6,200)                                                     CROS 129
  200 FORMAT (1H 5X 24H TRANSFORMED COORDINATES //                      CROS 130
     1          12X 1HX 13X 1HY 13X          2HT2 12X 2HT3  9X 5HSIN A  CROS 131
     2          6X 5HCOS A 7X 5HSIGMA 11X 1HN 13X 3HPHI //)             CROS 132
  210 WRITE (6,220) I,X1(I),Y1(I),X2(J),Y2(J),        T2(J,L),T3(J,L),  CROS 133
     1              SINA(J),COSA(J),SIG(J,L),XN(J,L),PHI(J,L)           CROS 134
  220 FORMAT (1H I3,2F14.7/ 4X 4F14.7,2F11.5,3F14.7)                    CROS 135
      I=I+1                                                             CROS 136
      J=J+1                                                             CROS 137
      IF (I.EQ.N) GU TO 230                                             CROS 138
      IF (I.LE.LCTR) GO TU 210                                          CROS 139
      LCTR=LCTR+22                                                      CROS 140
```

```
      GO TO 140                                                         CROS 141
  230 M=M+1                                                             CROS 142
      N=N+ND(M)                                                         CROS 143
      WRITE (6,240) I,X1(I),Y1(I)                                       CROS 144
  240 FORMAT (1H I3, 2F14.7 //)                                         CROS 145
      I=I+1                                                             CROS 146
      IF(J.GT.NT)GO TO 242                                              CROS 147
      GO TO 210                                                         CROS 148
  242 IF(FLG22.GT.0)GO TO 250                                           CROS 149
      WRITE(6,244) SUMM(L), SUMV                                        CROS 150
  244 FORMAT (1H0 10X,14H ADDED MASS = F12.7, 4X,10H VOLUME = F12.7)    CROS 151
  250 CONTINUE                                                          CROS 152
  252 IF (FLG05.EQ.0) RETURN                                            CROS 153
C                 * OFF-BODY POINT                                      CROS 154
      DO 300 I=1,NP                                                     CROS 155
C                 * READ MATRICES X,Y,Z                                 CROS 156
      READ (10) (A(J),J=1,NT),(B(J),J=1,NT),(Z(J),J=1,NT)               CROS 157
C                 * NO. OF FLOW                                         CROS 158
      DO 300 N=1,NSIG                                                   CROS 159
      SX=0.0                                                            CROS 160
      SY=0.0                                                            CROS 161
      SP=0.0                                                            CROS 162
C                 * NO. OF ELEMENTS LOOP                                CROS 163
      DO 260 J=1,NT                                                     CROS 164
      SX=SX+A(J)*SIG(J,N)                                               CROS 165
      SY=SY+B(J)*SIG(J,N)                                               CROS 166
  260 SP=SP+Z(J)*SIG(J,N)                                               CROS 167
      VX(I,N)=SX                                                        CROS 168
      PHI(I,N)=YP(I)*SP                                                 CROS 169
      IF (FLG22.GT.0) GO TO 270                                         CROS 170
      IF (FLG11.GT.0.OR.N.NE.1.OR.FLG17.GT.0) GO TO 270                 CROS 171
      VY(I,N)=SY+1.                                                     CROS 172
      VZ(I,N)=SP+1.                                                     CROS 173
      GO TO 300                                                         CROS 174
C                 * PERTURBATION OR NON-UNIFORM VY,VZ                   CROS 175
```

```
  270 VY(I,N)=SY                                                      CROS  176
      V7(I,N)=SP                                                      CROS  177
  300 CONTINUE                                                        CROS  178
C                 * PRINT CROSS FLOW (OFF-BODY) OUTPUT                CROS  179
  330 DO 450 L=1,NSIG                                                 CROS  180
      KC = L                                                          CROS  181
      IF (FLG17.LE.0) KC=L-1                                          CROS  182
      I=1                                                             CROS  183
      LCTR=45                                                         CROS  184
  340 WRITE(6,150)HEDR,CASF,PSF                                       CROS  185
      IF (FLG22.GT.0) GO TO 375                                       CROS  186
      IF (L.GT.1.OR.FLG17.NE.0) GO TO 370                             CROS  187
      WRITE (6,360)                                                   CROS  188
  360 FORMAT (1H 28H OFF-BODY UNIFORM CROSS FLOW )                    CROS  189
      GO TO 390                                                       CROS  190
  370 IF (TYPEC(KC).GE.0.) GO TO 375                                  CROS  191
      WRITE (6,172)                                                   CROS  192
  375 WRITE (6,380) NUNC(KC)                                          CROS  193
  380 FORMAT (1H 36H OFF-BODY NON-UNIFORM CROSS FLOW NO. I8)          CROS  194
  390 WRITE (6,400)                                                   CROS  195
  400 FORMAT (1H 5X, 24H TRANSFORMED COORDINATES //                   CROS  196
     1 12X 1HX 13X 1HY 13X 2HVX 12X 2HVY 12X 2HVZ 12X 3HPHI //)       CROS  197
  410 WRITE (6,420) I,XP(I),YP(I),VX(I,L),VY(I,L),VZ(I,L),PHI(I,L)    CROS  198
  420 FORMAT (1H I3, 6F14.7)                                          CROS  199
      I=I+1                                                           CROS  200
      IF (I.GT.NP) GO TO 450                                          CROS  201
      IF (I.LE.LCTR) GO TO 410                                        CROS  202
      LCTR=LCTR+45                                                    CROS  203
      GO TO 340                                                       CROS  204
  450 CONTINUE                                                        CROS  205
  500 CONTINUE                                                        CROS  206
C     RETURN                                                          CROS  207I
      END                                                             CROS  208
```

```
      OVERLAY(AXSY,4,3)                                                 EXCR 001C
      PROGRAM EXCROS                                                    EXCR 002C
C     SUBROUTINE EXCROS                                                 EXCR 003I
C***   ***COMPUTE EXTRA CROSS FLOW VELOCITY COMPONENTS AND PRINT        EXCR 004
      COMMON /IPSF/ PSF                                                 EXCR 005
      COMMON        HEDR(10)  ,CASE       ,NB        ,NNU               EXCR 006
     1             ,FLG03     ,FLG04      ,FLG05     ,FLG06     ,FLG07  EXCR 007
     2             ,FLG08     ,FLG09      ,FLG10     ,FLG11     ,FLG12  EXCR 008
     3             ,FLG13     ,FLG14      ,FLG15     ,FLG16     ,FLG17  EXCR 009
     4             ,FLG18     ,FLG19      ,FLG20     ,FLG21     ,FLG22  EXCR 010
     5             ,FLG23     ,FLG24      ,FLG25     ,FLG26     ,FLG27  EXCR 011
      COMMON   NT,        ND(11),    MN,        NUNA(5),  TYPEA(5),     EXCR 012
     1         NER1,      NER2,      NMA,       NSIGA,    NSIGC,        EXCR 013
     2         NUNC(5),   TYPEC(5),  NLF(11),   IFC,      NSIGEC,       EXCR 014
     3         TYPEEC(5),NUNEC(5)                                       EXCR 015
C     DOUBLE PRECISION  HEDR, CASE                                      EXCR 016I
      INTEGER       FLG03     ,FLG04      ,FLG05     ,FLG06     ,FLG07  EXCR 017
     1             ,FLG08     ,FLG09      ,FLG10     ,FLG11     ,FLG12  EXCR 018
     2             ,FLG13     ,FLG14      ,FLG15     ,FLG16     ,FLG17  EXCR 019
     3             ,FLG18     ,FLG19      ,FLG20     ,FLG21     ,FLG22  EXCR 020
     4             ,FLG23     ,FLG24      ,FLG25     ,FLG26     ,FLG27  EXCR 021
      REAL          MN                                                  EXCR 022
C                                                                       EXCR 023
      COMMON /C4/   X1(100),  Y1(100),  X2(100),  Y2(100),  DELS(100),  EXCR 024
     1              SINA(100),COSA(100),XP(100),  YP(100)               EXCR 025
      COMMON /TC/   RB(100,10),     SIG(100,5),     A(100),   B(100),   EXCR 026
     1              Z(100),         PHI(100,5),     XN(100,5),T(100,5), EXCR 027
     2              T3(100,5),      NSIG,           NP,       NI,       EXCR 028
     3              SUMV,           SUMM(5)                             EXCR 029
C                                                                       EXCR 030
      DIMENSION VX(100,5),VY(100,5),VZ(100,5),T2(100,5)                 EXCR 031
C                                                                       EXCR 032
      EQUIVALENCE ( VX(1,1), XN(1,1) ), ( VY(1,1), T(1,1) ),            EXCR 033
     1   (VZ(1,1), T3(1,1) ),  (T2(1,1), T(1,1) )                       EXCR 034
C                                                                       EXCR 035
```

```
      REWIND 8
      IF (FLG08.EQ.0) GO TO 10
C***   ***TITLE FOR MATRIX PRINT
      WRITE(6,150)HEDR,CASF,PSF
      WRITE (6,8)
    8 FORMAT (1H 42H MATRICES A,B,Z BY ROWS * EXTRA CROSS FLOW //)
C***   ***READ EXTRA CROSS SIGMAS
   10 DO 20 N = 1,NSIG
   20 READ (3) ( SIG(I,N),I = 1,NT )
C***   ***NO. OF MIDPOINTS LOOP
      DO 100 I = 1,NT
C***   ***READ MATRICES A,B,Z
C***   ***YOU MUST SOLVE POTENTIAL MATRIX FOR EXCROS
      READ (8) ( A(J),J = 1,NT),( B (J),J = 1,NT ), ( Z(J),J = 1,NT )
C***   ***NO. OF FLOWS LOOP
      M = 0
      DO 70 N = 1,NSIG
      M = M + 2
      SA = 0.0
      SB = 0.0
      SZ = 0.0
C***   ***NO. OF ELEMENTS LOOP
      DO 30 J = 1,NT
      SA = SA + A(J) * SIG(J,N)
      SB = SB + B(J) * SIG(J,N)
   30 SZ = SZ + Z(J) * SIG(J,N)
   40 T2(I,N) = SB
      T3(I,N) = SZ
      XN(I,N) = SA
      PHY(I,N) = Y2(I) * SZ / 2.0
   70 CONTINUE
      IF (FLG08.EQ.0) GO TO 100
      WRITE (6,80) I, (A(J),J = 1,NT)
   80 FORMAT (1H0 13H MATRIX A ROW I6/  (1H 10F10.5) )
      WRITE (6,85) I, (B(J),J = 1,NT)
```

```
   85 FORMAT (1H0 13H MATRIX B ROW I6/  (1H 10F10.5) )
      WRITE (6,90) I, ( Z(J),J = 1,NT)
   90 FORMAT (1H0 13H MATRIX Z ROW I6/  (1H 10F10.5) )
  100 CONTINUE
C***   ***PRINT EXTRA CROSS FLOW (ON BODY) OUTPUT
  130 DO 250 L = 1,NSIG
      KEC = L
      I = 1
      J = 1
      M = 1
      N = ND(M)
C***   ***M IS THE BODY NUMBER
C***   ***N IS THE NUMBER OF POINTS ON BODY M
      LCTR = 22
  140 WRITE(6,150)HEDR,CASE,PSF
  150 FORMAT (1H1 25X, 26HDOUGLAS  AIRCRAFT  COMPANY /
     1        28X, 21HLONG  BEACH  DIVISION ///
     2  6X,10A6,4X,10HCASE NO.  A6,10H    PSF = ,A4  //)
      IF (FLG22.GT.0) GO TO 160
      WRITE (6,155)NUNEC(KEC)
  155 FORMAT(41H ON-BODY NON-UNIFORM EXTRA CROSS FLOW NO. I8)
      GO TO 190
  160 WRITE  (6,162)
  162 FORMAT(68H  ON BODY   GENERATED (RESEP) BOUNDARY CONDITIONS   EXTR
     1A CROSS FLOW)
  190 WRITE (6,200)
  200 FORMAT (1H 5X 24H TRANSFORMED COORDINATES //
     1         12X 1HX 13X 1HY 13X            2HT2 12X 2HT3  9X 5HSIN A
     2         6X 5HCOS A 7X 5HSIGMA 11X 1HN 13X 3HPHI //)
  210 WRITE (6,220) I,X1(I),Y1(I),X2(J),Y2(J),        T2(J,L),T3(J,L),
     1            SINA(J),COSA(J),SIG(J,L),XN(J,L),PHI(J,L)
  220 FORMAT (1H I3,2F14.7/ 4X 4F14.7,2F11.5,3F14.7)
      I = I + 1
      J = J + 1
      IF (I.EQ.N) GO TO 230
```

```
      IF (I.LF.LCTR) GO TO 210                                          EXCR 106
      LCTR = LCTR + 22                                                  EXCR 107
      GO TO 140                                                         FXCR 108
  230 M = M + 1                                                         EXCR 109
      N = N + ND(M)                                                     EXCR 110
      WRITF (6,240)I , X1(T), Y1(I)                                     EXCR 111
  240 FORMAT (1H I3,2F14.7 //)                                          EXCR 112
      T = T + 1                                                         FXCR 113
      IF (J.GE.NT) GO TO 250                                            EXCR 114
      GO TO 210                                                         EXCR 115
  250 CONTINUE                                                          EXCR 116
C 252 IF (FLG05.EQ.0) RETURN                                             EXCR 117I
  252 IF (FLG05.EQ.0) CONTINUE                                          FXCR 118C
C***   ***OFF BODY POINTS                                               EXCR 119
      DO 300 I = 1,NP                                                   EXCR 120
C***   ***READ MATRICES X,Y,Z                                           EXCR 121
      READ (8) ( A(J),J=1,NT ),(B(J),J = 1,NT), ( Z(J),J = 1,NT )       EXCR 122
      DO 300 N = 1,NSIG                                                 EXCR 123
      SX = 0.0                                                          EXCR 124
      SY = 0.0                                                          EXCR 125
      SP = 0.0                                                          EXCR 126
C***   ***NUMBER OF ELEMENTS LOOP                                       EXCR 127
      DO 260 J = 1,NT                                                   EXCR 128
      SX = SX + A(J) * SIG (J,N)                                        EXCR 129
      SY = SY + B(J) * SIG (J,N)                                        EXCR 130
  260 SP = SP + Z(J) * SIG(J,N)                                         EXCR 131
      VX(I,N) = SX                                                      EXCR 132
      VY(I,N) = SY                                                      FXCR 133
      VZ(I,N) = SP                                                      EXCR 134
      PHI(I,N) = YP(I) * SP / 2.0                                       EXCR 135
  300 CONTINUE                                                          EXCR 136
C***   ***PRINT EXTRA CROSS FLOW (OFF-BODY) OUTPUT                      EXCR 137
  330 DO 450 L = 1,NSIG                                                 EXCR 138
      KEC = L                                                           EXCR 139
      I = 1                                                             EXCR 140
```

```
      LCTR = 45                                                         EXCR 141
  340 WRITE(6,150)HEDR,CASE,PSF                                         EXCR 142
      IF (FLG22.GT.0) GO TO 355                                         EXCR 143
      WRITF(6,350) NUNFC(KEC)                                           EXCR 144
  350 FORMAT (43H  OFF BODY NON-UNIFORM EXTRA CROSS FLOW NO. I8)        EXCR 145
      GO TO 390                                                         EXCR 146
  355 WRITE(6,357)                                                      EXCR 147
  357 FORMAT(68H OFF BODY   GENERATED (RFSEP) BOUNDARY CONDITIONS   FXTR EXCR 148
     1A CROSS FLOW)                                                     EXCR 149
  390 WRITE (6,400)                                                     EXCR 150
  400 FORMAT (1H 5X, 24H TRANSFORMFD COORDINATFS //                     EXCR 151
     1 12X 1HX 13X 1HY 13X 2HVX 12X 2HVY 12X 2HVZ 12X 3HPHI //)         EXCR 152
  410 WRITE (6,420) I,XP(I),YP(I),VX(I,L),VY(I,L),VZ(I,L),PHI(I,L)      EXCR 153
  420 FORMAT (1H I3, 6F14.7)                                            EXCR 154
      I = I + 1                                                         EXCR 155
      IF (I.GT.NP)GO TO 450                                             EXCR 156
      IF (I.LE.LCTR) GO TO 410                                          EXCR 157
      LCTR = LCTR + 45                                                  EXCR 158
      GO TO 340                                                         EXCR 159
  450 CONTINUE                                                          EXCR 160
C     RETURN                                                            EXCR 161I
  501 CONTINUE                                                          EXCR 162C
      END                                                               EXCR 163
```

```
      OVERLAY(AXSY,5,0)                                                      BOUN  001C
C     SUBROUTINE BOUNDL                                                      BOUN  002I
      PROGRAM BOUNDL                                                         BOUN  003C
C     * * * * * * * * P   R   O   G   R   A   M     K   9   Q   A * * * * * * * *  BOUN  004
C                                                                            BOUN  005
C     SOLUTION OF THE 2-D , YAWED WING, AND AXISYMMETRIC, COMPRESSIBLE      BOUN  006
C     BOUNDARY LAYER EQUATIONS USING KELLER≠S BOX METHOD                    BOUN  007
C                                                                            BOUN  008
C     *****************************************************************     BOUN  009
C                                                                            BOUN  010
C     *****************    FORMULATED BY T. CEBECI    *****************     BOUN  011
C     *****************  AERODYNAMICS RESEARCH GROUP  **M***************     BOUN  012
C     ******  DOUGLAS AIRCRAFT DIVISION , MCDONNELL-DOUGLAS CORP. ******     BOUN  013
C     *****************    LONG BEACH , CALIFORNIA    *****************     BOUN  014
C                                                                            BOUN  015
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -     BOUN  016
C                                                                            BOUN  017
      COMMON  NX,NP,NPPR,JI,IT,NRVP,LSP,NPM1,JI1,JIM1,NTC,NXT,NXW,NXM        BOUN  018
     1      ,TITLE(15)                                                       BOUN  019
      COMMON LG16,LG17,LG18,LG32,LG40                                        BOUN  020
     1      , IGOL, IGOT, IGOW, IGON, IGCV, IGEG, IGNP, IGRC, IGTR           BOUN  021
      COMMON /HEADR/ CASE, IPAGE                                             BOUN  022
      COMMON/BLC1/F(100,2),U(100,2),V(100,2),ETA(100),DELETA(100)            BOUN  023
      COMMON/BLC3/XI(100),XS (100),ETAINF(100),BETA(100)                     BOUN  024
      COMMON/BL11/VWPRI,UWPRI,DELV1                                          BOUN  025
      COMMON/BL13/FPSLN                                                      BOUN  026
      COMMON /BL16/ NTYPE,IOUT                                               BOUN  027
      COMMON/BLC5/EM(100,2),EDV(100,2),E(100,2),EB(100,2),VPRT(100)          BOUN  028
      COMMON/BLC7/VGP ,DETA1                                                 BOUN  029
      COMMON/BLC8/A(100),CEL(100)                                            BOUN  030
      COMMON/BL10/SWP,TANL,WE,W(100,2),WP(100,2)                             BOUN  031
      COMMON/BL12/TI,RMI,UI,RI,PR,PRT,FK,RL,RMUI,RHOI,PSI,HE                 BOUN  032
     1           ,UE(100),RO(100),TW(100),QW(100),RP(100),FW(100)            BOUN  033
     2           ,BR(100),TE(100),RHOE(100),RMUE(100),GW(100),GPW(100)       BOUN  034
     3           ,RF1(100),RF2(100),YS (100),IGX1(100),FPW(100),ROL(100)     BOUN  035
```

```
      COMMON /BL14/ RX1,RTH1, CF0,CF1,CF2,CFSUM0,CFSUM,
     1        THETA(100),DELS(100),FPPW(100)
      COMMON /BL15/ NXY
      COMMON /BL17/ RX(100),CFA(100),CF(100),ETAE(100),CDI(100),ST(100),
     1         INP(100)
      COMMON/BL19/C(100,2),G(100,2),GP(100,2),
     1              RHO(100),RMU(100),TVCT(100)
      COMMON/BL20/ RTHTR, UEIN,ROIN,GAMAT
      COMMON/BL21/ A1(100,2),A2(100,2)
      COMMON/RADIUS/ ROMAX
C
C     - - - - - - - - - - - - - - - * - - - - - - - - - - - - - - -
C
      REWIND 2
      REWIND 3
      NTC=0
      IPAGE=1
   50 NTC=NTC+1
      IGNP=0
      IGTR=0
      NX=0
      IT = 0
      LSP=0
      IOUT = 0
C ----
      CALL INPT
      LC=0
      LCMAX=61
C ----
  100 NX=NX+1
C ----
      ITC=0
      IGRC=0
  120 IGOL = 0
      IGOT = 0
```

```
      IF(NX .LT. NXT)  IGOL = 1
      IF(NX .GE. NXT)  IGOT = 1
C ----
      IGCV=0
      CALL FINF
      IF(LG32 .NE. 1  .OR.  NX .EQ. 1)  CALL HEAD
      IF(LG32.EQ.1)  GO TO 130
      WRITE(6,6015) NX,BETA(NX),XI(NX),XS (NX),ETAINF(NX)
      GO TO 138
  130 IF(NX .EQ. 1) WRITE(6,7000)
      LC = LC+3
      IF(LC .LT. LCMAX)  GO TO 135
      CALL HEAD
      LC=0
  135 WRITE(6,7015) NX,BETA(NX),XI(NX),XS (NX),ETAINF(NX)
      LC = LC+2
  138 IF(LSP.EQ.1) GO TO 700
C ----
      IF(NX.EQ.1)  CALL IVPF
      IF(LSP.EQ.1) GO TO 700
C ----
      IF(NX.EQ.1)  CALL FLPR
      IF(LSP .EQ. 1)  GO TO 700
C ----
      IF( NX.NE.1 .OR. XS(NX).EQ.0.)  GO TO 140
      CALL EDVS
      IF(LSP.EQ.1) GO TO 700
C ----
  140 IF(NX.EQ.1)  GO TO 145
      CALL SHFT
      IF(LSP.EQ.1) GO TO 700
      CALL FLPR
      IF(LSP .EQ. 1)  GO TO 700
C----
  145 IT=0
```

```
      LC = LC+2
      IF(NX-NXT)150,142,150
  142 ITC=1
  150 IT=IT+1
      LC = LC+1
      IF(IT.LE.9) GO TO 220
      IF(ITC .EQ. 0) GO TO 200
      WRITF(6,6000)
      ITC=0
      IT=1
      GO TO 220
  200 WRITE(6,6010)
      LSP=1
      GO TO 700
  220 CALL EDVS
      IF(LSP.EQ.1) GO TO 700
      CALL MOMX
  300 IF(IGOL.EQ.1) GO TO 540
      IF(IGOT.EQ.1) GO TO 550
  540 IF( ABS(DELV1  ).LT.EPSLN) GO TO 600
      IF(V(1,2).LT.0. .AND. LG16.NE.0) GO TO 670
      GO TO 150
  550 EAG= DELV1/((V(1,2)+VWPRI)*.5)
      IF( ABS(EAG).LT.0.02 ) GO TO 600
      IF(IGTR .LE. 1 .OR. V(1,2) .LE. 0.)  GO TO 150
      IGCV=1
      CALL EINF
      IF(NX .EQ. 1)  GO TO 150
      IF(LSP .EQ. 1)  GO TO 700
      IF(IGRC .EQ. 0)  GO TO 150
      CALL SHFT
      CALL FLPR
      GO TO 145
C----
  600 WRITE(6,6030)     V(1,2)
```

```
      LC = LC+1
      IF(IGTR.GT.1) IGTR=0
      IGCV=1
      CALL EINF
      LC=LC+3
      IF(LSP.EQ.1) GO TO 700
      IF(IGRC.EQ.0) GO TO 670
      CALL SHFT
      CALL FLPR
      IF(LSP .EQ. 1)  GO TO 700
      LC = LC+2
      GO TO 145
C ----
  670 CALL OTPT
      IF(NX.EQ.NXM) GO TO 700
C ----
      IF( IGOT .EQ. 1)  GO TO 100
      IF(NX .GT. 1 .AND. LG16 .NE. 0) CALL TRNS
      IF(IGTR .GT. 1) IGRC=1
      IF(LSP.EQ.1) GO TO 700
      IF(IGTR.GT.1) GO TO 120
C ----
      GO TO 100
  700 IF(NX .EQ. 0) GO TO 800
      IOUT=1
      CALL OTPT
  800 IF(LSP .EQ. 1) WRITE(6,9999)
C----
 5010 FORMAT( I3 ,39X,I1)
 6000 FORMAT(1H ,20X,43HCONVERGENCE IS SLOW - ITERATIONS CONTINUING,/)
 6010 FORMAT(1H ,15X,45H*** ITERATIONS EXCEED THE ALLOWABLF LIMIT *** /)
 6015 FORMAT(1H0,///5X,8HSTATION=,I3,3X,5HBETA=,E16.9,2X,3HXI=,E16.9,2X,
     1       2HS=,E16.9,2X,8HETAINF =,E16.9,////)
 6030 FORMAT(1H ,32X,E20.9)
 7000 FORMAT(1H ,45X,20HOUTPUT IN SHORT FORM, /)
```

```
 7015 FORMAT(1H0,5X,8HSTATION=,I3,3X,5HBETA=,E16.9,2X,3HXI=,E16.9,2X,2HS BOUN  176
     1=,    E16.9,2X,8HETAINF =,E16.9 )                                  BOUN  177
 9999 FORMAT(1H0/45X,37H********** CASE TERMINATED **********  // )      BOUN  178
C      RETURN                                                           BOUN  179I
 1000 CONTINUE                                                          BOUN  180C
      END                                                               BOUN  181
```

```
      SUBROUTINE INPT
C
C **  SUBROUTINE INPT
C     THIS SUBROUTINE PROCESSES ALL THE INPUT DATA TO THE PROGRAM
C
      COMMON  NX,NP,NPPR,JI,IT,NRVP,LSP,NPM1,JT1,JTM1,NTC,NXT,NXW,NXM
     1       ,TITLE(15)
      COMMON LG16,LG17,LG18,LG32,LG40
     1       , IGOL, IGOT, IGOW, IGON, IGCV, IGFG, IGNP, IGRC, IGTR
      COMMON /HEADR/ CASE, IPAGE
      COMMON/BLC7/VGP ,DETA1
      COMMON/BLC3/XI(100),XS (100),ETAINF(100),BETA(100)
      COMMON/BL12/TI,RMI,UI,RI,PR,PRT,FK,RL,RMUI,RHOI,PSI,HE
     1            ,UE(100),RO(100),TW(100),QW(100),RP(100),FW(100)
     2            ,RR(100),TE(100),RHOE(100),RMUE(100),GW(100),GPW(100)
     3            ,RF1(100),RF2(100),YS (100),IGX1(100),FPW(100),ROL(100)
      COMMON/BL13/EPSLN
      COMMON /BL15/ NXY
      COMMON/RADIUS/ ROMAX
      DIMENSION S(301) ,XR(301) ,DUEDX(100) ,PE(100)
      DATA DATA1/1.4/, DATA2/6035.0/
C
C     - - - - - - - - - - - - - - - * - - - - - - - - - - - - - - -
C
      EPSLN = .005
      PR = .72
C---- READ CASE DATA
      READ(5,5005) TITLE,CASE
      READ(5,5010) NXT,LG16,LG17,LG18,LG32,LG26,LG40,LG41
      READ(5,5020) TI,RMI,UI,FK,RL,RI
      READ(5,5025) ROMAX,DETA1,VGP
      IF(LG40 .EQ. 0) GO TO 7000
      READ(5,1013) NXM
      READ(5,1014) (XS(I),I=1,NXM)
      READ(5,1014) (YS(I),I=1,NXM)
```

```
      READ(5,1014) (UE(I),I=1,NXM)
      GO TO 7001
 7000 CONTINUE
      READ(3) NXM
      READ(3) (XS(I),I=1,NXM)
      READ(3) (YS(I),I=1,NXM)
      READ(3) (UE(I),I=1,NXM)
 7001 CONTINUE
      NXY=NXM
      DO 50 I=1,NXM
      RO(I) = YS(I)
      QW(I)=0.0
      RF2(I) = 0.
      FW(I) = 0.
      GW(I) = 0.
      GPW(I) = 0.
      RF1(I)=0.
      TW(I)=0.
      RP(I)=0.
      FPW(I)=0.
      BR(I)=0.
   50 IGX1(I)=0.
      ETAINF(1) = 6.
      ETAINF(2) = 10.
      NXNS=NXM
   85 CALL HEAD
      WRITE(6,2050) TITLE ,CASE
      WRITE(6,2500) LG16,LG17,LG18,LG32,NXT
  150 XS1=0.0
      SD1=0.0
  160 DO 180 I=2,NXM
      SDA1=(XS(I)-XS(I-1))**2+(YS(I)-YS(I-1))**2
      SQDA1= SQRT(SDA1)
      SD2=SD1+ ABS(SQDA1)
      S(2*I+1) = SD2
```

```
      SD1=SD2
      IF(I.EQ.2)  S(3)=XS1
  180 CONTINUF
      WRITF(2) NXM
      WRITF(2) (S(2*I+1),I=1,NXM)
      LC = 1
      LCMAX = 36
      WRITE(6,2550)
      DO 185 I=1,NXM
      IF(LC .LT. LCMAX) GO TO 182
      CALL HEAD
      WRITE(6,2550)
      LC = 1
      LCMAX = 49
  182 XBG = XS(I) * RL
      SBG = S(2*I+1) * RL
      WRITE(6,3100) I,XS(I),YS(I), XBG,SBG,S(2*I+1)
      LC = LC+1
      IF(FK .EQ. 1)  RO(I) = YS(I)*RL
      YS(I)=XS(I)
      XS(I) = SBG
  185 CONTINUE
      IF(LCMAX.EQ.36 .AND. LC.GT.18)  CALL HEAD
      IF(LCMAX.EQ.49 .AND. LC.GT.45)  CALL HEAD
      IF(FK .EQ. 0. .OR. LG18 .NE. 1) GO TO 203
      CALL SLOPE(NXM,XS,YS,RF1,1)
      IF(RL .EQ. 1.0)  GO TO 203
      DO 202 I=1,NXM
  202 RF1(I) = RF1(I)*RL
C----
  203 IF(UI.NE.0. .OR. RMI.NE.0.)  GO TO 204
      WRITE(6,9030)
      LSP = 1
      GO TO 1800
  204 IF(TT.NE.0.)  GO TO 205
```

```
      IF(LG41 .EQ. 0) GO TO 201
      WRITE(6,9045)
      TI=519. *(5./9.)
      GO TO 205
  201 CONTINUE
      WRITE(6,9040)
      TI = 519.0
  205 IF(RMI .NE. 0.)  UI = 0.
      IF(LG41 .EQ. 1) GO TO 206
      IF(UI.NE.0.) RMI=UI/( SQRT(TI)*49.1)
      IF(RMI.NE.0.) UI=RMI* SQRT(TI)*49.1
      RMUI= 1.0E-06*(.90311226E-03*TI+1.238522-(.56843634E-06*TI*TI
     1     +.38312556E-03*TI+1.436156)**0.5)
      RHOI=RMUI*RI/UI
      PSI=RHOI*TI*1718.0
      RMI2=RMI*RMI
      DK1=RMI2*(DATA1-1.0)*0.5
      UEA4=DATA1*RMI2*0.5
      SHI=DATA2*TI
  207 HE = SHI + .5*(UI**2 )
      GO TO 209
  206 TIR=TI*9./5.
      UII=UI/.3048
      IF(UI .NE. 0.) RMI=UII/(SQRT(TIR)*49.1)
      IF(RMI .NE. 0.) UI=(RMI*SQRT(TIR)*49.1)*.3048
      RMUI=1.0E-06*(.90311226E-03*TIR+1.238522-(.56843634E-06*TIR*TIR
     1+.38312556E-03*TIR+1.436156)**.5)
      RHOI=RMUI*RI/UII
      PSI=RHOI*TIR*1718.0
      SHI=DATA2*TIR
      HF=SHI+.5*(UII**2)
      RMUI=RMUI*47.88025
      RHOI=RHOI*515.379
      PSI=PSI*47.88025
      HE=HF*.3048*.3048
```

```
  209 CONTINUE
      IF(LG26.EQ.2) GO TO 270
      IF(LG26.EQ.3) GO TO 210
      WRITE(6,9050)
      LSP=1
      GO TO 1800
  210 CONTINUE
  208 DO 220 I=1,NXM
      UE(I)=UI* SQRT(1.0-UE(I))
  220 CONTINUE
      GO TO 300
  270 DO 280 I=1,NXM
      UE(I)=UE(I)*UI
  280 CONTINUE
C ----
  300 CONTINUE
      DO 320 I=1,NXM
      RHOE(I)=RHOI
      RMUE(I)=RMUI
      PE(I) = 0.
      TE(I) = 0.
  320 CONTINUE
  500 IST = 1
      MULT = 0
      CALL SLOPE(NXM,XS,UE,DUEDX,MULT)
C----
  510 DO 1500 I=1,NXM
      IF(I .GT. 1) GO TO 520
      VT1=RHOI*RMUI
  520 VT2=VT1*UE(I)
      VT3=VT2*UE(I)
      IF(FK.NE.0.) GO TO 550
      VT4=1.0
      VT5=1.0
      VT42=1.0
```

```
      GO TO 600
  550 IF(FK.NE.1.0) GO TO 560
      IF(RO(I) .NE. 0.)  GO TO 555
      IF(I .GT. 1)  WRITE(6,9095) I
      RO(I) = .0001*RL
  555 VT4=RO(I)/RL
      VT42=VT4*VT4
      VT5=RL/RO(I)
      GO TO 600
  560 WRITE(6,9060)
      LSP=1
      GO TO 1800
  600 ROL(I) = VT4
      FX2=VT2*VT42
      IF(I.EQ.1) XI(1)=FX2*XS(1)
      IF(I .EQ. 1)  GO TO 680





  650 XI(I)=XI(I-1)+(FX1+FX2)*(XS(I)-XS(I-1))*0.5
  680 FX1 = FX2
      IF(I .NE. 1)  GO TO 930
      IF(IST .EQ. 0)  GO TO 1500
      BETA(1) = 1.0
      IF(FK .EQ. 1.)  BETA(1) = BETA(1)/2.
      GO TO 1500
  930 IF(I .EQ. 2)  GO TO 950
      BETA(I)=2.*XI(I)/(VT3*VT42)*DUEDX(I)
      GO TO 1500
  950 BETA(I)=2.0*XI( I )*(UE(I)-UE(I-1))/(VT3*VT42*(XS(I)-XS(I-1)))
 1500 CONTINUE
C----
      WRITE(6,2600) DETA1, RL, PR, VGP, RHOI, SWP, FK,RMUI, HE, FPSLN
```

```
1     ,UI, TI, RI, RMI
      CALL HEAD
      WRITE(6,2900)
      WRITE(6,3000)
      LC=1
      LCMAX=45
      DO 1550 I=1,NXM
      IF(LC .LT. LCMAX) GO TO 1520
      CALL HEAD
      WRITE(6,3000)
      LC=1
      LCMAX=49
 1520 IF(FK .NE. 0.)  GO TO 1530
      WRITE(6,3200) I,YS(I),RO(I), TW(I), UE(I), PE(I), BR(I)
      GO TO 1540
 1530 WRITE(6,3200) I,YS(I),ROL(I),TW(I), UE(I), PE(I), BR(I)
 1540 CP=1.-UE(I)*UE(I)/(UI*UI)
      WRITE(6,3250) XS(I), RF1(I), QW(I),  CP  , RMUE(I), FPW(I)
      RMACH = 0.
      WRITE(6,3250) BETA(I), RF2(I), RP(I), RMACH, TE(I), XI(I)
      LC = LC+4
 1550 CONTINUE
 1590 IGXI=0
      IF(XI(1).GE.0.) GO TO 1600
      WRITE(6,9070)
      IGXI=1
 1600 IF(NXM .EQ. 1)  RETURN
      DO 1700 I=2,NXM
      IF(XI(I).GT.0.) GO TO 1620
      WRITE(6,9080) I
      IGXI=1
 1620 IF(XI(I).GT.XI(I-1)) GO TO 1700
      WRITE(6,9090) I
      IGXI=1
 1700 CONTINUE
```

```
      IF(IGXI.EQ.0) RETURN
      LSP=1
 1800 RETURN
C - - - -
 1013 FORMAT(I4)
 1014 FORMAT(6F10.0)
 2050 FORMAT(1H ,25X,15A4,10X,6HCASE ,A4,///1H ,54X,10H CASE DATA ,///)
 2500 FORMAT(1H0,10X,8HTRFLAG =,I1,10X,7HTRINT =,I1,10X,5HTVC =,I1,
     1 10X,8HSHORTP =,I1,//1H ,30X,31HTRANSITION SPECIFIED AT STATION,I4
     1)
 2550 FORMAT( 1H , 50X, 19HBODY GEOMETRY DATA  /
     1     1H0,21X,1HK,9X,3HX/C ,15X,3HY/C ,16X,1HX,17X,1HS ,16X,3HS/C /)
 2600 FORMAT(1H0/1H0,40X,43HREFERENCE QUANTITIES AND CONTROL PARAMETERS,
     A      /1H0,16X, 6HH1    = ,F9.5, 16X,8HC        = ,E15.7,10X,
     1     8HPRO    = ,F9.5, / 1H0,16X, 6HK     = ,F9.5, 16X,8HRHOREF = ,
     2     E15.7, 10X,8HSWEEP = ,F9.4 / 1H0,16X, 6HKK    = ,F9.5, 16X ,
     3     8HMUREF  = ,E15.7, 10X,8HHE     = ,E15.7 / 1H0,16X, 6HEPS1 = ,
     4     E15.7, 10X, 8HVREF    = ,E15.7, 10X, 8HTREF  = ,F10.3/ 1H0,16X,
     5     31X,          8HREY    = ,E15.7, 10X,8HMREF  = ,E15.7/         )
 2900 FORMAT(1H ,50X,12HSTATION DATA//)
 3000 FORMAT(1H0,7X,1HN,12X,3HX/C,13X,4HRO/C,14X,2HTW,16X,2HUE,15X,2HPE,
     1       14X,2HFW,/1H ,20X,4H  S ,12X,6HALPHA1,13X,2HQW,16X,2HCP,14X,
     2       3HMUE,13X,3HFPW,/1H ,20X,4HBETA,12X,6HALPHA2,13X,2HRR,16X,
     3       2HME,15X,2HTE,12X,5HSQUIG,/ )
 3100 FORMAT(1H ,19X,I3,5(3X,E15.7 ))
 3200 FORMAT(1H /1H ,I8,3X,6E17.6)
 3250 FORMAT(1H ,11X, 6E17.6)
 5005 FORMAT(15A4,A4)
 5010 FORMAT(I4,7I1)
 5020 FORMAT(5F10.0,E12.6)
 5025 FORMAT(3F10.0)
 5030 FORMAT(2F8.0,F6.0,F5.0,F6.0,F7.0,2F6.0,F7.0,8X,F4.0,I1 )
 5040 FORMAT(3E14.9)
 9004 FORMAT(1H ,37H**ERROR - INPUT REFERENCE LENGTH = 0. /)
 9005 FORMAT(1H ,51H**ERROR - INPUT SURFACE DISTANCE AT STATION 1 LT 0.)
```

```
9006 FORMAT(1H ,66H**ERROR - INPUT SURFACE DISTANCE NOT IN ASCENDING OR
    1DER AT STATION, I3 //)
9010 FORMAT(1H ,51H**ERROR - INPUT X NOT IN ASCENDING ORDER AT STATION,
    1       I3 //)
9020 FORMAT(1H0,51H**ERROR - INPUT NTR OR S AT STATION 1 ARE INCORRFCT)
9030 FORMAT(1H0,42H**ERROR - NO INPUT FOR EITHER VREF OR MREF)
9040 FORMAT(1H0,52H***** WARNING - TREF INPUT = 0., VALUE RESET TO 519.
    1)
9045 FORMAT(1H0,67H**** WARNING - TREF INPUT = 0., VALUE RESET TO 288.3
    133 DEGREES KELVIN    )
9050 FORMAT(1H0,27H**ERROR - CHECK CPCOM INPUT )
9060 FORMAT(1H0,48H**ERROR - INPUT FLOW INDEX NOT EQUAL TO 1. OR 0. )
9070 FORMAT(1H ,38H**ERROR - XI AT STATION 1 NE OR GT  0. )
9080 FORMAT(1H ,25H** ERROR - XI AT STATION ,I3,12H IS NEGATIVE)
9090 FORMAT(1H ,25H** ERROR - XI AT STATION ,I3,26H IS NOT IN ASCENDING
    1 ORDER)
9095 FORMAT(1H0,41H****** WARNING - ROIC INPUT=0. AT STATION , I3,
    1    23H - VALUE RESET TO .0001 )
9100 FORMAT(1H0, 40X,25HINSS NOT SUCCESSFUL NER = ,I2,2X,10HAT STATION,
    1       1X,I3/1H ,12X,1HI,15X,3HX/C,22X,3HY/C, //)
9150 FORMAT(1H0,47H** ERROR - INPUT CP EXCEEDS ALLOWABLE LIMITS OF,
    1       2E17.6,1X, 1QHAT STATION,I3 /)
9200 FORMAT(1H ,11X,I3,2E20.9)
9300 FORMAT(1H0,40X,25HINSR NOT SUCCESSFUL NER = ,I2,2X,10HAT STATION,
    1       1X,I3,/1H ,12X,1HI,15X,3HXIC,22X,3HYIC, //)
     END
```

```
      SUBROUTINE EINF
C **  SUBROUTINE EINF
C     THIS SUBROUTINE CALCULATES THE TRANSFORMED Y - GRID POINTS
C
      COMMON  NX,NP,NPPR,JI,IT,NRVP,LSP,NPM1,JT1,JTM1,NTC,NXT,NXW,NXM
     1       ,TITLE(15)
      COMMON LG16,LG17,LG18,LG32,LG40
     1       , IGOL, IGOT, IGOW, IGON, IGCV, IGEG, IGNP, IGRC, IGTR
      COMMON/BLC1/F(100,2),U(100,2),V(100,2),ETA(100),DELETA(100)
      COMMON/BLC3/XI(100),XS (100),ETAINF(100),BETA(100)
      COMMON/BLC7/VGP ,DETA1
C
C     - - - - - - - - - - - - - - - * - - - - - - - - - - - - - - -
C
      IF(IGCV.EQ.1) GO TO 30
   30 IF(NX.EQ.1) GO TO 50
      IF(NX.EQ.2) GO TO 250
      IF(IGNP.EQ.1) GO TO 300
      IF(IGNP.EQ.0) GO TO 800
      WRITE(6,9910)
      LSP=1
      GO TO 1800
C ----
   50 IF(IGNP.EQ.0) GO TO 1000
      IF(IGNP.EQ.1) GO TO 100
      WRITE(6,9920)
      LSP=1
      GO TO 1800
C ----
  100 DO 120 J=2,NP
      IF( ABS(V(J,2)).LT.1.E-5) GO TO 500
      IF( ABS(V(J,2)).LT.1.E-6) GO TO 500
  120 CONTINUE
      DO 140 J=2, NP
      IF( ABS(V(J,2)).LT.1.E-4) GO TO 500
```

```
      IF(U(J,2).GE..999999) GO TO 500
      IF(U(J,2).LT.0.) GO TO 400
  140 CONTINUE
      WRITE(6,9930)
      J = NP
      GO TO 530
C ----
  250 IF(IGNP.EQ.0) GO TO 1000
  300 DO 320 J=JI,NP
      IF( ABS(V(J,2)).LT.1.E-5) GO TO 500
      IF( ABS(V(J,2)).LT.1.E-6) GO TO 500
  320 CONTINUE
      DO 340 J=JI,NP
      IF( ABS(V(J,2)).LT.1.E-4) GO TO 500
      IF(J .EQ.NP) GO TO 330
      IF(U(J,2).GE..999999) GO TO 500
  330 IF(U(J,2).LT.0.) GO TO 400
  340 CONTINUE
C ----
      WRITE(6,9980)
      IGRC=1
      ETAINF(NX)=ETAINF(NX)+10.
      GO TO 1010
C ----
  400 WRITE(6,9940) J
      LSP=1
      GO TO 1800
C ----
  500 IF(IGTR .GT. 1)  GO TO 600
  530 ETAINF(NX)=ETA(J)
      JI=J
      IGNP=0
      WRITE(6,6010) ETAINF(NX)
      GO TO 1800
  600 IGTR=0
```

```
      RETURN
C ----
  800 K = NX-1
      IF(K .EQ. NXT)  GO TO 820
      IF((ETAINF(NX-1).GT.ETAINF(NX-2)).AND.(IGTR .LE. 1)) GO TO 850
      ETAINF(NX) = ETAINF(NX-1) + 2.
  820 IF(IGOT.EQ.1) ETAINF(NX)=ETAINF(NX-1)+10.
      GO TO 1000
  850 ETAINF(NX)=ETAINF(NX-2)+(XI(NX)-XI(NX-2))/(XI(NX-1)-XI(NX-2))*
     1(ETAINF(NX-1)-ETAINF(NX-2))
C ----
 1000 IF(NX.GT.1) NPPR=NP
 1010 IF(VGP.EQ.1.)GO TO  1020
      ARGLOG=1.+ETAINF(NX)/DETA1*(VGP-1.)
      DLOG1=ALOG(ARGLOG)
      ARGINT=1.+DLOG1/ALOG(VGP)
      NP=  INT(ARGINT)+1
      GO TO 1050
 1020 ARGINT=ETAINF(NX)/DETA1+1.
      NP=  INT(ARGINT)
 1050 NPM1=NP-1
      IF(NP.LE.100) GO TO 1060
      WRITE(6,9970) NX, NP
      LSP=1
      GO TO 1800
 1060 ETA(1)=0.
      DELETA(1)=DETA1
      M = 1
      M1 = M+1
      NP = M*(NP-1)+1
      NPM1 = NP-1
      DO 1080  J= M1,NP,M
      N = J-M+1
      ETA(J) = DETA1 + VGP*ETA(N-1)
      DELETA(J-1) = ETA(J) - ETA(N-1)
```

```
      IF(M .EQ. 1)  GO TO 1080
      DELETA(J-1) = DELETA(J-1)/M
      ETA(J-1) = ETA(J) - DELETA(J-1)
      DELETA(J-2) = DELETA(J-1)
      IF(M .EQ. 2)  GO TO 1080
      ETA(J-2) = ETA(J-1) - DELETA(J-2)
      DELETA(J-3) = DELETA(J-1)
 1080 CONTINUE
      IF(VGP.NE.1.)ETAINF(NX)=ETA(NP)
      IGNP=1
 1800 RETURN
C ----
 6010 FORMAT(1H ,/16X,10H* ETAE  = ,F10.6)
 9910 FORMAT(1H ,22H** ERROR AT ETAE(1) **)
 9920 FORMAT(1H ,22H** ERROR AT ETAE(2) **)
 9930 FORMAT(1H0,49H** WARNING - INPUT ETAE AT STATION   IS TOO SMALL /
     1      1H ,48H** CALCULATIONS CONTINUING WITH THE INPUT ETAINF )
 9940 FORMAT(1H ,1X,39H**ERROR - FP PROFILE IS NEGATIVE AT I =, I3)
 9970 FORMAT(1H ,1X,16H**ERROR - IMAX (, I3, 20H) EXCEEDS 100 -IMAX=,I3)
 9980 FORMAT(1H ,38H** WARNING - ETAE IS BEING REESTIMATED )
C2000 CONTINUE
      END
```

```
      SUBROUTINE IVPF
C
C **  SUBROUTINE IVPF
C     THIS SUBROUTINE GENERATES THE INITIAL VELOCITY PROFILE
C
      COMMON  NX,NP,NPPR,JI,IT,NRVP,LSP,NPM1,JI1,JIM1,NTC,NXT,NXW,NXM
     1       ,TITLE(15)
      COMMON/BLC1/F(100,2),U(100,2),V(100,2),ETA(100),DELETA(100)
      COMMON/BLC3/XI(100),XS (100),ETAINF(100),BETA(100)
      COMMON/BLC5/EM(100,2),EDV(100,2),E(100,2),EB(100,2),VPRT(100)
C     - - - - - - - - - - - - - - * - - - - - - - - - - - - - -
C
      IF(IT .LE. 1 .AND. NX.EQ.1)  E(1,1) = 1.
      F(1,2)=0.
      U(1,2)=0.
C ----POLHAUSEN INITIAL VELOCITY PROFILE
      VPGT = ETAINF(1)*BETA(1)/6.
      V(1,2)=2./ETAINF(1) + VPGT
      DO 50 J=2,NP
      EDVE=ETA(J)/ETAINF(1)
      EDVE2=EDVE*EDVE
      EDVE3=EDVE2*EDVE
      EDVE4=EDVE3*EDVE
      FPGT = (.5-EDVE+.75*EDVE2-.2*EDVE3)*ETA(J)**2*ETAINF(1)*BETA(1)/6.
      F(J,2)=EDVE2*ETAINF(1)*(1.-0.5*EDVE2+0.2*EDVE3) + FPGT
      UPGT = EDVE*(1.-3.*(EDVE-EDVE2)-EDVE3)*ETAINF(1)**2*BETA(1)/6.
      U(J,2)=2.*EDVE-2.*EDVE3+EDVE4 + UPGT
      VPGT = (1.-6.*EDVE+9.*EDVE2-4.*EDVE3)*ETAINF(1)*BETA(1)/6.
      V(J,2)=2./ETAINF(1)*(1.-3.*EDVE2+2.*EDVE3) + VPGT
   50 CONTINUE
 1800 RETURN
      END
```

```
      SUBROUTINE FLPR
C
C * * SUBROUTINE FLPR
C     CALCULATE THE FLUID PROPERTIES AND THE TVC TERM
C
      COMMON   NX,NP,NPPR,JI,IT,NRVP,LSP,NPM1,JI1,JIM1,NTC,NXT,NXW,NXM
     1      ,TITLE(15)
      COMMON LG16,LG17,LG18,LG32,LG40
     1      , IGOL, IGOT, IGOW, IGON, IGCV, IGEG, IGNP, IGRC, IGTR
      COMMON/BLC1/F(100,2),U(100,2),V(100,2),ETA(100),DELETA(100)
      COMMON/BLC3/XI(100),XS (100),ETAINF(100),BETA(100)
      COMMON/BL12/TI,RMI,UI,RI,PR,PRT,FK,RL,RMUI,RHOI,PSI,HE
     1           ,UE(100),RO(100),TW(100),QW(100),RP(100),FW(100)
     2           ,BR(100),TE(100),RHOE(100),RMUE(100),GW(100),GPW(100)
     3           ,RF1(100),RF2(100),YS (100),IGX1(100),FPW(100),ROL(100)
      COMMON/BL19/C(100,2),G(100,2),GP(100,2),
     1            RHO(100),RMU(100),TVCT(100)
C
C     - - - - - - - - - - - - - - * - - - - - - - - - - - - - - - - -
C
      A1 = 0.
      IF(XI(NX) .GT. 0.) A1 = SQRT(2.*XI(NX))/(  RHOI  *UE(NX))
C ----
      G(NP,2) = 1.0
      SUM = 0.
      F1 =  RF1(NX)
      TVCT(1) = 1.0
      DO 500 I=2,NP
      IF(LG18 .EQ. 0)  GO TO 450
      F2 =  RF1(NX)
      SUM = SUM + (F1+F2)/2.*DELETA(I-1)
      TVCT(I) = SQRT(1. + 2.*A1*SUM/(RL*ROL(NX)*ROL(NX)))
      F1 = F2
      GO TO 500
C---- IF NO TVC THEN TVC - TERM = 1.0
```

```
 450 TVCT(I) = 1.0                                         FLPR  036
 500 CONTINUE                                              FLPR  037
1800 RETURN                                                FLPR  038
     END                                                   FLPR  039
```

```
      SUBROUTINE ErVS
C
C  **  SUBROUTINE FDVS
C     THIS SUBROUTINE COMPUTES THE EDDY VISCOSITY
C
      COMMON  NX,NP,NPPR,JI,IT,NRVP,LSP,NPM1,JI1,JIM1,NTC,NXT,NXW,NXM
     1      ,TITLE(15)
      COMMON LG16,LG17,LG18,LG32,LG40
     1      , IGOL, IGOT, IGOW, IGON, IGCV, IGEG, IGNP, IGRC, IGTR
      COMMON/BLC1/F(100,2),U(100,2),V(100,2),ETA(100),DELETA(100)
      COMMON/BLC3/XI(100),XS (100),ETAINF(100),BETA(100)
      COMMON/BLC5/FM(100,2),EDV(100,2),E(100,2),FB(100,2),VPRT(100)
      COMMON/BL10/SWP,TANL,WE,W(100,2),WP(100,2)
      COMMON/BL12/TI,RMI,UI,RI,PR,PRT,FK,RL,RMUI,RHOI,PSI,HE
     1           ,UE(100),RO(100),TW(100),QW(100),RP(100),FW(100)
     2           ,BR(100),TE(100),RHOE(100),RMUE(100),GW(100),GPW(100)
     3           ,RF1(100),RF2(100),YS (100),IGX1(100),FPW(100),ROL(100)
      COMMON/BL19/C(100,2),G(100,2),GP(100,2),
     1            RHO(100),RMU(100),TVCT(100)
      COMMON/BL20/ RTHTR, UEIN,ROIN,GAMAT
      DIMENSION  EDVI(100), EDVO(100) ,EDVM(100)
      DATA  DATA1/.0168/,DATA2/.40 /,DATA3/.080/,DATA4/.44/
C
C     - - - - - - - - - - - * - - - - - - - - - -
C
      IF(IGOL.FQ.1) GO TO 500
      SQ2XI = SQRT(2.*XI(NX))
      TC = RHOI    *UE(NX)*ROL(NX)/SQ2XI
      IF(IGOT.FQ.1) GO TO 600
C---- F P S. F O R  L A M I N A R  F L O W S
  500 DO 520 J = 1, NP
      EM(J,2)= 1.0
      FDV(J,2) = 0.
      VPRT(J) = PRT
  520 CONTINUE
```

```
      GO TO 3000                                                        FDVS 036
C---- E P S   F O R   T U R B U L E N T   F L O W S                     FDVS 037
  600 SUM = 0.                                                          EDVS 038
      SUMT = 0.                                                         EDVS 039
      F1 = 1.0                                                          FDVS 040
      F3 = 0.                                                           FDVS 041
      DO  620 J=1,NP                                                    EDVS 042
      EM(J,2)=1.0                                                       EDVS 043
      EDV(J,2) = 0.                                                     EDVS 044
      IF(J .EQ. 1)  GO TO 620                                           EDVS 045
      F2 = (1.-U(J,2))/TVCT(J)                                          EDVS 046
      F4 = F2*U(J,2)                                                    EDVS 047
      SUM = SUM + (F1+F2)/2.*DELETA(J-1)                                EDVS 048
      SUMT = SUMT + (F3+F4)/2.*DELETA(J-1)                              EDVS 049
      F1 = F2                                                           EDVS 050
      F3 = F4                                                           EDVS 051
  620 CONTINUE                                                          FDVS 052
      RTHI = UE(NX)*(RHOI/RMUI     ) * SUMT/TC                          EDVS 053
      IF(RTHI .LT.  425.) GO TO 720                                     EDVS 054
      IF(RTHI .GT. 6000.) GO TO 750                                     EDVS 055
      XPHI= RTHI/425.-1.0                                               EDVS 056
      CPHI= .55*(1.-EXP(-.243*SQRT(XPHI)-.298*XPHI))                    EDVS 057
      GO TO 770                                                         EDVS 058
  720 CPHI = 0.0                                                        EDVS 059
      GO TO 770                                                         EDVS 060
  750 CPHI=.55                                                          EDVS 061
  770 DATAN=DATA1*(1.55/(1.+CPHI))                                      EDVS 062
C----                                                                   EDVS 063
      IFLGED = 0                                                        EDVS 064
      IF(IT .LE. 1)  E(1,2) = E(1,1)                                    EDVS 065
      J = 1                                                             EDVS 066
      SUM1 = 0.                                                         EDVS 067
      F1=1.0                                                            EDVS 068
      VWPSQT = V(1,2)                                                   EDVS 069
      DUDYW = TC*UE(NX)*ABS(VWPSQT)                                     EDVS 070
```

```
      TAUW = RMUI     *DUDYW *E(1,2)                                     EDVS  071
      USTAR = SQRT(TAUW/RHOI)                                            EDVS  072
 1025 DPDX = -TC*TC*UE(NX)*RMUI     *BETA(NX)                            EDVS  073
      PPLUS = -RMUI     *DPDX/(RHOI*RHOI        *USTAR*USTAR* USTAR)     EDVS  074
      A = 26.                                                            EDVS  075
      ARMT = 1.-11.8*PPLUS                                               EDVS  076
 1030 CONTINUE                                                           EDVS  077
 1045 APLUS = A/SQRT(ARMT)                                               EDVS  078
      EDVO(J) = DATAN*UE(NX)*(RHOI/RMUI     ) * ABS(SUM/TC)              EDVS  079
      VPRT(J) = PRT                                                      EDVS  080
      IF (IFLGED .EQ. 1) GO TO 1098                                      EDVS  081
      F2 = 1./TVCT(J)                                                    EDVS  082
      IF(J .EQ. 1)  GO TO 1060                                           EDVS  083
      SUM1 = SUM1 + (F1+F2)/2.*DELETA(J-1)                               EDVS  084
      F1 = F2                                                            EDVS  085
 1060 Y = SUM1  /TC                                                      EDVS  086
      IF(TVCT(J) .GT. 1.005)  Y = RO(NX)*ALOG(TVCT(J))                   EDVS  087
      YPLUS = Y*USTAR*RHOI/RMUI                                          FDVS  088
      YA = YPLUS/APLUS                                                   EDVS  089
      EL = DATA2*Y                                                       EDVS  090
      IF(YA .LT. 20.)  EL = EL *(1.-EXP(-YA))                            EDVS  091
      BPLUS = 34.                                                        EDVS  092
      IF(J .NE. 1)  GO TO 1065                                           EDVS  093
      VPRT(J) = DATA2/DATA4 * BPLUS/APLUS                                EDVS  094
      GO TO 1070                                                         EDVS  095
 1065 VPRT(J) = EL/(DATA4*Y)                                             EDVS  096
      YB = YA*APLUS/BPLUS                                                EDVS  097
      IF(YB .LT. 20.)  VPRT(J) = VPRT(J)/(1.-EXP(-YB))                   EDVS  098
 1070              VWPSQT=V(J,2)                                         FDVS  099
      DUDY = TC*UE(NX)*ABS(VWPSQT) / F2                                  EDVS  100
      EDVI(J) = EL*EL*DUDY*RHOI/RMUI          * TVCT(J)                  EDVS  101
      IF(EDVI(J) .LT. EDVO(J))  GO TO 1100                               EDVS  102
      IFLGED=1                                                           EDVS  103
      IF (J .LE. 2)  WRITE(6,9030)                                       EDVS  104
 1098 EDV(J,2)=EDVO(J)                                                   EDVS  105
```

```
      GO TO 1200
 1100 EDV(J,2) = EDVI(J)
 1200 J = J + 1
      IF (J .LE. NP) GO TO 1030
C----
      IF(IFLGED.EQ.1) GO TO 2050
      WRITE(6,9020)
      EDV(J,2)=EDVO(J)
 2050 IF(LG17.EQ.0 .OR. IGTR.EQ.2)  GO TO 2500
      UR = UE(NX)*RHOI/RMUI
      IF(NX .GT. NXT)  GO TO 2150
      F1 = 0.
      SUMT = 0.
      DO 2100 J=2,NP
      F2 = U(J,2)*(1.-U(J,2))
      SUMT = SUMT + (F1+F2)*DELETA(J-1)*.5
      F1 = F2
 2100 CONTINUE
      RTHTR = UR*SUMT/TC
      IF(LG16 .NE. 0)  GO TO 2300
      UEIN = 0.
      ROIN = 0.
      GO TO 2300
 2150 IF(IT .GT. 1)  GO TO 2500
      UEIN = UEIN + .5*((1./UE(NX))+(1./UE(NX-1)))*(XS(NX)-XS(NX-1))
      IF(FK .EQ. 0.)  GO TO 2200
      ROIN = ROIN + .5*((1./RO(NX))+(1./RO(NX-1)))*(XS(NX)-XS(NX-1))
      GO TO 2300
 2200 ROIN = XS(NX)-XS(NXT)
 2300 ATR = 60.
      GTR = ((UR/ATR)**2)*UE(NX)/(RTHTR**2.68)
      ARFXP = GTR*UEIN*ROIN
      IF(FK .NE. 0.)  AREXP = ARFXP*RO(NXT)
      IF(AREXP .GT. 10.)  GO TO 2500
      GAMAT = 1. - EXP(-ARFXP)
```

```
      WRITE(6,9500)   GAMAT
 2500 DO 2550 J=1,NP
      IF(J.GT.1) GO TO 2510
      EDVM(1) = EDV(1,2)
      GO TO 2550
 2510 IF(J.EQ.NP) GO TO 2520
      EDVM(J) =(EDV(J-1,2)+EDV(J,2)+EDV(J+1,2))/3.0
      GO TO 2550
 2520 EDVM(NP) =(EDV(NP-2,2)+EDV(NP-1,2)+EDV(NP,2))/3.0
 2550 CONTINUE
      DO 2560 J=1,NP
      EDV(J,2)=EDVM(J)
      IF(LG17.EQ.0 .OR. IGTR.EQ.2)  GO TO 2560
      EDV(J,2) = EDV(J,2)*GAMAT
 2560 CONTINUE
 3000 E(1,2)=(EM(1,2)+EDV(1,2))
      DO 3010 J=2,NP
      E(J,2)=(EM(J,2)+EDV(J,2))       *TVCT(J)*TVCT(J)
      EB(J-1,2) = 0.5* (E(J,2) + E(J-1,2))
 3010 CONTINUE
 1800 RETURN
C----
 9010 FORMAT(1H ,30X,43H**PPLUS EXCEEDS THE LAMINARIZATION LIMIT **)
 9020 FORMAT(1H ,30X,45H**NOTE - EPS DISTRIBUTION = EPS(INNER) ONLY**)
 9030 FORMAT(1H ,30X,45H**NOTE - EPS DISTRIBUTION = EPS(OUTER) ONLY**)
 9500 FORMAT(1H ,41X,11HGAMMA(TR) =, E17.6)
      END
```

```
      SUBROUTINE SHFT
C **  SUBROUTINE SHFT
C     THIS SUBROUTINE PROVIDES THE INITIAL GUESSES FOR EACH STATION
C
      COMMON  NX,NP,NPPR,JI,IT,NRVP,LSP,NPM1,JI1,JIM1,NTC,NXT,NXW,NXM
     1      ,TITLE(15)
      COMMON LG16,LG17,LG18,LG32,LG40
     1      , IGOL, IGOT, IGOW, IGON, IGCV, IGEG, IGNP, IGRC, IGTR
      COMMON/BLC1/F(100,2),U(100,2),V(100,2),ETA(100),DELETA(100)
      COMMON/BLC3/XI(100),XS (100),ETAINF(100),BETA(100)
      COMMON/BLC5/EM(100,2),EDV(100,2),E(100,2),EB(100,2),VPRT(100)
      COMMON/BL19/C(100,2),G(100,2),GP(100,2),
     1             RHO(100),RMU(100),TVCT(100)
      COMMON/BL21/ A1(100,2),A2(100,2)
C
C     - - - - - - - - - - - - - - - * - - - - - - - - - - - - - - -
C
      IF(IGRC.EQ.1) GO TO 200
                 JI1=JI+1
   50 JIM1=JI-1
      PHI=F(JI,2)-ETAINF(NX-1)
      DO 70 J=1,JI
   60 F(J,1)=F(J,2)
      U(J,1)=U(J,2)
      V(J,1)=V(J,2)
   65 EDV(J,1)=EDV(J,2)
      E(J,1)=E(J,2)
      IF(J.EQ.JI) GO TO 70
      EB(J,1)=EB(J,2)
   70 CONTINUE
   80 DO 90 J=JI1,NP
   85 F(J,1)=PHI+ETA(J)
      U(J,1)=1.
      V(J,1)=0.
      EDV(J,1)=EDV(JI,2)
```

```
      E(J,1)=E(JI,2)
      FB(J-1,1)=EB(JIM1,2)
   90 CONTINUE
      IF(IGRC.EQ.0) GO TO 100
      IGRC=0
      GO TO 1800
C ----
  100 DO 120 J=JI1,NP
      F(J,2)=PHI+ETA(J)
      U(J,2)=1.
      V(J,2)=0.
  120 CONTINUE
      IF(IGRC.EQ.1) GO TO 80
      GO TO 1800
  200 DO 220 J=1,JI
  210 F(J,2)=F(J,1)
      U(J,2)=U(J,1)
      V(J,2)=V(J,1)
  215 EDV(J,2)=EDV(J,1)
      F(J,2)=E(J,1)
      IF(J.EQ.JI) GO TO 220
      EB(J,2)=EB(J,1)
  220 CONTINUE
      PHI=F(JI,2)-ETAINF(NX-1)
      IF(IGTR .GT. 1)  PHI = F(JI,2)-ETAINF(NX)
      GO TO 100
 1800 RETURN
      END
```

```
      SUBROUTINE MOMX
C
C **  SUBROUTINE MOMX
C     FIND THE SOLUTION OF THE X-MOMENTUM EQUATION
C
      COMMON  NX,NP,NPPR,JT,IT,NRVP,LSP,NPM1,JT1,JIM1,NTC,NXT,NXW,NXM
     1      ,TITLE(15)
      COMMON/BLC1/F(100,2),U(100,2),V(100,2),ETA(100),DELETA(100)
      COMMON LG16,LG17,LG18,LG32,LG40
     1      , IGOL, IGOT, IGOW, IGON, IGCV, IGEG, IGNP, IGRC, IGTR
      COMMON/BLC3/XI(100),XS (100),ETAINF(100),BETA(100)
      COMMON/BLC5/FM(100,2),EDV(100,2),E(100,2),EB(100,2),VPRT(100)
      COMMON/BLC8/A(100),CEL(100)
      COMMON/BL11/VWPRI,UWPRI,DELV1
      COMMON/BL12/TI,RMI,UI,RI,PR,PRT,FK,RL,RMUI,RHOI,PSI,HE
     1           ,UE(100),RO(100),TW(100),QW(100),RP(100),FW(100)
     2           ,RR(100),TE(100),RHOE(100),RMUE(100),GW(100),GPW(100)
     3           ,RF1(100),RF2(100),YS (100),IGX1(100),FPW(100),ROL(100)
      COMMON/BL19/C(100,2),G(100,2),GP(100,2),
     1            RHO(100),RMU(100),TVCT(100)
      DIMENSION A1(100),B1(100),G1(100),D(100),SF(100),S(100),
     1                X(100),Y(100),Z(100),DELF(100),DELU(100),DELV(100)
C
C     -------------------- * --------------------
C
      IF(IT.GT.1) GO TO 100
      IF(NX.EQ.1) CEL(1)=0.
      IF(NX.GT.1) CEL(NX)=2.*XI(NX-1)/(XI(NX)-XI(NX-1))+1.
      VWPRI=V(1,1)
      UWPRT=U(1,1)
C ----
  100 VWPRI=V(1,2)
      UWPRT=U(1,2)
C ----
      A(1) = 0.
```

```
      DO 320 J = 2, NP
  320 A(J) = DELETA(J-1) / 2.
C ----
      DO 900 J = 2, NP
      FB       =(F(J,2) + F(J-1,2)) * 0.5
      VB       =(V(J,2) + V(J-1,2)) * 0.5
      IF (NX .GT. 1) GO TO 600
      CFB      = 0.
      CUB      = 0.
      CVB      = 0.
      GO TO 700
  600 CFB       =(F(J,1) + F(J-1,1)) * 0.5
      CUB       =(U(J,1) + U(J-1,1)) * 0.5
      CVB       =(V(J,1) + V(J-1,1)) * 0.5
C ----
  700 TM1 = A(J) /EB(J-1,2)
      A1(J) = TM1 * ((1. + CEL(NX)) * VB       + CEL(NX) * CVB      )
      B1(J) = 1. + TM1 * ((E  (J,2)-E  (J-1,2))/DELETA(J-1) + (1.
     1      + CEL(NX)) * FB      - CEL(NX) * CFB      )
C ----
      IF (NX .EQ. 1) RB    = 0.
      IF (NX .GT. 1) RB    =-(EB(J-1,1) * ((V(J,1) - V(J-1,1)) / DELETA
     1     (J-1)) + (((E  (J,1) - E  (J-1,1)) / DELETA(J-1)) + CFB
     2   )*CVB +BETA(NX-1)*.5                       -CUB*CUB*BETA(NX-1)
     3   -CEL(NX)*(CFB*CVB-CUB*CUB) + BETA(NX-1)*.5)
      S(J)=V(J-1,2)-V(J,2)-DELETA(J-1)/EB(J-1,2)           * ((1. + CEL(NX)
     1   ) *FB*VB     -   (BETA(NX)+CEL(NX))*((U(J,2)+U(J-1,2))*.5)**2
     2   -CEL(NX)*CFB*VB + BETA(NX)*.5                 +CEL(NX)*CVB*FB -RB
     3 +VB*(E(J,2)-E(J-1,2))/DELETA(J-1) + BETA(NX)*.5)
  900 CONTINUE
C ----
  905 D(2) = -.5*(-A(2)/EB(1,2)*(BETA(NX)+CEL(NX))*(U(2,2)+U(1,2))
     1   +A(2)*A1(2) + B1(2)/A(2))
      SE(2)= - A(2)
      G1(2) = - D(2) - 1. / A(2)
```

```
      Y(2) = F(1,2)-F(2,2) + DELFTA(1)*.5*(U(2,2)+U(1,2))
      X(2) =-0.5 * (S(2) + A1(2) * Y(2) + B1(2) * (U(1,2)-U(2,2)+
     1   DELETA(1)*(V(2,2)+V(1,2))*.5)/A(2))
      Z(2) = -X(2)-(A(2)*(V(2,2)+V(1,2)) +U(1,2)-U(2,2))      /A(2)
      DO 950 J = 3, NP
      TMR11 = -A(J) +SE(J-1)
      TMR21 = - A1(J) *SE(J-1) + G1(J-1) * (2. - B1(J))-(U(J,2)+U(J-1,2)
     1   )*A(J)/EB(J-1,2)*(BETA(NX)+CEL(NX))
      TMR31 = -1. + A(J) * G1(J-1)
      D(J) = (A(J) * A(J) * A1(J) -(A(J)**2)*(BETA(NX)+CEL(NX)) *
     1   (U(J,2)+U(J-1,2))/EB(J-1,2) + B1(J))
     2      / (-TMR11 * A1(J) * A(J) + A(J) * TMR21 + TMR31 * B1(J))
      SE(J)= - A(J) - TMR11 * D(J)
      G1(J) = (TMR31 * D(J) - 1.) / A(J)
      TMM1 = A(J)*(U(J-1,2)+U(J,2))+F(J-1,2)-F(J,2) + Y(J-1)
      TMM2 = S(J) - A1(J) * Y(J-1) - (B1(J) - 2.) * Z(J-1)
      TMM3 = A(J)*(V(J,2)+Z(J-1) +V(J-1,2)) - U(J,2)+U(J-1,2)
      DNTR = - A(J) * TMR11 * A1(J) + A(J) * TMR21 + TMR31 * B1(J)
      X(J) = (- A(J) * A1(J) * TMM1 + A(J) * TMM2 + B1(J) * TMM3) / DNTR
      Y(J) = TMM1 - TMR11 * X(J)
      Z(J) = (TMR31 * X(J) - TMM3) / A(J)
  950 CONTINUE
C ----
      DELF(NP) = Y(NP)
      DELU(NP-1) = X(NP)
      DELV(NP) = Z(NP)
C ----
      J = NP
 1000 J = J - 1
      DELF(J) = Y(J) -SE(J) * DELU(J)
      DELU(J-1) = X(J) - D(J) * DELU(J)
      DELV(J) = Z(J) - G1(J) * DELU(J)
      IF (J .GT. 3) GO TO 1000
      DELF(2) = Y(2) -SE(2) * DELU(2)
      DELV(2) = Z(2) - G1(2) * DELU(2)
```

```
      DELF(1) = 0.
      DELV(1) = X(2) - D(2) * DELU(2)
      DELU(1) = 0.
C ----
      IF (IT.EQ. 1) WRITE (6, 9510)
      WRITE (6, 9521)IT, V(1,2), DELV(1)
C ----
      DO 1020 J=1,NP
      IF (J .EQ. NP) GO TO 1010
      U(J,2) = U(J,2) + DELU(J)
 1010 F(J,2) = F(J,2) + DELF(J)
      V(J,2) = V(J,2) + DELV(J)
 1020 CONTINUE
      DELV1 = DELV(1)
 1800 RETURN
C ----
 9510 FORMAT (1H0,  21X,1HI,20X,4HFPPW ,  26X,5HDELVW      )
 9521 FORMAT(1H ,20X,I2,10X,E20.9,10X,E20.9)
      END
```

```
      SUBROUTINE TRNS
C
C **  SUBROUTINE TRNS
C     THIS SUBROUTINF COMPUTES THE LOCATION OF B. L. TRANSITION
C
      COMMON  NX,NP,NPPR,JI,IT,NRVP,LSP,NPM1,JI1,JIM1,NTC,NXT,NXW,NXM
     1       ,TITLE(15)
      COMMON LG16,LG17,LG18,LG32,LG40
     1      , IGOL, IGOT, IGOW, IGON, IGCV, IGEG, IGNP, IGRC, IGTR
      COMMON/BLC1/F(100,2),U(100,2),V(100,2),ETA(100),DELETA(100)
      COMMON/BLC3/XI(100),XS (100),ETAINF(100),BETA(100)
      COMMON/BL12/TI,RMI,UI,RI,PR,PRT,FK,RL,RMUI,RHOI,PSI,HE
     1            ,UE(100),RO(100),TW(100),QW(100),RP(100),FW(100)
     2            ,RR(100),TE(100),RHOE(100),RMUE(100),GW(100),GPW(100)
     3            ,RF1(100),RF2(100),YS (100),IGX1(100),FPW(100),ROL(100)
      COMMON /BL14/ RX1,RTH1, CF0,CF1,CF2,CFSUM0,CFSUM,
     1        THETA(100),DELS(100),FPPW(100)
      COMMON/BL20/ RTHTR, UEIN,ROIN,GAMAT
      DIMENSION C(3)
      DATA C1,C2,C3,C4,C5,C6 /66.4663,-3.357287,12.31885,48447.19 ,
     1    -19886.08 , 1. /
C
C     - - - - - - - - - - - - - - - * - - - - - - - - - - - - - - -
C
      K=NX-1
      IIGR=0
      IF(LG16.NE.0) GO TO 50
      WRITE(6,9010)
      LSP=1
      GO TO 1800
   50 IF(V(1,2) .LE. 0.)  GO TO 600
      AG1=UE(NX)*RHOI/RMUI
      IF(FK .EQ. 1.) GO TO 55
      RX12=AG1*XS(NX)
      RTH12=AG1*THETA(NX)
```

```
      GO TO 57
   55 RTH12=AG1*THETA(NX)*ROL(NX)
      S2=0.
      DO 56 I=2,NX
      DELS3= XS(I)-XS(I-1)
   56 S2=S2+(ROL(I)**2)*(DELS3)
      RX12=AG1*S2
   57 CONTINUE
      IF(IGTR.NE.0) GO TO 60
      RX1=1.E-05 * RX12
      RTH1=RTH12
      IGTR=1
      GO TO 1800
   60 RX2=1.E-05 * RX12
      RTH2=RTH12
      IF(RX2 .LT. 1.) GO TO 550
      RTHE9 = C1 + C2*RX2 + C6*SQRT(C3*RX2*RX2+C4*RX2+C5)
      RTD = RTHE9-RTH2
      IF(RTD.GT.0. .AND. RTD.GE.10.)  GO TO 550
      IF(ABS(RTD) .GE. 10.)  GO TO 65
      IGTR=3
      ROT1=0.
      ROT2=RX2
      GO TO 95
C ----
   65 IGTR=3
      AG1=RTH2-((RTH2-RTH1)/(RX2-RX1))*RX2
      AG2=(RTH2-RTH1)/(RX2-RX1)
      AG3=AG2+3.357287
      AG4=AG1-66.4663
      C(1)=12.31885-AG3*AG3
      C(2)=48447.19-2.0*AG3*AG4
      C(3)=-19886.08-AG4*AG4
      RSM4AC = C(2)*C(2) - 4.*C(1)*C(3)
      IF(RSM4AC .GE. 0.)  GO TO 70
```

```
      WRITE(6,7000) NX
      GO TO 550
   70 ROT1 = (-C(2) + SQRT(BSM4AC))/(2.*C(1))
      ROT2 = (-C(2) - SQRT(BSM4AC))/(2.*C(1))
      IF(ROT1.LE.0..AND.ROT2.LE.0.) GO TO 550
      IF(ROT1.GT.0.AND.ROT2.GT.0.) GO TO 80
      IF(ROT1.GT.0.) RX=1.E05*ROT1
      IF(ROT2.GT.0.) RX=1.E05*ROT2
      GO TO 100
   80 IIGR=1
      RX=ROT1 * 1.E05
      GO TO 100
   90 IIGR=2
      RX=ROT2 * 1.E05
C ----
      GO TO 100
   95 RX=1.E05*ROT2
      XTR=XS(NX)
      GO TO 200
  100 UETR = UE(NX) + (UE(NX)-UE(K))*(1.E-05*RX-RX1)/(RX2-RX1)
      XTR=RX*RMUI/(RHOI*UETR)
      IF(XTR-XS(NX)) 300,200,500
  200 WRITE(6,6010) NX
      GO TO 700
  300 IF(XTR .LE. XS(K))  GO TO 500
      WRITE(6,6020) XTR
      GO TO 1000
  500 IF(IIGR.EQ.1) GO TO 90
  550 IF(V(1,2).LE.0.) GO TO 600
      IF(IGTR.EQ.0) GO TO 1800
      RX1=RX2
      RTH1=RTH2
      CF0 = CF1
      CFSUM0 = CFSUM
      RETURN
```

```
  600 IGTR=2
      LG17 = 0
      IF(V(1,2).LT.0.) GO TO 800
      WRITF(6,6030) NX
  700 NXT=NX
      WRITF(6,6050) NXT
      CF1 = CF0
      CFSUM = CFSUMO
      IF(LG17 .EQ. 0)  GO TO 1800
      ROIN = 0.
      UEIN = 0.
      GO TO 1800
  800 XTR=XS(NX)-(XS(NX)-XS(K))* V(1,2)/(V(1,2)-V(1,1) )
      WRITE(6,6040) XTR
C ----
 1000 NXT=NX
      WRITE(6,6050) NXT
      CF1 = CF0
      CFSUM = CFSUMO
      IF(LG17 .EQ. 0)  GO TO 1800
      ROIN = XS(NX) - XTR
      UEIN = ROIN/UE(NX)
      IF(FK .NE. 0.)  ROIN = ROIN/RO(NX)
 1800 RETURN
C ----
 6010 FORMAT(1H1////////// 30X,
     1  34HTRANSITION HAS OCCURRED AT STATION, I3/)
 6020 FORMAT(1H1////////// 30X,
     1  30HTRANSITION HAS OCCURRFD AT S =, F12.6 /)
 6030 FORMAT(1H1///// 45X,38HLAMINAR SEPARATION OCCURRED AT STATION, I3,
     1 /)
 6040 FORMAT(1H1/////// 45X,34HLAMINAR SEPARATION OCCURRED AT S =,F12.6)
 6050 FORMAT(1H0,35X,33HTURBULENT FLOW STARTED WITH NTR = ,I3 ////)
 7000 FORMAT(1H1///40X,39HATTEMPT TO FIND X(TR) FAILED AT STATION ,I3/)
 9010 FORMAT(1H ,24H** ERROR IN TRFLAG INPUT, /)
```

```
                                                                 TRNS
                                                         TRNS  141C
 2000 CONTINUE                                           TRNS  142
      END
                                                                 TRNS
```

```
      SUBROUTINE SLOPE(NPX,XC, YC,DYDX, MER)
C
C **  SUBROUTINE SLOPE
C     COMPUTE THE DERIVATIVE DYDX FROM X VS Y INPUT
C
      DIMENSION  XC(150),YC(150),DYDX(150)
      DIMENSION X(300), Y(300),  XY(301)
      XY(1) = NPX
      IF(MER .NE. 0)  GO TO 20
      NP2M1 = NPX
      DO 10 I=1,NPX
      X(I) = XC(I)
      Y(I) = YC(I)
   10 CONTINUE
      GO TO 80
   20 NP2 = 2*NPX
      NP2M1 = NP2-1
      DO 40 I=1,NPX
      XY(I*2) = XC(I)
      XY(2*I+1) = YC(I)
   40 CONTINUE
      NLQ= 2
      DO 50 I=2,NP2,2
      X(I-1) = XY(I)
      Y(I-1) = XY(I+1)
      IF(I .EQ. NP2)  GO TO 50
      X(I) = (XY(I)+XY(I+2))*.5
      CALL INS1(X(I),XY , Y(I),NLQ,NER)
   50 CONTINUE
   80 DO 200 I=1,NP2M1
      IF(I .GT. 1) GO TO 100
      DYDX(I) = (Y(I+1)-Y(I)) / (X(I+1)-X(I))
      GO TO 200
  100 IF(I .LT. NP2M1)  GO TO 150
      DYDX(I) = (Y(I)-Y(I-1)) / (X(I)-X(I-1))
```

```
      GO TO 200
  150 IF(Y(I-1).EQ.Y(I) .AND. Y(I).EQ.Y(I+1))   GO TO 180
      A1 = (X(I)-X(I+1)) / ((X(I-1)-X(I))*(X(I-1)-X(I+1)))
      A2 = (2.*X(I)-X(I+1)-X(I-1)) / ((X(I)-X(I-1))*(X(I)-X(I+1)))
      A3 = (X(I)-X(I-1)) / ((X(I+1)-X(I-1))*(X(I+1)-X(I)))
      DYDX(I) = A1*Y(I-1) + A2*Y(I) + A3*Y(I+1)
      GO TO 200
  180 DYDX(I) = 0.
  200 CONTINUE
      IF(MER .EQ. 0)  RETURN
      DO 300 I=1,NPX
  300 DYDX(I) = DYDX(2*I-1)
      RETURN
      END
```

```
      SUBROUTINE OTPT
C
C  ** SUBROUTINE OTPT
C     OUTPUT THE RESULTS OF THE B. L. CALCULATIONS
C
      COMMON  NX,NP,NPPR,JI,IT,NRVP,LSP,NPM1,JI1,JIM1,NTC,NXT,NXW,NXM
     1       ,TITLE(15)
      COMMON LG16,LG17,LG18,LG32,LG40
     1       , IGOL, IGOT, IGOW, IGON, IGCV, IGEG, IGNP, IGRC, IGTR
      COMMON /HEADR/ CASE, IPAGE
      COMMON/BLC1/F(100,2),U(100,2),V(100,2),ETA(100),DELETA(100)
      COMMON/BLC3/XI(100),XS (100),ETAINF(100),BETA(100)
      COMMON/BLC5/EM(100,2),EDV(100,2),E(100,2),EB(100,2),VPRT(100)
      COMMON/BL12/TI,RMI,UI,RI,PR,PRT,FK,RL,RMUI,RHOI,PSI,HE
     1            ,UE(100),RO(100),TW(100),QW(100),RP(100),FW(100)
     2            ,BR(100),TE(100),RHOE(100),RMUE(100),GW(100),GPW(100)
     3            ,RF1(100),RF2(100),YS (100),IGX1(100),FPW(100),ROL(100)
      COMMON /BL14/ RX1,RTH1, CF0,CF1,CF2,CFSUM0,CFSUM,
     1        THETA(100),DELS(100),FPPW(100)
      COMMON /BL16/ NTYPE,IOUT
      COMMON /BL17/ RX(100),CFA(100),CF(100),ETAE(100),CDI(100),ST(100),
     1         INP(100)
      COMMON/BL19/C(100,2),G(100,2),GP(100,2),
     1             RHO(100),RMU(100),TVCT(100)
      COMMON/RADIUS/ ROMAX
      DIMENSION  Y(100)
C
C     - - - - - - - - - - - - - - - - * - - - - - - - - - - - - - - -
C
      IF(IOUT .NE. 0) GO TO 900
      IPRT = (NP+18)/30
      IF(NP .LT. 30) IPRT=1
      A1 =0.
      UEUI = UE(NX)/UI
      THETA(NX) = 0.
```

```
      DELS(NX) = 0.
      RX(NX)=XS(NX)*RHOI*UE(NX)/RMUI
      RTHETA = 0.
      H=0.
      CF(NX) = 0.
      USTUF = 0.
      YPLUS = 0.
      UPLUS = 0.
      IF(NX .EQ. 1)  CF1 = 0.
      IF(NX .EQ. 1)  CFSUM = 0.
      CFA(NX) = 0.
      ST(NX) = 0.
      TNP(NX)=NP
      ETAE(NX) = ETA(NP)
      FPPW(NX) = V(1,2)
C----
      IF(XI(NX) .EQ. 0.)  GO TO 300
      A1 = SQRT(2.*XI(NX))/( RHOI    *UE(NX)*ROL(NX))
      JINP = NP
      SUM1=0.0
      SUM2 = 0.
      F1=0.
      F3=1.0
      DO 90 J=2,JINP
      F2 = U(J,2)*(1.0-U(J,2))
      SUM1 = SUM1 + (F1+F2)/2.*DELETA(J-1)
      F1=F2
   90 CONTINUE
      THETA(NX) = SUM1*A1
      DELS(NX) = A1*(ETAE(NX)    + F(1,2) - F(JINP,2))
      RTHETA = RX(NX)*THETA(NX)/XS(NX)
      H = DELS(NX)/THETA(NX)
      CF(NX) = SQRT(2./XI(NX))* RMUI    *V(1,2)*ROL(NX)          *F(1,2)
      CF(NX) = ABS(CF(NX))
      USTUF = SQRT(CF(NX)/2.)
```

```
      IF(FK .GE. 1.0) GO TO 200
      IF(NX .EQ. 1)  CF1 = CF(NX)*UEUI*UEUI
      IF(NX .EQ. 1)  GO TO 300
      CF2 = CF(NX) *UEUI*UEUI
      CFSUM   = CFSUM  +  (CF1+CF2)*(YS(NX)-YS(NX-1))*.5
      IF(XI(NX-1) .EQ. 0.)  CFSUM = 2.*THETA(NX)
      CFA(NX) = CFSUM / (YS(NX)-YS(1))
      CF1 = CF2
      GO TO 300
  200 CONTINUE
      IF(NX .EQ. 1) CF1=CF(NX)*UEUI*UEUI*RO(NX)
      IF(NX .EQ. 1) GO TO 300
      CF2=CF(NX)*UEUI*UEUI*RO(NX)
      CFSUM=CFSUM + (CF1+CF2) * (YS(NX)-YS(NX-1))*.5*RL
      IF(XI(NX-1) .EQ. 0.) CFSUM=2.*THETA(NX)
      CFA(NX)=CFSUM * 2. /(ROMAX*ROMAX)
      CF1=CF2
  300 IF(LG32.EQ.1 .AND. IGX1(NX).EQ.0)  GO TO 420
      LCMAX=42
      LC=60
      SUMY = 0.
      F1=1.0
      DO 400 J=1,NP
      IF(LC .LT. LCMAX) GO TO 340
      LC=1
      CALL HEAD
      WRITE(6,2000)NX,YS(NX)
      IF((LG32.EQ.0.OR.IGX1(NX).NE.0))                 WRITE(6,2100)
      IF(LG32 .EQ. 2)  WRITE(6,2150)
  340 IF(J .EQ. 1)  GO TO 350
      F2=1./TVCT(J)
      SUMY = SUMY + (F1+F2)/2.*DFLETA(J-1)
      F1 = F2
  350 I = 1 + ((J-1)/IPRT)*IPRT
      IF(J.NE.I .AND. J.NE.NP)  GO TO 400
```

```
      Y(J) = SUMY*A1
      IF(USTUE .EQ. 0.)  GO TO 370
      YPLUS = Y(J)*UE(NX)*RHOE(NX)*USTUE/RMUE(NX)
      UPLUS = U(J,2)/USTUE
      LC=LC+1
  370 WRITE(6,6060)
     1 J,ETA(J),F(J,2),U(J,2),V(J,2),Y(J),YPLUS,UPLUS,FDV(J,2)
  400 CONTINUE
  420 CONTINUE
C----
C ----
  700 IF(LG32.EQ.1 .AND. IGX1(NX).EQ.0)  GO TO 800
      WRITE(6,3000)
      WRITE(6,3200) NX,XS(NX), THETA(NX), DELS(NX),CF(NX),V(1,2),GW(NX)
      WRITE(6,3250) YS(NX), RX(NX),RTHETA, H, CFA(NX),GPW(NX),ST(NX)
  800 IF(IOUT .EQ. 0) GO TO 1800
C----
  900 CALL HEAD
      WRITE(6,3500) TITLE
      LCMAX=45
      LC=1
      WRITE(6,4000)
      IF(LSP .EQ. 1 .AND. NX .GT. 1) NX=NX-1
      DO 1000 I=1,NX
      IF(LC .LT. LCMAX) GO TO 940
      CALL HEAD
      WRITE(6,4000)
      LC=1
  940 RTHETA=0.
      H=0.
      IF(XI(I) .EQ. 0.)  GO TO 950
      RTHETA = RX(I)*THETA(I)/XS(I)
      H = DELS(I)/THETA(I)
  950 WRITE(6,4200) I,XS(I),THETA(I),DELS(I),CF(I),FPPW(I),GW(I),INP(I)
      WRITE(6,4250) YS(I), RX(I),RTHETA, H, CFA(I),GPW(I),ST(I),ETAE(I)
```


OTPT

```
      LC=LC+3
 1000 CONTINUE
      DO 1003 I=1,NX
 1003 DELS(I)=DELS(I)/RL
      WRITE(2) NX
      WRITE(2) (DELS(K), K=1,NX)
C     THE CALCULATION OF THE BASE DRAG IS DONE AT THIS POINT USING
C     A METHOD GIVEN IN HOERNERS# BOOK ON AERODYNAMIC DRAG
      IF(RO(NX) .LT. ROMAX) GO TO 1010
      CDBASE=.029/SQRT(CFA(NX))
      GO TO 1020
 1010 CFAB=CFA(NX)
      CDBASE=.029*(RO(NX)/ROMAX)**3/SQRT(CFAB)
 1020 WRITE(6,1030) CDBASE
 1030 FORMAT(1H0, 77H THE BASE DRAG FOR THIS CONFIGURATION BASED ON THE
     1MAXIMUM FRONTAL AREA IS = ,  F15.8)
 1800 RETURN
C - - - -
 2000 FORMAT(1H ,3X,11HSTATION NO.,I3,30X, 5HS/C =,F12.6 /)
 2100 FORMAT(1H0,2X,1HI,7X,3HETA,11X,1HF,14X,2HFP,14X,3HFPP,14X,1HY,14X,
     1       5HYPLUS,12X,5HUPLUS,12X, 4HEPS+ /)
 2150 FORMAT(1H0,2X,1HI,7X,3HETA,11X,1HF,14X,2HFP,14X,3HFPP,11X,
     1        7HY/THETA,9X,5HYPLUS,12X,5HUPLUS,12X,4HEPS+, /)
 2200 FORMAT(1H0,2X,1HI,7X,3HETA,11X,1HF,14X,2HFP,14X,3HFPP,14X,1HY,12X,
     1       4HW/WE,12X,5H  WP ,12X,4HEPS+, /)
 2300 FORMAT(1H0,2X,1HI,7X,3HETA,11X,1HG,14X,2HGP,14X,2H Y,13X,4H   T ,
     1       14X,4H PRT,12X,2HMU,14X,2HM ,/)
 2400 FORMAT(1H0,2X,1HI,7X,3HETA,11X,1HG,14X,2HGP,11X,7HY/THETA, 10X,
     1       4HT/TE,11X,10H    PRT    ,8X, 6HMU/MUE,10X, 4HM/ME, / )
 3000 FORMAT(1H0// 7X, 1HN, 12X,4H  S ,13X,5HTHETA,12X,4HDELS,14X,2HCF,
     1      14X,4HFPPW,14X,2HGW, /1H ,5X, 3HX/C,12X,2HRX,13X,6HRTHETA,14X
     2      ,1HH,15X,3HCFA,14X,3HGPW, 14X, 2HST, / )
 3200 FORMAT(1H /1H ,I7,4X, 6E17.6 )
 3250 FORMAT(1H ,F11.5,6E17.6 )
 3500 FORMAT(1H ,42X,14HOUTPUT SUMMARY,15A4/ )
```

```
4000 FORMAT(1HO/ 7X,1HN,12X,4H   S ,13X,5HTHETA,12X,4HDELS,14X,2HCF,14X,   OTPT  176
    1      4HFPPW,14X,2HGW,15X,4HIMAX,/1H ,5X,3HX/C,12X,2HRX,13X,           OTPT  177
    2      6HRTHETA,14X,1HH,15X,3HCFA,14X,3HGPW,14X,2HST,14X,6HETAINF,/)   OTPT  178
4200 FORMAT(1H /1H ,I7,4X, 6E17.6, 8X, I4)                                  OTPT  179
4250 FORMAT(1H ,F11.6,6E17.6,  4X, F11.6)                                   OTPT  180
6060 FORMAT(1H ,I3,2X,F10.6,  7E16.6      )                                 OTPT  181
9000 CONTINUE                                                               OTPT  182C
     END                                                                    OTPT  183
```

```
      SUBROUTINE HFAD
C
C **  SUBROUTINE HFAD
C
      COMMON /HEADR/ CASF, IPAGF
      WRITE (6,100)  CASE
      IPAGE = IPAGE + 1
      RFTURN
  100 FORMAT(1H1,/1H ,2X,6H CASE ,A4,21X,51H****** CFBECI-KELLER BOUNDAR
     1Y LAYER PROGRAM *******, 23X , 13HPROGRAM K99A )
      END
```

```
      OVERLAY(AXSY,6,0)                                                   SMOT   001C
      PROGRAM SMOOTH                                                      SMOT   002C
C     SUBROUTINE SMOOTH                                                   SMOT   003I
C     ******************************************************************  SMOT   004
C     THIS SUBROUTINE CONTROLS THE SMOOTHING OF THE INPUT COORDINATES     SMOT   005
C     ******************************************************************  SMOT   006
      DIMENSION X(100),Y(100),XO(100),YO(100)                             SMOT   007
      REWIND 1                                                            SMOT   008
      REWIND 10                                                           SMOT   009
      READ(5,1) NPTS ,ITAPE                                               SMOT   010
      IF(ITAPE .NE. 0) GO TO 5                                            SMOT   011
      READ(5,2) (X(I),I=1,NPTS)                                           SMOT   012
      READ(5,2) (Y(I),I=1,NPTS)                                           SMOT   013
      GO TO 7                                                             SMOT   014
    5 READ(1) (X(I),I=1,NPTS)                                             SMOT   015
      READ(1) (Y(I),I=1,NPTS)                                             SMOT   016
    7 CONTINUE                                                            SMOT   017
      CALL SM5PT(X,Y,XO,YO,NPTS)                                          SMOT   018
      WRITE(10,10)     (XO(I),I=1,NPTS)                                   SMOT   019
      WRITE(10,10)     (YO(I),I=1,NPTS)                                   SMOT   020
      REWIND 10                                                           SMOT   021
    1 FORMAT(2I4)                                                         SMOT   022
    2 FORMAT(6F10.0)                                                      SMOT   023
   10 FORMAT(6F10.6)                                                      SMOT   024
C     RETURN                                                              SMOT   025I
   20 CONTINUE                                                            SMOT   026C
      END                                                                 SMOT   027
```

```
      SUBROUTINE SM5PT (XI,YI,XO,YO,N)
C
C  THIS ROUTINF USFS THE OPTIMUM 5 POINT SMOOTHING METHOD.  A 3 POINT
C  METHOD TS USED AT THE END POINTS.
C
      DIMENSION XI(1),YI(1),XO(1),YO(1)
C
C
      J = 2
      I = -1
   10 XO(J+I) = XI(J+I)
      YO(J+I) = YI(J+I)
      XO(J) = 0.25*(XI(J-1) + 2.0*XI(J) + XI(J+1))
      YO(J) = 0.25*(YI(J-1) + 2.0*YI(J) + YI(J+1))
      IF (I .EQ. 1) GO TO 20
      J = N-1
      I = 1
      GO TO 10
C
   20 CONTINUE
      N2 = N - 2
      DO 30 J=3,N2
      XO(J) = (-XI(J-2)+4.0*XI(J-1)+10.0*XI(J)+4.0*XI(J+1)-XI(J+2))*
     1   0.0625
   30 YO(J) = (-YI(J-2)+4.0*YI(J-1)+10.0*YI(J)+4.0*YI(J+1)-YI(J+2))*
     1   0.0625
C
      RETURN
      END
```

```
      OVERLAY(AXSY,7,0)                                                 ITRT 001C
      PROGRAM ITERAT                                                    ITRT 002C
C     SUBROUTINE ITERAT                                                 ITRT 003I
      DIMENSION S(100),DELLS(100),X(100),Y(100),SURF(100),SINAL(100),   ITRT 004
     1 COSAL(100),SMD(100),DFLSTR(201),TSINAL(201),TCOSAL(201),         ITRT 005
     2 XNEW(100),YNEW(100) ,DESU(100)                                   ITRT 006
      REWIND 15                                                         ITRT 007
      REWIND 2                                                          ITRT 008
C     SURFACE DISTANCES FROM BOUNDARY LAYER INPUT                       ITRT 009
      READ(2) N                                                         ITRT 010
      READ(2) (S(I),I=1,N)                                              ITRT 011
C     BOUNDARY LAYER DISPLACEMENT THICKNESS                             ITRT 012
      READ(2) NN                                                        ITRT 013
      READ(2) (DELLS(I),I=1,NN)                                         ITRT 014
C     THIS DO LOOP IS USED IN CASE THE BOUNDARY LAYER DOES NOT          ITRT 015
C     CALCULATE A COMPLETE BOUNDARY DISPLACEMENT THICKNESS ARRAY        ITRT 016
C     DUE TO TURBULENT BOUNDARY LAYER SEPARATION                        ITRT 017
      DO 10 I=NN,N                                                      ITRT 018
   10 DELLS(I) = DELLS(NN)                                              ITRT 019
C     THE COORDINATES OF THE TRANSFORMED BODY ARE READ IN AT THIS POINT ITRT 020
      READ(15) NTS                                                      ITRT 021
      READ(15) (X(I),I=1,NTS)                                           ITRT 022
      READ(15) (Y(I),I=1,NTS)                                           ITRT 023
C     THE SURFACE DISTANCE OF THE INPUT BODY COORDINATES ARE CALCULATED ITRT 024
      SURF(1)=0.0                                                       ITRT 025
      DO 30 I=2,NTS                                                     ITRT 026
      DESURF=SQRT((X(I)-X(I-1))**2+(Y(I)-Y(I-1))**2)                    ITRT 027
   30 SURF(I)=DESURF+SURF(I-1)                                          ITRT 028
      S(N)=SURF(NTS)                                                    ITRT 029
C     NOTE S(I) IS DURFACE DISTANCE FROM LEADING EDGF TO TRAILING EDGE  ITRT 030
C     BASED ON COORDINATES ASSOCIATED WITH THE BOUNDARY LAYER SOLUTION  ITRT 031
C     SURF(I) IS SURFACE DISTANCE FROM LEADING EDGE TO TRAILING FDGE    ITRT 032
C     BASED ON THE X AND Y COORDINATES OF THE TRANSFORMED ORIGINAL      ITRT 033
C     BODY AT WHICH THE VALUE OF DISPAACEMENT THICKNFSS IS TO BE ADDED  ITRT 034
C     NEXT THE COSINE AND SIN OF THE LOCAL SURFACE ANGLES               ITRT 035
```

```
C     ARE FOUND AT THE MIDPOINTS OF THE X AND Y COORDINATES               ITRT 036
      NTSM=NTS-1                                                          ITRT 037
      NTSMM=NTS+1                                                         ITRT 038
      DO 40 I=1,NTSM                                                      ITRT 039
      DESU(I)=SQRT((X(I+1)-X(I))**2+(Y(I+1)-Y(I))**2)                     ITRT 040
      SINAL(I+1) = (Y(I+1)-Y(I))/DESU(I)                                  ITRT 041
   40 COSAL(I+1) = (X(I+1)-X(I))/DESU(I)                                  ITRT 042
      SINAL(1) = SINAL(2)                                                 ITRT 043
      COSAL(1) = COSAL(2)                                                 ITRT 044
      SINAL(NTSMM)=SINAL(NTS)                                             ITRT 045
      COSAL(NTSMM)=COSAL(NTS)                                             ITRT 046
C     THE SURFACE DISTANCE CORRESPONDING TO EACH OF THESE SIN AND COSINE  ITRT 047
C     PAIRS ARE CALCULATED HERE                                           ITRT 048
      SMD(1)=0.0                                                          ITRT 049
      SMD(2)=.5*SURF(2)                                                   ITRT 050
      DO 50 I=2,NTSM                                                      ITRT 051
   50 SMD(I+1) = SMD(I)+.5*(SURF(I+1)-SURF(I-1))                          ITRT 052
      SMD(NTSMM)=SMD(NTS)+.5*(SURF(NTS)-SURF(NTSM))                       ITRT 053
C     DISPLACEMENT THICKNESS AT THE VALUES OF S AND Y ARE FOUND HERE      ITRT 054
      CALL TABLE1(N,S,DELLS,DELSTB)                                       ITRT 055
      CALL TABLE1(NTSMM,SMD,SINAL,TSINAL)                                 ITRT 056
      CALL TABLE1(NTSMM,SMD,COSAL,TCOSAL)                                 ITRT 057
C     NEW COORDINATES ARE FORMED HERE                                     ITRT 058
      DO 60 I=1,NTS                                                       ITRT 059
      SURFF=SURF(I)                                                       ITRT 060
      CALL INS1(SURFF,DELSTB,DELST,1,NER)                                 ITRT 061
      CALL INS1(SURFF,TSINAL,SINU,1,NER)                                  ITRT 062
      CALL INS1(SURFF,TCOSAL,COSU,1,NER)                                  ITRT 063
      XNFW(I)=X(I)-DELST*SINU                                             ITRT 064
   60 YNFW(I)=Y(I)+DELST*COSU                                             ITRT 065
      XNFW(1) = X(1) - DELLS(2)                                           ITRT 066
C     IF SEPARATION HAS OCCURRED, THE BODY IS MODIFIED TO ACCOUNT         ITRT 067
C     FOR THIS BY ADDING A CIRCULAR RADIUS TO CREATE A SEPARATION BUBBLE  ITRT 068
      IF(NN .EQ. N) GO TO 80                                              ITRT 069
      XNFW1=XNFW(NN-3)                                                    ITRT 070
```

```
      XNEW2=XNEW(NN-2)
      XNEW3=XNEW(NN-1)
      YNEW1=YNEW(NN-3)
      YNEW2=YNEW(NN-2)
      YNEW3=YNEW(NN-1)
      CALL CIRCLE(XNEW1,XNEW2,XNEW3,YNEW1,YNEW2,YNEW3,RADIUS,XCENT,
     1  YCENT,DYDX)
      NNN=NN-1
      DO 70 I=NNN,NTS
      DELTA=X(I)-XCENT
      IF(DELTA .GE. 0.) KM=I
      IF(DELTA .GE. 0.)  GO TO 90
      YCIR=(RADIUS **2 - DELTA **2)
      IF(DYDX .GE. 0.) GO TO 65
      YNEW(I)=YCENT-SQRT(YCIR)
      GO TO 70
   65 YNEW(I)=YCENT+SQRT(YCIR)
   70 CONTINUE
      GO TO 80
   90 CONTINUE
      DO 100 I=KM,NTS
  100 YNEW(I)=YNEW(KM-1)
   80 CONTINUE
C     IF THE BODY RADIUS BECOMES EQUAL TO THE DISPLACEMENT THICKNESS AT
C     SOME POINT THEN THE NEW BODY IS MODIFIED TO KEEP THE SAME AREA
C     DUE TO THE DISPLACEMENT THICKNESS
      NXSL=NTS/2
      DO 105 K=NXSL,NTS
      DYNEW=YNEW(K)-Y(K)
      IF(DYNEW .GE. Y(K)) KSL=K-2
      IF(DYNEW .GE. Y(K)) GO TO 110
  105 CONTINUE
      GO TO 115
  110 DAREA=3.14159*(YNEW(KSL)**2-Y(KSL)**2)
      DO 112 I=KSL,NTS
```

```
      ARFA=3.14159*Y(I)*Y(I)+DARFA                                      ITRT 106
  112 YNFW(I)=SQRT(AREA/3.14159)                                        ITRT 107
  115 WRITF(6,4)                                                        ITRT 108
      WRITF(6,5) (XNEW(I),YNEW(I),I=1,NTS)                              ITRT 109
C     XNFW AND YNEW ARE THF VISCOUS COORDINATES WHICH SHOULD BE WRITTEN ITRT 110
C     ON TAPE AND TRANSFERRED TO THE SMOOTHING ROUTINE                  ITRT 111
      REWIND 1                                                          ITRT 112
      WRITE(1) (XNFW(I),I=1,NTS)                                        ITRT 113
      WRITE(1) (YNEW(I),I=1,NTS)                                        ITRT 114
    4 FORMAT(1H ,10X,4HXNEW,20X,4HYNFW)                                 ITRT 115
    5 FORMAT(2F20.8)                                                    ITRT 116
      RETURN                                                            ITRT 117
      END                                                               ITRT 118
```

```
      SUBROUTINE TABLE1(N,X,Y,TABLE)
      DIMENSION X(100),Y(100),TABLE(201)
C     THIS ROUTINE SETS UP TABLES FOR INPUT TO SUBROUTINE INS1
C     N IS THE NUMBER OF VALUES OF X AND Y TO BE PUT INTO ARRAYS
      J=2
      DO 200 I=1,N
      TABLE(J)=X(I)
      TABLE(J+1) = Y(I)
      J=J+2
  200 CONTINUE
      TABLE(1)=N
      RETURN
      END
```

```
      SUBROUTINE CIRCLE (X1,X2,X3,Y1,Y2,Y3,R,XCENT,YCENT,DYDX)
      XY1=-(X1*X1+Y1*Y1 )
      XY2=-(X2*X2+Y2*Y2 )
      XY3=-(X3*X3+Y3*Y3 )
      E1=(XY1-XY2)*(X2-X3)-(XY2-XY3)*(X1-X2)
      F2=(Y1-Y2)*(X2-X3)-(Y2-Y3)*(X1-X2)
      E=F1/E2
      CENTK=-E/2.
      D=((XY2-XY3)-E*(Y2-Y3))/(X2-X3)
      H=-D/2.
      F=XY1-D*X1-E*Y1
      R=SQRT(H*H+CENTK**2-F)
      DYDX=-(X3-H)/(Y3-CENTK)
      C=1./R
      DYDXS=DYDX*DYDX
      CC=C*(1.+DYDXS)**1.5
      CC=ABS(CC)
      DDYDX=ABS(DYDX)
      PHI=ATAN(DDYDX)
      IF(DYDX .GE. 0.) GO TO 20
      XCFNT=X3+R*SIN(PHI)
      YCENT=Y3+R*COS(PHI)
      GO TO 30
   20 XCENT=X3+R*SIN(PHI)
      YCENT=Y3-R*COS(PHI)
   30 CONTINUE
      RETURN
      END
```

REFERENCES

1. Thwaites, B.: Incompressible Aerodynamics. Oxford at the Clarendon Press, p. 62, 1960.

2. Callaghan, J. G. and Beatty, T. D.: A Theoretical Method for the Analysis and Design of Multi-element Airfoils. Journal of Aircraft Volume 9, No. 12, December 1972.

3. Stevens, W. A.; Goradia, S. H.; and Braden, J. A.: Mathematical Model for Two-Dimensional Multi-Component Airfoils in Viscous Flow, NASA CR-1843, July 1971.

4. Bhateley, I. C. and McWhirter, J. W.: Development of Theoretical Method for Two-Dimensional Multi-element Airfoil Analysis and Design. Air Force Flight Dynamics Laboratory, TR-72-96, Part I, August 1972.

5. Hess, J. L.: Calculation of Potential Flow about Arbitrary Three-Dimensional Lifting Bodies. McDonnell Douglas Report No. MDC J5679-01, done under Contract No. N00019-71-C-0524 for Naval Air Systems Command.

6. Hess, J. L. and Smith, A. M. O.: Calculation of Potential Flow about Arbitrary Bodies. Progress in Aeronautical Sciences, Volume 8, Pergamon Press, New York, 1966.

7. Smith, A. M. O. and Pierce, J.: Exact Solution of the Neumann Problem. Calculation of Plane and Axially Symmetric Flows about or within Arbitrary Boundaries. Douglas Aircraft Company Report No. 26988, April 1958. (A brief summary is contained in the preceedings of the third U.S. National Congress of Applied Mechanics, Brown University, 1958).

8. Cebeci, T. and Smith, A. M. O.: A Finite-Difference Solution of the Incompressible Turbulent Boundary Layer Equations by an Eddy-Viscosity Concept. Computation of Turbulent Boundary Layers, AFOSR-IFP Stanford Conference, Volume 1, Stanford University Press, Stanford, California, 1968, pp. 346-356.

9. Faulkner, S.; Hess, J. L.; and Giesing, J. P.: Comparison of Experimental Pressure Distributions with those Calculated by the Neumann Program. Douglas Aircraft Company Report LB 31831, December 1964.

10. Bauer, A. B.; Smith, A. M. O.; and Hess, J. L.: Potential Flow and Boundary Layer Theory as Design Tools in Aerodynamics. Canadian Aeronautics and Space Journal, Volume 16, No. 2, February 1970.

11. Hess, J. L.: Numerical Solution of the Integral Equation for the Neumann Problem with Application to Aircraft and Ships. Presented to Symposium on Numerical Solution of Integral Equations with Physical Applications. SIAM Meeting, October 11, 12, 13, 1971, University of Wisconsin, Madison, Wisconsin, Douglas Engineering Paper 5987.

12. Hess, J. L.: Calculation of Potential Flow about Bodies of Revolution Having Axes Perpendicular to the Freestream Direction. Douglas Aircraft Company Report No. ES 29812, October 1, 1960.

13. Hess, J. L.: Extension of the Douglas-Neumann Program for Axisymmetric Bodies to Include Calculation of Potential, Non-uniform Cross Flow, Added Mass, and Conductor Problems. Douglas Aircraft Company Report No. 31765, September 1, 1964. This work performed for Naval Ordnance Test Station, Pasadena Annex under Contract No N60530-10053.

14. Hess, J. L.: Extension of the Douglas Axisymmetric Potential Flow Program to Include the Effects of Ring Vorticity with Application to the Program of Specified Tangential Velocity. Douglas Aircraft Company Report No. 33195, June 10, 1966. This work performed for Naval Ordinance Test Station, Pasadena Annex under Contract No. N60530-11208.

15. Hess, J. L.: Improved Ring-Source Formulas for Small Values of Distance from the Symmetry Axis. A Modification of the Douglas-Neumann Program for Axisymmetric Bodies. Douglas Aircraft Company Report No. 70002, August 1969.

16. Hess, J. L.: Modification of the Douglas-Neumann Program for Axisymmetric Bodies to Include the Direchlet Problem for a Potential that Varies as the Cosine of Twice the Circumferential Angle. Douglas Aircraft Company Report No. 70001, August 1969. This work performed under Air Force Contract AFO(694)-953 on the Reentry Systems Environment Protection Program.

17. Hess, J. L. and Schoor, C.: Extension of the Douglas-Neumann Axisymmetric Potential Flow Program to the Problem of a Ring Wing Having a Known Ring Vortex Wake Issuing from its Trailing Edge. McDonnell Douglas Report No. MDC J0741/01, April 25, 1970. This work performed for Naval Undersea Research and Development Center under Contract No. N66001-70-C-0436.

18. Probstein, R. F. and Elliott, D.: The Transverse Curvature Effect in Compressible Axially Symmetric Laminar-Boundary-Layer Flow. Journal of Aeronautical Sciences, March 1956.

19. Hartree, D. R. and Womersley, J. R.: A Method for the Numerical or Mechanical Solution of Certain Types of Partial Differential Equations. Procedure Royal Society Series A, Volume 161, No. 906, p. 353, August 1937.

20. Keller, H. B.: A New Difference Scheme for Parabolic Problems in "Numerical Solution of Partial Differential Equations." Volume II, Academic Press, New York, 1970.

21. Keller, H. B.; and Cebeci, T.: Simple Accurate Numerical Methods for Boundary Layers. I. Two-Dimensional Laminar Flows. Proceedings of the Second International Conference on Numerical Methods in Fluid Dynamics. Lecture Notes in Physics, Volume 8, Springer-Verlag, New York, 1971.

22. Keller, H. B.; and Cebeci, T.: Simple Accurate Numerical Methods for Boundary Layers. II. Two-Dimensional Turbulent Flows, AIAA Journal Volume 19, No. 9, pp. 1197-1200, September 1972.

23. Van Driest, E. R.: On Turbulent Flow Near a Wall. Journal Aeronautical Sciences, Volume 23, no. 11, p. 1007, November 1956.

24. Cebeci, T.: Eddy-Viscosity Distribution in Thick Axisymmetric Turbulent Boundary Layers. Journal of Fluids Engineering, June 1973, pp. 319 to 326.

25. Cebeci, T.: Kinematic Eddy Viscosity at Low Reynolds Numbers. AIAA Journal, Volume 11, No. 1, January 1973, pp. 102-104.

26. Coles, D.: The Turbulent Boundary Layer in a Compressible Fluid. Report R-403-PR., September 1962, Rand Corporation, Santa Monica, California.

27. Cebeci, T.: Laminar and Turbulent Incompressible Boundary Layers on Slender Bodies of Revolution in Axial Flow. Journal of Basic Engineering, Trans. ASME, Series D, Volume 92, No. 3, September 1979, pp. 545-554.

28. Cebeci, T.: Wall Curvature and Transition Effects in Turbulent Boundary Layers. AIAA Journal, Volume 9, No. 9, September 1971, pp. 1868-1870.

29. Chen, K. K. and Thyson, W. A.: Extension of Emmons' Spot Theory to Flows on Blunt Bodies. AIAA Journal, Volume 9, No. 5, pp. 821-825.

30. Emmons, H. W.: The Laminar-Turbulent Transition in a Boundary Layer. Journal of the Aerospace Sciences, Volume 18, Part I, 1950, p. 490.

31. Michel, R.: Etude de la Transition Sur Les Profils D'Aile-Establissement d'un critere de Determination du Point de Transition et Calcul de la Tratnee de Profil en Incompressible. Onera Rapport 1/1578A, July 1951.

32. Smith, A. M. O.: Transition, Pressure Gradient, and Stability Theory. Proceedings of the 9th International Congress of Applied Mechanics, Volume 4, 1956, p. 234.

33. Kaups, K.: Transition Prediction on Bodies of Revolution. McDonnell Douglas Report No. MDC J6530, prepared under U.S. Navy Undersea Center Contract No. N66001-74-C-0020, April 1974.

34. Cebeci, T.; Mosinskis, G. J.; and Smith, A. M. O.: Calculation of Viscous Drag and Turbulent Boundary Layer Separation on Two-Dimensional and Axisymmetric Bodies in Incompressible Flow. McDonnell Douglas Report No. MDC J0973-01, prepared under Contract No. N00014-70-C-0099, for the Naval Ship and Systems Command, November 1970.

35. Hoerner, S. F.: Base Drag and Thick Trailing Edges. Journal of the Aeronautical Sciences, 1959, p. 622.

36. Bauer, A. B.: Body of Revolution Drag Measurement and Results. McDonnell Douglas Corporation Report No. MDC J5167/01, December 1970.

37. Tomotike, S. and Imai, I.: On the Transition from Laminar to Turbulent Flow in the Boundary Layer of a Sphere. Aeronautical Research Institute of Tokyo University Report No. 167, p. 389-423, August 1938.

38. Achenbach, Elmar: Experiments on the Flow Past Spheres at Very High Reynolds Numbers. Journal of Fluid Mechanics Volume 54, Part 3, 1972, pp. 565-575.

39. Jacob, K.: Theoretische Berechung von Druckverteilung und Kraftbeiwerten Für Beliebige Profile bej Inkompressibler Strömung mit Ablösung. Ava-Bericht 67 A 62 (1967).

40. Beatty, T.D.: Prediction of Flows with and without Partial Separation. Masters Thesis presented to Mechanical Engineering Department, California State University, Long Beach, July 1972.

41. Hahn, M.; Rubbert, P. E.; and Mahal, A.: Evaluation of Separation Criteria and Their Application to Separated Flow Analysis. Air Force Flight Dynamics Laboratory Report No. AFFDL-TR-72-145, January 1973.

42. Cebeci, T.; Mosinskis, G. J.: and Kaups, K.: A General Method for Calculating Three-Dimensional Incompressible Laminar and Turbulent Boundary Layers. 1. Swept Infinite Cylinders and Small Cross Flow McDonnell Douglas Aircraft Corporation Report No. MDC J5694, prepared under Contract No. N00014-72-C-0111, for the Naval Ship Systems Command.

43. Chang, P.K.: Separation of Flow. Pergamon Press, 1970.

44. Wang, K. C.: Separation Patterns of Boundary Layer Over an Inclined Body of Revolution. AIAA Journal, Volume 10, No. 8, August 1972.

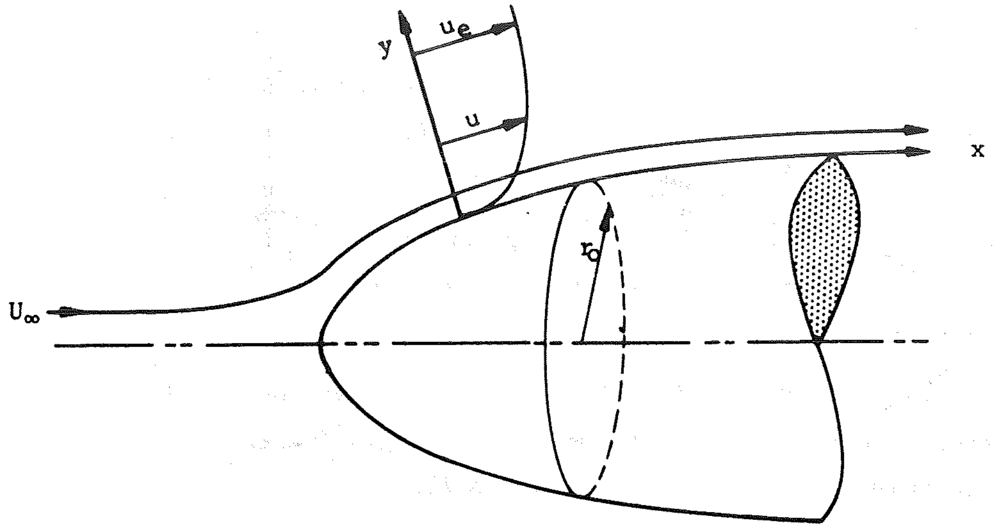


FIGURE 1. COORDINATE SYSTEM FOR THE BOUNDARY LAYER ON A BODY OF REVOLUTION

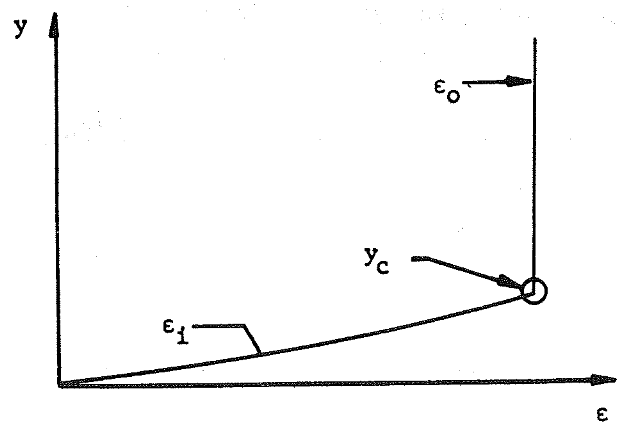


FIGURE 2. EDDY-VISCOSITY DISTRIBUTION ACROSS A BOUNDARY LAYER

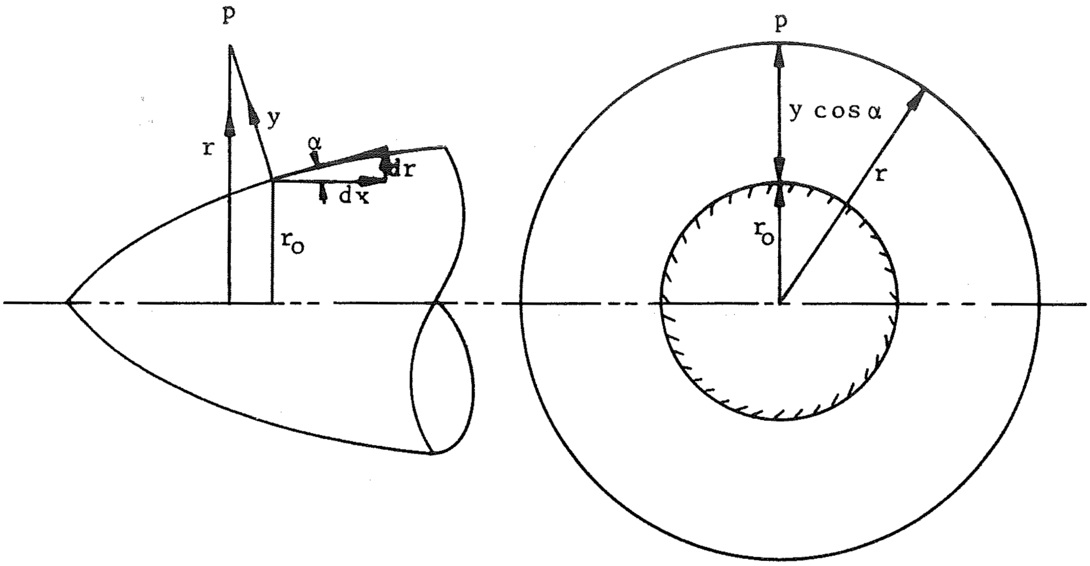


FIGURE 3. COORDINATES FOR AXIALLY SYMMETRIC BODY WITH THICK BOUNDARY LAYER

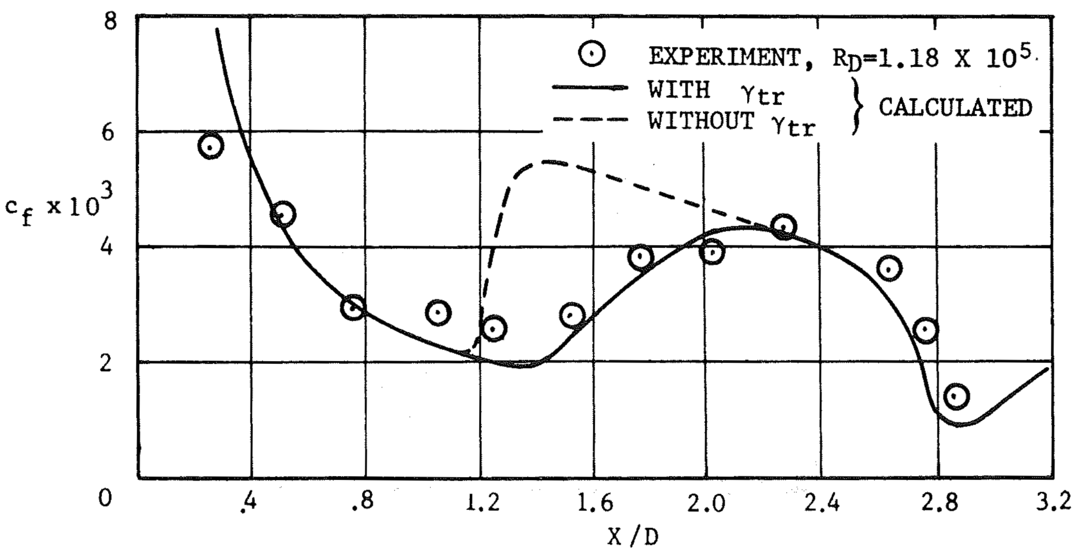


FIGURE 4. EFFECT OF TRANSITION REGION MODIFICATION ON THE SKIN FRICTION

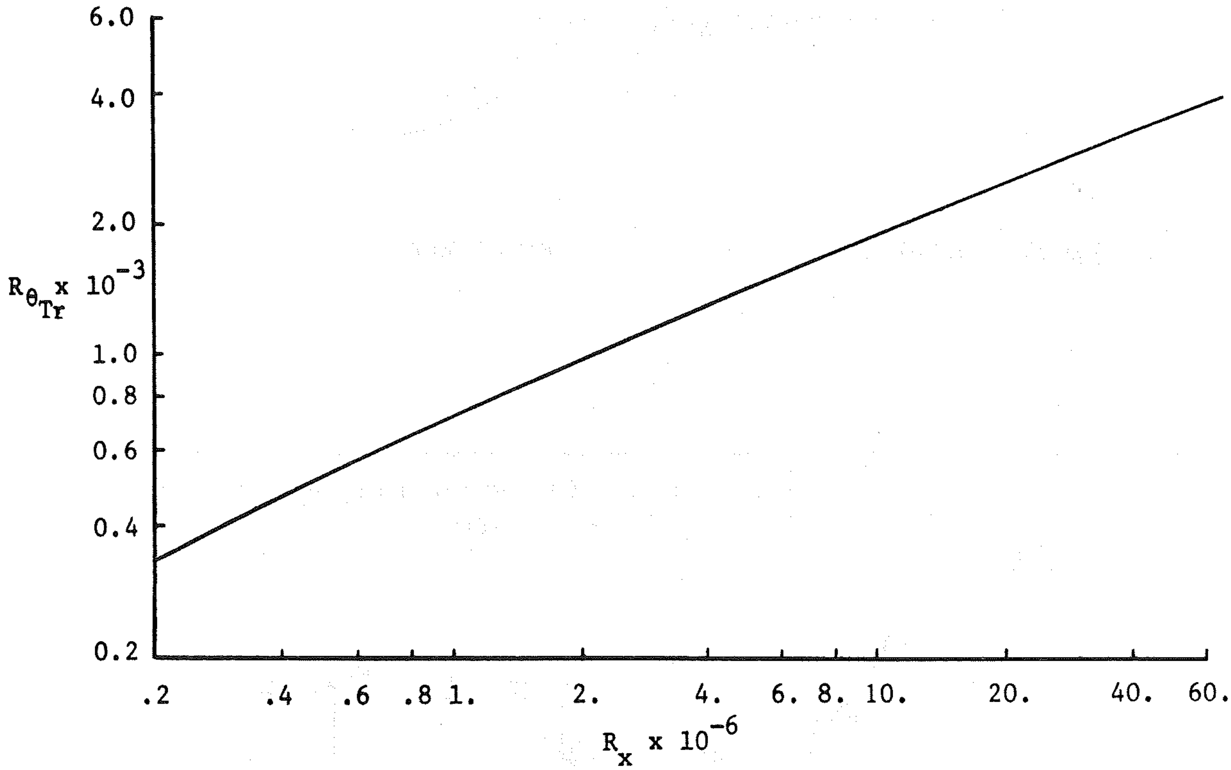


FIGURE 5. TRANSITION CORRELATION CURVE FROM REFERENCE 32

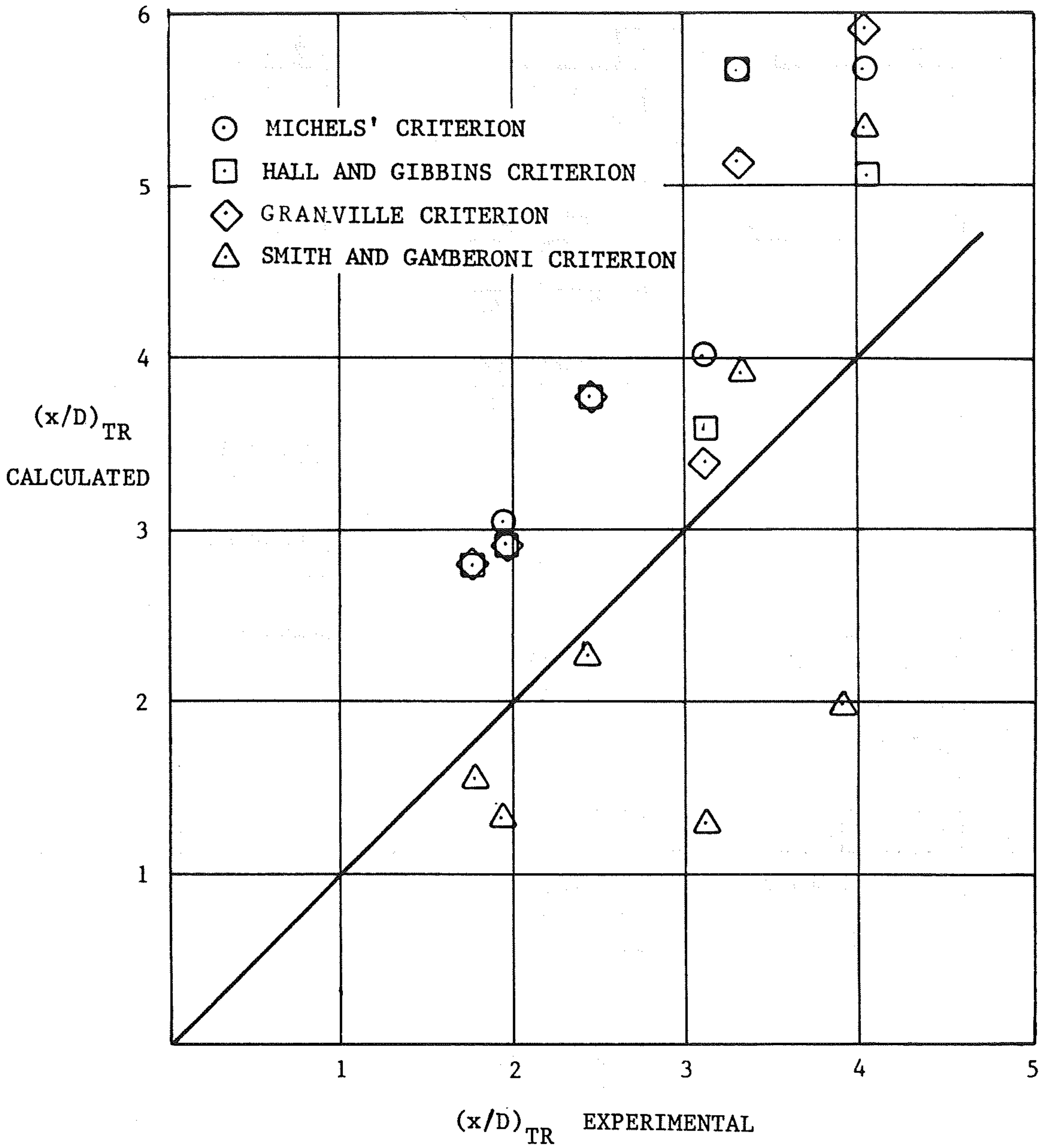


FIGURE 6. COMPARISON OF EXPERIMENTAL AND CALCULATED TRANSITION LOCATIONS FROM VARIOUS METHODS FOR FAVORABLE GRADIENT FLOWS

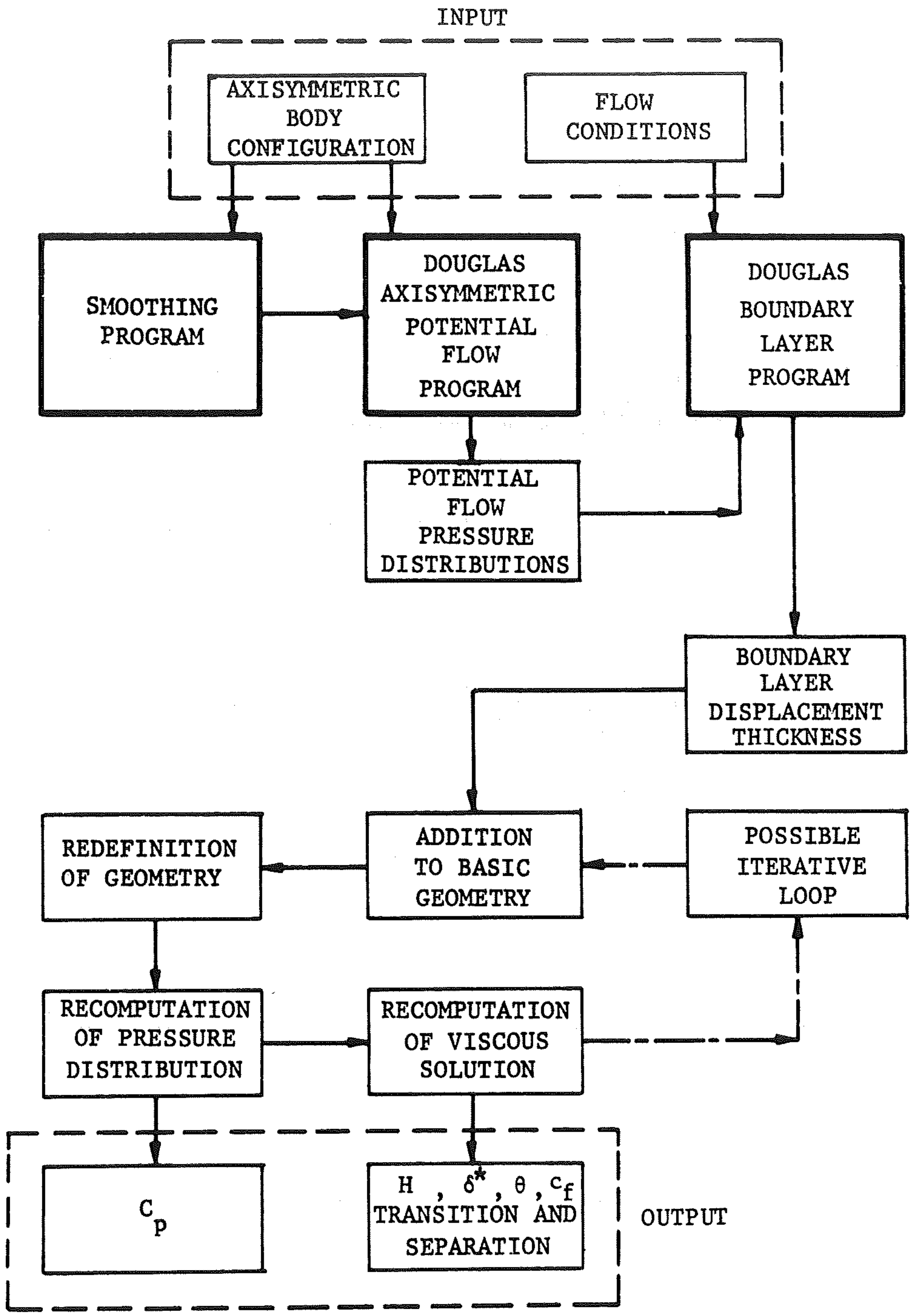


FIGURE 7. FLOW DIAGRAM OF COMPUTER PROGRAM FOR AXISYMMETRIC ANALYSIS AND DESIGN METHOD (ADAM)

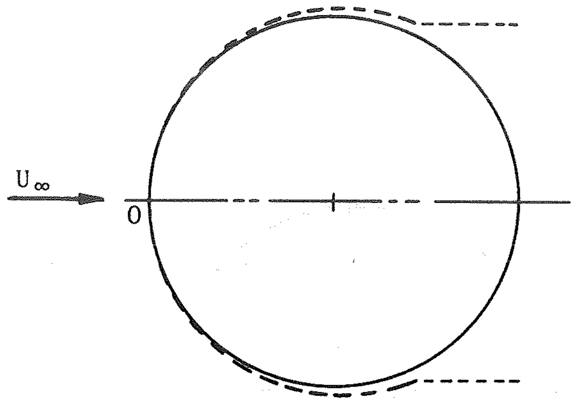


FIGURE 8. SCHEMATIC DIAGRAM OF CYLINDRICAL WAKE SHAPE USED TO MODEL SEPARATION

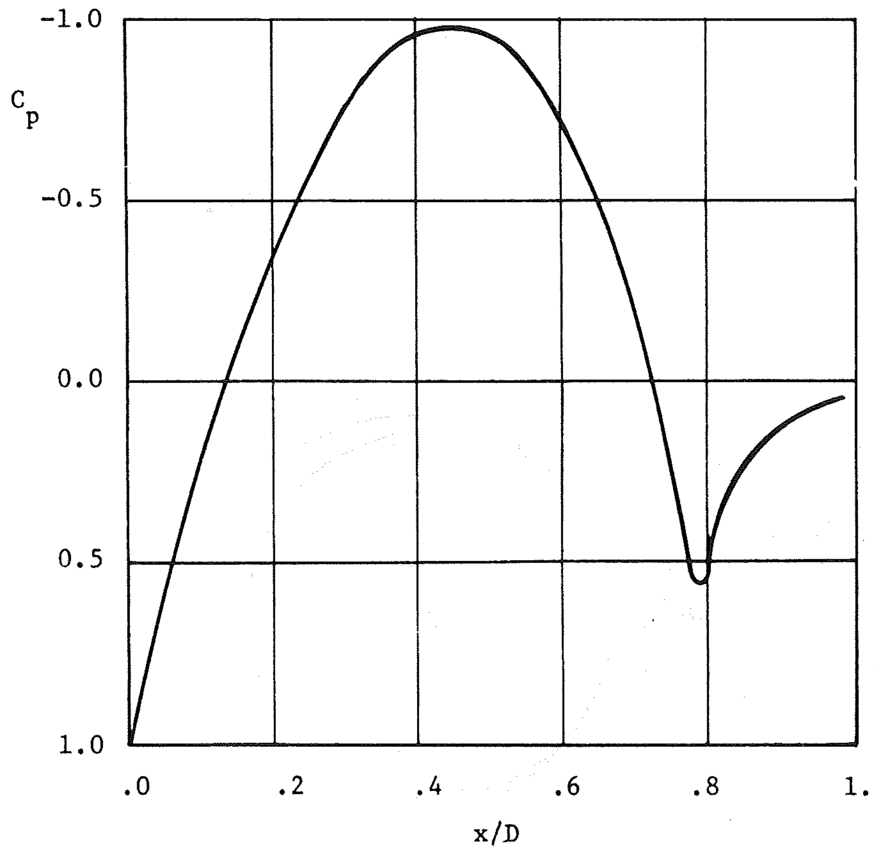
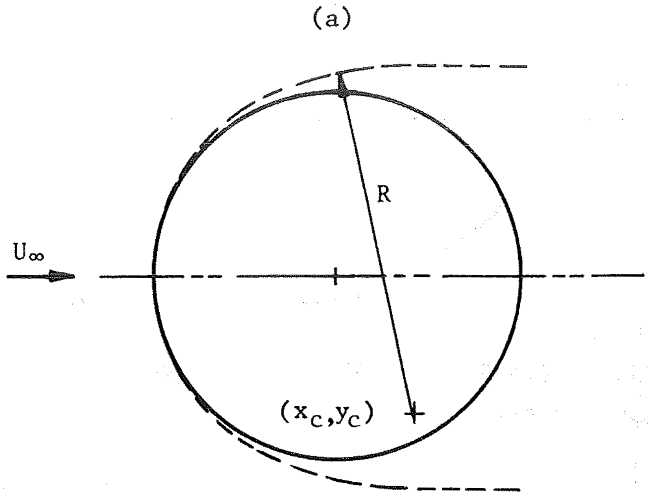


FIGURE 9. PRESSURE DISTRIBUTION FOR SPHERE IN SUPERCRITICAL REGION USING CYLINDRICAL SEPARATION MODEL



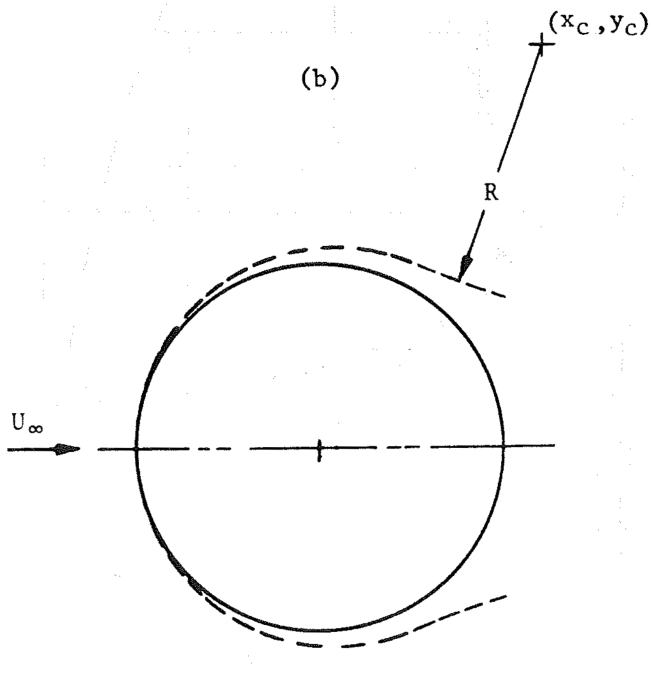


FIGURE 10. SCHEMATIC DIAGRAMS OF CIRCULAR ARC FAIRING USED IN THE MODEL FOR SEPARATED FLOW.

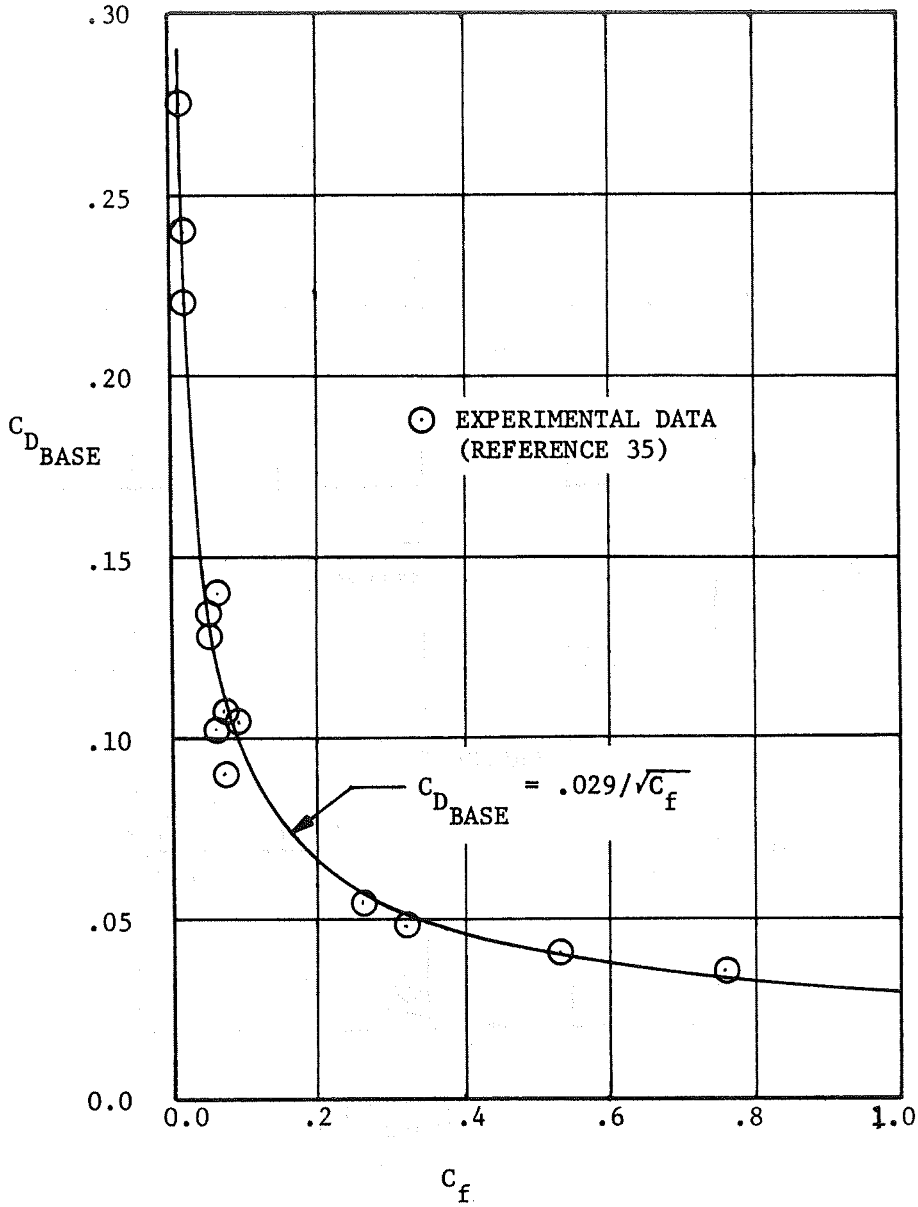


FIGURE 11 AXISYMMETRIC BASE DRAG AS A FUNCTION OF FOREBODY SKIN FRICTION COEFFICIENT

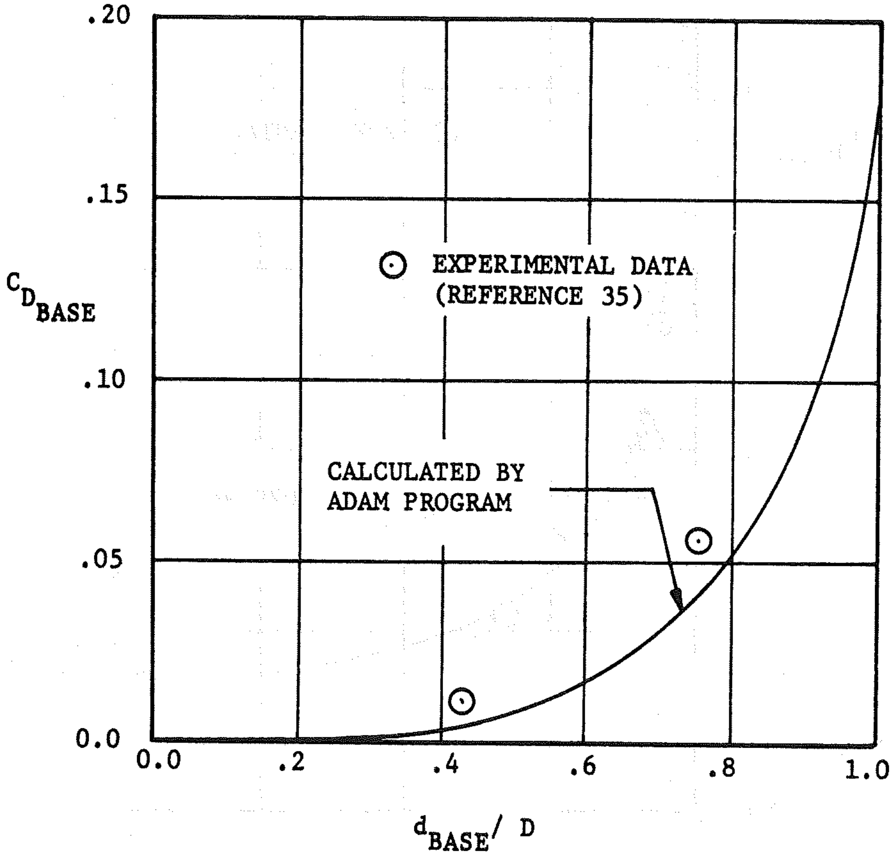


FIGURE 12 COMPARISON OF BASE DRAG CALCULATED BY ADAM TO EXPERIMENTAL DATA

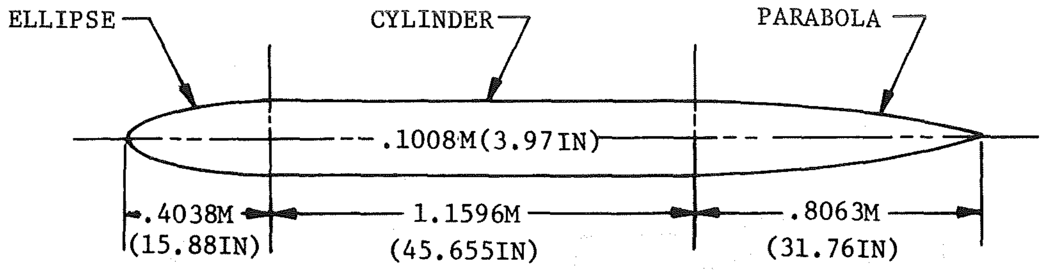


FIGURE 13. SCHEMATIC OF HIGH FINENESS RATIO BODY FROM REFERENCE 35

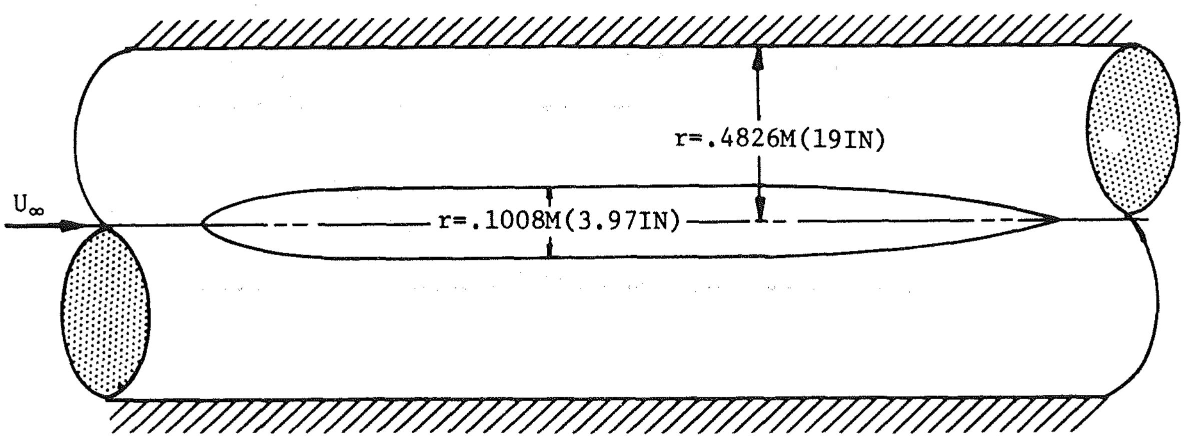


FIGURE 14. HIGH FINENESS RATIO BODY AND SIMULATED TUNNEL USED IN POTENTIAL FLOW PROGRAM TO ACCOUNT FOR WALL EFFECTS ON PRESSURE DISTRIBUTION

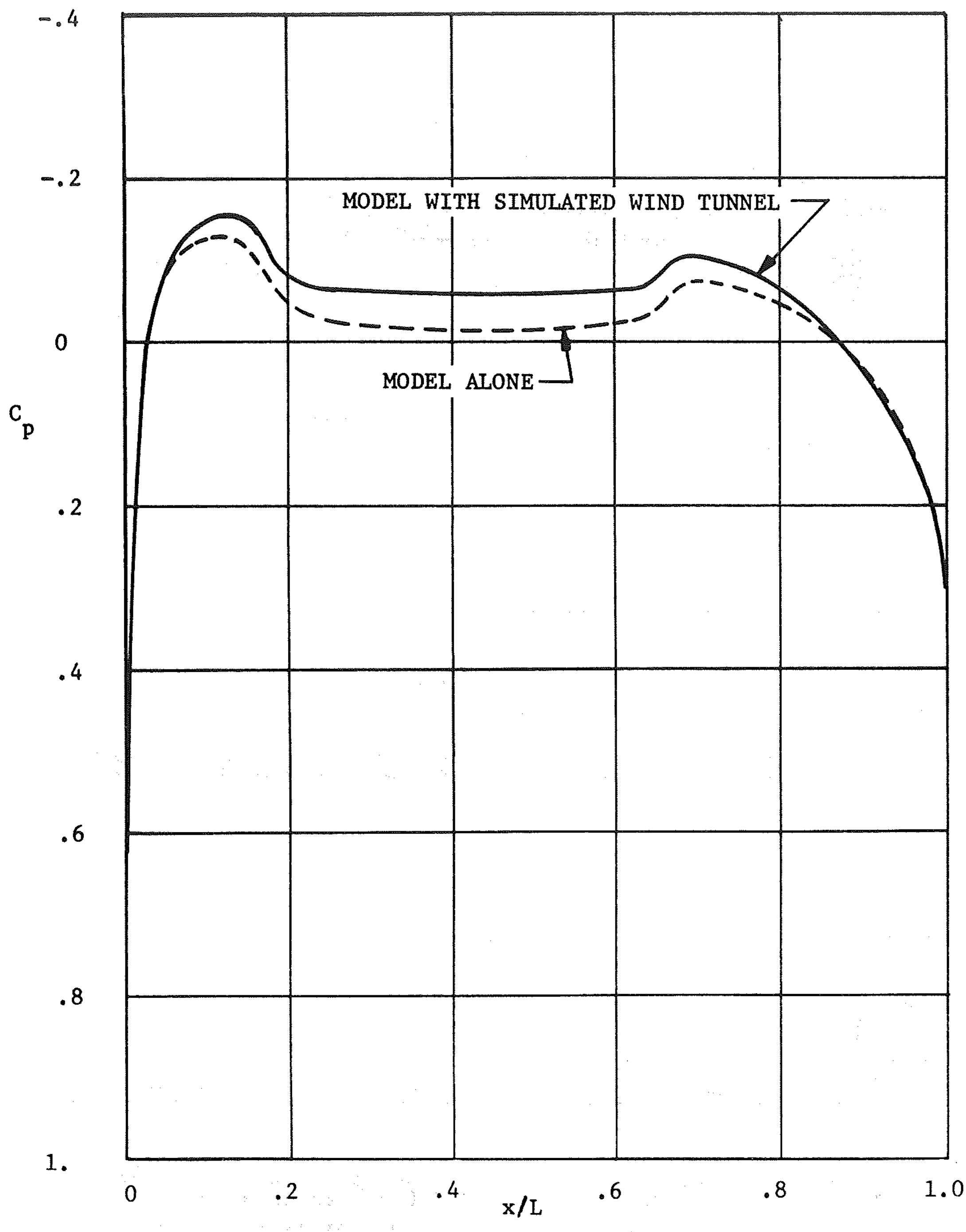


FIGURE 13. EFFECT OF WIND TUNNEL WALLS ON INVISCID PRESSURE DISTRIBUTION FOR HIGH FINENESS RATIO BODY AS CALCULATED BY POTENTIAL FLOW PROGRAM

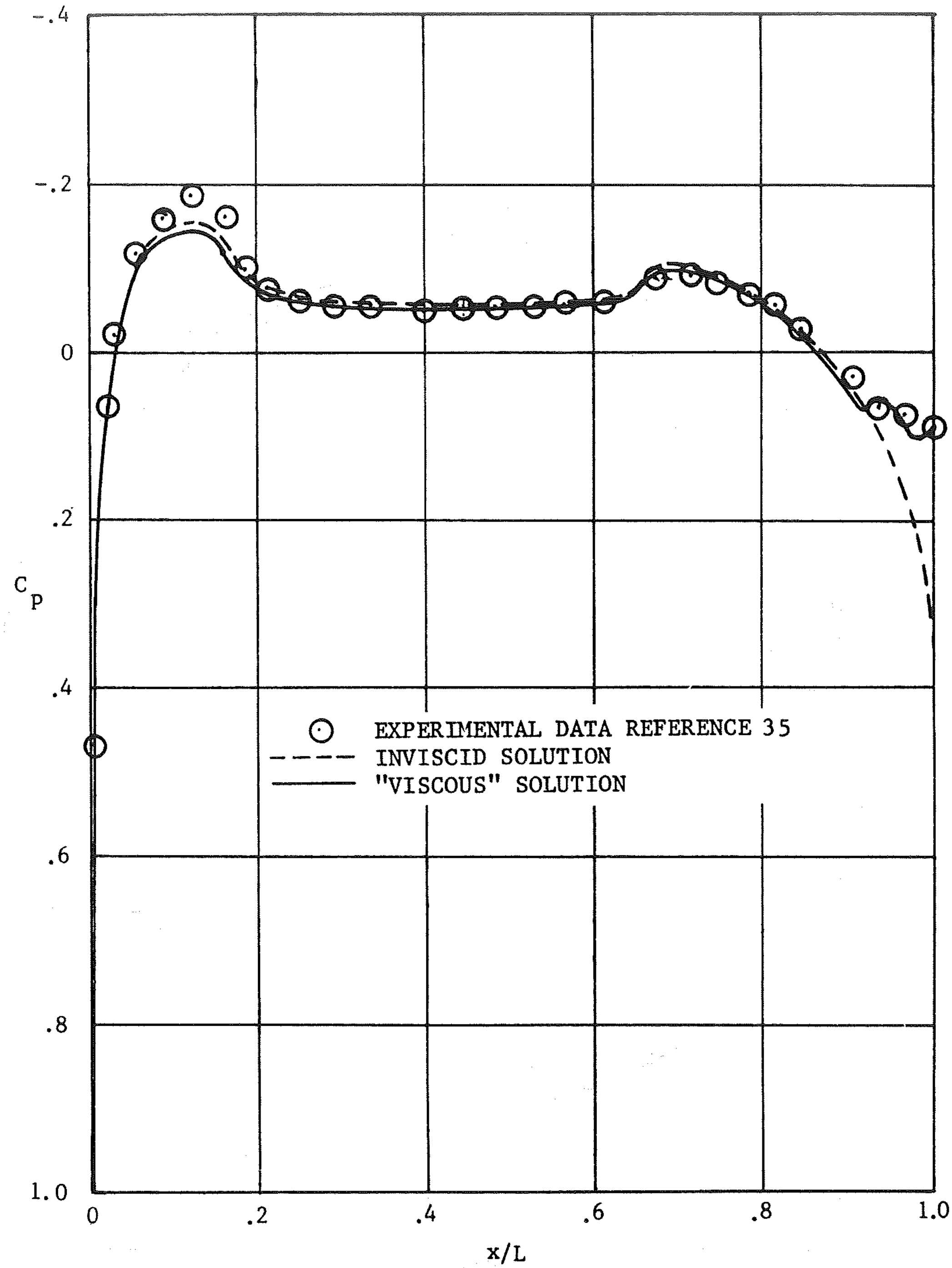


FIGURE 14. COMPARISON OF CALCULATED "VISCOUS" PRESSURE DISTRIBUTION FOR HIGH FINENESS RATIO BODY TO EXPERIMENTAL DATA

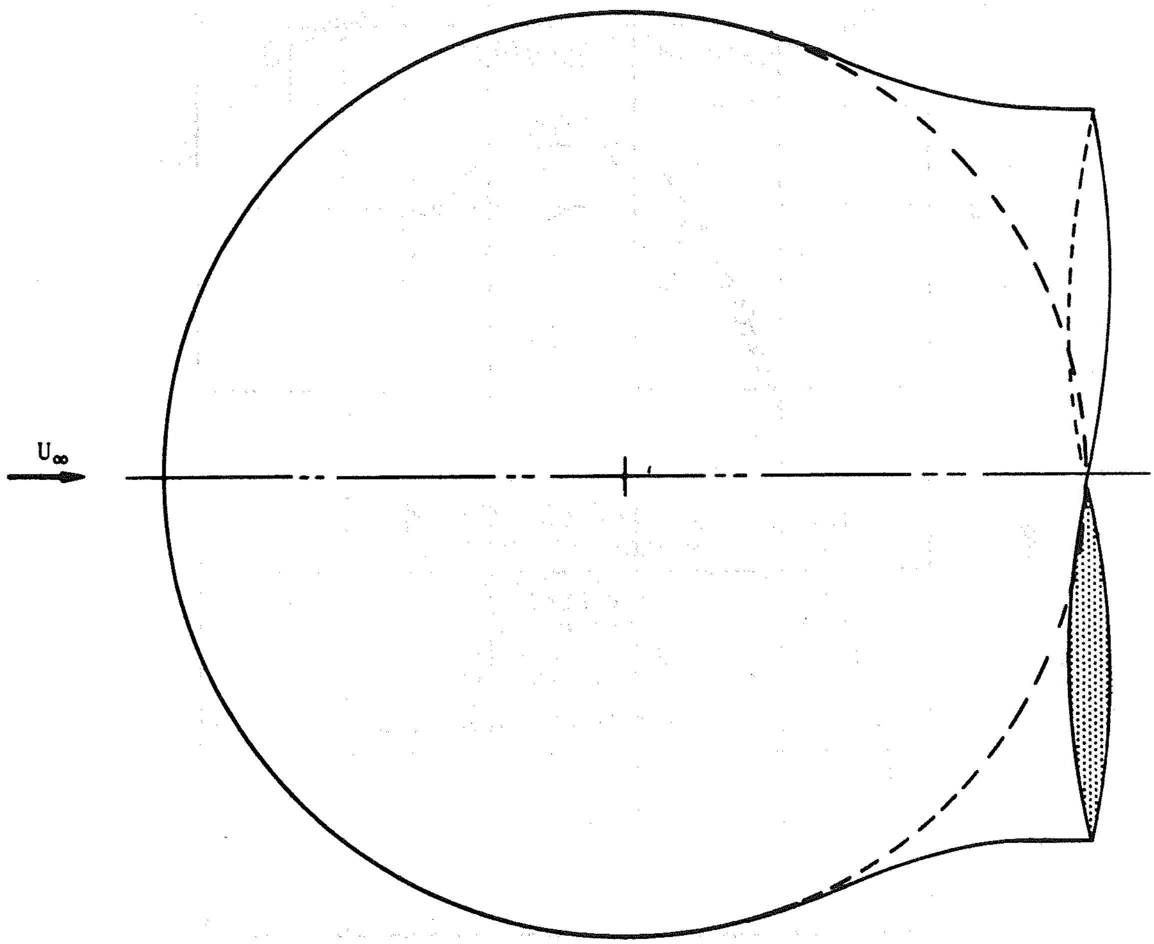


FIGURE 15. EQUIVALENT BODY INCLUDING SEPARATED WAKE USED TO CALCULATE "VISCOUS" FLOW ABOUT SPHERE IN SUPERCRITICAL REGIME

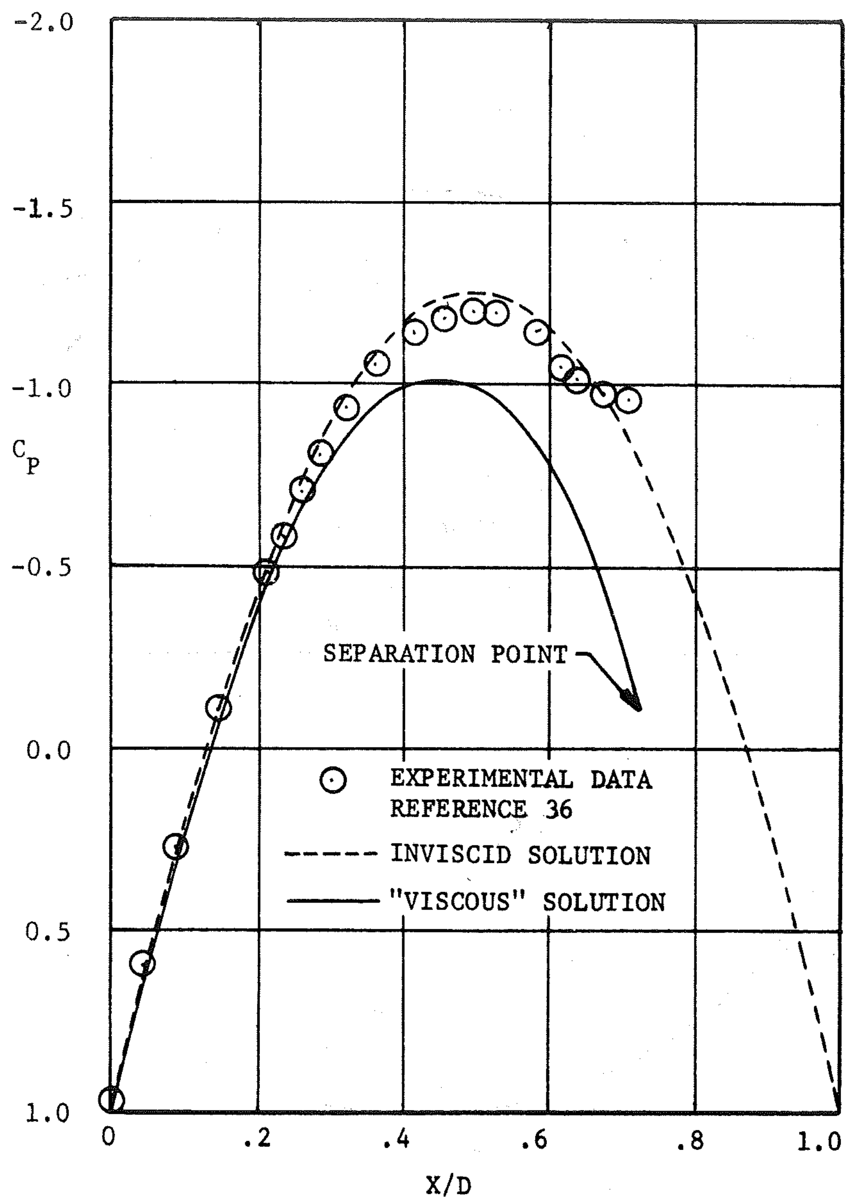


FIGURE 16. COMPARISON OF CALCULATED "VISCOUS" PRESSURE DISTRIBUTION FOR SPHERE IN SUPERCRITICAL REGIME TO EXPERIMENTAL DATA

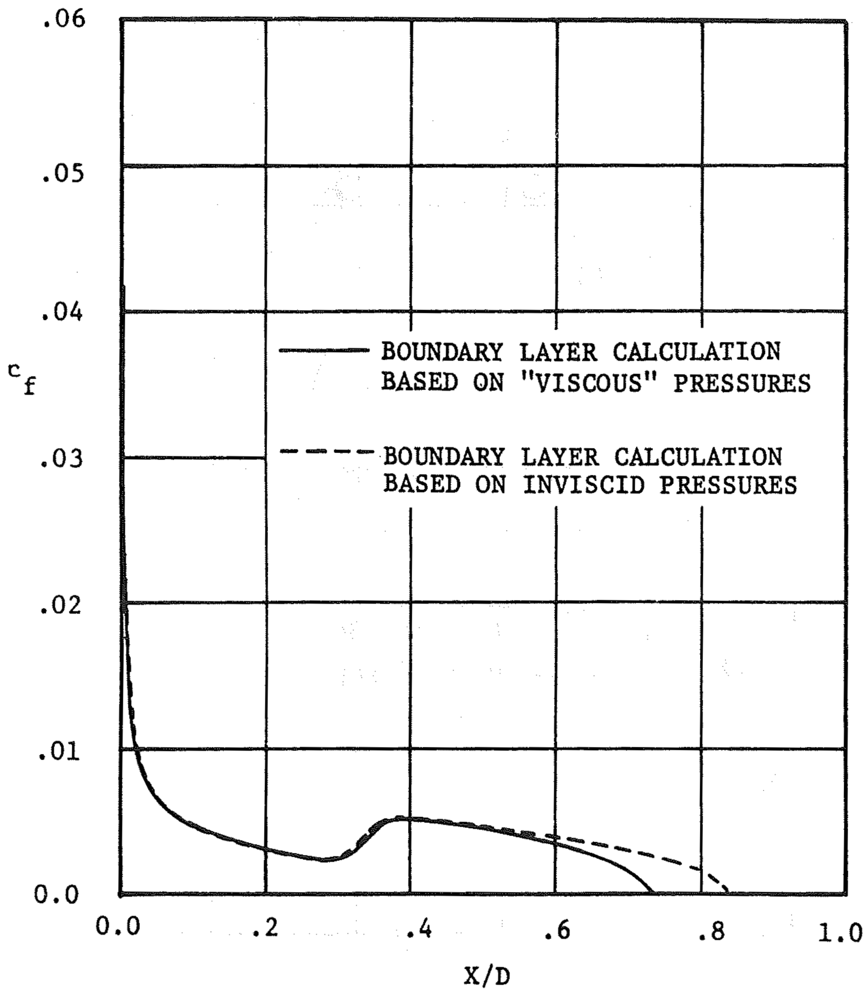


FIGURE . EFFECT OF "VISCOUS" MODELING ON CALCULATION OF LOCAL SKIN FRICTION COEFFICIENT FOR SPHERE IN SUPERCRITICAL REGIME

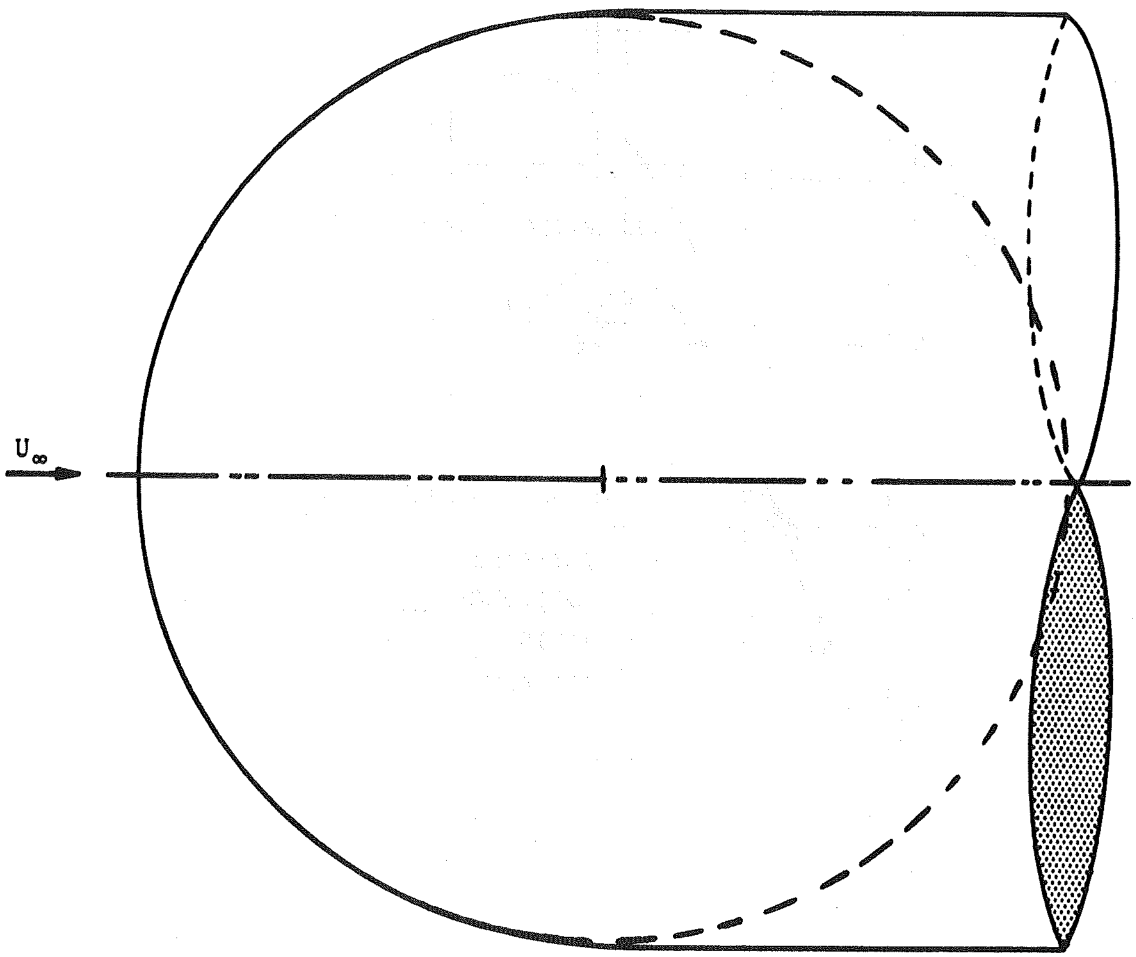


FIGURE 17. EQUIVALENT BODY INCLUDING SEPARATED WAKE USED TO CALCULATE "VISCOUS" FLOW ABOUT SPHERE IN SUBCRITICAL REGIME

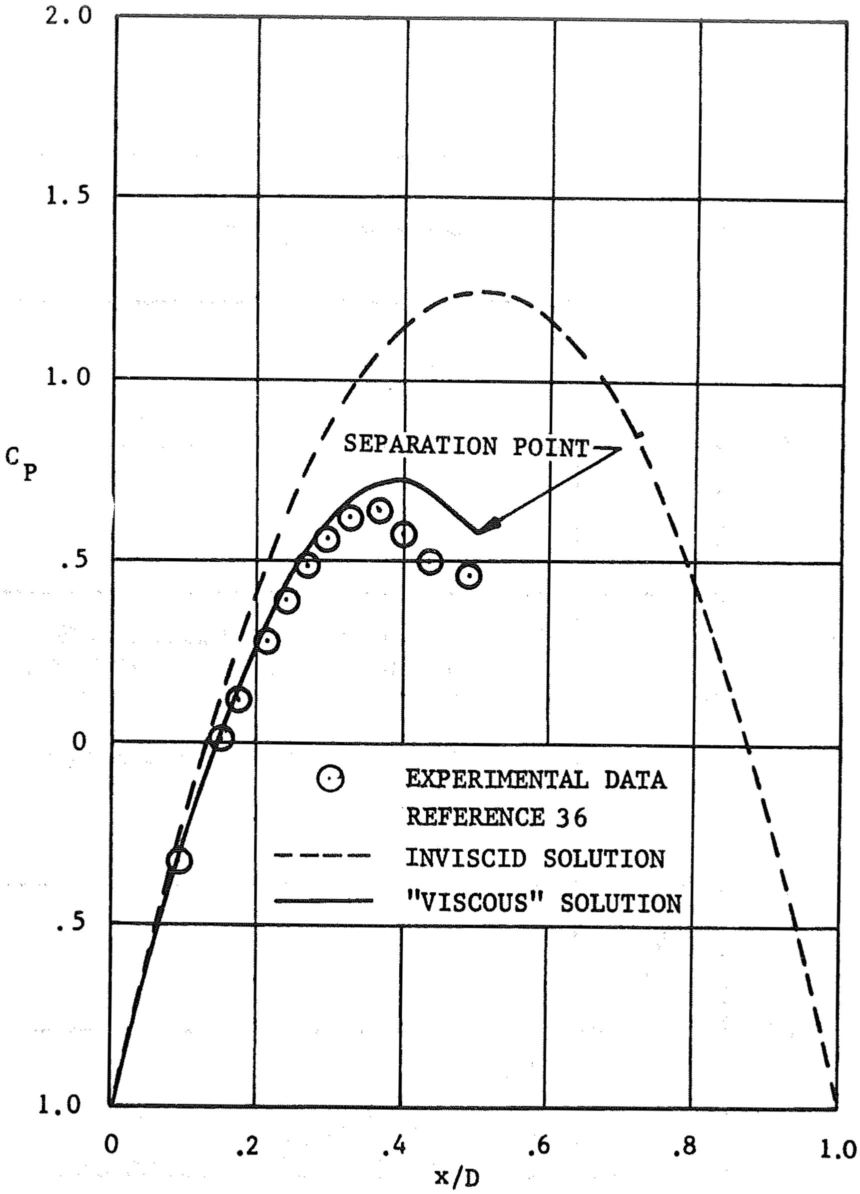


FIGURE 18. COMPARISON OF CALCULATED "VISCOUS" PRESSURE DISTRIBUTION FOR SPHERE IN SUBCRITICAL REGIME TO EXPERIMENTAL DATA

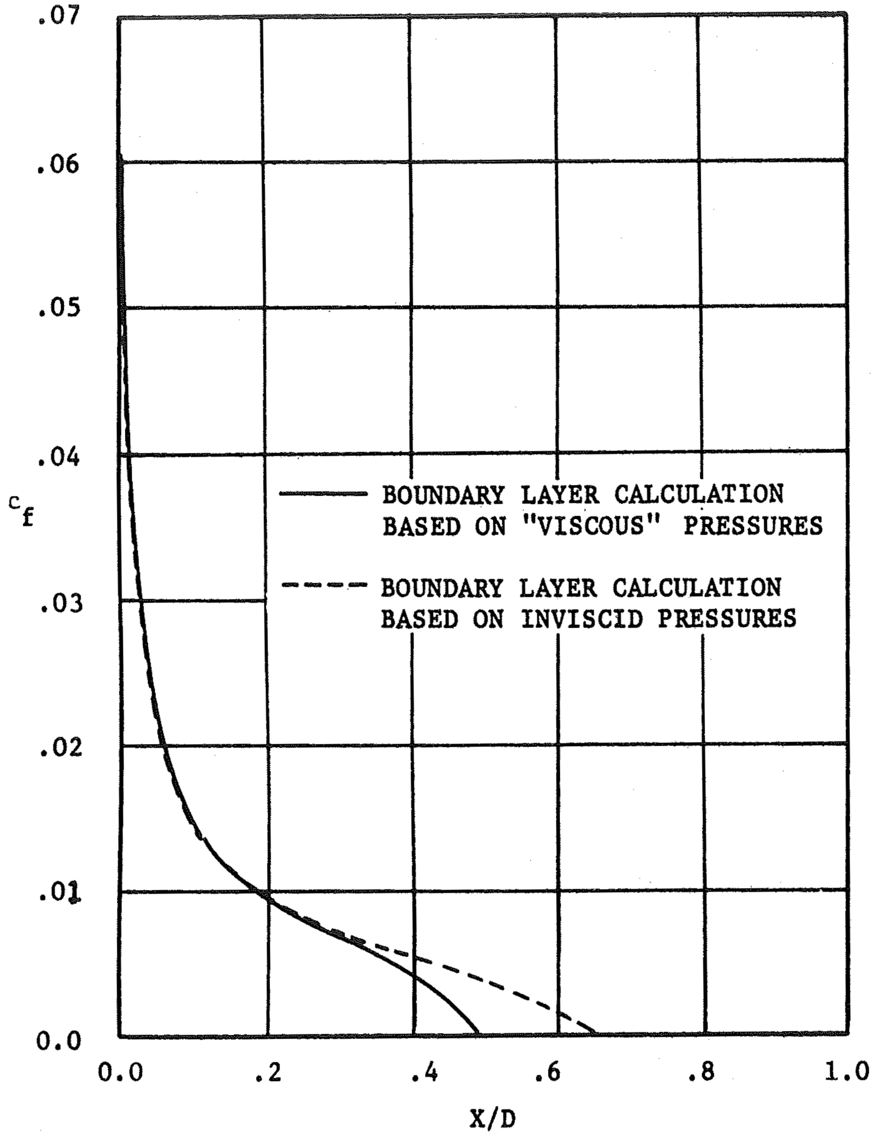


FIGURE . EFFECT OF "VISCOUS" MODELING ON CALCULATION OF LOCAL SKIN FRICTION COEFFICIENT FOR SPHERE IN SUBCRITICAL REGIME

☆ U.S. GOVERNMENT PRINTING OFFICE: 1975—635-049 / 69

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

SPECIAL FOURTH-CLASS RATE
BOOK

POSTAGE AND FEES PAID
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
451

U.S.MAIL

POSTMASTER: If Undeliverable (Section 158 Postal Manual) Do Not Return

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons. Also includes conference proceedings with either limited or unlimited distribution.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include final reports of major projects, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546