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NUMERICAL ANALYSIS OF SUPERSONIC FLOW THROUGH CURVED CHANNELS

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AEROSPACE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
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AEROSPACE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

FOREWORD

This final technical report was prepared by Northrop Norair, Hawthorne, California on Contract AF 33(657)-8851 for the Aeronautical Research Laboratories, Office of Aerospace Research, United States Air Force. The work reported herein was accomplished on Task 7065-01, "Fluid Dynamics Facilities Research" of Project 7065, "Aerospace Simulation Techniques Research" under the technical cognizance of Lt Arthur Wennerstrom of the Fluid Dynamics Facilities Laboratory of ARL. Report number NOR 63-59 has been assigned to this report for internal control.

ABSTRACT

This report describes an IBM FORTRAN program for calculating supersonic flows through curved channels. Included in the program are: 1) a second order Belotserkovskii procedure for calculating the flow field around the forward part of blunt blades, 2) a general method of characteristics procedure for calculating supersonic flow fields, 3) automatic procedures for calculating interactions of shocks of opposite families, shock interactions with a wall and with a vortex sheet or slipstream, 4) a finite difference laminar boundary-layer procedure for calculating viscous region of the flow. Three sample calculations as well as the listing of the FORTRAN program are presented.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (continued)

LIST OF TABLES

LIST OF SYMBOLS
(BLUNT BODY SOLUTIONS)

SYMBOL	DESCRIPTION
x, y	Cartesian coordinates
r, θ	Polar coordinates
M	Mach number
w, p, ρ	Dimensionless speed, pressure, density
w_x, w_y	Velocity components (x, y directions)
u, v	Velocity components (r, θ directions)
$\varphi = p/\rho^{\gamma}$	Entropy function
ψ	Stream function
γ	Adiabatic index
k	$(\gamma-1)/2\gamma$
σ	Angle between tangent to shock wave and incident stream
$\epsilon(\theta)$	Distance between body and shock measured along radius vector
t	τv
τ	$(1-w^2)^{\frac{1}{\gamma-1}}$
s	ρuv
g	$2kp + \rho v^2$
H	$kp + \rho u^2$
h	τu

Other symbols are defined in the text. Velocities are made dimensionless in terms of the maximum velocity, pressure and density in terms of corresponding stagnation values.

LIST OF SYMBOLS (Continued)

INDEXES

∞	Value in free stream
0	Value on body surface
1	Value behind shock
2	Value on half way line

LIST OF SYMBOLS
(BOUNDARY LAYER EQUATIONS)

SYMBOL	DESCRIPTION
$(\bar{\ })$, $(\ )'$	dimensional quantity
$(\ )_o$	reference quantity
$(\ )_{i,j,k}$	lattice quantity
a, b, c	lattice spacings
C_p	specific heat at constant pressure
$h_1\ h_2, h_3$	metrical coefficients; $\bar{h}_1 = \frac{\partial \bar{x}}{\partial \xi}$, $\bar{h}_2 = \frac{\partial \bar{y}}{\partial \eta}$, $\bar{h}_3 = \frac{\partial \bar{z}}{\partial \zeta}$ where $\bar{x}$, $\bar{y}$, and $\bar{z}$ curvilinear distance along ξ, η, and ζ respectively
i,j,k	lattice indices
ℓ	total enthalpy
p	absolute static pressure
$\mathfrak{R}$	universal gas constant
t	boundary-layer internal absolute temperature
u,v,w	boundary-layer internal velocity components in ξ, η, ζ directions; i.e., the velocity components within the boundary layer
x, y, z	curvilinear distances along body surfaces in ξ, η, ζ directions
A	flow parameter, defined in Eq 6
B	coefficients of the differential equations (7) defined in Eq 13
L	geometrical length
M	Mach number
P_r	Prandtl number, $P_r = \frac{\bar{\mu}\,\bar{c}_p}{\bar{k}}$
Q	resultant velocity

LIST OF SYMBOLS (Continued)

SYMBOL	DESCRIPTION
R	Reynolds number
T	absolute temperature (external)
U, V, W	boundary-layer external velocity components in ξ, η, ζ directions; i.e., the velocity components appropriate to the inviscid flow field evaluated at the outer edge of the boundary layer
δ	boundary-layer thickness
κ	thermal conductivity
λ	boundary-layer internal density
μ	boundary-layer internal absolute viscosity
$(\mu)_{\zeta=0}$	boundary-layer external viscosity
ξ, η, ζ	curvilinear coordinates
ξ^*	singularity factor
φ	shear coefficient
Λ	boundary-layer external density

LIST OF SYMBOLS
(APPENDICES)

SYMBOL		DESCRIPTION
A, B, C, D	-	Coefficients of a cubic $(AX^3 + BX^2 + CX + D)$
M	-	Mach Number
P	-	Local Static Pressure
R	-	Local Total Pressure
X, Y	-	Coordinates of a point
γ	-	Ratio of Specific Heats
δ	-	Flow Deflection Angle
θ	-	Flow Direction
μ	-	Mach Angle
ω	-	Shock Angle

SUBSCRIPTS

o	-	Zeroth Approximation
i	-	Current (ith) Approximation
$\overline{2, 3}$, $\overline{1, 2}$, etc.	-	Average of Properties at the two points
+	-	Incident Shock Properties
-	-	Transmitted Shock Properties

I INTRODUCTION

The behavior of supersonic flow through cascade depends strongly on the complex system of the shock wave and vortex sheet interactions which develop from the blade leading edges during the turning process. The flow system in a supersonic inlet channel must swallow the initial shocks generated by the leading edges of the blades. The bow shocks will eventually interact and a vortex sheet (or slipstream) or new shocks and/or expansion waves will be generated which will cause various combinations of shock wave interactions further downstream (Figure 2). To determine the true performances of a supersonic cascade, these interactions must be accurately calculated.

Near the two surfaces of the channel the flow is also complicated by the existence of the boundary layer. On the concave or compression side of the walls, the strong positive pressure gradient can cause boundary layer separation which greatly decreases the channel efficiency. Shock wave-boundary layer interaction occur when shocks impinge on the blade surfaces. The sudden pressure rise across the shocks can easily cause boundary layer separation or even boundary layer transition. Also, the fact that the boundary layer displaces the inviscid flow field gives rise to viscous-inviscid interaction effects.

Another problem arises from the fact that the velocity is discontinuous across a vortex sheet. In actual flows, this velocity discontinuity is modified by viscous mixing. The mixing problem, however, is beyond the scope of the present report.

This report describes a FORTRAN language computer program, developed for the IBM 7090, for calculating inviscid and viscous flow fields within two-dimensional supersonic curved channels. The channel surface leading edges can be either sharp or blunted. The complete channel flow field is divided into three regions; each of which is calculated by an independently developed numerical procedure. These procedures are chained together in the overall program to provide automatic calculation. These three regions are the blunt body, supersonic, and boundary layer flow fields. The blunt body flow field, located ahead of a blunt leading edge is computed by the second order Pelotserkovskii method (Reference 1), the supersonic flow field is computed by the method of characteristics, (References 4, 5 and 6), and the boundary layer or the viscous flow field is computed by a finite difference procedure (References 2 & 3). Singularities that can be treated by the program are: interactions of shocks of opposite family; vortex sheet; interactions of shocks with a vortex sheet; the wall of the boundary layer; and viscous-inviscid interaction effects which are directly related to the boundary displacement. It is assumed that the inviscid flow field is supersonic throughout, except in the blunt leading edge region.

Three sample calculations are presented. Mach 4 and Mach 6 cases were computed for a sharp leading-edge channel, and a Mach 4 case was computed for a blunt leading-edge channel.

II CHANNEL AND FLOW MODELS

The flow channels as formed by a cascade are shown in Figure 1. The blades or the turning vanes being treated can have either sharp or blunt leading edges. Typical design values initially given for studies are the incident angle α, turning angle β, and the incident Mach number M_∞. In the numerical calculation, the channel and flow characteristics are defined on a cartesian coordinate system x and y, where x is parallel and y is perpendicular to the incident flow direction.

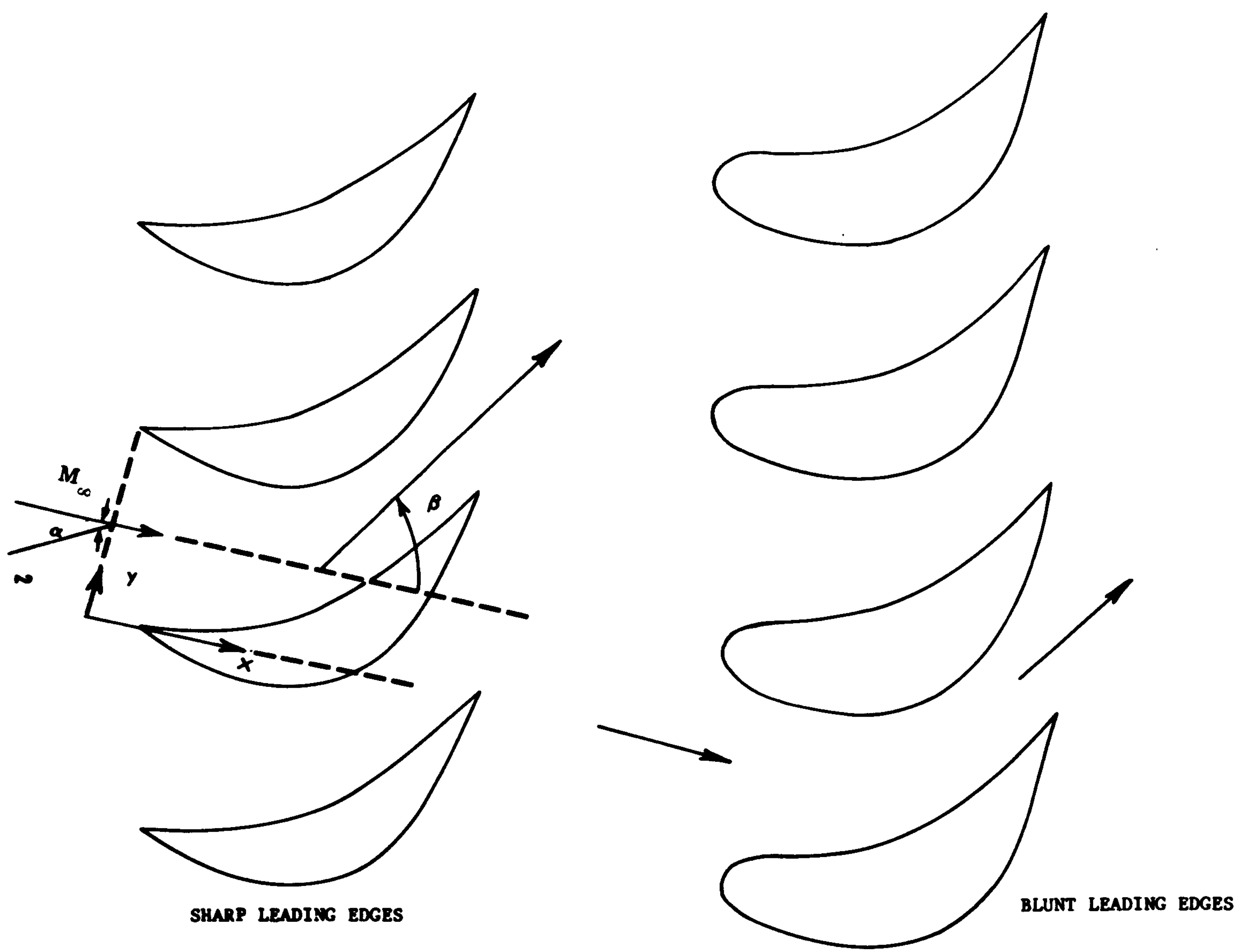


FIGURE 1 CHANNEL FLOW IN CASCADE

Figure 2 shows a schematic diagram of the channel flow model considered in the present computer program in which it is assumed that the inviscid flow field remains supersonic downstream of the leading edges. Two initial bow shocks will be generated by the two leading edges. For the cases with blunt leading edges, a blunt body procedure is required to calculate the initial portions of the bow shocks along with a special procedure to calculate the two starting supersonic characteristics. For sharp leading edges, the usual wedge flow solutions apply. The bow shocks will eventually intersect as they extend downstream. At the shock intersection point, a vortex sheet or slipstream will be created. When the shocks impinge on the blade surfaces, they will be deflected again into the flow field and interact with the vortex sheet. At the point of shock interaction with a vortex sheet, a new expansion (Prandtl-Meyer fan) or a compression (shock) wave will be created depending on the flow conditions.

When the inviscid flow solution has been determined, the boundary layers developed on the blade surfaces can be calculated. Shock wave-boundary layer interactions are treated by spreading the pressure jump (or velocity discontinuity) across the shock along the surface. The spreading distance is a function of the local boundary layer thicknesses. Viscous-inviscid interaction effects are treated by increasing the channel width locally by the boundary layer displacement distribution.

III EQUATIONS AND NUMERICAL TECHNIQUE

Three basic numerical procedures are used in constructing the overall computer program. These procedures are: the Belotserkovskii method for calculating flows around the blunt leading edges, the method of characteristics for calculating supersonic flow fields, and a finite difference procedure for calculating boundary layers. These methods and their equations are described below. Since the basic theory of the method of characteristics has been extensively described in the literature (References 4, 5, and 6), the basic inviscid flow equations have not been included. The calculation procedures, however, are summarized in the appendices. Since the methods described here have been described previously in the literature, the symbols used in the equations are essentially those of the originals. Since no attempt has been made to generalize the nomenclature, a list of symbols is given for each of the methods.

A. BLUNT BODY SOLUTIONS

The flow about the blunted nose is determined by using the direct method developed by Belotserkovskii (Reference 1). This method is based on a general technique proposed by Dorodnitsyn (Reference 7) for solving a system of first order partial differential equations of mixed type which have two independent variables. The technique consists of reducing the partial differential equations to ordinary differential equations in one independent variable by specifying the variation of the unknowns with the other independent variable.

The ordinary differential equations which result are integrated numerically. Most of the boundary conditions are given at the beginning of the range of integration but these must be supplemented by conditions that the solutions of one or more of the equations shall pass smoothly from the elliptic (subsonic) to the hyperbolic (supersonic) region. The conditions of smooth transition, together with the other boundary conditions, determine solutions of all unknowns uniquely (Reference 8).

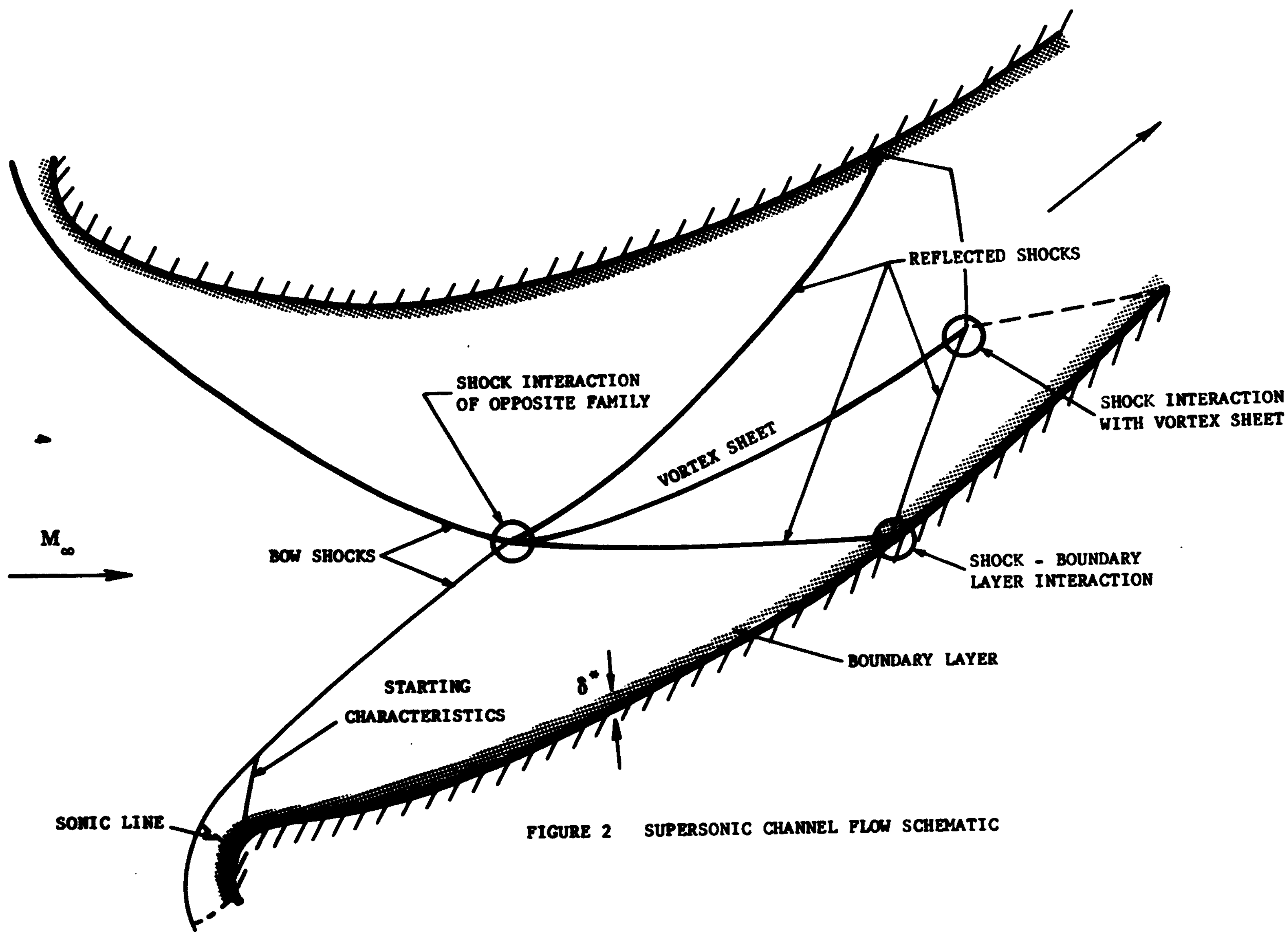


FIGURE 2 SUPERSONIC CHANNEL FLOW SCHEMATIC

Since the nose of the body is a circular cylinder, polar coordinates with the origin taken at the body geometric center are used. Figure 3 illustrates the geometry of the problem. Dimensionless variables are used whereby length is referred to cylinder radius, velocities are referred to the limiting speed, and pressure and density are referred to corresponding stagnation values in the free stream.

The fluid motion is governed by Bernoulli's equation, the equation of continuity, an equation obtained by combining the radial momentum equation with continuity, the condition of conservation of entropy along streamlines and the equation of state. The equations may be written:

Continuity equation

$$\frac{\partial}{\partial r}(rh) + \frac{\partial t}{\partial \theta} = 0 \tag{3a.1}$$

Modified momentum in the r-direction

$$\frac{\partial}{\partial r}(rH) + \frac{\partial s}{\partial \theta} - g = 0 \tag{3a.2}$$

In equations 3a.1 and 3a.2

$$H = kp + \rho u^2$$

$$s = \rho uv$$

$$g = kp + \rho v^2$$

$$h = \tau u$$

$$t = \tau v$$

Bernoulli's equation

$$p = \rho(1 - w^2) \tag{3a.3}$$

Conservation of entropy

$$\varphi = p/\rho^{\gamma} = \varphi(\psi) \tag{3a.4}$$

where ψ is the stream function defined below, and φ is a function of entropy.

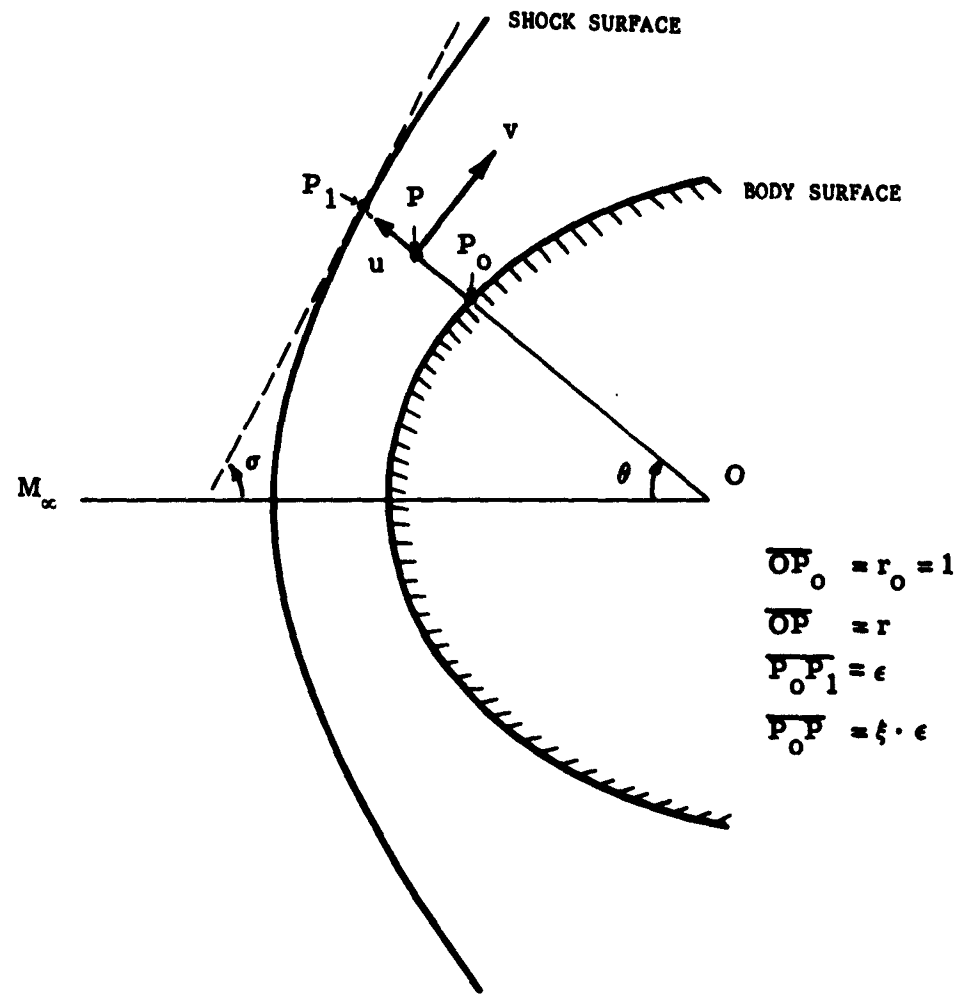


FIGURE 3 GEOMETRY OF BODY AND SHOCK

Stream function

The equation of continuity leads to the stream function defined by:

$$\frac{\partial \psi}{\partial \theta} = -r \rho u$$

$$\frac{\partial \psi}{\partial r} = \rho v \tag{3a.5}$$

From Eqs (3a.3) and (3a.4):

$$p = \tau^{\gamma} \varphi^{-\frac{\gamma}{\gamma-1}} \tag{3a.6}$$

$$\rho = \tau \varphi^{-\frac{1}{\gamma-1}} \tag{3a.7}$$

where: $\tau = (1 - w^2)^{\frac{1}{\gamma-1}}$.

From Eq (3a.5), on any line:

$$\frac{d\psi}{d\theta} = \rho \left(v \frac{dr}{d\theta} - ru\right). \tag{3a.8}$$

The speed of sound is determined from Bernoulli's equation:

$$c^2 = \gamma \frac{kp}{\rho} = \frac{\gamma-1}{2}(1 - w^2). \tag{3a.9}$$

The boundary conditions on the surface of the cylinder $(r = r_o = 1)$ are:

$u = \psi = 0$

and:

$$\varphi = \frac{4\gamma}{\gamma^2-1}\left(\frac{\gamma-1}{\gamma+1}\right)^{\gamma} \frac{1}{w_\infty^{2\gamma}} \left[\frac{w_\infty^2}{1-w_\infty^2} - \frac{(\gamma-1)^2}{4\gamma}\right]. \tag{3a.10}$$

The equation of the shock wave is:

$$r = r_1(\theta) = 1 + \epsilon(\theta) \tag{3a.11}$$

where $\epsilon(\theta)$ is the distance from the body surface to the shock wave along a line θ = constant.

The conservation conditions across the shock wave lead to the following relations. The velocity components behind the shock wave parallel and normal to the free stream velocity vector are:

$$w_x = w_\infty \left[1 - \frac{2}{\gamma+1} \sin^2\sigma \left(1 - \frac{1}{M_\infty^2 \sin^2\sigma}\right)\right] \tag{3a.12}$$

$$w_y = w_\infty \sin 2\sigma \left(1 - \frac{1}{M_\infty^2 \sin^2\sigma}\right) \frac{1}{\gamma+1} .$$

The radial and transverse velocity components are given by:

$$u_1 = w_y \sin\theta - w_x \cos\theta$$

$$v_1 = w_x \sin\theta + w_y \cos\theta . \tag{3a.13}$$

The pressure and density are given by:

$$p_1 = \frac{4\gamma}{\gamma^2 - 1} \left(1 - w_\infty^2\right)^{\frac{\gamma}{\gamma-1}} \left[\frac{w_\infty^2 \sin^2\sigma}{1 - w_\infty^2} - \frac{(\gamma-1)^2}{4\gamma}\right] \tag{3a.14}$$

$$\rho_1 = \frac{\gamma+1}{\gamma-1} \left(1 - w_\infty^2\right)^{\frac{1}{\gamma-1}} \frac{w_\infty^2}{1 + (1 - w_\infty^2)\cot^2\sigma} . \tag{3a.15}$$

Since $\varphi = p/\rho^\gamma$, one obtains:

$$\varphi = \frac{4\gamma}{\gamma^2 - 1} \left(\frac{\gamma-1}{\gamma+1}\right)^\gamma \left[\omega - \frac{(\gamma-1)^2}{4\gamma}\right] \left(1 + \frac{1}{\omega}\right)^\gamma \tag{3a.16}$$

where:

$$\omega = \frac{w_\infty^2 \sin^2\sigma}{1 - w_\infty^2} .$$

The value of the stream function ψ is determined from the condition of continuity across the shock wave. Thus:

$$\psi = \psi_\infty = w_\infty \left(1 - w_\infty^2\right)^{\frac{1}{\gamma-1}} (1 + \epsilon) \sin\theta . \tag{3a.17}$$

From the geometric relationship on the shock wave, $\frac{dy}{dx} = \tan\sigma$, one obtains the equation for $\epsilon(\theta)$.

$$\frac{d\epsilon}{d\theta} = -(1+\epsilon)\cot(\sigma+\theta) \tag{3a.18}$$

The approximating system of equations is obtained as follows. Introduce the new independent variable:

$$\xi = \frac{r-1}{\epsilon(\theta)} \tag{3a.19}$$

After changing independent variables from (r,θ) to (ξ,θ) and integrating Eqs (3a.1) and (3a.2) along a line θ = constant from $\xi = 0$ to $\xi = \xi_i$, one gets:

$$r_i h_i - r_i' t_i + \frac{\partial}{\partial\theta}\int_0^{\xi_i} \epsilon t \, d\xi = 0 \tag{3a.20}$$

$$r_i H_i - H_o - r_i' s_i + \frac{\partial}{\partial\theta}\int_0^{\xi_i} \epsilon s \, d\xi = \int_0^{\xi_i} \epsilon g \, d\xi . \tag{3a.21}$$

To obtain the approximating system of ordinary differential equations, the layer between the body and shock wave is divided into N equally spaced strips and the integrals in Eqs (3a.20) and (3a.21) are evaluated on successive boundaries of these strips. The unknown functions in the integrals are approximated by interpolation polynomials of degree N in ξ taking the interpolation points to be the strip boundaries:

$$f(\xi,\theta) = \sum_{k=0}^{N} a_k(\theta)\,\xi^k, \tag{3a.22}$$

where the coefficients $a_k(\theta)$ are linear functions of the values of f on the strip boundaries.

Writing Eqs (3a.20) and (3a.21) along each of the N-1 intermediate lines, $\xi_i = \frac{N-i+1}{N}$ (ψ and φ on the shock wave and on the body are determined from the boundary conditions), and taking Eq (3a.18) into account, one obtains an approximating system of 4N-1 equations for the unknowns:

$$\epsilon,\ \sigma,\ v_o,\ u_i,\ v_i,\ \psi_i,\ \varphi_i\ (i = 2, 3, \ldots N).$$

In Reference 1 it was shown that the convergence of this method with increasing N is extremely rapid, so that N = 2 is sufficient for most purposes. This is termed the "second approximation" and is the one that is used here.

In the second approximation, the system of equations is:

$$\frac{d\epsilon}{d\theta} = -(1+\epsilon)\cot(\sigma+\theta)$$

$$\frac{d\sigma}{d\theta} = F_2 \tag{3a.23}$$

$$\frac{dv_o}{d\theta} = \frac{E_o}{D_o} \tag{3a.24}$$

where:

$$E_o = \frac{2\, c_o^{\,2}}{(\gamma+1)\, \tau_o}\, t_o' , \; D_o = \frac{\gamma-1}{\gamma+1} - v_o^{\,2}$$

$$\frac{d\psi_2}{d\theta} = \rho_2 \left[\frac{1}{2} v_2\, \epsilon' - \left(1 + \frac{\epsilon}{2}\right) u_2\right] \tag{3a.25}$$

$$\frac{du_2}{d\theta} = \frac{1}{t_2\, \varphi_2^{-\frac{1}{\gamma-1}}} \left[S_2' - u_2\, \varphi_2^{-\frac{1}{\gamma-1}}\, t_2' + \frac{S_2}{\gamma-1} \frac{d\ln\varphi_2}{d\psi_2} \frac{d\psi_2}{d\theta}\right] \tag{3a.26}$$

$$\frac{dv_2}{d\theta} = \frac{E_2}{D_2} \tag{3a.27}$$

where:

$$E_2 = \frac{2}{\gamma+1} \frac{c_2^{\,2}}{\tau_2} \left(t_2' + \frac{t_2\, u_2}{c_2^{\,2}}\, u_2'\right)$$

$$D_2 = \frac{\gamma-1}{\gamma+1} - w_2^{\,2} + \frac{2}{\gamma+1}\, u_2^{\,2}$$

$$\varphi_2 = \varphi\,(\psi_2) \tag{3a.28}$$

Quantities appearing in Eqs (3a.18), (3a.23-3a.28) are given by:

$$F_2 = \left[S_1' - \rho_1 (v_1^{\,2} - u_1^{\,2})\right] \Big/ D_1 \tag{3a.29}$$

$$S_1' = \frac{\epsilon'}{\epsilon}\, (3\, S_1 - 4\, S_2) - \frac{4}{\epsilon} \left[H_0 + (1+\epsilon)\, H_1 - (2+\epsilon)\, H_2\right] + g_1 - g_0 \tag{3a.30}$$

$$S_2' = \frac{1}{2\epsilon}\left[\epsilon' S_1 + 5 H_0 - 2(2+\epsilon) H_2 - (1+\epsilon) H_1\right] + g_2 + \frac{1}{2} g_0 \quad (3a.31)$$

$$t_0' = t_1' + \frac{\epsilon'}{\epsilon}(4 t_2 - t_0 - 3 t_1) + \frac{4}{\epsilon}\left[(1+\epsilon) h_1 - (2+\epsilon) h_2\right] \quad (3a.32)$$

$$t_2' = -\frac{t_1'}{2} + 2\frac{\epsilon'}{\epsilon}(t_1 - t_2) + \left(\frac{2+\epsilon}{\epsilon}\right) h_2 - \frac{5}{2}\ \frac{1+\epsilon}{\epsilon} h_1 \quad (3a.33)$$

$$t_1' = G_1 \frac{d\sigma}{d\theta} - h_1 \quad (3a.34)$$

and:

$$\frac{d\ell n\, \varphi_2}{d\psi_2} = \left[\frac{d\ell n\, \varphi_1}{d\sigma} \cdot \frac{d\sigma}{d\theta} \Big/ \frac{d\psi_1}{d\theta}\right]_{\psi_2 = \psi_1} \quad (3a.35)$$

where:

$$\frac{d\ell n\, \varphi_1}{d\sigma} = 2\cot\sigma \frac{\left(\omega - \frac{\gamma-1}{2}\right)^2}{(1+\omega)\left[\omega - \frac{(\gamma-1)^2}{4\gamma}\right]} \quad (3a.36)$$

$$\frac{d\psi_1}{d\theta} = w_\infty (1 - w_\infty^2)^{\frac{1}{\gamma-1}}\left[\epsilon' \sin\theta + (1+\epsilon)\cos\theta\right] \quad (3a.37)$$

and:

$$D_1 = \frac{4\gamma}{\gamma^2-1} w_\infty^2 (1 - w_\infty^2)^{\frac{1}{\gamma+1}} \frac{u_1 v_1 \sin 2\sigma}{1 - w_1^2} \quad (3a.38)$$

$$+ \rho_1 \left\{ v_1 m_1 - u_1 \left[n_1 + \frac{2v_1}{1 - w_1^2}(v_1 n_1 - u_1 m_1)\right]\right\} \quad (3a.39)$$

$$G_1 = \tau_1 \left[\frac{v_1}{c_1^2}(v_1 n_1 - u_1 m_1) - n_1\right]$$

$$m_1 = \frac{d w_y}{d\sigma}\sin\theta - \frac{d w_x}{d\sigma}\cos\theta \quad (3a.40)$$

$$n_1 = -\frac{d\,w_x}{d\,\sigma}\sin\theta - \frac{d\,w_y}{d\,\sigma}\cos\theta \tag{3a.41}$$

$$\frac{dw_x}{d\,\sigma} = -\frac{2\,w_\infty}{\gamma+1}\sin 2\,\sigma \tag{3a.42}$$

$$\frac{d\,w_y}{d\sigma} = \frac{2\,w_\infty}{\gamma+1}\left(\cos 2\sigma + \frac{1}{M_\infty^2\,\sin^2\sigma}\right) \tag{3a.43}$$

The integration of the above system is carried out numerically and begins at the axis of symmetry $\theta = 0$, where $\sigma = \frac{\pi}{2}$, $v_o = v_2 = \psi_2 = 0$ while the values $\epsilon(0)$ and $u_2(0)$ are unknown.

Examination of the equations for v_o and v_2 reveals that singular points exist where:

$$v_o^2 = \frac{\gamma-1}{\gamma+1} \quad \text{and} \quad w_2^2 = \frac{\gamma-1}{\gamma+1} + \frac{2\,u_2^2}{\gamma+1}\,;$$

that is, where the transverse velocity components on the body and on the mid-way line become sonic. In order for a continuous solution to exist, one requires that:

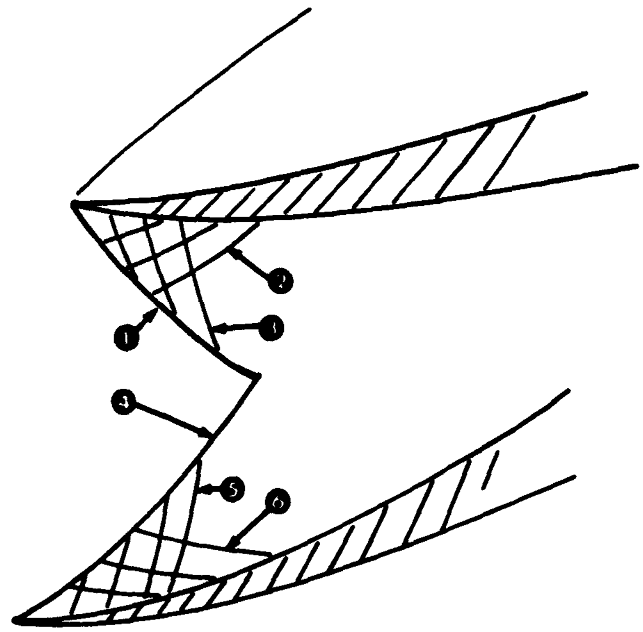
$$\left.\begin{aligned} E_o &= 0 \quad \text{when} \quad D_o = 0 \\ E_2 &= 0 \quad \text{when} \quad D_2 = 0. \end{aligned}\right\} \tag{3a.44}$$

Otherwise v_o' and v_2' become infinite at the singular points and the solution is physically meaningless. Thus the two conditions of smoothness determine the proper values of $\epsilon(0)$ and $u_2(0)$. Since one is dealing with a two point boundary value problem, iteration must be used to determine the correct values of $\epsilon(0)$ and $u_2(0)$. Once this is done the numerical integration is continued a short distance into the supersonic region where an initial value line is generated to start the characteristic procedure.

The initial value line is a set of 20 equally spaced points along a line θ = constant between body and shock wave. Since only the flow quantities on the body, mid-way line and shock are known from the solution, additional quantities in between are obtained by fitting quadratics to u, v and φ. All other flow properties may be determined from these three.

B. METHOD OF CHARACTERISTICS

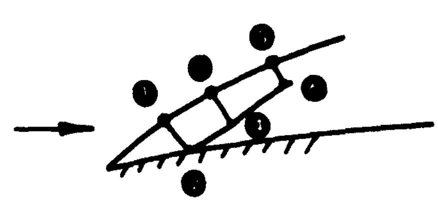
The supersonic inviscid flow field is solved by the method of characteristics, with the calculation proceeding along left-running characteristics. Special treatment is required for singularities in the form of shocks and contact surfaces. In the following discussion the characteristics and shocks will be labeled as follows:



1 Left running shock of the second family
2 Right running characteristics of the second family
3 Left running characteristic of the second family
4 Left running shock of the first family
5 Left running characteristic of the first family
6 Right running characteristic of the first family

Starting Region For Pointed Blades

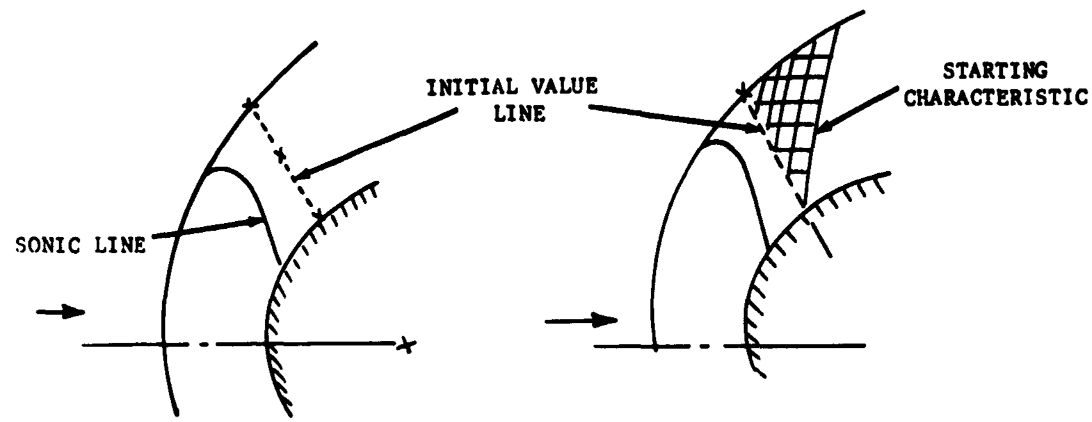
Initial values for the method of characteristics on pointed blades are obtained from the solution for the flow on a two dimensional wedge. The shock angle at the leading edge of the blade is determined by incident flow and leading edge angle. The procedure then enters a body point procedure and erects a right running characteristic from the shock to the body. Using this body point a new shock point is calculated which is used to calculate a new field point. The order in which the points are calculated is shown in the sketch below:



Left running characteristics are built up until they intersect the shock wave. In this way the inviscid flow field behind the bow shocks can be calculated up to the point where the shock waves interact.

Starting Region For Blunt Blades

The determination of the subsonic flow region of blunt blades has been described in the previous section. The Belotserkovskii solution can be used for a short distance into the supersonic flow region to provide an initial value line for the method of characteristics solution. The blunt body solution provides values at three points: at the shock, midway between the shock and body, and at the body. Twenty points are then generated on a straight line running from the shock to the body using quadratic interpolation.

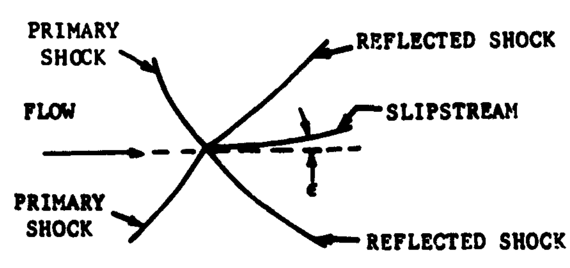


The initial value line is chosen such that the minimum Mach number of the three points from the Belotserkovskii solution is 1.1 The characteristics network is then built up until a complete left running characteristic is formed. After this the calculation proceeds as before until a shock interaction is reached.

Shock Interactions

a. Interactions Of Shocks Of Opposite Families

When two shocks of opposite family interact, two reflected shocks and a slipstream are produced:



The solution for the two reflected shocks must be iterated to determine a common flow deflection angle ϵ behind each shock.

A good first approximation for this turning angle is the difference of the two flow turning angles across the primary shocks. The angle ϵ is altered in the iteration process until the pressures match across the two reflected shocks. A similar procedure is used to calculate each point along the slipstream.

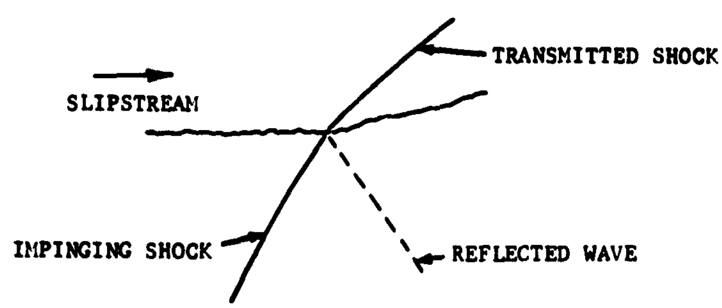
Conditions to be satisfied across the slipstream are that the pressure and flow direction match across it. Discontinuities exist, however, in temperature, velocity and stagnation pressure.

b. <u>Shock Interactions With The Wall</u>

The problem of calculating the interaction of a shock with a surface resembles that of calculating the interaction of two shocks of opposite families in that the surface corresponds to the slipstream. In the case of the interaction with a surface, however, the stream direction after the reflection is determined by the wall. The reflected shock is such that it matches the flow previously calculated downstream of the impinging shock with the flow calculated along left running characteristics after the reflected shock.

c. <u>Shock Interaction With A Slipstream</u>

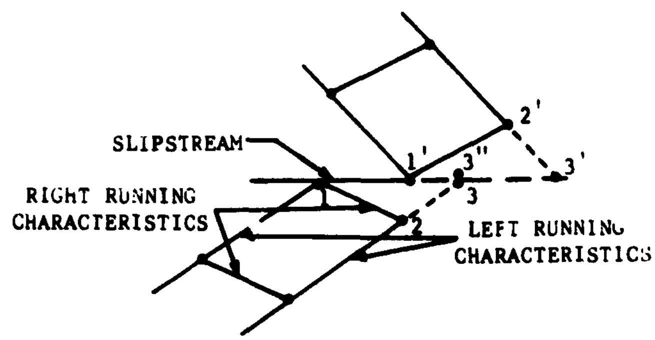
A shock interacting with a slipstream will produce a transmitted shock and a reflected wave, either expansion or compression:



As in the case of the interaction of shocks of opposite families, an initial slipstream direction is chosen which determines the angle (and strength) of the transmitted shock. The first approximation to the slipstream direction is taken as the flow direction after the impinging shock. The pressure matching condition is then imposed, and the flow direction is altered until this condition is satisfied. The flow direction immediately after the interaction point determines whether the reflected wave is an expansion or a compression.

Slipstream Calculation

The flow direction and the static pressure must be the same across a slipstream. To calculate points along a slipstream, the flow direction must be iterated by applying the compatibility equations along the left running characteristics from both sides.



C. BOUNDARY LAYER SOLUTIONS

Laminar boundary-layer solutions are obtained by a numerical method described in References (2 & 3). In this method, an explicit finite-difference technique is utilized to solve the exact boundary-layer equations for steady compressible flows. It is applicable to any smooth surface with arbitrary boundary conditions (pressure and temperature distributions, etc.).

Since the procedure used in this program was originally a general three-dimensional program, the equations described here are the original boundary layer equations in three dimensions. The equations in general curvilinear coordinates ξ , η , ζ are:

$$\frac{\bar{u}}{\bar{h}_1}\frac{\partial \bar{u}}{\partial \xi} + \frac{\bar{v}}{\bar{h}_2}\frac{\partial \bar{u}}{\partial \eta} + \frac{\bar{w}}{\bar{h}_3}\frac{\partial \bar{u}}{\partial \zeta} + \frac{\bar{u}\bar{v}}{\bar{h}_1\bar{h}_2}\frac{\partial \bar{h}_1}{\partial \eta} - \frac{\bar{v}^2}{\bar{h}_1\bar{h}_2}\frac{\partial \bar{h}_2}{\partial \xi} = -\frac{1}{\lambda \bar{h}_1}\frac{\partial \bar{p}}{\partial \xi} + \frac{1}{\lambda \bar{h}_3}\frac{\partial}{\partial \zeta}\left(\frac{\bar{\mu}}{\bar{h}_3}\frac{\partial \bar{u}}{\partial \zeta}\right) \tag{1a}$$

$$\frac{\bar{u}}{\bar{h}_1}\frac{\partial \bar{v}}{\partial \xi} + \frac{\bar{v}}{\bar{h}_2}\frac{\partial \bar{v}}{\partial \eta} + \frac{\bar{w}}{\bar{h}_3}\frac{\partial \bar{v}}{\partial \zeta} - \frac{\bar{u}^2}{\bar{h}_1\bar{h}_2}\frac{\partial \bar{h}_1}{\partial \eta} + \frac{\bar{u}\bar{v}}{\bar{h}_1\bar{h}_2}\frac{\partial \bar{h}_2}{\partial \xi} = -\frac{1}{\lambda \bar{h}_2}\frac{\partial \bar{p}}{\partial \eta} + \frac{1}{\lambda \bar{h}_3}\frac{\partial}{\partial \zeta}\left(\frac{\bar{\mu}}{\bar{h}_3}\frac{\partial \bar{v}}{\partial \zeta}\right) \tag{1b}$$

$$\frac{\bar{u}}{\bar{h}_1}\frac{\partial\bar{\ell}}{\partial\xi}+\frac{\bar{v}}{\bar{h}_2}\frac{\partial\bar{\ell}}{\partial\eta}+\frac{\bar{w}}{\bar{h}_3}\frac{\partial\bar{\ell}}{\partial\zeta}=\frac{1}{\bar{\lambda}\bar{h}_3}\frac{\partial}{\partial\zeta}\left[\frac{\bar{\mu}}{\bar{h}_3}\left(\bar{u}\frac{\partial\bar{u}}{\partial\zeta}+\bar{v}\frac{\partial\bar{v}}{\partial\zeta}\right)+\frac{\bar{\kappa}}{\bar{h}_3}\frac{\partial\bar{t}}{\partial\zeta}\right] \quad (1c)$$

$$\frac{\partial}{\partial\xi}(\bar{h}_2\bar{h}_3\bar{\lambda}\bar{u})+\frac{\partial}{\partial\eta}(\bar{h}_1\bar{h}_3\bar{\lambda}\bar{v})+\frac{\partial}{\partial\zeta}(\bar{h}_1\bar{h}_2\bar{\lambda}\bar{w})=0 \quad (1d)$$

where ξ and η represent a two-dimensional orthogonal curvilinear dimensionless coordinate system which is defined appropriately for the given body surface, and ζ is orthogonal to ξ and η and corresponds to the vertical distance. h_1, h_2 and h_3 are the metrical coefficients in the ξ, η and ζ directions respectively. For two dimensional flows, all properties, of course, are independent of the η coordinate.

The total enthalpy $\bar{\ell}$ in Eq (1c) can be eliminated by making use of the relation:

$$\bar{\ell}=\frac{\bar{u}^2-\bar{v}^2}{2}+\int\bar{c}_p\,dt \quad (2)$$

Substituting this expression into (1c) and combining it with Eq (1a), the energy equation becomes

$$\frac{\bar{u}}{\bar{h}_1}\frac{\partial\bar{t}}{\partial\xi}+\frac{\bar{v}}{\bar{h}_2}\frac{\partial\bar{t}}{\partial\eta}+\frac{\bar{w}}{\bar{h}_3}\frac{\partial\bar{t}}{\partial\zeta}=\frac{1}{\bar{c}_p\bar{\lambda}}\left(\frac{\bar{u}}{\bar{h}_1}\frac{\partial\bar{p}}{\partial\xi}+\frac{\bar{v}}{\bar{h}_2}\frac{\partial\bar{p}}{\partial\eta}\right)+\frac{\bar{\mu}}{\bar{c}_p\bar{\lambda}\bar{h}_3^2}\left[\left(\frac{\partial\bar{u}}{\partial\zeta}\right)^2+\left(\frac{\partial\bar{v}}{\partial\zeta}\right)^2\right]+\frac{1}{\bar{c}_p\bar{\lambda}\bar{h}_3}\frac{\partial}{\partial\zeta}\left(\frac{\bar{\kappa}}{\bar{h}_3}\frac{\partial\bar{t}}{\partial\zeta}\right) \quad (1e)$$

The coordinate ζ is defined as:

$$\zeta=\left(1-\frac{\bar{u}}{\bar{U}}\right)^{1/2} \quad (3)$$

where $\bar{u}$ and $\bar{U}$ are the dimensional internal and external longitudinal velocity components respectively. Therefore, ζ varies, 0 to 1, from the outer edge of the boundary layer to the surface of the body.

A shear coefficient $\bar{\varphi}$ is introduced, defined as:

$$\bar{\varphi}=\frac{\bar{\mu}}{2\zeta}\frac{\partial}{\partial\bar{z}}\frac{\bar{u}}{\bar{U}}=-\frac{\bar{\mu}}{\bar{h}_3}. \quad (4)$$

The equation of state:

$$\bar{p}=\bar{\lambda}\bar{R}\bar{t} \quad (5)$$

is introduced to eliminate the density $\bar{\lambda}$, and the definition of ζ removes explicit dependence on $\bar{u}$. As a result, the system of Eqs (1) is reduced to a system of four equations in the four unknowns v, t, φ and w.

$$A_5 (1 - \zeta^2)^2 + A_6 (1 - \zeta^2) v + A_3 \frac{\zeta \varphi w}{\mu} - A_7 v^2 = - A_8 t - A_4 \frac{\varphi}{\mu} \frac{\partial (\zeta \varphi)}{\partial \zeta} \tag{6a}$$

$$\begin{aligned} A_1 (1 - \zeta^2) \frac{\partial v}{\partial \xi} + A_2 v \frac{\partial v}{\partial \eta} - A_3 \frac{\varphi w}{\mu} \frac{\partial v}{\partial \zeta} - A_9 (1 - \zeta^2)^2 \\ + A_{10} (1 - \zeta^2) v + A_{11} v^2 = - A_{12} t + A_4 \frac{\varphi}{\mu} \frac{\partial}{\partial \zeta} \left(\varphi \frac{\partial v}{\partial \zeta} \right) \end{aligned} \tag{6b}$$

$$\begin{aligned} A_1 (1 - \zeta^2) \frac{\partial t}{\partial \xi} + A_2 v \frac{\partial t}{\partial \eta} - A_3 \frac{\varphi w}{\mu} \frac{\partial t}{\partial \zeta} = A_{13} (1 - \zeta^2) \frac{t}{c_p} + A_{14} \frac{vt}{c_p} \\ + \left[A_{15} \zeta^2 + A_{16} \left(\frac{\partial v}{\partial \zeta} \right)^2 \right] \frac{\varphi^2}{c_p \mu} + A_4 \frac{\varphi}{c_p \mu} \frac{\partial}{\partial \zeta} \left(\kappa \varphi \frac{\partial t}{\partial \zeta} \right) \end{aligned} \tag{6c}$$

$$\begin{aligned} A_1 (1 - \zeta^2) \frac{\partial}{\partial \xi} \left(\frac{\mu}{\varphi} \right) + A_2 \frac{\partial}{\partial \eta} \left(\frac{\mu v}{\varphi} \right) - A_3 \frac{\partial w}{\partial \zeta} + (4 A_5 + A_{17}) (1 - \zeta^2) \frac{\mu}{\varphi} \\ + (2 A_6 + A_{18}) \frac{\mu v}{\varphi} = 0 \end{aligned} \tag{6d}$$

where

$$A_1 = \xi^* \qquad A_2 = \frac{h_1}{h_2} \frac{\xi^*}{U} \qquad A_3 = \frac{h_1}{\xi^*}$$

$$A_4 = \frac{h_1}{\xi^* (\mu)_{\zeta=0}} \qquad A_5 = \frac{\xi^*}{2} \frac{\partial \ln (UQ)}{\partial \xi} \qquad A_6 = \frac{\xi^* h_1}{2 h_2 U} \frac{\partial \ln}{\partial \eta} (h_1 U Q)$$

$$A_7 = \frac{\xi^*}{2 h_2 U^2} \frac{\partial h_2}{\partial \xi} \qquad A_8 = \frac{\xi^*}{2 U^2 Q^2 p} \frac{\partial p}{\partial \xi} \qquad A_9 = \frac{\xi^* U}{h_2} \frac{\partial h_1}{\partial \eta}$$

$$A_{10} = \xi^* \frac{\partial \ln (h_2 Q)}{\partial \xi} \qquad A_{11} = \frac{\xi^* h_1}{h_2 U Q} \frac{\partial Q}{\partial \eta} \qquad A_{12} = \frac{\xi^* h_1}{h_2 U Q^2 p} \frac{\partial p}{\partial \eta}$$

$$A_{13} = \frac{\xi^*}{p} \frac{\partial p}{\partial \xi} \qquad A_{14} = \frac{\xi^* h_1}{h_2 U p} \frac{\partial p}{\partial \eta} \qquad A_{15} = \frac{4 h_1 U^2 Q^2}{\xi^* (\mu)_{\zeta=0}}$$

$$A_{16} = \frac{h_1 Q^2}{\xi^* (\mu)_{\zeta=0}} \qquad A_{17} = \xi^* \frac{\partial}{\partial \zeta} \ln \left(\frac{\xi^* h_2 p}{R^{1/2} \cup QT} \right)$$

$$A_{18} = \frac{\xi^* h_1}{h_2 \cup} \frac{\partial}{\partial \eta} \ln \left(\frac{\xi^* p}{R^{1/2} \cup T} \right)$$

Here, $A_1 \cdots A_{18}$ are the boundary quantities that must be specified for the boundary layer integration. They are completely determined by the external inviscid flow conditions and the body surface geometry. They are evaluated in terms of the inviscid flow velocity vector distribution and the metrical coefficients in the ξ and η coordinates. Thus they are independent of the ζ coordinates.

The dimensional physical quantities in Eqs (1) are replaced by their dimensionless equivalents which are defined as:

$$x = \frac{\bar{x}}{\bar{L}_o} \qquad y = \frac{\bar{y}}{\bar{L}_o} \qquad z = \frac{R^{1/2}}{\xi^* \bar{L}_o} \int_o \frac{\bar{\lambda}}{\bar{\Lambda}} \, d\bar{z}$$

$$h_1 = \frac{\bar{h}_1}{\bar{L}_o} \qquad h_2 = \frac{\bar{h}_2}{\bar{L}_o} \qquad h_3 = \frac{\bar{h}_3}{\bar{L}_o} \left(\frac{R^{1/2}}{\xi^*} \right) \left(\frac{\bar{\lambda}}{\bar{\Lambda}} \right)$$

$$u = \frac{\bar{u}}{\bar{Q}} \qquad v = \frac{\bar{v}}{\bar{Q}} \qquad w = \frac{\bar{w}}{\bar{U}} \left(\frac{\bar{\lambda}}{\bar{\Lambda}} \right) R^{1/2} \xi^*$$

$$t = \frac{\bar{\mathfrak{R}} \bar{t}}{\bar{Q}_o} \qquad p = \frac{\bar{p}}{\bar{\Lambda}_o \bar{Q}_o^2} \qquad Q = \frac{\bar{Q}}{\bar{Q}_o}$$

$$\mu = \frac{\bar{\mu}}{t \bar{\mu}_o} \qquad k = \frac{\bar{k}}{\bar{\mathfrak{R}} \bar{\mu}} \qquad c_p = \frac{\bar{c}_p}{\bar{\mathfrak{R}}}$$

$$\varphi = \frac{\mu}{2\zeta} \frac{\partial}{\partial z} \left(\frac{u}{U} \right) = - \frac{\mu}{h_3} \qquad U = \frac{\bar{U}}{\bar{Q}}$$

Subscript "o" denotes reference quantities. Upper case letters denote boundary layer external quantities.

$\overline{L}_o$ is an arbitrary reference length; R is the local Reynolds number defined as $\overline{U}\,\overline{\Lambda}\,\overline{L}_o/\overline{\mu}_{\zeta=0}$ A singularity factor ξ^* is incorporated in the quantities associated with ζ, where by definition ξ^* is identical to ξ in a segment adjoining a stagnation or sharp leading point or line and is any convenient positive constant or function of ξ and η elsewhere.

Finally w is eliminated by substituting its expression from Eq (6a) into the remainder of Eqs (6) yielding:

$$B_1 \frac{\partial v}{\partial \xi} + B_2 \frac{\partial v}{\partial \eta} + (B_3 + B_5) \frac{\partial v}{\partial \zeta} = B_3\, \zeta\, \frac{\partial^2 v}{\partial \zeta^2} + B_6 \tag{7a}$$

$$\begin{aligned} B_1 \frac{\partial t}{\partial \xi} + B_2 \frac{\partial t}{\partial \eta} + (B_3 + B_5) \frac{\partial t}{\partial \zeta} &= B_4\, \zeta\, \frac{\partial^2 t}{\partial \zeta^2} + B_7 + B_9 \left(\frac{\partial v}{\partial \zeta}\right)^2 \\ &+ B_{10} \left(\frac{\partial t}{\partial \zeta}\right)^2 + B_{11} \frac{\partial t}{\partial \zeta} \frac{\partial \varphi}{\partial \zeta} \end{aligned} \tag{7b}$$

$$\begin{aligned} B_1 \frac{\partial \varphi}{\partial \xi} + B_2 \frac{\partial \varphi}{\partial \eta} + (-B_3 + B_5) \frac{\partial \varphi}{\partial \zeta} &= B_3\, \zeta\, \frac{\partial^2 \varphi}{\partial \zeta^2} + B_8 + B_{12} \frac{\partial v}{\partial \eta} \\ &+ B_{13} \frac{\partial v}{\partial \zeta} + B_{14} \frac{\partial t}{\partial \xi} \Big| + B_{15} \frac{\partial t}{\partial \eta} + B_{16} \frac{\partial t}{\partial \zeta} \end{aligned} \tag{7c}$$

$B_1 \cdot\cdot\cdot B_{16}$ are differential coefficients defined as functions of the boundary conditions (surface geometry and inviscid flow properties), the transport properties of the fluid, and the non-dimensional quantities v, t, and φ :

$$\begin{aligned} B_1 &= A_1\, \zeta\, (1 - \zeta^2) & B_4 &= \frac{B_3}{P_r} \\ B_2 &= A_2\, \zeta\, v & B_5 &= A_5\, (1 - \zeta^2)^2 + A_6\, (1 - \zeta^2)\, v - A_7\, v^2 + A_8 t \\ B_3 &= A_4 \frac{\varphi^2}{\mu}\,. & B_6 &= \left[A_9\, (1 - \zeta^2)^2 - A_{10}\, (1 - \zeta^2)\, v - A_{11}\, v^2 - A_{12}\, t\right] \zeta \end{aligned}$$

$$B_7 = \left[A_{13} (1 - \zeta^2) \ t + A_{14} \, v \, t + A_{15} \frac{\zeta^2 \varphi^2}{\mu} \right] \frac{\zeta}{c_p}$$

$$B_8 = - (B_3 + B_5) \frac{\varphi}{\zeta} + \left[A_{17} (1 - \zeta^2) + A_{18} \, v \right] \zeta \varphi$$

$$B_9 = A_{16} \frac{\zeta \varphi^2}{\mu c_p}$$

$$B_{10} = \frac{B_4}{\kappa} \frac{\partial \kappa}{\partial t} \zeta$$

$$B_{11} = A_4 \left(\frac{1 - P_r}{P_r \, \mu} \right) \zeta \varphi$$

$$B_{12} = A_2 \, \zeta \varphi$$

$$B_{13} = \left[A_6 (1 - \zeta^2) - 2 \, A_7 \, v \right] \varphi$$

$$B_{14} = B_1 \frac{\varphi}{\mu} \frac{\partial \mu}{\partial t}$$

$$B_{15} = B_2 \frac{\varphi}{\mu} \frac{\partial \mu}{\partial t}$$

$$B_{16} = \left(\frac{B_5}{\mu} \frac{\partial \mu}{\partial t} + A_8 \right) \varphi$$

For two dimensional flows the crossflow velocity V, and crossflow gradients $\partial(\ )/\partial \eta$ are equal to zero.

In the three dimensional procedure, each boundary layer segment is replaced by a lattice of points with constant spacings a, b, c and integer indices i, j, k in the ξ, η, ζ directions respectively. In Eqs (7a), (7b), and (7c), first order derivatives appear with respect to all three coordinates, ξ, η, and ζ; second order derivatives appear only with respect to the ζ coordinate. In the central difference approximation, the first derivative difference equations are written as:

$$\left[\frac{\partial(\ )}{\partial \xi}\right]_{i,j,k} = \frac{1}{2a} \left[(\ )_{i+1,j,k} - (\ )_{i-1,j,k} \right] \tag{8a}$$

$$\frac{\partial(\ )}{\partial \eta}_{i,j,k} = \frac{1}{2b} \left[(\ )_{i,j+1,k} - (\ )_{i,j-1,k} \right] \tag{8b}$$

$$\frac{\partial(\ )}{\partial \zeta}\bigg|_{i,j,k} = \frac{1}{2c}\left[(\ )_{i,j,k+1} - (\ )_{i,j,k-1}\right]. \tag{8c}$$

The errors introduced in this approximation are of the order of:

$$\frac{a^2}{6}\frac{\partial^3(\ )}{\partial \xi^3}\ ;\ \frac{b^2}{6}\frac{\partial^3(\ )}{\partial \eta^3}\ ;\quad \frac{c^2}{6}\frac{\partial^3(\ )}{\partial \zeta^3} \tag{9}$$

in Eqs (8a), (8b), and (8c) respectively. In a similar manner, the second derivative difference equation is written as:

$$\left[\frac{\partial^2(\ )}{\partial \zeta^2}\right]_{i,j,k} = \frac{1}{4c^2}\left[(\ )_{i,j,k+1} - 2(\ )_{i,j,k} + (\ )_{i,j,k-1}\right] \tag{10a}$$

The errors introduced in the approximation are of the order of:

$$\frac{c^2}{12}\frac{\partial^4(\ )}{\partial \zeta^4}. \tag{11a}$$

This form of difference equation however, is usually numerically unstable for the parabolic type of equation (References 3, 9, 10). It was found in Reference 3 that numerical stability can be obtained if the second derivative difference Eq (10a) is rewritten as:

$$\left[\frac{\partial^2(\ )}{\partial \zeta^2}\right]_{i,j,k} = \frac{1}{4\,c^2}\left[(\ )_{i,j,k+1} - 2(\ )_{i-1,j,k} + (\ )_{i,j,k-1}\right]. \tag{10b}$$

The errors introduced in this approximation are of the order of:

$$\frac{c^2}{12}\frac{\partial^4(\ )}{\partial \zeta^4} + \left(\frac{a}{c}\right)^2\frac{\partial^2(\ )}{\partial \xi^2}. \tag{11b}$$

The requirement for this approximation, therefore, is that:

$$a << c. \tag{12a}$$

Other conditions which must also be satisfied in this procedure are:

(1) a, b, c are small in general (12b)

(2) $a << b$ (12c)

(3) $a\, h_1 |v| \le b\, h_2\, u.$ (12d)

Equations (7a), (7b), and (7c) therefore, can be written in the difference form by substituting Eqs (8a), (8b), (8c), and (10b) for the respective differentials.

$$\left(\frac{B_1}{2a} + k\frac{B_3}{c}\right) v_a = -\frac{B_2}{2b} v_b - \frac{(B_3 + B_5)}{2c} v_c + k\frac{B_3}{c} v_d + B_6 \tag{13a}$$

$$\left(\frac{B_1}{2a} + k\frac{B_4}{c}\right) t_a = -\frac{B_2}{2b} t_b - \frac{(B_3 + B_5)}{2c} t_c + k\frac{B_4}{c} t_d + B_7 + \frac{B_9}{4c^2} v_c^{\,2}$$

$$+ \frac{B_{10}}{4c^2} t_c^{\,2} + \frac{B_{11}}{4c^2} t_c \varphi_c \tag{13b}$$

$$\left(\frac{B_1}{2a} + k\frac{B_3}{c}\right) \varphi_a = -\frac{B_2}{2b} \varphi_b + \frac{(B_3 - B_5)}{2c} \varphi_c + k\frac{B_3}{c} \varphi_d + B_8 + \frac{B_{12}}{2b} v_b$$

$$+ \frac{B_{13}}{2c} v_c + \frac{B_{14}}{2a} t_a + \frac{B_{15}}{2b} t_b + \frac{B_{16}}{2c} t_c \tag{13c}$$

where ζ has been replaced by ck, and:

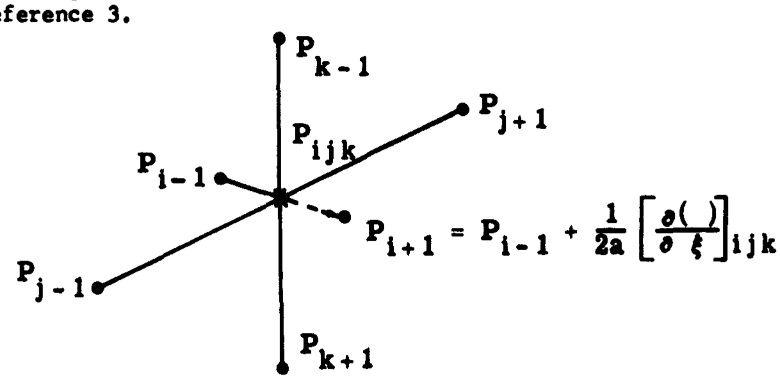
$$(\ )_a \equiv (\ )_{i+1,j,k} - (\ )_{i-1,j,k}$$

$$(\ )_b \equiv (\ )_{i,j+1,k} - (\ )_{i,j-1,k}$$

$$(\ )_c \equiv (\ )_{i,j,k+1} - (\ )_{i,j,k-1}$$

$$(\ )_d \equiv (\ )_{i,j,k+1} - 2(\ )_{i-1,j,k} + (\ )_{i,j,k-1}.$$

The numerical integration procedure is followed by a "leap-frogging" technique as described in Reference 3.



Consider the point $P_{i,j,k}$ in the above sketch. The forward derivatives $\left.\frac{\partial(\cdot)}{\partial \xi}\right|_{i,j,k}$ in the i direction at $P_{i,j,k}$ are calculated by Eqs (13a), (13b) and (13c) using values from the five nearest neighboring points shown on the ith and (i-1)th planes. The value of the new point $(\ \ \ \ )_{i+1,j,k}$ in the (i+1)th plane is calculated from the relation:

$$(\;)_{i+1,j,k} = (\;)_{i-1,j,k} + \frac{1}{2a} \left[\frac{\partial(\;)}{\partial \zeta}\right]_{i,j,k}$$

without calculating the value at $P_{i,j,k}$.

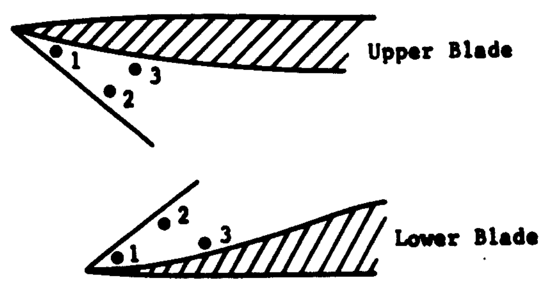
In this procedure, therefore, if the indices i, j, k start from 0,0,0, the forward derivatives are calculated from Eqs (13a), (13b), and (13c) when (i+j+k) is odd, and the values are calculated by Eq (14) when (i+j+k) is even.

IV PROGRAM CONSTRUCTION

This program contains ten chains for the various phases of computation. Figure 18 is an overall diagram showing the linkage of the system. The functions of each chain are as follows:

CHAIN I

Chain I reads in the first data card which contains a blade type indicator; free stream Mach number, pressure, and temperature; and the specific heat ratio . These data are stored on tape 2 for use by the entire program. If a blunt leading edge case is indicated, Chain VII is immediately called to calculate the flow field ahead of the blunt noses. If a sharp leading edge case is indicated, the wedge program is used to determine three initial field points for each surface as shown in the following sketch.



The calculation of these points are controlled by Subroutine WEDGE. The first point (1) is calculated by Subroutine SHK1, and the other two Points (2) and (3) are calculated by a special shock-body subroutine (Subroutine SHOCK). The procedure of calculation used in these routines are described in Appendix A.

The blade geometry data are then read from cards, and the surface data are fitted with a series of cubics using Subroutines CURFIT and CUBIC. The coefficients of these fitted equations are stored on tape 2 for later use in the program.

CHAIN VII:

Chain VII calculates the flow about a cylindrical body of unit radius by a 2nd order Belotserkovskii procedure. This chain determines the data along an initial value line in a radial direction from the body center of curvature to the shock.

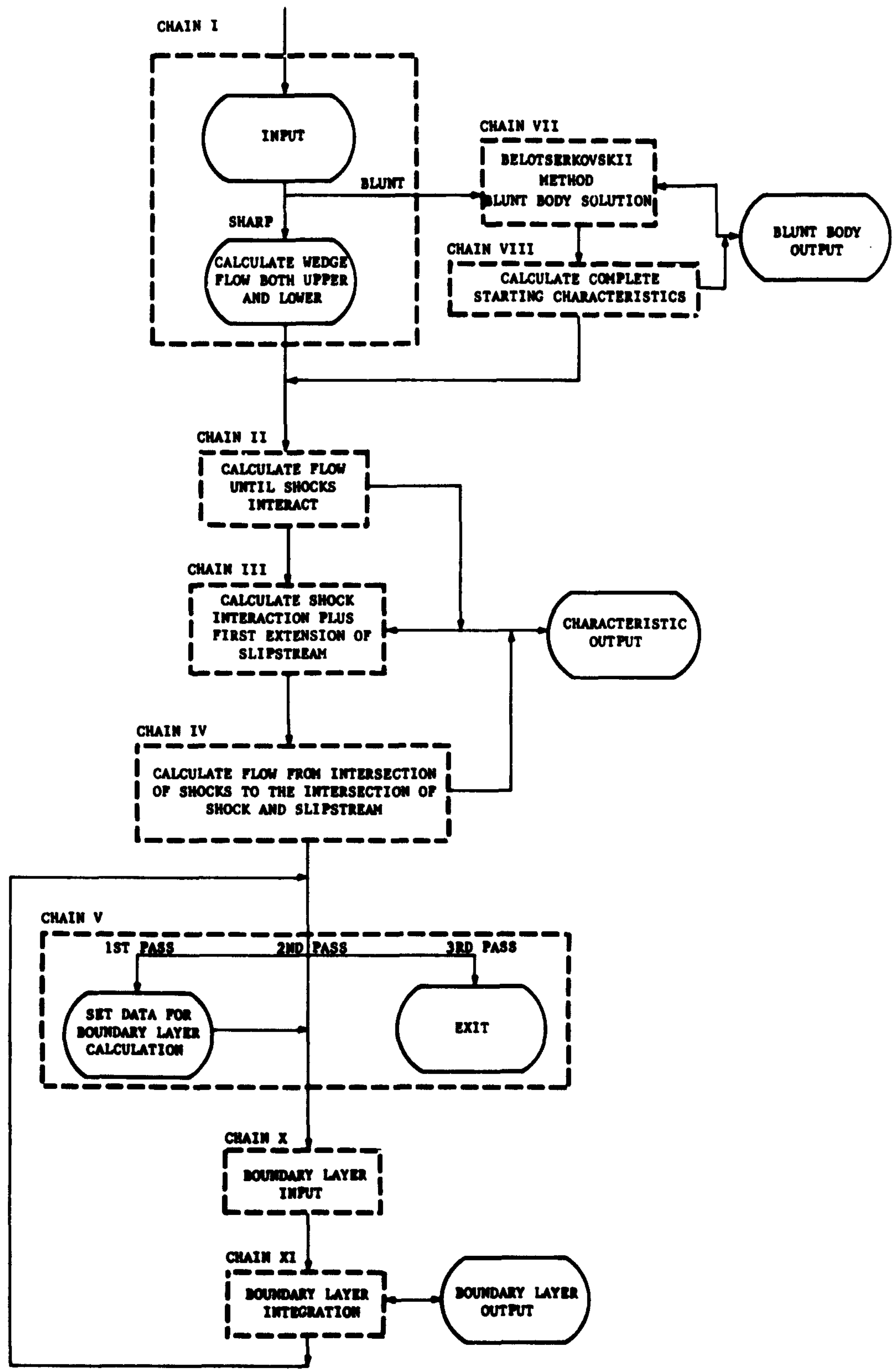
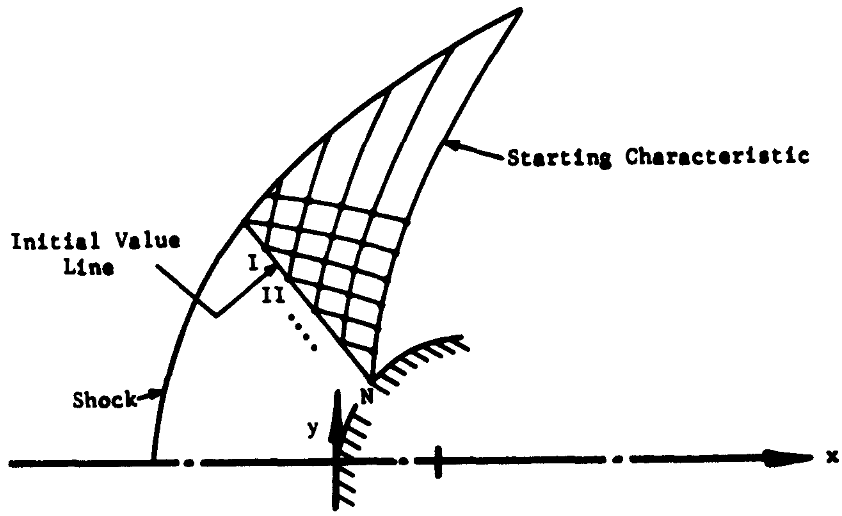


FIGURE 10 PROGRAM CONSTRUCTION DIAGRAM

CHAIN VIII

This chain uses the initial value line obtained in Chain VII and calculates a complete left running characteristic from body to shock, as shown in the following sketch.



The calculation starts at the shock. Characteristic I is first calculated, then II, etc., until a complete characteristic from the body to the shock is obtained. This starting characteristic can be used for the upper and lower blade surfaces by proper data transformation.

The blade geometry data are then read from cards. The starting characteristics just calculated are dimensionalized with the given body leading edge radius. The blade geometry data are then curve fitted, merging smoothly to the cylindrical blunt leading edge sections. The coefficients of the body description equations are stored on tape 2 for later use in the program.

CHAIN II

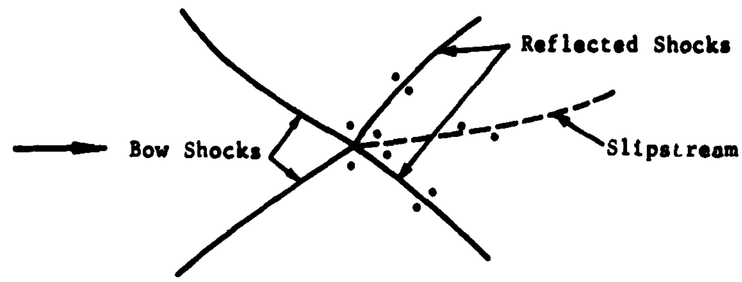
This chain calculates the flow field of the upper and lower blade surfaces using the starting characteristics calculated in Chain I or Chain VIII, and continuing until the two bow shocks cross (Figure 2).

CHAIN III:

Chain III calculates the interaction of shocks of opposite families. The location of the interaction point is calculated by a curve fit method for intersecting two curves (Subroutine MEET).

The properties behind each shock are calculated by Subroutine SHK1, and the slipstream deflection and the properties behind each of the reflected shocks are calculated by an iteration procedure which is discussed in Appendix A.

Next, the first extensions of the reflected shock waves and slipstream are calculated. The sketch below shows the points being calculated in this chain.



CHAIN IV:

This chain controls the remaining characteristic calculation, which includes the slipstream, shock-body interactions, and shock-slipstream interactions.

CHAIN V:

This chain reads the characteristic data from tapes 3 and 4 and calculates the surface velocity vs surface distance data. These data are then written on tape 9 for the boundary layer calculation.

CHAIN X:

Chain X is the boundary layer input program which calculates the "A" coefficients from the surface velocity data. These coefficients are the input data for the boundary layer integration program.

CHAIN XI:

Chain XI is the boundary layer integration program which calculates properties across the boundary layer (velocity, temperature and shear profiles). From these properties, the boundary layer thickness and skin friction, etc., are calculated.

V SAMPLE RESULTS AND DISCUSSION

Three sample cases have been calculated. The flow in a sharp leading-edge channel was calculated for incident flows of Mach 4 and Mach 6 while only a Mach 4 case was calculated for a blunt leading-edge channel. The calculated flow geometry for these three cases are shown in Figures 4, 5, and 6. For the two sharp leading-edge cases, inviscid flow fields were calculated up to and including the shock-slipstream interaction point. For the blunt leading-edge case, however, the calculation could not be carried as far, due to the fact that adjacent characteristics overlapped, which indicates that envelope shocks are being formed in this region. As yet an envelope shock routine has not been developed. The reason for the envelope shock formation is due, of course, to the particular channel geometry selected. These results show that an envelope shock subroutine is needed to complete the present type of flow field calculation.

The sharp leading-edge geometry selected for calculation has 20° and 15° leading-edge angles on the lower and upper surfaces, respectively. The initial shock strength, therefore, is higher on the lower surface. Also, because the flow along the lower surface is being compressed while the flow along the upper surface is being expanded, the lower shock strength will be even stronger at the shock interaction point. When two shocks of different strengths interact, the resulting flow is deflected toward the side generating the weaker shock. For the Mach 4 and Mach 6 cases, the flow deflection angle was found to be about 7° and 8°, respectively. The general flow pattern for the two cases are similar except that at the point of shock-slipstream interaction, a compression wave was created for the Mach 4 case, while for the Mach 6 case, an expansion wave was created. These waves were found to be extremely weak and can be neglected in the downstream flow field calculation. Although the calculations have not been carried farther downstream, the shock shapes indicated that interaction of shocks of the same family is likely to occur only slightly downstream of the last computations. This is due to the fact that the deflected shocks from the upper surface extend much farther downstream than those of the lower surface.

Because the flows are being expanded near the upper surface and the flows are being compressed near the lower surface, large pressure gradients exist across the channel during the turning process. Figures 7 to 10 show the pressure and Mach number distribution along the upper and lower surfaces for the two sharp leading edge cases, and Figure 11 shows the pressure variation across the channel at various longitudinal stations for the M=6 case only.

A blunt leading-edge radius of 1.0 was selected for the blunt leading-edge channel geometry. The incident angle α for this channel is about 13.75° (Figure 6). For the selected body shape, the flow has turned to an angle of approximately 30° before two adjacent characteristics overlapped.

The laminar boundary layers were calculated for the two sharp leading-edge cases. The boundary layer displacement thickness distributions are plotted in Figures 12 and 13, (note that the vertical scale has been highly magnified). The calculations show that for both cases the boundary layer on the lower surfaces had separated at about the same longitudinal station - X = 10.0 for the Mach 4 case and X = 10.65 for the Mach 6 case. These boundary layer separation points are also indicated in Figures 4, 5, 7, and 8. Separation occurs at the point where the shear, which is proportional to the velocity derivative du'/dz' at the wall, becomes zero. Some velocity and shear profiles along the lower surfaces

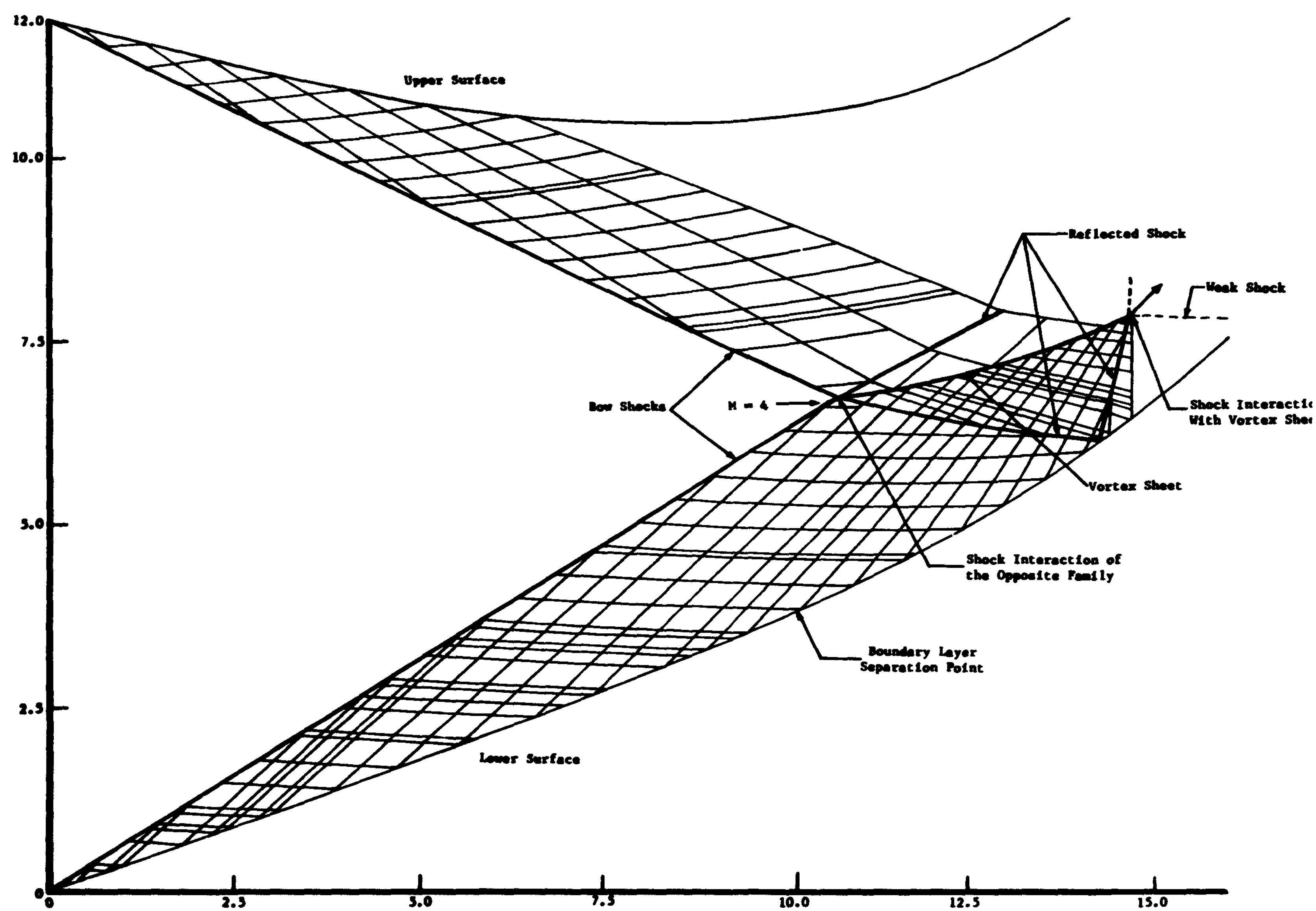


FIGURE 4 INVISCID FLOW FIELD FOR A SHARP LEADING-EDGE CURVED CHANNEL $M_{\infty} = 4.0$

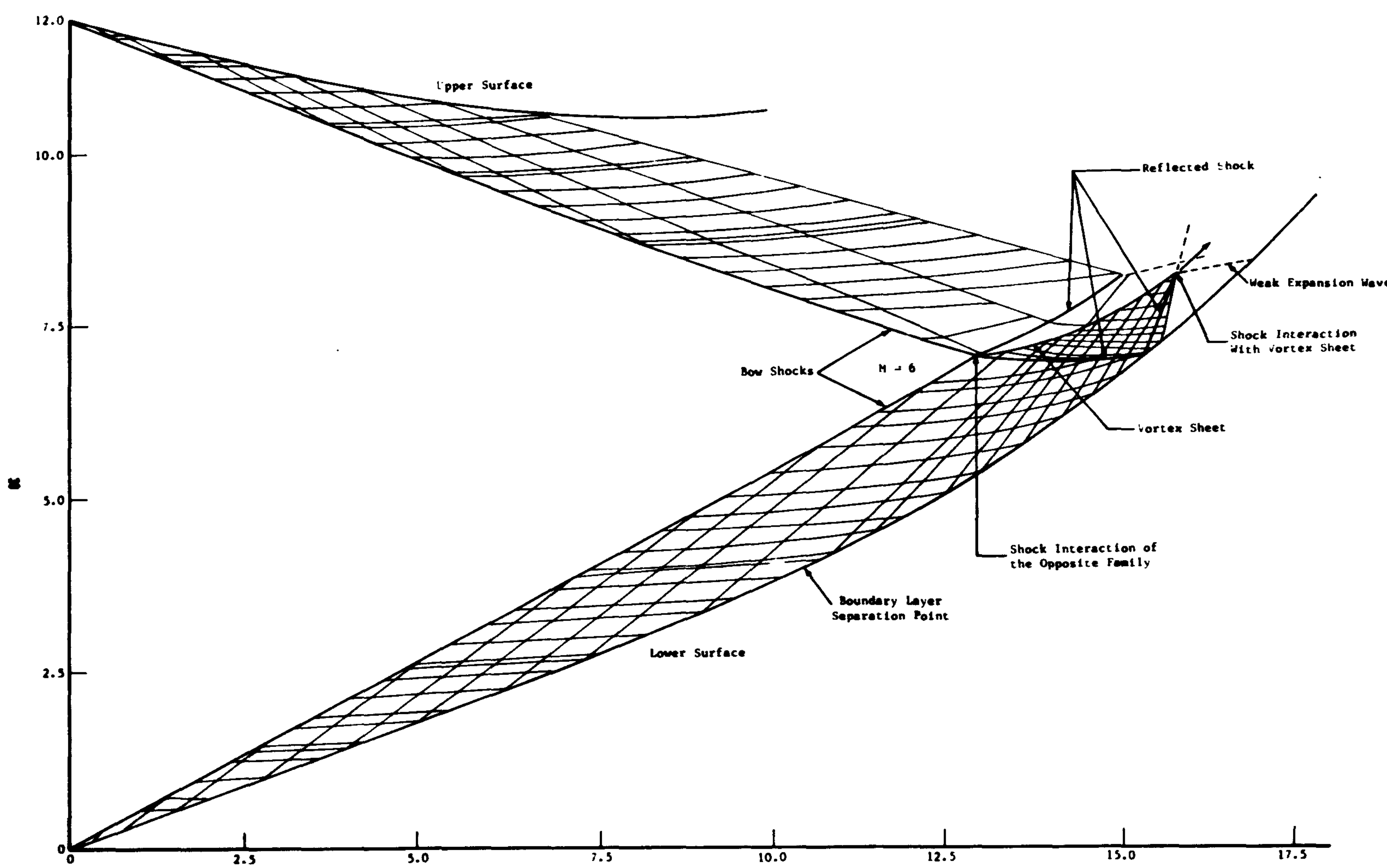


FIGURE 5 INVISCID FLOW FIELD FOR A SHARP LEADING-EDGE CURVED CHANNEL $M_{\infty} = 6.0$

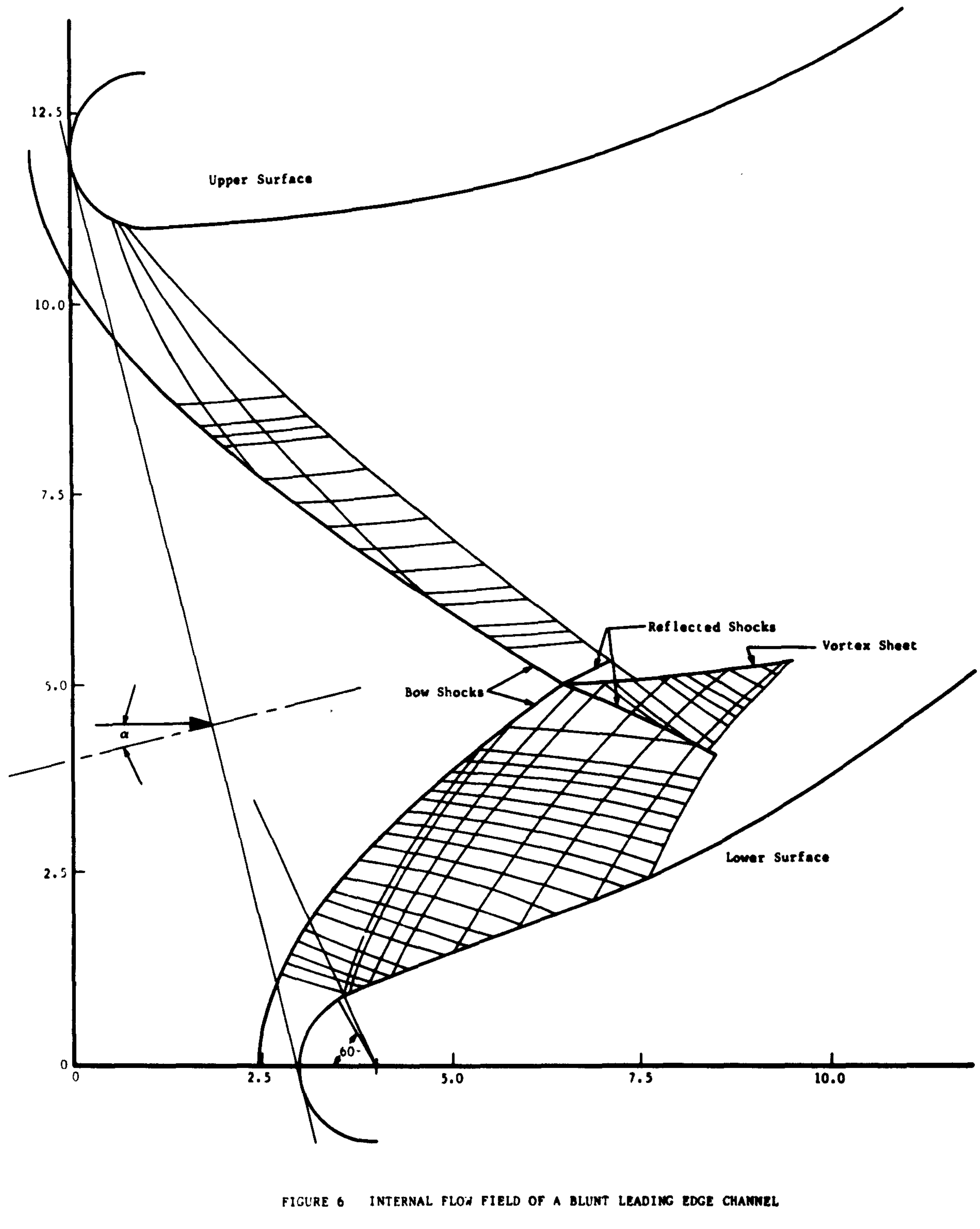


FIGURE 6 INTERNAL FLOW FIELD OF A BLUNT LEADING EDGE CHANNEL

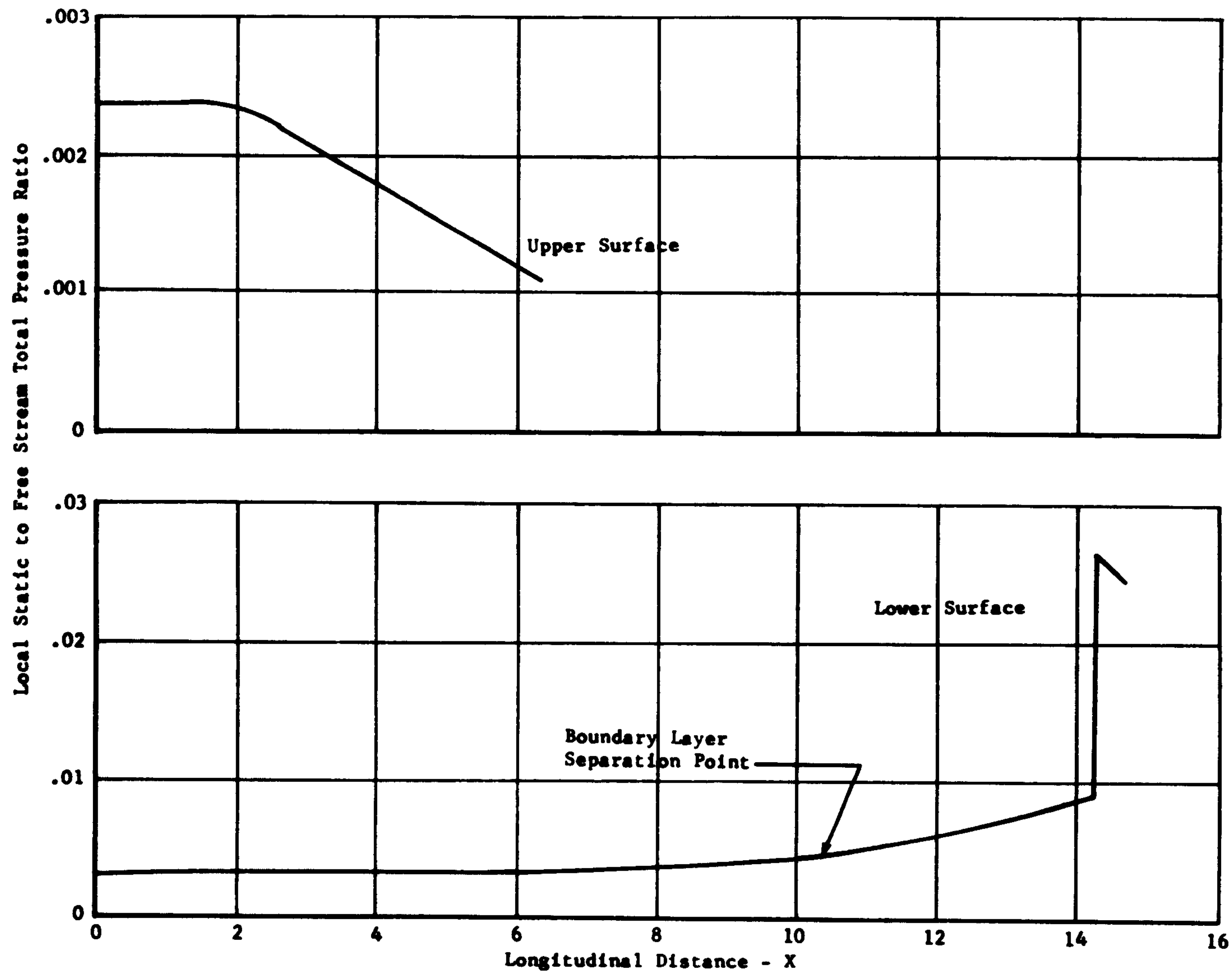


FIGURE 7 PRESSURE DISTRIBUTION ALONG THE SURFACES OF A SHARP LEADING-EDGE CHANNEL $M_{\infty} = 4.0$

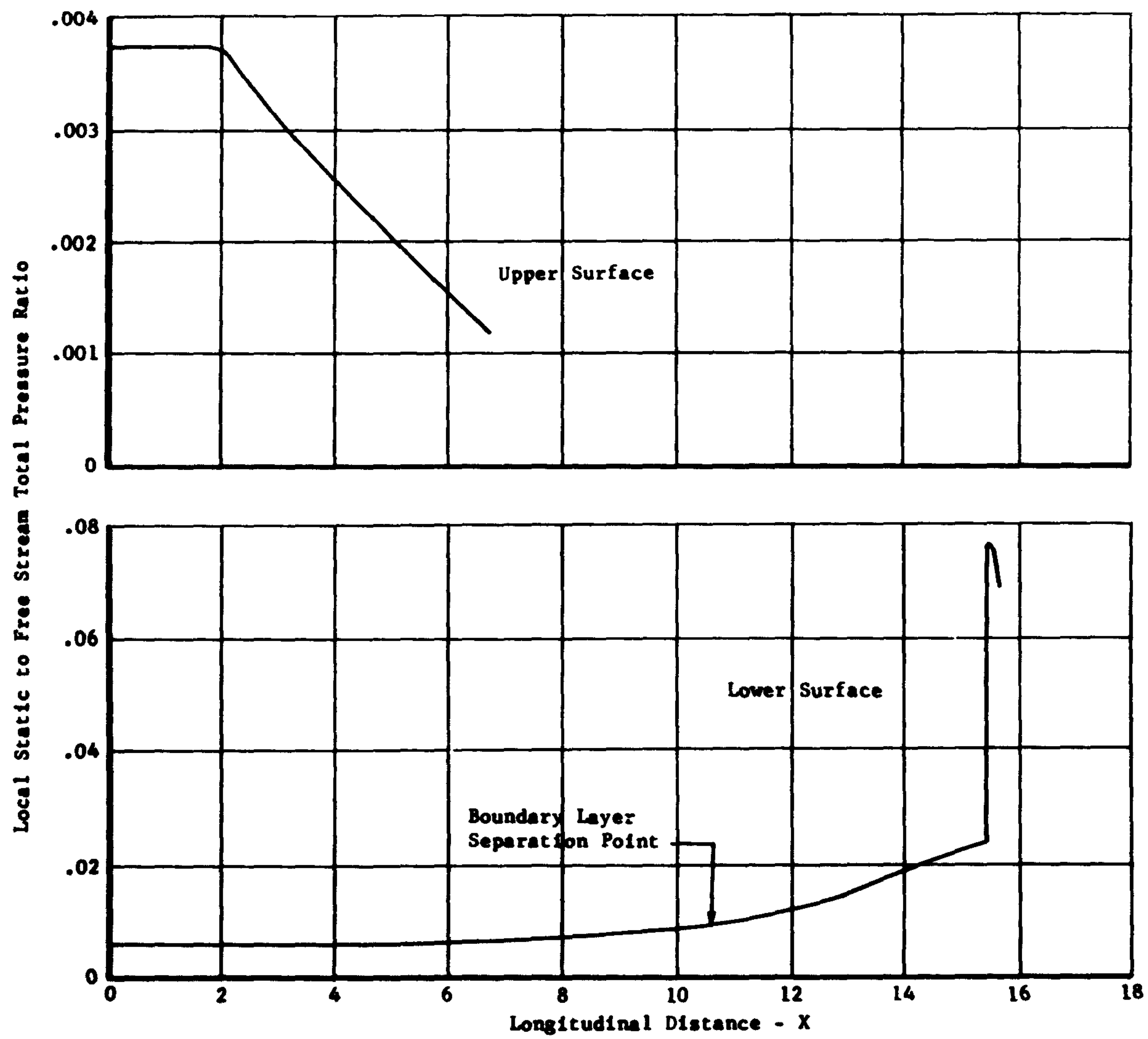


FIGURE 8 PRESSURE DISTRIBUTION ALONG THE SURFACES OF A SHARP LEADING-EDGE CHANNEL $M_\infty = 6.0$

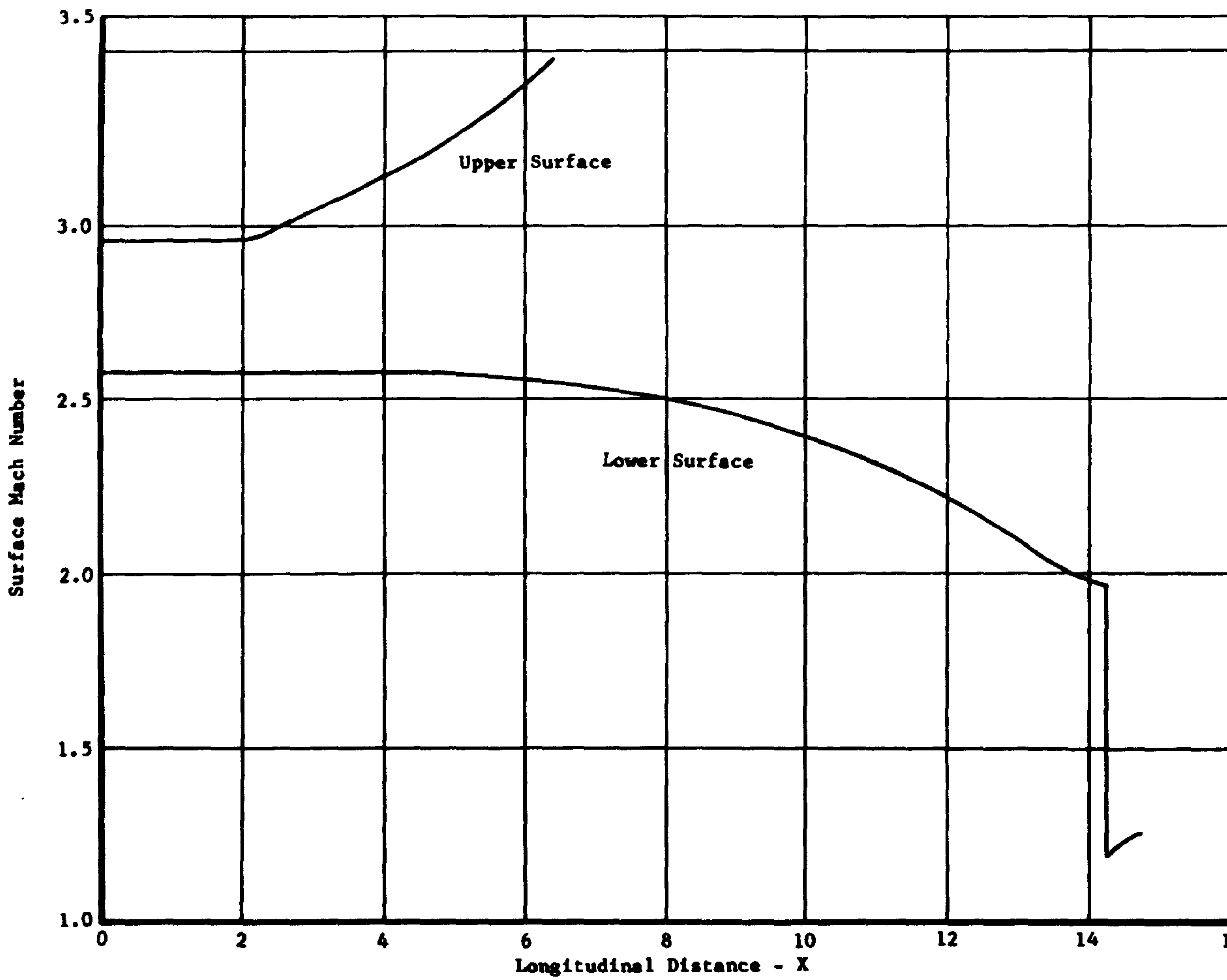


FIGURE 9 MACH NUMBER DISTRIBUTION ALONG THE SURFACES OF A SHARP LEADING-EDGE CHANNEL $M_\infty = 4.0$

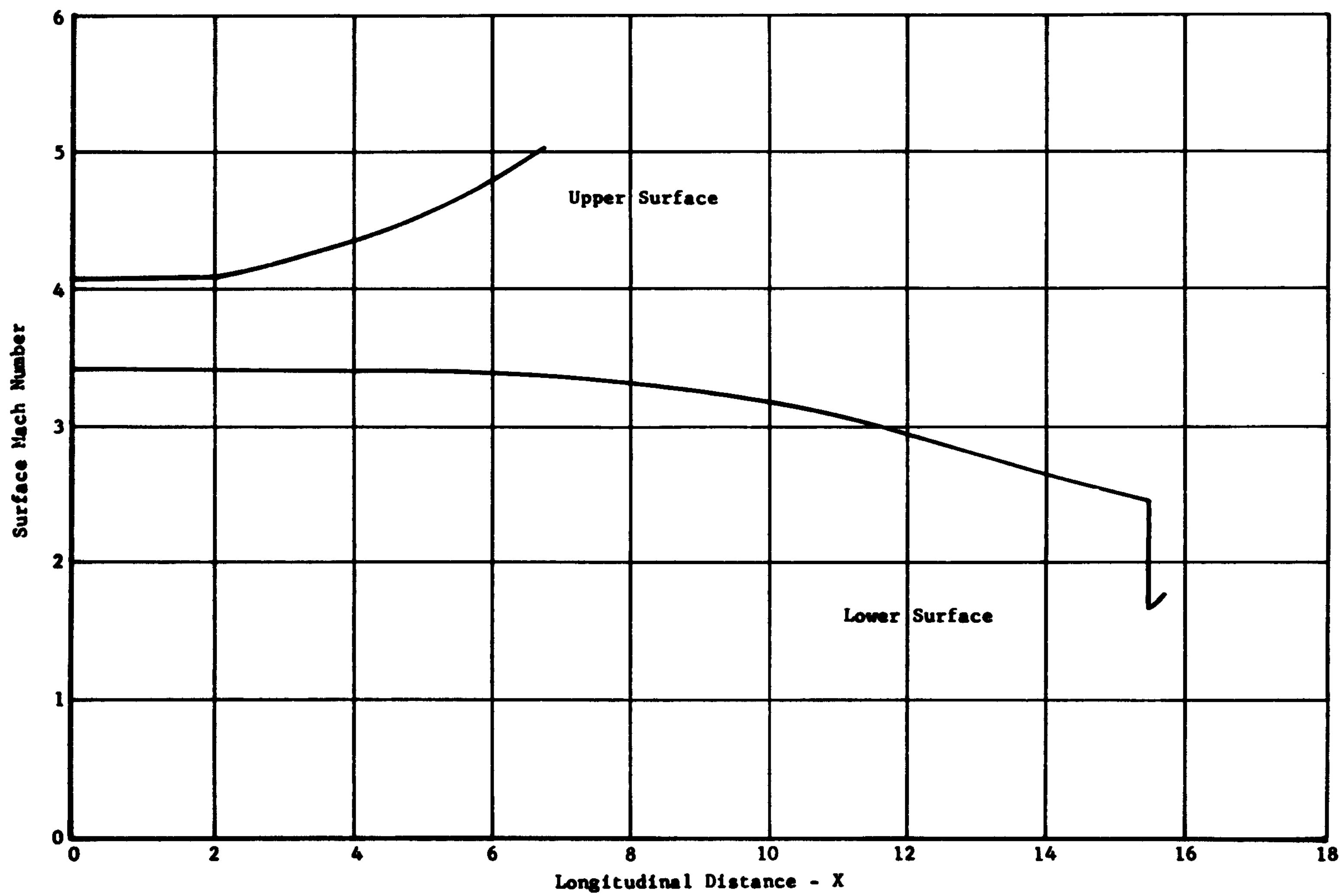


FIGURE 10 MACH NUMBER DISTRIBUTION ALONG THE SURFACES OF A SHARP LEADING-EDGE CHANNEL $M_\infty = 6.0$

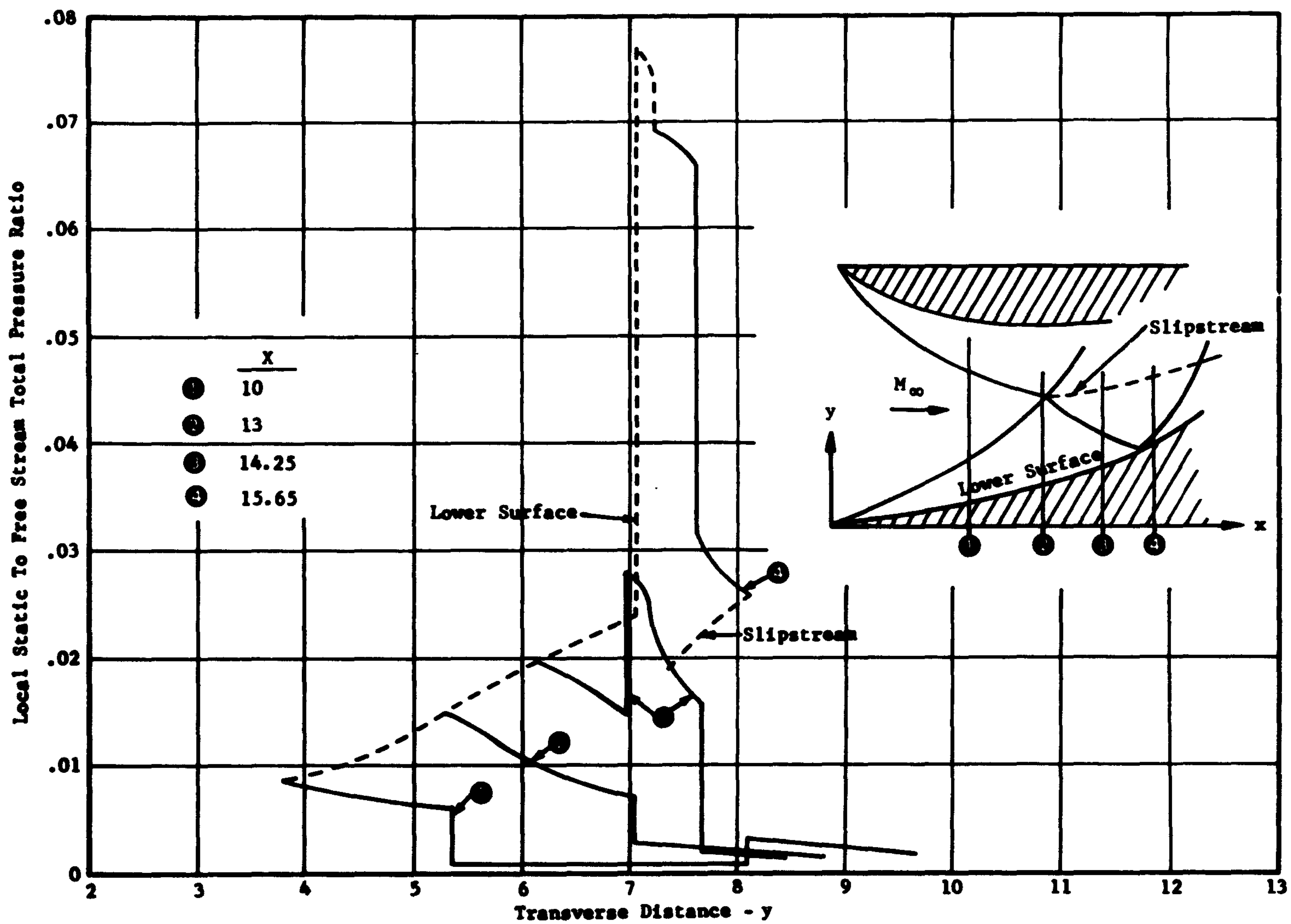


FIGURE 11 TRANSVERSE PRESSURE DISTRIBUTION AT VARIOUS LONGITUDINAL STATIONS FOR A SHARP LEADING-EDGE CHANNEL $M_\infty = 6.0$

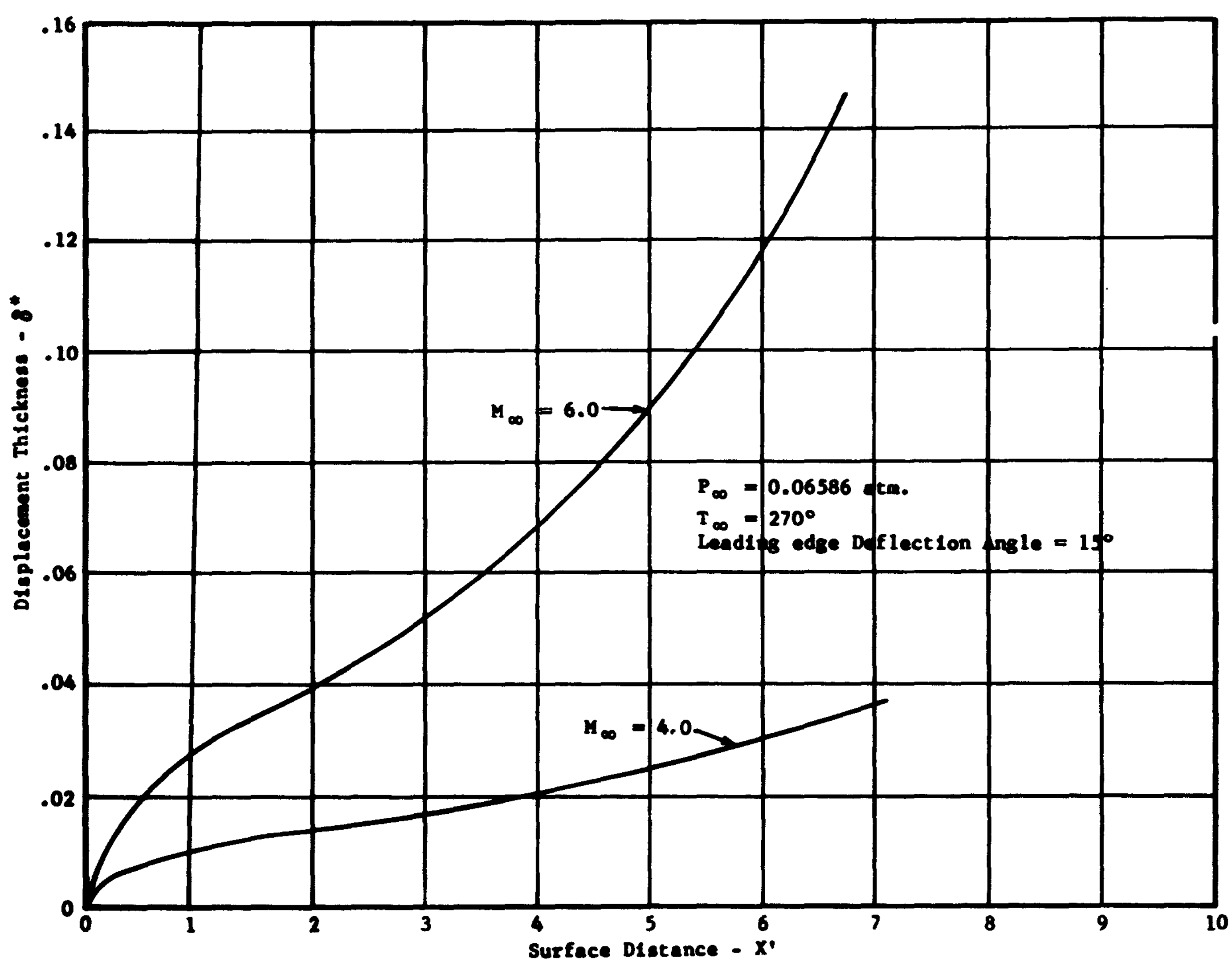


FIGURE 12 BOUNDARY LAYER DISPLACEMENT THICKNESS DISTRIBUTION ON THE UPPER (EXPANSION) SURFACE OF A SHARP LEADING-EDGE CHANNEL

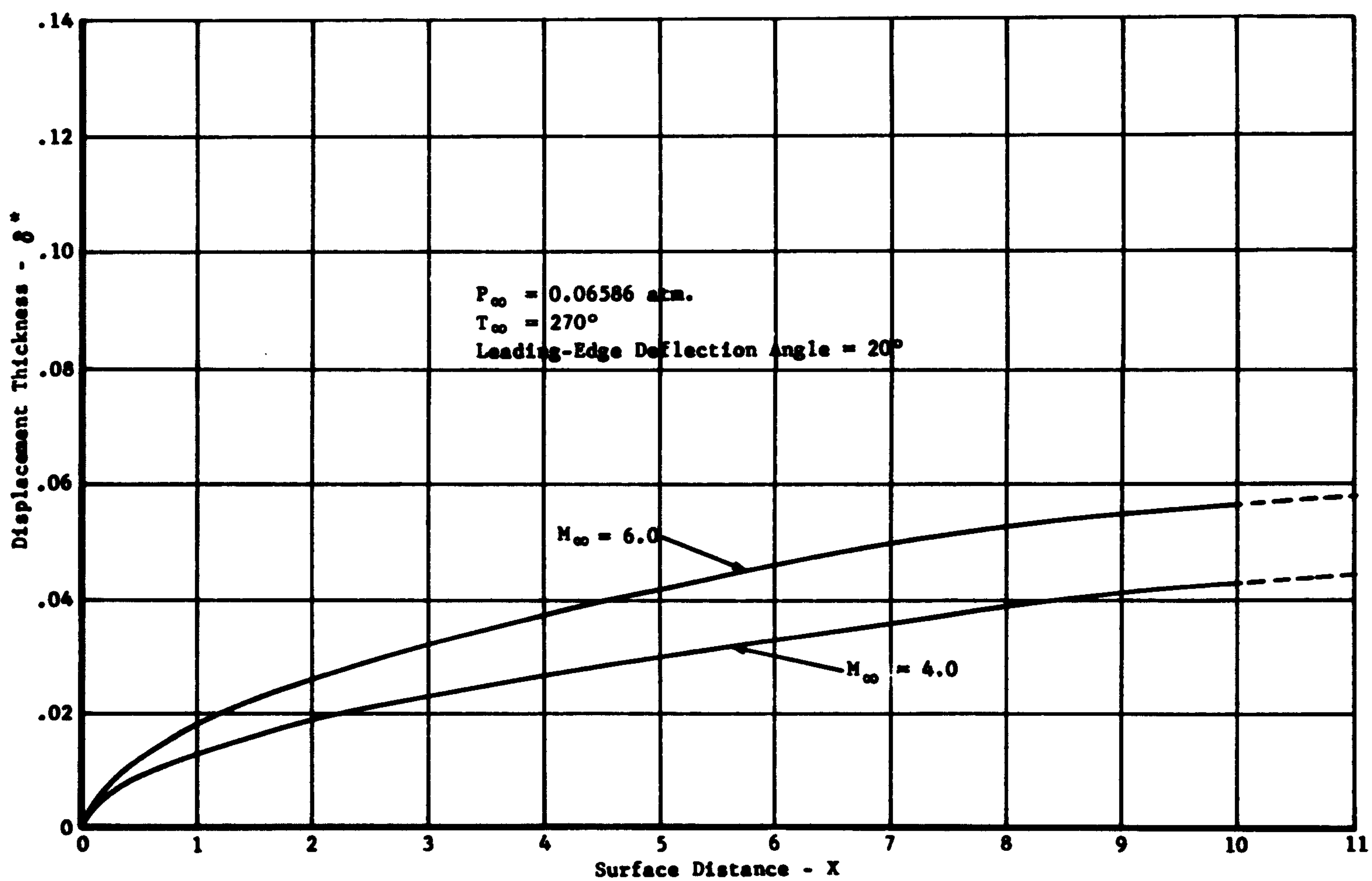


FIGURE 13 BOUNDARY LAYER DISPLACEMENT THICKNESS DISTRIBUTION ON THE LOWER (COMPRESSION) SURFACE OF A SHARP LEADING-EDGE CHANNEL

are plotted in Figures 14 to 17. The separation points indicated on the pressure distribution curves in Figures 7 and 8 show that the boundary layer separates even with a very weak adverse pressure gradient. This indicates that in order to maintain a non-separated boundary layer, the pressure gradient must be kept small. To do this, however, a very long channel is required in order to obtain a reasonably high flow turning angle. A more practical solution which should be investigated in the future, is to use boundary layer suction so that the wall shear values can be controlled externally.

In view of the results obtained with this program, the following conclusions can be drawn:

1. To calculate the complete internal inviscid flow field with turning, two additional IBM subroutines are needed; (a) envelope shock, and (b) interactions of shocks of the same family.

2. Boundary layer on the compression surface can be easily separated by the adverse pressure gradient. Boundary layer suction may be needed to maintain an attached boundary layer.

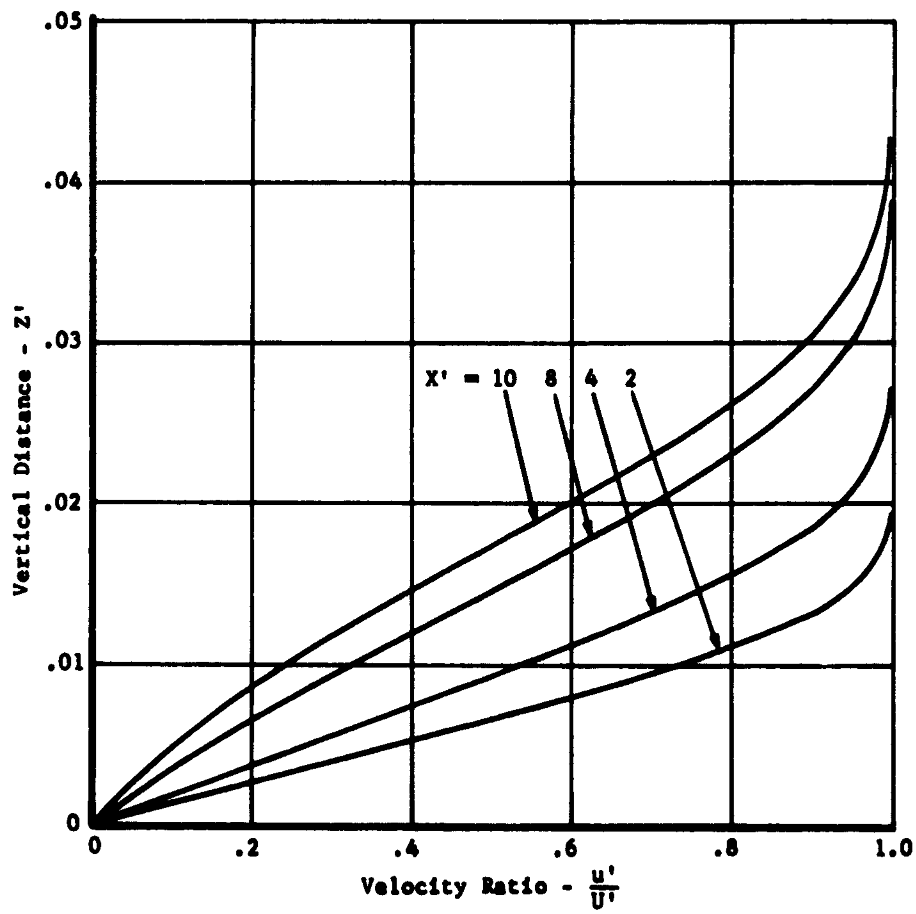


FIGURE 14 VELOCITY PROFILES ALONG THE LOWER (COMPRESSION) SURFACE OF A SHARP LEADING-EDGE CHANNEL $M_\infty = 4.0$

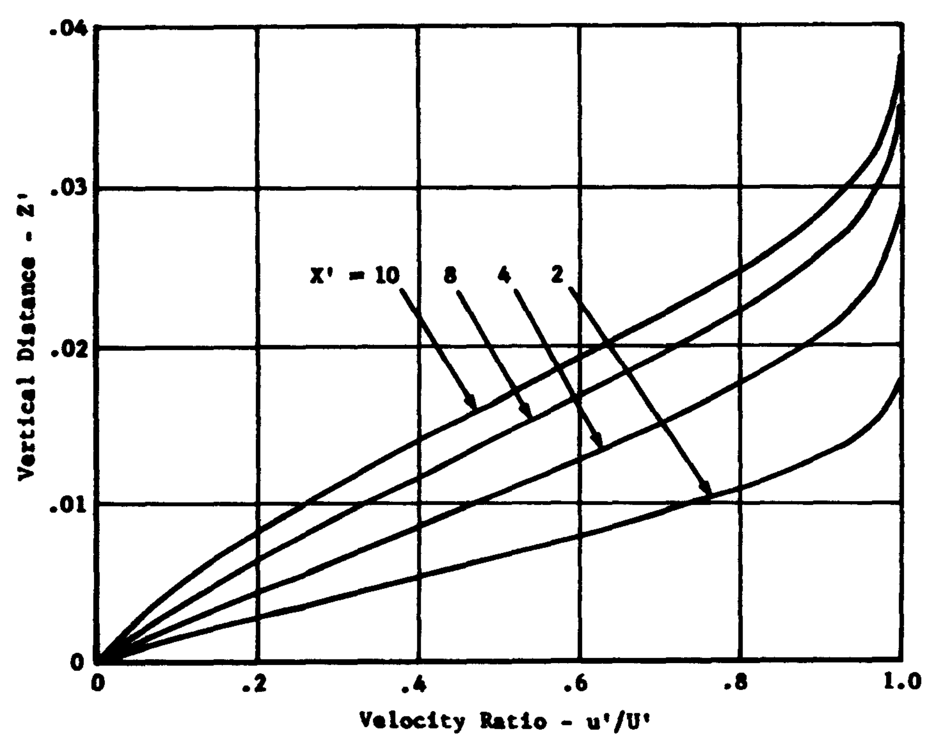


FIGURE 15 BOUNDARY LAYER VELOCITY PROFILES ALONG THE COMPRESSION SURFACE OF A SHARP LEADING-EDGE CHANNEL M_∞ = 6.0

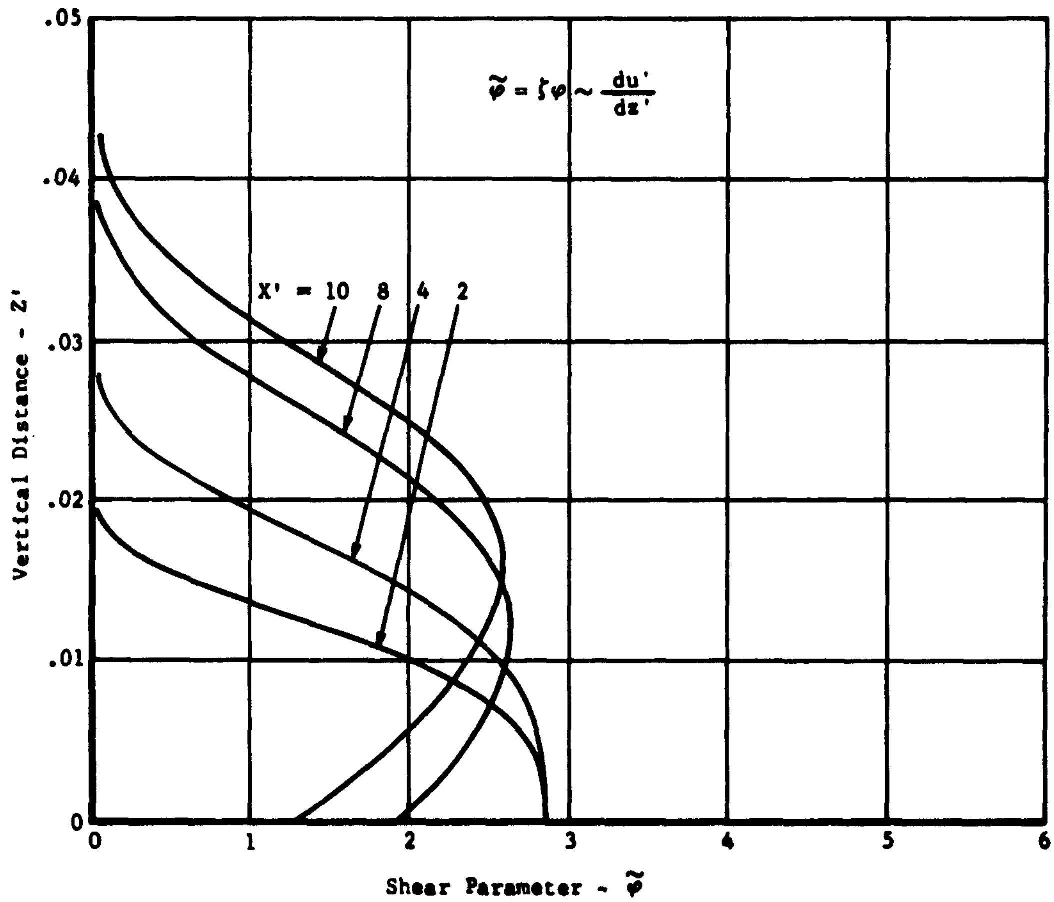


FIGURE 16 BOUNDARY LAYER SHEAR PROFILES ALONG THE COMPRESSION SURFACE OF A SHARP LEADING-EDGE CHANNEL $M_{\infty} = 4.0$

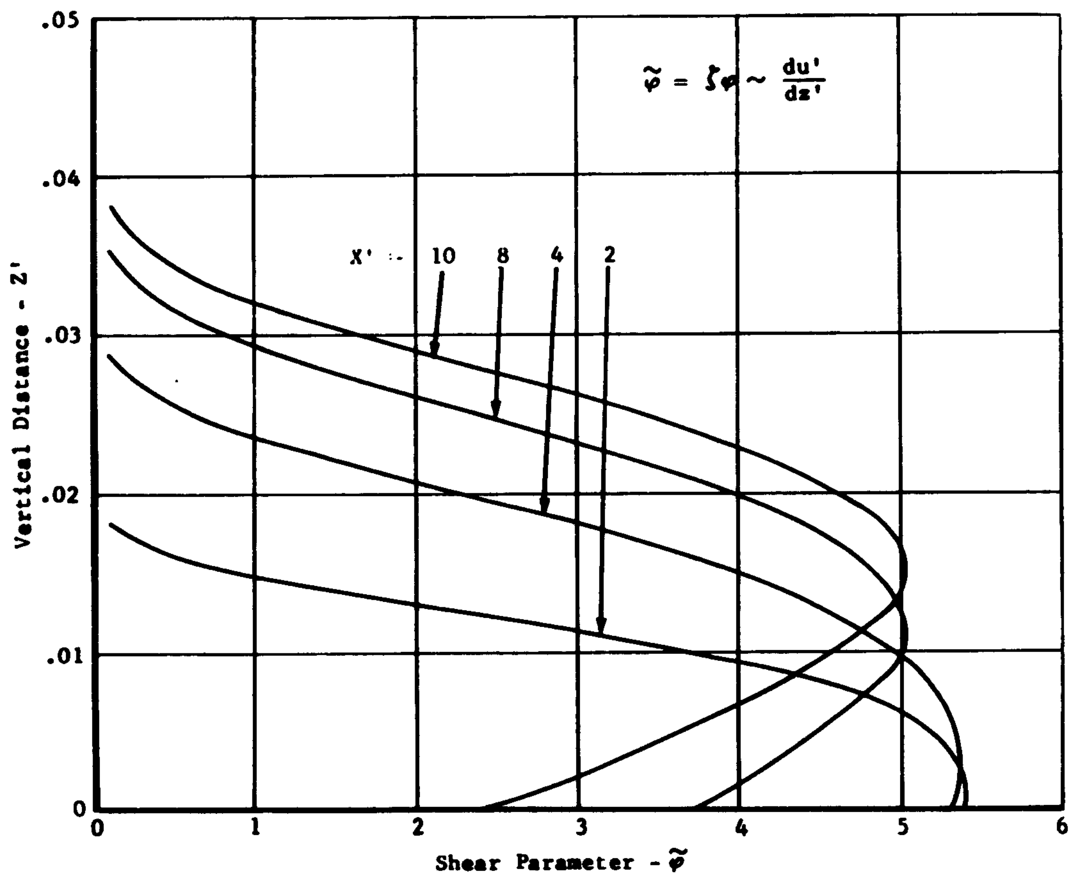


FIGURE 17 BOUNDARY LAYER SHEAR PROFILES ALONG THE COMPRESSION SURFACE OF A SHARP LEADING-EDGE CHANNEL $M_\infty = 6.0$

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APPENDIX A

SHOCK POINT CALCULATION

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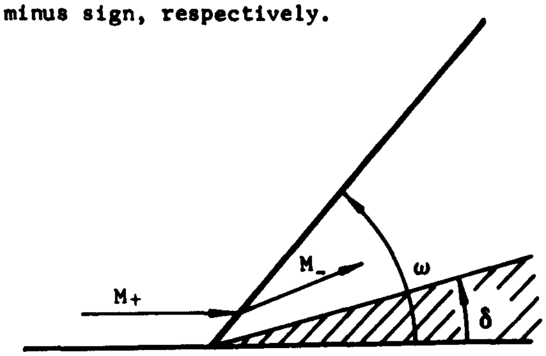
SHOCK POINT CALCULATION

Two major shock subroutines are used for most of the shock point calculations. One is for an oblique shock calculation which is used to initiate a shock wave at a point of discontinuity in flow direction. The other is for a general field shock calculation which is used to extend a shock from a previously calculated shock segment. There are special cases, however, such as the shock-boundary interaction and shock-slipstream interaction, where modifications of these two basic methods must be made. The two major shock routines are described in detail in this appendix and the differences for the special cases are outlined.

OBLIQUE SHOCK ROUTINE

In the following, quantities ahead of and behind the shock will be denoted by a subscript plus or minus sign, respectively.



The oblique shock routine calculates a shock angle ω from a given wedge or flow deflection angle δ . With a known incident Mach number M_+ and the fluid specific heat ratio γ , ω and δ are related through

$$\cot \delta = \tan \omega \left[\frac{(\gamma + 1) M_+^2}{2 (M_+^2 \sin^2 \omega - 1)} - 1 \right]. \qquad \text{A-1}$$

Eq. A-1 is a transcedental equation in ω , and an iterative solution must be used. Using the Newton iteration procedure, ω is calculated by

$$\omega_{i+1} = \omega_i + \frac{\delta - \delta_i}{\frac{d\delta_i}{d\omega_i}} \qquad \text{A-2}$$

Where subscript i denotes the i^{th} cycle of iteration, and

$$\frac{d\delta}{d\omega} = \frac{2\cos^2\delta}{M_+^2(\gamma + \cos 2\omega) + 2}\left[\frac{M_+^2 \cos 2\omega + \frac{1}{\sin^2\omega}}{} + (M_+^2 \sin 2\omega - 2\cot\omega)\left(\frac{M_+^2 \sin 2\omega}{M_+^2(\gamma + \cos 2\omega) + 2}\right)\right] . \qquad \text{A-3}$$

Here ω_{i+1} represents a new approximation to the shock angle. To start the calculation, the first approximation to the shock angle is taken to be the incident Mach angle, i.e.,

$$\omega_o = \tan^{-1}\left(\frac{1}{M_+^2 - 1}\right)^{1/2} . \qquad \text{A-4}$$

The general oblique shock calculation procedure can be summarized as follows:

1. Assume a shock angle ω_o (Eq. A-4)
2. Calculate a δ_i by Eq. A-1
3. Check the accuracy by comparing δ_i with δ . $|\delta - \delta_i| \geq 10^{-5}$ is generally considered as satisfactory.
4. When the accuracy check is satisfied, the solution is converged; otherwise, a new shock angle ω_{i+1} is computed (Eq. A-2);
5. Go back to Step (2) and repeat the calculation until convergence occurs in Step (4).

Equation A-1 contains two roots in ω ; one corresponds to a weak shock solution, and the other corresponds to a strong shock solution. Only the weak shock solution has meaning here. For a given set of M_+ and γ , the desired root of Eq. A-1 will be in the range

$$\omega_o \leq \omega < \omega_{max} .$$

Where ω_{max} is the shock wave angle for which $M_- = 1.0$. Similarly, δ_{max} is the deflection angle corresponding to ω_{max}.

$$\delta_{max} = \tan^{-1}\left[\frac{M_+^2 \sin(2\omega_{max}) - 2\cot(\omega_{max})}{M_+^2\left[\gamma + \cos(2\omega_{max})\right] + 2}\right] , \qquad \text{A-5a}$$

where

$$\omega_{max} = \frac{1}{4\gamma M_+^2}\Big\{(\gamma+1)M_+^2 - 3 - \gamma + \,.$$

$$\sqrt{(\gamma+1)\left[(\gamma+1)M_+^4 - 2(3-\gamma)M_+^2 + (\gamma+9)\right]}\Big\}. \qquad \text{A-5b}$$

It is necessary therefore, to first calculate δ_{max} to make certain that $\delta < \delta_{max}$. Also, since $d\delta/d\omega$ approaches infinity at δ_{max}, $d\delta_i/d\omega_i$ in Eq. A-2 is arbitrarily restricted to a maximum value of 1.0 during iteration.

With ω calculated, flow properties immediately behind the shock can be determined directly. These properties are:

1. Static pressure

$$P_- = P_+\left[\frac{2\gamma M_+^2 \sin^2 \omega - (\gamma-1)}{\gamma+1}\right] \qquad \text{A-6}$$

2. Total pressure

$$R_- = R_+\left[\frac{(\gamma+1)M_+^2 + \sin^2 \omega}{(\gamma-1)M_+^2 \sin^2 \omega + 2}\right]^{\frac{\gamma}{\gamma-1}}$$

A-7

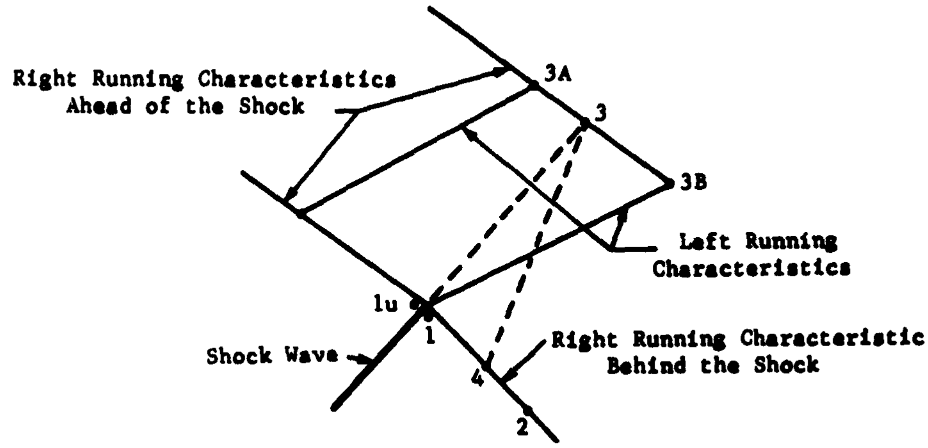
$$\times\left[\frac{\gamma+1}{2\gamma M_+^2 \sin^2 \omega - (\gamma-1)}\right]^{\frac{1}{\gamma-1}}$$

3. Mach number

$$M_-^2 = \frac{2}{\gamma-1}\left[\left(\frac{R_-}{P_-}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] \qquad \text{A-8}$$

GENERAL FIELD SHOCK CALCULATION

The general field shock routine calculates extensions of an existing shock wave. The flow field immediately ahead of the shock can be either uniform or non-uniform. The shock wave calculated in a uniform field is a bow wave and the shock wave calculated in a non-uniform field is a secondary wave.



In the sketch above, a shock wave segment is to be inserted from 1 to 3. A double iteration procedure is required to calculate the shock angle ω and the flow direction θ at 3. The general iteration procedure is as follows:

> First assume a linear extension of the shock wave at Point 1 to approximate the location of Point 3, which lies between 3A and 3B. Then by interpolation, using the data at 3A and 3B, and the oblique shock relation, the incident and the transmitted shock properties at 3 can be determined. The results are then checked with the compatibility equation along a right running characteristic from 3 to 4. Point 4 is also an interpolated point, which in this case lies between Points 1 and 2.

The calculation for both cases (bow or secondary wave) is similar except that for the case of the bow wave, the locations of Points 3A and 3B have not been previously established, but the flow properties are known (free stream conditions). So, for the case of the bow wave, Points 3A and 3B are determined by

$$X_{3A} = X_3 - \frac{\beta}{2}\cos(-\mu_{3A})$$

$$Y_{3A} = Y_3 \mp \frac{\beta}{2}\sin(-\mu_{3A})$$

$$X_{3B} = X_3 + \frac{\beta}{2}\cos(-\mu_{3A}) \qquad \text{A-9}$$

$$Y_{3B} = Y_3 \pm \frac{\beta}{2}\sin(-\mu_{3A})$$

where

$$\mu_{3A} = \tan^{-1}\left[\frac{1}{M_\infty^2 - 1}\right]^{1/2}$$

ω_3 and $(\theta_+)_3$ are related by the equation

$$\frac{Y_3 - Y_1}{X_3 - X_1} = \tan(\omega \pm \theta_+)_{\overline{1,\,3}}$$

y_3 can be eliminated by writing

$$\frac{Y_3 - Y_{3A}}{X_3 - X_{3A}} = \tan(\theta \pm \mu)_{\overline{3A,\,3B}} ,$$

so that

$$X_3 = \frac{Y_{3A} - Y_1 + X_1 \tan(\theta_+ \pm \omega)_{\overline{1,\,3}} - X_{3A} \tan(\theta \pm \mu)_{\overline{3A,\,3B}}}{\tan(\theta_+ \pm \omega)_{\overline{1,\,3}} - \tan(\theta \pm \mu)_{\overline{3A,\,3B}}} . \qquad \text{A-10}$$

Eq. A-10 related X_3 and $(\Theta_+)_3$ for an assumed ω_3. Since all incident shock properties at 3 are interpolated, it is convenient to calculate the ratio RR1 = $(X_3 - X_{3A})/\ (X_{3B} - X_{3A})$ directly by the Newton iteration procedure. Thus,

$$f(RR1) = RR1 + \frac{Y_{3A} - Y_1}{Y_{3B} - Y_{3A}} - \left(RR1 + \frac{X_{3A} - X_1}{X_{3B} - X_{3A}}\right) \frac{X_{3B} - X_{3A}}{Y_{3B} - Y_{3A}}$$

$$\left\{ \tan\left[\frac{\pm(\omega_3 + \omega_1) + \theta_{1u} + \theta_{3A}}{2} + RR1 \quad \frac{\theta_{3B} - \theta_{3A}}{2} \right] \right\} . \qquad \text{A-12}$$

With RR1 calculated, the incident properties can be determined by

$$\begin{aligned}
X_3 &= X_{3A} + RR1(X_{3B} - X_{3A}) \\
Y_3 &= Y_{3A} + RR1(Y_{3B} - Y_{3A}) \\
(P_+)_3 &= P_{3A} + RR1(P_{3B} - P_{3A}) \\
(\theta_+)_3 &= \theta_{3A} + RR1(\theta_{3B} - \theta_{3A}) \\
(\mu_+)_3 &= \mu_{3A} + RR1(\mu_{3B} - \mu_{3A}) \\
(M_+)_3 &= M_{3A} + RR1(M_{3B} - M_{3A}) \\
(R_+)_3 &= R_{3A} + RR1(R_{3B} - R_{3A}) .
\end{aligned} \qquad \text{A-13}$$

Also, the transmitted shock properties can be determined from the following equations:

$$(P_-)_3 = (P_+)_3 \left[\frac{(M_+)_3^2 \sin^2 \omega_3 - \frac{\gamma - 1}{2\gamma}}{\frac{\gamma + 1}{2\gamma}} \right]$$

$$(R_-)_3 = (R_+)_3 \left[\frac{\frac{\gamma+1}{\gamma-1} (M_+)_3^2 \sin^2 \omega_3}{(M_+)_3^2 \sin^2 \omega_3 + \frac{2}{\gamma - 1}} \right]^{\frac{\gamma}{\gamma-1}}$$

$$\times \left\{ \frac{2\gamma}{\gamma+1} \left[(M_+)_3^2 \sin^2 \omega_3 - \frac{\gamma - 1}{2\gamma} \right] \right\}^{\frac{-1}{\gamma - 1}}$$

$$(\theta_-)_3 = (\theta_+)_3 + \delta_3$$

$$\delta_3 = \tan \left[\frac{(M_+)_3^2 \sin 2\omega_3 - 2 \cot \omega_3}{(M_+)_3^2 (\gamma + \cos 2\omega_3) + 2} \right] .$$

Before a new value for ω_3 is calculated, however, the currently calculated pressure $(P_-)_3$ is compared with the previous value to determine if the solution had converged. For this

$$\left| (P_-)_{3\,(i)} - (P_-)_{3\,(i+1)} \right| < .001 \, (P_-)_{3\,(i)}$$

is considered satisfactory. To calculate Point 4, the Newton iteration procedure is used. Thus

$$f\,(RR2) = RR2 - \left(\frac{X_2 - X_1}{Y_2 - Y_1} \right) \left[\frac{Y_3 - Y_1}{X_2 - X_1} + \left(RR2 + \frac{X_1 - X_3}{X_2 - X_1} \right) \right.$$

$$\tan \left\{ \frac{1}{2} \, RR2 \left[(\theta \pm \mu)_2 - (\theta_- \pm \mu_-)_1 \right] + \right.$$

$$\left. \left. \frac{1}{2} \left[(\theta_- + \mu_-)_1 + (\theta_- \pm \mu_-)_3 \right] \right\} \right]$$

where

$$RR2 = \frac{X_4 - X_1}{X_2 - X_1} \quad .$$

With RR2 calculated, properties at 4 are determined as

$$X_4 = X_1 + RR2\ (X_2 - X_1)$$

$$Y_4 = Y_1 + RR2\ (Y_2 - Y_1)$$

$$P_4 = P_1 + RR2\ (P_2 - P_1)$$

$$\theta_4 = \theta_1 + RR2\ (\theta_2 - \theta_1)$$

$$\mu_4 = \mu_1 + RR2\ (\mu_2 - \mu_1)$$

so that a shock angle correction $\Delta\omega$ can be calculated by

$$\Delta\omega = \frac{-\left[\frac{P_3 - P_4}{\gamma\ P_{3,4}} + \frac{\theta_3 - \theta_4}{\cos\mu_{3,4}\ \sin\mu_{3,4}}\right]}{\frac{1}{\gamma P_{3,4}}\left(\frac{\partial P_-}{\partial\omega}\right)_3 + \frac{1}{\cos\mu_{3,4}\ \sin\mu_{3,4}}\left(\frac{\partial\theta}{\partial\omega}\right)}$$

where

$$\left(\frac{d\theta}{d\omega}\right) = (\gamma + 1)\sin^2\delta_3\ \frac{(M_+)_3^{\,4}\ \sin^2\omega_3}{\left[(M_+)_3^{\,2}\ \sin^2\omega_3 - 1\right]^2} - \frac{\sin 2\ \delta_3}{\sin 2\ \omega_3} \quad .$$

The new approximation to the shock angle, therefore, is determined by the equation

$$\omega_{3\,(i+1)} = \omega_{3\,(i)} + \Delta\omega \quad . \qquad \text{A-18}$$

The process now is to recalculate the position of Point 3 using a new average value for flow properties.

This iteration procedure continues until the pressure values in two successive iterations satisfy the criterion given above.

The procedure for the field shock calculation is summarized as follows:

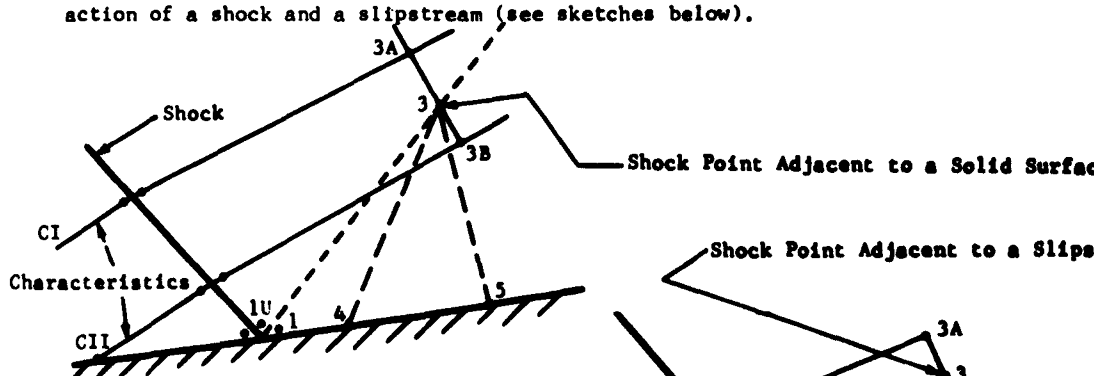
1. Assume a shock angle ω_3. The initial approximation is taken as ω_1.
2. Calculate RR1 by iterating Eq. A12 until $\left|RR1_{(i)} - RR1_{(i+1)}\right| \leq 10^{-5}$.
3. Calculate the incident and transmitted shock properties at 3 and determine if $\left|(P_-)_{3\,(i)} - (P_-)_{3\,(i+1)}\right| < .001\,(P_-)_{3\,(i)}$.
4. If the above condition is satisfied the solution is converged; otherwise, calculate RR2 by iterating Eq. A15 until

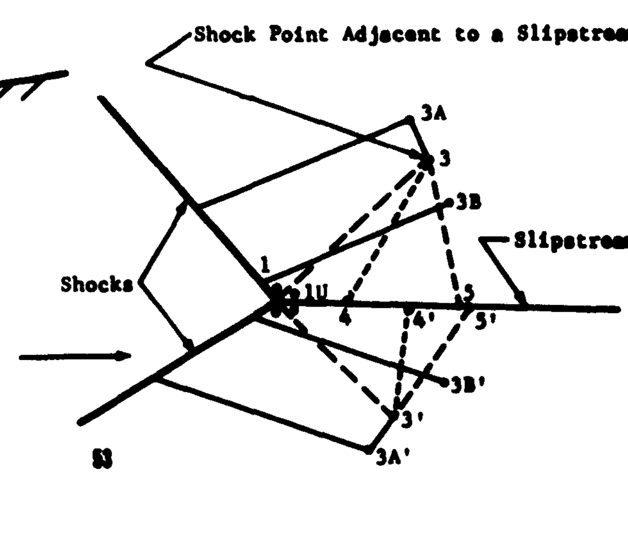
$$\left|RR2_{(i)} - RR2_{(i+1)}\right| < 10^{-5}.$$

5. Calculate a new ω_{i+1} by Eq.'s A18 and A17.
6. Go back to (1) and repeat the calculation.

SPECIAL SHOCK-BODY, SHOCK-SLIPSTREAM CALCULATION

In the previous section, the procedure for calculating a field shock was described, in which certain specific data are required for the computation. There are cases, however, that the same data are not available; these cases being the first extension of a shock wave which emanated from the body and the first extension of a shock which has arisen due to either the intersection of two shocks or the interaction of a shock and a slipstream (see sketches below).

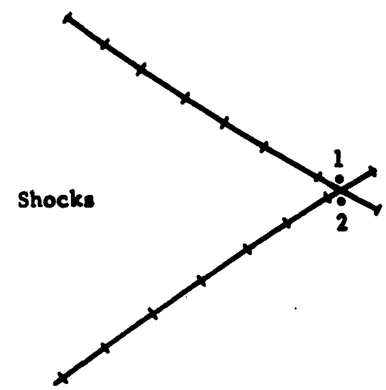




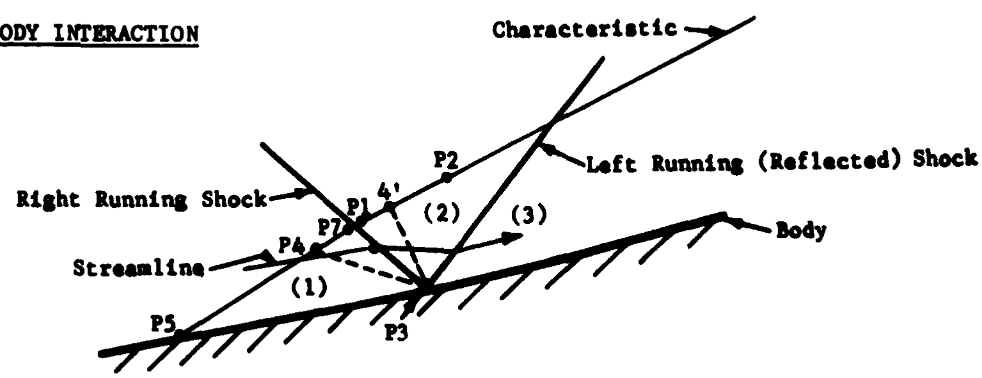
In these calculations, the data at Point 2 shown in the sketch of the previous section are not available. A body or slipstream Point 5 must be first determined by calculating a right running characteristic from Points 3 to 5 so that the values at Point 4 can be interpolated between Points 1 and 5. The body point and slipstream point calculation procedures are described in Appendix C.

INTERSECTION OF SHOCK OF THE OPPOSITE FAMILY

The location of the shock interaction of opposite family is calculated by a special curve fit procedure. This procedure utilizes the coordinate points of the two shocks to determine the location and the respective slopes at the point of shock interaction. From these slopes the shock wave angles and the incident flow properties, the transmitted shock properties (M-, P-, δ , and R- at Points 1 and 2), can be directly calculated by the oblique shock relationships given in section A-1.

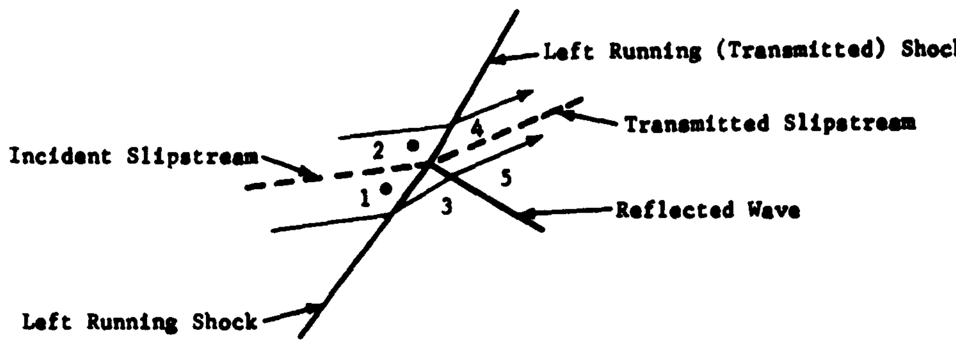


SHOCK-BODY INTERACTION



This routine calculates a shock point at the body surface P_3 from Points P_7 and P_1 in the above sketch. Here, the flow properties in regions (1) and (2) are calculated in a manner similar to the field shock procedure and the flow properties at region (3) are calculated by the oblique shock procedure. The incident properties in region (1), however, must be determined by calculating a characteristic from P_4 to P_3 (right runner in the sketch). The shock strength between regions (2) and (3) must be adjusted so that the resulting flow in region (3) is parallel to the solid surface.

SHOCK-SLIPSTREAM INTERACTION



This routine calculates the reflected wave, the transmitted shock, and the transmitted slipstream resulting from a shock-slipstream interaction. The location of the interaction point is first determined in a manner similar to that of the shock-shock interaction procedure described in Appendix A-4. The properties at Points 1 and 2 can be determined by interpolating the values along the incident slipstream which had been calculated beyond the point of interaction. Now, the procedure is to first assume a transmitted slipstream angle, and from this angle, the properties at Point 4 can be calculated by the oblique shock routine (Appendix A-1) and the properties at Point 3 can be calculated by the field shock routine (Appendix A-2). The reflected wave can be an expansion or compression type depending on the change in flow direction from Points 3 to 5. The flow angle at Point 5, of course, is the assumed transmitted slipstream angle. The properties at Point 5 are determined by the expansion routine (Appendix D) when the reflected wave is an expansion wave; when it is a compression wave, the oblique shock routine is used. The condition to be satisfied here is that the static pressure across the slipstream (Points 4 and 5) must be equal. It is seen that for each assumed transmitted slipstream angle two values of pressure (P_{4_i} and P_{5_i}) are generally obtained. The procedure, therefore, is to iterate on the transmitted slipstream angle until the pressure at Points 4 and 5 are equal.

APPENDIX B

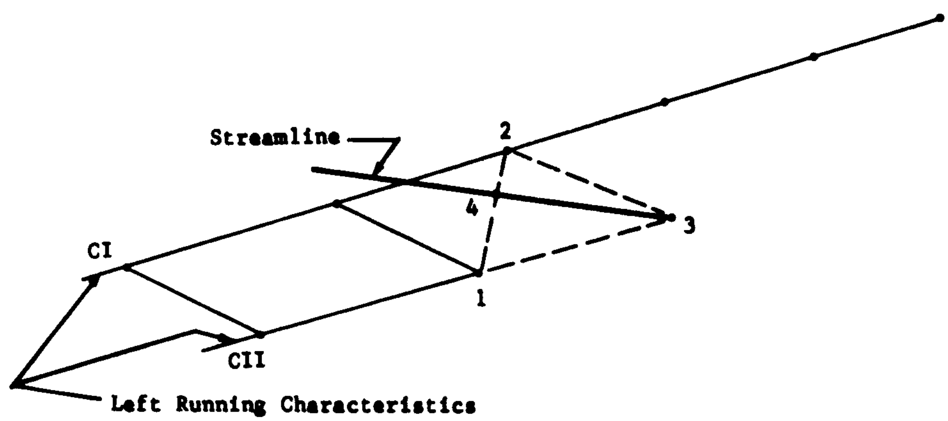
FIELD POINT CALCULATION

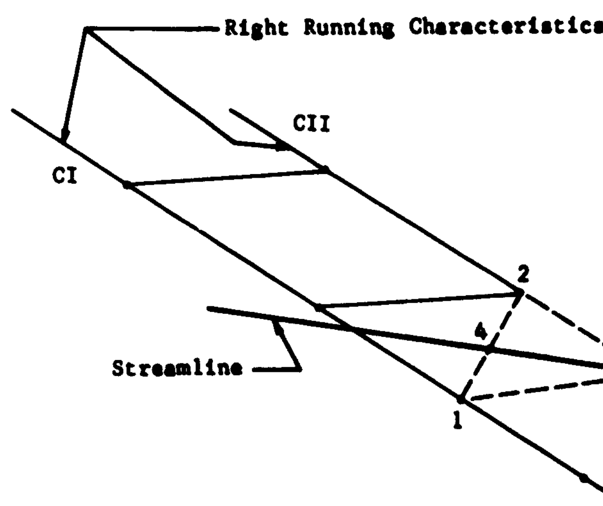
APPENDIX B

FIELD POINT CALCULATION

Field points are points at which all flow properties are continuous. The method of calculation is to determine the point of intersection of two characteristics of opposite families passing through two known base points, and compute the flow properties at this new point through the use of the compatibility equations,

$$\frac{dp}{\gamma p} \pm \frac{d\theta}{\cos\mu \sin\mu} = 0$$





The above sketches show the two base Points (1 and 2) and the point to be determined (3). Point 4 is the intersection of the upstream portion of the streamline passing through Point 3 and a straight line connecting Points 1 and 2. Since the total pressure is constant along a streamline, the total pressure at Point 3 can be determined by interpolating between 1 and 2 to obtain the value at 4. The location of Point 3 is found by solving the equations of the characteristics passing through Points 1 and 2;

$$Y_3 = \frac{\left[X_2 - X_1 - \dfrac{Y_2}{\tan(\theta \pm \mu)_{\overline{2,3}}} + \dfrac{Y_1}{\tan(\ \ \pm \mu)_{\overline{1,3}}}\right]}{\left[\dfrac{1}{\tan(\theta \pm \mu)_{\overline{1,3}}} - \dfrac{1}{\tan(\theta \pm \mu)_{\overline{2,3}}}\right]} \qquad \text{B-1}$$

$$X_3 = X_1 + \frac{Y_3 - Y_1}{\tan(\theta \pm \mu)_{\overline{1,3}}} \qquad \text{B-2}$$

where the average values ($\overline{2,3}, \overline{1,3}$) are first assumed to be the values at Points 1 and 2. Now, the compatibility equations may be solved in their finite difference form for P_3 and θ_3.

$$P_3 = P_2 + \gamma \frac{P_2 + P_3}{2} \left[\frac{\theta_3 - \theta_2}{\cos\mu_{\overline{2,3}} \sin\mu_{\overline{2,3}}}\right]$$

$$\theta_3 = \theta_2 + \frac{\dfrac{\dfrac{P_1 - P_2}{\gamma}}{\dfrac{P_1 + P_3}{2}} + \dfrac{\theta_1 - \theta_2}{\cos\mu_{\overline{1,3}} \sin\mu_{\overline{1,3}}}}{\dfrac{1}{\cos\mu_{\overline{1,3}} \sin\mu_{\overline{1,3}}} + \dfrac{\dfrac{P_2 + P_3}{2}}{\dfrac{P_1 + P_3}{2}} \dfrac{}{\cos\mu_{\overline{2,3}} \sin\mu_{\overline{2,3}}}}$$

In order to compute μ_3, the stagnation pressure ratio (R) at Point 3, is needed, and is computed by first locating Point 4. Assuming R varies linearly between Points 1 and 2, R_3 is determined by

$$R_3 = R_4 = R_2 + \frac{X_4 - X_2}{X_1 - X_2}(R_1 - R_2)$$

The only unknown in this equation is X_4 which is calculated by

$$X_4 = X_2 + \Delta X$$

where

$$\Delta X = -D \pm \sqrt{D^2 - E}$$

$$D = \frac{1}{2} \left[\frac{(X_1 - X_2)(\tan \theta_3 + \tan \theta_2)}{\tan \theta_1 - \tan \theta_2} + (X_2 - X_3) - \frac{2 (Y_1 - Y_2)}{\tan \theta_1 - \tan \theta_2} \right] \qquad \text{B-3}$$

$$E = \left(\frac{X_1 - X_2}{\tan \theta_1 - \tan \theta_2} \right) \left[(X_2 - X_3)(\tan \theta_3 - \tan \theta_2) - 2 (Y_2 - Y_3) \right]$$

These equations are derived from the following relations:

$$\frac{\tan \theta_4 - \tan \theta_2}{\tan \theta_1 - \tan \theta_2} = \frac{X_4 - X_2}{X_1 - X_2}$$

$$\frac{Y_4 - Y_3}{X_4 - X_3} = \frac{1}{2} (\tan \theta_4 - \tan \theta_3)$$

$$\frac{Y_1 - Y_2}{X_1 - X_2} = \frac{Y_4 - Y_2}{X_4 - X_2}$$

which assume a linear variation of the flow properties between Points 1 and 2. The root being used in equation B-3 is the one which makes $\left| \frac{1}{2} - \frac{E}{X_1 - X_2} \right|$ a minimum.

Finally, the Mach angle at Point 3 (μ_3) is calculated from

$$\mu_3 = \tan^{-1} \left\{ \frac{2}{1-\gamma} \left[1 - \left(\frac{P_3}{R_3} \right)^{\frac{1-\gamma}{\gamma}} \right] - 1 \right\}^{\frac{1}{2}}$$

This completes one cycle of the calculation of Point 3. These new flow properties are used to determine new average values ($\overline{1,3}$, $\overline{2,3}$) which are substituted back into the geometric equations (B-1 and B-2) to recalculate a new location of Point 3. The calculation is repeated until

$$\left| P_{3(i)} - P_{3(i-1)} \right| \leq .001\, P_{3(i)}$$

at which time the calculation of the field point is complete.

APPENDIX C

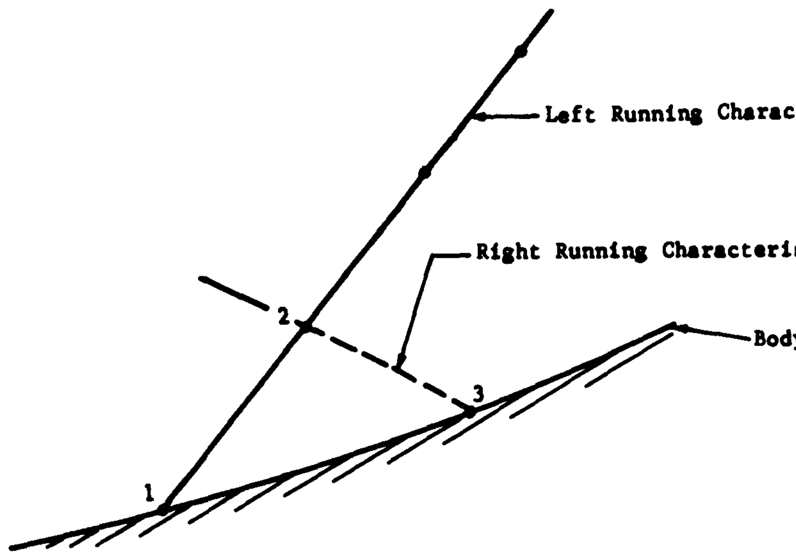
BOUNDARY POINT CALCULATION

APPENDIX C

BOUNDARY POINT CALCULATION

Boundary points considered here are those being calculated along the solid surfaces and slipstreams.

SOLID BOUNDARY



In the above sketch, a body Point 3 is to be determined by calculating along a characteristic from 2. Since the total pressure is constant along a solid surface, the total pressure at 3 is obtained from the known value at 1.

The procedure is to first approximate the location of Point 3. The body curvature is defined locally by a cubic in the form

$$Y = AX^3 + BX^2 + CX + D \ , \qquad \text{C-1}$$

and the characteristic equation between 2 and 3 is given as

$$\frac{Y_3 - Y_2}{X_3 - X_2} = \tan\,(\theta \pm \mu)_{\overline{2,3}} \qquad \text{C-2}$$

Combining, we have

$$f(X_3) = AX_3^3 + BX_3^2 + CX_3 + D - Y_3 - (X_3 - X_2)\tan(\theta \pm \mu)_{\overline{2,3}} \qquad \text{C-3}$$

from which X_3 can be determined by a Newton iteration procedure. With X_3 computed, the properties (θ, P, μ) at 3 can be determined directly by

$$\theta_3 = \tan^{-1}(Y_3) = \tan^{-1}(3AX_3^2 + 2BX_3 + C)$$

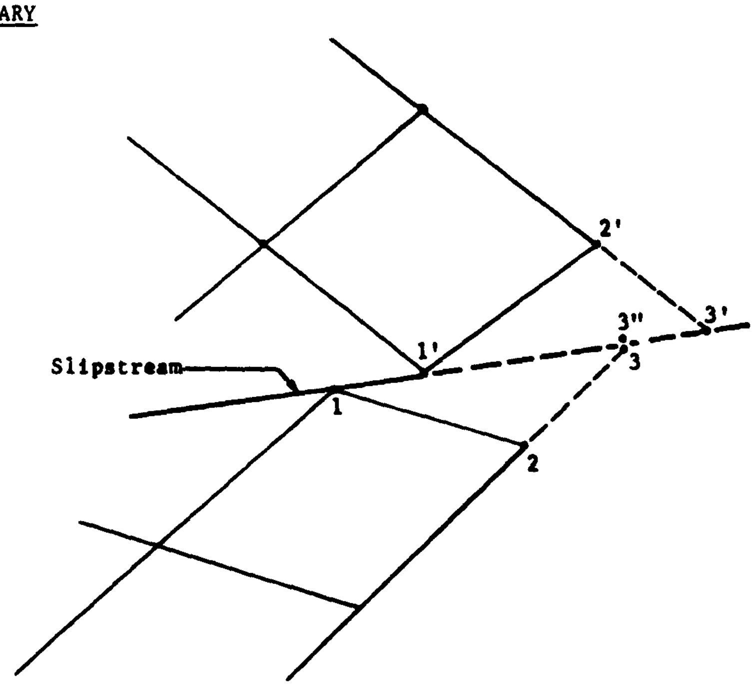
$$P_3 = P_2 + \gamma \overline{P_{2,3}} \left[\pm \frac{\theta 3 - \theta 2}{\overline{\cos(\mu)_{2,3}} \, \overline{\sin(\mu)_{2,3}}} \right]$$

$$\mu_3 = \tan^{-1} \sqrt{\frac{1}{\frac{2}{1-\gamma}\left[1 - \left(\frac{P_3}{R_3}\right)^{\frac{\gamma-1}{\gamma}}\right] - 1}}$$

With these properties determined, a new set of average properties $\overline{(2, 3)}$ can now be calculated, and hence, a new approximate location of X_3 can be determined. The calculation is repeated until

$$\left| P_{3(i+1)} - P_{3(i)} \right| \leq .001 \, P_{3(i)}$$

SLIPSTREAM BOUNDARY



In the sketch on the previous page, Points 3 and 3' on the slipstream are to be calculated from Points 2 and 2' respectively. The procedure for calculating points on slipstream is similar to that for a solid surface except that here, the boundary location is not given and must be determined by matching the condition calculated from both sides of the slipstream. The conditions to be satisfied along a streamline are that the flow direction and static pressure must be equal.

Each segment of the streamline is assumed to be a straight line. Thus, by assuming a slipstream direction (from Point 1 to Point 3') the properties at Points 3 and 3' can be calculated by a procedure similar to that of a solid boundary. In order to compare the pressure at the same location along the slipstream, however, a P_3'' is interpolated between Points 1' and 3' which should be equal to P_3. In this way, by assuming a series of slipstream directions, a table of P_3 and P_3'' vs the slipstream angle can be established. The solution of the slipstream angle will be the value at which $P_3 = P_3''$. This value can be calculated by the special curve fit procedure (Subroutine MEET) which determines the intersection point of two given curves.

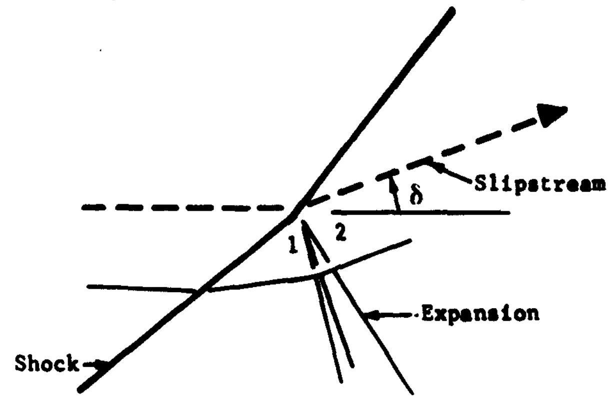
APPENDIX D

EXPANSION WAVE CALCULATION

APPENDIX D

EXPANSION WAVE CALCULATION

The configuration considered in the present program is shown in the sketch below where a discontinuity in flow direction is caused by a shock slipstream interaction.



The calculation here is to determine the flow properties at 2 for a given flow deflection angle δ which is equal to the increase in the Prandtl-Meyer angle $\nu(M)$ from 1 to 2. The Prandtl-Meyer angle is defined as

$$\nu(M) = \sqrt{\frac{\gamma+1}{\gamma-1}} \tan^{-1} \sqrt{\frac{\gamma-1}{\gamma+1} (M^2-1)} - \tan^{-1} \sqrt{M^2-1} \qquad \text{D-1}$$

From a known Mach number at 1 (M_1), ν_1 (M_1) can be directly calculated. To determine M_2 for a given deflection angle, however, an iteration must be carried out. The flow deflection δ, is related to the Prandtl-Meyer angle by

$$\delta = \nu_2(M_2) - \nu_1(M_1) \qquad \text{D-2}$$

The method of calculation is to first establish a table of M vs ν (Eq. D-1) and by interpolating this table, M_2 can be determined directly from a ν_2 calculated by Eq. D-2. Thus, from M_2, the properties at 2 can be calculated from

$$P_2 = R_2\left(1 + \frac{\gamma-1}{2} M_2^2\right)^{-\frac{\gamma}{\gamma-1}}$$

$$\mu_2 = \tan^{-1}\left(\frac{1}{\sqrt{M_2^2-1}}\right)$$

where $R_2 = R_1$, since the flow expansion from 1 to 2 is isentropic.

APPENDIX E

AUXILIARY SUBROUTINES

APPENDIX E

AUXILIARY SUBROUTINES

SUBROUTINES CURFIT *

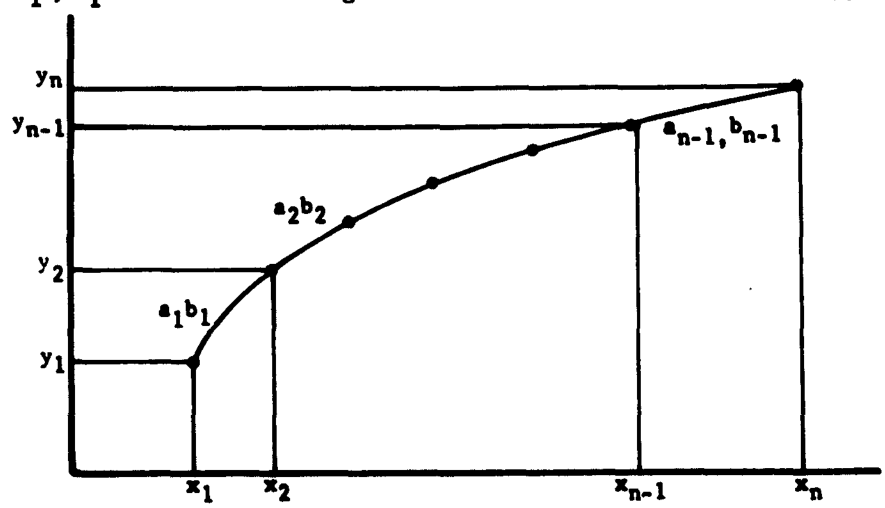
Subroutine CURFIT computes the coefficients of the curve-fit function

$$y = f_i(x)$$

for a given table of y vs x such that the first and second derivations $[f_i'(x),\ f_i''(x)]$ are continuous within the range of the given table. The function $f_i(x)$ is defined as

$$y = y_i + \frac{y_{i+1} - y_i}{x_{i+1} - x_i}(x - x_i) + a_i(x - x_i)(x_{i+1} - x) + b_i(x-x_i)^2(x_{i+1} - x) \qquad \text{E-1}$$

which is a cubic expression defined by the points at i and i+1, and the two coefficients (a_i, b_i) for each of the given i^{th} intervals (see sketch below).



The coefficients a_i and b_i are determined by setting the first and second derivatives of the interpolation formulae for the ith and (i+1) th intervals equal at $x = x_{i+1}$. That is

$$\left(\frac{dy}{dx}\right)_i \Big|_{x=x_{i+1}} = \left(\frac{dy}{dx}\right)_{i+1} \Big|_{x=x_{i+1}} \qquad \text{E-2}$$

* This routine is an extension of the SHARE subroutine E2-GEFCDIS.

$$\left(\frac{d^2y}{dx^2}\right)_i \Bigg|_{x = x_{i+1}} = \left(\frac{d^2y}{dx^2}\right)_{i+1} \Bigg|_{x = x_{i+1}} \qquad \text{E-3}$$

Substitute Eq. E-1 into E-2 and E-3 respectively; one obtains

$$\left[\frac{(x_{i+1}-x_i)}{(x_{i+2}-x_{i+1})}\right] a_i + \left[\frac{(x_{i+1}-x_i)^2}{(x_{i+2}-x_{i+1})}\right] b_i + a_{i+1}$$

$$= \frac{(y_{i+1}-y_i)}{(x_{i+1}-x_i)(x_{i+2}-x_{i+1})} - \frac{(y_{i+2}-y_{i+1})}{(x_{i+2}-x_{i+1})^2} \qquad \text{E-4}$$

$$\frac{(x_{i+1}-x_i)}{(x_{i+2}-x_{i+1})} b_i - \frac{(x_{i+2}-x)}{(x_{i+1}-x_i)(x_{i+2}-x_{i+1})} a_{i+1} + b_{i+1}$$

$$= \frac{(y_{i+2}-y_{i+1})}{(x_{i+1}-x_i)(x_{i+2}-x_{i+1})^2} - \frac{(y_{i+1}-y_i)}{(x_{i+1}-x_i)^2(x_{i+2}-x_{i+1})} \qquad \text{E-5}$$

Equations E-4 and E-5 apply for the $i + 2$, $n-2$ intervals, and hence, represent a system of $2n-4$ equations in $2n-2$ unknowns. Two additional equations, therefore, are needed, and they can be obtained by specifying either the first or second derivatives at both ends of the table. These equations are

$$\left(\frac{dy}{dx}\right)_{x=x_1} = \frac{y_2 - y_1}{x_2 - x_1} + a_1(x_2 - x_1)$$

$$\left(\frac{d^2y}{dx^2}\right)_{x=x_1} = -2a_1 + 2b_1(x_2 - x_1) \qquad \text{E-6}$$

$$\left(\frac{dy}{dx}\right)_{x=x_n} = \frac{y_n - y_{n-1}}{x_n - x_{n-1}} - a_{n-1}(x_n - x_{n-1}) - b_{n-1}(x_n - x_{n-1})^2$$

$$\left(\frac{d^2y}{dx^2}\right)_{x=x_n} = -2a_{n-1} + 4b_{n-1}(x_n - x_{n-1}) \qquad \text{E-7}$$

Equations E-4, E-5, E-6 and E-7 represent a tri-diagonal matrix system of the simultaneous linear equations in a_i and b_i. Hence, the solution (a_i, b_i) can be obtained by a special matrix inversion procedure which is done in CURFIT.

SUBROUTINE CURVE

Subroutine CURVE utilizes the curve fit coefficient computed in subroutine CURFIT to calculate the quantities $y(x)$ and $y'(x)$ for a given x. The subroutine will also perform straight line extrapolations beyond both ends of the table.

SUBROUTINE CUBIC

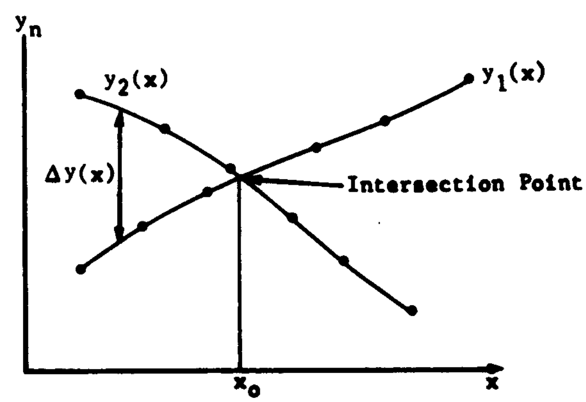
Subroutine CUBIC recalculates coefficients computed by subroutine CURFIT to those corresponding to equations of the form

$$y(x) = Ax^3 + Bx^2 + Cx + D$$

A combination of straight lines and cubic curves can be also fitted smoothly within a given table.

SUBROUTINE MEET

Subroutine MEET determines the intersection point of two given curves which are specified as two independent tables $y_1(x)$ and $y_2(x)$



By using subroutine CURFIT, a table of x vs $\Delta y(x)$ can be first established, where

$$\Delta y(x) = y_2(x) - y_1(x)$$

This table can then be curve fitted to obtain x_o of the intersection point where $\Delta y = o$. With x_o determined, therefore, the y and the derivatives $y'_1(x_o)$ and $y'_2(x_o)$ at the intersection point can be again determined by subroutine CURFIT.

APPENDIX F

DESCRIPTION OF DATA INPUT

AND OUTPUT

APPENDIX F

DESCRIPTION OF DATA INPUT
AND OUTPUT

INPUT

This program requires the following input data:

(1) A title or job description card.
(2) Blade type indicator (sharp or blunt leading edges).
(3) M_∞ - free stream Mach number.
(4) P_∞ - free stream pressure (atmospheres).
(5) T_∞ - free stream temperature (°K).
(6) γ - specific heat ratio.
(7) Channel geometry - in numerical form. Two X vs Y tables must be provided, one for the upper (expansion) surface and the other for the lower (compression) surface. For blunt leading edge cases, the leading edge radii, the location of the radius centers, and the tangent point angles (θ_U and θ_L, in degrees) are also required. The formats and the ordering of the data are described in Table F-1.

In preparing the input data, the following assumptions and rules should be observed:

1) N_U, N_L cannot be greater than 20 for a sharp leading edge case and cannot be greater than 18 for a blunt leading edge case.
2) $R_L = R_U$.
3) $\theta_L, \theta_U > 65°$.
4) To be compatible with the present boundary layer program, γ should be set equal to 1.4.
5) For a sharp leading edge case, straight lines are fitted for the first and the last segments in the two X vs Y tables (between Points 1 and 2 and between Points N-1 and N). If the surfaces are curvilinear in those regions, these points should be closely tabulated so that the straight line approximation is valid.
6) For a blunt leading edge case, the first tabulated point on each surface is the tangent point, and the first interval should be greater than one leading edge radius. This is required to fit a smooth curve in that region. A key punch form and two examples of data input are included in the following:

TABLE F1

INPUT DATA AND FORMAT

FORMAT*	DATA	DESCRIPTION	No. of CARDS
(10A6)	Title or Job Description Card	Maximum of 60 alphanumeric characters col. 1-60).	1
(I1, 9X, 4F10.6)	IND, M_∞, P_∞, T_∞,	IND = 1 for sharp leading edge IND = 2 for blunt leading edge	1
(I5, 4F10.6/ (6F10.6))	N_U, R_U, θ_U, X_{CU}, Y_{CU}, ($X_U(I)$, $Y_U(I)$, I = 1, N_U)	Upper surface geometry Symbols are defined in Figures F1 & F2. For sharp leading-edge case, R_U, θ_U, X_{CU}, Y_{CU} data are not required.	1 + 1 per 3 points
(I5, 4F10.6/ (6F10.6))	N_L, R_L, θ_L, X_{CL}, Y_{CL}, (($X_L(I)$, $Y_L(I)$, I = 1, N_L)	Lower surface geometry. Symbols are defined in Figures F1 & F2. For sharp leading edge case, R_L, θ_L, X_{CL}, Y_{CL} data are not required.	1 + 1 per 3 points

* In FORTRAN II Language

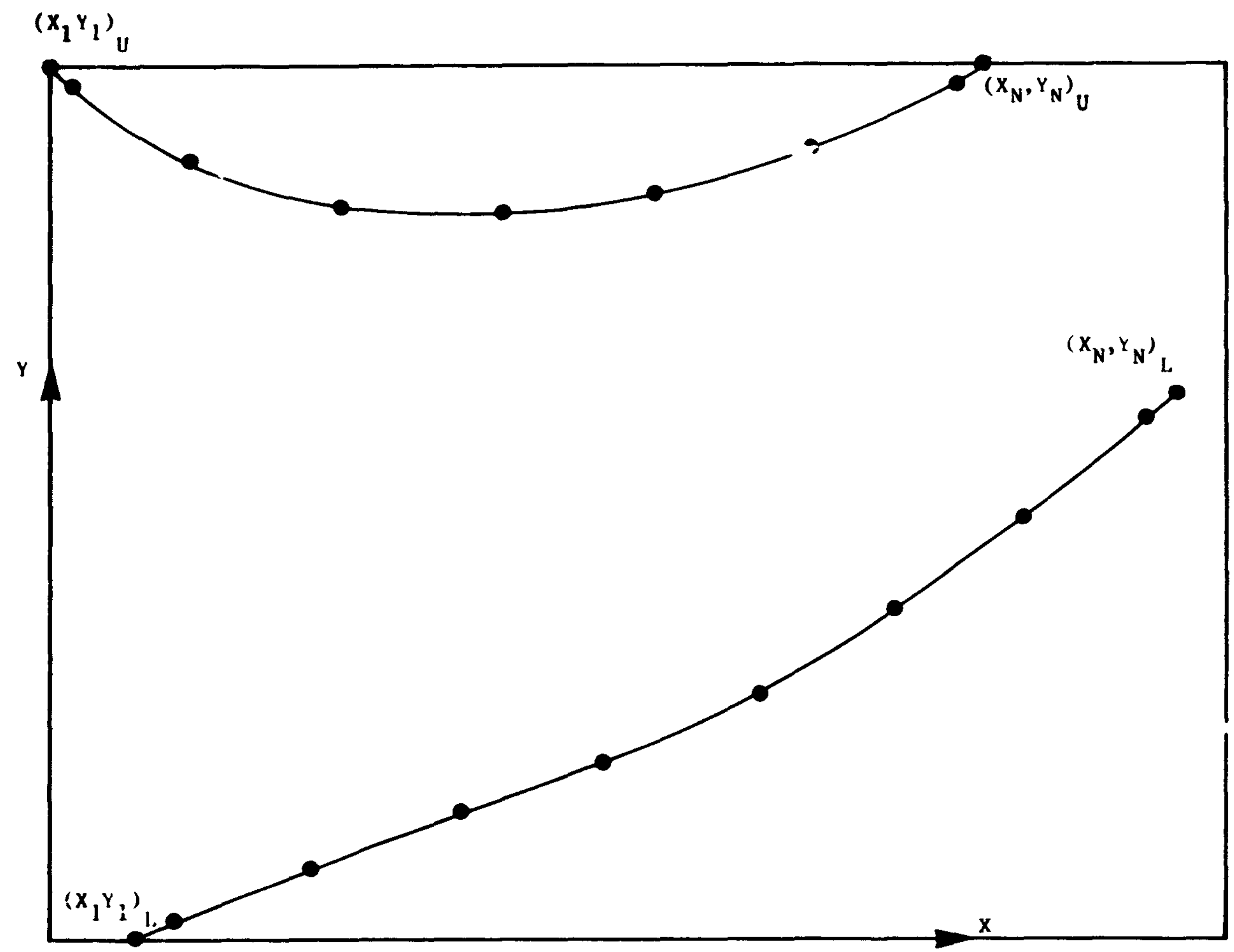


FIGURE F1 SHARP LEADING-EDGE CHANNEL GEOMETRY INPUT

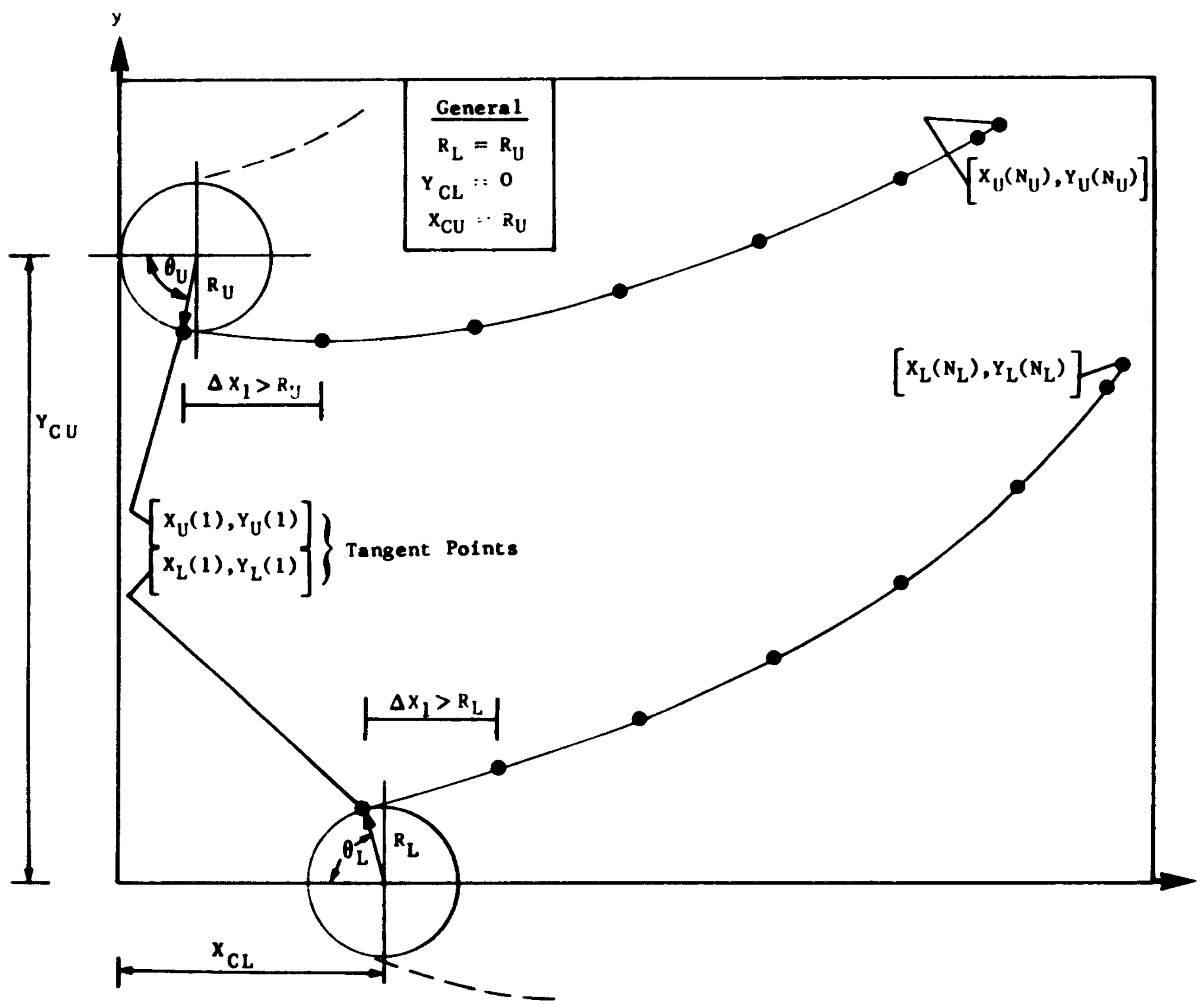


FIGURE F2 BLUNT LEADING-EDGE CHANNEL GEOMETRY INPUT

KEY PUNCH FORM - GENERAL PURPOSE
Form 20-700 (R.1-60)

JOB TITLE	ENGINEER	PAGE OF
EWO NO. / FOR ORGN. NO.	ANALYST	DATE

TURNING VANE INPUT DATA

TITLE CARD (ALPHANUMERIC COLS. 1 - 60)

M	M_∞	P_∞	T_∞	γ	
N_U	R_U	$\beta_U{}^\circ$	X_{CU}	Y_{CU}	
X_{U1}	Y_{U1}	X_{U2}	Y_{U2}	X_{U3}	Y_{U3}
X_{NU-2}	Y_{NU-2}	X_{NU-1}	Y_{NU-1}	X_{NU}	Y_{NU}
N_L	R_L	$\beta_L{}^\circ$	X_{CL}	Y_{CL}	
X_{L1}	Y_{L1}	X_{L2}	Y_{L2}	X_{L3}	Y_{L3}
X_{NL-2}	Y_{NL-2}	X_{NL-1}	Y_{NL-1}	X_{NL}	Y_{NL}

KEY PUNCH FORM - GENERAL PURPOSE
Form 20-708 (R.1-60)

JOB TITLE	ENGINEER	PAGE OF
SEC CODE / DIV. / SALES ORDER / DASH / EWO NO. / FOR ORGN. NO.	ANALYST	DATE

INPUT DATA FOR MACH 4 BLUNT LEADING EDGE CASE

```
    TURNING  VANE     BLUNT  LEADING  EDGE
2           4.0      .006586   .2381     1.4
   9   1.0        -90.0       1.0       12.0
 1.0        11.0      3.0     11.2       5.0       11.45
 7.0        12.0      9.0     12.8      11.0       13.9
 3.0        15.35    15.0     17.22     15.68      18.0
  11   1.0        65.0       4.0        0.0
 3.5          .88     5.0      1.48      6.0        1.8505
 7.0         2.225    8.0      2.660     9.0        3.219
11.0         4.55    12.12     5.375    13.0        6.05
13.92        7.025   15.54     8.11
```

KEY PUNCH FORM - GENERAL PURPOSE
Form 20-708 (R.1-60)

JOB TITLE			ENGINEER	PAGE OF
CONTROL NO. / SALES ORDER / BASE	EWO NO.	FOR ORGN. NO.	ANALYST	DATE

INPUT DATA FOR MACH 6 SHARP LEADING EDGE CASE

```
     TURNING VANE     SHARP  LEADING  EDGE
1            6.0       .006586  270.0      1.4
  11
 0.0       12.0        2.0       11.475     4.0       11.015
 6.0       10.7        8.0       10.569    10.0       10.64
12.0       11.09      14.0       12.07     16.0       13.47
17.5       14.77      19.5       16.79
  8
 0.0        0.0        5.0        1.81      9.0        3.352
11.0        4.248     13.0        5.338    15.0        6.735
17.0        8.50      25.0       16.68
```

OUTPUT

I INVISCID PROGRAM

(1) Job title
(2) M_∞
P_∞ (atm)
T_∞ (°K)
(3) Body Description

X Y A B C D

where (X, Y) - input points
(A, B, C, D) - coefficients of cubics

(4) Characteristic Output (along a characteristic)

X Y P THETA ZMU R INDICATOR W

P - $P/P_{t\infty}$
THETA - Flow Direction (radians)
ZMU - Mach Angle (radians)
R - $P_t/P_{t\infty}$
Indicator - defines point type - shock, body, vortex, or field
(field points are denoted by ***)
W - shock angle (radians)

II BOUNDARY DATA FOR BOUNDARY LAYER CALCULATION

(1) Boundary Layer Input Data - Upper surface

T2T1 = temperature ratio
P2P1 = pressure ratio
U2U1 = velocity ratio
across the primary shock at leading edge
P3P2 = pressure ratio across shock body interaction point,

X Y Surface Distance (X') Velocity (U'/Q_o')

(2) Boundary Layer Input Data - Lower surface

T2T1 = temperature ratio
P2P1 = pressure ratio
U2U1 = velocity ratio
across primary shock at leading edge

P3P2 = pressure ratio across shock body interaction point

X	Y	Surface Distance (X')	Velocity (U'/Q_o')
↓	↓	↓	↓

III BOUNDARY LAYER PROGRAM

(1)

		Shock	
	T(1)	*	T(2)
M(1)	P(1)	*	P(2)
	U(1)	*	U(2)
		*	
		*	
		*	
		*	
free stream properties			Properties across primary shock

where

T - temperature (^oK)
P - pressure (atm)
U - velocity (ft/sec)

(2) RE/FT - Reynolds number per ft.

(3) L(O) - L_o'
SOLAR HEAT (set to zero)
EMISSIVITY OF SURFACE (set to zero)
DEL 1, DEL 2 (Surface distance over which pressure jump is being spread fore and aft of a shock boundary layer interaction point)

(4) INVISCID DATA

S(surface distance)	U* (U'/Q_o')
↓	↓

Shock boundary layer interaction comment

(5) FIX DATA

$\underline{S\ (\xi^2)}$ ↓ $\qquad$ $\underline{U^*\ (U'/Q_o')}$ ↓

(6)

I, J, V, T

where

I, J - integration step counter in the longitudinal and transverse directions

V - inviscid transverse velocity component

T - non-dimensional temperature

A - coefficients

} defined in List of Symbols (Boundary Layer Equations)

XI-SQ(ξ^2)

CP (C_p) - pressure coefficient = $\dfrac{P - P_\infty}{\frac{\gamma}{2} P_\infty M_\infty^2}$

U* (U'/Qo) - velocity ratio

T* - inviscid temperature (^{o}K)

F(O)* - suction velocity (set to zero)

(7) I, J - defined in (6)

<u>K</u> ↓ $\quad$ <u>V</u> ↓ $\quad$ <u>T</u> ↓ $\quad$ <u>PHI</u> ↓ $\quad$ <u>MU</u> ↓ $\quad$ <u>S</u> ↓ $\quad$ <u>N</u> ↓ $\quad$ <u>Z</u> ↓

K - vertical step counter

V - transverse velocity component (v)

T - non-dimensional temperature (t)

PHI - non-dimensional shear parameters (φ)

MU - non-dimensional viscosity (μ)

} defined in List of Symbols (Boundary Layer Equations)

S - longitudinal velocity component (parallel to Q)

N - transverse velocity component (perpendicular to Q)

Z - vertical distance

DELS = δ^* (displacement thickness)

DELSS= δ^{**} (momentum thickness)

APPENDIX G

FORTRAN PROGRAM LISTING

```
C        TURNING VANE PROGRAM                                            950J1000
C                                                                        950J1001
      DIMENSION IND(100),X(100),Y(100)                                   950J1002
      DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),     950J1003
     1          XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)                  950J1004
      DIMENSION AC1(6,20),AC2(6,20)                                      950J1005
      DIMENSION ARRAY(12)                                                950J1006
C                                                                        950J1007
      COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2             950J1008
      COMMON GAMMA,FSM,FSP,FST,SW                                        950J1009
C                                                                        950J1010
      EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(950J1011
     15),ZMU1),                                                          950J1012
     2(XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),    950J1013
     3(XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),    950J1014
     4(XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),    950J1015
     5(XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),    950J1016
     6(XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),    950J1017
     7(XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),950J1018
     1 ZMU3A)                                                            950J1019
      EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),    950J1020
     1  (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),              950J1021
     2  (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),              950J1022
     3  (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),              950J1023
     4  (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),      950J1024
     5  (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),      950J1025
     8(XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),950J1026
     1 ZMU3B),                                                           950J1027
     9(XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),                950J1028
     6(XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)                 950J1029
      EQUIVALENCE (XX1(10),NPONT1),(XX2(10),NPONT2),                     950J1030
```

```
     1  (XX3(10),NPONT3),(XX5(10),NPONT5)                          950J1031
C                                                                  950J1032
 400  FORMAT (6F10.6)                                              950J1033
 401  FORMAT (10I1,5F10.6)                                         950J1034
 402  FORMAT (48X10HINPUT DATA///10X20HFREE STREAM MACH NO.,       950J1035
     1  1PE15.5/10X20HFREE STREAM PRESSURE,1PE15.5/10X,            950J1036
     2  23HFREE STREAM TEMPERATURE,1PE15.5///)                     950J1037
 410  FORMAT (44X,16HBODY DESCRIPTION//10X1HX,16X1HY,33X1HA,       950J1038
     4  16X1HB,16X1HC,16X1HD//)                                    950J1039
 403  FORMAT (12A6)                                                950J1040
 404  FORMAT (I5,2E10.5)                                           950J1041
 409  FORMAT (1P2E17.7/52X,1P4E17.7)                               950J1042
      READ INPUT TAPE 5,403,(ARRAY(I),I=1,12)                      950J1043
      CALL PAGE2 (-1,ARRAY)                                        950J1044
C                                                                  950J1045
      READ INPUT TAPE 5,401,(M(I),I=1,10),FSM,FSP,FST,GAMMA        950J1046
      WRITE OUTPUT TAPE 6,402,FSM,FSP,FST                          950J1047
      REWIND 2                                                     950J1048
      WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY                       950J1049
      IF (M(1)-2) 50,888,50                                        950J1050
 888  CALL CHAIN (7,8)                                             950J1051
C                                                                  950J1052
 50   CONTINUE                                                     950J1053
      WRITE OUTPUT TAPE 6,410                                      950J1054
      READ INPUT TAPE 5,404,N1,S1,S2                               950J1055
      READ INPUT TAPE 5,400,(X(I),Y(I),I=1,N1)                     950J1056
      DO 10 I=1,20                                                 950J
 10   IND(I) = 0                                                   950J
      IND(1) = 1
      IND(N1-1) =1
      CALL CUBIC (X,Y,IND,N1,S1,S2,AC1)                            950J1057
      NN = N1                                                      950J1058
      N = 0                                                        950J1059
C                                                                  950J1060
 70   DO 100 I=2,NN                                                950J1061
C                                                                  950J1062
      IF (N) 80,80,90                                              950J1063
 80   WRITE OUTPUT TAPE 6,409,X(I-1),Y(I-1),AC1(2,I-1),AC1(3,I-    950J1064
     11),  AC1(4,I-1),AC1(5,I-1)                                   950J1065
      GO TO 100                                                    950J1066
C                                                                  950J1067
```

```
 90   WRITE OUTPUT TAPE 6,409,X(I-1),Y(I-1),AC2(2,I-1),AC2(3,I-          950J1068
     11),  AC2(4,I-1),AC2(5,I-1)                                          950J1069
C                                                                         950J1070
 100  CONTINUE                                                            950J1071
      IF (N) 110,110,120                                                  950J1072
 110  N = 1                                                               950J1073
      WRITE OUTPUT TAPE 6,409,X(N1),Y(N1)                                 950J1074
      READ INPUT TAPE 5,404,N2,S1,S2                                      950J1075
      NN = N2                                                             950J1076
      READ INPUT TAPE 5,400,(X(I),Y(I),I=1,N2)
      DO 20 I=1,20                                                        950J
 20   IND(I) = 0                                                          950J
      IND(1) = 1
      IND(N2-1) = 1
      CALL CUBIC (X,Y,IND,N2,S1,S2,AC2)                                   950J1078
      GO TO 70                                                            950J1079
 120  WRITE OUTPUT TAPE 6,409,X(N2),Y(N2)                                 950J1080
      N1 = N1-1                                                           950J1081
      N2 = N2-1                                                           950J1082
      WRITE TAPE 2,AC1,AC2,N1,N2                                          950J1083
      CALL LOCATE (-1,T,ITT,DUM,DUM,DUM,DUM,DUM)                          950J1084
C                                                                         950J1085
C     TEST TYPE BODY.                                                     950J1086
C                                                                         950J1087
      IF (M(1)-1) 999,130,999                                             950J1088
C                                                                         950J1089
 130  CALL PAGE2 (0,ARRAY)                                                950J1090
      CALL WEDGE                                                          950J1091
      CALL CHAIN (2,8)                                                    950J1092
C                                                                         950J1093
 999  CALLDUMP                                                            950J1094
      END
```

```
      SUBROUTINE WEDGE                                                  950JA000
*     LABEL
 950JA                                                                  950JA
C                                                                       950JA001
      DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),    950JA002
     1          XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)                 950JA003
      DIMENSION AC1(6,20),AC2(6,20)                                     950JA004
C                                                                       950JA005
      COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2            950JA006
      COMMON GAMMA,FSM,FSP,FST,SW                                       950JA007
C                                                                       950JA008
      EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(950JA009
     15),ZMU1),                                                         950JA010
     2(XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),   950JA011
     3(XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),   950JA012
     4(XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),   950JA013
     5(XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),   950JA014
     6(XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),   950JA015
     7(XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),950JA016
     1 ZMU3A)                                                           950JA017
      EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),   950JA018
     1  (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),             950JA019
     2  (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),             950JA020
     3  (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),             950JA021
     4  (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),     950JA022
     5  (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),     950JA023
     8(XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),950JA024
     1 ZMU3B),                                                          950JA025
     9(XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),               950JA026
     6(XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)                950JA027
C                                                                       950JA028
      EQUIVALENCE (XX3(7),NPT3),(XX1(7),NPT1),(NPT5,XX5(7))             950JA029
      EQUIVALENCE (XX1(10),NPONT1),(XX2(10),NPONT2),                    950JA030
     1  (XX3(10),NPONT3),(XX5(10),NPONT5)                               950JA031
  100 FORMAT (1P6E15.5)                                                 950JA032
      REWIND 3                                                          950JA033
      REWIND 4                                                          950JA034
C                                                                       950JA035
C     CALCULATION ON UPPER BODY                                         950JA036
C                                                                       950JA037
```

```
      X1 = AC1(1,1)                                                     950JA038
      Y1 = ((AC1(2,1)*X1+AC1(3,1))*X1+AC1(4,1))                         950JA039
     1  *X1+AC1(5,1)                                                    950JA040
      TH1 = 0.0                                                         950JA041
      R1 = 1.0                                                          950JA042
      STH = ATANF((3.*AC1(2,1)*X1+2.*AC1(3,1))*X1+AC1(4,1))             950JA043
      FSMS = FSM**2                                                     950JA044
      P1 = (1.+(GAMMA-1.)/2.*FSMS)**(-GAMMA/(GAMMA-1.))                 950JA045
      ZMU1 = ATANF(SQRTF(1./(FSMS-1.)))                                 950JA046
      W1 = ZMU1                                                         950JA047
      ZZMU = ZMU1                                                       950JA048
      PP1 = P1                                                          950JA049
      CALL SHK1 (-1.0,STH,XX1,XX3,GAMMA,M1)                             950JA050
      IF (M1-1) 999,20,999                                              950JA051
   20 NPT3 = -2                                                         950JA052
      NPT1 = -1                                                         950JA053
      CALL DMOVE (W,XX3)                                                950JA054
      NPT1 = 12345                                                      950JA055
      CALL DMOVE (W(1,2),XX1)                                           950JA056
      CALL STORE (B,W,3,M,ARRAY)                                        950JA057
C                                                                       950JA058
      CALL SHOCK (1,M1,-1.,XXA,XXB,XX1,XX3,XX2,XX3U,XX3,XX5,            950JA059
     1  GAMMA,.10,FSM)                                                  950JA060
      IF (M1-1) 999,10,999                                              950JA061
   10 NPT3 = 2                                                          950JA062
      NPT5 = -2                                                         950JA063
C                                                                       950JA064
      XX3(8) = -XX3(8)                                                  950JA065
      CALL DMOVE (W,XX3)                                                950JA066
      CALL DMOVE (W(1,2),XX5)                                           950JA067
      NPT1 = 12345                                                      950JA068
      CALL DMOVE (W(1,3),XX1)                                           950JA069
      CALL STORE (B,W,3,M,ARRAY)                                        950JA070
C                                                                       950JA071
C     CALCULATION ON LOWER BODY                                         950JA072
C                                                                       950JA073
      X1 = AC2(1,1)                                                     950JA074
      Y1 =((AC2(2,1)*X1+AC2(3,1))*X1+AC2(4,1))*X1+AC2(5,1)              950JA075
      TH1 = 0.0                                                         950JA076
      R1 = 1.0                                                          950JA077
      STH = ATANF((3.*AC2(2,1)*X1+2.*AC2(3,1))*X1+AC2(4,1))             950JA078
```

```
      W1 = ZZMU                                                         950JA079
      P1 = PP1                                                          950JA080
      ZMU1 = ZZMU                                                       950JA081
C                                                                       950JA082
      ZMU1 = ATANF(SQRTF(1./(FSMS-1.)))                                 950JA083
      CALL SHK1 (1.0,STH,XX1,XX3,GAMMA,M1)                              950JA084
      IF (M1-1) 999,30,999                                              950JA085
   30 NPT3 = -1                                                         950JA086
      CALL DMOVE (W,XX3)                                                950JA087
      NPT1 = 12345                                                      950JA088
      CALL DMOVE (W(1,2),XX1)                                           950JA089
      CALL STORE (B,W,4,M,ARRAY)                                        950JA090
C                                                                       950JA091
      NPT3 = 1                                                          950JA092
      NPT5 = -1                                                         950JA093
      CALL SHOCK (1,M1,1.,XXA,XXB,XX1,XX3,XX2,XX3U,XX3,XX5,GAMMA,.1,    950JA094
     1  FSM)                                                            950JA095
      IF (M1-1) 999,50,999                                              950JA096
   50 CALL DMOVE (W,XX3)                                                950JA097
C                                                                       950JA098
      CALL DMOVE (W(1,2),XX5)                                           950JA099
      NPT1 = 12345                                                      950JA100
      CALL DMOVE (W(1,3),XX1)                                           950JA101
      CALL STORE (B,W,4,M,ARRAY)                                        950JA102
      RETURN                                                            950JA103
  999 CALL EXIT                                                         950JA104
      END
```

```
C     MAIN PROGRAM CHAIN VII - TURNING VANE.                             950J7000
C     BELOTSERKOVSKIIS METHOD, SECOND APPROXIMATION                      950J7001
*     LABEL
 950J7                                                                   950J7
C                                                                        950J7002
      DIMENSION V(7),DER(7),EK(4),ER(7),XNO(750),DNO(750),XN2(750),      950J7003
     1DN2(750),ZNMS(50),EP(50),VR(50),CFT(4),VB4(50),VB7(50),CF4(4),     950J7004
     2CF7(4)                                                             950J7005
      DIMENSION GAMMA(13)                                                950J7006
C                                                                        950J7007
      COMMON V,DER,E0,DEN0,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5,  950J7008
     1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,   950J7009
     2FSMS,FSW,FSWS,PHI0,FENT,RORT,PRAT,EPS0,U20,PSI1,PHI1,PHI2,DLPP1,   950J7010
     3DLPP2,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,X0,S0,S1,S2,T0,T1,950J7011
     4T2,G0,G1,G2,W2S,W1S,V1,U1,M5,M6,THX,DTHX,CF4,CF7,NPT               950J7012
C                                                                        950J7013
 2    FORMAT(1H1)                                                        950J7014
 5    FORMAT(1H0)                                                        950J7015
 4    FORMAT(3X,1P7E16.7)                                                950J7016
 7    FORMAT(1H0,4X,6HU2U1 =1P1E15.7,5X,5HITR =I3,5X,5HKTR =I3)          950J7017
 11   FORMAT(1H0,4X,14HEPSILON ZERO =1P1E15.7)                           950J7018
 25   FORMAT(1H1,4X,38HUNABLE TO CONVERGE BLUNT BODY SOLUTION)           950J7019
C                                                                        950J7020
      EK(1)=0.5                                                          950J7021
      EK(2)=1.0-SQRTF(0.5)                                               950J7022
      EK(3)=2.0-EK(2)                                                    950J7023
      EK(4)=0.33333333                                                   950J7024
C                                                                        950J7025
      REWIND 2                                                           950J7026
      READ TAPE 2,C1,FSM                                                 950J7027
      X0 = 1.0                                                           950J7028
      A=1.0                                                              950J7029
      TMN=1.10                                                           950J7030
      CTF=1.0E-04                                                        950J7031
      DTH=0.02                                                           950J7032
      THT=2.2*DTH                                                        950J7033
      DEL=0.15                                                           950J7034
      EPS0=0.386*EXPF(5.16/(FSM**1.96))                                  950J7035
      U2U1=(0.665/FSM-0.042)/FSM+0.530                                   950J7036
      NIN=6                                                              950J7037
```

```
      NOPT=5                                                            950J7038
      NDIM=0                                                            950J7039
      M5=0                                                              950J7040
   53 N1=NIN+1                                                          950J7041
      NS2=1                                                             950J7042
C                                                                       950J7043
      C2=1.0/(C1-1.0)                                                   950J7044
      C3=1.0/(C1+1.0)                                                   950J7045
      C4=C3/C2                                                          950J7046
      C5=C2/C3                                                          950J7047
      C6=2.0*C3                                                         950J7048
      C8=0.5/C2                                                         950J7049
      C7=C8/C1                                                          950J7050
      C9=C6/C7                                                          950J7051
      C10=SQRTF(C4)                                                     950J7052
      C11=2.0*C7                                                        950J7053
      C12=C9*C4**C1                                                     950J7054
      C13=C8**2/C1                                                      950J7055
      FSMS=FSM**2                                                       950J7056
      FSWS=1.0/(1.0/(C8*FSMS)+1.0)                                      950J7057
      FSW=SQRTF(FSWS)                                                   950J7058
      FS1=1.0-FSWS                                                      950J7059
      RORT=FS1**C2                                                      950J7050
      FS2=FSWS*RORT                                                     950J7061
      FS5=FSW*RORT                                                      950J7062
      FS3=FSWS/FS1                                                      950J7063
      FS4=((FSMS-1.0)**2)*(1.0-C1)/(FSW*(FSMS-C7)*FS1**(C2-1.0))        950J7064
      PRAT=RORT**C1                                                     950J7065
      PHI0=C12*(FS3-C13)/(FSWS**C1)                                     950J7066
      FENT=1.0/(PHI0**C2)                                               950J7067
      TERM=C6*(1.0-1.0/FSMS)                                            950J7068
      U1=-FSW*(1.0-TERM)                                                950J7069
      UONE=U1                                                           950J70.0
      U1S=U1**2                                                         950J7071
      XN1=FSW*TERM                                                      950J7072
      TAU1=(1.0-U1S)**C2                                                950J7073
      Q1=TAU1*U1                                                        950J7074
      Q2=TAU1*XN1                                                       950J7075
      Q3=TAU1*(C7*(1.0-U1S)+U1S)                                        950J7076
      Q4=Q1*XN1                                                         950J7077
C                                                                       950J7078
```

```
      GO TO(60,61,64,62,63),NOPT                                        950J7079
   60 CT1=X0/A-1.0                                                      950J7080
      CT2=CT1**2-1.0                                                    950J7081
      CT3=1.0-(A/B)**2                                                  950J7082
      GO TO 64                                                          950J7083
   61 CT1=X0/A                                                          950J7084
      CT2=CT1-1.0                                                       950J7085
      GO TO 64                                                          950J7086
   62 CT1=1.0+X0/A                                                      950J7087
      CT2=CT1**2-1.0                                                    950J7088
      CT3=1.0+(A/B)**2                                                  950J7089
      GO TO 64                                                          950J7090
   63 RB=A                                                              950J7091
      ETA=0.0                                                           950J7092
      ETAP=0.0                                                          950J7093
C                                                                       950J7094
   64 U20=U2U1*U1                                                       950J7095
      NS1=1                                                             950J7096
      NS3 = 1                                                           950J7097
      KTR=1                                                             950J7098
      EPSLB=-1000.0                                                     950J7099
      EPSUB=-500.0                                                      950J7100
   98 U2N=500.0                                                         950J7101
      U2P=1000.0                                                        950J7102
      ESP=-1000.0                                                       950J7103
      ESN=1000.0                                                        950J7104
      IPT=0                                                             950J7105
      ITR=0                                                             950J7106
C                                                                       950J7107
  100 IF(ITR-35) 101,50,50                                              950J7108
  101 M2=1                                                              950J7109
      ITR=ITR+1                                                         950J7110
      JPT=0                                                             950J7111
      M6=1                                                              950J7112
      IF(NDIM) 102,102,103                                              950J7113
  102 CALL NASTY                                                        950J7114
      GO TO 104                                                         950J7115
  103 CALL MESSY                                                        950J7116
  104 E0=C4*DER(4)                                                      950J7117
      DEN0=C4                                                           950J7118
      DEN2=C4*(1.0-U20**2)                                              950J7119
```

```
      E2=DEN2*DER(7)                                                    950J7120
      IF (NS3-2) 79,70,70                                               950J7121
 70   CALL POOH(1)                                                      950J7122
 79   URA=U20/UONE                                                      950J7123
C                                                                       950J7124
 82   DO 90 I=1,7                                                       950J7125
 90   ER(I)=0.0                                                         950J7126
 105  DO 125 I=1,4                                                      950J7127
      IF(I-1) 107,107,106                                               950J7128
 106  M3=1                                                              950J7129
      IF(NDIM) 1061,1061,1062                                           950J7130
 1061 CALL NASTY                                                        950J7131
      GO TO 107                                                         950J7132
 1062 CALL MESSY                                                        950J7133
 107  IF(I-4) 115,110,110                                               950J7134
 110  EEK1=0.5                                                          950J7135
      EEK2=0.5                                                          950J7136
      GO TO 120                                                         950J7137
 115  EEK1=1.0                                                          950J7138
      EEK2=EK(I)                                                        950J7139
 120  DO 125 J=1,7                                                      950J7140
      QER=EK(I)*(EEK1*DER(J)-ER(J))                                     950J7141
      V(J)=V(J)+QER*DTH                                                 950J7142
 125  ER(J)=ER(J)+3.0*QER-EEK2*DER(J)                                   950J7143
C                                                                       950J7144
      M3=2                                                              950J7145
      IF(NDIM) 126,126,127                                              950J7146
 126  CALL NASTY                                                        950J7147
      GO TO 128                                                         950J7148
 127  CALL MESSY                                                        950J7149
 128  IF (NS3-2) 145,135,135                                            950J7150
 135  CALL POOH(2)                                                      950J7151
C                                                                       950J7152
 145  IF(NS1-2) 150,320,610                                             950J7153
 150  WO=V(4)*SQRTF(1.0+ETA**2)                                         950J7154
      IF(WO-(1.0-DEL)*C10) 152,157,157                                  950J7155
 152  IF(EO) 153,153,156                                                950J7156
 153  U2N=U20                                                           950J7157
      IF(U2P) 155,154,154                                               950J7158
 154  IF(KTR-2) 1400,1400,1410                                          950J7159
 1400 U20=(1.0+1.0E-02)*U20                                             950J7160
```

```
      GO TO 100                                                         950J7161
 1410 U20=(1.0+1.0E-07)*U20                                             950J7162
      GO TO 100                                                         950J7163
 155  U20=0.5*(U2P+U2N)                                                 950J7164
      GO TO 180                                                         950J7165
 156  JPT=JPT+1                                                         950J7166
      IF(JPT-750) 190,190,50                                            950J7167
 190  DNO(JPT)=DENO                                                     950J7168
      XNO(JPT)=E0                                                       950J7169
      DN2(JPT)=DEN2                                                     950J7170
      XN2(JPT)=E2                                                       950J7171
      GO TO 105                                                         950J7172
 157  J0=JPT-N1                                                         950J7173
      DO 1500 I=1,N1                                                    950J7174
      J=J0+I                                                            950J7175
 1500 VR(I)=DNO(J)                                                      950J7176
      NS2=1                                                             950J7177
      NFT=NIN                                                           950J7178
      CALL LSTSQR                                                       950J7179
 1502 BX=0.5                                                            950J7180
      DO 159 IN=1,25                                                    950J7181
      POL=((CFT(4)*BX+CFT(3))*BX+CFT(2))*BX+CFT(1)                      950J7182
      POLP=(3.0*CFT(4)*BX+2.0*CFT(3))*BX+CFT(2)                         950J7183
      IF(POLP) 158,1505,1505                                            950J7184
 158  IF(ABSF(POL)-1.0E-07) 1507,1507,159                               950J7185
 159  BX=BX-POL/POLP                                                    950J7186
 1507 IF(NS2-1) 160,160,1511                                            950J7187
 1505 IF(NS2-1) 153,153,197                                             950J7188
 160  DO 1510 I=1,N1                                                    950J7189
      J=J0+I                                                            950J7190
 1510 VR(I)=XNO(J)                                                      950J7191
      GO TO 1513                                                        950J7192
 1511 DO 1512 I=1,N1                                                    950J7193
      J=J0+I                                                            950J7194
 1512 VR(I)=XN2(J)                                                      950J7195
 1513 CALL LSTSQR                                                       950J7196
      ES=((CFT(4)*BX+CFT(3))*BX+CFT(2))*BX+CFT(1)                       950J7197
      THS=V(1)+DTH*(FLOATF(NFT)*(BX-0.5)-1.0)                           950J7198
      IF(NS2-1) 1517,1517,1518                                          950J7199
 1517 EOS=ES                                                            950J7200
      IF(ABSF(EOS)-CTF) 166,166,170                                     950J7201
```

```
170   IF(EOS) 1000,166,161                                          950J7202
1000  IF(NOPT-1) 1001,171,1001                                      950J7203
1001  IF(DER(3)) 171,1002,1002                                      950J7204
1002  U2P=U20                                                       950J7205
      GO TO 177                                                     950J7206
171   ESN=EOS                                                       950J7207
      U2N=U20                                                       950J7208
      IF(ESP) 172,172,173                                           950J7209
172   U20=1.005*U20                                                 950J7210
      GO TO 100                                                     950J7211
173   U20=U2P+(U2N-U2P)/(ESP-ESN)*ESP                               950J7212
      GO TO 180                                                     950J7213
161   ESP=EOS                                                       950J7214
      U2P=U20                                                       950J7215
      IF(ESN) 173,174,174                                           950J7216
174   IF(IPT) 176,176,175                                           950J7217
175   IF(EOS**2/ZNMS(IPT)-1.0) 176,177,177                          950J7218
176   IPT=IPT+1                                                     950J7219
      ZNMS(IPT)=EOS**2                                              950J7220
      EP(IPT)=U20                                                   950J7221
      IF(IPT-2) 177,162,162                                         950J7222
162   FX=0.0                                                        950J7223
      DO 165 IA=1,IPT                                               950J7224
      CFX=1.0                                                       950J7225
      DO 164 IB=1,IPT                                               950J7226
      IF(IA-IB) 163,164,163                                         950J7227
163   CFX=CFX*(ZNMS(IA)/ZNMS(IB)-1.0)                               950J7228
164   CONTINUE                                                      950J7229
165   FX=FX+EP(IA)/CFX                                              950J7230
      U20=-ABSF(FX)                                                 950J7231
      IF(U20/U2P-1.0) 178,177,177                                   950J7232
177   IF(U2N) 155,151,151                                           950J7233
151   IF(KTR-2) 1420,1420,1430                                      950J7234
1420  U20=(1.0-1.0E-02)*U2P                                         950J7235
      GO TO 100                                                     950J7236
1430  U20=(1.0-1.0E-07)*U2P                                         950J7237
      GO TO 100                                                     950J7238
178   IF(U2N) 179,100,100                                           950J7239
179   IF(U20/U2N-1.0) 155,155,180                                   950J7240
180   IF(ABSF((U2P-U2N)/UONE)-2.0E-08) 166,166,194                  950J7241
194   IF(ABSF((U2P-U20)/UONE)-2.0E-08) 196,196,195                  950J7242
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```
 195  IF(ABSF((U20-U2N)/UONE)-2.0E-08) 196,196,100                    950J7243
 196  U20=0.5*(U2N+U2P)                                               950J7244
      GO TO 100                                                       950J7245
 166  DO 167 I=1,N1                                                   950J7246
      J=J0+I                                                          950J7247
 167  VR(I)=DN2(J)                                                    950J7248
      NS2=2                                                           950J7249
      CALL LSTSQR                                                     950J7250
      GO TO 1502                                                      950J7251
C                                                                     950J7252
 1518 E2S=ES                                                          950J7253
      IF(ABSF(E2S)-CTF) 300,300,200                                   950J7254
 200  KTR=KTR+1                                                       950J7255
      IF(KTR-2) 202,202,209                                           950J7256
 202  DM1=E2S                                                         950J7257
      DM2=U20                                                         950J7258
      DM3=EPS0                                                        950J7259
      IF(E2S) 204,300,207                                             950J7260
 197  KTR=KTR+1                                                       950J7261
 204  EPSUB=EPS0                                                      950J7262
      U2UB=U20                                                        950J7263
      IF(EPSLB) 205,205,206                                           950J7264
 205  EPS0=0.99*EPSUB                                                 950J7265
      GO TO 226                                                       950J7266
 206  EPS0=0.5*(EPSLB+EPSUB)                                          950J7267
      U20=0.5*(U2LB+U2UB)                                             950J7268
      GO TO 225                                                       950J7269
 207  EPSLB=EPS0                                                      950J7270
      U2LB=U20                                                        950J7271
      IF(EPSUB) 208,208,206                                           950J7272
 208  EPS0=1.01*EPSLB                                                 950J7273
      GO TO 226                                                       950J7274
 209  DM1L=DM1                                                        950J7275
      DM2L=DM2                                                        950J7276
      DM3L=DM3                                                        950J7277
      DM1=E2S                                                         950J7278
      DM2=U20                                                         950J7279
      DM3=EPS0                                                        950J7280
      IF(E2S) 210,300,211                                             950J7281
 210  EPSUB=EPS0                                                      950J7282
      U2UB=U20                                                        950J7283
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      GO TO 212                                                         950J7284
  211 EPSLB=EPSO                                                        950J7285
      U2LB=U20                                                          950J7286
  212 RR1=1.0/(1.0-DM1/DM1L)                                            950J7287
      EPSO=DM3L+RR1*(DM3-DM3L)                                          950J7288
      U20=DM2L+RR1*(DM2-DM2L)                                           950J7289
      IF(EPSUB*EPSLB) 214,214,213                                       950J7290
  213 RR2=(EPSO-EPSLB)/(EPSUB-EPSLB)                                    950J7291
      IF(ABSF(RR2-0.5)-0.5) 225,206,206                                 950J7292
  214 IF(E2S) 215,300,216                                               950J7293
  215 IF(EPSUB-EPSO) 205,205,226                                        950J7294
  216 IF(EPSO-EPSLB) 208,208,226                                        950J7295
  225 IF(EPSUB-EPSLB-2.0E-08) 300,300,226                               950J7296
  226 IF(KTR-25) 98,50,50                                               950J7297
  50  WRITE OUTPUT TAPE 6,25                                            950J7298
      CALL EXIT                                                         950J7299
C                                                                       950J7300
  300 L1=1                                                              950J7301
      NS1=2                                                             950J7302
  320 CALL PATCH(L1,L2,NDIM,JPT,DTH,ER,DNO,XNO,DN2,XN2)                 950J7303
      IF(L2-2) 156,700,600                                              950J7304
  700 NPT=JPT+1                                                         950J7305
      GO TO 105                                                         950J7306
  600 IF(M5-1) 605,607,607                                              950J7307
  605 NS1=1                                                             950J7308
      NS3 = 2                                                           950J7309
      CTF=1000.0                                                        950J7310
      M5=1                                                              950J7311
      GO TO 101                                                         950J7312
  607 NS1=3                                                             950J7313
      C14=SQRTF(1.0/(1.0/(C8*TMN**2)+1.0))                              950J7314
      GO TO 105                                                         950J7315
  610 W0=V(4)*SQRTF(1.0+ETA**2)                                         950J7316
      W2=SQRTF(W2S)                                                     950J7317
      W1=SQRTF(W1S)                                                     950J7318
      IF(W0-C14) 105,615,615                                            950J7319
  615 IF(W2-C14) 105,620,620                                            950J7320
  620 IF(W1-C14) 105,625,625                                            950J7321
  625 CALL POOH(3)                                                      950J7322
      CALL CPX                                                          950J7323
      END
```

```
      SUBROUTINE CPX                                                    950JJ000
*     LABEL
 950JJ                                                                  950JJ
C                                                                       950JJ001
      DIMENSION V(7),DER(7),VR(50),CFT(4),CF4(4),CF7(4)                 950JJ002
      DIMENSION M(10),ARRAY(12)                                         950JJ003
C                                                                       950JJ004
      COMMON V,DER,E0,DEN0,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5, 950JJ005
     1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,  950JJ006
     2FSMS,FSW,FSWS,PHI0,FENT,RORT,PRAT,EPS0,U20,PSI1,PHI1,PHI2,DLPP1,  950JJ007
     3DLPP2,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,X0,S0,S1,S2,T0,T1,950JJ008
     4T2,G0,G1,G2,W2S,W1S,V1,U1,M5,M6,THX,DTHX,CF4,CF7                  950JJ009
C                                                                       950JJ010
 1    FORMAT(1H1)                                                       950JJ011
 2    FORMAT(1H0)                                                       950JJ012
 3    FORMAT(3X,1P7E16.7)                                               950JJ013
C                                                                       950JJ014
      REWIND 2                                                          950JJ015
      READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY                             950JJ016
      V0 = V(4)                                                         950JJ017
      V2 = V(7)                                                         950JJ018
      U0 = ETA*V0                                                       950JJ019
      U2 = V(6)                                                         950JJ020
      CC1=C1-1.0                                                        950JJ021
      CC2=C1/CC1                                                        950JJ022
      X=X0-RB*F2                                                        950JJ023
      Y=RB*F1                                                           950JJ024
      ZM=SQRTF(1.0/(C8*(1.0/V(4)**2-1.0)))                              950JJ025
      TH = 1.570796-V(1)                                                950JJ026
      P = FENT*(1.0-(1.0+ETA**2)*V(4)**2)**CC2                          950JJ027
      R = FENT                                                          950JJ028
      ZMU = ATANF(1./SQRTF(ZM**2-1.0))                                  950JJ029
      NPT = -1                                                          950JJ030
      DUM = 0.0                                                         950JJ031
      WRITE TAPE 2,X,Y,P,TH,ZMU,R,NPT,DUM,DUM,DUM                       950JJ032
      XI=0.0                                                            950JJ033
      NPT = 0                                                           950JJ034
C                                                                       950JJ035
      L = 10                                                            950JJ036
      XL =L                                                             950JJ037
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      DDX = 1.0/XL                                                      950JJ038
      DO 10 I=1,L                                                       950JJ039
      XI = XI+DDX                                                       950JJ040
      PHIXI=((PHI0+PHI1-2.0*PHI2)*2.0*XI+4.0*PHI2-3.0*PHI0-PHI1)*XI+PHI0950JJ041
      P1=PHIXI**C2                                                      950JJ042
      VVEL = ((VO+V1-2.0*V2)*2.*XI+4.*V2-3.*VO-V1)*XI+VO                950JJ043
      UVEL = ((U0+U1-2.*U2)*2.*XI+4.*U2-3.*U0-U1)*XI+U0                 950JJ044
      WS=UVEL**2+VVEL**2                                                950JJ045
      ZM=SQRTF(1.0/(C8*(1.0/WS-1.0)))                                   950JJ046
      ZMU = ATANF(1./SQRTF(ZM**2-1.0))                                  950JJ047
      TH = 3.14159763*(.5+SIGNF(.5,UVEL))-ATANF(ABSF(VVEL/UVEL))*       950JJ048
     1  SIGNF(1.0,UVEL)-V(1)                                            950JJ049
      R = 1.0/P1                                                        950JJ050
      P = R*(1.0-WS)**CC2                                               950JJ051
      RXI=RB+XI*V(2)                                                    950JJ052
      X=X0-RXI*F2                                                       950JJ053
      Y=RXI*F1                                                          950JJ054
      WRITE TAPE 2,X,Y,P,TH,ZMU,R,NPT,DUM,DUM,DUM                       950JJ055
   10 CONTINUE                                                          950JJ056
      NPT = 1                                                           950JJ057
      W = V(3)                                                          950JJ058
      REWIND 9                                                          950JJ059
      WRITE TAPE 9,X,Y,P,TH,ZMU,R,NPT,W,DUM,DUM                         950JJ060
   30 BACKSPACE 2                                                       950JJ061
      BACKSPACE 2                                                       950JJ062
      READ TAPE 2,X,Y,P,TH,ZMU,R,NPT,W,DUM,DUM                          950JJ063
      WRITE TAPE 9,X,Y,P,TH,ZMU,R,NPT,W,DUM,DUM                         950JJ064
      IF (NPT) 40,30,30                                                 950JJ065
C                                                                       950JJ066
   40 END FILE 9                                                        950JJ067
      L = L+1                                                           950JJ068
      REWIND 9                                                          950JJ069
      BACKSPACE 2                                                       950JJ070
      DO 50I=1,L                                                        950JJ071
      READ TAPE 9,X,Y,P,TH,ZMU,R,NPT,W,DUM,DUM                          950JJ072
   48 WRITE TAPE 2,X,Y,P,TH,ZMU,R,NPT,W,DUM,DUM                         950JJ073
   50 CONTINUE                                                          950JJ074
      END FILE 2                                                        950JJ075
      REWIND 2                                                          950JJ076
      REWIND 9                                                          950JJ077
      CALL CHAIN (8,8)                                                  950JJ078
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      RETURN                                                    950JJ079
      END
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```
      SUBROUTINE NASTY                                                  950JP000
*     LABEL
 950JP                                                                  950JP
C                                                                       950JP001
      DIMENSION V(7),DER(7),PS(750),PH(750),DLP(750),VR(50),CFT(4),     950JP002
     1CF4(4),CF7(4)                                                     950JP003
C                                                                       950JP004
      COMMON V,DER,E0,DEN0,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5, 950JP005
     1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,  950JP006
     2FSMS,FSW,FSWS,PHI0,FENT,RORT,PRAT,EPS0,U20,PSI1,PHI1,PHI2,DLPP1,  950JP007
     3DLPP2,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,X0,S0,S1,S2,T0,T1,950JP008
     4T2,G0,G1,G2,W2S,W1S,V1,U1,M5,M6,THX,DTHX,CF4,CF7,NPT              950JP009
C                                                                       950JP010
 30   FORMAT(64H0    ERROR IN ENTROPY INTERPOLATION. PROGRAM UNABLE TO C950JP011
     1ONTINUE.)                                                         950JP012
C                                                                       950JP013
      NPT=NPT                                                           950JP014
      IF(M2-2) 1,2,2                                                    950JP015
 1    M2=2                                                              950JP016
      V(1)=0.0                                                          950JP017
      V(2)=EPS0                                                         950JP018
      V(3)=1.5707963                                                    950JP019
      V(4)=0.0                                                          950JP020
      V(5)=0.0                                                          950JP021
      V(6)=U20                                                          950JP022
      V(7)=0.0                                                          950JP023
      DER(1)=1.0                                                        950JP024
      DER(2)=0.0                                                        950JP025
      DER(6)=0.0                                                        950JP026
      RB=X0                                                             950JP027
      Z=RB/EPS0                                                         950JP028
      Z1=2.0*Z+1.0                                                      950JP029
      Z2=4.0*Z+3.0                                                      950JP030
      U2S=U20**2                                                        950JP031
      F3=1.0-U2S                                                        950JP032
      TAU2=F3**C2                                                       950JP033
      H2=TAU2*U20                                                       950JP034
      DER(3)=(Q3*Z2-4.0*TAU2*Z1*(C7*F3+U2S)+C7*(4.0*Z+1.0))/Q4          950JP035
      DER(4)=-Q2*DER(3)+Z2*Q1-4.0*Z1*H2                                 950JP036
      DER(5)=-TAU2*FENT*(RB+0.5*V(2))*V(6)                              950JP037
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      DER(7)=(0.5*(Q2*DER(3)-(5.0*Z+4.0)*Q1)+Z1*H2)/TAU2                950JP038
      NAXIS=-1                                                          950JP039
      NPT=1                                                             950JP040
      PS(NPT)=0.0                                                       950JP041
      PH(NPT)=PHIO                                                      950JP042
      DLP(NPT)=0.0                                                      950JP043
      PSI1=0.0                                                          950JP044
      PHI1=PHIO                                                         950JP045
      DLPP1=0.0                                                         950JP046
      PHI2=PHIO                                                         950JP047
      DLPP2=0.0                                                         950JP048
      RETURN                                                            950JP049
C                                                                       950JP050
 2    IF(NOPT-5) 50,40,50                                               950JP051
 40   F1=SINF(V(1))                                                     950JP052
      F2=COSF(V(1))                                                     950JP053
      F4=(SINF(V(3)))**2                                                950JP054
      F5=SINF(2.0*V(3))                                                 950JP055
      F6=COSF(V(3))/SINF(V(3))                                          950JP056
      F7=RB+V(2)                                                        950JP057
      DER(2)=-F7*COSF(V(1)+V(3))/SINF(V(1)+V(3))                        950JP058
      Z=RB/V(2)                                                         950JP059
      Z1=Z+1.0                                                          950JP060
      Z2=2.0*Z+1.0                                                      950JP061
      Z3=DER(2)/V(2)                                                    950JP062
C                                                                       950JP063
      VOS=V(4)**2                                                       950JP064
      F8=1.0-VOS                                                        950JP065
      RHOO=(F8/PHIO)**C2                                                950JP066
      S0=0.0                                                            950JP067
      T0=V(4)*F8**C2                                                    950JP068
      G0=RHOO*(C7*F8+VOS)                                               950JP069
      BH0=RHOO*C7*F8                                                    950JP070
C                                                                       950JP071
      F9=1.0/(FSMS*F4)                                                  950JP072
      F10=1.0-F9                                                        950JP073
      WX=1.0-C6*F4*F10                                                  950JP074
      WY=C3*F5*F10                                                      950JP075
      DWX=-C6*F5                                                        950JP076
      DWY=C6*(COSF(2.0*V(3))+F9)                                        950JP077
      XM1=FSW*(DWY*F1-DWX*F2)                                           950JP078
```

```
      XN1=-FSW*(DWX*F1+DWY*F2)                                          950JP079
      U1=FSW*(WY*F1-WX*F2)                                              950JP080
      U1S=U1**2                                                         950JP081
      V1=FSW*(WX*F1+WY*F2)                                              950JP082
      V1S=V1**2                                                         950JP083
      W1S=U1S+V1S                                                       950JP084
      F11=V1*XN1-U1*XM1                                                 950JP085
      F12=1.0-W1S                                                       950JP086
      RHO1=C5*FS2/(1.0+FS1*F6**2)                                       950JP087
      TAU1=F12**C2                                                      950JP088
      T1=TAU1*V1                                                        950JP089
      H1=TAU1*U1                                                        950JP090
      S1=RHO1*U1*V1                                                     950JP091
      G1=RHO1*(C7*F12+V1S)                                              950JP092
      BH1=RHO1*(C7*F12+U1S)                                             950JP093
      BG1=TAU1*(V1*F11/(C8*F12)-XN1)                                    950JP094
      D1=C9*FS2*U1*V1*F5/F12+RHO1*(V1*XM1-U1*(XN1+2.0*V1*F11/F12))      950JP095
C                                                                       950JP096
      IF(M3-1) 5,5,3                                                    950JP097
    3 NPT=NPT+1                                                         950JP098
      PS(NPT)=FS5*F7*F1                                                 950JP099
      PH(NPT)=C12*((FS3*F4)-C13)*(1.0+1.0/(FS3*F4))**C1                 950JP100
    5 NPT=NPT                                                           950JP101
      IKT=NPT                                                           950JP102
      IF(NAXIS) 22,22,6                                                 950JP103
    6 IF(V(5)-PS(NPT)) 4,8,10                                           950JP104
    4 IKT=IKT-1                                                         950JP105
      IF(IKT) 20,20,7                                                   950JP106
    7 IF(V(5)-PS(IKT)) 4,8,9                                            950JP107
   20 WRITE OUTPUT TAPE 6,30                                            950JP108
      CALL EXIT                                                         950JP109
   22 NAXIS=1                                                           950JP110
    8 PHI2=PH(IKT)                                                      950JP111
      M4=1                                                              950JP112
      GO TO 11                                                          950JP113
    9 H=(V(5)-PS(IKT))/(PS(IKT+1)-PS(IKT))                              950JP114
      PHI2=PH(IKT)+H*(PH(IKT+1)-PH(IKT))                                950JP115
      M4=2                                                              950JP116
      GO TO 11                                                          950JP117
   10 PSI1=FS5*F7*F1                                                    950JP118
      PHI1=C12*((FS3*F4)-C13)*(1.0+1.0/(FS3*F4))**C1                    950JP119
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```
      H=(V(5)-PS(NPT))/(PSI1-PS(NPT))                                   950JP120
      PHI2=PH(NPT)+H*(PHI1-PH(NPT))                                     950JP121
      M4=3                                                              950JP122
C                                                                       950JP123
   11 U2S=V(6)**2                                                       950JP124
      V2S=V(7)**2                                                       950JP125
      W2S=U2S+V2S                                                       950JP126
      F13=1.0-W2S                                                       950JP127
      TAU2=F13**C2                                                      950JP128
      RHO2=(F13/PHI2)**C2                                               950JP129
      T2=TAU2*V(7)                                                      950JP130
      H2=TAU2*V(6)                                                      950JP131
      G2=RHO2*(C7*F13+V2S)                                              950JP132
      S2=RHO2*V(6)*V(7)                                                 950JP133
      BH2=RHO2*(C7*F13+U2S)                                             950JP134
C                                                                       950JP135
      S1P=Z3*(3.0*S1-4.0*S2)-4.0*(Z*BH0+Z1*BH1-Z2*BH2)+G1-G0            950JP136
      S2P=0.5*(Z3*S1+5.0*Z*BH0-2.0*Z2*BH2-Z1*BH1+G0)+G2                 950JP137
      DER(3)=(S1P-RHO1*(V1S-U1S))/D1                                    950JP138
      T1P=BG1*DER(3)-H1                                                 950JP139
      T0P=T1P+Z3*(4.0*T2-T0-3.0*T1)+4.0*(Z1*H1-Z2*H2)                   950JP140
      T2P=-0.5*T1P+2.0*Z3*(T1-T2)+Z2*H2-2.5*Z1*H1                       950JP141
      E0=C4*(F8**(1.0-C2))*T0P                                          950JP142
      DEN0=C4-V0S                                                       950JP143
      DER(4)=E0/DEN0                                                    950JP144
      DER(5)=RHO2*(0.5*V(7)*DER(2)-(RB+0.5*V(2))*V(6))                  950JP145
   23 F14=1.0/(PHI2**C2)                                                950JP146
      IF(M3-1) 13,13,12                                                 950JP147
   12 F15=FS3*F4                                                        950JP148
      DLPDS=2.0*F6*(F15-C8)**2/((1.0+F15)*(F15-C13))                    950JP149
      DPSDTH=FS5*(DER(2)*F1+F7*F2)                                      950JP150
      DLP(NPT)=DLPDS*DER(3)/DPSDTH                                      950JP151
   13 IF(M4-2) 14,15,16                                                 950JP152
   14 DLPP2=DLP(IKT)                                                    950JP153
      GO TO 17                                                          950JP154
   15 DLPP2=DLP(IKT)+H*(DLP(IKT+1)-DLP(IKT))                            950JP155
      GO TO 17                                                          950JP156
   16 F15=FS3*F4                                                        950JP157
      DLPDS=2.0*F6*(F15-C8)**2/((1.0+F15)*(F15-C13))                    950JP158
      DPSDTH=FS5*(DER(2)*F1+F7*F2)                                      950JP159
      DLPP1=DLPDS*DER(3)/DPSDTH                                         950JP160
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      DLPP2=DLP(NPT)+H*(DLPP1-DLP(NPT))                                 950JP161
   17 IF(THT-V(1)) 18,19,19                                             950JP162
   18 DER(6)=(S2P-V(6)*F14*T2P+S2*C2*DLPP2*DER(5))/(T2*F14)             950JP163
   19 DEN2=C4+C6*U2S-W2S                                                950JP164
      E2=C6*(C8*F13*T2P+T2*V(6)*DER(6))/TAU2                            950JP165
      DER(7)=E2/DEN2                                                    950JP166
      IF(M3-1) 26,26,25                                                 950JP167
   25 PSI1=PS(NPT)                                                      950JP168
      PHI1=PH(NPT)                                                      950JP169
      DLPP1=DLP(NPT)                                                    950JP170
   26 IF(M6-1) 27,27,28                                                 950JP171
   27 RETURN                                                            950JP172
   28 ZET=V(1)-THX                                                      950JP173
      DER(4)=((CF4(4)*ZET+CF4(3))*ZET+CF4(2))*ZET+CF4(1)                950JP174
      DER(7)=((CF7(4)*ZET+CF7(3))*ZET+CF7(2))*ZET+CF7(1)                950JP175
      RETURN                                                            950JP176
C                                                                       950JP177
   50 F1=SINF(V(1))                                                     950JP178
      F2=COSF(V(1))                                                     950JP179
      F4=SINF(V(3))**2                                                  950JP180
      F5=SINF(2.0*V(3))                                                 950JP181
      F6=COSF(V(3))/SINF(V(3))                                          950JP182
      CALL BODY                                                         950JP183
      F7=RB+V(2)                                                        950JP184
      DER(2)=-ETA*RB-F7*COSF(V(1)+V(3))/SINF(V(1)+V(3))                 950JP185
      Z=RB/V(2)                                                         950JP186
      Z1=Z+1.0                                                          950JP187
      Z2=2.0*Z+1.0                                                      950JP188
      Z3=DER(2)/V(2)                                                    950JP189
      Z4=ETA*Z                                                          950JP190
C                                                                       950JP191
      U0=ETA*V(4)                                                       950JP192
      U0S=U0**2                                                         950JP193
      V0S=V(4)**2                                                       950JP194
      W0S=U0S+V0S                                                       950JP195
      F8=1.0-W0S                                                        950JP196
      A0S=C8*F8                                                         950JP197
      TAU0=F8**C2                                                       950JP198
      RHO0=TAU0*FENT                                                    950JP199
      T0=TAU0*V(4)                                                      950JP200
      H0=TAU0*U0                                                        950JP201
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      S0=RHOC*U0*V(4)                                                   950JP202
      G0=RHO0*(C7*F8+V0S)                                               950JP203
      BH0=RHO0*(C7*F8+U0S)                                              950JP204
C                                                                       950JP205
      F9=1.0/(FSMS*F4)                                                  950JP206
      F10=1.0-F9                                                        950JP207
      WX=1.0-C6*F4*F10                                                  950JP208
      WY=C3*F5*F10                                                      950JP209
      DWX=-C6*F5                                                        950JP210
      DWY=C6*(COSF(2.0*V(3))+F9)                                        950JP211
      XM1=FSW*(DWY*F1-DWX*F2)                                           950JP212
      XN1=-FSW*(DWX*F1+DWY*F2)                                          950JP213
      U1=FSW*(WY*F1-WX*F2)                                              950JP214
      U1S=U1**2                                                         950JP215
      V1=FSW*(WX*F1+WY*F2)                                              950JP216
      V1S=V1**2                                                         950JP217
      W1S=U1S+V1S                                                       950JP218
      F11=V1*XN1-U1*XM1                                                 950JP219
      F12=1.0-W1S                                                       950JP220
      RHO1=C5*FS2/(1.0+FS1*F6**2)                                       950JP221
      TAU1=F12**C2                                                      950JP222
      T1=TAU1*V1                                                        950JP223
      H1=TAU1*U1                                                        950JP224
      S1=RHO1*U1*V1                                                     950JP225
      G1=RHO1*(C7*F12+V1S)                                              950JP226
      BH1=RHO1*(C7*F12+U1S)                                             950JP227
      BG1=TAU1*(V1*F11/(C8*F12)-XN1)                                    950JP228
      D1=C9*FS2*U1*V1*F5/F12+RHO1*(V1*XM1-U1*(XN1+2.0*V1*F11/F12))      950JP229
C                                                                       950JP230
      IF(M3-1) 55,55,53                                                 950JP231
   53 NPT=NPT+1                                                         950JP232
      PS(NPT)=FS5*F7*F1                                                 950JP233
      PH(NPT)=C12*((FS3*F4)-C13)*(1.0+1.0/(FS3*F4))**C1                 950JP234
   55 NPT=NPT                                                           950JP235
      IKT=NPT                                                           950JP236
      IF(NAXIS) 72,72,56                                                950JP237
   56 IF(V(5)-PS(NPT)) 54,58,60                                         950JP238
   54 IKT=IKT-1                                                         950JP239
      IF(IKT) 20,20,57                                                  950JP240
   57 IF(V(5)-PS(IKT)) 54,58,59                                         950JP241
   72 NAXIS=1                                                           950JP242
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58    PHI2=PH(IKT)                                                     950JP243
      M4=1                                                             950JP244
      GO TO 61                                                         950JP245
59    H=(V(5)-PS(IKT))/(PS(IKT+1)-PS(IKT))                             950JP246
      PHI2=PH(IKT)+H*(PH(IKT+1)-PH(IKT))                               950JP247
      M4=2                                                             950JP248
      GO TO 61                                                         950JP249
60    PSI1=FS5*F7*F1                                                   950JP250
      PHI1=C12*((FS3*F4)-C13)*(1.0+1.0/(FS3*F4))**C1                   950JP251
      H=(V(5)-PS(NPT))/(PSI1-PS(NPT))                                  950JP252
      PHI2=PH(NPT)+H*(PHI1-PH(NPT))                                    950JP253
      M4=3                                                             950JP254
C                                                                      950JP255
61    U2S=V(6)**2                                                      950JP256
      V2S=V(7)**2                                                      950JP257
      W2S=U2S+V2S                                                      950JP258
      F13=1.0-W2S                                                      950JP259
      TAU2=F13**C2                                                     950JP260
      RHO2=(F13/PHI2)**C2                                              950JP261
      T2=TAU2*V(7)                                                     950JP262
      H2=TAU2*V(6)                                                     950JP263
      G2=RHO2*(C7*F13+V2S)                                             950JP264
      S2=RHO2*V(6)*V(7)                                                950JP265
      BH2=RHO2*(C7*F13+U2S)                                            950JP266
C                                                                      950JP267
      A2=4.0*(Z4*(2.0*T2-T1-T0)+Z*H0-Z2*H2+Z1*H1)-Z3*(T0-4.0*T2+3.0*T1) 950JP268
      B2=4.0*(Z4*(2.0*S2-S1-S0)+Z*BH0-Z2*BH2+Z1*BH1)-Z3*(S0-4.0*S2+3.0*S950JP269
     11)+G0-G1                                                         950JP270
      DEN0=C4-W0S                                                      950JP271
      TERM=DEN0+C6*A0S                                                 950JP272
      DER(3)=(FENT*(ETAP*(DEN0+C6*U0S)*T0*V(4)+U0*TERM*(A2-H1))-       950JP273
     1DEN0*(RHO1*(V1S-U1S)+B2))/(DEN0*D1-TERM*U0*FENT*BG1)             950JP274
      S0P=RHO1*(V1S-U1S)+D1*DER(3)+B2                                  950JP275
      S2P=0.5*(Z*BH0-5.0*Z1*BH1+G1-S1P-Z4*(S0+4.0*S2-5.0*S1))+G2       950JP276
     1+Z2*BH2+2.0*Z3*(S1-S2)                                           950JP277
      T1P=BG1*DER(3)-H1                                                950JP278
      T0P=T1P+A2                                                       950JP279
      T2P=0.5*(Z*H0-5.0*Z1*H1-T1P-Z4*(T0+4.0*T2-5.0*T1))+Z2*H2         950JP280
     1+2.0*Z3*(T1-T2)                                                  950JP281
      E0=C6*(A0S*T0P/TAU0+U0*V0S*ETAP)                                 950JP282
      DER(4)=E0/DEN0                                                   950JP283
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      DER(5)=RHO2*(V(7)*(ETA*RB+0.5*DER(2))-(RB+0.5*V(2))*V(6))          950JP284
      GO TO 23                                                             950JP285
      END                                                                  950JP286
```

```
      SUBROUTINE PATCH(L1,L2,NDIM,JPT,DTH,ER,DNO,XNO,DN2,XN2)           950JK000
*     LABEL
 950JK                                                                  950JK
C                                                                       950JK001
      DIMENSION V(7),DER(7),ER(7),ERE(7),VE(7),CF4(4),CF7(4),DNO(750),  950JK002
     1XNO(750),DN2(750),XN2(750)                                        950JK003
      DIMENSION VR(50),CFT(4)                                           950JK004
C                                                                       950JK005
      COMMON V,DER,EO,DENO,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5, 950JK006
     1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,  950JK007
     2FSMS,FSW,FSWS,PHIO,FENT,RORT,PRAT,EPSO,U20,PSI1,PHI1,PHI2,DLPP1,  950JK008
     3DLPP2,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,XO,SO,S1,S2,TO,T1,950JK009
     4T2,G0,G1,G2,W2S,W1S,V1,U1,M5,M6,THX,DTHX,CF4,CF7,NPT              950JK010
C                                                                       950JK011
 2    FORMAT(1H1)                                                       950JK012
 3    FORMAT(6E12.7)                                                    950JK013
 4    FORMAT(3X,1P7E16.7)                                               950JK014
 5    FORMAT(1H0)                                                       950JK015
 7    FORMAT(5X,4HIC0=I4,5X,4HIC2=I4)                                   950JK016
 10   FORMAT(1H0,4X,27HUNABLE TO CONVERGE PATCHING)                     950JK017
C                                                                       950JK018
      EOWIGL=EOWIG                                                      950JK019
      E2WIGL=E2WIG                                                      950JK020
      EOWIG=DER(4)*DENO                                                 950JK021
      E2WIG=DER(7)*DEN2                                                 950JK022
      WRITE OUTPUT TAPE 6,4,V(1),EO,EOWIG,E2,E2WIG                      950JK023
      IF(L1-1) 300,300,320                                              950JK024
 300  DO 310 J=1,7                                                      950JK025
      VE(J)=V(J)                                                        950JK026
 310  ERE(J)=ER(J)                                                      950JK027
      L1=2                                                              950JK028
      M6=2                                                              950JK029
      JDO=0                                                             950JK030
      JD2=0                                                             950JK031
      NBR=0                                                             950JK032
      IC2=1                                                             950JK033
      NTR=1                                                             950JK034
      MPT=JPT                                                           950JK035
      THX=V(1)                                                          950JK036
      TDT=2.0*DTH                                                       950JK037
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      IF(M5) 312,312,311                                                950JK038
  311 CUT1=1000.0                                                       950JK039
      CUT2=CUT1                                                         950JK040
      GO TO 156                                                         950JK041
  312 CF4(1)=DER(4)                                                     950JK042
      CF4(2)=(DER(4)-XNO(JPT-1)/DNO(JPT-1))/(2.0*DTH)                   950JK043
      CF4(3)=0.0                                                        950JK044
      CF4(4)=0.0                                                        950JK045
      CF7(1)=DER(7)                                                     950JK046
      CF7(2)=(DER(7)-XN2(JPT-1)/DN2(JPT-1))/(2.0*DTH)                   950JK047
      CF7(3)=CF7(2)/(4.0*DTH)+(XN2(JPT-3)/DN2(JPT-3)-DER(7))/(4.*DTH)**2950JK048
      CF7(4)=0.0                                                        950JK049
      CUT1=1.0E-05                                                      950JK050
      CUT2=1.0E-05                                                      950JK051
  315 WRITE OUTPUT TAPE 6,5                                             950JK052
      WRITE OUTPUT TAPE 6,4,(CF4(J),J=1,4)                              950JK053
      WRITE OUTPUT TAPE 6,4,(CF7(J),J=1,4)                              950JK054
      GO TO 156                                                         950JK055
  320 IF(DENO) 330,340,350                                              950JK056
  330 IF(JDO) 340,340,350                                               950JK057
  340 A1=DNO(JPT)*DNO(JPT-1)/((DENO-DNO(JPT))*(DENO-DNO(JPT-1)))        950JK058
      A2=DENO*DNO(JPT-1)/((DNO(JPT)-DENO)*(DNO(JPT)-DNO(JPT-1)))        950JK059
      A3=DENO*DNO(JPT)/((DNO(JPT-1)-DENO)*(DNO(JPT-1)-DNO(JPT)))        950JK060
      THOS=V(1)*A1+(V(1)-DTH)*A2+(V(1)-2.0*DTH)*A3                      950JK061
      EOS=EO*A1+XNO(JPT)*A2+XNO(JPT-1)*A3                               950JK062
      WRITE OUTPUT TAPE 6,4,THOS,EOS                                    950JK063
      JDO=1                                                             950JK064
  350 IF(DEN2) 360,360,156                                              950JK065
  360 IF(JD2) 370,370,375                                               950JK066
  370 A1=DN2(JPT)*DN2(JPT-1)/((DEN2-DN2(JPT))*(DEN2-DN2(JPT-1)))        950JK067
      A2=DEN2*DN2(JPT-1)/((DN2(JPT)-DEN2)*(DN2(JPT)-DN2(JPT-1)))        950JK068
      A3=DEN2*DN2(JPT)/((DN2(JPT-1)-DEN2)*(DN2(JPT-1)-DN2(JPT)))        950JK069
      TH2S=V(1)*A1+(V(1)-DTH)*A2+(V(1)-2.0*DTH)*A3                      950JK070
      E2S=E2*A1+XN2(JPT)*A2+XN2(JPT-1)*A3                               950JK071
      WRITE OUTPUT TAPE 6,4,TH2S,E2S                                    950JK072
      JD2=1                                                             950JK073
      IF(NBR) 372,372,375                                               950JK074
  372 FAT=1.0-(V(1)-TH2S)/DTH                                           950JK075
      FOR=XNO(JPT)+(EO-XNO(JPT))*FAT                                    950JK076
      FOW=EOWIGL+(EOWIG-EOWIGL)*FAT                                     950JK077
      FOS=FOR-FOW                                                       950JK078
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375   IF(JD2-JD0) 156,380,156                                               950JK079
380   IF(ABSF(E0S)-CUT1) 390,390,400                                        950JK080
390   IF(ABSF(E2S)-CUT1) 500,500,400                                        950JK081
400   NBR=NBR+1                                                             950JK082
      IF(NBR-2) 410,420,430                                                 950JK083
410   CF7L=CF7(2)                                                           950JK084
      E0SLL=E0S                                                             950JK085
      E2SLL=E2S                                                             950JK086
      CF7(2)=0.99*CF7L                                                      950JK087
      GO TO 440                                                             950JK088
420   CF4L=CF4(2)                                                           950JK089
      E0SL=E0S                                                              950JK090
      E2SL=E2S                                                              950JK091
      CF4(2)=1.01*CF4L                                                      950JK092
      GO TO 440                                                             950JK093
430   IF(NTR-15) 435,50,50                                                  950JK094
50    WRITE OUTPUT TAPE 6,10                                                950JK095
      CALL EXIT                                                             950JK096
435   NTR=NTR+1                                                             950JK097
      NBR=0                                                                 950JK098
      DE0D4=(E0S-E0SL)/(CF4(2)-CF4L)                                        950JK099
      DE2D4=(E2S-E2SL)/(CF4(2)-CF4L)                                        950JK100
      DE0D7=(E0SL-E0SLL)/(CF7(2)-CF7L)                                      950JK101
      DE2D7=(E2SL-E2SLL)/(CF7(2)-CF7L)                                      950JK102
      DCF4=(E2SLL/DE2D7-E0SLL/DE0D7)/(DE0D4/DE0D7-DE2D4/DE2D7)              950JK103
      DCF7=(E2SLL/DE2D4-E0SLL/DE0D4)/(DE0D7/DE0D4-DE2D7/DE2D4)              950JK104
      WRITE OUTPUT TAPE 6,4,E0SLL,E0SL,E0S,E2SLL,E2SL,E2S,CF4L,CF4(2),CF950JK105
     17L,CF7(2),DE0D4,DE2D4,DE0D7,DE2D7,DCF4,DCF7                           950JK106
      CF4(2)=CF4L+DCF4                                                      950JK107
      CF7(2)=CF7L+DCF7                                                      950JK108
      WRITE OUTPUT TAPE 6,5                                                 950JK109
      WRITE OUTPUT TAPE 6,4,CF4(2),CF7(2)                                   950JK110
C                                                                           950JK111
440   DO 450 J=1,7                                                          950JK112
      V(J)=VE(J)                                                            950JK113
450   ER(J)=ERE(J)                                                          950JK114
      M3=2                                                                  950JK115
      M6=1                                                                  950JK116
      IF(NDIM) 460,460,465                                                  950JK117
460   CALL NASTY                                                            950JK118
      GO TO 470                                                             950JK119
```

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 465  CALL MESSY                                             950JK120
 470  M6=2                                                   950JK121
      JPT=MPT                                                950JK122
      JD0=0                                                  950JK123
      JD2=0                                                  950JK124
      WRITE OUTPUT TAPE 6,2                                  950JK125
      L2=2                                                   950JK126
      RETURN                                                 950JK127
C                                                            950JK128
 500  NTR=1                                                  950JK129
      IC2=IC2+1                                              950JK130
      WRITE OUTPUT TAPE 6,5                                  950JK131
      WRITE OUTPUT TAPE 6,7,IC0,IC2                          950JK132
      WRITE OUTPUT TAPE 6,4,TH2S,FOR,FOW,FOS                 950JK133
      IF(ABSF(FOS)-CUT2) 600,600,502                         950JK134
 502  IF(IC2-2) 505,505,510                                  950JK135
 505  BF7L=CF7(3)                                            950JK136
      CF7(3)=BF7L-0.1                                        950JK137
      FOSL=FOS                                               950JK138
      WRITE OUTPUT TAPE 6,4,BF7L,FOSL                        950JK139
      GO TO 440                                              950JK140
 510  IF(IC2-15) 515,515,50                                  950JK141
 515  FOSP=(FOS-FOSL)/(CF7(3)-BF7L)                          950JK142
      BF7L=CF7(3)                                            950JK143
      FOSL=FOS                                               950JK144
      CF7(3)=BF7L-FOSL/FOSP                                  950JK145
      WRITE OUTPUT TAPE 6,4,BF7L,FOSL                        950JK146
      GO TO 440                                              950JK147
C                                                            950JK148
 156  L2=1                                                   950JK149
      RETURN                                                 950JK150
 600  L2=3                                                   950JK151
      RETURN                                                 950JK152
      END
```

```
      SUBROUTINE POOH(J)                                                950JL000
*     LABEL
 950JL                                                                  950JL
C                                                                       950JL001
      DIMENSION V(7),DER(7),VR(50),CFT(4),CF4(4),CF7(4)                 950JL002
      DIMENSION BL(2,300)                                               950JL003
      DIMENSION BBB(10,100),M(10),ARRAY(12)                             950JL004
C                                                                       950JL005
      COMMON V,DER,E0,DEN0,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5, 950JL006
     1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,  950JL007
     2FSMS,FSW,FSWS,PHI0,FENT,RORT,PRAT,EPS0,U20,PSI1,PHI1,PHI2,DLPP1,  950JL008
     3DLPP2,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,X0,S0,S1,S2,T0,T1,950JL009
     4T2,G0,G1,G2,W2S,W1S,V1,U1,M5,M6,THX,DTHX,CF4,CF7                  950JL010
C                                                                       950JL011
      ZMACHF(X)=SQRTF(1.0/(C8*(1.0/X-1.0)))                             950JL012
C                                                                       950JL013
      CC2=C1*C2                                                         950JL014
      IF(J-2) 1,10,20                                                   950JL015
 1    X=-EPS0                                                           950JL016
      Y=0.0                                                             950JL017
      U1S=(FSW*(1.0-C6*(1.0-1.0/FSMS)))**2                              950JL018
      P=FENT*(1.0-U1S)**CC2                                             950JL019
      DEL=0.0                                                           950JL020
      ZM=ZMACHF(U1S)                                                    950JL021
      K=1                                                               950JL022
      REWIND 3                                                          950JL023
      CALL SPMOVE (X,Y,P,DEL,ZM,FENT,K,V(3),BBB,1)                      950JL024
      X=-EPS0/2.0                                                       950JL025
      U2S=V(6)**2                                                       950JL026
      P=FENT*(1.0-U2S)**CC2                                             950JL027
      ZM=ZMACHF(U2S)                                                    950JL028
      K=0                                                               950JL029
      DUM=0.0                                                           950JL030
      CALL SPMOVE (X,Y,P,DEL,ZM,FENT,K,DUM,BBB,2)                       950JL031
      X=0.0                                                             950JL032
      DEL=1.5707963                                                     950JL033
      K=-1                                                              950JL034
      CALL SPMOVE (X,Y,FENT,DEL,X,FENT,K,DUM,BBB,3)                     950JL035
      NRL=1                                                             950JL036
      BL(1,1)=0.0                                                       950JL037
```

```
      BL(2,1) = 0.0                                                     950JL038
      WRITE TAPE 3,BBB                                                  950JL039
      RETURN                                                            950JL040
C                                                                       950JL041
 10   NRL=NRL+1                                                         950JL042
      BL(1,NRL)=V(1)                                                    950JL043
      BL(2,NRL) =V(4)/FSW                                               950JL044
      RXI=1.0+V(2)                                                      950JL045
      X=1.0-RXI*F2                                                      950JL046
      Y=RXI*F1                                                          950JL047
      R=PHI1**(-C2)                                                     950JL048
      P=R*(1.0-W1S)**CC2                                                950JL049
      ZM=ZMACHF(W1S)                                                    950JL050
      DEL=3.14159763*(0.5+SIGNF(0.5,U1))-ATANF(ABSF(V1/U1))*SIGNF(1.0,U1950JL051
     1)-V(1)                                                            950JL052
      K=1                                                               950JL053
      CALL SPMOVE (X,Y,P,DEL,ZM,R,K,V(3),BBB,1)                         950JL054
      RXI=1.0+0.5*V(2)                                                  950JL055
      X=1.0-RXI*F2                                                      950JL056
      Y=RXI*F1                                                          950JL057
      R=PHI2**(-C2)                                                     950JL058
      P=R*(1.0-W2S)**CC2                                                950JL059
      DEL=3.14159763*(0.5+SIGNF(0.5,V(6)))-ATANF(ABSF(V(7)/V(6)))*SIGNF(950JL060
     11.0,V(6))-V(1)                                                    950JL061
      ZM=ZMACHF(W2S)                                                    950JL062
      K=0                                                               950JL063
      CALL SPMOVE (X,Y,P,DEL,ZM,R,K,DUM,BBB,2)                          950JL064
      X=1.0-F2                                                          950JL065
      Y=F1                                                              950JL066
      WOS=V(4)**2                                                       950JL067
      P=FENT*(1.0-WOS)**CC2                                             950JL068
      DEL=1.5707963-V(1)                                                950JL069
      ZM=ZMACHF(WOS)                                                    950JL070
      K=-1                                                              950JL071
      CALL SPMOVE (X,Y,P,DEL,ZM,FENT,K,DUM,BBB,3)                       950JL072
      WRITE TAPE 3,BBB                                                  950JL073
      RETURN                                                            950JL074
C                                                                       950JL075
 20   REWIND 2                                                          950JL076
      READ TAPE 2,C1,FSM,FSP,FST,M,ARRAY                                950JL077
      RBAR = 1.0                                                        950JL078
```

```
      REWIND 2                                                          950JL079
      WRITE TAPE 2,C1,FSM,FSP,FST,M,ARRAY,RBAR,DUM,DUM,BBB,BBB,         950JL080
     1  NRL,((BL(N,M),N=1,2),M=1,NRL)                                   950JL081
      RETURN                                                            950JL082
      END
```

```
      SUBROUTINE BODY                                                   950JMM00
C                                                                       950JMM01
      DIMENSION V(7),DER(7),VR(50),CFT(4),CF4(4),CF7(4)                 950JMM02
C                                                                       950JMM03
      COMMON V,DER,E0,DEN0,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5, 950JMM04
     1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,  950JMM05
     2FSMS,FSW,FSWS,PHI0,FENT,RORT,PRAT,EPS0,U20,PSI1,PHI1,PHI2,DLPP1,  950JMM06
     3DLPP2,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,X0,S0,S1,S2,T0,T1,950JMM07
     4T2,G0,G1,G2,W2S,W1S,V1,U1,M5,M6,THX,DTHX,CF4,CF7                  950JMM08
C                                                                       950JMM09
      GO TO(30,40,50,60,100),NOPT                                       950JMM10
C                                                                       950JMM11
 30   CT4=CT1*F2                                                        950JMM12
      XI=(CT4+SQRTF(CT4**2-CT2*(1.0-(CT3*F1**2))))/(1.0-(CT3*F1**2))    950JMM13
 35   CT5=XI*CT3                                                        950JMM14
      CT6=CT2-XI*CT4                                                    950JMM15
      ETA=XI*F1*(CT1-CT5*F2)/CT6                                        950JMM16
      ETAP=XI*(F2*((CT1*ETA-2.0*CT5*F1)*ETA+CT1-2.0*CT5*F2)+XI*CT3)/CT6 950JMM17
      RB=XI*A                                                           950JMM18
      RETURN                                                            950JMM19
C                                                                       950JMM20
 40   XI=CT1/(F2+SQRTF(1.0+CT2*F1**2))                                  950JMM21
      CT3=XI*F2                                                         950JMM22
      CT4=CT1-CT3                                                       950JMM23
      CT5=XI*F1                                                         950JMM24
      ETA=CT5*(1.0-CT3)/CT4                                             950JMM25
      ETAP=XI*(F2*((ETA-2.0*CT5)*ETA+1.0-2.0*CT3)+XI)/CT4               950JMM26
      RB=XI*2.0*A                                                       950JMM27
      RETURN                                                            950JMM28
C                                                                       950JMM29
 50   RB=X0/F2                                                          950JMM30
      ETA=F1/F2                                                         950JMM31
      ETAP=1.0/(F2**2)                                                  950JMM32
 100  RETURN                                                            950JMM33
C                                                                       950JMM34
 60   CT4=CT1*F2                                                        950JMM35
      XI=CT2/(CT4+SQRTF(CT4**2-CT2*(1.0-CT3*F1**2)))                    950JMM36
      GO TO 35                                                          950JMM37
      END                                                               950JMM38
```

```
      SUBROUTINE LSTSQR                                                 950JRR00
C                                                                       950JRR01
      DIMENSION V(7),DER(7),VR(50),CFT(4),CF4(4),CF7(4)                 950JRR02
      COMMON V,DER,E0,DEN0,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5, 950JRR03
     1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,  950JRR04
     2FSMS,FSW,FSWS,PHI0,FENT,RORT,PRAT,EPS0,U20,PSI1,PHI1,PHI2,DLPP1,  950JRR05
     3DLPP2,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,X0,S0,S1,S2,T0,T1,950JRR06
     4T2,G0,G1,G2,W2S,W1S,V1,U1,M5,M6,THX,DTHX,CF4,CF7                  950JRR07
C                                                                       950JRR08
      N1=NFT+1                                                          950JRR09
      N2=NFT/2+1                                                        950JRR10
      BN=NFT/2                                                          950JRR11
      BN1=BN+1.0                                                        950JRR12
      SX0=N1                                                            950JRR13
      SX2=BN1*(2.0*BN+1.0)/(12.0*BN)                                    950JRR14
      SX4=BN1*(((6.0*BN+9.0)*BN+1.0)*BN-1.0)/(240.0*BN**3)              950JRR15
      SX6=BN1*(((((6.0*BN+15.0)*BN+6.0)*BN-6.0)*BN-1.0)*BN+1.0)/(1344.0*950JRR16
     1BN**5)                                                            950JRR17
      SY0=0.0                                                           950JRR18
      SY1=0.0                                                           950JRR19
      SY2=0.0                                                           950JRR20
      SY3=0.0                                                           950JRR21
      DO 10 I=1,N1                                                      950JRR22
      TJ=I-N2                                                           950JRR23
      SY0=SY0+VR(I)                                                     950JRR24
      SY1=SY1+VR(I)*TJ                                                  950JRR25
      SY2=SY2+VR(I)*TJ**2                                               950JRR26
   10 SY3=SY3+VR(I)*TJ**3                                               950JRR27
      SN=NFT                                                            950JRR28
      SY1=SY1/SN                                                        950JRR29
      SY2=SY2/(SN**2)                                                   950JRR30
      SY3=SY3/(SN**3)                                                   950JRR31
      CFT(1)=(SY0/SX2-SY2/SX4)/(SX0/SX2-SX2/SX4)                        950JRR32
      CFT(2)=(SY1/SX4-SY3/SX6)/(SX2/SX4-SX4/SX6)                        950JRR33
      CFT(3)=(SY0/SX0-SY2/SX2)/(SX2/SX0-SX4/SX2)                        950JRR34
      CFT(4)=(SY1/SX2-SY3/SX4)/(SX4/SX2-SX6/SX4)                        950JRR35
      RETURN                                                            950JRR36
      END                                                               950JRR37
```

```
      SUBROUTINE SPMOVE (X,Y,P,TH,ZM,R,NPT,W,E,IB)                      950JGG00
*     LABEL
 950JGG                                                                 950JGG
      DIMENSION B(10,100)                                               950JGG01
      B(1,IB) = X                                                       950JGG02
      EQUIVALENCE (XNPT,NPT1)                                           950JGG03
      NPT1 = NPT                                                        950JGG04
      B(2,IB) = Y                                                       950JGG05
      B(3,IB) = P                                                       950JGG06
      B(4,IB) = TH                                                      950JGG07
      B(5,IB) = ZM                                                      950JGG08
      B(6,IB) = R                                                       950JGG09
      B(7,IB) = XNPT                                                    950JGG10
      B(8,IB) = W                                                       950JGG11
      RETURN                                                            950JGG12
      END
```

```
C     MAIN PROGRAM CHAIN VIII - TURNING VANE.                              950J8000
*     LABEL
 950J8                                                                     950J8
C        PROGRAM TO START CALCULATION FROM INITIAL VALUE                   950J8001
C        LINE.                                                             950J8002
C                                                                          950J8003
      DIMENSION IND(100),X(100),Y(100)                                     950J8004
      DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),       950J8005
     1          XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)                    950J8006
      DIMENSION AC1(6,20),AC2(6,20)                                        950J8007
      DIMENSION ARRAY(12)                                                  950J8008
      DIMENSION BU(10,100),WU(10,100)                                      950J8009
      DIMENSION BBB(2,100)                                                 950J8010
C                                                                          950J8011
      COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2               950J8012
      COMMON GAMMA,FSM,FSP,FST,SW                                          950J8013
C                                                                          950J8014
      EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(950J8015
     15),ZMU1),                                                            950J8016
     2(XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),      950J8017
     3(XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),      950J8018
     4(XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),      950J8019
     5(XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),      950J8020
     6(XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),      950J8021
     7(XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),950J8022
     1 ZMU3A)                                                              950J8023
      EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),      950J8024
     1  (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),                950J8025
     2  (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),                950J8026
     3  (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),                950J8027
     4  (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),        950J8028
     5  (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),        950J8029
     8(XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),950J8030
     1 ZMU3B),                                                             950J8031
     9(XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),                  950J8032
     6(XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)                   950J8033
      EQUIVALENCE (XX1(10),NPONT1),(XX2(10),NPONT2),                       950J8034
     1  (XX3(10),NPONT3),(XX5(10),NPONT5)                                  950J8035
C                                                                          950J8036
 400  FORMAT (1H1,10X1HX,16X1HY,33X1HA,16X1HB,16X1HC,16X1HD//)             950J8037
```

```
 409  FORMAT (1P2E17.7/52X,1P4E17.7)                                        950J8038
C                                                                           950J8039
      DO 5 I=1,100                                                          950J8040
 5    IND(I) = 0                                                            950J8041
      IP = 2                                                                950J8042
      REWIND 2                                                              950J8043
      REWIND 3                                                              950J8044
      READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,R1,R1,B,B,NRL,             950J8045
     1  ((BBB(M,L),M=1,2),L=1,NRL)                                          950J8046
      CALL PAGE2 (0,ARRAY)                                                  950J8047
      REWIND 9                                                              950J8048
      DO 6 I=1,NRL                                                          950J8049
      READ TAPE 3,B                                                         950J8050
      WRITE TAPE 9,B                                                        950J8051
 6    CONTINUE                                                              950J8052
      REWIND 3                                                              950J8053
      REWIND 4                                                              950J8054
C                                                                           950J8055
      DO 10 I=1,100                                                         950J8056
      READ TAPE 2,(BU(J,I),J=1,10)                                          950J8057
      IF (BU(7,I)) 20,10,10                                                 950J8058
 10   CONTINUE                                                              950J8059
C                                                                           950J8060
 20   SW = .2*(SQRTF((BU(1,1)-BU(1,I))**2+(BU(2,1)-BU(2,I))**2))            950J8061
      CALL DMOVE (B,BU)                                                     950J8062
      CALL DMOVE (B(1,2),BU)                                                950J8063
      NPT1 = 12345                                                          950J8064
      CALL DMOVE (B(1,3),XX1)                                               950J8065
C                                                                           950J8066
      NN = 1                                                                950J8067
 30   NN = NN+1                                                             950J8068
      CALL CHLIN8 (B,W,BU,1.0,GAMMA,NN,SW,FSM)                              950J8069
      DO 35 I=1,100                                                         950J8070
      DO 35 J=1,10                                                          950J8071
      B(J,I) = W(J,I)                                                       950J8072
 35   CONTINUE                                                              950J8073
C                                                                           950J8074
      IF (BU(7,NN))40,30,30                                                 950J8075
 40   SENSE LIGHT 1                                                         950J8076
      NT = 0                                                                950J8077
      REWIND 2                                                              950J8078
```

```
      WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,R1,R1,B,BU,NRL,       950J8079
     1  ((BBB(M,L),M=1,2),L=1,NRL)                                      950J8080
      CALL NEWBDY (RBAR,B,RAD1,X,Y,N1,XCNTR,YOPEN)                      950J8081
      NPT1 = 12345                                                      950J8082
      RRBAR = RAD1/RBAR                                                 950J8083
      REWIND 9                                                          950J8084
      DO 45 I=1,NRL                                                     950J8085
      READ TAPE 9,WU                                                    950J8086
      IF (I-IP*(I/IP)) 41,45,41                                         950J8087
   41 DO 42 J=1,3                                                       950J8088
      WU(1,J) = (WU(1,J)-RBAR)*RRBAR+XCNTR                              950J8089
      WU(2,J) = ABSF(YOPEN-WU(2,J)*RRBAR)                               950J8090
      WU(4,J) = -WU(4,J)                                                950J8091
      WU(8,J) = -WU(8,J)                                                950J8092
   42 CONTINUE                                                          950J8093
      CALL DMOVE (WU(1,4),XX1)                                          950J8094
      CALL STORE (BU,WU,3,M,ARRAY)                                      950J8095
   45 CONTINUE                                                          950J8096
      CALL STORE (WU,B,3,M,ARRAY)                                       950J8097
      S1 = SINF(B(4,1))/COSF(B(4,1))                                    950J8098
      IND(N1-1) = 1                                                     950J8099
      IND(2) = 1                                                        950J8100
      CALL CUBIC (X,Y,IND,N1,S1,S2,AC1)                                 950J8101
      NN = N1                                                           950J8102
      N = 0                                                             950J8103
C                                                                       950J8104
   70 WRITE OUTPUT TAPE 6,400                                           950J8105
      DO 100 I=2,NN                                                     950J8106
      IF (N) 80,80,90                                                   950J8107
   80 WRITE OUTPUT TAPE 6,409,X(I-1),Y(I-1),AC1(2,I-1),AC1(3,I-         950J8108
     11),  AC1(4,I-1),AC1(5,I-1)                                        950J8109
      GO TO 100                                                         950J8110
C                                                                       950J8111
   90 WRITE OUTPUT TAPE 6,409,X(I-1),Y(I-1),AC2(2,I-1),AC2(3,I-         950J8112
     11),  AC2(4,I-1),AC2(5,I-1)                                        950J8113
C                                                                       950J8114
  100 CONTINUE                                                          950J8115
      IF (N) 110,110,120                                                950J8116
  110 N = 1                                                             950J8117
      WRITE OUTPUT TAPE 6,409,X(N1),Y(N1)                               950J8118
      CALL NEWBDY (RBAR,W,RAD2,X,Y,N2,XCNTR,YOPEN)                      950J8119
```

```
      REWIND 9                                                          950J8120
      RRBAR = RAD2/RBAR                                                 950J8121
      DO 130 I=1,NRL                                                    950J8122
      READ TAPE 9,WU                                                    950J8123
      IF (I-IP*(I/IP)) 111,130,111                                      950J8124
  111 DO 125 J=1,3                                                      950J8125
      WU(1,J) = (WU(1,J)-RBAR)*RRBAR+XCNTR                              950J8126
      WU(2,J) = ABSF(YOPEN-WU(2,J)*RRBAR)                               950J8127
  125 CONTINUE                                                          950J8128
      CALL DMOVE (WU(1,4),XX1)                                          950J8129
      CALL STORE (BU,WU,4,M,ARRAY)                                      950J8130
  130 CONTINUE                                                          950J8131
      DO 131 I=1,100                                                    950J8132
  131 IND(I) = 0                                                        950J8133
      NN = N2                                                           950J8134
      S1 = SINF(W(4,1))/COSF(W(4,1))                                    950J8135
      IND(N2-1) = 1                                                     950J8136
      IND(2) = 1                                                        950J8137
      CALL CUBIC (X,Y,IND,N2,S1,S2,AC2)                                 950J8138
      GO TO 70                                                          950J8139
  120 WRITE OUTPUT TAPE 6,409,X(N2),Y(N2)                               950J8140
      CALL STORE (B,W,4,M,ARRAY)                                        950J8141
      N1 = N1-1                                                         950J8142
      N2 = N2-1                                                         950J8143
      REWIND 2                                                          950J8144
      READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,DUM,DUM,B,BU           950J8145
     1  ,N,((BBB(M,L),M=1,2),L=1,N)                                     950J8146
      REWIND 2                                                          950J8147
      WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,RAD1,RAD2,B,BU        950J8148
     1  ,N,((BBB(M,L),M=1,2),L=1,N)                                     950J8149
      WRITE TAPE 2,AC1,AC2,N1,N2                                        950J8150
      CALL LOCATE (-1,T,ITT,DUM,DUM,DUM,DUM,DUM)                        950J8151
C                                                                       950J8152
   60 CALL CHAIN (2,8)                                                  950J8153
  999 CALLDUMP                                                          950J8154
      END
```

```
      SUBROUTINE CHLIN8 (B,W,BU,TT,GAMMA,NN,SWL,FSM)                    950JM000
*     LABEL
 950JM                                                                  950JM
C                                                                       950JM001
C     TT NEGATIVE -- UPPER BODY                                         950JM002
C     TT POSITIVE -- LOWER BODY                                         950JM003
C     THE BU ARRAY CONTAINS THE INITIAL VALUE LINE.                     950JM004
C                                                                       950JM005
      DIMENSION B(10,100),W(10,100),BU(10,100),XX1U(10),XX1(10),        950JM006
     1  XX3(10),XX3U(10)                                                950JM007
      EQUIVALENCE (NPT1,XX1(7)),(NPT3,XX3(7))                           950JM008
C                                                                       950JM009
      IW = 1                                                            950JM010
      IB = 0                                                            950JM011
      T = TT                                                            950JM012
      C1 = GAMMA                                                        950JM013
      N =NN                                                             950JM014
      SW = SWL                                                          950JM015
      CALL DMOVE (W,BU(1,N))                                            950JM016
C                                                                       950JM017
      IF (T) 10,10,20                                                   950JM018
 10   NPT = 2                                                           950JM019
      GO TO 30                                                          950JM020
 20   NPT = 1                                                           950JM021
C                                                                       950JM022
 30   IW = IW+1                                                         950JM023
 40   IB = IB+1                                                         950JM024
      CALL DMOVE (XX1,B(1,IB))                                          950JM025
      IF (NPT1-NPT) 50,40,80                                            950JM026
 50   IF (T) 60,60,70                                                   950JM027
C                                                                       950JM028
 60   CALL FDPT (B(1,IB),W(1,IW-1),W(1,IW),C1,M1)                       950JM029
      GO TO 30                                                          950JM030
 70   CALL FDPT (W(1,IW-1),B(1,IB),W(1,IW),C1,M1)                       950JM031
      GO TO 30                                                          950JM032
C                                                                       950JM033
 80   CONTINUE                                                          950JM034
      XX1U(1) = B(1,IB-2)                                               950JM
      XX1U(2) = B(2,IB-2)                                               950JM035
      CALL SHOCK (2,M1,T,XXA,XXB,XX1U,B(1,IB-2),W(1,IW-1),XX3U,XX3,XX5, 950JM036
```

```
     1  C1,SW,FSM)                                            950JM037
      M1 = M1                                                 950JM038
      GO TO (100,999,999,999,90,90),M1                        950JM039
   90 IF (SWL/SW-4.0) 95,105,105                              950JM040
   95 SW = SW/2.0                                             950JM041
      GO TO 80                                                950JM042
C                                                             950JM043
  100 NPT3 = NPT                                              950JM044
      CALL DMOVE (B(1,IB-2),XX3)                              950JM045
      CALL DMOVE (W(1,IW),XX3)                                950JM046
      IF (T) 101,101,102                                      950JM047
  101 CALL FDPT (W(1,IW),W(1,IW-1),W(1,IW+1),C1,M1)           950JM048
      IW = IW+2                                               950JM049
      GO TO 80                                                950JM050
  102 CALL FDPT (W(1,IW-1),W(1,IW),W(1,IW+1),C1,M1)           950JM051
      IW = IW+2                                               950JM052
      GO TO 80                                                950JM053
  999 CALL DUMP                                               950JM054
C                                                             950JM055
  105 NPT1 = 12345                                            950JM056
      CALL DMOVE (W(1,IW),XX1)                                950JM057
      RETURN                                                  950JM058
      END
```

```
      SUBROUTINE NEWBDY (RBAR,B,RADIUS,X,Y,NN1,XCNTR,YCNTR)             950JN000
*     LABEL
 950JN                                                                   950JN
      DIMENSION X(100),Y(100),B(10,100),XX1(10)                         950JN001
      EQUIVALENCE (XX1(7),NPT1)                                         950JN002
 3    FORMAT (3X,1P7E16.7)                                              950JN003
 401  FORMAT (6E10.5)                                                   950JN004
 400  FORMAT (4(2E8.5,I2))                                              950JN005
 404  FORMAT (I5,5E10.5)                                                950JN006
      RBAR = 1.0                                                        950JNJ07
      READ INPUT TAPE 5,404,N1,RADIUS,T ANGLE,XCNTR,YCNTR               950JN008
      NN1 = N1+2                                                        950JN009
      READ INPUT TAPE 5,401,(X(I),Y(I),I=3,NN1)                         950JN010
      T ANGLE = T ANGLE/57.29578                                        950JN011
      IF (T ANGLE) 20,20,10                                             950JN012
 10   S1 = 1.0                                                          950JN013
      GO TO 30                                                          950JN014
 20   S1 = -1.0                                                         950JN015
 30   RRBAR = RADIUS/RBAR                                               950JN016
      T1 = COSF(T ANGLE)                                                950JN017
      T2 = SINF(T ANGLE)                                                950JN018
      T3 = RADIUS/50.0                                                  950JN019
      X(2) = XCNTR-RADIUS*T1                                            950JN020
      Y(2) = YCNTR+RADIUS*T2                                            950JN021
      X(3) = X(2)+T3                                                    950JN022
      Y(3) = Y(2)+T3   *T1/T2                                           950JN023
      DO 50 I=1,100                                                     950JN024
      CALL DMOVE (XX1,B(1,I))                                           950JN025
      IF (NPT1-12345) 40,60,40                                          950JN026
 40   CONTINUE                                                          950JN027
      B(1,I) = (B(1,I)-RBAR)*RRBAR+XCNTR                                950JN028
      B(2,I) = ABSF(YCNTR-B(2,I)*RRBAR)                                 950JN029
      B(4,I) = SIGNF(B(4,I),S1)                                         950JN030
      B(8,I) = SIGNF(B(8,I),S1)                                         950JN031
 50   CONTINUE                                                          950JN032
 60   IF (S1) 65,68,68                                                  950JN033
 65   CALL DMOVE (XX1,B(1,1))                                           950JN034
      NPT1 = -2                                                         950JN035
      CALL DMOVE (B(1,1),XX1)                                           950JN036
      DO 67 I=2,100                                                     950JN037
```

```
      CALL DMOVE (XX1,B(1,I))                                          950JN038
      IF (NPT1-1) 67,66,68                                             950JN039
66    NPT1 = 2                                                         950JN040
      CALL DMOVE (B(1,I),XX1)                                          950JN041
67    CONTINUE                                                         950JN042
68    X(1) = B(1,1)                                                    950JN043
      Y(1) = B(2,1)                                                    950JN044
      IF (B(1,1)-X(3)) 70,62,62                                        950JN045
62    WRITE OUTPUT TAPE 6,410                                          950JN046
410   FORMAT (32H THE FIRST POINT OF THE BODY IS                       950JN047
     1  32HUPSTREAM OF THE BLUNT BODY DATA.)                           950JN048
      CALL DUMP                                                        950JN049
70    CONTINUE                                                         950JN050
      RETURN                                                           950JN051
      END
```

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C       MAIN PROGRAM SECOND CHAIN  -  TURNING VANE                      950J2000
C                                                                       950J2001
      DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),    950J2002
     1          XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)                 950J2003
      DIMENSION AC1(6,20),AC2(6,20)                                     950J2004
      DIMENSION XX1U(10),XX3U(10),XXA(10),XXB(10)                       950J2005
      DIMENSION ARRAY(12)                                               950J2006
      DIMENSION BU(10,100),WU(10,100)                                   950J2007
C                                                                       950J2008
      COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2            950J2009
      COMMON GAMMA,FSM,FSP,FST,SW                                       950J2010
      COMMON XX1,XX3U,XXA,XXB                                           950J2011
C                                                                       950J2012
      EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(950J2013
     15),ZMU1),                                                         950J2014
     2(XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),   950J2015
     3(XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),   950J2016
     4(XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),   950J2017
     5(XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),   950J2018
     6(XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),   950J2019
     7(XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),950J2020
     1 ZMU3A)                                                           950J2021
      EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),   950J2022
     1  (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),             950J2023
     2  (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),             950J2024
     3  (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),             950J2025
     4  (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),     950J2026
     5  (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),     950J2027
     8(XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),950J2028
     1 ZMU3B),                                                          950J2029
     9(XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),               950J2030
     6(XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)                950J2031
      EQUIVALENCE (XX1(10),NPONT1),(XX2(10),NPONT2),                    950J2032
     1  (XX3(10),NPONT3),(XX5(10),NPONT5)                               950J2033
C                                                                       950J2034
  500 FORMAT (///19H ERROR IN CHAIN II.)                                950J2035
  510 FORMAT (1P6E15.5)                                                 950J2036
C                                                                       950J2037
C                                                                       950J2038
   20 CCC = 1.                                                          950J2039
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30    BACKSPACE 3                                                      950J2040
      BACKSPACE 4                                                      950J2041
      READ TAPE 3,BU                                                   950J2042
      READ TAPE 4,B                                                    950J2043
      CALL MOVE1 (IB,B)                                                950J2044
      XXL = B(1,IB-2)                                                  950J2045
      YYL = B(2,IB-2)                                                  950J2046
      YYU = YYL                                                        950J2047
      XXU = 100.0                                                      950J2048
      YYL1 = YYL                                                       950J2049
      XXL1 = 100.0                                                     950J2050
      REWIND 2                                                         950J2051
      READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY                            950J2052
      CALL LOCATE (-1,T,ITT,DUM,DUM,DUM,DUM,DUM)                       950J2053
      C1 = GAMMA                                                       950J2054
      SW = (BU(2,1)-B(2,1))/20.                                        950J2055
      SWL = SW                                                         950J2056
      FSMS = FSM**2                                                    950J2057
      XX1U(3) = (1.+(GAMMA-1.)/2.*FSMS)**(-GAMMA/(GAMMA-1.))           950J2058
      XX1U(4) = 0.0                                                    950J2059
      XX1U(5) = ATANF(SQRTF(1./(FSMS-1.)))                             950J2060
      XX1U(6) = 1.0                                                    950J2061
C                                                                      950J2062
 301  IBU = 2                                                          950J2063
 3010 IWU = 1                                                          950J2064
      SW = SWL/2.0                                                     950J2065
      IF (BU(7,IBU-1)) 303,303,302                                     950J2066
 302  CALL DMOVE (WU(1,1),BU(1,IBU))                                   950J2067
      GO TO 40                                                         950J2068
 303  IF (BU(7,IBU)) 999,305,304                                       950J2069
 304  CALL BODYPT (-1.,BU(1,IBU-1),BU(1,IBU+1),WU(1,IWU),C1,M1)        950J2070
      IBU = IBU+1                                                      950J2071
      CALL DMOVE (XX1,BU(1,IBU+1))                                     950J2072
      IF (NPT1-12345) 32,40,32                                         950J2073
 305  CONTINUE                                                         950J2074
      CALL BODYPT (-1.,BU(1,IBU-1),BU(1,IBU),WU(1,IWU),C1,M1)          950J2075
      M1 = M1                                                          950J2076
      GO TO (31,999),M1                                                950J2077
C                                                                      950J2078
 31   WU(7,1) = BU(7,1)                                                950J2079
 32   IWU = IWU+1                                                      950J2080
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 33   IBU = IBU+1                                                       950J2081
C                                                                       950J2082
      IF (BU(7,IBU)) 999,35,33                                          950J2083
 35   CALL FDPT (BU(1,IBU),WU(1,IWU-1),WU(1,IWU),C1,M1)                 950J2084
      CALL DMOVE (XX1,BU(1,IBU+1))                                      950J2086
      WU(7,IWU) = 0.0                                                   950J2087
      IF (NPT1-12345) 32,40,32                                          950J2088
C                                                                       950J2089
 40   CONTINUE                                                          950J2090
      XX1U(1) = BU(1,IBU-1)                                             950J2091
      XX1U(2) = BU(2,IBU-1)                                             950J2092
      CALL SHOCK (2,M1,-1.,XXA,XXB,XX1U,BU(1,IBU-1),WU(1,IWU),          950J2093
     1  XX3U,XX3,XX5,C1,SW,FSM)                                         950J2094
      M1 = M1                                                           950J2095
      GO TO (50,999,999,999,45),M1                                      950J2096
 45   IF (SWL/SW-4.0) 47,145,145                                        950J2097
 145  IF (IWU-1) 999,47,55                                              950J2098
 47   SW = SW/2.0                                                       950J2099
      GO TO 40                                                          950J2100
C                                                                       950J2101
 50   NPT3 = 2                                                          950J2102
      XXU1 = XXU                                                        950J2103
      YYU1 = YYU                                                        950J2104
      XXU = XX3(1)                                                      950J2105
      YYU = XX3(2)                                                      950J2106
      CALL DMOVE (WU(1,IWU+1),XX3)                                      950J2107
      CALL FDPT (WU(1,IWU+1),WU(1,IWU),WU(1,IWU+2),C1,M1)               950J2108
      IWU = IWU+2                                                       950J2109
      CALL DMOVE (BU(1,IBU-1),WU(1,IWU-1))                              950J2110
      GO TO 40                                                          950J2111
C                                                                       950J2112
 55   NPT3 = 12345                                                      950J2113
      IF (WU(7,IWU-1)) 3011,3012,3011                                   950J2114
 3012 SW = SW/2.0                                                       950J2115
      IF (SWL/SW-10.0) 40,999,999                                       950J2116
 3011 CALL DMOVE (WU(1,IWU+1),XX3)                                      950J2117
      IF (WU(7,IWU-3)) 3100,3100,3080                                   950J2118
 3080 N1 = IWU-5                                                        950J2119
 3085 IF (N1) 3100,3100,3086                                            950J2120
 3086 IF (WU(7,N1)) 3090,3090,3088                                      950J2120
 3088 N1 = N1-2                                                         950J2121
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      GO TO 3085                                                        950J2122
 3090 N1 = N1+2                                                         950J2123
      XXU1 = WU(1,N1)                                                   950J2124
      YYU1 = WU(2,N1)                                                   950J2125
 3100 CONTINUE                                                          950J2126
      CALL STORE (BU,WU,3,M,ARRAY)                                      950J2127
      GO TO 123                                                         950J2128
C                                                                       950J2129
C     CALCULATE CHARACTERISTIC TO LOWER BODY                            950J2130
C                                                                       950J2131
 60   IB = 2                                                            950J2132
 3015 IW = 1                                                            950J2133
      SW = SWL                                                          950J2134
      IF (B(7,IB-1)) 602,602,601                                        950J2135
 601  CALL DMOVE (W(1,1),B(1,IB))                                       950J2136
      GO TO 70                                                          950J2137
 602  IF (B(7,IB)) 999,605,604                                          950J2138
 604  CALL BODYPT (1.,B(1,IB-1),B(1,IB+1),W(1,IW),C1,M1)                950J2139
      IB = IB+1                                                         950J2140
      CALL DMOVE (XX1,B(1,IB+1))                                        950J2141
      IF (NPT1-12345) 62,70,62                                          950J2142
 605  CONTINUE                                                          950J2143
      CALL BODYPT (1.,B(1,IB-1),B(1,IB),W(1,IW),C1,M1)                  950J2144
      M1 = M1                                                           950J2145
      GO TO (61,999),M1                                                 950J2146
C                                                                       950J2147
 61   W(7,1) = B(7,1)                                                   950J2148
 62   IW = IW+1                                                         950J2149
 63   IB = IB+1                                                         950J2150
C                                                                       950J2151
      IF (B(7,IB)) 999,65,63                                            950J2152
 65   CALL FDPT (W(1,IW-1),B(1,IB),W(1,IW),C1,M1)                       950J2153
      CALL DMOVE (XX1,B(1,IB+1))                                        950J2155
      W(7,IW) = 0.0                                                     950J2156
      IF (NPT1-12345) 62,70,62                                          950J2157
C                                                                       950J2158
 70   CONTINUE                                                          950J2159
      XX1U(1) = B(1,IB-1)                                               950J2160
      XX1U(2) = B(2,IB-1)                                               950J2161
      CALL SHOCK (2,M1,1.,XXA,XXB,XX1U,B(1,IB-1),W(1,IW),XX3U,XX3,XX5,  950J2162
     1  C1,SW,FSM)                                                      950J2163
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      M1 = M1                                                           950J2164
      GO TO (80,999,999,999,75),M1                                      950J2165
 75   IF (SWL/SW-2.0) 77,185,185                                        950J2166
 185  IF (IW-1) 999,77,85                                               950J2167
 77   SW = SW/2.0                                                       950J2168
      GO TO 70                                                          950J2169
C                                                                       950J2170
 80   NPT3 = 1                                                          950J2171
      XXL1 = XXL                                                        950J2172
      YYL1 = YYL                                                        950J2173
      XXL = XX3(1)                                                      950J2174
      YYL = XX3(2)                                                      950J2175
      CALL DMOVE (W(1,IW+1),XX3)                                        950J2176
      CALL FDPT (W(1,IW),W(1,IW+1),W(1,IW+2),C1,M1)                     950J2177
      CALL DMOVE (B(1,IB-1),W(1,IW+1))                                  950J2178
      IW = IW+2                                                         950J2179
      GO TO 70                                                          950J2180
C                                                                       950J2181
 85   NPT3 = 12345                                                      950J2182
      IF (W(7,IW-1)) 3013,3014,3013                                     950J2183
 3014 SW = SW/2.0                                                       950J2184
      IF (SWL/SW-10.0) 70,999,999                                       950J2185
 3013 CALL DMOVE (W(1,IW+1),XX3)                                        950J2186
      IF (W(7,IW-3)) 3070,3070,3030                                     950J2187
 3030 N1 = IW-5                                                         950J2188
 3040 IF (N1) 3070,3070,3045                                            950J2189
 3045 IF (W(7,N1)) 3060,3060,3050                                       950J2189
 3050 N1 = N1-2                                                         950J2190
      GO TO 3040                                                        950J2191
 3060 N1 = N1+2                                                         950J2192
      XXL1 = W(1,N1)                                                    950J2193
      YYL1 = W(2,N1)                                                    950J2194
 3070 CONTINUE                                                          950J2195
      CALL STORE (B,W,4,M,ARRAY)                                        950J2196
C                                                                       950J2197
 123  CONTINUE                                                          950J2198
      CALL XY (XXU1,YYU1,XXU,YYU,XXL1,YYL1,XXL,YYL,X,Y)                 950J2199
      IF (X-XXU) 121,122,122                                            950J2200
 121  IF (X-XXL) 120,122,122                                            950J2201
 122  CONTINUE                                                          950J2202
      IF (XXL-XXU) 60,60,301                                            950J2203
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C                                                         950J2204
 120  CALL CHAIN (3,8)                                    950J2205
 999  WRITE OUTPUT TAPE 6,500                             950J2206
      CALL DUMP                                           950J2207
C                                                         950J2208
      END
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C     TURNING VANES - HEAD-ON COLLISION OF SHOCK WAVES IN               950J3000
C     A UNIFORM SUPERSONIC FLOW FIELD.                                  950J3001
*     LABEL
 950J3                                                                  950J3
C                                                                       950J3002
C                                                                       950J3003
      DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),    950J3004
     1            XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)               950J3005
      DIMENSION AC1(6,20),AC2(6,20)                                     950J3006
      DIMENSION XX1U(10),XX3U(10),XXA(10),XXB(10)                       950J3007
      DIMENSION ARRAY(12)                                               950J3008
      DIMENSION BU(10,100),WU(10,100)                                   950J3009
      DIMENSION XXX1(100),YY1(100),XXX2(100),YY2(100)                   950J3010
C                                                                       950J3011
      COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2            950J3012
      COMMON GAMMA,FSM,FSP,FST,SW                                       950J3013
      COMMON XX1,XX3U,XXA,XXB                                           950J3014
      COMMON BU,WU                                                      950J3015
C                                                                       950J3016
      EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(950J3017
     15),ZMU1),                                                         950J3018
     2(XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),   950J3019
     3(XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),   950J3020
     4(XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),   950J3021
     5(XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),   950J3022
     6(XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),   950J3023
     7(XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),950J3024
     1 ZMU3A)                                                           950J3025
      EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),   950J3026
     1  (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),             950J3027
     2  (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),             950J3028
     3  (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),             950J3029
     4  (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),     950J3030
     5  (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),     950J3031
     8(XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),950J3032
     1 ZMU3B),                                                          950J3033
     9(XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),               950J3034
     6(XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)                950J3035
      EQUIVALENCE (XX1(10),NPONT1),(XX2(10),NPONT2),                    950J3036
     1  (XX3(10),NPONT3),(XX5(10),NPONT5)                               950J3037
```

```
 500  FORMAT (//1P6E15.5/3X1P6E15.5/6X1P6E15.5)                      950J3038
 510  FORMAT (1P6E14.5,I5,1PE14.5)                                   950J3039
 520  FORMAT (1P2E15.5)                                              950J3040
C                                                                    950J3041
      REWIND 2                                                       950J3042
      READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY                          950J3043
      CALL PAGE2 (0,ARRAY)                                           950J3044
      BACKSPACE 4                                                    950J3045
      BACKSPACE 3                                                    950J3046
      C1 = GAMMA                                                     950J3047
      C2 = 1./(1.-C1)                                                950J3048
      C3 = C1/(C1-1.0)                                               950J3049
      C4 = 2.*C1/(C1+1.)                                             950J3050
      C6 = 2./(C1+1.0)                                               950J3051
      C7 = (C1-1.0)/C1                                               950J3052
      C10 = (C1-1.0)/2.0                                             950J3053
      C11 = (C1-1.0)/(2.*C1)                                         950J3054
      C12 = 2./(1.-C1)                                               950J3055
C                                                                    950J3056
C     TAPE 3 CONTAINS FIELD ABOUT UPPER BODY, AND                    950J3057
C       TAPE 4 CONTAINS DATA ABOUT LOWER BODY.                       950J3058
C                                                                    950J3059
      READ TAPE 3,W                                                  950J3060
      READ TAPE 4,B                                                  950J3061
      ZMU1U = ASINF(1./FSM)                                          950J3062
      P1U = (1.+C10*FSM**2)**(-C3)                                   950J3063
      TH1U = 0.0                                                     950J3064
      R1U = 1.0                                                      950J3065
C                                                                    950J3066
      CALL MOVE1 (IB,W)                                              950J3067
      XLAST1 = W(1,IB-2)                                             950J3068
      CALL MOVE1 (IB,B)                                              950J3069
      XLAST2 = B(1,IB-2)                                             950J3070
      END FILE 3                                                     950J3071
      END FILE 4                                                     950J3072
      REWIND 3                                                       950J3073
      REWIND 4                                                       950J3074
      N1 = 0                                                         950J3075
      N2 = 0                                                         950J3076
C                                                                    950J3077
      READ TAPE 3,WU                                                 950J3078
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      READ TAPE 3,WU                                          950J3079
      READ TAPE 4,W                                           950J3080
      READ TAPE 4,W                                           950J3081
      DO 200 I=1,100                                          950J3082
      READ TAPE 3,WU                                          950J3083
      DO 180 J=1,100                                          950J3084
      CALL DMOVE (XX1,WU(1,J))                                950J3085
      IF (NPT1 -2) 180,170,200                                950J3086
  170 N1 = N1+1                                               950J3087
      XXX1(N1) = WU(1,J)                                      950J3088
      YY1(N1) = WU(2,J)                                       950J3089
      IF (XXX1(N1)-XLAST1) 180,210,180                        950J3090
  180 CONTINUE                                                950J3091
  200 CONTINUE                                                950J3092
C                                                             950J3093
  210 NPT1 = 1                                                950J3094
      DO 230 I=1,100                                          950J3095
      READ TAPE 4,W                                           950J3096
      DO 220 J=1,100                                          950J3097
      CALL DMOVE (XX1,W(1,J))                                 950J3098
      IF (NPT1-1) 220,212,230                                 950J3099
  212 N2 = N2+1                                               950J3100
      XXX2(N2) = W(1,J)                                       950J3101
      YY2(N2) = W(2,J)                                        950J3102
      IF (XXX2(N2)-XLAST2) 220,215,220                        950J3103
  220 CONTINUE                                                950J3104
  230 CONTINUE                                                950J3105
  215 IF (N1-100) 240,240,999                                 950J3106
  240 IF (N2-100) 250,250,999                                 950J3107
  250 CONTINUE                                                950J3108
C                                                             950J3109
      CALL MEET (XXX1,YY1,N1,XXX2,YY2,N2,X,Y,DY1,DY2)         950J3110
C                                                             950J3111
      W1 = ATANF(DY1)                                         950J3112
      W2 = ATANF(DY2)                                         950J3113
      XX5(1) = X                                              950J3114
      XX5(2) = Y                                              950J3115
      XX5(3) = P1U                                            950J3116
      XX5(4) = 0.0                                            950J3117
      XX5(5) = ZMU1U                                          950J3118
      XX5(6) = 1.0                                            950J3119
```

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      CALL OBLSHK (XX5,W1,XX1,GAMMA)                                    950J3120
      CALL OBLSHK (XX5,W2,XX2,GAMMA)                                    950J3121
  300 BACKSPACE 3                                                       950J3122
      BACKSPACE 3                                                       950J3123
      READ TAPE 3,WU                                                    950J3124
      CALL MOVE1 (IW,WU)                                                950J3125
      IF (WU(1,IW-2)-X) 310,310,300                                     950J3126
  310 READ TAPE 3,WU                                                    950J3127
C                                                                       950J3128
  320 BACKSPACE 4                                                       950J3129
      BACKSPACE 4                                                       950J3130
      READ TAPE 4,W                                                     950J3131
      CALLMOVE1 (IW,W)                                                  950J3132
      IF (W(1,IW-2)-X) 330,330,320                                      950J3133
  330 READ TAPE 4,W                                                     950J3134
      CALL DMOVE (XX3,XX1)                                              950J3135
      CALL DMOVE (XX5,XX2)                                              950J3136
C                                                                       950J3137
      NPT3 = 2                                                          950J3138
      NPT5 = 1                                                          950J3139
      CALL DMOVE (BU(1,1),XX3)                                          950J3140
      CALL DMOVE (B(1,1),XX5)                                           950J3141
C                                                                       950J3142
      STH = TH1U+TH3+TH5                                                950J3143
      IF (STH) 20,10,20                                                 950J3144
   10 DSTH = .1                                                         950J3145
      GO TO 30                                                          950J3146
   20 DSTH = .1*ABSF(STH)                                               950J3147
   30 DO 120 JJ=1,10                                                    950J3148
      STH = STH-DSTH                                                    950J3149
      DSTH = DSTH/4.                                                    950J3150
      DO 100 I=1,10                                                     950J3151
      M1 = I                                                            950J3152
      CALL SHK1 (1.0,STH,XX3,XX1,GAMMA,M2)                              950J3153
      IF (M2-1) 999,32,999                                              950J3154
C                                                                       950J3155
   32 CALL SHK1 (-1.0,STH,XX5,XX2,GAMMA,M2)                             950J3156
      IF (M2-1) 999,90,999                                              950J3157
C                                                                       950J3158
   90 CALL CONV (P1,P2,STH,DSTH,M1)                                     950J3159
  100 CONTINUE                                                          950J3160
```

```
C                                                         950J3161
 110  CALL SHK1 (1.0,STH,XX3,XX1,GAMMA,M2)                950J3162
      IF (M2-1) 999,35,999                                950J3163
  35  CALL SHK1 (-1.0,STH,XX5,XX2,GAMMA,M2)               950J3164
      IF (M2-1) 999,38,999                                950J3165
  38  NPT1 = -21                                          950J3166
      NPT2 = -11                                          950J3167
      IF (ABSF(P1-P2)-.001*P1) 130,130,120                950J3168
C                                                         950J3169
 120  DSTH = DSTH*2.                                      950J3170
 130  CALL DMOVE (BU(1,2),XX1)                            950J3171
      W2 = -W2                                            950J3172
      CALL DMOVE (B(1,2),XX2)                             950J3173
C                                                         950J3174
      CALL SHKCAL (XLAST1,XLAST2)                         950J3175
C                                                         950J3176
      CALL CHAIN (4,8)                                    950J3177
 999  CALL DUMP                                           950J3178
      END
```

```
      SUBROUTINE SHOCK5 (M1,AA,XXA,XXB,XX1U,XX1,XX3U,XX3,XX5,C1)        950JC000
*     LABEL
 950JC                                                                   950JC
C                                                                        950JC001
C        AA =  1.  FOR LEFT RUNNING SHOCKS.                              950JC002
C        AA = -1.  FOR RIGHT RUNNING SHOCKS.                             950JC003
C     N + FOR BOW WAVE, NEGATIVE FOR SHOCK WAVE IN FIELD.                950JC004
C                                                                        950JC005
      DIMENSION XXA(10),XXB(10),XX1U(10),XX1(10),XX2(10),XX3U(10),XX3(10950JC006
     1          ),XX5(10)                                                950JC007
C                                                                        950JC008
 21   FORMAT (1P6E15.7,I15)                                              950JC009
 22   FORMAT (28H  P3/R3 IS NEGATIVE OR ZERO.)                           950JC010
 23   FORMAT (43H  RR2 OUT OF BOUNDS WHILE NPT2 IS NEGATIVE.)            950JC011
 24   FORMAT (1H ///, 21H  SHOCK IS TOO WEAK. )                          950JC012
 25   FORMAT (1P7E15.5)                                                  950JC013
C                                                                        950JC014
      R = 0.0                                                            950JC015
      C2 = 1./(1.-C1)                                                    950JC016
      C3 = C1/(C1-1.)                                                    950JC017
      C4 = 2.*C1/(C1+1.)                                                 950JC018
      C5 = (C1-1.)/(C1+1.)                                               950JC019
      C7 = (C1-1.)/C1                                                    950JC020
      C10 = (C1-1.)/2.                                                   950JC021
      C11 = (C1-1.)/(2.0*C1)                                             950JC022
      C12 = 2./(1.-C1)                                                   950JC023
      SFW = SW/2.                                                        950JC024
      DW3 =0.0                                                           950JC025
      X1U = XX1U(1)                                                      950JC026
      Y1U = XX1U(2)                                                      950JC027
      P1U = XX1U(3)                                                      950JC028
      TH1U = XX1U(4)                                                     950JC029
      ZMU1U = XX1U(5)                                                    950JC030
      R1U = XX1U(6)                                                      950JC031
      X1 = XX1(1)                                                        950JC032
      Y1 = XX1(2)                                                        950JC033
      P1 = XX1(3)                                                        950JC034
      TH1 = XX1(4)                                                       950JC035
      ZMU1 = XX1(5)                                                      950JC036
      R1 = XX1(6)                                                        950JC037
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      W1 = ABSF(XX1(8))                                                950JC038
 9011 X3A = XXA(1)                                                     950JC039
      Y3A = XXA(2)                                                     950JC040
      P3A = XXA(3)                                                     950JC041
      TH3A = XXA(4)                                                    950JC042
      ZMU3A = XXA(5)                                                   950JC043
      R3A = XXA(6)                                                     950JC044
      X3B = XXB(1)                                                     950JC045
      Y3B = XXB(2)                                                     950JC046
      P3B = XXB(3)                                                     950JC047
      TH3B = XXB(4)                                                    950JC048
      ZMU3B = XXB(5)                                                   950JC049
      R3B = XXB(6)                                                     950JC050
      XA = X3A                                                         950JC051
      XB = X3B                                                         950JC052
  762 ZM3A = 1./SINF(ZMU3A)                                            950JC053
      ZM3B = 1. / SINF(ZMU3B)                                          950JC054
C                                                                      950JC055
  783 NFLAG = XABSF(N)                                                 950JC056
      W3 = W1                                                          950JC057
  737 SLP1 =(Y3B-Y3A)/(X3B-X3A)                                        950JC058
      T61  = P3B - P3A                                                 950JC059
      T62  = TH3B -TH3A                                                950JC060
      T83 = ZMU3B - ZMU3A                                              950JC061
      T63  = ZM3B -ZM3A                                                950JC062
      T64  = R3B -R3A                                                  950JC063
  700 RR2 = 0.5                                                        950JC064
      P3LS = 1000.                                                     950JC065
      KTR = 0                                                          950JC066
      RR1=.5                                                           950JC067
      SH1 = T62/2.                                                     950JC068
      SH2 = (TH1U+TH3A)/2.                                             950JC069
      SH3 = 1./SLP1                                                    950JC070
      SH4 = (Y3A-Y1)/(Y3B-Y3A)                                         950JC071
      SH5 = (X3A-X1)/(X3B-X3A)                                         950JC072
  701 SH6 =(AA*(W3+W1) + TH1U + TH3A)/2.                               950JC073
      DO 771 I=1,20                                                    950JC074
      SH8 = SH6+RR1*SH1                                                950JC075
      SH9 = SINF(SH8)                                                  950JC076
      SH10= COSF(SH8)                                                  950JC077
      SH11= SH9/SH10                                                   950JC078
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      SH12= RR1+SH4-(RR1+SH5)*SH3*SH11                                   950JC079
      SH13= 1. -SH3*(SH11+SH1*(RR1+SH5)/(SH10)**2)                       950JC080
      IF (ABSF(SH13) - .00000001) 773,773,772                            950JC081
 772  DRR1 = SH12 /SH13                                                  950JC082
      RR1 = RR1 - DRR1                                                   950JC083
      IF (ABSF(DRR1) - MAX1F(ABSF(RR1 * .000001) , .00001)) 773,773,771  950JC084
 771  CONTINUE                                                           950JC085
 773  X3 = X3A +RR1*(X3B-X3A)                                            950JC086
      Y3 = Y3A +RR1*(Y3B-Y3A)                                            950JC087
      P3U = P3A +RR1*T61                                                 950JC088
      TH3U =TH3A + RR1*T62                                               950JC089
      ZMU3U = ZMU3A + T83* RR1                                           950JC090
      ZM3U =ZM3A + RR1*T63                                               950JC091
      R3U = R3A +RR1*T64                                                 950JC092
      T29 = SINF(2.0*W3)                                                 950JC093
      T31 = SINF(W3)**2                                                  950JC094
      T32 = ZM3U**2                                                      950JC095
      DEL3=ATANF((T32*T29-2.*COSF(W3)/SINF(W3))/(T32*(C1+COSF(2.*W3))+2.950JC096
     1))                                                                 950JC097
      T28 = SINF(DEL3)**2                                                950JC098
      TH3 = TH3U +AA*DEL3                                                950JC099
      ERASB = C4*(T32*T31-C11)                                           950JC100
      P3= P3U*ERASB                                                      950JC101
      R3= ((T32*T31)/(C5*((T32*T31)-C12)))**C3*ERASB**C2*R3U             950JC102
      T30 = P3/R3                                                        950JC103
      IF (T30) 651,651,703                                               950JC104
 651   M1 = 2                                                            950JC105
      WRITE OUTPUT TAPE 6,22                                             950JC106
      GO TO 100                                                          950JC107
 703  T30 = C12*(1.-(T30)**(-C7))-1.                                     950JC108
      IF (T30-.04) 651,651,705                                           950JC109
 705  ZMU3 = ATANF(SQRTF(1.0/T30))                                       950JC110
 778  IF (ABSF(P3 - P3LS) - .00001) 780,780, 715                         950JC111
 715  P3LS=P3                                                            950JC112
      IF (KTR-100) 1019,1019,780                                         950JC113
 1019 KTR = KTR+1                                                        950JC114
 776  X2=X3                                                              950JC115
      Y2=Y3                                                              950JC116
      P2=P3                                                              950JC117
      TH2=TH3                                                            950JC118
      ZMU2=ZMU3                                                          950JC119
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      R2=R3                                              950JC120
      NPT2=NPT3                                          950JC121
      XX2(1) = X2                                        950JC122
      XX2(2) = Y2                                        950JC123
      XX2(3) = P2                                        950JC124
      XX2(4) = TH2                                       950JC125
      XX2(5) = ZMU2                                      950JC126
      XX2(6) = R2                                        950JC127
      CALL DMOVE (XX3,XX5)                               950JC128
10    CALL SLPSTM (AA,XX1,XX2,XX3,C1)                    950JC129
      X5 = XX3(1)                                        950JC130
      Y5 = XX3(2)                                        950JC131
      P5 = XX3(3)                                        950JC132
      TH5 = XX3(4)                                       950JC133
      ZMU5 = XX3(5)                                      950JC134
      R5 = XX3(6)                                        950JC135
      CALL DMOVE (XX5,XX3)                               950JC136
      X3=X2                                              950JC137
      Y3=Y2                                              950JC138
      P3=P2                                              950JC139
      TH3=TH2                                            950JC140
      ZMU3=ZMU2                                          950JC141
      R3=R2                                              950JC142
      X2=X5                                              950JC143
      Y2=Y5                                              950JC144
      P2=P5                                              950JC145
      TH2=TH5                                            950JC146
      ZMU2=ZMU5                                          950JC147
      R2=R5                                              950JC148
740   T42 = Y1 -Y3                                       950JC149
      T36 = X2 -X1                                       950JC150
      T37 = Y2 -Y1                                       950JC151
      T39 = (TH2 +AA*ZMU2)/2.                            950JC152
      T40 = (TH1 +AA*ZMU1)/2.                            950JC153
      T38 = P2- P1                                       950JC154
      T35 = TH2 -TH1                                     950JC155
      T33 = ZMU2 -ZMU1                                   950JC156
      T45 = T39 -T40                                     950JC157
      T46 = T37/T36                                      950JC158
      T43 = X1 -X3                                       950JC159
      T47 = T42/T36                                      950JC160
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      T48 = T43/T36                                                     950JC161
      T50 = (TH3 +AA*ZMU3)/2.                                           950JC162
      T49 = T40 + T50                                                   950JC163
      RR2 = .5                                                          950JC164
 706  DO 750 I=1,20                                                     950JC165
      T51 = RR2*T45 +T49                                                950JC166
      T52 = SINF(T51)                                                   950JC167
      T53 =COSF(T51)                                                    950JC168
      T54 =T52/T53                                                      950JC169
      FR  =T47 +RR2*T46 -(RR2 +T48)*T54                                 950JC170
      FPR =T46 -T54 -(RR2 +T48)*T45/T53**2                              950JC171
      IF (ABSF(FPR) - .00000001) 711,711, 751                           950JC172
 751  DRR = FR/FPR                                                      950JC173
      RR2= RR2 -DRR                                                     950JC174
 708  CONTINUE                                                          950JC175
 725  IF (ABSF(DRR) - MAX1F(.00001 * ABSF(RR2) , .00001)) 711, 711, 750 950JC176
 750  CONTINUE                                                          950JC177
 711  IF (ABSF(RR2-.5)-.5) 747,747,111                                  950JC178
 111  IF (NPT2) 60,61,61                                                950JC179
 60   IF (RR2 + .01)  1160,747,747                                      950JC180
 1160 WRITE OUTPUT TAPE 6,23                                            950JC181
 500  M1 = 3                                                            950JC182
      GO TO 100                                                         950JC183
C                                                                       950JC184
 61   IF (RR2)  666,661,661                                             950JC185
 666  IF (RR2 + .001)  670,747,747                                      950JC186
 670  WRITE OUTPUT TAPE 6,25,X1,Y1,P1,TH1,ZMU1,W1                       950JC187
      WRITE OUTPUT TAPE 6,25,X2,Y2,P2,TH2,ZMU2,W2                       950JC188
      WRITE OUTPUT TAPE 6,25,X3,Y3,P3,TH3,ZMU3,W3                       950JC189
      WRITE OUTPUT TAPE 6,25,X4,Y4,P4,TH4,ZMU4,W4                       950JC190
      WRITE OUTPUT TAPE 6,25,RR2,DRR,DPDW,DTHDW,DW3,T30                 950JC191
      WRITE OUTPUT TAPE 6,25,X3A,Y3A,X3B,Y3B,                           950JC192
      GO TO 500                                                         950JC193
 661  M1 = 5                                                            950JC194
C                                                                       950JC195
C       THE NEXT POINT MUST BE USED AS POINT 2.                         950JC196
C                                                                       950JC197
      GO TO 100                                                         950JC198
C                                                                       950JC199
 747  X4 = X1 +RR2*T36                                                  950JC200
      Y4 = Y1 +RR2*T37                                                  950JC201
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      P4 = P1 +RR2*T38                                                  950JC202
      TH4 =TH1 +RR2*T35                                                 950JC203
      ZMU4 =ZMU1+RR2*T33                                                950JC204
      DPDW = P3U*C4*T32*T29                                             950JC205
      DTHDW = (C1+1.0)*T28*T31*T32**2/(T32*T31-1.0)**2 - SINF(2.0*DEL3)/950JC206
     1T29                                                               950JC207
      T13 =(TH4 +TH3)/2.0                                               950JC208
      T60 = (TH4 +AA*ZMU4)/2.                                           950JC209
      T11 =(P4 +P3)/2.0                                                 950JC210
      T12 =(ZMU4 +ZMU3)/2.0                                             950JC211
      T34 = (Y4 +Y3)/2.0                                                950JC212
      DW3 = -((P3-P4)/(C1*T11)+A*(TH3-TH4)/((COSF(T12))*(SINF(T12))))   950JC213
  774 W3=W3+DW3/(DPDW/(C1*T11)+DTHDW/(SINF(T12)/COSF(T12)))             950JC214
      GO TO 701                                                         950JC215
  780 M1 = 1                                                            950JC216
  765 IF (RR1) 763,763,1900                                             950JC217
 1900 IF (RR1-1.0) 100,100,1904                                         950JC218
C                                                                       950JC219
  763 M1 = 6                                                            950JC220
C                                                                       950JC221
C         NEW 3A AND 3B POINTS UPSTREAM MUST BE USED.                   950JC222
C                                                                       950JC223
      GO TO 100                                                         950JC224
C                                                                       950JC225
 1904 M1 = 7                                                            950JC226
C                                                                       950JC227
C         NEW 3A AND 3B POINTS DOWNSTREAM MUST BE USED.                 950JC228
C                                                                       950JC229
  100 XX3U(1) = X3                                                      950JC230
      XX3(1) = X3                                                       950JC231
      XX3U(2) = Y3                                                      950JC232
      XX3(2) = Y3                                                       950JC233
      XX3U(3) = P3U                                                     950JC234
      XX3U(4) = TH3U                                                    950JC235
      XX3U(5) = ZMU3U                                                   950JC236
      XX3U(6) = R3U                                                     950JC237
      XX3(3) = P3                                                       950JC238
      XX3(4) = TH3                                                      950JC239
      XX3(5) = ZMU3                                                     950JC240
      XX3(6) = R3                                                       950JC241
      XX3(8) = SIGNF(W3,XX1(8))                                         950JC242
```

```
      RETURN                                                        950JC243
      END
```

```
      SUBROUTINE SHKCAL (XLASTU,XLASTL)                                 950JB000
*     LABEL
 950JB                                                                  950JB
C                                                                       950JB001
      DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),    950JB002
     1          XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)                 950JB003
      DIMENSION AC1(6,20),AC2(6,20)                                     950JB004
      DIMENSION XX1U(10),XX3U(10),XXA(10),XXB(10)                       950JB005
      DIMENSION ARRAY(12)                                               950JB006
      DIMENSION BU(10,100),WU(10,100)                                   950JB007
      DIMENSION TH(20),PPD(20),PPU(20)                                  950JB008
      DIMENSION DATA(10,8)                                              950JB009
C                                                                       950JB010
      COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2            950JB011
      COMMON GAMMA,FSM,FSP,FST,SW                                       950JB012
      COMMON XX1,XX3U,XXA,XXB                                           950JB013
      COMMON BU,WU                                                      950JB014
C                                                                       950JB015
      EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(950JB016
     15),ZMU1),                                                         950JB017
     2(XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),   950JB018
     3(XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),   950JB019
     4(XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),   950JB020
     5(XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),   950JB021
     6(XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),   950JB022
     7(XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),950JB023
     1 ZMU3A)                                                           950JB024
      EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),   950JB025
     1  (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),             950JB026
     2  (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),             950JB027
     3  (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),             950JB028
     4  (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),     950JB029
     5  (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),     950JB030
     8(XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),950JB031
     1 ZMU3B),                                                          950JB032
     9(XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),               950JB033
     6(XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)                950JB034
      EQUIVALENCE (XX1(10),NPONT1),(XX2(10),NPONT2),                    950JB035
     1  (XX3(10),NPONT3),(XX5(10),NPONT5)                               950JB036
 400  FORMAT (1P7E14.5)                                                 950JB037
```

```
C                                                                       950JB038
      PPUDF(XY1,XY2,XY3,XY4,XY5) = (XY1-XY3)/(XY2-XY3)*(XY4-XY5)+XY5    950JB039
      C1 = GAMMA                                                        950JB040
 2    DO 15 I=2,100                                                     950JB041
      II = I+1                                                          950JB042
      IF (W(7,I)) 5,5,15                                                950JB043
 5    IF (W(7,II)) 7,7,6                                                950JB044
 6    II = II+1                                                         950JB045
 7    OMEGA = -ABSF(B(8,2))                                             950JB046
      CALL XY (B(1,1),B(2,1),0,OMEGA,W(1,I),W(2,I),W(1,II),W(2,II),X,Y) 950JB047
      RR = (X-W(1,I))/(W(1,II)-W(1,I))                                  950JB048
      IF (RR) 999,10,10                                                 950JB049
 10   IF (RR-1.0) 17,17,15                                              950JB050
 15   CONTINUE                                                          950JB051
C                                                                       950JB052
 17   DSL = SQRTF((B(1,1)-X)**2+(B(2,1)-Y)**2)                          950JB053
      DO 30 J=2,100                                                     950JB054
      JJ = J+1                                                          950JB055
      IF (WU(7,J)) 20,20,30                                             950JB056
 20   IF (WU(7,JJ)) 25,25,22                                            950JB057
 22   JJ = JJ+1                                                         950JB058
 25   CALL XY (BU(1,1),BU(2,1),0.0,BU(8,2),WU(1,J),WU(2,J),             950JB059
     1  WU(1,JJ),WU(2,JJ),X,Y)                                          950JB060
      RR = (X-WU(1,J))/(WU(1,JJ)-WU(1,J))                               950JB061
      IF (RR) 999,27,27                                                 950JB062
 27   IF (RR-1.0) 35,35,30                                              950JB063
 30   CONTINUE                                                          950JB064
C                                                                       950JB065
 35   DSU = SQRTF((B(1,1)-X)**2+(B(2,1)-Y)**2)                          950JB066
      IF (DSU/2.-DSL) 40,40,50                                          950JB067
 40   IF (DSL/2.-DSU) 70,70,60                                          950JB068
 50   CALL MOVE1 (IW,W)                                                 950JB069
      IF (W(1,IW-2)-XLASTL) 55,70,55                                    950JB070
 55   READ TAPE 4,W                                                     950JB071
      GO TO 2                                                           950JB072
 60   CALL MOVE1 (IWU,WU)                                               950JB073
      IF (WU(1,IWU-2)-XLASTU) 65,70,65                                  950JB074
 65   READ TAPE 3,WU                                                    950JB075
      GO TO 2                                                           950JB076
 70   IK = I                                                            950JB077
      IIK = II                                                          950JB078
```

```
      JK = J                                                            950JB079
      JJK = JJ                                                          950JB080
C                                                                       950JB081
      DDTH = .04                                                        950JB082
      L = 9                                                             950JB083
      CALL DMOVE (DATA(1,3),BU(1,2))                                    950JB084
      CALL DMOVE (DATA(1,6),B(1,2))                                     950JB085
      DO 100 IJ=1,5                                                     950JB086
      DTH = DDTH/4.                                                     950JB087
      DATA(4,3) = DATA(4,3)-DDTH                                        950JB088
      DATA(4,6) = DATA(4,3)                                             950JB089
  901 CONTINUE                                                          950JB090
      DO 90 I=1,L                                                       950JB091
  190 CALL DMOVE (XXA,WU(1,JK))                                         950JB092
      CALL DMOVE (XXB,WU(1,JJK))                                        950JB093
      CALL DMOVE (XX1U,BU(1,1))                                         950JB094
      CALL DMOVE (XX1,BU(1,2))                                          950JB095
      CALL DMOVE (XX5,DATA(1,3))                                        950JB096
      CALL SHOCK5 (M1,1.0,XXA,XXB,XX1U,XX1,XX3U,XX3,XX5,C1)             950JB097
C                                                                       950JB098
      M1 = M1                                                           950JB099
      GO TO (220,999,999,999,999,200,210),M1                            950JB100
  200 JJK = JK                                                          950JB101
  205 JK = JK-1                                                         950JB102
      CALL DMOVE (XX1,WU(1,JK))                                         950JB103
      IF (NPT1-2) 190,205,220                                           950JB104
  210 JK = JJK                                                          950JB105
  215 JJK = JJK+1                                                       950JB106
      CALL DMOVE (XX1,WU(1,JJK))                                        950JB107
      IF (NPT1-2) 190,215,220                                           950JB108
  220 CALL DMOVE (DATA(1,1),XX3U)                                       950JB109
      CALL DMOVE (DATA(1,2),XX3)                                        950JB110
      CALL DMOVE (DATA(1,3),XX5)                                        950JB111
C                                                                       950JB112
  225 CALL DMOVE (XXA,W(1,IK))                                          950JB113
      CALL DMOVE (XXB,W(1,IIK))                                         950JB114
      CALL DMOVE (XX1U,B(1,1))                                          950JB115
      CALL DMOVE (XX1,B(1,2))                                           950JB116
      CALL DMOVE (XX5,DATA(1,6))                                        950JB117
C                                                                       950JB118
      CALL SHOCK5 (M1,-1.0,XXA,XXB,XX1U,XX1,XX3U,XX3,XX5,C1)            950JB119
```

```
      M1 = M1                                                           950JB120
      GC TO (250,999,999,999,999,230,240),M1                            950JB121
  230 IIK = IK                                                          950JB122
  235 IK = IK-1                                                         950JB123
      CALL DMOVE (XX1,W(1,IK))                                          950JB124
      IF (NPT1-1) 225,235,250                                           950JB125
C                                                                       950JB126
  240 IK = IIK                                                          950JB127
  245 IIK = IIK+1                                                       950JB128
      CALL DMOVE (XX1,W(1,IIK))                                         950JB129
      IF (NPT1-1) 225,245,250                                           950JB130
C                                                                       950JB131
  250 CALL DMOVE (DATA(1,4),XX3U)                                       950JB132
      CALL DMOVE (DATA(1,5),XX3)                                        950JB133
      CALL DMOVE (DATA(1,6),XX5)                                        950JB134
      TH(I) = XX5(4)                                                    950JB135
      DATA (4,3) = XX5(4)+DTH                                           950JB136
      DATA (4,6) = DATA(4,3)                                            950JB137
      IF (DATA(1,6)-DATA(1,3)) 80,80,85                                 950JB138
C                                                                       950JB139
   85 PPD(I) = PPUDF(DATA(1,3),DATA(1,6),B(1,2),DATA(3,6),B(3,2))       950JB140
      PPU(I) = DATA(3,3)                                                950JB141
      GO TO 90                                                          950JB142
   80 PPD(I) = DATA(3,6)                                                950JB143
      PPU(I) = PPUDF(DATA(1,6),DATA(1,3),BU(1,2),DATA(3,3),BU(3,2))     950JB144
C                                                                       950JB145
   90 CONTINUE                                                          950JB146
      IF (L-9) 96,94,96                                                 950JB147
C                                                                       950JB148
   94 L = 1                                                             950JB149
C                                                                       950JB150
      CALL MEET (TH,PPU,9,TH,PPD,9,DATA(4,3),DATA(3,3),DY1,DY2)         950JB151
      DATA(4,6) = DATA(4,3)                                             950JB152
      DTH = 0.0                                                         950JB153
      DATA(3,6) = DATA(3,3)                                             950JB154
      GO TO 901                                                         950JB155
C                                                                       950JB156
   96 L = 9                                                             950JB157
      DDTH = DDTH/2.                                                    950JB158
      IF (ABSF(PPD(1)-PPU(1)) -.0001*B(3,2)) 110,110,100                950JB159
  100 CONTINUE                                                          950JB160
```

```
110   CONTINUE                                                   950JB161
      IBU = JK+4                                                 950JB162
      IB = IK+4                                                  950JB163
      CALL DMOVE (W(1,IB-3),B(1,1))                              950JB164
      CALL DMOVE (W(1,IB-2),B(1,2))                              950JB165
      CALL DMOVE (W(1,IB-1),DATA(1,4))                           950JB166
      CALL DMOVE (W(1,IB),DATA(1,5))                             950JB167
      W(7,IB) = ABSF(W(7,IB))                                    950JB168
      CALL DMOVE (W(1,IB+1),DATA(1,6))                           950JB169
      NPT1 = 12345                                               950JB170
      CALL DMOVE (W(1,IB+2),XX1)                                 950JB171
      CALL DMOVE (WU(1,IBU-3),BU(1,1))                           950JB172
      CALL DMOVE (WU(1,IBU-2),BU(1,2))                           950JB173
      CALL DMOVE (WU(1,IBU-1),DATA(1,1))                         950JB174
      CALL DMOVE (WU(1,IBU),DATA(1,2))                           950JB175
      WU(7,IBU) = ABSF(WU(7,IBU))                                950JB176
      CALL DMOVE (WU(1,IBU+1),DATA(1,3))                         950JB177
      NPT1 = 12345                                               950JB178
      CALL DMOVE (WU(1,IBU+2),XX1)                               950JB179
      BACKSPACE 3                                                950JB180
      BACKSPACE 4                                                950JB181
      CALL STORE (BU,WU,3,M,ARRAY)                               950JB182
      CALL STORE (B,W,4,M,ARRAY)                                 950JB183
      RETURN                                                     950JB184
999   CALL DUMP                                                  950JB185
      END
```

```
C     MAIN PROGRAM FOURTH CHAIN - TURNING VANE                          950J4000
*     LABEL
 950J4                                                                  950J4
C                                                                       950J4001
      DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),    950J4002
     1          XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)                 950J4003
      DIMENSION AC1(6,20),AC2(6,20)                                     950J4004
      DIMENSION XX1U(10),XX3U(10),XXA(10),XXB(10)                       950J4005
      DIMENSION ARRAY(12)                                               950J4006
      DIMENSION DATA(10,8)                                              950J4007
      DIMENSION BU(10,100),WU(10,100)                                   950J4008
C                                                                       950J4009
      COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2            950J4010
      COMMON GAMMA,FSM,FSP,FST,SW                                       950J4011
      COMMON XX1,XX3U,XXA,XXB                                           950J4012
C                                                                       950J4013
      EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(950J4014
     15),ZMU1),                                                         950J4015
     2(XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),   950J4016
     3(XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),   950J4017
     4(XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),   950J4018
     5(XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),   950J4019
     6(XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),   950J4020
     7(XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),950J4021
     1 ZMU3A)                                                           950J4022
      EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),   950J4023
     1  (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),             950J4024
     2  (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),             950J4025
     3  (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),             950J4026
     4  (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),     950J4027
     5  (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),     950J4028
     8(XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),950J4029
     1 ZMU3B),                                                          950J4030
     9(XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),               950J4031
     6(XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)                950J4032
      EQUIVALENCE (XX1(10),NPONT1),(XX2(10),NPONT2),                    950J4033
     1  (XX3(10),NPONT3),(XX5(10),NPONT5)                               950J4034
C                                                                       950J4035
 500  FORMAT (15H ERROR IN SHOCK)                                       950J4036
 510  FORMAT (1P6E15.5)                                                 950J4037
```

```
C                                                                       950J4038
C                                                                       950J4039
      REWIND 9                                                          950J4040
      BACKSPACE 3                                                       950J4041
      BACKSPACE 4                                                       950J4042
      READ TAPE 3,BU                                                    950J4043
      READ TAPE 4,B                                                     950J4044
      DO 10 I=1,100                                                     950J4045
      NPONT3 = I                                                        950J4046
      B(10,I) = XX3(10)                                                 950J4047
      BU(10,I) = XX3(10)                                                950J4048
   10 CONTINUE                                                          950J4049
      REWIND 2                                                          950J4050
      READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY                             950J4051
      CALL PAGE2 (0,ARRAY)                                              950J4052
      CALL LOCATE (-1,T,ITT,DUM,DUM,DUM,DUM,DUM)                        950J4053
      C1 = GAMMA                                                        950J4054
      CALL MOVE1 (IBU,BU)                                               950J4055
      XXU = BU(1,IBU-1)                                                 950J4056
      CALL MOVE1 (IB,B)                                                 950J4057
      XXL = B(1,IB-1)                                                   950J4058
      IF (XXU-XXL) 25,25,20                                             950J4059
   20 BACKSPACE 3                                                       950J4060
      DO 299 I=1,100                                                    950J4061
      DO 299 J=1,10                                                     950J4062
  299 WU(J,I) = BU(J,I)                                                 950J4063
      IWU = IBU-2                                                       950J4064
      IF (WU(7,IBU-4)) 21,999,999                                       950J4065
   21 IBU = IBU-4                                                       950J4066
      CALL DMOVE (BU(1,IBU),WU(1,IBU))                                  950J4067
      GO TO 80                                                          950J4068
   25 BACKSPACE 4                                                       950J4069
      DO 259 I=1,100                                                    950J4070
      DO 259 J=1,10                                                     950J4071
  259 W(J,I) = B(J,I)                                                   950J4072
      IW = IB-2                                                         950J4073
      IF (W(7,IB-4)) 26,999,999                                         950J4074
   26 IB = IB-4                                                         950J4075
      CALL DMOVE (B(1,IB),W(1,IB))                                      950J4076
   30 CALL CHLIN4 (BU,WU,C1,1.0,IBU,IWU,M1,FSM)                         950J4077
      M1 = M1                                                           950J4078
```

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      GO TO (170,175,999),M1                                             950J4079
  170 CONTINUE                                                           950J4080
   34 CALL XY (WU(1,IWU-1),WU(2,IWU-1),WU(1,IWU),WU(2,IWU),BU(1,IBU),    950J4081
     1  BU(2,IBU),0.0,BU(4,IBU),XXU,YYU)                                 950J4082
C                                                                        950J4083
      IF (XXU-XXL) 35,35,75                                              950J4084
   35 CALL CONV4 (BU(1,IBU),WU(1,IWU),B(1,IB),W(1,IW),WU(1,IWU+1),XX5,   950J4085
     1  C1,M1)                                                           950J4086
      XXU = WU(1,IWU+1)                                                  950J4087
      YYU = WU(2,IWU+1)                                                  950J4088
      XX3(10) = BU(10,IBU)                                               950J4089
      NPONT3 = NPONT3+1                                                  950J4090
      WU(10,IWU+1) = XX3(10)                                             950J4091
      NPT1 = 12345                                                       950J4092
      WU(7,IWU+1) = BU(7,IBU)                                            950J4093
      CALL DMOVE (WU(1,IWU+2),XX1)                                       950J4094
      CALL STORE (BU,WU,3,M,ARRAY)                                       950J4095
      GO TO 30                                                           950J4096
C                                                                        950J4097
   75 CALL CONV4 (BU(1,IBU),WU(1,IWU),B(1,IB),W(1,IW),XX3,W(1,IW+1),     950J4098
     1  C1,M1)                                                           950J4099
      XXL = W(1,IW+1)                                                    950J4100
      YYL = W(2,IW+1)                                                    950J4101
      XX3(10) = B(10,IB)                                                 950J4102
      NPONT3 = NPONT3+1                                                  950J4103
      W(10,IW+1) = XX3(10)                                               950J4104
      NPT1 = 12345                                                       950J4105
      W(7,IW+1) = B(7,IB)                                                950J4106
      CALL DMOVE (W(1,IW+2),XX1)                                         950J4107
      CALL STORE (B,W,4,M,ARRAY)                                         950J4108
C                                                                        950J4109
   80 CALL CHLIN4 (B,W,C1,-1.0,IB,IW,M1,FSM)                             950J4110
      M1 = M1                                                            950J4111
      GO TO (180,185,999),M1                                             950J4112
  180 CONTINUE                                                           950J4113
   85 CALL XY (W(1,IW-1),W(2,IW-1),W(1,IW),W(2,IW),B(1,IB),B(2,IB),      950J4114
     1  0.0,B(4,IB),XXL,YYL)                                             950J4115
      IF (XXL-XXU) 75,75,35                                              950J4116
C                                                                        950J4117
  175 CONTINUE                                                           950J4118
      CALL CONT5 (WU,-1.0,GAMMA,FSM,N1,M1)                               950J4119
```

```
      NPT1 = 12345                                                      950J4120
      CALL DMOVE (WU(1,7),XX1)                                          950J4121
      CALL STORE (BU,WU,9,M,ARRAY)                                      950J4122
  177 CONTINUE                                                          950J4123
      CALL CHLIN5 (BU,WU,GAMMA,N1,-1.0,IBU,IWU,M1,FSM)                  950J4124
      M1 = M1                                                           950J4125
      NPT1 = 12345                                                      950J4126
      CALL DMOVE (WU(1,IWU+1),XX1)                                      950J4127
      CALL STORE (BU,WU,9,M,ARRAY)                                      950J4128
      GO TO (177,888,999),M1                                            950J4129
C                                                                       950J4130
  185 CONTINUE                                                          950J4131
      CALL CONT5 (W,1.0,GAMMA,FSM,N2,M1)                                950J4132
      NPT1 = 12345                                                      950J4133
      CALL DMOVE (W(1,7),XX1)                                           950J4134
      CALL STORE (B,W,9,M,ARRAY)                                        950J4135
C                                                                       950J4136
  187 B(1,100) = 32000.0                                                950J4137
      WRITE TAPE 4,B                                                    950J4138
      BACKSPACE 4                                                       950J4139
  189 CONTINUE                                                          950J4140
      CALL CHLIN5 (B,W,GAMMA,N2,1.0,IB,IW,M1,FSM)                       950J4141
      NPT1 = 12345                                                      950J4142
      CALL DMOVE (W(1,IW+1),XX1)                                        950J4143
      CALL STORE (B,W,9,M,ARRAY)                                        950J4144
      M1 = M1                                                           950J4145
      GO TO (189,999,190),M1                                            950J4146
  190 CALL CONT6 (DATA,GAMMA)                                           950J4147
      CALL DMOVE (W(1,1),DATA(1,1))                                     950J4148
      CALL DMOVE (W(1,2),DATA(1,3))                                     950J4149
      W(7,2) = W(7,1)                                                   950J4150
      CALL DMOVE (XX1,DATA(1,2))                                        950J4151
      NPT1 = 11                                                         950J4152
      CALL DMOVE (W(1,3),XX1)                                           950J4153
      CALL DMOVE (XX1,DATA(1,4))                                        950J4154
      NPT1 = 21                                                         950J4155
      CALL DMOVE (W(1,4),XX1)                                           950J4156
      CALL DMOVE (W(1,5),DATA(1,5))                                     950J4157
      W(7,5) = W(7,1)                                                   950J4158
      NPT1 = 12345                                                      950J4159
      CALL DMOVE (W(1,6),XX1)                                           950J4160
```

```
      B(1,100) = 3333.0
      BU(1,100) = 3333.0                                                950J4161
      CALL STORE (B,W,4,M,ARRAY)                                        950J4162
      CALL DMOVE (WU(1,IWU+1),XX1)                                      950J4163
      BACKSPACE 3                                                       950J4164
      CALL STORE (BU,WU,3,M,ARRAY)                                      950J4165
  888 CALL CHAIN (5,8)                                                  950J4166
  999 WRITE OUTPUT TAPE 6,500                                           950J4167
      CALL DUMP                                                         950J4168
C                                                                       950J4169
      END                                                               950J4170
```

```
      SUBROUTINE CHLIN5 (B,W,GAMMA,N,TT,IBB,IWW,MM1,FSM)                950JF000
*     LABEL
 950JF                                                                  950JF
C                                                                       950JF001
C     T  POSITIVE  LOWER BODY.                                          950JF002
C     T  NEGATIVE UPPER BODY.                                           950JF003
C                                                                       950JF004
      DIMENSION B(10,100),W(10,100),XX3U(10),XX3(10),XXA(10),XXB(10)    950JF005
      EQUIVALENCE (XX3(7),NPT3)                                         950JF006
C                                                                       950JF007
      C1 = GAMMA                                                        950JF008
      T = TT                                                            950JF009
      N2 = N                                                            950JF010
C                                                                       950JF011
      IF (SENSE LIGHT 1) 60,60                                          950JF012
 60   IB = 1                                                            950JF013
      IW = 0                                                            950JF014
C                                                                       950JF015
 62   IB = IB+1                                                         950JF016
      IW = IW+1                                                         950JF017
      NN = IW                                                           950JF018
C                                                                       950JF019
      IF (B(7,IB-1)) 100,90,90                                          950JF020
C                                                                       950JF021
 80   CONTINUE                                                          950JF022
      IF (XXA(7)) 870,81,81                                             950JF023
 81   N2 = N2+1                                                         950JF024
      CALL SELECT (XXA,T,N2,-1)                                         950JF025
      GO TO 98                                                          950JF026
 83   CALL SHOCK (-2,M1,T,XXA,XXB,B(1,IB-2),B(1,IB-1),W(1,IW),          950JF027
     1  XX3U,XX3,DUM,C1,DUM,FSM)                                        950JF028
      M1 = M1                                                           950JF029
C                                                                       950JF030
      GO TO (85,110,110,110,86,87,110),M1                               950JF031
 85   XX3U(7) = 0.0                                                     950JF032
      XX3(7) = B(7,IB-1)                                                950JF033
      CALL DMOVE (W(1,IW+1),XX3U)                                       950JF034
      CALL DMOVE (W(1,IW+2),XX3)                                        950JF035
      CALL DMOVE (B(1,1),XX3U)                                          950JF036
      CALL DMOVE (B(1,2),XX3)                                           950JF037
```

```
      IB = 2                                                            950JF038
      NN = IW                                                           950JF039
      IW = IW+2                                                         950JF040
      NPT3 = 12345                                                      950JF041
      CALL DMOVE (B(1,3),XX3)                                           950JF042
      SENSE LIGHT 1                                                     950JF043
      GO TO 91                                                          950JF044
C                                                                       950JF045
C       CHARACTERISTIC IS COMPLETE.                                     950JF046
C                                                                       950JF047
 86   IWW = IW                                                          950JF048
      MM1 = 1                                                           950JF049
      N = N2-1                                                          950JF050
      GO TO 200                                                         950JF051
C                                                                       950JF052
 87   IF (XXA(7)) 870,875,875                                           950JF053
 870  MM1 = 3                                                           950JF054
      IWW = IW                                                          950JF055
      N = N2                                                            950JF056
      GO TO 200                                                         950JF057
 875  CALL DMOVE (XXB,XXA)                                              950JF058
      CALL SELECT (XXA,T,N2,1)                                          950JF059
      GO TO 83                                                          950JF060
C                                                                       950JF061
 90   CALL DMOVE (XX3,B(1,IB))                                          950JF062
      IF (NPT3) 999,901,900                                             950JF063
 901  IF (B(7,IB+1)) 999,91,97                                          950JF064
 900  IF (NPT3-12345) 97,910,999                                        950JF065
 910  IF (SENSE LIGHT 1) 80,911                                         950JF066
 911  IB = IB-1                                                         950JF067
      GO TO 80                                                          950JF068
 91   IF (T) 95,95,92                                                   950JF069
 92   CALL FDPT (W(1,NN),B(1,IB),W(1,IW+1),C1,M1)                       950JF070
      GO TO 62                                                          950JF071
 95   CALL FDPT (B(1,IB),W(1,NN),W(1,IW+1),C1,M1)                       950JF072
      GO TO 62                                                          950JF073
 97   IB = IB+2                                                         950JF074
      GO TO 91                                                          950JF075
C                                                                       950JF076
 98   IF (T) 980,980,981                                                950JF077
 980  CALL FDPT (XXA,B(1,IB-2),XXB,C1,M1)                               950JF078
```

```
      GO TO 83                                                          950JF079
  981 CALL FDPT (B(1,IB-2),XXA,XXB,C1,M1)                               950JF080
      GO TO 83                                                          950JF081
  110 MM1 = 2                                                           950JF082
      GO TO 200                                                         950JF083
C                                                                       950JF084
  100 IF (B(7,IB)) 102,101,102                                          950JF085
  101 IF (B(7,IB+1)) 999,104,103                                        950JF086
  103 CALL BODYPT (T,B(1,IB-1),B(1,IB+2),W(1,IW),C1,M1)                 950JF087
      IB = IB+2                                                         950JF088
      GO TO 105                                                         950JF089
  104 CALL BODYPT (T,B(1,IB-1),B(1,IB),W(1,IW),C1,M1)                   950JF090
  105 IW = 0                                                            950JF091
      W(7,1) = B(7,1)                                                   950JF092
      M1 = M1                                                           950JF093
      GO TO (62,999),M1                                                 950JF094
  102 IB = 6                                                            950JF095
      CALL DMOVE (W(1,1),B(1,IB))                                       950JF096
      N2 = N2+1                                                         950JF097
      CALL SELECT (XXA,T,N2,0)                                          950JF098
      GO TO 98                                                          950JF099
  999 CALL DUMP                                                         950JF100
  200 RETURN                                                            950JF101
      END
```

```
      SUBROUTINE MCAL (XM1,G,DEL,XM2)                                   950JAA00
*     LABEL
 950JAA                                                                 950JAA
C     XM1 = INITIAL MACH NO.    (INPUT)                                 950JAA01
C     G = GAMMA                                                         950JAA02
C     DEL = TURN ANGLE IN RADIAN    (INPUT)                             950JAA03
C     ......DEL = (+) EXPANSION FLOW                                    950JAA04
C     ......DEL = (-) COMPRESSION FLOW                                  950JAA05
C     XM2 = FINAL MACH NO.    (OUTPUT)                                  950JAA06
      DIMENSION X(100),Y(100),A(200)                                    950JAA07
      ZNUF(SM) =ATANF(C1*SM)/C1-ATANF(SM)                               950JAA08
 10   FORMAT (7H NU =  E12.5,10H  NU/G =  E12.5)                        950JAA09
      IF (GI-G) 1,3,1                                                   950JAA10
 1    YMAX = 2.3                                                        950JAA11
      DX = YMAX*1.3/99.                                                 950JAA12
      GI = G                                                            950JAA13
      C1 = SQRTF((GI-1.)/(GI+1.))                                       950JAA14
      DO 2 I=1,100                                                      950JAA15
      XI = I-1                                                          950JAA16
      X(I) = EXPF (XI*DX)                                               950JAA17
      SSM = SQRTF(X(I)**2-1.)                                           950JAA18
      Y(I) = ZNUF(SSM)                                                  950JAA19
 2    CONTINUE                                                          950JAA20
      XM = X(30)                                                        950JAA21
      DY2 = XM*(1.+(GI-1.)*XM*XM/2.)/SSM                                950JAA22
      CALL CURFIT (Y,X,A,100,0.,DY2,2,1)                                950JAA23
 3    SSM = SQRTF (XM1*XM1-1.)                                          950JAA24
      XU2 = ZNUF(SSM)+DEL                                               950JAA25
      CALL CURVE (A,Y,X,XU2,XM2,ANY,100,3)                              950JAA26
 101  RETURN                                                            950JAA27
      END
```

```
      SUBROUTINE OBLSHK (XX1,W1,XX3,GAMMA)                              950JBB00
*     LABEL
 950JBB                                                                 950JBB
C                                                                       950JBB01
C         ROUTINE TO CALCULATE PROPERTIES ACROSS                        950JBB02
C         AN OBLIQUE SHOCK HAVING THE UPSTREAM                          950JBB03
C         PROPERTIES AND THE SHOCK ANGLE GIVEN                          950JBB04
C         (SHOCK ANGLE IS TH1U+W).                                      950JBB05
C                                                                       950JBB06
      DIMENSION XX1(10),XX3(10),GAMMA(13)                               950JBB07
      R2RF(A,B,D) = A*(B*(C6*(1./D+C10))**C1)**C2                       950JBB08
      ZZM2F(A,B) = ATANF(SQRTF(1./(C12*(1.-(A/B)**(-C7))-1.0)))         950JBB09
      PRODF(A,B) = (A*SINF(B))**2                                       950JBB10
      PR2F(A) = C4*(A-C11)                                              950JBB11
C                                                                       950JBB12
      C1 = GAMMA                                                        950JBB13
      C2 = 1.0/(1.0-C1)                                                 950JBB14
      C4 = 2.0*C1/(C1+1.0)                                              950JBB15
      C6 = 2.0/(C1+1.0)                                                 950JBB16
      C7 = (C1-1.0)/C1                                                  950JBB17
      C10 = (C1-1.0)/2.0                                                950JBB18
      C11 = (C1-1.0)/(2.0*C1)                                           950JBB19
      C12 = 2.0/(1.0-C1)                                                950JBB20
      XMACH =1./SINF(XX1(5))                                            950JBB21
      XMACH2 = XMACH**2                                                 950JBB22
      W = ABSF(W1)                                                      950JBB23
      Z = PRODF(XMACH,W)                                                950JBB24
      P2P1 = PR2F(Z)                                                    950JBB25
      R1 = R2RF(XX1(6),P2P1,Z)                                          950JBB26
      P1 = P2P1*XX1(3)                                                  950JBB27
      XX3(5) = ZZM2F(P1,R1)                                             950JBB28
      T1 = SINF(W1)                                                     950JBB29
      T2 = T1**2                                                        950JBB30
      XX3(4) = ATANF((2.*COSF(W)/T1*(XMACH2*T2-1.0))                    950JBB31
     1  /(2.0+XMACH2*(C1+1.0-2.0*T2))) +XX1(4)                          950JBB32
      XX3(1) = XX1(1)                                                   950JBB33
      XX3(2) = XX1(2)                                                   950JBB34
      XX3(3) = P1                                                       950JBB35
      XX3(6) = R1                                                       950JBB36
      XX3(8) = W1                                                       950JBB37
```

```
      RETURN                                                   950JBB38
      END
```

```
      SUBROUTINE EXPAN (M1,STH,GAMMA,W,IW)                            950JCC00
*     LABEL
 950JCC                                                               950JCC
C                                                                     950JCC01
      DIMENSION W(10,100)                                             950JCC02
C                                                                     950JCC03
      C1 = GAMMA                                                      950JCC04
      C3 = C1/(C1-1.0)                                                950JCC05
      C10 = (C1-1.0)/2.0                                              950JCC06
      DEL = STH-W(4,IW)                                               950JCC07
      XM1 = 1.0/SINF(W(5,IW))                                         950JCC08
C                                                                     950JCC09
      CALL MCAL (XM1,C1,DEL,XM2)                                      950JCC10
C                                                                     950JCC11
      XM2SQ = XM2**2                                                  950JCC12
      IW = IW+1                                                       950JCC13
      W(1,IW) = W(1,IW-1)                                             950JCC14
      W(2,IW) = W(2,IW-1)                                             950JCC15
      W(3,IW) = (1.0+C10*XM2SQ)**(-C3)*W(6,IW-1)                      950JCC16
      W(4,IW) = STH                                                   950JCC17
      W(5,IW) = ATANF(1.0/SQRTF(XM2SQ-1.0))                           950JCC18
      W(6,IW) = W(6,IW-1)                                             950JCC19
C                                                                     950JCC20
      RETURN                                                          950JCC21
      END
```

```
      SUBROUTINE CONT5 (W,TT,GAMMA,FSM,NN,M1)                          950JG000
*     LABEL
 950JG                                                                 950JG
C                                                                      950JG001
C     ROUTINE TO CONTROL THE CALCULATION OF                            950JG002
C       SHOCK-BODY INTERACTION AND THE FIRST                           950JG003
C       CHARACTERISTIC DOWNSTREAM.                                     950JG004
C     T NEGATIVE UPPER BODY.                                           950JG005
C     T POSITIVE LOWER BODY.                                           950JG006
C     K IS TAPE NUMBER.                                                950JG007
C                                                                      950JG008
      DIMENSION B(10,100),W(10,100),XXA(10),XXB(10),XX2(10)            950JG009
      EQUIVALENCE (NPTA,XXA(10)),(NPTB,XXB(10))                        950JG010
C                                                                      950JG011
      C1 = GAMMA                                                       950JG012
      T = TT                                                           950JG013
      IF (T) 199,199,198                                               950JG014
 198  K = 4                                                            950JG015
      GO TO 197                                                        950JG016
 199  K = 3                                                            950JG017
 197  BACKSPACE K                                                      950JG018
      READ TAPE K,B                                                    950JG019
C                                                                      950JG020
      DO 10 I=2,20                                                     950JG021
      IF (B(7,I)) 10,10,15                                             950JG022
 10   CONTINUE                                                         950JG023
      WRITE OUTPUT TAPE 6,500                                          950JG024
 500  FORMAT (//30H DATA FOR SHOCK4 IS INCORRECT.)                     950JG025
      CALL DUMP                                                        950JG026
C                                                                      950JG027
 15   IB = I                                                           950JG028
      N = IB+1                                                         950JG029
 18   CALL SHOCK4 (-T,B(1,IB),B(1,N),B(1,1),B(1,IB-1),W(1,1),          950JG030
     1  W(1,2),C1,M1)                                                  950JG031
      M1 = M1                                                          950JG032
      GO TO (30,999,20),M1                                             950JG033
 20   N = N+1                                                          950JG034
      GO TO 18                                                         950JG035
C                                                                      950JG036
 30   STH = W(4,1)                                                     950JG037
```

```
      W(7,1) = B(7,1)                                                   950JG038
      CALL SHK1 (T,STH,W(1,2),W(1,3),C1,M1)                             950JG039
      CALL DMOVE (XXA,B(1,N))                                           950JG040
      CALL FDPT (W(1,2),XXA,XXB,C1,M1)                                  950JG041
   40 CALL SHOCK (-1,M1,T,XXA,XXB,W(1,2),W(1,3),XX2,W(1,4),             950JG042
     1  W(1,5),W(1,6),C1,DUM,FSM)                                       950JG043
      M1 = M1                                                           950JG044
      GO TO (50,999,999,999,999,70,999),M1                              950JG045
   70 CALL DMOVE (XXB,XXA)                                              950JG046
      BACKSPACE K                                                       950JG047
      BACKSPACE K                                                       950JG048
      READ TAPE K,B                                                     950JG049
      DO 80 I=1,100                                                     950JG050
      CALL DMOVE (XXA,B(1,I))                                           950JG051
      IF (NPTA-NPTB) 80,40,80                                           950JG052
   80 CONTINUE                                                          950JG053
C                                                                       950JG054
   50 W(7,5) = W(7,3)                                                   950JG055
      W(7,6) = W(7,1)                                                   950JG056
      NN = NPTA                                                         950JG057
      RETURN                                                            950JG058
  999 WRITE OUTPUT TAPE 6,501                                           950JG059
  501 FORMAT (//24H ERROR IN CONT5 ROUTINE.)                            950JG060
      CALL DUMP                                                         950JG061
      END
```

```
      SUBROUTINE CONT6 (DATA,GAMMA)                                     950JH000
*     LABEL
 950JH                                                                  950JH
      DIMENSION W(10,100),B(10,100),XXX1(100),XXX2(100),                950JH001
     1  YY1(100),YY2(100)                                               950JH002
      DIMENSION DATA(10,8),XX1(10),XX2(10)                              950JH003
      DIMENSION TH(20),PPU(20),PPD(20)                                  950JH004
      EQUIVALENCE (XX1(7),NPT1)                                         950JH005
 500  FORMAT (1P2E15.5)                                                 950JH006
 501  FORMAT (10X1P2E15.5)                                              950JH007
 502  FORMAT (1P6E15.5)                                                 950JH008
      DINTPF(XY1,XY2,XY3,XY4,XY) = XY2+(XY4-XY2)/(XY3-XY1)*(XY-XY1)     950JH009
      REWIND 2                                                          950JH010
      READ TAPE 2                                                       950JH011
      READ TAPE 2                                                       950JH012
      REWIND 4                                                          950JH013
      NP1 = 0                                                           950JH014
      DO 40 I=1,200                                                     950JH015
      READ TAPE 4,W                                                     950JH016
      IF (W(1,100)-32000.0) 10,50,10                                    950JH017
 10   CALL MOVE1 (IBB,W)                                                950JH018
      CALL DMOVE (XX1,W(1,IBB-1))                                       950JH019
      IF (NPT1+2) 20,40,40                                              950JH020
 20   NP1 = NP1+1                                                       950JH021
      XXX1(NP1) = XX1(1)                                                950JH022
      YY1(NP1) = XX1(2)                                                 950JH023
      WRITE TAPE 2,XX1                                                  950JH024
 40   CONTINUE                                                          950JH025
 50   BACKSPACE 4                                                       950JH026
      B(1,100) = 3000.0                                                 950JH027
      WRITE TAPE 9,B                                                    950JH028
      END FILE 9                                                        950JH029
      REWIND 9                                                          950JH030
      NP2 = 0                                                           950JH031
      DO 70 I=1,200                                                     950JH032
      READ TAPE 9,W                                                     950JH033
      WRITE TAPE 4,W                                                    950JH034
      IF (W(1,100)-3000.0) 60,80,60                                     950JH035
 60   DO 65 II=1,100                                                    950JH036
      CALL DMOVE (XX1,W(1,II))                                          950JH037
```

```
      IF (NPT1-12345) 61,70,61                                          950JH038
   61 IF (NPT1) 65,65,62                                                950JH039
   62 IF (XXX2(NP2)-XX1(1)) 64,65,64                                    950JH040
   64 NP2 = NP2+1                                                       950JH041
      XXX2(NP2) = XX1(1)                                                950JH042
      YY2(NP2) = XX1(2)                                                 950JH043
   65 CONTINUE                                                          950JH044
   70 CONTINUE                                                          950JH045
   80 CONTINUE                                                          950JH046
      CALL MEET (XXX1,YY1,NP1,XXX2,YY2,NP2,X,Y,DY1,DY2)                 950JH047
C                                                                       950JH048
      REWIND 2                                                          950JH049
      READ TAPE 2                                                       950JH050
      READ TAPE 2                                                       950JH051
  110 READ TAPE 2,XX1                                                   950JH052
      IF (XX1(1)-X) 110,120,120                                         950JH053
  120 BACKSPACE 2                                                       950JH054
      BACKSPACE 2                                                       950JH055
      READ TAPE 2,XX2                                                   950JH056
      DATA(1,1) = X                                                     950JH057
      DATA(2,1) = Y                                                     950JH058
      DATA(3,1) = DINTPF(XX1(1),XX1(3),XX2(1),XX2(3),X)                 950JH059
      DATA(4,1) = ATANF(DY1)                                            950JH060
      DATA(5,1) = DINTPF(XX1(1),XX1(5),XX2(1),XX2(5),X)                 950JH061
      DATA(6,1) = DINTPF(XX1(1),XX1(6),XX2(1),XX2(6),X)                 950JH062
      DATA(7,1) = XX2(7)                                                950JH063
      W1 = ATANF(DY2)-DATA(4,1)                                         950JH064
      CALL OBLSHK (DATA(1,1),W1,DATA(1,2),GAMMA)                        950JH065
      B(1,100) = 32000.0                                                950JH066
      WRITE TAPE 3,B                                                    950JH067
  130 BACKSPACE 3                                                       950JH068
      BACKSPACE 3                                                       950JH069
      READ TAPE 3,W                                                     950JH070
      CALL MOVE1 (IBB,W)                                                950JH071
      IF (X-W(1,IBB-1)) 130,130,140                                     950JH072
  140 CALL DMOVE (XX1,W(1,IBB-1))                                       950JH073
      READ TAPE 3,W                                                     950JH074
      CALL MOVE1 (IBB,W)                                                950JH075
      CALL DMOVE (XX2,W(1,IBB-1))                                       950JH076
      DATA(1,3) = X                                                     950JH077
      DATA(2,3) = Y                                                     950JH078
```

```
      DATA(3,3) = DINTPF(XX1(1),XX1(3),XX2(1),XX2(3),X)          950JH079
      DATA(4,3) = DATA(4,1)                                      950JH080
      DATA(5,3) = DINTPF(XX1(1),XX1(5),XX2(1),XX2(5),X)          950JH081
      DATA(6,3) = DINTPF(XX1(1),XX1(5),XX2(1),XX2(6),X)          950JH082
      DATA(7,3) = XX2(7)                                         950JH083
      SPTH = DATA(4,2)-DATA(4,1)                                 950JH084
      DTH = SPTH/12.0                                            950JH085
      TH(1) = DATA(4,2)-3.5*DTH                                  950JH086
      DO 290 J=1,5                                               950JH087
      L = 9                                                      950JH088
  200 DO 250 I=1,L                                               950JH089
      STH =TH(I)                                                 950JH090
      IF (STH-DATA(4,3)) 999,999,210                             950JH091
  210 CALL SHK1 (1.0,STH,DATA(1,3),DATA(1,4),GAMMA,M1)           950JH092
      IF (DATA(4,2)-STH) 220,220,230                             950JH093
  220 CALL DMOVE (W,DATA(1,2))                                   950JH094
      IW=1                                                       950JH095
      CALL EXPAN (M1,STH,GAMMA,W,IW)                             950JH096
      PPD(I) = W(3,IW)                                           950JH097
      CALL DMOVE (DATA(1,5),W(1,IW))                             950JH098
      GO TO 240                                                  950JH099
  230 CALL SHK1 (-1.0,STH,DATA(1,2),DATA(1,5),GAMMA,M1)          950JH100
      PPD(I) = DATA(3,5)                                         950JH101
  240 PPU(I) = DATA(3,4)                                         950JH102
      TH(I+1) = TH(I)+DTH                                        950JH103
  250 CONTINUE                                                   950JH104
C                                                                950JH105
      IF (L-9) 270,260,270                                       950JH106
  260 L = 1                                                      950JH107
      CALL MEET (TH,PPU,9,TH,PPD,9,TH(1),P,DY1,DY2)              950JH108
      GO TO 200                                                  950JH109
C                                                                950JH110
  270 DTH = DTH/2.0                                              950JH111
      TH(1) = TH(1)-4.*DTH                                       950JH112
      IF (ABSF(DATA(3,5)-DATA(3,4))-.0001*DATA(3,4)) 300,300,290 950JH113
  290 CONTINUE                                                   950JH114
C                                                                950JH115
  300 NPT1 = 12345                                               950JH116
      RETURN                                                     950JH117
  999 CALL DUMP                                                  950JH118
      END
```

```
      SUBROUTINE CONV4 (ZZ1,ZZ2,ZZ7,ZZ4,ZZ3,ZZ5,C1,M1)                  950JE000
*     LABEL
 950JE                                                                  950JE
C                                                                       950JE001
C               INPUT                                                   950JE002
C     ZZ1 IS UPPER POINT ON SLIPSTREAM.                                 950JE003
C     ZZ2 IS UPPER POINT IN FIELD.                                      950JE004
C     ZZ7 IS LOWER POINT ON SLIPSTREAM.                                 950JE005
C     ZZ4 IS LOWER POINT IN FIELD.                                      950JE006
C              OUTPUT                                                   950JE007
C     ZZ3 IS UPPER POINT ON SLIPSTREAM.                                 950JE008
C     ZZ5 IS LOWER POINT ON SLIPSTREAM.                                 950JE009
C                                                                       950JE010
      DIMENSION ZZ1(10),XX1(10),ZZ2(10),XX2(10),ZZ3(10),XX3(10),        950JE011
     1  ZZ4(10),XX4(10),ZZ5(10),XX5(10),ZZ7(10),XX7(10)                 950JE012
      DIMENSION          PPI(10),PP5(10),TH(10)                         950JE013
C                                                                       950JE014
      PPUDF(XY1,XY2,XY3,XY4,XY5) = (XY1-XY3)/(XY2-XY3)*(XY4-XY5)+XY5    950JE015
C                                                                       950JE016
      DO 5 I=1,10                                                       950JE017
      XX1(I) = ZZ1(I)                                                   950JE018
      XX2(I) = ZZ2(I)                                                   950JE019
      XX7(I) = ZZ7(I)                                                   950JE020
      XX4(I) = ZZ4(I)                                                   950JE021
 5    CONTINUE                                                          950JE022
C                                                                       950JE023
      CALL DMCVE (XX3,XX1)                                              950JE024
      CALL DMOVE (XX5,XX7)                                              950JE025
C                                                                       950JE026
      IF (XX1(1)-XX7(1)) 6,6,4                                          950JE027
 6    XX3(4) = XX7(4)                                                   950JE028
 4    DDTH = .04                                                        950JE029
      L =9                                                              950JE030
      DO 20 IJ=1,5                                                      950JE031
      DTH = DDTH/4.                                                     950JE032
      XX3(4) = XX3(4)-DDTH                                              950JE033
 7    DO 10 I=1,L                                                       950JE034
      XX5(4) = XX3(4)                                                   950JE035
      CALL SLPSTM (1.,XX1,XX2,XX3,C1)                                   950JE036
      CALL SLPSTM (-1.,XX7,XX4,XX5,C1)                                  950JE037
```

```
      TH(I) = XX3(4)                                                    950JE038
      XX3(4) = XX3(4) + DTH                                             950JE039
C                                                                       950JE040
      IF (XX3(1)-XX5(1)) 40,40,50                                       950JE041
 40   PPI(I) = XX3(3)                                                   950JE042
      PP5(I) = PPUDF(XX3(1),XX5(1),XX7(1),XX5(3),XX7(3))                950JE043
      GO TO 10                                                          950JE044
 50   PP5(I) = XX5(3)                                                   950JE045
      PPI(I) = PPUDF(XX5(1),XX3(1),XX1(1),XX3(3),XX1(3))                950JE046
 10   CONTINUE                                                          950JE047
C                                                                       950JE048
      IF (L-9) 70,60,70                                                 950JE049
 60   CALL MEET (TH,PPI,L,TH,PP5,L,XX3(4),XX3(3),DY1,DY2)               950JE050
      XX5(4) = XX3(4)                                                   950JE051
      XX5(3) =XX3(3)                                                    950JE052
      L = 1                                                             950JE053
      DTH = 0.0                                                         950JE054
      GO TO 7                                                           950JE055
C                                                                       950JE056
 70   L = 9                                                             950JE057
      DDTH = DDTH/2.                                                    950JE058
      IF (ABSF(PPI(1)-PP5(1))-.0001*XX1(3)) 30,30,20                    950JE059
 20   CONTINUE                                                          950JE060
C                                                                       950JE061
 30   CALL DMOVE (ZZ3,XX3)                                              950JE062
      CALL DMOVE (ZZ5,XX5)                                              950JE063
      RETURN                                                            950JE064
      END
```

```
      SUBROUTINE CHLIN4 (B,W,GAMMA,TT,IBB,IWW,M11,FSMM)                 950JD000
*     LABEL
 950JD                                                                  950JD
C                                                                       950JD001
C     T = +1  RIGHT RUNNING CHARACTERISTIC                              950JD002
C     T = -1  LEFT RUNNING CHARACTERISTIC                               950JD003
C                                                                       950JD004
      DIMENSION B(10,100),W(10,100),XX1(10),XXA(10),XXB(10),XX2(10),   950JD005
     1 XX3(10),XX3U(10),XX5(10)                                         950JD006
      EQUIVALENCE (NPT1,XX1(7)),(NPT2,XX2(7))                           950JD007
      C1 = GAMMA                                                        950JD008
      T = TT                                                            950JD009
      FSM = FSMM                                                        950JD010
      IF (T) 10,10,20                                                   950JD011
 10   NPT = 11                                                          950JD012
      GO TO 30                                                          950JD013
 20   NPT = 21                                                          950JD014
 30   CONTINUE                                                          950JD015
 60   IB = 2                                                            950JD016
      IW = 1                                                            950JD017
      CALL BODYPT (-T,B(1,IB-1),B(1,IB),W(1,IW),C1,M1)                  950JD018
      M1 = M1                                                           950JD019
      GO TO (61,999),M1                                                 950JD020
C                                                                       950JD021
 61   W(7,1) = B(7,1)                                                   950JD022
 62   IW = IW+1                                                         950JD023
 63   IB = IB+1                                                         950JD024
C                                                                       950JD025
 65   CALL DMOVE (XX1,B(1,IB))                                          950JD026
      IF (NPT1-NPT) 69,66,69                                            950JD027
 66   IW = IW-1                                                         950JD028
 660  CALL DMOVE (XXA,W(1,IW-1))                                        950JD029
      CALL DMOVE (XXB,W(1,IW))                                          950JD030
      IF (XXB(7)) 685,662,662                                           950JD031
 662  N = IB+1                                                          950JD032
 661  CALL DMOVE (XX2,B(1,N))                                           950JD033
 67   CALL SHOCK (-2,M1,T,XXA,XXB,B(1,IB-1),B(1,IB),XX2,XX3U,XX3,      950JD034
     1 XX5,C1,SW,FSM)                                                   950JD035
      M1 = M1                                                           950JD036
      GO TO (68,999,999,999,681,682,683),M1                             950JD037
```

```
 68   XX3U(7) = 0.0                                              950JD038
      XX3(7) = B(7,IB)                                           950JD039
      CALL DMOVE (W(1,IW),XX3U)                                  950JD040
      CALL DMOVE (W(1,IW+1),XX3)                                 950JD041
      IW = IW+1                                                  950JD042
      IB = N-1                                                   950JD043
      GO TO 62                                                   950JD044
C                                                                950JD045
 681  IF (NPT2) 210,200,210                                      950JD046
 200  N = N+1                                                    950JD047
      GO TO 661                                                  950JD048
 210  CALL MOVE1 (IB,B)                                          950JD049
 215  CALL DMOVE (XX1,B(1,IB))                                   950JD050
      IF (NPT1) 217,220,220                                      950JD051
 217  IF (NPT1+2) 220,230,230                                    950JD052
 220  CALL DMOVE (B(1,IB+1),B(1,IB))                             950JD053
      IB = IB-1                                                  950JD054
      GO TO 215                                                  950JD055
 230  DO 240 I=1,6                                               950JD056
      B(I,2) = (B(I,3)+B(I,1))/2.0                               950JD057
 240  CONTINUE                                                   950JD058
      GO TO 60                                                   950JD059
 682  IF (XXA(7)) 685,684,686                                    950JD060
 684  IW = IW-1                                                  950JD061
      GO TO 660                                                  950JD062
 683  IW = IW+1                                                  950JD063
      GO TO 660                                                  950JD064
 685  M1 = 2                                                     950JD065
      GO TO 75                                                   950JD066
 686  M1 = 3                                                     950JD067
      GO TO 75                                                   950JD068
C                                                                950JD069
 69   IF (B(7,IB)) 692,694,690                                   950JD070
 690  IB = IB+1                                                  950JD071
      GO TO 65                                                   950JD072
 692  CALL DMOVE (XX1,B(1,IB+1))                                 950JD073
      IF (NPT1-12345) 63,694,63                                  950JD074
 694  IF (T) 390,390,392                                         950JD075
 390  CALL FDPT (W(1,IW-1),B(1,IB),W(1,IW),C1,M1)                950JD076
      GO TO 394                                                  950JD077
 392  CALL FDPT (B(1,IB),W(1,IW-1),W(1,IW),C1,M1)                950JD078
```

```
394   CONTINUE                                          950JD079
      W(10,IW) = B(10,IB)                               950JD080
      CALL DMOVE (XX1,B(1,IB))                          950JD081
      IF (NPT1) 70,62,62                                950JD082
70    M1 = 1                                            950JD083
75    IBB = IB                                          950JD084
      IWW = IW                                          950JD085
      M11 = M1                                          950JD086
      RETURN                                            950JD087
999   CALL DUMP                                         950JD088
      END
```

```
      SUBROUTINE SHOCK4 (AA,XX1,XX2,XX5,XX7,XX3U,XX3,GAMMA,M1)          950JI000
C                                                                       950JI001
      DIMENSION XX1(10),XX2(10),XX3U(10),XX3(10)                        950JI002
      DIMENSION XX5(10),XX7(10)                                         950JI003
C                                                                       950JI004
 21   FORMAT (1P6E15.5,I15)                                             950JI005
      TANF(XXX) = SINF(XXX)/COSF(XXX)                                   950JI006
C                                                                       950JI007
      X1 = XX1(1)                                                       950JI008
      Y1 = XX1(2)                                                       950JI009
      P1 = XX1(3)                                                       950JI010
      TH1 = XX1(4)                                                      950JI011
      ZMU1 = XX1(5)                                                     950JI012
      R1 = XX1(6)                                                       950JI013
      W1 = ABSF(XX1(8))                                                 950JI014
C                                                                       950JI015
      X2 = XX2(1)                                                       950JI016
      Y2 = XX2(2)                                                       950JI017
      P2 = XX2(3)                                                       950JI018
      TH2 = XX2(4)                                                      950JI019
      ZMU2 = XX2(5)                                                     950JI020
      R2 = XX2(6)                                                       950JI021
      W2 = XX2(8)                                                       950JI022
C                                                                       950JI023
      X7 = XX7(1)                                                       950JI024
      Y7 = XX7(2)                                                       950JI025
      P7 = XX7(3)                                                       950JI026
      TH7 = XX7(4)                                                      950JI027
      ZMU7 = XX7(5)                                                     950JI028
      R7 = XX7(6)                                                       950JI029
      W7 = XX7(8)                                                       950JI030
C                                                                       950JI031
      X5 = XX5(1)                                                       950JI032
      Y5 = XX5(2)                                                       950JI033
      P5 = XX5(3)                                                       950JI034
      TH5 = XX5(4)                                                      950JI035
      ZMU5 = XX5(5)                                                     950JI036
      R5 = XX5(6)                                                       950JI037
      W5 = XX5(8)                                                       950JI038
      A = AA                                                            950JI039
```

```
      C1 = GAMMA
C
C
      RR = .5
      C2 = 1./(1.-C1)
      C3 = C1/(C1-1.)
      C4 = 2.*C1/(C1+1.)
      C5 = (C1-1.)/(C1+1.)
      C7 = (C1-1.)/C1
      C11 = (C1-1.)/(2.*C1)
      C12 = 2./(1.-C1)
      T1 = TANF(TH7 + A*W1)
      T2 = TANF(TH5)
      X3 =  (Y1 - X1*T1 + X5*T2 - Y5)/(T2-T1)
      W3 = W1
      CALL LOCATE (1,-A,ITT,AC,BC,CC,DC,X3)
      R3U = R5
      P3U = P7
      ZMU3U = ZMU7
      P3LS = 1000.
      TH3U = ATANF((3.*AC*X3 + 2.*BC)*X3 + CC)
      DO 425 J = 1,100
C
  290 DO 310  I = 1,20
      CALL LOCATE (0,-A,ITT,AC,BC,CC,DC,X3)
      TH3U = ATANF((3.*AC*X3 + 2.*BC)*X3 + CC)
      T1 =   (TH3U  + TH7 + A* (W3+W1))/2.
      T1 = TANF(T1)
      FX = (X3*(AC *X3 + BC ) + CC )*X3 + DC  - Y1 + T1*(X1-X3)
      DFX =  (3.*AC *X3 + 2.*BC )*X3 + CC  - T1
      IF (ABSF(DFX)- .00000001)  20, 20,300
C
  300 DDFX= FX/DFX
      X3 = X3 - DDFX
      IF (ABSF(DDFX) - MAX1F(.00001*X3, .00001))  20, 20,310
C
  310 CONTINUE
C
   20 Y3 = Y7 - T1 * (X7-X3)
      T7 = TH3U + A*ZMU3U
      T4 = TH7 + A*ZMU7
```

```
      T6 = TH5 + A*ZMU5                                                 950JI081
C                                                                       950JI082
      T8 =  Y7 - Y5                                                     950JI083
      T9 =  X7 - X5                                                     950JI084
      T10 = Y5 - Y3                                                     950JI085
      T11 = X5 - X3                                                     950JI086
      DO 55  KK = 1,100                                                 950JI087
      T3 = (RR * (T4-T6) + (T6+T7))/2.                                  950JI088
      T12 = TANF(T3)                                                    950JI089
      FR =  RR * T8/T9  + T10/T9  -  (RR + T11/T9)* T12                 950JI090
      FPR = T8/T9 - T12 - (RR+T11/T9) * .5 * (T4-T6)/COSF(T3)**2        950JI091
      IF (ABSF(FPR) - .00000001)  57,57,52                              950JI092
 52   DRR = FR/FPR                                                      950JI093
      RR = RR - DRR                                                     950JI094
C                                                                       950JI095
 50   CONTINUE                                                          950JI096
C                                                                       950JI097
 51   IF (ABSF(DRR) - .00000001) 57,57,55                               950JI098
 55   CONTINUE                                                          950JI099
C                                                                       950JI100
 57   Y4 = Y5 + RR* T8                                                  950JI101
      X4 = X5 + RR* T9                                                  950JI102
      TH4 = TH5 + RR* (TH7-TH5)                                         950JI103
      P4 = P5 + RR* (P7-P5)                                             950JI104
      R4 = R5 + RR* (R7-R5)                                             950JI105
      ZMU4 = ZMU5 + RR* (ZMU7-ZMU5)                                     950JI106
      PB4 = (P4+P3U)/2.                                                 950JI107
      ZMUB4 = (ZMU4+ZMU3U)/2.                                           950JI108
      THB4 = (TH4+TH3U)/2.                                              950JI109
      YB4 = (Y4 + Y3)/2.                                                950JI110
      T2 =  (T7 +  TH4 + A*ZMU4)/2.                                     950JI111
C                                                                       950JI112
      P3U = P4+C1*PB4*(-A*(TH3U-TH4)/(COSF(ZMUB4)*SINF(ZMUB4)))         950JI113
      T30 = P3U/R3U                                                     950JI114
C                                                                       950JI115
      IF (T30)  370,70,70                                               950JI116
C                                                                       950JI117
 70   T30 = C12 * (1.- T30**(-C7)) - 1.                                 950JI118
      IF (T30)  370,370,80                                              950JI119
 80   ZMU3U= ATANF(SQRTF(1./T30))                                       950JI120
C                                                                       950JI121
```

```
C                                                                        950JI122
C                                                                        950JI123
 100  ZM3U  = 1./SINF(ZMU3U )                                            950JI124
      T32 = ZM3U **2                                                     950JI125
      T29 = SINF(2.*W3)                                                  950JI126
      T31 = SINF(W3)**2                                                  950JI127
      DEL3 = ATANF((T32*T29 - 2./TANF(W3))/(T32* (C1 + COSF(2.*W3))+2.))950JI128
      TH3  = TH3U  + A*DEL3                                              950JI129
      ERASB = C4*(T32*T31 - C11)                                         950JI130
      P3   = P3U *ERASB                                                  950JI131
      R3   = ((T32*T31)/(C5*((T32*T31)-C12)))**C3*ERASB**C2 * R3U        950JI132
      T30 = P3 /R3                                                       950JI133
      IF (T30)  370,370,380                                              950JI134
C                                                                        950JI135
 370  M1 = 2                                                             950JI136
      GO TO 430                                                          950JI137
C                                                                        950JI138
 380  T30 = C12 * (1. - T30**(-C7)) -1.                                  950JI139
      IF (T30 - .04) 370,370,390                                         950JI140
C                                                                        950JI141
 390  ZMU3  = ATANF(SQRTF(1./T30))                                       950JI142
      IF (ABSF(P3 - P3LS) - .001*P3) 428,428,400                         950JI143
C                                                                        950JI144
 400  P3LS = P3                                                          950JI145
C                                                                        950JI146
      T4 = TH1 + A*ZMU1                                                  950JI147
      T6 = TH2 + A*ZMU2                                                  950JI148
      T7 = TH3 + A*ZMU3                                                  950JI149
      T8 = Y2 - Y1                                                       950JI150
      T9 = X2 - X1                                                       950JI151
      T10 = Y1 -Y3                                                       950JI152
      T11 = X1 - X3                                                      950JI153
      DO 30  KK = 1,100                                                  950JI154
      T3 = (RR*(T6-T4) + (T4+T7))/2.                                     950JI155
      T12 = TANF(T3)                                                     950JI156
      FR = RR * T8/T9 + T10/T9 - (RR + T11/T9)* T12                      950JI157
      FPR = T8/T9 - T12 - (RR+T11/T9) * .5 * (T6-T4)/COSF(T3)**2         950JI158
      IF (ABSF(FPR) -.00000001)  31,31,42                                950JI159
 42   DRR = FR/FPR                                                       950JI160
      RR = RR - DRR                                                      950JI161
 40   WRITE OUTPUT TAPE 6,21,RR,DRR,FR,FPR                               950JI162
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```
 45   IF (ABSF(DRR) - .0000001)  31,31,30                                 950JI163
 30   CONTINUE                                                            950JI164
 31   IF (RR)  220,210,210                                                950JI165
 210  IF (RR - 1.)    270,270,220                                         950JI166
 220  IF (NPT2)  370,230,230                                              950JI167
 230  M1 = 3                                                              950JI168
C                                                                         950JI169
C     USE THE NEXT POINT ON THE CHARACTERISTIC AS                         950JI170
C       A POINT 2.                                                        950JI171
C                                                                         950JI172
      GO TO 430                                                           950JI173
C                                                                         950JI174
 270  Y4 = Y1 + RR*T8                                                     950JI175
      X4 = X1 + RR*T9                                                     950JI176
      TH4 = TH1 + RR*(TH2-TH1)                                            950JI177
      P4 = P1 + RR*(P2-P1)                                                950JI178
      R4 = R1 + RR*(R2-R1)                                                950JI179
      ZMU4 = ZMU1 + RR*(ZMU2-ZMU1)                                        950JI180
      T28 = SINF(DEL3)**2                                                 950JI181
      DPDW = P3U *C4*T32*T29                                              950JI182
      DTHDW =(C1+1.)*T28*T31*T32**2/(T32*T31-1.)**2-SINF(2.*DEL3)/T29     950JI183
      T13 = (TH4 + TH3 )/2.                                               950JI184
      T60 = (TH4 + A*ZMU4)/2.                                             950JI185
      T11=(P4 + P3U)/2.                                                   950JI186
      T12= (ZMU4 + ZMU3 )/2.                                              950JI187
      T34 = (Y4 + Y3)/2.                                                  950JI188
      DW3 = -((P3-P4)/(C1*T11)+A*(TH3-TH4)/((COSF(T12))*(SINF(T12))))     950JI189
      W3 = W3 +DW3/(DPDW/(C1*T11) + DTHDW/TANF(T12))                      950JI190
C                                                                         950JI191
C                                                                         950JI192
 425  CONTINUE                                                            950JI193
 428  M1 = 1                                                              950JI194
      XX3U(1) = X3                                                        950JI195
      XX3U(2) = Y3                                                        950JI196
      XX3U(3) = P3U                                                       950JI197
      XX3U(4) = TH3U                                                      950JI198
      XX3U(5) = ZMU3U                                                     950JI199
      XX3U(6) = R3U                                                       950JI200
      XX3U(7) = 0.0                                                       950JI201
      XX3(1) = X3                                                         950JI202
      XX3(2) = Y3                                                         950JI203
```

```
      XX3(3) = P3                                                       950JI204
      XX3(4) = TH3                                                      950JI205
      XX3(5) = ZMU3                                                     950JI206
      XX3(6) = R3                                                       950JI207
      XX3(7) = XX1(7)                                                   950JI208
      XX3(8) = SIGNF(W3,XX1(8))                                         950JI209
  430 RETURN                                                            950JI210
      END
```

```
C     PROGRAM TO SET UP DATA FOR BOUNDARY LAYER.                        950J5000
*     LABEL
 950J5                                                                  950J5
C                                                                       950J5001
      DIMENSION ARRAY(12),UL(200),SL(200),M(10),B(10,100),BU(2,100) ,   950J5002
     1  BL(2,100),UU(200),SU(200),XU(200),YU(200),XL(200),YL(200)       950J5003
      DIMENSION YINTGU(200),YINTGL(200),W(10,100)                       950J5004
      DIMENSION AC1(6,20),AC2(6,20)                                     950J5005
C                                                                       950J5006
 410  FORMAT (20X43HBOUNDARY LAYER INPUT DATA  -  UPPER SURFACE///      950J5007
     110X6HT2T1 =1PE15.5/10X6HP2P1 =1PE15.5/10X6HU2U1 =1PE15.5/         950J5008
     210X6HP3P2 =1PE15.5//                                              950J5009
     39X1HX,19X1HY,12X16HSURFACE DISTANCE,9X8HVELOCITY//                950J5010
     4(1PE15.5,1P3E20.5))                                               950J5011
 420  FORMAT (20X43HBOUNDARY LAYER INPUT DATA  -  LOWER SURFACE///      950J5012
     110X6HT2T1 =1PE15.5/10X6HP2P1 =1PE15.5/10X6HU2U1 =1PE15.5/         950J5013
     210X6HP3P2 =1PE15.5//9X1HX,19X1HY,12X16HSURFACE DISTANCE,          950J5014
     39X8HVELOCITY//(1PE15.5,1P3E20.5))                                 950J5015
C                                                                       950J5016
      P3P2U = 1.0                                                       950J5017
      P3P2L = 1.0                                                       950J5018
      REWIND 2                                                          950J5019
      READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY                             950J5020
      IF (M(1)-1) 200,210,200                                           950J5021
 200  READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,R1,R2,                 950J5022
     1  B,W,N,((BU(I,L),I=1,2),L=1,N),((BL(I,L),I=1,2),L=1,N)           950J5023
 210  READ TAPE 2,AC1,AC2,N1,N2                                         950J5024
      REWIND 2                                                          950J5025
      IF (M(10)-1)3,2,1                                                 950J5026
 1    CALL EXIT                                                         950J5027
C                                                                       950J5028
 2    M(10) = 2                                                         950J5029
      IF (M(1)-1) 225,220,225                                           950J5030
 220  WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY                            950J5031
      GO TO 228                                                         950J5032
 225  WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,R1,R2,                950J5033
     1  B,W,N,((BU(I,L),I=1,2),L=1,N),((BL(I,L),I=1,2),L=1,N)           950J5034
 228  WRITE TAPE 2,AC1,AC2,N1,N2                                        950J5035
      CALL CHAIN (10,8)                                                 950J5036
C                                                                       950J5037
```

```
3     M(10) = 1                                                         950J5038
      IF (M(1)-1) 235,230,235                                           950J5039
230   WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY                            950J5040
      GO TO 238                                                         950J5041
235   WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,R1,R2,                950J5042
     1  B,W,N,((BU(I,L),I=1,2),L=1,N),((BL(I,L),I=1,2),L=1,N)           950J5043
238   WRITE TAPE 2,AC1,AC2,N1,N2                                        950J5044
      CALL LOCATE (-1,T,ITT,DUM,DUM,DUM,DUM,DUM)                        950J5045
      REWIND 3                                                          950J5046
      REWIND 4                                                          950J5047
      REWIND 9                                                          950J5048
      IF (M(1)-2) 5,8,5                                                 950J5049
5     N = 0                                                             950J5050
      P1 = (1.0+(GAMMA-1.0)/2.0*FSM**2)**(-GAMMA/(GAMMA-1.0))           950J5051
      GO TO 12                                                          950J5052
8     DO 10 I=1,N                                                       950J5053
      UU(I) = BU(2,I)                                                   950J5054
      SU(I) = BU(1,I)*R1                                                950J5055
      UL(I) = BL(2,I)                                                   950J5056
      SL(I) = BL(1,I)*R2                                                950J5057
      READ TAPE 3                                                       950J5058
      READ TAPE 4                                                       950J5059
10    CONTINUE                                                          950J5060
12    J = 0                                                             950J5061
      K = N                                                             950J5062
      B(1,100) = 100.0                                                  950J5063
15    IF (B(1,100)-3333.0) 20,40,20                                     950J5064
20    READ TAPE 3,B                                                     950J5065
      WRITE OUTPUT TAPE 6,700,B(1,1),B(2,1),B(3,1),B(1,100)             950J5066
700   FORMAT (1P4E16.5)                                                 950J5067
      IF (B(7,1)) 22,15,15                                              950J5068
22    IF (J) 25,38,25                                                   950J5069
25    IF (B(1,1)-XU(J)) 30,15,30                                        950J5070
38    B(1,2) = 100.0                                                    950J5071
30    J = J+1                                                           950J5072
      K = K+1                                                           950J5073
      CALL USPREP (-1.0,B,XU(J),YU(J),YINTGU(J),UU(K),FST)              950J5074
      IF (B(1,1)-B(1,2)) 15,32,15                                       950J5075
32    J = J+1                                                           950J5076
      K = K+1                                                           950J5077
      CALL USPREP (-1.,B(1,3),XU(J),YU(J),YINTGU(J),UU(K),FST)          950J5078
```

```
      P3P2U = B(3,3)/B(3,2)                                             950J5079
      GO TO 15                                                          950J5080
C                                                                       950J5081
 40   I = 0                                                             950J5082
      L = N                                                             950J5083
      B(1,100) = 100.0                                                  950J5084
 50   READ TAPE 4,B                                                     950J5085
      WRITE OUTPUT TAPE 6,700,B(1,1),B(2,1),B(3,1),B(1,100)             950J5086
      IF (B(1,100)-3333.0) 60,90,60                                     950J5087
 60   IF (B(7,1)) 65,50,50                                              950J5088
 65   IF (I) 66,67,66                                                   950J5089
 66   IF (B(1,1)-XL(I)) 70,50,70                                        950J5090
 67   B(1,2) = 100.0                                                    950J5091
 70   I = I+1                                                           950J5092
      L = L+1                                                           950J5093
      CALL USPREP (1.0,B,XL(I),YL(I),YINTGL(I),UL(L),FST)               950J5094
      IF (B(1,1)-B(1,2)) 50,80,50                                       950J5095
 80   I = I+1                                                           950J5096
      L = L+1                                                           950J5097
      CALL USPREP (1.0,B(1,3),XL(I),YL(I),YINTGL(I),UL(L),FST)          950J5098
      P3P2L = B(3,3)/B(3,2)                                             950J5099
      GO TO 50                                                          950J5100
C                                                                       950J5101
 90   IF (K-200) 100,100,888                                            950J5102
 100  IF (L-200) 110,110,888                                            950J5103
 110  IF (N) 116,115,116                                                950J5104
 115  N = 1                                                             950J5105
      SU(1) = 0.0                                                       950J5106
      SL(1) = 0.0                                                       950J5107
 116  CALL SURFCL (XU,YU,YINTGU,J,N,SU(N))                              950J5108
      CALL SURFCL (XL,YL,YINTGL,I,N,SL(N))                              950J5109
      IF (M(1)-1) 120,130,120                                           950J5110
 120  TERM1 = FSM**2                                                    950J5111
      TERM2 = 2.0*GAMMA*TERM1                                           950J5112
      TERM3 = GAMMA-1.0                                                 950J5113
      TERM4 =GAMMA+1.0                                                  950J5114
      P2P1U = (TERM2-TERM3)/TERM4                                       950J5115
      T2T1U = ((TERM2-TERM3)*(TERM3*TERM1+2.0))/(TERM4**2*TERM1)        950J5116
      U2U1U = (TERM3*TERM1+2.0)/(TERM4*TERM1)                           950J5117
      P2P1L = P2P1U                                                     950J5118
      T2T1L = T2T1U                                                     950J5119
```

```
      U2U1L = U2U1U                                                     950J5120
      GO TO 140                                                         950J5121
  130 REWIND 3                                                          950J5122
      REWIND 4                                                          950J5123
      TERM5 =FSM*SQRTF(FST)                                             950J5124
      READ TAPE 3,B                                                     950J5125
      P2P1U = B(3,1)/P1                                                 950J5126
      TERM1 = FSM**2*SINF(B(8,1))**2                                    950J5127
      TERM2 = GAMMA-1.0                                                 950J5128
      T2T1U = (2.0*GAMMA*TERM1-TERM2)*(TERM2*TERM1+2.)                  950J5129
     1 /((GAMMA+1.0)**2*TERM1)                                          950J5130
      U2U1U = (SQRTF(FST*T2T1U)/SINF(B(5,1)))/TERM5                     950J5131
      READ TAPE 4,B                                                     950J5132
      P2P1L = B(3,1)/P1                                                 950J5133
      TERM1 = FSM**2*SINF(B(8,1))**2                                    950J5134
      T2T1L = (2.0*GAMMA*TERM1-TERM2)*(TERM2*TERM1+2.0)                 950J5135
     1 /((GAMMA+1.0)**2*TERM1)                                          950J5136
      U2U1L = (SQRTF(FST*T2T1L)/SINF(B(5,1)))/TERM5                     950J5137
  140 CONTINUE                                                          950J5138
      UIU= UU(1)                                                        950J5139
      UIL= UL(1)                                                        950J5140
      WRITE TAPE 9,ARRAY,FSM,FST,FSP,UIU,T2T1U,P2P1U,U2U1U,K,R1,P3P2U   950J5141
      WRITE TAPE 9,(SU(JJ),UU(JJ),JJ=1,K)                               950J5142
      WRITE TAPE 9,ARRAY,FSM,FST,FSP,UIL,T2T1L,P2P1L,U2U1L,             950J5143
     1 L,R2,P3P2L                                                       950J5144
      WRITE TAPE 9,(SL(JJ),UL(JJ),JJ=1,L)                               950J5145
      REWIND 9                                                          950J5146
      CALL PAGE2 (0,ARRAY)                                              950J5147
      WRITE OUTPUT TAPE 6,410,T2T1U,P2P1U,U2U1U,P3P2U,                  950J5148
     1 (XU(JJ),YU(JJ),SU(JJ),UU(JJ),JJ=1,K)                             950J5149
      CALL PAGE2 (0,ARRAY)                                              950J5150
      WRITE OUTPUT TAPE 6,420,T2T1L,P2P1L,U2U1L,P3P2L,                  950J5151
     1 (XL(JJ),YL(JJ),SL(JJ),UL(JJ),JJ=1,L)                             950J5152
      CALL CHAIN (10,8)                                                 950J5153
  888 WRITE OUTPUT TAPE 6,400                                           950J5154
  999 CALL DUMP                                                         950J5155
  400 FORMAT (32H THERE ARE TOO MANY BODY POINTS.)                      950J5156
      END
```

```
      SUBROUTINE US PREP (T,XX1,X,Y,Y1,U,FST)                         950JEE00
*     LABEL
 950JEE                                                               950JEE
      DIMENSION XX1(10)                                               950JEE01
      IF (T-2.0) 10,20,10                                             950JEE02
 10   X = XX1(1)                                                      950JEE03
      Y = XX1(2)                                                      950JEE04
      CALL LOCATE (1,T,ITT,AC,BC,CC,DC,X)                             950JEE05
      Y1 = SQRTF(1.0+(X*(3.0*AC*X+2.0*BC)+CC)**2)                     950JEE06
 20   CONTINUE                                                        950JEE07
      ZM2 = (1.0/SINF(XX1(5)))**2                                     950JEE08
      U = 49.1*SQRTF(FST/(1.0+ZM2/5.0))                               950JEE09
      RETURN                                                          950JEE10
      END
```

```
      SUBROUTINE SURFCL (X,Y,YINTG,J,N,S)                            950JFF00
*     LABEL
 950JFF                                                              950JFF
C                                                                    950JFF01
C     SUBROUTINE TO CALCULATE SURFACE DISTANCE.                      950JFF02
C                                                                    950JFF03
      DIMENSION X(200),Y(200),S(200),YINTG(200),A(400)               950JFF04
C                                                                    950JFF05
      K = N                                                          950JFF06
      CALL CURFIT (X,YINTG,A,J,0,0,2,2)                              950JFF07
C                                                                    950JFF08
      DO 20 I=2,J                                                    950JFF09
      CALL SIGMA (A,X,YINTG,J,X(I-1),X(I),SUM)                       950JFF10
      S(K+1) = S(K)+SUM                                              950JFF11
      K = K+1                                                        950JFF12
 20   CONTINUE                                                       950JFF13
C                                                                    950JFF14
      RETURN                                                         950JFF15
      END
```

```
CMAIN.....2D-GENERAL
C  2-D (1) BOUNDARY-LAYER INPUT PROGRAM
C  THIS PROGRAM REQUIRES......

      DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)

      DIMENSION ARRAY(12),A(30),UX(10),SYM(10)
      DIMENSION XI2U(201),DUK(201),AU(400)
      DIMENSION XI2R(201),DRK(201),AR(400)
      DIMENSION XX(201),YY(201),UU(201)
      DIMENSION XACT(2),ACT(2),YACT(2)

      COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI
      COMMON T,T0,TK,TE,P,P0,PK,PE,Q,Q2,QK,QE,XK,XK2,ETA,REO
      COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,BETAE,STRK,STRKK,STRKE
      COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRK,VSTRE,F,FOSTR,G,TSTAR
      COMMON RSTR,RSTRK,RSTRE
      COMMON XN,SIG1,RSIG,TDNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY
      COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1
      COMMON NU,XI2U,DUK,AU
      COMMON NR,XI2R,DRK,AR
      COMMON XNU1,XNU2,XNU3,NBC,XNOP
      COMMON T00,P00,QS2,KASE,RNOSE,Q0PRM
      COMMON XACT,ACT,YACT,P3P2
      COMMON COM
C
 99   FORMAT (8HORE/FT =E15.7)
 100  FORMAT (33H0ERROR OCCURRED....JOB TERMINATED )
 108  FORMAT(10H0      I = ,I4,8H    J = ,I2,08H     V = ,E15.8,      8H
     1    T = ,E15.8,8H     G = ,E15.8/09H    A01 = E15.8,8H   A02 = E15
     2.8,8H   A03 = E15.8,8H   A04 = E15.8,8H   A05 = E15.8/09H    A06 =
     3 E15.8,8H   A07 = E15.8,8H   A08 = E15.8,8H   A09 = E15.8,8H   A10
     4 = E15.8/09H   A11 = E15.8,8H   A12 = E15.8,8H   A13 = E15.8,8H
     5 A14 = E15.8,8H   A15 = E15.8/09H   A16 = E15.8,8H   A17 = E15.8,
     68H   A18 = E15.8,8H   A19 = E15.8,8H   A20 = E15.8/09H   A21 = E1
     75.8,8H   A22 = E15.8,8H   A23 = E15.8,8H   A24 = E15.8,3X,
     8  5HA25 =E15.8/4X7HXI-SQ =E13.6,6X4HCP =E13.6,6X4HU* =E13.6,
     9  6X4HT* =E13.6,3X7HF(0)* =E13.6)
 198  FORMAT (1H05X6HDEL XIF8.5/6X7HDEL ETAF8.5/6X5HI-MAXI9/
     1  6X7HI-FREQNI7/6X5HI-MIDI9/6X5HJ-MAXI9/6X7HJ-FREQNI8)
```

```
200   FORMAT (1H038X5HSHOCK/30X3H(1)8X1H*6X3H(2)/41X1H*/22X2HT,         909JU205
     1  E15.7,3H   *E15.7/3X5HM(1)=F10.6,4X2HP  E15.7,3H   *E15.7/        909JU210
     2  22X2HU E15.7,3H   *E15.7/41X1H*/41X1H*)                          909JU215
C                                                                        909JU220
      REWIND 3                                                           909JU225
      REWIND 4                                                           909JU230
      READ TAPE 9,ARRAY,XMACH,TOPRM,POPRM,UI,T2T1,P2P1,U2U1,NU,RNOSE    909JU235
     1  ,P3P2                                                            909JU240
      CALL PAGE1 (ARRAY)                                                 909JU245
      EPSLN = 0.                                                         909JU250
      SOLAR = 0.                                                         909JU255
      DELKSI = .0005                                                     909JU260
      IMAX = 2000                                                        909JU265
      G = 0.                                                             909JU270
      IFRQ = 20                                                          909JU275
      IT = 11                                                            909JU280
      DELETA = 0                                                         909JU285
      IMID = 0                                                           909JU290
      JMAX = 0                                                           909JU295
      JFRQ = 0                                                           909JU300
      KASE = 0                                                           909JU305
      IF (NU-7) 70,70,10                                                 909JU310
10    IF (NU-201) 20,20,70                                               909JU315
20    CONTINUE                                                           909JU320
      CALL FLUID                                                         909JU325
      WRITE TAPE 3,XMACH,TOPRM,POPRM,QOPRM,TSTAR,PSTAR,XNOP,DELKSI,     909JU330
     1  DELETA,JMAX,ARRAY                                                909JU335
C                                                                        909JU340
      WRITE OUTPUT TAPE 6,200,T1,T2,XMACH,P1,P2,U1,U2                    909JU345
      WRITE OUTPUT TAPE 6,99,REO                                         909JU350
      IFRQD = 0                                                          909JU355
      JFRQD = 0                                                          909JU360
      I = 0                                                              909JU365
      J = 0                                                              909JU370
      L = 25                                                             909JU375
30    CALL UNV                                                           909JU380
31    IF (I) 70,32,33                                                    909JU385
32    CALL SUB2                                                          909JU390
      GO TO 35                                                           909JU395
C                                                                        909JU400
33    CALL SUB1                                                          909JU405
```

```
      CALL TPQ                                                          909JU410
      CALL FLOPRM                                                       909JU415
C                                                                       909JU420
 35   DO 350 IG=1,L                                                     909JU425
      AAA(J+1,IG) = A(IG)                                               909JU430
 350  CONTINUE                                                          909JU435
      DUM1(J+1) = V                                                     909JU440
      DUM2(J+1) = T                                                     909JU445
      DUM3(J+1) = P                                                     909JU450
      TW(J+1) = G                                                       909JU455
      IF (I) 150,140,150                                                909JU460
 140  WRITE TAPE 4,V,T                                                  909JU465
 150  CONTINUE                                                          909JU470
C                                                                       909JU475
 40   IF (I-IFRQD) 53,42,70                                             909JU480
 42   IF (KNT) 70,43,44                                                 909JU485
 43   CALL PAGE1 (ARRAY)                                                909JU490
      KNT=5                                                             909JU495
 44   CALL SUB4                                                         909JU500
      KNT=KNT-1                                                         909JU505
      WRITE OUTPUT TAPE 6,108,I,J,V,T,G, (A(II),II=1,L),                909JU510
     1(UX(N),N=1,5)                                                     909JU515
 55   IFRQD=IFRQD+IFRQ                                                  909JU520
 53   IF(I-IMAX-1)54,60,70                                              909JU525
 54   WRITE TAPE 3,I,DUM1,DUM2,DUM3,Q,TW,AAA                            909JU530
      I = I+1                                                           909JU535
      GO TO 31                                                          909JU540
C                                                                       909JU545
 60   CONTINUE                                                          909JU550
      REWIND 2                                                          909JU555
      END FILE 3                                                        909JU560
      END FILE 4                                                        909JU565
      REWIND 3                                                          909JU570
      REWIND 4                                                          909JU575
C                                                                       909JU580
      DO 1111 I=1,12000                                                 909JU585
      A(I) = 0.                                                         909JU590
 1111 CONTINUE                                                          909JU595
      CALL CHAIN (IT,8)                                                 909JU600
C                                                                       909JU605
 70   WRITE OUTPUT TAPE 6, 100                                          909JU610
```

```
      REWIND 2                                                  909JU615
      REWIND 3                                                  909JU620
      CALL DUMP                                                 909JU625
      END
```

```
CUNV......2D-GENERAL                                                    909JU005
      SUBROUTINE UNV                                                    909JU010
                                                                        909JU015
      DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)                 909JU020
                                                                        909JU025
      DIMENSION ARRAY(12),A(30),UX(10),SYM(10)                          909JU030
      DIMENSION XI2U(201),DUK(201),AU(400)                              909JU035
      DIMENSION XI2R(201),DRK(201),AR(400)                              909JU040
      DIMENSION XX(201),YY(201),UU(201)                                 909JU045
      DIMENSION XACT(2),ACT(2),YACT(2)                                  909JU050
                                                                        909JU055
      COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI                 909JU060
      COMMON T,TO,TK,TE,P,PO,PK,PE,Q,Q2,QK,QF,XK,XK2,ETA,REO             909JU065
      COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,BETAE,STRK,STRKK,STRKE          909JU070
      COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRK,VSTRE,F,FOSTR,G,TSTAR       909JU075
      COMMON RSTR,RSTRK,RSTRE                                           909JU080
      COMMON XN,SIG1,RSIG,TDNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY           909JU085
      COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1         909JU090
      COMMON NU,XI2U,DUK,AU                                             909JU095
      COMMON NR,XI2R,DRK,AR                                             909JU100
      COMMON XNU1,XNU2,XNU3,NBC,XNOP                                    909JU105
      COMMON T00,P00,QS2,KASE,RNOSE,QOPRM                               909JU110
      COMMON XACT,ACT,YACT,P3P2                                         909JU115
      COMMON COM                                                        909JU120
C                                                                       909JU125
      DIMENSION AA(400),XX1(201),UU1(201)                               909JU130
                                                                        909JU135
      FOSTR = 0.0                                                       909JU140
      NBC = 101                                                         909JU145
      READ TAPE 9,(XX(II),UU(II),II=1,NU)                               909JU150
      NU = NU                                                           909JU155
      EOP = XX(NU)                                                      909JU160
      DEL1 = 0.0                                                        909JU165
      DEL2 = 0.0                                                        909JU170
      XCHECK = XX(1)                                                    909JU175
      DO 1 II=2,NU                                                      909JU180
      K = II                                                            909JU185
      IF (XX(II)-XCHECK) 4,2,1                                          909JU190
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```
1     XCHECK = XX(II)                                                   909JU195
      GO TO 4                                                           909JU200
2     USTR = UU(K-1)                                                    909JU205
      XK2 = XX(K-1)/EOP                                                 909JU210
      XACT(1) = 2.0*XK2                                                 909JU215
      CALL TPQ                                                          909JU220
      DEL1 = 2650.*SQRTF(XN/(REO*P*USTR*EOP*XK2))*T                     909JU225
      USTR = UU(K)                                                      909JU230
      XK2 = XX(K)/EOP                                                   909JU235
      CALL TPQ                                                          909JU240
      DEL2 = 2650.*SQRTF(XN/(REO*P*USTR*EOP*XK2))*T                     909JU245
4     CONTINUE                                                          909JU250
      WRITE OUTPUT TAPE 6,600,EOP,SOLAR,EPSLN                           909JU255
      WRITE OUTPUT TAPE 6,602,DEL1,DEL2                                 909JU260
      WRITE OUTPUT TAPE 6,601,(XX(II),UU(II),II=1,NU)                   909JU265
      CALL SMOOTH (XX,UU,NU,12,UU1,0)                                   909JU270
      DO 3 II=1,NU                                                      909JU275
3     XX(II) = XX(II)/EOP                                               909JU280
      DEL1 = DEL1/EOP                                                   909JU285
      DEL2 = DEL2/EOP                                                   909JU290
      CALL SDATA (XX,UU,AU,NU,DEL1,DEL2,XX1,UU1,N2,XACT)                909JU295
      YACT(1) = 1.0                                                     909JU300
      YACT(2) = P3P2                                                    909JU305
      CALL CURFIT (XACT,YACT,ACT,2,0.,0.,1,1)                           909JU310
      WRITE OUTPUT TAPE 6,604,(II,XX1(II),UU1(II),II=1,N2)              909JU315
      NN = 2*N2-2                                                       909JU320
      DO 5 II=1,NN                                                      909JU325
5     AA(II) = AU(II)                                                   909JU330
      NU = NBC                                                          909JU335
      CALL TABINT (AA,XX1,UU1,N2,XI2U,NU,3)                             909JU340
      DO 20 II=1,NU                                                     909JU345
      CALL CURVE (AU,XX1,UU1,XI2U(II),UU(II),DUK(II),N2,1)              909JU350
20    CONTINUE                                                          909JU355
      CALL CURFIT (XI2U,UU,AA,NU,0.,0.,2,2)                             909JU360
      DO 30 II=1,NU                                                     909JU365
30    CALL CURVE (AA,XI2U,UU,XI2U(II),ANY,DUK(II),NU,2)                 909JU370
      BETA = 1.0                                                        909JU375
      BETAK = 0.0                                                       909JU380
      ALFAK = 2.0                                                       909JU385
      ALFAE = 0.0                                                       909JU390
      BETAE = 0.0                                                       909JU395
      STRKK = 1.0                                                       909JU400
      ETA = 1.0                                                         909JU405
```

```
      VSTR = 0.0                                                          909JU410
      USTRE = 0.0                                                         909JU415
      VSTRK = 0.0                                                         909JU420
      VSTRE = 0.0                                                         909JU425
      RSTRE = 0.                                                          909JU430
      EOC = 1.0                                                           909JU435
      CALL CURFIT (XI2U,DUK,AU,NU,0.,0.,2,2)                              909JU440
  500 FORMAT (7F10.5)                                                     909JU445
  501 FORMAT (I5/( 8F9.6))                                                909JU450
  600 FORMAT (8HOL(O)* =F10.6/13HOSOLAR HEAT =F12.6,2X                    909JU455
     1  10HBTU/HR-FT2/14HOEMMISSIVITY =F5.2)                              909JU460
  601 FORMAT (18H1INVISCID DATA..../19X1HS18X2HU*//(2E20.7))              909JU465
  602 FORMAT (8HODFL-1 =F10.6,5X,7HDEL-2 =F10.6)                          909JU470
  603 FORMAT (1HO17X3HXI218X2HU*17X3HDUK//(3E20.7))                       909JU475
  604 FORMAT (9H1FIX-DATA//24X1HS18X2HU*//(I5,2F20.7))                    909JU480
  609 FORMAT (1HO16X,3HXI218X2HU*17X,3HDU*/(3E20.7))                      909JU485
C                                                                         909JU490
      RETURN                                                              909JU495
      END
```

```
CTPQ......2D-GENERAL                                                    909JA000
      SUBROUTINE TPQ                                                    909JA005
C                                                                       909JA010
      DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)                 909JA015
                                                                        909JA020
      DIMENSION ARRAY(12),A(30),UX(10),SYM(10)                          909JA025
      DIMENSION XI2U(201),DUK(201),AU(400)                              909JA030
      DIMENSION XI2R(201),DRK(201),AR(400)                              909JA035
      DIMENSION XX(201),YY(201),UU(201)                                 909JA040
      DIMENSION XACT(2),ACT(2),YACT(2)                                  909JA045
                                                                        909JA050
      COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI                909JA055
      COMMON T,TO,TK,TE,P,PO,PK,PE,Q,Q2,QK,QE,XK,XK2,ETA,REO            909JA060
      COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,BETAE,STRK,STRKK,STRKE         909JA065
      COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRK,VSTRE,F,FOSTR,G,TSTAR      909JA070
      COMMON RSTR,RSTRK,RSTRE                                           909JA075
      COMMON XN,SIG1,RSIG,TDNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY          909JA080
      COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1        909JA085
      COMMON NU,XI2U,DUK,AU                                             909JA090
      COMMON NR,XI2R,DRK,AR                                             909JA095
      COMMON XNU1,XNU2,XNU3,NBC,XNOP                                    909JA100
      COMMON TOO,POO,QS2,KASE,RNOSE,QOPRM                               909JA105
      COMMON XACT,ACT,YACT,P3P2                                         909JA110
      COMMON COM                                                        909JA115
C                                                                       909JA120
      IF (XK2-XACT(1)) 8,8,5                                            909JA125
 5    CALL CURVE (ACT,XACT,YACT,XK2,CHANGE,ANY,2,1)                     909JA130
      POO = PO*P2P1*CHANGE                                              909JA135
      ANY = CHANGE*(6.+CHANGE)/(1.+6.*CHANGE)                           909JA140
      TOO = TO*T2T1*ANY                                                 909JA145
 8    CONTINUE                                                          909JA150
C                                                                       909JA155
      Q2 = USTR**2+VSTR**2                                              909JA160
      Q = SQRTF(Q2)                                                     909JA165
      QK = (USTR*USTRK+VSTR*VSTRK)/Q                                    909JA170
      TK = -Q*QK/ SIG1                                                  909JA175
C                                                                       909JA180
      IF (XMACH-1.0) 2,1,2                                              909JA185
 1    T = 1.0                                                           909JA190
      P = 1.0                                                           909JA195
```

```
      XN = 1.0
      GO TO 3                                                            909JA200
C                                                                        909JA205
    2 T = T00+(QS2-Q2)/(2.*SIG1)                                         909JA210
      P = P00*(T/T00)**SIG1                                              909JA215
      XN = XNU1 /( SQRTF(T)*(1.0+XNU2/ T + XNU3/ T**2 ))                 909JA220
      TDNNDT = -.5+(XNU2/T+2.0*XNU3/T**2)/(1.0+XNU2/T+XNU3/T**2)         909JA225
C                                                                        909JA230
    3 ANY = SIG1*(P2P1/T2T1)*(T/T00)**(SIG1-1.0)                         909JA235
      PK = ANY*TK                                                        909JA240
      RETURN                                                             909JA245
      END                                                                909JA250
```

```
CFLUID....2D-GENERAL                                                    909JB000
      SUBROUTINE FLUID                                                  909JB005
C                                                                       909JB010
C                                                                       909JB015
      DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)                 909JB020
                                                                        909JB025
      DIMENSION ARRAY(12),A(30),UX(10),SYM(10)                          909JB030
      DIMENSION XI2U(201),DUK(201),AU(400)                              909JB035
      DIMENSION XI2R(201),DRK(201),AR(400)                              909JB040
      DIMENSION XX(201),YY(201),UU(201)                                 909JB045
      DIMENSION XACT(2),ACT(2),YACT(2)                                  909JB050
                                                                        909JB055
      COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI                909JB060
      COMMON T,TO,TK,TE,P,PO,PK,PE,Q,Q2,QK,QE,XK,XK2,ETA,REO            909JB065
      COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,BETAE,STRK,STRKK,STRKE         909JB070
      COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRK,VSTRE,F,FOSTR,G,TSTAR      909JB075
      COMMON RSTR,RSTRK,RSTRE                                           909JB080
      COMMON XN,SIG1,RSIG,TDNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY          909JB085
      COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1        909JB090
      COMMON NU,XI2U,DUK,AU                                             909JB095
      COMMON NR,XI2R,DRK,AR                                             909JB100
      COMMON XNU1,XNU2,XNU3,NBC,XNOP                                    909JB105
      COMMON TOO,POO,QS2,KASE,RNOSE,QOPRM                               909JB110
      COMMON XACT,ACT,YACT,P3P2                                         909JB115
      COMMON COM                                                        909JB120
C                                                                       909JB125
      SIG1 = 3.5                                                        909JB130
      IF (XMACH-1.0) 20,1,30                                            909JB135
 1    TO = 1.0                                                          909JB140
      PO = 1.0                                                          909JB145
      QS2 = 1.0                                                         909JB150
      T2T1 = 1.0                                                        909JB155
      P2P1 = 1.0                                                        909JB160
      GO TO 3                                                           909JB165
C                                                                       909JB170
 20   T2T1 = 1.0                                                        909JB175
      P2P1 = 1.0                                                        909JB180
      QS2 = 1.0                                                         909JB185
      GO TO 2                                                           909JB190
C                                                                       909JB195
```

```
 30   QS2 = U2U1*U2U1                                                      909JB200
C                                                                          909JB205
 2    SIG2P = 0.0                                                          909JB210
      SIG3P = 0.0                                                          909JB215
      XNU1P = 1.46E-5                                                      909JB220
      XNU2P = 112.0                                                        909JB225
      XNU3P = 0.0                                                          909JB230
      RSIG = (1.0+SIG3P*TOPRM**4)/(SIG1*(1.0+SIG2P*TOPRM**4))              909JB235
      TSTAR = XMACH**2*TOPRM/(1.0-RSIG)                                    909JB240
      XNOP= XNU1P*SQRTF(TOPRM)/(1.0+ XNU2P/TOPRM+XNU3P/TOPRM**2)           909JB245
      XNU1 = XNU1P*SQRTF(TSTAR)/XNOP                                       909JB250
      XNU2 = XNU2P/TSTAR                                                   909JB255
      XNU3 = XNU3P/TSTAR**2                                                909JB260
      TO = (SIG1-1.0)/(SIG1*XMACH**2)                                      909JB265
      PO = TO                                                              909JB270
C                                                                          909JB275
 3    COM = 6.0875555E-10*TSTAR**3/XNOP*EPSLN                              909JB280
      TOO = TO*T2T1                                                        909JB285
      POO = PO*P2P1                                                        909JB290
      QOPRM = 49.1*SQRTF(TOPRM*1.8)*XMACH                                  909JB295
      REO = 3.2794397E2*POPRM*QOPRM/(XNOP*TOPRM)                           909JB300
      T1 = TOPRM                                                           909JB305
      P1 =   POPRM                                                         909JB310
      U1 = QOPRM                                                           909JB315
      T2 = T2T1*T1                                                         909JB320
      P2 = P2P1*P1                                                         909JB325
      U2 = U2U1*U1                                                         909JB330
      RETURN                                                               909JB335
      END
```

```
CFLOPRM...2D-GENERAL
      SUBROUTINE FLOPRM
C
      DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)

      DIMENSION ARRAY(12),A(30),UX(10),SYM(10)
      DIMENSION XI2U(201),DUK(201),AU(400)
      DIMENSION XI2R(201),DRK(201),AR(400)
      DIMENSION XX(201),YY(201),UU(201)
      DIMENSION XACT(2),ACT(2),YACT(2)

      COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI
      COMMON T,TO,TK,TE,P,PO,PK,PE,Q,Q2,QK,QE,XK,XK2,ETA,REO
      COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,BETAE,STRK,STRKK,STRKE
      COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRK,VSTRE,F,FOSTR,G,TSTAR
      COMMON RSTR,RSTRK,RSTRE
      COMMON XN,SIG1,RSIG,TDNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY
      COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1
      COMMON NU,XI2U,DUK,AU
      COMMON NR,XI2R,DRK,AR
      COMMON XNU1,XNU2,XNU3,NBC,XNOP
      COMMON T00,P00,QS2,KASE,RNOSE,Q0PRM
      COMMON XACT,ACT,YACT,P3P2
      COMMON COM
C
C
  997 U = USTR/Q
  999 V = VSTR/Q
C
 1001 A(1)=STRK
C
 1005 A(3)=U
 1007 A(4)=ALFA/(STRK*XN)
 1009 A(5)=STRK*USTRK/(2.0*USTR)
 1013 A(7)=STRK*BETAK/(2.0*BETA*U**2)
 1015 A(8)=STRK*PK/(2.0*P*USTR**2)
C
 1019 A(10)=STRK*(QK/Q+BETAK/BETA)
C
 1025 A(13)=STRK*PK/P
```

```
1029 A(15)=4.0*USTR**2*A(4)                                  909JC200
1031 A(16)=Q2*A(4)                                           909JC205
1033 A(17)=STRKK+STRK*BETAK/BETA-3.0*A(5)+0.5*A(13)*         909JC210
    .1(1.0 + TDNNDT/SIG1)                                    909JC215
1037 A(19)=A(8)/A(4)                                         909JC220
     A(20) = 0.C                                             909JC225
1044 ANY = STRK*SQRTF((EOP*XN)/(REO*P*USTR))                 909JC230
C                                                            909JC235
1045 A(23) = COM*ANY                                         909JC240
     A(24) = P                                               909JC245
1046 A(25) = ANY*T                                           909JC250
     RETURN                                                  909JC255
     END
```

```
CSUB-1....2D-GENERAL
      SUBROUTINE SUB1
C
      DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)

      DIMENSION ARRAY(12),A(30),UX(10),SYM(10)
      DIMENSION XI2U(201),DUK(201),AU(400)
      DIMENSION XI2R(201),DRK(201),AR(400)
      DIMENSION XX(201),YY(201),UU(201)
      DIMENSION XACT(2),ACT(2),YACT(2)

      COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI
      COMMON T,TO,TK,TE,P,PO,PK,PE,Q,Q2,QK,QE,XK,XK2,ETA,REO
      COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,BETAE,STRK,STRKK,STRKE
      COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRK,VSTRE,F,FOSTR,G,TSTAR
      COMMON RSTR,RSTRK,RSTRE
      COMMON XN,SIG1,RSIG,TDNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY
      COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1
      COMMON NU,XI2U,DUK,AU
      COMMON NR,XI2R,DRK,AR
      COMMON XNU1,XNU2,XNU3,NBC,XNOP
      COMMON TOO,POO,QS2,KASE,RNOSE,QOPRM
      COMMON XACT,ACT,YACT,P3P2
      COMMON COM
C
C
      FLOATI = I
      XK = FLOATI*DELKSI
      XK2 = XK**2
      STRK = XK
C
      ALFA = 2.*XK
      XKD = (XK-DELKSI)**2
      IF (KASE) 20,10,20
 10   RSTRK = 0.0
    . GO TO 25
 20   CONTINUE
      CALL CURVE (AR,XI2R,DRK,XK2,RSTRK2,ANY,NBC,1)
      RSTRK = 2.*XK*RSTRK2
 25   CONTINUE
```

```
      CALL CURVE (AU,XI2U,DUK,XK2,USTRK2,ANY,NBC,1)                     909JD200
      USTRK = 2.*XK*USTRK2                                              909JD205
      IF (I) 1,2,1                                                      909JD210
2     CONTINUE                                                          909JD215
      RSTR = 0.                                                         909JD220
      USTR = UI                                                         909JD225
      GO TO 3                                                           909JD230
1     CONTINUE                                                          909JD235
      IF (KASE) 40,30,40                                                909JD240
30    RSTR = 0.0                                                        909JD245
      GO TO 45                                                          909JD250
40    CONTINUE                                                          909JD255
      CALL SIGMA (AR,XI2R,DRK,NBC,XKD,XK2,SUM)                          909JD260
      RSTR = RSTR+SUM                                                   909JD265
      BETA = 6.2831853*RSTR                                             909JD270
      BETAK = 6.2831853*RSTRK                                           909JD275
45    CONTINUE                                                          909JD280
      CALL SIGMA (AU,XI2U,DUK,NBC,XKD,XK2,SUM)                          909JD285
      USTR = USTR+SUM                                                   909JD290
3     CONTINUE                                                          909JD295
      RETURN                                                            909JD300
      END (0) 909J6000                                                  909JD305
      END
```

```
CSUB-4,,,,,2D-GENERAL
      SUBROUTINE SUB4
C
      DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)

      DIMENSION ARRAY(12),A(30),UX(10),SYM(10)
      DIMENSION XI2U(201),DUK(201),AU(400)
      DIMENSION XI2R(201),DRK(201),AR(400)
      DIMENSION XX(201),YY(201),UU(201)
      DIMENSION XACT(2),ACT(2),YACT(2)

      COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI
      COMMON T,TO,TK,TE,P,PO,PK,PE,Q,Q2,QK,QE,XK,XK2,ETA,REO
      COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,BETAE,STRK,STRKK,STRKE
      COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRK,VSTRE,F,FOSTR,G,TSTAR
      COMMON RSTR,RSTRK,RSTRE
      COMMON XN,SIG1,RSIG,TDNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY
      COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1
      COMMON NU,XI2U,DUK,AU
      COMMON NR,XI2R,DRK,AR
      COMMON XNU1,XNU2,XNU3,NBC,XNOP
      COMMON T00,P00,QS2,KASE,RNOSE,Q0PRM
      COMMON XACT,ACT,YACT,P3P2
      COMMON COM
C
C
      UX(1) = XK2
      UX(2) = 2.0*(P-PO)
      UX(3) = USTR
      UX(4) = TSTAR*T
      UX(5) = FOSTR
      UX(6) = RSTR
      UX(7) = RSTRK
      UX(8) = USTRK
      UX(9) = VSTR
      UX(10) = VSTRE
      RETURN
      END (0) 909J9000
      END
```

```
CSDATA                                                               909JH000
      SUBROUTINE SDATA (X,Y,A,N,DEL1,DEL2,XT,YT,N2,XACT)             909JH005
C                                                                    909JH010
      DIMENSION X(1),Y(1),A(1),A1(400),XT(1),YT(1)                   909JH015
      DIMENSION XACT(2)                                              909JH020
C                                                                    909JH025
      IT1 = 1                                                        909JH030
      IT2 = 1                                                        909JH035
      XCHECK = X(1)                                                  909JH040
C                                                                    909JH045
      DO 10 I=2,N                                                    909JH050
      K = I                                                          909JH055
      IF (X(I)-XCHECK) 90,15,10                                      909JH060
 10   XCHECK = X(I)                                                  909JH065
      CALL CURFIT (X,Y,A,N,0.,0.,2,2)                                909JH070
      N2 = N                                                         909JH075
      DO 11 I=1,N                                                    909JH080
      XT(I) = X(I)                                                   909JH085
 11   YT(I) = Y(I)                                                   909JH090
      XACT(1) = X(N)*2.0                                             909JH095
      XACT(2) = X(N)*3.0                                             909JH100
 12   WRITE OUTPUT TAPE 6,600                                        909JH105
      GO TO 99                                                       909JH110
 15   KK = K                                                         909JH115
      K = K-1                                                        909JH120
      N1 = 1                                                         909JH125
      WRITE OUTPUT TAPE 6,601,X(K),Y(K),Y(KK)                        909JH130
      IF (K-N) 16,12,16                                              909JH135
 16   CALL CURFIT (X,Y,A1,K,0.,0.,2,2)                               909JH140
      XP1 = X(K)-DEL1                                                909JH145
      IF (XP1-X(1)) 20,20,25                                         909JH150
 20   XP1 = X(1)                                                     909JH155
      IT1 = 2                                                        909JH160
 25   CALL CURVE (A1,X,Y,XP1,YP1,DYP1,K,3)                           909JH165
      XACT(1) = XP1                                                  909JH170
C                                                                    909JH175
      NT = N-K                                                       909JH180
      XP2 = X(K)+DEL2                                                909JH185
      XACT(2) = XP2                                                  909JH190
      CALL CURFIT (X(KK),Y(KK),A1,NT,0.,0.,2,2)                      909JH195
```

```
      CALL CURVE (A1,X(KK),Y(KK),XP2,YP2,DYP2,NT,3)
C
      IF (XP2-X(N)) 35,30,30
 30   IT2 = 2
 35   GO TO (40,50),IT1
C
 40   DO 45 I=1,N
      N1 = I
      IF (X(I)-XP1)42,50,50
C
 42   XT(I) = X(I)
      YT(I) = Y(I)
 45   CONTINUE
C
 50   XT(N1) = XP1
      YT(N1) = YP1
      GO TO (51,52),IT1
 51   CALL CURFIT (XT,YT,A,N1,0.,DYP1,2,1)
 52   IA = 2*N1-1
C
      XT(N1+1) = XP2
      YT(N1+1) = YP2
C
      CALL CURFIT (XT(N1),YT(N1),A(IA),2,DYP1,DYP2,1,1)
C
      N1 = N1+1
      N2 = N1
      GO TO (55,99),IT2
C
 55   IC = 1
C
      DO 60 I=KK,N
      IF (X(I)-XP2) 60,60,56
 56   IC = IC+1
      N2 = N2+1
      XT(N2) = X(I)
      YT(N2) = Y(I)
 60   CONTINUE
      IA = 2*N1-1
      CALL CURFIT (XT(N1),YT(N1),A(IA),IC,DYP2,0.,1,2)
C
```

```
90   CONTINUE                                                                909JH405
99   RETURN                                                                  909JH410
600  FORMAT (38HONO SHOCK-B.L. INTERACTION POINT GIVEN )                     909JH415
601  FORMAT (41HOSHOCK-B.L. INTERACTION POINT GIVEN AT...                    909JH420
    1  /5HOX- =E15.7,6X4HU* =E15.7/30XE15.7 )                                909JH425
     END(0)921K0000                                                          909JH430
```

```
C  3-D BOUNDARY LAYER INTEGRATION PROGRAM                                 910J0010
C     THIS PROGRAM REQUIRES......                                         910J0015
C     AIR,BBB,SIDE,SUBA,VSUBC,TSUBC,SUMARY,BCDT                           910J0020
C     JLOOP1,JLOOP2,CCDIS,TDSEQ,SIGMAI,SUMI,INJ                           910J0025
C                                                                         910J0030
      DIMENSION IND(12),ARRAY(12)                                         910J0035
      DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)               910J0040
      DIMENSION A(1,30),B(17),ZETA(22),UP(22)                             910J0045
      DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)        910J0050
      DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)              910J0055
      DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)                910J0060
      DIMENSION CNU(1,22),CK(1,22)                                        910J0065
      DIMENSION VB(1,22),TB(1,22),SB(1,22)                                910J0070
      DIMENSION ZZZ(2),VV(2),AA(4)                                        910J0075
      DIMENSION VCC(22),TCC(22),SCC(22)                                   910J0076
      COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P           910J0080
      COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND        910J0085
      COMMON BO,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY            910J0090
      COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5                        910J0095
      COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KL1,INDEX,J0                      910J0100
      COMMON VCC,TCC,QPR,TSTAR,PSTAR,Q0,CNURAT,CKRAT,SCC,XNOPR            910J0101
C                                                                         910J0105
      EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)                    910J0110
C                                                                         910J0115
 100  FORMAT (50H0*MOUNT INPUT TAPE (SPECIFIED ON JOB REQUEST FORM)  /    910J0120
     1  19H  ON TAPE UNIT *B3* /17H *AND PRESS START ///1H0)              910J0125
 101  FORMAT (34H0*DISMOUNT TAPE ON TAPE UNIT  B3--/10H  AND SAVE//       910J0130
     1  30H *PRESS START TO TERMINATE JOB ///1H0)                         910J0135
 200  FORMAT (13I5,1X,A6)                                                 910J0140
 201  FORMAT (4E15.8)                                                     910J0145
 300  FORMAT (1H1,13A6)                                                   910J0150
 301  FORMAT (1H0,11X,9HMACH NO =F8.3//3X18HFREE-STREAM TEMP =F8.3//      910J0155
     1 15X6HPRES =F8.3//16X5HVEL =F8.3//                                  910J0160
     2 11X10HDELTA XI =F10.5//10X11HDELTA ETA =F10.5//                    910J0165
     3 14X7HI MAX =I5//14X7HJ MAX =I5)                                    910J0170
 302  FORMAT (21H PROGRAM OPTIONS...../38X12HSTARTING I -I5/              910J0175
     1  14X36HNO. ITERATIONS ON STARTING PROFILE -,I5/                    910J0180
     2  16X34HPRINT FREQUENCY DURING ITERATION -,I5/                      910J0185
     3  14X36HPRINT FREQUENCY DURING INTEGRATION -,I5/                    910J0190
     4  31X19HPUNCH-OUT CONTROL -,I5/3X23HTYPE DATA FOR STARTING          910J0195
```

```
     5  24H(=1 COMP.. =0 INCOMP.) -I5/26X24HINTERMEDIATE PRINT-OUT -,    910J0200
     6  I5/11X39HNO. ITERATIONS BEFORE CHANGING B-ZERO -,I5/              910J0205
     7  16X34HJ INTERVAL (J = 0 2-DIMENSIONAL) -I5)                       910J0210
C                                                                         910J0215
      DO 707 J=1,12
  707 IND(J) = 0
      IO = 2000
      IND(2) = 600
      IND(3) = 50
      IND(4) = 20
      REWIND 3                                                            910J0240
      REWIND 4                                                            910J0245
C                                                                         910J0250
C  READ AND WRITE GENERAL INPUT DATA                                      910J0255
C                                                                         910J0260
      IF (SENSE LIGHT 2)700,700                                           910J0265
  700 SENSE LIGHT 1                                                       910J0270
      READ TAPE 3,XMACH,TO,PO,QO,TSTAR,PSTAR,XNOPR,DA,DB,JO,(ARRAY(I),I=910J0280
     11,12)                                                               910J
      IND(2) = IND(2)+(IND(2)-2*(IND(2)/2))                               910J0285
      IO = IO-(IO-2*(IO/2))                                               910J0290
      FLJO=JO                                                             910J0295
      DB=1.0/FLJO                                                         910J0300
C                                                                         910J0330
CONSTANTS OF SUTHERLAND VISCOSITY LAW                                     910J0335
C                                                                         910J0340
      X1=SQRTF(1.4)*XMACH*(1.0+110.3/TO)                                  910J0345
      X2=110.3/(1.4*XMACH**2*TO)                                          910J0350
      KO = 20                                                             910J0355
      ANY =KO                                                             910J0360
      DC = 1./ANY                                                         910J0365
      DC2 = 2.*DC                                                         910J0370
      TABLE1(1) = -DC                                                     910J0375
      TABLE2(1) = 0.0                                                     910J0380
      DO 777 N=2,11                                                       910J0385
      TABLE1(N) = TABLE1(N-1)+DC2                                         910J0390
      TABLE2(N) = TABLE2(N-1)+DC2                                         910J0395
  777 CONTINUE                                                            910J0400
      TABLE1(1) = 0.0                                                     910J0405
      TABLE1(12) = TABLE1(11)+DC2                                         910J0410
C                                                                         910J0415
```

```
      IND(5) = IND(5)+1                                                 910J0420
      IND(6) = IND(6)+1                                                 910J0425
      J0=J0+1                                                           910J0430
      JMAX=J0                                                           910J0435
 7772 KMAX = K0+2                                                       910J0440
      KMID = KMAX-1                                                     910J0445
      KLO = K0/2                                                        910J0450
      NON = 1                                                           910J0455
      KL1 = KLO+1                                                       910J0460
C                                                                       910J0665
CALCULATE ZETA ARRAY                                                    910J0670
C                                                                       910J0675
      DO 4 K=1,KMAX                                                     910J0490
      ANY = K-1                                                         910J0495
      ZETA(K) = ANY*DC                                                  910J0500
 4    UP(K) = 1.-ZETA(K)**2                                             910J0505
C                                                                       910J0465
C  READ INITIAL PROFILES                                                910J0470
C                                                                       910J0475
      IF (IND(8)) 10,10,20                                              910J0480
 10   CONTINUE                                                          910J0485
      CALL SHEAR (S)
      DO 50 J=1,JMAX                                                    910J0515
      READ TAPE 4,V(J,1),T(J,1)                                         910J0520
      ZZZ(1)=0.0                                                        910J0525
      ZZZ(2)=1.0                                                        910J0530
      VV(1)=V(J,1)                                                      910J0535
      VV(2)=0.0                                                         910J0540
      CALL CURFIT (ZZZ,VV,AA,2,0.0,0.0,1,2)                             910J0545
      S(J,1)=S(1,1)                                                     910J0550
      IF (TW(J)) 30,40,30                                               910J0555
 40   WALL=T(J,1)                                                       910J0560
      GO TO 31                                                          910J0565
 30   WALL=TW(J)                                                        910J0570
 31   DO 80 K=2,KMID                                                    910J0575
      CALL CURVE (AA,ZZZ,VV,ZETA(K),V(J,K),DUM,2,1)                     910J0580
      T(J,K)=T(J,K-1)+(WALL-T(J,1))*DC                                  910J0585
 80   S(J,K)=S(1,K)                                                     910J0590
      V(J,KMAX-1) = 0.                                                  910J0595
 50   CONTINUE                                                          910J0600
      GO TO 2                                                           910J0605
```

```
 20    DO 1 J=1,JMAX                                           910J0610
       READ INPUT TAPE 5,201,(V(J,K),K=1,KMAX)                 910J0615
       READ INPUT TAPE 5,201,(T(J,K),K=1,KMAX)                 910J0620
       READ INPUT TAPE 5,201,(S(J,K),K=1,KMAX)                 910J0625
 1     CONTINUE                                                910J0630
C                                                              910J0635
CHECK  FOR I-START                                             910J0640
C                                                              910J0645
 2     READ TAPE 3,IG                                          910J0650
       IF (IG-IND(1)) 2,3,2                                    910J0655
 3     BACKSPACE 3                                             910J0660
       KM = KMAX-1                                             910J0685
C                                                              910J0690
       DO 5 J=1,JMAX                                           910J0695
       VA(J,KM) = 0.0                                          910J0700
       TA(J,KM) = 0.                                           910J0705
       SA(J,KM) = 0.                                           910J0710
       VB = 0.0                                                910J0715
       V(J,KM) = 0.0                                           910J0720
       S(J,1) = 0.0                                            910J0725
 5     CONTINUE                                                910J0730
C                                                              910J0735
       DA = 2.*DA                                              910J0740
       DB = 2.*DB                                              910J0745
       DC = 2.*DC                                              910J0750
C                                                              910J0755
CHECK  ON ITERATION REQUIREMENT                                910J0760
C                                                              910J0765
       IF (IND(1)) 7,6,7                                       910J0770
 6     BO = 2.0                                                910J0775
       IMAX = IND(2)+1                                         910J0780
       IPRINT = IND(3)                                         910J0785
       NO = 0                                                  910J0790
       L = 1                                                   910J0795
       GO TO 9                                                 910J0800
C                                                              910J0805
 7     NO = 1                                                  910J0810
 8     BO = 1.0                                                910J0815
       IMAX = IO+1                                             910J0820
       IPRINT = IND(4)                                         910J0825
       IND(10) = 0                                             910J0830
```

```
      L = 2                                                     910J0835
 9    IT=1                                                      910J0840
C                                                               910J0845
 999  DO 5000 I=L,IMAX                                          910J0850
      I = I                                                     910J0855
      IF (SENSE LIGHT 1) 109,108                                910J0860
 108  IF (NO-1) 120,110,120                                     910J0865
 109  READ TAPE 3,IG,DUM3,DUM4,P,QPR,TW,A                       910J0870
      GO TO 120                                                 910J0875
 110  READ TAPE 3,IG,DUM1,DUM2,P,QPR,TW,A                       910J0880
C                                                               910J0885
 120  QPR = QPR*Q0                                              910J0890
      CALL JLOOP1                                               910J0891
      CALL SIDE                                                 910J0895
      CALL JLOOP2                                               910J0900
C                                                               910J0905
      IF (NO) 660,620,660                                       950J0901
 620  DO 650 J=1,JMAX                                           950J0902
      DO 650 K=1,KMID                                           950J0903
      IF (ABSF(TA(J,K))-.000001) 650,650,660
 650  CONTINUE                                                  950J0907
      GO TO 69
 660  CONTINUE                                                  950J0908
C                                                               950J0909
      IF (IT-1) 52,51,52                                        910J0910
 51   IT = IPRINT                                               910J0915
      IF (I-2) 96,53,96                                         910J0920
 53   IF (NO) 96,96,52                                          910J0922
 52   IT = IT-1                                                 910J0925
 96   DO 5000 J=1,JMAX                                          910J0930
      IF (S(J,KMID)) 600,600,5000                               910J0935
 600  CALL SUMARY                                               910J0940
      WRITE OUTPUT TAPE 6,610,I,J                               910J0942
 610  FORMAT (30H SEPARATION HAS OCCURED AT I =I5,              910J0945
     1 4HJ = I5,1H.)                                            910J0950
      GO TO 75                                                  910J0955
 5000 CONTINUE                                                  910J0000
C                                                               910J0005
 69   IF (IND(7)-3) 70,71,71                                    910J0010
 70   IF (IND(7)-NO-1) 73,71,73                                 910J0015
C                                                               910J0020
```

```
 71   DO 72 J=1,JMAX                                        910J0025
      JJ = J*10                                             910J0030
      ANY = BCDT(JJ)                                        910J0035
C                                                           910J0040
      CALL DECKID (5H V   1,ANY)                            910J0045
      WRITE OUTPUT TAPE 7,201,(V(J,K),K=1,KMAX)             910J0050
C                                                           910J0055
      CALL DECKID (5H T   2,ANY)                            910J0060
      WRITE OUTPUT TAPE 7,201,(T(J,K),K=1,KMAX)             910J0065
C                                                           910J0070
      CALL DECKID (5HPHI  3,ANY)                            910J0075
      WRITE OUTPUT TAPE 7,201,(S(J,K),K=1,KMAX)             910J0080
 72   CONTINUE                                              910J0085
C                                                           910J0090
C                                                           910J0095
 73   NO = NO+1                                             910J0100
      NON = NON+1                                           910J0105
      GO TO (8,75), NO                                      910J0110
C                                                           910J0115
 75   REWIND 4                                              910J0120
      CALL CHAIN (5,8)                                      910J0135
      END(0) 910J0000                                       910J0140
```

```
      SUBROUTINE SUMARY                                                 910J9000
C                                                                       910J9005
      DIMENSION IND(12),ARRAY(12)                                       910J9010
      DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)             910J9015
      DIMENSION A(1,30),B(17),ZETA(22),UP(22)                           910J9020
      DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)      910J9025
      DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)            910J9030
      DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)              910J9035
      DIMENSION CNU(1,22),CK(1,22)                                      910J9040
      DIMENSION VB(1,22),TB(1,22),SB(1,22)                              910J9045
      DIMENSION AB(50),AB1(50),AB2(50),AB3(50)                          910J9050
      DIMENSION DELU(22),DELV(22),DELUU(22),DELUV(22),DELVV(22)         910J9055
      DIMENSION TT(22),ES(22),EN(22),Z(22),GAMMA(22),ZDUM(22)           910J9060
      DIMENSION V1(22),T1(22),S1(22)                                    910J9065
      DIMENSION VCC(22),TCC(22),SCC(22)                                 910J0076
      COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P         910J9070
      COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND      910J9075
      COMMON BO,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY          910J9080
      COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5                      910J9085
      COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KL1,INDEX,J0                    910J9090
      COMMON VCC,TCC,QPR,TSTAR,PSTAR,QO,CNURAT,CKRAT,SCC,XNOPR          910J0101
      COMMON DELU,DELV,DELUV,DELVU,DELUU,TT,LL,LL1                      910J9095
      COMMON AB,AB1,AB2,AB3,ES,EN,Z,GAMMA                               910J9100
C                                                                       910J9105
      EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)                  910J9110
C                                                                       910J9115
  100 FORMAT (//21X1HV19X,1HT17X3HPHI// (I10,3E20.7))                   910J9120
  101 FORMAT (4H0I =I5,5H, J =I4//6H  ZETA8X1HS14X1HN12X4HT/T111X2HZR   910J9125
     1 //(1XF6.3,4E15.6))                                               910J9130
  102 FORMAT (4H0V =E16.7,6H   T =E16.7,6H   P =E16.7,6H   G =E16.7//   910J9135
     1 (5(5X1HAI2,1H=E15.7)))                                           910J9140
  103 FORMAT (5H0 I =I5,5X3HJ =I3//)                                    910J9145
  104 FORMAT (I10,1P3E20.7)                                             910J9150
  110 FORMAT (I3,0PF12.7,1PE13.6,1PE15.7,1PE13.5,0PF11.7,0PF12.8,       910J9155
     1  1PE13.6,1P3E13.5)                                               910J9160
  115 FORMAT (3H  K,6X1HV,10X1HT,11X3HPHI,13X2HMU,9X1HS,                910J9165
     1  10X1HN,14X1HZ,10X5HDT/DZ,9X5HDS/DZ,9X5HDN/DZ)                   910J9170
  120 FORMAT (8H0DELS  =1PE12.5,4X7HDELN  =1PE12.5,4X7HDELSS =          910J9175
     1  1P12.5,4X7HDELNS =1PE12.5,4X7HDELNN =1PE12.5/8H DELU  =         910J9180
     2  1P12.5,4X7HDELV  =1PE12.5,4X7HDELUU =1PE12.5,4X7HDELUV =        910J9185
```

```
     3  1PE12.5,4X,7HDELVV =1PE12.5//)                                   910J9190
C                                                                        910J9195
      J=J                                                                910J9200
      CALL PAGE1 (ARRAY)                                                 910J9205
      IACT=I-1                                                           910J9210
      JACT=J-1                                                           910J9215
      WRITE OUTPUT TAPE 6,103,IACT,JACT                                  910J9220
 1    IF (NO) 5,3,5                                                      910J9225
 3    WRITE OUTPUT TAPE 6,100,(K,V(J,K),T(J,K),S(J,K),K=1,KMAX)          910J9230
      GO TO 15                                                           910J9235
C                                                                        910J9240
 5    N=(I+J)-2*((I+4)/2)                                                910J9245
      NN=2+N                                                             910J9250
      KO=KMAX-2                                                          910J9255
      DO 25 K=1,KMAX                                                     910J9260
      V1(K)=V(J,K)                                                       910J9265
      T1(K)=T(J,K)                                                       910J9270
 25   S1(K)=S(J,K)                                                       910J9275
      DO 26 K=NN,KO,2                                                    910J9280
      V1(K)=V1(K)+0.5*VA(J,K)                                            910J9285
      T1(K)=T1(K)+0.5*TA(J,K)                                            910J9290
 26   S1(K)=S1(K)+0.5*SA(J,K)                                            910J9295
      DO 27 LL=1,KMAX                                                    910J9300
      TT(LL)=T1(LL)/T1(1)                                                910J9305
      GAMMA(LL)=(CNU(J,LL)/S1(LL))*TT(LL)*A(J,25)                        910J9310
      DELU(LL)=GAMMA(LL)*(TT(LL)-UP(LL))                                 910J9315
      DELV(LL)=GAMMA(LL)*(TT(LL)*V1(1)-V1(LL))                           910J9320
      CC=GAMMA(LL)*(1.0-UP(LL))                                          910J9325
      DELUU(LL)=CC*UP(LL)                                                910J9330
      DELUV(LL)=CC*V1(LL)                                                910J9335
      DELVV(LL)=GAMMA(LL)*(V1(1)-V1(LL))*V1(LL)                          910J9340
      ES(LL)=A(J,3)**2*UP(LL)+V1(1)*V1(LL)                               910J9345
 27   EN(LL)=A(J,3)*(V1(LL)-V1(1)*UP(LL))                                910J9350
      DX=DC/2.0                                                          910J9355
      CALL SIMP (DELU,0.0,1.0,DX,21,DELUS,0.0,1)                         910J9360
      CALL SIMP (DELV,0.0,1.0,DX,21,DELVS,0.0,1)                         910J9365
      CALL SIMP (DELUU,0.0,1.0,DX,21,DELUUS,0.0,1)                       910J9370
      CALL SIMP (DELUV,0.0,1.0,DX,21,DELUVS,0.0,1)                       910J9375
      CALL SIMP (DELVV,0.0,1.0,DX,21,DELVVS,0.0,1)                       910J9380
      CALL SIMP (GAMMA(2),0.05,1.0,DX,20,ZDUM,0.0,0)                     910J9385
      Z(1)=0.0                                                           910J9390
```

```
      DO 28 LL=2,KMID                                                  910J9395
   28 Z(LL)=ZDUM(KMID-1)-ZDUM(LL-1)                                    910J9400
      DO 29 LL=1,KMID                                                  910J9405
   29 ZDUM(LL)=-Z(LL)                                                  910J9410
      CALL CURFIT (ZDUM,ES,AB2,KMID,0.0,0.0,2,2)                       910J9415
      CALL CURFIT (ZDUM,TT,AB1,KMID,0.0,0.0,2,2)                       910J9420
      CALL CURFIT (ZDUM,EN,AB3,KMID,0.0,0.0,2,2)                       910J9425
      DO 30 K=1,KMID                                                   910J9430
      IF (K-1) 31,32,31                                                910J9435
   32 DTZ=0.0                                                          910J9440
      DESZ=0.0                                                         910J9445
      DENZ=0.0                                                         910J9450
      WRITE OUTPUT TAPE 6,115                                          910J9455
      GO TO 33                                                         910J9460
   31 CALL CURVE (AB1,ZDUM,TT,ZDUM(K),DUMMY,DTZ,KMID,2)                910J9465
      CALL CURVE (AB2,ZDUM,ES,ZDUM(K),DUMMY,DESZ,KMID,2)               910J9470
      CALL CURVE (AB3,ZDUM,EN,ZDUM(K),DUMMY,DENZ,KMID,2)               910J9475
   33 WRITE OUTPUT TAPE 6,110,K,V1(K),T1(K),S1(K),CNU(J,K),ES(K),EN(K), 910J9480
     1 Z(K)                                                            910J9485
   30 CONTINUE                                                         910J9490
      C1=A(J,3)**2                                                     910J9495
      DELS=C1*DELUS+V1(1)*DELVS                                        910J9500
      DELN=A(J,3)*(V1(1)*DELUS-DELVS)                                  910J9505
      DELSS=V1(1)*(-A(J,3)*DELN+2.0*C1*DELUVS+V1(1)*DELVVS)            910J9510
     1   +C1**2*DELUUS                                                 910J9515
      DELNS=C1*(DELN+A(J,3)*V1(1)*DELUUS)-A(J,3)*((C1-V1(1)**2)        910J9520
     1   *DELUVS+V1(1)*DELVVS)                                         910J9525
      DELNN=-A(J,3)*V1(1)*DELN+C1*(-(-V1(1)**2)*DELUUS+2.0*V1(1)       910J9530
     1   *DELUVS-DELVVS)                                               910J9535
      WRITE OUTPUT TAPE 6,120,DELS,DELN,DELSS,DELNS,DELNN,             910J9540
     1   DELUS,DELVS,DELUUS,DELUVS,DELVVS                              910J9545
   15 WRITE OUTPUT TAPE 6,102,V(J,1),T(J,1),P(J),TW(J),(II,            910J9550
     1 A(J,II),II=1,30)                                                910J9555
   20 RETURN                                                           910J9560
      END
```

```
      SUBROUTINE SIMP (Y,X1,XL,DX,NMAX,A,CON,K)
C     Y IS DIMENSIONED ARRAY OF DEPENDENT VARIABLES
C     X1 IS THE LOWER INTEGRATION LIMIT
C     XL IS THE UPPER INTEGRATION LIMIT
C     DX IS THE INTEGRATION STEP SIZE
C     A IS DIMENSIONED ARRAY FOR RUNNING INTEGRALS,A SINGLE
C          LOCATION FOR TOTAL INTEGRALS.
C     K = 0 INDICATES RUNNING INTEGRALS TO BE COMPUTED
C     K = 1 INDICATES TOTAL INTEGRAL ONLY TO BE COMPUTED
C
      DIMENSION Y(1),A(1)
      A(1)=CON
      IF (XL-X1) 1,2,2
    1 DX=-1.0*ABSF(DX)
    2 IF (NMAX-3) 3,4,4
    4 IF (K) 5,5,6
    6 NDEL=0
      NN = 2
      KK = NMAX - 2*(NMAX/2)
      IF (KK) 7,10,7
    5 NDEL=2
      NN=1
    7 N=3
      M=1+NDEL
    9 L=M-NDEL
      A(M)=A(L)+DX/3.0*(Y(N-2)+4.0*Y(N-1)+Y(N))
      N=N+2
   13 M=M+NDEL
      IF (NMAX-N) 8,9,9
    8 GO TO (10,11),NN
   10 NN=2
      N=4
      YY=(3.0*Y(1)+6.0*Y(2)-Y(3))/8.0
      M=1+NDEL/2
      A(M)=A(1)+DX/6.0*(Y(1)+4.0*YY+Y(2))
      GO TO 13
    3 K=-1
   11 RETURN
      END (0)
```

```
      SUBROUTINE CURVE (A,X,Y,XP,YP,DYP,N,IT)                   900K2000
CURVE COMPUTES A -Y- AND/OR A -DY/DX- FOR A GIVEN -X-           900K2001
C.....USING A(I) COMPUTED IN CURFIT SUBROUTINE                  900K2002
C     XP = A PARTICULAR VALUE OF -X-  (GIVEN)                   900K2003
C     YP = A PARTICULAR VALUE OF -Y-                            900K2004
C     DYP = DY/DX AT -XP-                                       900K2005
C     IT = EFFICIENCY CONTROL INDEX  (GIVEN)                    900K2006
C       IT = 1 .....ONLY YP IS COMPUTED                         900K2007
C       IT = 2 .....ONLY DYP IS COMPUTED                        900K2008
C       IT = 3.....BOTH YP AND DYP ARE COMPUTED                 900K2009
      DIMENSION A(1),X(1),Y(1)                                  900K2010
      IF (X(1)-XP) 11,11,10                                     900K2011
 10   C1 = X(2)-X(1)                                            900K2012
      DYP = (Y(2)-Y(1))/C1+A(1)*C1                              900K2013
      GO TO (20,16,20),IT                                       900K2014
 20   YP = Y(1)+DYP*(XP-X(1))                                   900K2015
      GO TO 16                                                  900K2016
 11   N = N                                                     900K2017
      IF (XP-X(N)) 13,12,12                                     900K2018
 12   N2 = 2*(N-1)                                              900K2019
      C1 = X(N)-X(N-1)                                          900K2020
      DYP = (Y(N)-Y(N-1))/C1-A(N2-1)*C1-A(N2)*C1*C1             900K2021
      GO TO (40,16,40),IT                                       900K2022
 40   YP = Y(N)+DYP*(XP-X(N))                                   900K2023
      GO TO 16                                                  900K2024
 13   I = 1                                                     900K2025
 14   I = I+1                                                   900K2026
      IF (X(I)-XP) 14,15,15                                     900K2027
 15   K = 2*I-3                                                 900K2028
      C1 = XP-X(I-1)                                            900K2029
      C2 = X(I)-XP                                              900K2030
      SLOPE = (Y(I)-Y(I-1))/(X(I)-X(I-1))                       900K2031
      GO TO (60,70,60),IT                                       900K2032
 60   YP = Y(I-1)+(SLOPE+A(K)*C2+A(K+1)*C1*C2)*C1               900K2033
      GO TO (16,70,70),IT                                       900K2034
 70   DYP = SLOPE +A(K)*(C2-C1)+      A(K+1)*(2.*C2-C1)*C1      900K2035
 16   RETURN                                                    900K2036
      END
```

```
CCURFIT       (FEB 1963)
      SUBROUTINE CURFIT (X,Y,A,N,DY1,DY2,K1,K2)
C
CONTINUOUS DERIVATIVE INTERPOLATION SUBROUTINES
CURFIT COMPUTES COEFFICIENTS OF CUBICS  --  A(I)...I=1,2*N-2
C.....FOR THE WHOLE TABULATED TABLE
C     X(I) = INDEPENDENT VARIABLE.....I=1,N  (GIVEN)
C     Y(I) = DEPENDENT VARIABLE.....I=1,N  (GIVEN)
C     N = LENGTH OF Y-VS-X TABLE  (GIVEN)
C     DY1 = 1ST OR 2ND DERIVATIVE AT LOWER END OF TABLE
C     DY2 = 1ST OR 2ND DERIVATIVE AT UPPER END OF TABLE
C     K1 = 1 ......DY1 = 1ST DERIVATIVE  (GIVEN)
C     K1 = 2 ......DY1 = 2ND DERIVATIVE  (GIVEN)
C     K2 = 1 ......DY2 = 1ST DERIVATIVE  (GIVEN)
C     K2 = 2 ......DY2 = 2ND DERIVATIVE  (GIVEN)
C
      DIMENSION X(1),Y(1),A(1)
      DIMENSION B(200),C(1)
C
C    THE DIMENSION C(1) MUST FOLLOWS THE DIMENSION OF B
C    MINIMUM DIMENSION OF B IS......(2*N-2)
C    DIMENSION OF A IS SAME AS B, BUT GIVEN IN MAIN PROGRAM
C
C    CALCULATE STORAGE PROVIDED FOR B
      NUMB = XABSF(XLOCF(C(1))-XLOCF(B(1)))
      NRNG=NUMB/2+1
C
      N1 = N-2
      C1 = X(2)-X(1)
      IF (C1) 70,70,1
 1    GO TO (2,4),K1
 2    B(1) = 0.0
      A(1) = (DY1-(Y(2)-Y(1))/C1)/C1
      GO TO 5
 4    B(1) = -C1
      A(1) = -DY1/2.0
 5    J = 1
C
      IF (N1) 80,42,100
 100  IF (NRNG-N) 80,110,110
```

```
C                                                                 900K0040
 110  DO 10 I=1,N1                                                900K0041
      K = I+1                                                     900K0042
      J = J+1                                                     900K0043
      C1 = X(K)-X(I)                                              900K0044
      C2 = X(K+1)-X(K)                                            900K0045
      C3 = Y(K)-Y(I)                                              900K0046
      C4 = Y(K+1)-Y(K)                                            900K0047
      C5 = C3/C1-C4/C2                                            900K0048
      C6 = C1/C2                                                  900K0049
      C7 = C1*C2                                                  900K0050
      B(J) = 1.0/(C6*(C1-B(J-1)))                                 900K0051
      A(J) = (C5/C2-C6*A(J-1))*B(J)                               900K0052
      J = J+1                                                     900K0053
      B(J) = 1.0/((-C1-C2)/C7-C6*B(J-1))                          900K0054
      A(J) =(-C5/C7-C6*A(J-1))*B(J)                               900K0055
  10  CONTINUE                                                    900K0056
C                                                                 900K0057
      GO TO (20,30),K2                                            900K0058
  20  A(J+1) = (DY2-C4/C2+C2*A(J))/(C2*(B(J)-C2))                 900K0059
      GO TO 45                                                    900K0060
  30  A(J+1) = (DY2/2.+A(J))/(-2.*C2+B(J))                        900K0061
      GO TO 45                                                    900K0062
C                                                                 900K0063
C     STATEMENTS 42 TO 44 ARE FOR N=2 ONLY                        900K0064
C                                                                 900K0065
  42  C3 = K1                                                     900K0066
      C2 = 1.0/C3                                                 900K0067
      GO TO (43,44),K2                                            900K0068
  43  A(J+1) = ((Y(2)-Y(1))/C1-A(J)*C1-DY2)/(C1*C1)*C2           900K0069
      GO TO 45                                                    900K0070
  44  A(J+1) = C3*((DY2+2.0*A(1))/(4.0*C1))                       900K0071
C                                                                 900K0072
  45  J = 2*(N-1)                                                 900K0073
C                                                                 900K0074
  50  J = J-1                                                     900K0075
      IF (J) 70,70,60                                             900K0076
  60  A(J) = A(J)-B(J)*A(J+1)                                     900K0077
      GO TO 50                                                    900K0078
C                                                                 900K0079
  70  RETURN                                                      900K0080
```

```
C
80    WRITE OUTPUT TAPE 6,500,N,NRNG                                    900K0081
      CALL EXIT                                                         900K0082
500   FORMAT(4HON =I5,3X9HIN CURFIT/31H ......N MUST BE IN THE RANGE    900K0083
     1 13HBETWEEN 2 ANDI5/39HO*INCREASE DIMENSION OF  B  IN  CURFIT     900K0084
     2 19HIF  N  IS TOO LARGE /12HOB = 2*(N-1) )                        900K0085
      END                                                               900K0086
```

```
      SUBROUTINE PAGE1 (A)                                              936K1000
C                                                                       936K1005
      DIMENSION NAME(2),X(2),A(12)                                      936K1010
C                                                                       936K1015
 1010 FORMAT (1H1,12A6,5X2A6,5XA6,A2,5X4HPAGEI3/1H )                    936K1020
C                                                                       936K1025
      IF (J-1962) 10,20,10                                              936K1030
 10   J = 1962                                                          936K1035
      NPAGE = 0                                                         936K1040
      CALL DATT (NAME,X)                                                936K1045
C                                                                       936K1050
 20   NPAGE = NPAGE+1                                                   936K1055
      WRITE OUTPUT TAPE 6,1010,(A(I),I=1,12),NAME(1),NAME(2),           936K1060
     1  X(1),X(2),NPAGE                                                 936K1065
 100  RETURN                                                            936K1070
      END
```

```
      FUNCTION SUMI (A1,A2,X1,X2,Y1,Y2,XP1,XP2)                  900K4000
      SLOPE = (Y2-Y1)/(X2-X1)                                    900K4001
      X1X2 = X1*X2                                               900K4002
      C1 = Y1-SLOPE*X1-X1X2*(A1-A2*X1)                           900K4003
      C2 = (SLOPE+A1*(X1+X2)-A2*X1*(X1+2.*X2))/2.0               900K4004
      C3 = (-A1+A2*(2.*X1+X2))/3.0                               900K4005
      C4 = -A2/4.0                                               900K4006
      SUMI = ((((C4*XP2+C3)*XP2)+C2)*XP2)+C1)*XP2                900K4007
     1       -((((C4*XP1+C3)*XP1)+C2)*XP1)+C1)*XP1               900K4008
      RETURN                                                     900K4009
      END
```

```
      SUBROUTINE MNM (X,NX,XMAX,XMIN)                                   910K0000
      DIMENSION X(151)                                                  910K0005
      XMAX = X(1)                                                       910K0010
      XMIN = X(1)                                                       910K0015
      DO 12 I=2,NX                                                      910K0020
      IF (X(I)-XMAX) 12,12,11                                           910K0025
   11 XMAX = X(I)                                                       910K0030
   12 CONTINUE                                                          910K0035
      DO 14 I=2,NX                                                      910K0040
      IF (X(I)-XMIN) 13,14,14                                           910K0045
   13 XMIN = X(I)                                                       910K0050
   14 CONTINUE                                                          910K0055
      RETURN                                                            910K0060
      END (0) 925K0000                                                  910K0065

CLINEAR                                                                 919K0000
      SUBROUTINE LINEAR (X,Y,N,XP,YP)                                   919K0001
      DIMENSION X(1),Y(1)                                               919K0002
      DO 30 I=2,N                                                       919K0003
      IP = I                                                            919K0004
      IF (XP-X(I)) 40,40,30                                             919K0005
   30 CONTINUE                                                          919K0006
   40 YP = Y(IP-1)+(Y(IP)-Y(IP-1))*(XP-X(IP-1))/(X(IP)-X(IP-1))         919K0007
      RETURN                                                            919K0008
      END
```

```
      SUBROUTINE LSQD (X,Y,L,M,N,B)                                    902K0000
      DIMENSION X(20),Y(20,50),A(10,10),B(10,50),C(20,10)              902K0001
   10 DO 20 I=1,N                                                      902K0002
   20 C(I,1)=1.0                                                       902K0003
   30 DO 50 J=2,M                                                      902K0004
   40 DO 50 I=1,N                                                      902K0005
   50 C(I,J)=C(I,J-1)*X(I)                                             902K0006
   60 DO 100 I=1,M                                                     902K0007
   70 DO 100 J=1,M                                                     902K0008
   80 A(I,J)=0.0                                                       902K0009
   90 DO 100 K=1,N                                                     902K0010
  100 A(I,J)=A(I,J)+C(K,I)*C(K,J)                                      902K0011
  105 DO 150 J=1,L                                                     902K0012
  110 DO 150 I=1,M                                                     902K0013
  120 B(I,J)=0.0                                                       902K0014
  130 DO 150 K=1,N                                                     902K0015
  150 B(I,J)=B(I,J)+C(K,I)*Y(K,J)                                      902K0016
  170 CALL MATINV (A,M,B, L,DETERM)                                    902K0017
  210 RETURN                                                           902K0018
      END
```

```
      SUBROUTINE SIGMA (A,X,Y,N,XL,XU,SUM)                              900K3000
      DIMENSION A(1),X(1),Y(1)                                          900K3001
      SUM = 0.0                                                         900K3002
      IF (XU-XL) 1,21,2                                                 900K3003
1     WRITE OUTPUT TAPE 6,100,XL,XU                                     900K3004
      CALL EXIT                                                         900K3005
2     K = N                                                             900K3006
3     IF (X(K)-XU) 6,5,4                                                900K3007
4     K = K-1                                                           900K3008
      GO TO 3                                                           900K3009
5     K = K-1                                                           900K3010
6     L = N                                                             900K3011
7     IF (X(L)-XL) 9,9,8                                                900K3012
8     L = L-1                                                           900K3013
      GO TO 7                                                           900K3014
9     IF (K-L-1) 10,19,17                                               900K3015
10    IA = 2*L-1                                                        900K3016
      IB = 2*L                                                          900K3017
      SUM = SUMI (A(IA),A(IB),X(L),X(L+1),Y(L),Y(L+1),XL,XU)            900K3018
      GO TO 21                                                          900K3019
17    II = L+1                                                          900K3020
      IJ = K-1                                                          900K3021
      DO 18 I=II,IJ                                                     900K3022
      IA = 2*I-1                                                        900K3023
      IB = 2*I                                                          900K3024
      SUMP = SUMI (A(IA),A(IB),X(I),X(I+1),Y(I),Y(I+1),X(I),X(I+1))     900K3025
18    SUM = SUM+SUMP                                                    900K3026
19    IA = 2*L-1                                                        900K3027
      IB = 2*L                                                          900K3028
      SUM1 = SUMI (A(IA),A(IB),X(L),X(L+1),Y(L),Y(L+1),XL,X(L+1))       900K3029
      IA = 2*K-1                                                        900K3030
      IB = 2*K                                                          900K3031
      SUM2 = SUMI (A(IA),A(IB),X(K),X(K+1),Y(K),Y(K+1),X(K),XU)         900K3032
      SUM = SUM+SUM1+SUM2                                               900K3033
100   FORMAT (32H0ERROR IN THE INTEGRATION LIMITS /                     900K3034
     19H   X(L) =E15.6,7H X(U) = E15.6/                                 900K3035
     237H ......X(L) IS LARGER THAN X(U)...... )                        900K3036
21    RETURN                                                            900K3037
      END
```

```
      SUBROUTINE YDY (X1,Y1,X2,Y2,A,K,XP,YP,DYP,IT,DX)                  910J
      DIMENSION A(1)
      C1 = XP-X1
      C2 = X2-XP
      SLOPE = (Y2-Y1)/(X2-X1)
      GO TO (60,70,60),IT
60    YP = Y1+(SLOPE+A(K)*C2+A(K+1)*C1*C2)*C1
      GO TO (80,70,70),IT
70    DYP = SLOPE + A(K)*(C2-C1)+A(K+1)*(C2+C2-C1)*C1
      DYP=DYP*DX                                                        910J
80    RETURN
      END
```

```
      SUBROUTINE  FILL IN (Y,DYDX,N,DX,ID,IT,DY1,DY2,K1,K2)
      DIMENSION Y(1),DYDX(1),A(200),B(200)
      NO = 1
      N1 = N-4
      XID = ID
      X2 = DX*XID/2.
      C1 = X2
1     GO TO (2,3),K1
2     B(1) = 0.
      A(1) = (DY1-(Y(ID+1)-Y(1))/C1)/C1
      GO TO 4
3     B(1) = -C1
      A(1) =-DY1/2.0
4     J = 1
      C2 = DX
      I1 = 1
      I2 = ID+1
      I3 = 2
      I = -1
5     I = I+2
      J = J+1
      C3 = Y(I2)-Y(I1)
      I2I3 = I2+I3
      C4 = Y(I2I3)-Y(I2)
      C5 = C3/C1-C4/C2
      C6 = C1/C2
      C7 = C1*C2
      B(J) = 1.0/(C6*(C1-B(J-1)))
      A(J) = ( C5/C2-C6*A(J-1))*B(J)
      J = J+1
      B(J) = 1.0/((-C1-C2)/C7-C6*B(J-1))
      A(J) = (-C5/C7-C6*A(J-1))*B(J)
      C1 = DX
      I1 = I2
      I2 = I2+2
      IF (N1-I) 10,6,5
6     GO TO (7,10),ID
7     I3 = 1
      C2 = C2/2.
      GO TO 5
```

```
11    GO TO (12,13),K2
12    A(J+1) = (DY2-C4/C2+C2*A(J))/(C2*(B(J)-C2))
      GO TO 14
13    A(J+1)=(DY2/2.0+A(J))/(-2.0*C2+B(J))
14    B(J+1) = 0.0
      GO TO 16
15    J = J-1
      IF (J) 17,17,16
16    A(J) = A(J)-B(J)*A(J+1)
      GO TO 15
17    CONTINUE
CALCULATION OF CURFIT COEFFICIENTS COMPLETED....NOW, FILL IN.
      IA = 1
      IY = ID+1
      XP = 0.
      K = 1
      Y2 = Y(IY)
      DO 30 I=1,2
      CALL YDY ( 0.0,Y(1),X2,Y2,A,1,XP,Y(K),DYDX(K),IT,DX)               910J
      GO TO (40,20),ID
20    XP = DX/2.0
      K = 2
30    CONTINUE
40    K = K+2
      IA = IA+2
      XP = XP+DX
      X1 = X2
      Y1 = Y2
      IF (K-N) 50,45,60
45    GO TO (80,46,46),IT
46    X2 = X1+DX/2.0
      XP=X2
      Y2=Y(K)
47    NO = 2
      ITT = IT
      IF (IT-2) 101,59,100
100   IT=2
      GO TO 59
50    X2 = X1+DX
      Y2 = Y(K+1)
59    CALL YDY(X1,Y1,X2,Y2,A,IA,XP,Y(K),DYDX(K),IT,DX)                   910J
```

```
      GO TO (40,101),NO
101   IT=ITT
      GO TO 80
60    GO TO (70,61),ID                                    721J
61    K = K-1                                             721J
      IA = IA - 2
      XP =X2
      X1=X1-DX
      Y1 = Y(K-2)
      GO TO 47                                            721J
70    IA = IA-2
      DYP = (Y(N)-Y(N-2))/C1-A(IA)*C1-A(IA+1)*C1*C1
      YP = Y(N) + DYP *DX*0.5
      GO TO (21,22,21),IT
21    Y(K)=YP
      GO TO (80,80,22),IT
22    DYDX(K)=DYP*DX                                      910J
80    RETURN
      END
```

```
        FUNCTION BCDT (I)                                                        929K0000
        EQUIVALENCE (NA,CNA)                                                     929K0010
        II = I/10                                                                929K0020
        IA = I-10*II                                                             929K0030
        IC = II/10                                                               929K0040
        IB = II-10*IC                                                            929K0050
        IF (IC) 1,1,3                                                            929K0060
1       IF (IB) 2,2,3                                                            929K0070
2       IB = 48                                                                  929K0090
3       NA = IA+64*IB+4096*IC                                                    929K0100
        IF (IC) 4,4,5                                                            929K0105
B4      CNA = CNA+600000000000                                                   929K0110
B5      CNA = CNA+000000606060                                                   929K0115
        BCDT = CNA                                                               929K0120
        RETURN                                                                   929K0130
        END
```

```
      SUBROUTINE JLOOP1                                                 910J1000
C                                                                       910J1005
      DIMENSION IND(12),ARRAY(12)                                       910J1010
      DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)             910J1015
      DIMENSION A(1,30),B(17),ZETA(22),UP(22)                           910J1020
      DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)      910J1025
      DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)            910J1030
      DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)              910J1035
      DIMENSION CNU(1,22),CK(1,22)                                      910J1040
      DIMENSION VB(1,22),TB(1,22),SB(1,22)                              910J1042
      COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P         910J1045
      COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND      910J1050
      COMMON BO,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY          910J1055
      COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5                      910J1060
      COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KL1,INDEX,JO                    910J1065
C                                                                       910J1070
      EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)                  910J1075
C                                                                       910J1080
 303  FORMAT (28HOTEMPERATURE NEGATIVE AT I =I5,4H J =I4,4H K =I3)      910J1085
 304  FORMAT (49H REMOVE INPUT TAPE.  PRESS START FOR TERMINATION.)     910J1090
C                                                                       910J1095
      KO=KMAX-2                                                         910J1100
      DO 2000 J=1,JMAX                                                  910J1105
C                                                                       910J1110
CALCULATE VALUES AT....(I-1)+(J-1)+(K-1) = EVEN                         910J1115
C                                                                       910J1120
 15   INDEX = (I+J)-2*((I+J)/2)                                         910J1125
      N=2-INDEX+1                                                       910J1130
      DO 1000 K=N,KO,2                                                  910J1135
 150  V(J,K) = V(J,K)+VA(J,K)                                           910J1140
      T(J,K) = T(J,K)+TA(J,K)                                           910J1145
      IF (T(J,K)) 180,180,151                                           910J1150
 151  S(J,K) = S(J,K)+SA(J,K)                                           910J1155
 1000 CONTINUE                                                          910J1160
C                                                                       910J1165
CALCULATE VALUES AT THE WALL   (I-1)+(J-1)+(K-1) = EVEN                 910J1170
C                                                                       910J1175
      IF (INDEX) 2000,16,2000                                           910J1180
 16   K = KMAX-1                                                        910J1185
C                                                                       910J1190
```

```
CHECK FOR WALL THERMAL BOUNDARY CONDITIONS                  910J1195
C                                                           910J1200
      IF (TW(J)) 18,17,18                                   910J1205
C                                                           910J1210
C  HEAT TRANSFER RATE SPECIFIED                             910J1215
C                                                           910J1220
 17   T(J,K) = T(J,K)+TA(J,K)                               910J1225
      IF (T(J,K)) 180,180,19                                910J1230
 180  REWIND 2                                              910J1235
      WRITE OUTPUT TAPE 6,303,I,J,K                         910J1240
      PRINT   304                                           910J1245
      PAUSE 222                                             910J1250
      CALL DUMP                                             910J1255
C                                                           910J1260
C  WALL TEMPERATURE SPECIFIED                               910J1265
C                                                           910J1270
 18   T(J,K) = TW(J)                                        910J1275
 19   S(J,K) = S(J,K)+SA(J,K)                               910J1280
 2000 CONTINUE                                              910J1285
      RETURN                                                910J1290
      END
```

```
      SUBROUTINE BBB                                                    910J3000
C                                                                       910J3005
      DIMENSION IND(12),ARRAY(12)                                       910J3010
      DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)             910J3015
      DIMENSION A(1,30),B(17),ZETA(22),UP(22)                           910J3020
      DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)      910J3025
      DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)            910J3030
      DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)              910J3035
      DIMENSION CNU(1,22),CK(1,22)                                      910J3040
      DIMENSION VB(1,22),TB(1,22),SB(1,22)                              910J3045
      COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P         910J3050
      COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND      910J3055
      COMMON B0,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY          910J3060
      COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5                      910J3065
      COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KL1,INDEX,JO                    910J3070
C                                                                       910J3075
      EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)                  910J3080
C                                                                       910J3085
C                                                                       910J3090
      K=K                                                               910J3095
      J=J                                                               910J3100
      CALL AIR                                                          910J3105
      T1=UP(K)**2                                                       910J3110
      T2=S(J,K)*DVISC                                                   910J3115
      T3=ZETA(K)*S(J,K)                                                 910J3120
      T4=S(J,K)**2/CNU(J,K)*ZT(J,K)                                     910J3125
      T5=DC**2                                                          910J3130
      T6=A(J,6)*UP(K)                                                   910J3135
      T7=A(J,7)*V(J,K)                                                  910J3140
      B(1)=(A(J,1)*UP(K)*ZETA(K))/DA                                    910J3145
      B(3)=T4*A(J,4)                                                    910J3150
      B(4)=B(3)/PR                                                      910J3155
      B(5)=A(J,5)*T1+V(J,K)*(T6-T7)+A(J,8)*T(J,K)*ZT(J,K)               910J3160
      B(6)=(A(J,9)*T1-V(J,K)*(A(J,10)*UP(K)+A(J,11)*V(J,K))             910J3165
     1    -A(J,12)*T(J,K)*ZT(J,K))*ZETA(K)                              910J3170
      B(7)=(T(J,K)*ZT(J,K)*(A(J,13)*UP(K)+A(J,14)*V(J,K))+              910J3175
     1     A(J,15)*ZETA(K)**2*T4)*ZETA(K)/SIG(J,K)                      910J3180
      B(9)=A(J,16)*T4/SIG(J,K)*ZETA(K)/T5                               910J3185
      B(10)=B(4)*DCOND*ZETA(K)/T5                                       910J3190
      B(11)=A(J,4)*(1.0-PR)/(PR*CNU(J,K))*T3/T5*ZT(J,K)                 910J3195
```

```
      B(13)=(T6-2.0*T7)*S(J,K)/(DC*ZT(J,K))                              910J3200
      B(14)=B(1)*S(J,K)*(DVISC-DZT(J)/ZT(J,K))                           910J3205
      B(15)=B(2)*S(J,K)*(DVISC-DZT(J)/ZT(J,K))                           910J3210
      B(8)=-(B(3)+B(5))*S(J,K)/ZETA(K)+ZETA(K)*S(J,K)*(A(J,17)*UP(K)     910J3215
     1   +A(J,18)*V(J,K))-(1.0/ZT(J,K)*(DZP(J)+DCNUP(J))*(A(J,13)        910J3220
     2   +A(J,14)))                                                      910J3225
      B(16)=S(J,K)*(B(5)*DVISC+A(J,8)*ZT(J,K))/DC+(DZT(J)*(B(5)          910J3230
     1   /ZT(J,K)**2-A(J,8)*CNU(J,K)*DVISC/ZT(J,K)))/DC                  910J3235
      B(17)=(A(J,4)*S(J,K)*DZT(J)/(ZT(J,K)*CNU(J,K)))/T5                 910J3240
      B(3)=B(3)/DC                                                       910J3245
      B(4)=B(4)/DC                                                       910J3250
      B(5)=B(5)/DC                                                       910J3255
      IF (JMAX-1) 20,10,20                                               910J3260
   10 B(2)=0.0                                                           910J3265
      B(12)=0.0                                                          910J3270
      B(15)=0.0                                                          910J3275
      GO TO 30                                                           910J3280
   20 B(2)=(A(J,2)*ZETA(K)*V(J,K))/DB                                    910J3285
      B(12)=A(J,2)*T3/DB                                                 910J3290
      B(15)=B(2)*T2                                                      910J3295
   30 RETURN                                                             910J3300
      END
```

```
      SUBROUTINE VSUBC
      DIMENSION IND(12),ARRAY(12)
      DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)
      DIMENSION A(1,30),B(17),ZETA(22),UP(22)
      DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
      DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
      DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
      DIMENSION CNU(1,22),CK(1,22)
      DIMENSION VB(1,22),TB(1,22),SB(1,22)
      COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
      COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
      COMMON BO,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
      COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
      COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KL1,INDEX,JO
C
      EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)
C
      XK=K+K-2
      VC=(B(2)*VB(J,K)-XK*F*B(3)-B(6))/((XK-1.0)*B(3)-B(5))
      RETURN
      END
```

```
      SUBROUTINE TSUBC
C
      DIMENSION IND(12),ARRAY(12)
      DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)
      DIMENSION A(1,30),B(17),ZETA(22),UP(22)
      DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
      DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
      DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
      DIMENSION CNU(1,22),CK(1,22)
      DIMENSION VB(1,22),TB(1,22),SB(1,22)
      COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
      COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
      COMMON BO,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
      COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
      COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KL1,INDEX,JO
C
      EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)
C
      XK=K+K-2
      A1 = B(10)
      A2 = XK*B(4)-B(3)-B(5)+B(11)*SC
      A3=-BO*(B(1)+XK*B(4))*TA(J,K)-B(2)*TB(J,K)+XK*B(4)*F+B(7)
     1  +B(9)*VC**2
      TC = -A3/A2
C
      RETURN
      END
```

```
      SUBROUTINE SIDE
      DIMENSION IND(12),ARRAY(12)
      DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)
      DIMENSION A(1,30),B(17),ZETA(22),UP(22)
      DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
      DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
      DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
      DIMENSION CNU(1,22),CK(1,22)
      DIMENSION VB(1,22),TB(1,22),SB(1,22)
      DIMENSION V1(22),VMAX(22),T1(22),TMAX(22),S1(22),SMAX(22)
      COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
      COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
      COMMON BO,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
      COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
      COMMON J,K,JMAX,KMAX,IND,I,KL0,IT,KL1,INDEX,JJ
C
      EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)
C
      DO 20 K=1,KMAX
      V1(K)=V(1,K)
      VMAX(K)=V(JMAX,K)
      T1(K)=T(1,K)
      TMAX(K)=T(JMAX,K)
      S1(K)=S(1,K)
   20 SMAX(K)=S(JMAX,K)
      INDEX=(1+I)-2*((1+I)/2)
      IF (IND(11)-1) 1,2,3
    2 ITT=1
      ID=2-INDEX
      N=KMAX-INDEX-1
      DO 4 K=1,KMAX
    4 DUM3(K)=V(1,K)
      CALL FILLIN (DUM3,DUM4,N,DC,ID,ITT,0.0,0.0,2,2)
      DO 5 K=1,KMAX
      V(1,K)=DUM3(K)
    5 DUM3(K)=T(1,K)
      CALL FILLIN (DUM3,DUM4,N,DC,ID,ITT,0.0,0.0,2,2)
      DO 6 K=1,KMAX
      T(1,K)=DUM3(K)
    6 DUM3(K)=S(1,K)
```

```
      CALL FILLIN (DUM3,DUM4,N,DC,ID,ITT,0.0,0.0,2,2)                   910J7200
      DO 7 K=1,KMAX                                                     910J7205
      S(1,K)=DUM3(K)                                                    910J7210
    7 DUM3(K)=V(JMAX,K)                                                 910J7215
      CALL FILLIN (DUM3,DUM4,N,DC,ID,ITT,0.0,0.0,2,2)                   910J7220
      DO 8 K=1,KMAX                                                     910J7225
      V(JMAX,K)=DUM3(K)                                                 910J7230
    8 DUM3(K)=T(JMAX,K)                                                 910J7235
      CALL FILLIN (DUM3,DUM4,N,DC,ID,ITT,0.0,0.0,2,2)                   910J7240
      DO 9 K=1,KMAX                                                     910J7245
      T(JMAX,K)=DUM3(K)                                                 910J7250
    9 DUM3(K)=S(JMAX,K)                                                 910J7255
      CALL FILLIN (DUM3,DUM4,N,DC,ID,ITT,0.0,0.0,2,2)                   910J7260
      DO 10 K=1,KMAX                                                    910J7265
   10 S(JMAX,K)=DUM3(K)                                                 910J7270
      N=JMAX                                                            910J7275
      ID=1+INDEX                                                        910J7280
      ITT=2                                                             910J7285
      DO 11 K=2,KMAX                                                    910J7290
      CALL FILLIN (V(1,K),VB(1,K),N,DB,ID,ITT,0.0,0.0,2,2)              910J7295
      CALL FILLIN (T(1,K),TB(1,K),N,DB,ID,ITT,0.0,0.0,1,1)              910J7300
      CALL FILLIN (S(1,K),SB(1,K),N,DB,ID,ITT,0.0,0.0,1,1)              910J7305
   11 ID=3-ID                                                           910J7310
    3 CONTINUE                                                          910J7315
   15 DO 21 K=1,KMAX                                                    910J7320
      V(1,K)=V1(K)                                                      910J7325
      V(JMAX,K)=VMAX(K)                                                 910J7330
      T(1,K)=T1(K)                                                      910J7335
      T(JMAX,K)=TMAX(K)                                                 910J7340
      S(1,K)=S1(K)                                                      910J7345
   21 S(JMAX,K)=SMAX(K)                                                 910J7350
      RETURN                                                            910J7355
    1 DO 12 K=1,KMAX                                                    910J7360
      VB(1,K)=0.0                                                       910J7365
      TB(1,K)=0.0                                                       910J7370
      SB(1,K)=0.0                                                       910J7375
      VB(JMAX,K)=0.0                                                    910J7380
      TB(JMAX,K)=0.0                                                    910J7385
   12 SB(JMAX,K)=0.0                                                    910J7390
      IF (JMAX-2) 15,15,16                                                  7395
   16 ID = 3-INDEX                                                          7396
```

```
      JJ=JMAX-2                                                         910J7400
      DO 13 K=2,KMAX                                                    910J7405
      DO 14 J=ID,JJ,2                                                   910J7410
      VB(J,K)=V(J+1,K)-V(J-1,K)                                         910J7415
      TB(J,K)=T(J+1,K)-T(J-1,K)                                         910J7420
   14 SB(J,K)=S(J+1,K)-S(J-1,K)                                         910J7425
   13 ID=5-ID                                                           910J7430
      GO TO 15                                                          910J7435
      END
```

```
      SUBROUTINE TABINT (A,X,Y,N,XX,M,IT)                               942K0000
      DIMENSION A(1),X(1),Y(1),DY(101),S(101),ROOT(101),XX(1)           942K0005
      S(1) = 0.0                                                        942K0010
      GO TO (1,3),IT                                                    942K0015
    1 DO 2 I=1,N                                                        942K0020
    2 DY(I) = Y(I)                                                      942K0025
      GO TO 11                                                          942K0030
    3 CALL CURFIT (X,Y,A,N,0.,0.,2,2)                                   942K0035
      DO 10 I=1,N                                                       942K0040
      CALL CURVE (A,X,Y,X(I),ANY,DY(I),N,2)                             942K0045
   10 CONTINUE                                                          942K0050
   11 CALL MNM (X,N,XMAX,XMIN)                                          942K0055
      CALL MNM (DY,N,YMAX,YMIN)                                         942K0060
      FACTOR = (XMAX-XMIN)/(YMAX-YMIN)                                  942K0065
      CALL CURFIT (X,DY,A,N,0.,0.,2,2)                                  942K0070
      DO 20 I=1,N                                                       942K0075
      CALL CURVE (A,X,DY,X(I),ANY,DDY,N,2)                              942K0080
      ROOT(I) = SQRTF((DDY*FACTOR)**2+1.)                               942K0085
   20 CONTINUE                                                          942K0090
      CALL CURFIT (X,ROOT,A,N,0.,0.,2,2)                                942K0095
      DO 30 I=2,N                                                       942K0100
      CALL SIGMA (A,X,ROOT,N,X(I-1),X(I),SUM)                           942K0105
      S(I) = S(I-1)+SUM                                                 942K0110
   30 CONTINUE                                                          942K0115
      ANY = M-1                                                         942K0120
      DELS =(1./ANY)*S(N)                                               942K0125
      DO 40 I=1,M                                                       942K0130
      XI = I-1                                                          942K0135
      ANY = XI*DELS                                                     942K0140
      XX(I) = FINTER (X,S,N,ANY)                                        942K0145
   40 CONTINUE                                                          942K0150
      RETURN                                                            942K0155
      END
```

```
*       LABEL(728KA)
*       FAP                                                          A7760000
        ENTRY DATT
 DATT   CLA     1,4
        STA     A
        SUB     ONE                   1 IN ADDRESS
        STA     B
        CLA     37
 A      STO     A
        CLA     38
 B      STO     B
        CLA     2,4
        STA     C
        SUB     ONE
        STA     D
        CLA     98
        LRS     24
        ALS     6
        ADD     CON
        LLS     12
        ALS     6
        ADD     CON
 C      STO     C
        LLS     36
 D      STO     D
        TRA     3,4
 ONE    PZE     1
 CON    OCT     000000000061
        END
```

```
CLSQD
      SUBROUTINE LSQD (X,Y,L,M,N,B)                                     902K0000
      DIMENSION X(1),Y(1,1),A(8,8),B(8,1),C(101,8)
   10 DO 20 I=1,N                                                       902K0002
   20 C(I,1)=1.0                                                        902K0003
   30 DO 50 J=2,M                                                       902K0004
   40 DO 50 I=1,N                                                       902K0005
   50 C(I,J)=C(I,J-1)*X(I)                                              902K0006
   60 DO 100 I=1,M                                                      902K0007
   70 DO 100 J=1,M                                                      902K0008
   80 A(I,J)=0.0                                                        902K0009
   90 DO 100 K=1,N                                                      902K0010
  100 A(I,J)=A(I,J)+C(K,I)*C(K,J)                                       902K0011
  105 DO 150 J=1,L                                                      902K0012
  110 DO 150 I=1,M                                                      902K0013
  120 B(I,J)=0.0                                                        902K0014
  130 DO 150 K=1,N                                                      902K0015
  150 B(I,J)=B(I,J)+C(K,I)*Y(K,J)                                       902K0016
  170 CALL MATINV (A,M,B, L,DETERM)                                     902K0017
  210 RETURN                                                            902K0018
      END
```

```
      SUBROUTINE JLOOP2                                                 910J2000
C                                                                       910J2005
      DIMENSION IND(12),ARRAY(12)                                       910J2010
      DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)             910J2015
      DIMENSION A(1,30),B(17),ZETA(22),UP(22)                           910J2020
      DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)      910J2025
      DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)            910J2030
      DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)              910J2035
      DIMENSION CNU(1,22),CK(1,22)                                      910J2040
      DIMENSION VB(1,22),TB(1,22),SB(1,22)                              910J2045
      DIMENSION VCC(22),TCC(22),SCC(22)                                 910J0076
      COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P         910J2050
      COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND      910J2055
      COMMON B0,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY          910J2060
      COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5                      910J2065
      COMMON J,K,JMAX,KMAX,IND,I,KL0,IT,KL1,INDEX,J0                    910J2070
      COMMON VCC,TCC,QPR,TSTAR,PSTAR,Q0,CNURAT,CKRAT,SCC,XNOPR          910J0101
C                                                                       910J2075
      EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)                  910J2080
C                                                                       910J2085
 1    FORMAT (1H 1P9E13.5)                                              910J2090
 2    FORMAT (1H ///,5H I = I6,5H J = I6,5H K = I6,//)                  910J2095
      K0=KMAX-2                                                         910J2100
 159  DO 4000 J=1,JMAX                                                  910J2105
      INDEX = (I+J)-2*((I+J)/2)                                         910J2110
      J = J                                                             910J2111
C                                                                       910J2115
      N=2+INDEX                                                         910J2120
      DO 3000 K=N,K0,2                                                  910J2125
      K = K                                                             910J2130
 160  CALL BBB                                                          910J2135
C                                                                       910J2140
 24   VC = V(J,K+1)-V(J,K-1)                                            910J2150
      TC = T(J,K+1)-T(J,K-1)                                            910J2155
      SC = S(J,K+1)-S(J,K-1)                                            910J2160
      VCC(K) = VC*DC                                                    910J2161
      TCC(K) = TC*DC                                                    910J2162
      SCC(K) = SC*DC                                                    910J2163
      VD = V(J,K+1)+V(J,K-1)-2.*V(J,K)                                  910J2165
      TD = T(J,K+1)+T(J,K-1)-2.*T(J,K)                                  910J2170
```

```
      SD = S(J,K+1)+S(J,K-1)-2.*S(J,K)                                  910J2175
C                                                                       910J2160
CALCULATE FORWARD DERIVATIVES                                           910J2185
C                                                                       910J2190
      CALL SUBA (4)                                                     910J2195
      J = J                                                             910J2200
      IF (IND(9)) 3000,3000,10                                          910J2205
 10   WRITE OUTPUT TAPE 6,2,I,J,K                                       910J2210
      WRITE OUTPUT TAPE 6,1,V(J,K),T(J,K),S(J,K),VA(J,K),TA(J,K),       910J2215
     1  SA(J,K),VB(J,K),TB(J,K),SB(J,K)                                 910J2220
      WRITE OUTPUT TAPE 6,1,VC,TC,SC,VD,TD,SD                           910J2225
      WRITE OUTPUT TAPE 6,1,(B(II),II=1,16)                             910J2230
 3000 CONTINUE                                                          910J2235
C                                                                       910J2240
CALCULATE VALUES AT THE WALL  (I-1)+(J-1)+(K-1) = ODD                   910J2245
C                                                                       910J2250
      IF (INDEX) 25,161,25                                              910J2255
 25   K = KMAX-1                                                        910J2260
      CALL BBB                                                          910J2265
      F = 2.0*V(J,K-1)                                                  910J2270
      CALL VSUBC                                                        910J2275
      IF (A(J,20)) 45,45,40                                             910J2278
 40   A(J,20) = 0                                                       910J2278
 45   CONTINUE                                                          910J2278
      A(J,29) = A(J,20)/(X1/(SQRTF(T(J,1))*(1.0+X2/T(J,1))))            910J2279
     1  *A(J,1)**2*A(J,25)*17.4545*T(J,K)/T(J,1)                        910J2279
      SC = DC*(-S(J,K)-A(J,19)*CNU(J,K)*T(J,K)/S(J,K)-A(J,20))          910J2280
      SD = SC+2.*(S(J,K-1)-S(J,K))                                      910J2285
C                                                                       910J2290
CHECK FOR SIDE CALCULATIONS                                             910J2295
C                                                                       910J2300
CHECK FOR WALL THERMAL BOUNDARY CONDITIONS                              910J2305
C                                                                       910J2310
 30   IF (TW(J)) 37,36,37                                               910J2315
C                                                                       910J2320
C  HEAT TRANSFER RATE SPECIFIED                                         910J2325
C                                                                       910J2330
 36   TC = -DC*(A(J,21)+T(J,K)*(A(J,22)+A(J,23)*T(J,K)**3)/(CK(J,K)     910J2335
     1  *S(J,K)))                                                       910J2340
      TD = TC+2.*(T(J,K-1)-T(J,K))                                      910J2345
      CALL SUBA (2)                                                     910J2350
```

```
      GO TO 38                                                          910J2355
C                                                                       910J2360
C  WALL TEMPERATURE SPECIFIED                                           910J2365
C                                                                       910J2370
 37   TA(J,K) = 0.5*(TW(J)-T(J,K))                                      910J2375
      F = 2.0*(T(J,K-1)-T(J,K))                                         910J2380
      CALL TSUBC                                                        910J2385
      CALL SUBA (3)                                                     910J2390
C                                                                       910J2395
CALCULATE FICTITIOUS WALL QUANTITIES                                    910J2400
C                                                                       910J2405
 38   V(J,K+1) = VC+V(J,K-1)                                            910J2410
      T(J,K+1) = TC+T(J,K-1)                                            910J2415
      S(J,K+1) = SC+S(J,K-1)                                            910J2420
C                                                                       910J2425
 161  IF (IT-1) 4000,48,4000                                            910J2430
 48   CALL SUMARY                                                       910J2435
C                                                                       910J2440
 4000 CONTINUE                                                          910J2445
      RETURN                                                            910J2450
      END
```

```
      SUBROUTINE AIR                                                    910J8000
C                                                                       910J8005
      DIMENSION IND(12),ARRAY(12)                                       910J8010
      DIMENSION TABLF1(12),TABLE2(12),TABLE4(21),TABLE5(61)             910J8015
      DIMENSION A(1,30),B(17),ZETA(22),UP(22)                           910J8020
      DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)      910J8025
      DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)            910J8030
      DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)              910J8035
      DIMENSION CNU(1,22),CK(1,22)                                      910J8040
      DIMENSION VB(1,22),TB(1,22),SB(1,22)                              910J8045
      COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P         910J8050
      COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND      910J8055
      COMMON BC,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY          910J8060
      COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5                      910J8065
      COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KL1,INDEX,JO                    910J8070
C                                                                       910J8075
      EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)                  910J8080
C                                                                       910J8085
C                                                                       910J8090
      K=K                                                               910J8095
      J=J                                                               910J8100
      CNU(J,K)=X1*SQRTF(T(J,K))/(T(J,K)+X2)                             910J8105
      DVISC=(X2-T(J,K))/(2.0*T(J,K)*(X2+T(J,K)))                        910J8110
      CK(J,K)=4.753972                                                  910J8115
      DCOND=0.0                                                         910J8120
      SIG(J,K)=3.5                                                      910J8125
      PR=SIG(J,K)/CK(J,K)                                               910J8130
      DZP(J)=0.0                                                        910J8135
      DZT(J)=0.0                                                        910J8140
      DCNUP(J)=0.0                                                      910J8145
      ZT(J,K)=1.0                                                       910J8150
      RETURN                                                            910J8155
      END
```

```
      SUBROUTINE SUBA (N)
C
      DIMENSION IND(12),ARRAY(12)
      DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)
      DIMENSION A(1,30),B(17),ZETA(22),UP(22)
      DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
      DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
      DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
      DIMENSION CNU(1,22),CK(1,22)
      DIMENSION VB(1,22),TB(1,22),SB(1,22)
      COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
      COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
      COMMON B0,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
      COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
      COMMON J,K,JMAX,KMAX,IND,I,KL0,IT,KL1,INDEX,J0
C
      EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)
C
      K = K
      J = J
      XK = K+K-2
      T1 = B(3)+B(5)
      T2 = XK*B(3)
      T3 = B0*(B(1)+T2)
      GO TO (1,2,3,1),N
 1    VA(J,K)=(-B(2)*VB(J,K)-T1*VC+T2*VD+B(6))/T3
      GO TO (4,4,4,2),N
 2    TA(J,K) = XK*B(4)
      TA(J,K)=(-B(2)*TB(J,K)+TC*(B(11)*SC+B(10)*TC-T1)
     1  +TA(J,K)*TD+B(7)+B(9)*VC**2)/(B0*(B(1)+TA(J,K)))
      GO TO (4,3,4,3),N
 3    SA(J,K)=(-B(2)*SB(J,K)+SC*(B(3)-B(5))+T2*SD+B(8)+B(12)
     1  *VB(J,K)+B(13)*VC+B(14)*TA(J,K)+B(15)*TB(J,K)+B(16)*TC)/T3
 4    RETURN
      END
```

```
CMATINV
      SUBROUTINE MATINV(A,N,B,M,DETERM)                                 901K0000
      DIMENSION IPIVOT(8),A(8,8),B(8,1),INDEX(8,2),PIVOT(8)
      EQUIVALENCE (IROW,JROW), (ICOLUM,JCOLUM), (AMAX, T, SWAP)         901K0002
C                                                                       901K0003
C     INITIALIZATION                                                    901K0004
   10 DETERM=1.0                                                        901K0005
   15 DO 20 J=1,N                                                       901K0006
   20 IPIVOT(J)=0                                                       901K0007
   30 DO 550 I=1,N                                                      901K0008
C                                                                       901K0009
C     SEARCH FOR PIVOT ELEMENT                                          901K0010
   40 AMAX=0.0                                                          901K0011
   45 DO 105 J=1,N                                                      901K0012
   50 IF (IPIVOT(J)-1) 60, 105, 60                                      901K0013
   60 DO 100 K=1,N                                                      901K0014
   70 IF (IPIVOT(K)-1) 80, 100, 740                                     901K0015
   80 IF (ABSF(AMAX)-ABSF(A(J,K))) 85, 100, 100                         901K0016
   85 IROW=J                                                            901K0017
   90 ICOLUM=K                                                          901K0018
   95 AMAX=A(J,K)                                                       901K0019
  100 CONTINUE                                                          901K0020
  105 CONTINUE                                                          901K0021
  110 IPIVOT(ICOLUM)=IPIVOT(ICOLUM)+1                                   901K0022
C     INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL                 901K0023
  130 IF (IROW-ICOLUM) 140, 260, 140                                    901K0024
  140 DETERM=-DETERM                                                    901K0025
  150 DO 200 L=1,N                                                      901K0026
  160 SWAP=A(IROW,L)                                                    901K0027
  170 A(IROW,L)=A(ICOLUM,L)                                             901K0028
  200 A(ICOLUM,L)=SWAP                                                  901K0029
  205 IF(M) 260, 260, 210                                               901K0030
  210 DO 250 L=1, M                                                     901K0031
  220 SWAP=B(IROW,L)                                                    901K0032
  230 B(IROW,L)=B(ICOLUM,L)                                             901K0033
  250 B(ICOLUM,L)=SWAP                                                  901K0034
  260 INDEX(I,1)=IROW                                                   901K0035
  270 INDEX(I,2)=ICOLUM                                                 901K0036
  310 PIVOT(I)=A(ICOLUM,ICOLUM)                                         901K0037
  320 DETERM=DETERM*PIVOT(I)                                            901K0038
```

```
C       DIVIDE PIVOT ROW BY PIVOT ELEMENT                    901K0039
  330 A(ICOLUM,ICOLUM)=1.0                                   901K0040
  340 DO 350 L=1,N                                           901K0041
  350 A(ICOLUM,L)=A(ICOLUM,L)/PIVOT(I)                       901K0042
  355 IF(M) 380, 380, 360                                    901K0043
  360 DO 370 L=1,M                                           901K0044
  370 B(ICOLUM,L)=B(ICOLUM,L)/PIVOT(I)                       901K0045
C       REDUCE NON-PIVOT ROWS                                901K0046
  380 DO 550 L1=1,N                                          901K0047
  390 IF(L1-ICOLUM) 400, 550, 400                            901K0048
  400 T=A(L1,ICOLUM)                                         901K0049
  420 A(L1,ICOLUM)=0.0                                       901K0050
  430 DO 450 L=1,N                                           901K0051
  450 A(L1,L)=A(L1,L)-A(ICOLUM,L)*T                          901K0052
  455 IF(M) 550, 550, 460                                    901K0053
  460 DO 500 L=1,M                                           901K0054
  500 B(L1,L)=B(L1,L)-B(ICOLUM,L)*T                          901K0055
  550 CONTINUE                                               901K0056
C       INTERCHANGE COLUMNS                                  901K0057
  600 DO 710 I=1,N                                           901K0058
  610 L=N+1-I                                                901K0059
  620 IF (INDEX(L,1)-INDEX(L,2)) 630, 710, 630               901K0060
  630 JROW=INDEX(L,1)                                        901K0061
  640 JCOLUM=INDEX(L,2)                                      901K0062
  650 DO 705 K=1,N                                           901K0063
  660 SWAP=A(K,JROW)                                         901K0064
  670 A(K,JROW)=A(K,JCOLUM)                                  901K0065
  700 A(K,JCOLUM)=SWAP                                       901K0066
  705 CONTINUE                                               901K0067
  710 CONTINUE                                               901K0068
  740 RETURN                                                 901K0069
      END
```

```
      SUBROUTINE SMOOTH (X,Y,N,LAPS,YSMOTH,IT)                          904K0000
      DIMENSION X(1),Y(1),YSMOTH(1),XX(6),YY(6),B(3),YD(101)            904K0005
C     X = INDEPENDENT VARIABLE --- (INPUT ARRAY)                        904K0010
C     Y = DEPENDENT VARIABLE --- (INPUT ARRAY)                          904K0015
C     LAPS = NO. OF TIMES THE TABLE TO BE SMOOTHED                      904K0020
C     YSMOTH = SMOOTHED Y --- (OUTPUT ARRAY)                            904K0025
C     IT = PRINT CONTROL......                                          904K0030
C          0 .... NO PRINTOUT                                           904K0035
C          1 .... PRINT COMMENT WHEN A POINT WAS CONSIDERED WILD        904K0040
      NN = N-1                                                          904K0045
      YSMOTH (N) = Y(N)                                                 904K0050
      YSMOTH (1) = Y(1)                                                 904K0055
      NOMAX = 3*N*LAPS                                                  904K0060
      IF (N-7) 1,93,93                                                  904K0065
    1 WRITE OUTPUT TAPE 6,600,N                                         904K0070
      GO TO 90                                                          904K0075
   93 DO 94 J=1,N                                                       904K0080
   94 YD(J) = Y(J)                                                      904K0085
      DO 80 K=1,LAPS                                                    904K0090
      NO = 0                                                            904K0095
    2 L = 2                                                             904K0100
    3 CONTINUE                                                          904K0105
      DO 70 I=L,NN                                                      904K0110
      NO = NO+1                                                         904K0115
      IF (NO-NOMAX) 95,95,90                                            904K0120
   95 CONTINUE                                                          904K0125
      INDEX = I-3                                                       904K0130
      IF (INDEX-1) 4,8,5                                                904K0135
    4 INDEX = 1                                                         904K0140
      GO TO 8                                                           904K0145
    5 IF (INDEX-N+6) 8,8,6                                              904K0150
    6 INDEX = N-6                                                       904K0155
    8 CONTINUE                                                          904K0160
      JT = 0                                                            904K0165
      JP = INDEX                                                        904K0170
      DO 20 J=1,7                                                       904K0175
      IF (JP-I) 10,20,10                                                904K0180
   10 JT = JT+1                                                         904K0185
      XX(JT) = X(JP)                                                    904K0190
      YY(JT) = YD(JP)                                                   904K0195
```

```
20    JP = JP+1                                                      904K0200
      CALL LSQD (XX,YY,1,3,6,B)                                      904K0205
      SUM = 0.                                                       904K0210
      JP = INDEX                                                     904K0215
      DO 50 J=1,7                                                    904K0220
      VALUE = ((B(3)*X(JP))+B(2))*X(JP)+B(1)                         904K0225
      IF (JP-I) 40,30,40                                             904K0230
30    CHECK = ABSF(YD(JP)-VALUE)                                     904K0235
      POINT = VALUE                                                  904K0240
      GO TO 50                                                       904K0245
40    SUM = SUM+(VALUE-YD(JP))**2                                    904K0250
50    JP = JP+1                                                      904K0255
      DDD = SQRTF(SUM/6.)*3.0                                        904K0260
      IF (DDD-CHECK) 55,70,70                                        904K0265
55    IF (IT) 60,65,60                                               904K0270
60    WRITE OUTPUT TAPE 6,601,I,X(I),Y(I),POINT                      904K0275
65    YD(I) = POINT                                                  904K0280
      Y(I) = POINT                                                   904K0285
      L = I-3                                                        904K0290
      IF (L-1) 2,2,3                                                 904K0295
70    YSMOTH(I) = POINT                                              904K0300
      DO 80 J=1,N                                                    904K0305
80    YD(J) = YSMOTH(J)                                              904K0310
90    RETURN                                                         904K0315
600   FORMAT (36H0TABLE TOO SMALL FOR SMOOTHING...... /              904K0320
     1  10H ......N =I2,35H,  *THERE MUST BE 7 OR MORE POINTS*)      904K0325
601   FORMAT (24H0A POINT WAS WILD AT I =I3,5H, X =E14.6/            904K0330
     1  4H Y =E14.6,26H...HAS BEEN CHANGED TO ...E14.6)              904K0335
      END
```

```
      SUBROUTINE SHEAR (X)                                              950JNN00
      DIMENSION X(22)                                                   950JNN01
C                                                                       950JNN02
      X(1) = 0.0                                                        950JNN03
      X(2) = 1.987                                                      950JNN04
      X(3) = 3.353                                                      950JNN05
      X(4) = 4.415                                                      950JNN06
      X(5) = 5.257                                                      950JNN07
      X(6) = 5.922                                                      950JNN08
      X(7) = 6.441                                                      950JNN09
      X(8) = 6.832                                                      950JNN10
      X(9) = 7.112                                                      950JNN11
      X(10) = 7.293                                                     950JNN12
      X(11) = 7.386                                                     950JNN13
      X(12) = 7.401                                                     950JNN14
      X(13) = 7.347                                                     950JNN15
      X(14) = 7.231                                                     950JNN16
      X(15) = 7.062                                                     950JNN17
      X(16) = 6.849                                                     950JNN18
      X(17) = 6.600                                                     950JNN19
      X(18) = 6.324                                                     950JNN20
      X(19) = 6.032                                                     950JNN21
      X(20) = 5.735                                                     950JNN22
      X(21) = 5.450                                                     950JNN23
      X(22) = 5.190                                                     950JNN24
      RETURN                                                            950JNN25
      END                                                               950JNN26
```

```
      SUBROUTINE SELECT (XXA,T,N,II)                                    950JDD00
*     LABEL
 950JDD                                                                 950JDD
C                                                                       950JDD01
      DIMENSION B(10,100),XXA(10),XX1(10)                               950JDD02
      EQUIVALENCE (XX1(10),NPONT)                                       950JDD03
C                                                                       950JDD04
      IF (T) 10,10,20                                                   950JDD05
   10 K = 3                                                             950JDD06
      GO TO 30                                                          950JDD07
   20 K = 4                                                             950JDD08
C                                                                       950JDD09
   30 IF (II) 35,33,31                                                  950JDD10
   31 BACKSPACE K                                                       950JDD11
   33 BACKSPACE K                                                       950JDD12
      READ TAPE K,B                                                     950JDD13
C                                                                       950JDD14
   35 DO 40 I=1,100                                                     950JDD15
      CALL DMOVE (XX1,B(1,I))                                           950JDD16
      IF (NPONT-N) 40,50,40                                             950JDD17
   40 CONTINUE                                                          950JDD18
C                                                                       950JDD19
   50 CALL DMOVE (XXA,XX1)                                              950JDD20
      RETURN                                                            950JDD21
      END
```

```
      SUBROUTINE STORE (B,W,K,M,ARRAY)                                  950JR000
*     LABEL
 950JR                                                                  950JR
C                                                                       950JR001
C         ROUTINE TO MOVE W-ARRAY TO B-ARRAY,                           950JR002
C         TO PRINT IF DESIRED, M(1)=1 ALL DATA.                         950JR003
C         K IS TAPE DATA GOES ON--4 FOR LOWER                           950JR004
C         FLOW --3 FOR UPPER FLOW.                                      950JR005
C                                                                       950JR006
      DIMENSION B(10,100),W(10,100),M(10)                               950JR007
      EQUIVALENCE (XNPT,NPT)                                            950JR008
C                                                                       950JR009
 500  FORMAT (1P6E15.5,3XA6,1PE15.5)                                    950JR010
 510  FORMAT (///9X1HX,14X1HY,14X1HP,11X5HTHETA,12X3HZMU,13X1HR,        950JR011
     1  8X9HINDICATOR,3X1HW)                                            950JR012
B     SHOCK1 = 436230462342                                             950JR013
B     SHOCK2 = 646230462342                                             950JR014
B     FIELD = 605460546054                                              950JR015
B     BODY1 = 436022462470                                              950JR016
B     BODY2 = 646022462470                                              950JR017
B     SLPST = 654651632567                                              950JR018
      CALL PAGE2 (5,ARRAY)                                              950JR019
      WRITE OUTPUT TAPE 6,510                                           950JR020
C                                                                       950JR021
      DO 100 I=1,100                                                    950JR022
      CALL PAGE2 (1,ARRAY)                                              950JR023
      CALL DMOVE (B(1,I),W(1,I))                                        950JR024
      XNPT = B(7,I)                                                     950JR025
      IF (NPT-12345) 90,200,90                                          950JR026
 90   CONTINUE                                                          950JR027
      IF (NPT) 10,20,30                                                 950JR028
 10   IF (NPT+2)50,40,40                                                950JR029
 20   AF = FIELD                                                        950JR030
      GO TO 60                                                          950JR031
 30   IF (NPT-1) 34,34,38                                               950JR032
 34   AF = SHOCK1                                                       950JR033
      GO TO 65                                                          950JR034
 38   IF (NPT-11) 39,34,39                                              950JR035
 39   AF = SHOCK2                                                       950JR036
 65   WRITE OUTPUT TAPE 6,500,(B(J,I),J=1,6),AF,B(8,I)                  950JR037
```

```
      GO TO 100                                                         950JR038
C                                                                       950JR039
 40   IF (NPT+1) 48,44,44                                               950JR040
 44   AF = BODY1                                                        950JR041
      GO TO 60                                                          950JR042
 48   AF = BODY2                                                        950JR043
      GO TO 60                                                          950JR044
C                                                                       950JR045
 50   AF = SLPST                                                        950JR046
 60   CONTINUE                                                          950JR047
      WRITE OUTPUT TAPE 6,500,(B(J,I),J=1,6),AF                         950JR048
100   CONTINUE                                                          950JR049
200   WRITE TAPE K,B                                                    950JR050
      RETURN                                                            950JR051
      END
```

```
      SUBROUTINE XY (X1,Y1,X2,Y2,X3,Y3,X4,Y4,X,Y)                       950JS000
*     LABEL
 950JS                                                                  950JS
C                                                                       950JS001
C        ROUTINE TO INTERSECT TWO STRAIGHT LINES                        950JS002
C         IF X2 = 0  Y2 = SLOPE AT X1,Y1.                               950JS003
C     IF X4 = 0   Y4 = SLOPE AT X3,Y3.                                  950JS004
C                                                                       950JS005
      IF (X2) 10,20,10                                                  950JS006
 10   S1 = (Y2-Y1)/(X2-X1)                                              950JS007
      GO TO 30                                                          950JS008
C                                                                       950JS009
 20   S1 = Y2                                                           950JS010
 30   IF (X4) 40,50,40                                                  950JS011
 40   S2 = (Y3-Y4)/(X3-X4)                                              950JS012
      GO TO 60                                                          950JS013
C                                                                       950JS014
 50   S2 = Y4                                                           950JS015
 60   X = (S1*X1-S2*X3+Y3-Y1)/(S1-S2)                                   950JS016
      Y = Y1+(X-X1)*S1                                                  950JS017
C                                                                       950JS018
      RETURN                                                            950JS019
      END
```

```
      SUBROUTINE PAGE2 (J,A)                                            950JT000
*     LABEL
 950JT                                                                  950JT
C                                                                       950JT001
C     J = -1  READ HEADING CARD.                                        950JT002
C     J =  0  EJECT PAGE.                                               950JT003
C     J =  N  N IS NUMBER OF LINES TO BE PRINTED.                       950JT004
C                                                                       950JT005
      DIMENSION X(2),A(12),NAME(2)                                      950JT006
C                                                                       950JT007
 1010 FORMAT (1H1,12A6,5X2A6,5XA6,A2,5X4HPAGE,I3//)                     950JT008
C                                                                       950JT009
      IF (J) 10,20,30                                                   950JT010
C                                                                       950JT011
 10   NPAGE = 0                                                         950JT012
C                                                                       950JT013
 20   CALL DATT (NAME,X)                                                950JT014
      NPAGE = NPAGE+1                                                   950JT015
      NLINE = 40                                                        950JT016
      WRITE OUTPUT TAPE 6,1010,(A(I),I=1,12),NAME(1),NAME(2),           950JT017
     1  X(1),X(2),NPAGE                                                 950JT018
      GO TO 100                                                         950JT019
C                                                                       950JT020
 30   NLINE = NLINE-J                                                   950JT021
      IF (NLINE) 20,20,100                                              950JT022
C                                                                       950JT023
 100  RETURN                                                            950JT024
      END
```

```
C            2-D BODY POINT ROUTINE                                     950JU000
*     LABEL
 950JU                                                                  950JU
      SUBROUTINE BODYPT (T,XX1,XX2,XX3,C1,M1)                           950JU001
C                                                                       950JU002
C       T = 1.  - - INTERSECT BODY WITH RIGHT RUNNING CHAR.             950JU003
C       T = -1. - - INTERSECT BODY WITH LEFT RUNNING CHAR.              950JU004
C       XX1(10) IS THE BASE POINT ON BODY.                              950JU005
C       XX2(10) IS THE BASE POINT IN THE FIELD.                         950JU006
C       XX3(10) IS THE NEW BODY POINT.                                  950JU007
C       GAMMA(13) IS AN ARRAY OF FUNCTIONS OF GAMMA.                    950JU008
C       M1 IS A CONTROL INDICATOR . .                                   950JU009
C         = 1  MEANS CALCULATION IS COMPLETE.                           950JU010
C         = 2  MEANS THERE IS AN ERROR IN THE CALCULATION.              950JU011
C                                                                       950JU012
      DIMENSION XX1(10),XX2(10),XX3(10)                                 950JU013
C                                                                       950JU014
 23   FORMAT (//39H T34,T35, OR P3/R3 IS ZERO.  THE MACH ,              950JU015
     133HNUMBER FOR THIS APPROXIMATION IS ,1PE16.5,1H.///)              950JU016
      X1 = XX1(1)                                                       950JU017
      Y1 = XX1(2)                                                       950JU018
      P1 = XX1(3)                                                       950JU019
      TH1 = XX1(4)                                                      950JU020
      ZMU1 = XX1(5)                                                     950JU021
      R1 = XX1(6)                                                       950JU022
      X2 = XX2(1)                                                       950JU023
      Y2 = XX2(2)                                                       950JU024
      P2 = XX2(3)                                                       950JU025
      TH2 = XX2(4)                                                      950JU026
      ZMU2 = XX2(5)                                                     950JU027
C                                                                       950JU028
      IF (NN-4321) 10,20,10                                             950JU029
 10   NN = 4321                                                         950JU030
      C7 = (C1-1.0)/C1                                                  950JU031
      C12 = 2./(1.-C1)                                                  950JU032
C                                                                       950JU033
C       CALCULATE THE FIRST APPROXIMATION OF X3 ON THE                  950JU034
C       BODY.  THIS X3 IS USED BY SUBROUTINE LOCATE TO PICK             950JU035
C       THE COEFICIENTS OF THE APPROPRIATE CUBIC FOR THIS               950JU036
C       PART OF THE BODY.                                               950JU037
```

```
C                                                                 950JU038
 20   T1 = SINF(TH1)/COSF(TH1)                                    950JU039
      T2 = SINF(TH2-T*ZMU2)/COSF(TH2-T*ZMU2)                      950JU040
      X3 = (Y2-Y1+X1*T1-X2*T2)/(T1-T2)                            950JU041
      CALL LOCATE (1,T,ITT,AC,BC,CC,DC,X3)                        950JU042
 401  ARG4 = ZMU2                                                 950JU043
      ARG6 = TH2                                                  950JU044
      K = 0                                                       950JU045
      P3L = 1000.C                                                950JU046
      T11 = P2                                                    950JU047
      R3 = R1                                                     950JU048
      GO TO 403                                                   950JU049
 402  ARG4 = 0.5*(ZMU2+ZMU3)                                      950JU050
      ARG6 = 0.5*(TH2+TH3)                                        950JU051
      T11 = 0.5*(P2+P3)                                           950JU052
 403  ARG2 = ARG6 - T*ARG4                                        950JU053
      T10 = SINF(ARG6)                                            950JU054
      T8  = COSF(ARG4)                                            950JU055
      T9  = SINF(ARG4)                                            950JU056
      T3  = COSF(ARG2)                                            950JU057
      T4  = SINF(ARG2)                                            950JU058
      T81 = T4/T3                                                 950JU059
      T82 = CC -T81                                               950JU060
      T33 = DC-Y2+X2*T81                                          950JU061
C                                                                 950JU062
C       THE FOLLOWING LOOP CALCULATES THE INTERSECTION            950JU063
C       OF A CHARACTERISTIC WITH THE BODY.  THE METHOD            950JU064
C       USED IS NEWTON ITERATION.                                 950JU065
C                                                                 950JU066
 404  DO 431 I=1,20                                               950JU067
      POL = ((AC*X3+BC)*X3+T82)*X3+T33                            950JU068
      POLP = (3.*AC*X3+2.*BC)*X3+T82                              950JU069
      IF (ABSF(POLP) - .00000001) 405, 405, 430                   950JU070
 430  DPOL = POL/POLP                                             950JU071
      X3 = X3- DPOL                                               950JU072
      IF (ABSF(DPOL) - MAX1F(.00001 * X3, .00001)) 405, 405, 431  950JU073
 431  CONTINUE                                                    950JU074
 405  Y3 = Y2+ T81*(X3-X2)                                        950JU075
C                                                                 950JU076
C       CALCULATE FLOW DIRECTION (TH3), PRESSURE (P3),            950JU077
C         MACH ANGLE (ZMU3).                                      950JU078
```

```
C                                                                       950JU079
  407 T18 = 1.0/(T8*T9)                                                 950JU080
      TH3 = ATANF((3.*AC*X3+2.*BC)*X3+CC)                               950JU081
      P3 = P2+C1*T11*(T*T18*(TH3-TH2))                                  950JU082
  373 T30 = P3/R3                                                       950JU083
      IF (T30) 406,406,375                                              950JU084
  375 T30 = C12*(1.-T30**(-C7)) -1.                                     950JU085
      IF (T30-.04) 406,406,377                                          950JU086
  406 M1 = 2                                                            950JU087
      WRITE OUTPUT TAPE 6,23                                            950JU088
      GO TO 380                                                         950JU089
  377 ZMU3 = ATANF(SQRTF(1.0/T30))                                      950JU090
C                                                                       950JU091
C       CONVERGENCE TEST (DIFFERENCE IN PRESSURE                        950JU092
C       ON TWO SUCCESSIVE APPROXIMATIONS MUST BE                        950JU093
C       LESS THAN .001 OF CURRENT PRESSURE).                            950JU094
C                                                                       950JU095
      IF (ABSF(P3-P3L)-.001*P3) 378,378,379                             950JU096
  379 P3L=P3                                                            950JU097
      IF (K-100) 1,1,378                                                950JU098
  1   K = K +1                                                          950JU099
      GO TO 402                                                         950JU100
  378 M1 = 1                                                            950JU101
C       X3 MUST BE CHECKED BY SUBROUTINE LOCATE                         950JU102
C       TO MAKE SURE THAT THE COEFICIENTS USED IN                       950JU103
C       THE CALCULATION ARE THE RIGHT COEFICIENTS.                      950JU104
C                                                                       950JU105
      CALL LOCATE (0,T,ITT,AC,BC,CC,DC,X3)                              950JU106
      IF (ITT) 380,380,401                                              950JU107
C                                                                       950JU108
  380 XX3(1) = X3                                                       950JU109
      XX3(2) = Y3                                                       950JU110
      XX3(3) = P3                                                       950JU111
      XX3(4) = TH3                                                      950JU112
      XX3(5) = ZMU3                                                     950JU113
      XX3(6) = R3                                                       950JU114
      XX3(7) = XX1(7)                                                   950JU115
      RETURN                                                            950JU115
      END
```

```
CCUBIC                                                                  950JV000
*     LABEL
 950JV                                                                  950JV
      SUBROUTINE  CUBIC (X,Y,IND,N,DY1,DY2,ACI)                         950JV001
      DIMENSION X(1),Y(1),IND(1)                                        950JV002
      DIMENSION XX(50),YY(50),A(100),ACI(6,1)                           950JV003
      DDY1 = DY1                                                        950JV004
      IL = 1                                                            950JV005
      K = 0                                                             950JV006
      DO 60 I=1,N                                                       950JV007
      K = K+1                                                           950JV008
      XX(K) = X(I)                                                      950JV009
      YY(K) = Y(I)                                                      950JV010
      IF (I-N) 5,20,5                                                   950JV011
 5    IF (IND(I)) 60,60,30                                              950JV012
 20   DDY2 = DY2                                                        950JV013
      IF (K-2) 60,60,40                                                 950JV014
 30   SLOPE = (Y(I+1)-Y(I)) / (X(I+1)-X(I))                             950JV015
      IF (I-1) 35,50,35                                                 950JV016
 35   DDY2 = SLOPE                                                      950JV017
 40   IA = 2*IL-1                                                       950JV018
      CALL CURFIT (XX,YY,A(IA),K,DDY1,DDY2,1,1)                         950JV019
      IF (I-N) 50,60,50                                                 950JV020
 50   IA = 2*I-1                                                        950JV021
      A(IA) = 0.                                                        950JV022
      A(IA+1) = 0.                                                      950JV023
      IL = I+1                                                          950JV024
      K = 0                                                             950JV025
      DDY1 = SLOPE                                                      950JV026
 60   CONTINUE                                                          950JV027
      NN = N-1                                                          950JV028
      DO 70 I=1,NN                                                      950JV029
      IA = 2*I-1                                                        950JV030
      A1 = A(IA)                                                        950JV031
      A2 = A(IA+1)                                                      950JV032
      X1 = X(I)                                                         950JV033
      X2 = X(I+1)                                                       950JV034
      Y1 = Y(I)                                                         950JV035
      Y2 = Y(I+1)                                                       950JV036
      SLOPE = (Y2-Y1) / (X2-X1)                                         950JV037
```

```
      X1X2 = X1*X2                                                      950JV038
      ACI(6,I) = X2                                                     950JV039
      ACI(5,I) = Y1-SLOPE*X1-X1X2*(A1-A2*X1)                            950JV040
      ACI(4,I) = SLOPE+A1*(X1+X2)-A2*X1*(X1+2.*X2)                      950JV041
      ACI(3,I) = -A1+A2*(2.*X1+X2)                                      950JV042
      ACI(2,I) = -A2                                                    950JV043
      ACI(1,I) = X1                                                     950JV044
   70 CONTINUE                                                          950JV045
      RETURN                                                            950JV046
      END
```

```
C        2-D FIELD POINT CALCULATION                                  950JW000
*     LABEL
 950JW                                                                950JW
      SUBROUTINE FDPT (XX1,XX2,XX3,GAMMA,M1)                          950JW001
C                                                                     950JW002
      DIMENSION XX1(10),XX2(10),XX3(10)                               950JW003
C                                                                     950JW004
 22   FORMAT(25H  Y3 IS ZERO OR NEGATIVE.)                            950JW005
 23   FORMAT (21H  T34 OR T35 IS ZERO.)                               950JW006
 24   FORMAT (23H  RAD OR P3/R3 IS ZERO.)                             950JW007
C                                                                     950JW008
      C1 = GAMMA                                                      950JW009
      RRRR = 0.0                                                      950JW010
      X1 = XX1(1)                                                     950JW011
      Y1 = XX1(2)                                                     950JW012
      P1 = XX1(3)                                                     950JW013
      TH1 = XX1(4)                                                    950JW014
      ZMU1 = XX1(5)                                                   950JW015
      R1 = XX1(6)                                                     950JW016
      X2 = XX2(1)                                                     950JW017
      Y2 = XX2(2)                                                     950JW018
      P2 = XX2(3)                                                     950JW019
      TH2 = XX2(4)                                                    950JW020
      ZMU2 = XX2(5)                                                   950JW021
      R2 = XX2(6)                                                     950JW022
C                                                                     950JW023
      C7 = (C1-1.0)/C1                                                950JW024
      C12 = 2./(1.-C1)                                                950JW025
 362  CT1 = (P1-P2)/C1                                                950JW026
      CT2 = TH1-TH2                                                   950JW027
      ARG3 = ZMU1                                                     950JW028
      ARG5 = TH1                                                      950JW029
      ARG4 = ZMU2                                                     950JW030
      ARG6 = TH2                                                      950JW031
      T35 = Y1                                                        950JW032
      T34 = Y2                                                        950JW033
      NPT3 = 0                                                        950JW034
      T11 = P1                                                        950JW035
      T12 = P2                                                        950JW036
      T7 = SINF(ARG5)                                                 950JW037
```

```
      T10 = SINF(ARG6)                                                  950JW038
      T22 = COSF(ARG5)                                                  950JW039
      T23 = COSF(ARG6)                                                  950JW040
      T25 = T10/T23                                                     950JW041
      T24 = T7/T22 -T25                                                 950JW042
      T26 = X1-X2                                                       950JW043
      T27 = Y1-Y2                                                       950JW044
      T28 = R1-R2                                                       950JW045
      P3L = 1000.0                                                      950JW046
      KTR = 0                                                           950JW047
      GO TO 364                                                         950JW048
C                                                                       950JW049
C     ENTER 363 ON SECOND AND SUBSEQUENT ITERATIONS TO FIND AVERAGE MACH950JW050
C     ANGLES,FLOW DIRECTIONS,AND PRESSURE.                              950JW051
C                                                                       950JW052
  363 ARG3 = 0.5*(ZMU1+ZMU3)                                            950JW053
      ARG5 = 0.5*(TH1+TH3)                                              950JW054
      ARG4 = 0.5*(ZMU2+ZMU3)                                            950JW055
      ARG6 = 0.5*(TH2+TH3)                                              950JW056
      T7 = SINF(ARG5)                                                   950JW057
      T10 = SINF(ARG6)                                                  950JW058
      T11 = 0.5*(P1+P3)                                                 950JW059
      T12 = 0.5*(P2+P3)                                                 950JW060
C                                                                       950JW061
C     PREPARE TERMS NECESSARY FOR CALC. OF COEFS. OF COMPATIBILITY EQS. 950JW062
C     FIND INTERSECTION OF LEFT AND RIGHT CHAR. THRU PT.1 AND PT.2,RESP.950JW063
C     ,TO LOCATE APPROX. PT.3. TEST FOR VANISHING OF AVERAGE ORDINATES  950JW064
C     BEFORE PROCEEDING.                                                950JW065
C                                                                       950JW066
  364 ARG1 = ARG5 + ARG3                                                950JW067
      ARG2 = ARG6 - ARG4                                                950JW068
      T1 = COSF(ARG1)                                                   950JW069
      T2 = SINF(ARG1)                                                   950JW070
      T3 = COSF(ARG2)                                                   950JW071
      T4 = SINF(ARG2)                                                   950JW072
      T5 = COSF(ARG3)                                                   950JW073
      T6 = SINF(ARG3)                                                   950JW074
      T8 = COSF(ARG4)                                                   950JW075
      T9 = SINF(ARG4)                                                   950JW076
      T13 = T3/T4                                                       950JW077
      T14 = T1/T2                                                       950JW078
```

```
      T15 = T12/T11                                                     950JW079
      T16 = 1.0/(T5*T6)                                                 950JW080
      T18 = 1.0/(T8*T9)                                                 950JW081
      Y3 = (X2-Y2*T13-X1+Y1*T14)/(T14-T13)                              950JW082
      IF (Y3) 1,1,2                                                     950JW083
 1    M1 = 2                                                            950JW084
      WRITE OUTPUT TAPE 6,22                                            950JW085
      GO TO 380                                                         950JW086
 2    X3 = X1 +(Y3-Y1)*T14                                              950JW087
      IF (ABSF(P1-P2) - .000001) 10,10,11                               950JW088
 10   IF (ABSF(TH1-TH2)-.000001)  12,12,11                              950JW089
 12   P3 = P1                                                           950JW090
      TH 3 = TH1                                                        950JW091
      ZMU3 = ZMU1                                                       950JW092
      R3 = R1                                                           950JW093
      W3 = W1                                                           950JW094
      GO TO 378                                                         950JW095
 11   T35 = 0.5*(Y1+Y3)                                                 950JW096
      T34= 0.5*(Y2+Y3)                                                  950JW097
      IF (T35) 366,650,366                                              950JW098
 366  IF (T34) 367,650,367                                              950JW099
 650  M1 = 2                                                            950JW100
      WRITE OUTPUT TAPE 6,23                                            950JW101
      GO TO 380                                                         950JW102
C                                                                       950JW103
C     COMPLETE CALC. OF COEFS. OF COMP. EQS..CALCULATE FLOW DIRECTION   950JW104
C     AND PRESSURE.                                                     950JW105
C                                                                       950JW106
 367  T17 = T7/(T5*T1*T35)                                              950JW107
      T19 = T10/(T8*T3*T34) *RRRR                                       950JW108
      T20 = (X3-X1)*RRRR                                                950JW109
      T21 = X3-X2                                                       950JW110
      TH3 = TH2 +(CT1/T11 +T16*CT2 -T17*T20 +T19*T15*T21)/(T16+ T15*T18)950JW111
      P3 = P2 + C1*T12*(T18*(TH3-TH2)-T19*T21)                          950JW112
C                                                                       950JW113
C     PREPARE FACTOR RR USED IN CALC. OF STAG. PRESSURE RATIO. OF TWO   950JW114
C     VALUES FOR RR,CHOOSE VALUE NEAREST 1/2. THEN CALC. STAG. PRESSURE 950JW115
C     RATIO FOR PT.3.                                                   950JW116
C                                                                       950JW117
      T29 = SINF(TH3)/COSF(TH3) +T25                                    950JW118
      D = 0.5*((T26*T29-2.0*T27)/T24 -T21)                              950JW119
```

```
      E = (-T21*T29-2.0*(Y2-Y3))*T26/T24                                 950JW120
      RAD = D**2-E                                                       950JW121
      IF (RAD) 370,368,368                                               950JW122
  370 M1 = 2                                                             950JW123
      WRITE OUTPUT TAPE 6,24                                             950JW124
 1111 FORMAT (1P6E15.5)                                                  950JW125
      WRITE OUTPUT TAPE 6,1111,(XX1(I),I=1,6)                            950JW126
      WRITE OUTPUT TAPE 6,1111,(XX2(I),I=1,6)                            950JW127
      CALL DUMP                                                          950JW128
  368 RAD = SQRTF(RAD)                                                   950JW129
      RR1 =(-D+RAD)/T26                                                  950JW130
      RR2 =(-D-RAD)/T26                                                  950JW131
      RRR = SINF(TH3)/COSF(TH3)                                          950JW132
      RRF =-((X2-X3)*RRR-Y2+Y3)/((X1-X2)*RRR-Y1+Y2)                      950JW133
      IF (ABSF(RRF-RR1)-ABSF(RRF-RR2)) 369,371,371                       950JW134
  369 RR =RR1                                                            950JW135
      GO TO 372                                                          950JW136
  371 RR =RR2                                                            950JW137
  372 R3 =R2 +RR*T28                                                     950JW138
C                                                                        950JW139
  373 T30 = P3/R3                                                        950JW140
      IF (T30) 370,370,375                                               950JW141
  375 T30 = C12*(1.-T30**(-C7)) -1.                                      950JW142
      IF (T30-.04) 374,374,377                                           950JW143
  374 M1 = 3                                                             950JW144
      GO TO 380                                                          950JW145
  377 ZMU3 = ATANF(SQRTF(1.0/T30))                                       950JW146
C                                                                        950JW147
      IF (ABSF(P3-P3L)-.001*P3) 378,378,379                              950JW148
  379 P3L=P3                                                             950JW149
      IF (KTR-100) 1017,1017,378                                         950JW150
 1017 KTR = KTR+1                                                        950JW151
      GO TO 363                                                          950JW152
  378 M1 = 1                                                             950JW153
  380 XX3(1) = X3                                                        950JW154
      XX3(2) = Y3                                                        950JW155
      XX3(3) = P3                                                        950JW156
      XX3(4) = TH3                                                       950JW157
      XX3(5) = ZMU3                                                      950JW158
      XX3(6) = R3                                                        950JW159
      XX3(7) = 0.0                                                       950JW160
```

```
      RETURN                                                          950JW161
      END
```

```
      SUBROUTINE SHK1 (AA,STH,XX1,XX3,C1,M1)                            950JY000
*     LABEL
 950JY                                                                  950JY
C                                                                       950JY001
C        AA = 1.   FOR LEFT RUNNING SHOCHS.                             950JY002
C        AA = -1.  FOR RIGHT RUNNING SHOCHS.                            950JY003
C        STH IS THE DIRECTION TO WHICH THE FLOW TURN.                   950JY004
C        XX1(10) IS THE INCIDENT PROPERTIES AT THE TURNING POINT        950JY005
C        XX3(10) IS THE TRANSMITTED PROPERTIES (OUTPUT).                950JY006
C        C1 IS GAMMA                                                    950JY007
C        M1 IS INDICATOR                                                950JY008
C          M1=1 MEANS CALCULATION WAS SUCCESSFUL.                       950JY009
C          M1=2 MEANS ERROR IN CALCULATION.                             950JY010
C                                                                       950JY011
      DIMENSION XX1(10),XX3(10)                                         950JY012
C                                                                       950JY013
 22   FORMAT (//44H ERROR IN SUBROUTINE SHK1.  THE DESIRED TURN         950JY014
     140H IS TOO GREAT FOR THE LOCAL MACH NUMBER./12H MACH NO. IS,      950JY015
     21PE15.5,15H   DESIRED TURN,1PE15.5,21H (RADIANS)  MAX. TURN,1PE15.950JY016
     35,10H (RADIANS)/5H X1 =1PE15.5,6H  Y1 =1PE15.5,6H  P1 =1PE15.5,   950JY017
     47H  TH1 =1PE15.5,8H  ZMU1 =1PE15.5//)                             950JY018
C                                                                       950JY019
      R2RF(A,B,D)=A*(B*(C6*(1./D+C10))**C1)**C2                         950JY020
      ZM2F(A,B)  =ATANF(SQRTF(1./(C12*(1.-(A/B)**(-C7))-1.)))           950JY021
      PRODF(A,B)=(A*SINF(B))**2                                         950JY022
      PR2F(A)=C4*(A-C11)                                                950JY023
C                                                                       950JY024
C                                                                       950JY025
      P1U = XX1(3)                                                      950JY026
      TH1U = XX1(4)                                                     950JY027
      ZMU1U = XX1(5)                                                    950JY028
      R1U = XX1(6)                                                      950JY029
      IF (NN-4321) 10,20,10                                             950JY030
 10   NN = 4321                                                         950JY031
      C2 = 1./(1.-C1)                                                   950JY032
      C4 = 2.*C1/(C1+1.)                                                950JY033
      C7 = (C1-1.)/C1                                                   950JY034
      C10 = (C1-1.)/2.                                                  950JY035
      C11 = (C1-1.)/(2.0*C1)                                            950JY036
      C12 = 2./(1.-C1)                                                  950JY037
```

```
      C6 = 2./(C1+1.)                                                   950JY038
      C9 = (C1+1.0)/2.0                                                 950JY039
C                                                                       950JY040
 20   DEL = AA*(STH-TH1U)                                               950JY041
      NPT3 = NPT1U                                                      950JY042
C                                                                       950JY043
C       THE FOLLOWING STATEMENTS CALCULATE THE QUANTITY                 950JY044
C       DELIM WHICH IS THE MAXIMUM DEFLECTION ANGLE                     950JY045
C       POSSIBLE FOR FLOW TO REMAIN SUPERSONIC.                         950JY046
C       THIS ANGLE IS THEN COMPARED WITH THE DESIRED                    950JY047
C       TURNING ANGLE. IF THE DESIRED TURN IS TO GREAT                  950JY048
C       THE CALCULATION IS TERMINATED.                                  950JY049
C                                                                       950JY050
 62   T32= (1./SINF(ZMU1U))**2                                          950JY051
      WW= ATANF(SQRTF(1.0/(T32-1.0)))                                   950JY052
      DW = -.001                                                        950JY053
      WL =WW                                                            950JY054
      SSW2 =(1./(4.*T32*C1)) * (2.*C9* T32- (3.-C1) +                   950JY055
     1      SQRTF(2.*C9*(2.* C9*T32**2-2.*T32*(3.-C1) +  C1+9.)))       950JY056
      WLIM =ATANF(SQRTF(1./(1. /SSW2-1.)))                              950JY057
      T29 = SINF(2.0*WLIM)                                              950JY058
      T65 = COSF(2.*WLIM)                                               950JY059
      T66  =T32 * T29 - 2. * COSF(WLIM)/SINF(WLIM)                      950JY060
      T67  =T32 * (C1 + T65) + 2.0                                      950JY061
      DELIM=ATANF (T66/T67)                                             950JY062
      IF (DEL-DELIM) 905,97,97                                          950JY063
 97   K = K                                                             950JY064
      T32 = SQRTF(T32)                                                  950JY065
      WRITE OUTPUT TAPE 6,22,T32,DEL,DELIM,X1,Y1,P1,TH1,ZMU1            950JY066
      M1 = 2                                                            950JY067
      RETURN                                                            950JY068
C                                                                       950JY069
C       THE FOLLOWING LOOP IS AN ITERATION ON THE SHOCK                 950JY070
C       ANGLE (WW).                                                     950JY071
C                                                                       950JY072
 905  DO 60  K = 1,100                                                  950JY073
 903  WW= WW+DW                                                         950JY074
      T29 = SINF(2.0*WW)                                                950JY075
      T65 = COSF(2.0*WW)                                                950JY076
      T66 = T32*T29 -2.0*COSF(WW)/SINF(WW)                              950JY077
      T67 = T32*(C1 + T65) + 2.0                                        950JY078
```

```
      DELL = ATANF(T66/T67)                                             950JY079
      IF (ABSF(DEL - DELL) - .00001) 904,904,900                        950JY080
 900  DDDW = 2.0*COSF(DELL)**2/T67 *(T32*T65 + 1.0/SINF(WW)**2+T66*T32*T950JY081
     129/T67)                                                           950JY082
      IF (DDDW) 901,904,901                                             950JY083
 901  DW = SIGNF(MIN1F(1.,ABSF(1./DDDW)),DDDW)*(DEL-DELL)               950JY084
 60   CONTINUE                                                          950JY085
 904  Z = PRODF((1./SINF(ZMU1U)),WW)                                    950JY086
C                                                                       950JY087
C        CALCULATION OF PRESSURE (PRES), MACH ANGLE (ZMU),              950JY088
C        TOTAL PRESSURE (R1) BY USING THE OBLIQUE SHOCK                 950JY089
C        RELATIONS.                                                     950JY090
C                                                                       950JY091
      P1P2 = PR2F(Z)                                                    950JY092
      R1   = R2RF(R1U,P1P2,Z)                                           950JY093
      PRES = P1P2 * P1U                                                 950JY094
      ZMU = ZM2F(PRES,R1 )                                              950JY095
C                                                                       950JY096
C                                                                       950JY097
      XX3(1) = XX1(1)                                                   950JY098
      XX3(2) = XX1(2)                                                   950JY099
      XX3(3) = PRES                                                     950JY100
      XX3(4) = STH                                                      950JY101
      XX3(5) = ZMU                                                      950JY102
      XX3(6) = R1                                                       950JY103
      XX3(7) = XX1(7)                                                   950JY104
      XX3(8) = WW                                                       950JY105
C                                                                       950JY106
      M1 = 1                                                            950JY107
      RETURN                                                            950JY108
      END
```

```
      SUBROUTINE SLPSTM (T,XX1,XX2,XX3,C1)                               950JQ000
*     LABEL
 950JQ                                                                   950JQ
C                                                                        950JQ001
C     ROUTINE TO CALCULATE A POINT ON A SLIPSTREAM.                      950JQ002
C                                                                        950JQ003
C       T = 1.  - - INTERSECT BODY WITH RIGHT RUNNING CHAR.              950JQ004
C       T = -1. - - INTERSECT BODY WITH LEFT RUNNING CHAR.               950JQ005
C                                                                        950JQ006
      DIMENSION XX1(10),XX2(10),XX3(10)                                  950JQ007
C                                                                        950JQ008
C                                                                        950JQ009
 21   FORMAT (1P4E16.5)                                                  950JQ010
 23   FORMAT (26H T34,T35 OR P3/R3 IS ZERO.)                             950JQ011
      RRR = 0.0                                                          950JQ012
      X1 = XX1(1)                                                        950JQ013
      Y1 = XX1(2)                                                        950JQ014
      P1 = XX1(3)                                                        950JQ015
      TH1 = XX1(4)                                                       950JQ016
      ZMU1 = XX1(5)                                                      950JQ017
      R1 = XX1(6)                                                        950JQ018
      X2 = XX2(1)                                                        950JQ019
      Y2 = XX2(2)                                                        950JQ020
      P2 = XX2(3)                                                        950JQ021
      TH2 = XX2(4)                                                       950JQ022
      ZMU2 = XX2(5)                                                      950JQ023
      P3 = XX3(3)                                                        950JQ024
      TH3 = XX3(4)                                                       950JQ025
      ZMU3 = XX3(5)                                                      950JQ026
      R3 = R1                                                            950JQ027
C                                                                        950JQ028
      C7 = (C1-1.0)/C1                                                   950JQ029
      C12 = 2./(1.-C1)                                                   950JQ030
      DO 379 I=1,20                                                      950JQ031
      T1 = (TH1+TH3)/2.                                                  950JQ032
      T1 = SINF(T1)/COSF(T1)                                             950JQ033
      T2 = (TH2+TH3)/2.-T*(ZMU2+ZMU3)/2.                                 950JQ034
      T2 = SINF(T2)/COSF(T2)                                             950JQ035
      X3 = (Y2-Y1+X1*T1-X2*T2)/(T1-T2)                                   950JQ036
 402  ARG4 = 0.5*(ZMU2+ZMU3)                                             950JQ037
```

```
      ARG6 = 0.5*(TH2+TH3)                                    950JQ038
      T11 = 0.5*(P2+P3)                                       950JQ039
  403 ARG2 = ARG6 - T*ARG4                                    950JQ040
      T10 = SINF(ARG6)                                        950JQ041
      T8  = COSF(ARG4)                                        950JQ042
      T9  = SINF(ARG4)                                        950JQ043
      T3  = COSF(ARG2)                                        950JQ044
      T4  = SINF(ARG2)                                        950JQ045
      T81 = T4/T3                                             950JQ046
  405 Y3 = Y2+ T81*(X3-X2)                                    950JQ047
      T34 = 0.5*(Y2 +Y3)                                      950JQ048
      IF (T34) 407,406,407                                    950JQ049
  406 M1 = 2                                                  950JQ050
      WRITE OUTPUT TAPE 6,23                                  950JQ051
      GO TO 360                                               950JQ052
  407 T18 = 1.0/(T8*T9)                                       950JQ053
      T19 = T10/(T8*T3*T34)*RRR                               950JQ054
      P3L = P3                                                950JQ055
      P3 = P2 +C1*T11*(T*T18*(TH3-TH2)-T19*(X3-X2))           950JQ055
  373 T30 = P3/R3                                             950JQ056
      IF (T30) 406,406,375                                    950JQ057
  375 T30 = C12*(1.-T30**(-C7)) -1.                           950JQ058
      IF (T30-.04) 376,376,377                                950JQ059
  376 M1 = 3                                                  950JQ060
      GO TO 380                                               950JQ061
  377 ZMU3 = ATANF(SQRTF(1.0/T30))                            950JQ062
      IF (ABSF(P3-P3L)-.001*P3) 380,380,379                   950JQ062
  379 CONTINUE                                                950JQ063
C                                                             950JQ064
  380 XX3(1) = X3                                             950JQ065
      XX3(2) = Y3                                             950JQ066
      XX3(3) = P3                                             950JQ067
      XX3(4) = TH3                                            950JQ068
      XX3(5) = ZMU3                                           950JQ069
      XX3(6) = R3                                             950JQ070
      RETURN                                                  950JQ071
      END
```

```
      SUBROUTINE MEET (X1,Y1,N1,X2,Y2,N2,XP,YP,DY1,DY2)                 950JX000
*     LABEL
 950JX                                                                  950JX
      DIMENSION X1(1),Y1(1),X2(1),Y2(1),A1(100),A2(100)                950JX001
      DIMENSION X(21),D(21),A(40)                                      950JX002
      XL = MAX1F(X2(1),X1(1))                                          950JX003
      XU = MIN1F(X2(N2),X1(N1))                                        950JX004
      IF (XU-XL) 2,2,4                                                 950JX005
 2    WRITE OUTPUT TAPE 6,601,XL,XU                                    950JX006
 601  FORMAT (24H0ERROR IN MEET......XL =E14.6,4HXU =E14.6)            950JX007
      WRITE OUTPUT TAPE 6 ,600,XP,YP,DY1,DY2,ERROR,                    950JX008
     1  (X(I),D(I), I=1,N)                                             950JX009
      GO TO 90                                                         950JX010
 4    CONTINUE                                                         950JX011
      N = 21                                                           950JX012
      ANY = N-1                                                        950JX013
      DELX = (XU-XL)/ANY                                               950JX014
      CALL CURFIT (X1,Y1,A1,N1,0.,0.,2,2)                              950JX015
      CALL CURFIT (X2,Y2,A2,N2,0.,0.,2,2)                              950JX016
      DO 10 I=1,N                                                      950JX017
      XI = I-1                                                         950JX018
      X(I) = XL+XI*DELX                                                950JX019
      CALL CURVE (A1,X1,Y1,X(I),YY1,ANY,N1,1)                          950JX020
      CALL CURVE (A2,X2,Y2,X(I),YY2,ANY,N2,1)                          950JX021
      D(I) = YY2-YY1                                                   950JX022
 10   CONTINUE                                                         950JX023
      IF (D(2)-D(1))20,90,40                                           950JX024
 20   DO 30 I=1,N                                                      950JX025
 30   D(I) = -D(I)                                                     950JX026
 40   CALL CURFIT (D,X,A,N,0.,0.,2,2)                                  950JX027
      CALL CURVE (A,D,X,0.,XP,ANY,N,1)                                 950JX028
      CALL CURVE (A1,X1,Y1,XP,YP1,DY1,N1,3)                            950JX029
      CALL CURVE (A2,X2,Y2,XP,YP2,DY2,N2,3)                            950JX030
      ERROR = YP2-YP1                                                  950JX031
      YP = (YP2+YP1)*.5                                                950JX032
 90   CONTINUE                                                         950JX033
 600  FORMAT (1H05E20.7//19X1HX17X3HDEL//(2E20.7))                     950JX034
      RETURN                                                           950JX035
      END
```

```
      SUBROUTINE CONV (P1,P2,DEL,DSTH,M1)                               950JHH00
*     LABEL
 950JHH                                                                 950JHH
C                                                                       950JHH01
C     ROUTINE TO CONTROL COVERGENCE OF SLIP-STREAM                      950JHH02
C     CALCULATION                                                       950JHH03
C                                                                       950JHH04
      DIMENSION X(20),Y1(20),Y2(20)                                     950JHH05
C                                                                       950JHH06
      IF (M1-9) 10,10,20                                                950JHH07
 10   Y1(M1) = P1                                                       950JHH08
      Y2(M1) = P2                                                       950JHH09
      X(M1) = DEL                                                       950JHH10
      DEL = DEL+DSTH                                                    950JHH11
      GO TO 30                                                          950JHH12
C                                                                       950JHH13
 20   CALL MEET (X,Y1,9,X,Y2,9,DEL,P,DUM,DUM)                           950JHH14
C                                                                       950JHH15
 30   RETURN                                                            950JHH16
      END
```

```
      SUBROUTINE DMOVE (X,Y)                                            950JII00
*     LABEL
 950JII                                                                 950JII
C                                                                       950JII01
C        MOVE DATA FROM Y TO X.   (X=Y)                                 950JII02
C                                                                       950JII03
      DIMENSION X(10),Y(10)                                             950JII04
C                                                                       950JII05
      DO 10 I=1,10                                                      950JII06
      X(I) = Y(I)                                                       950JII07
 10   CONTINUE                                                          950JII08
C                                                                       950JII09
      RETURN                                                            950JII10
      END
```

```
      SUBROUTINE LOCATE (IT,T,ITT,AC,BC,CC,DC,X)                        950J0000
*     LABEL
 950JO                                                                  950JO
      DIMENSION AC1(6,20),AC2(6,20)                                     950J0001
 20   FORMAT (28H ERROR IN SUBROUTINE LOCATE.)                          950J0002
C                                                                       950J0003
      X3 = X                                                            950J0004
      IB = IB                                                           950J0005
      JB = JB                                                           950J0006
      IF (IT) 1500,1000,100                                             950J0007
 100  IB = 1                                                            950J0008
      JB = 1                                                            950J0009
 110  IF (T) 9,99,99                                                    950J0010
 9    IF (X3-AC1(1,1))240,10,10                                         950J0011
 10   IF (X3-AC1(1,IB))  140,120,120                                    950J0012
 120  IF (AC1(6,IB) - X3)  150,150,130                                  950J0013
C                                                                       950J0014
 130  AC = AC1(2,IB)                                                    950J0015
      BC = AC1(3,IB)                                                    950J0016
      CC = AC1(4,IB)                                                    950J0017
      DC = AC1(5,IB)                                                    950J0018
      GO TO 401                                                         950J0019
C                                                                       950J0020
 140  IB = IB -1                                                        950J0021
      GO TO 10                                                          950J0022
C                                                                       950J0023
 150  IB = IB+1                                                         950J0024
      IF (IB-NN1) 10,10,240                                             950J0025
 99   IF (X3-AC2(1,1)) 240,11,11                                        950J0026
 11   IF (X3 - AC2(1,JB))  180,160,160                                  950J0027
 160  IF (AC2(6,JB) - X3)  190,190,170                                  950J0028
C                                                                       950J0029
 170  AC = AC2(2,JB)                                                    950J0030
      BC = AC2(3,JB)                                                    950J0031
      CC = AC2(4,JB)                                                    950J0032
      DC = AC2(5,JB)                                                    950J0033
      GO TO 401                                                         950J0034
C                                                                       950J0035
 180  JB = JB-1                                                         950J0036
      GO TO 11                                                          950J0037
```

```
C
 190  JB = JB+1
      IF (JB - NN2)   11,11,240
C
 401  ITT = 1
      GO TO 2000
 1000 IF (T) 200,220,220
 200  IF (X3 - AC1(1,IB))  140,210,210
 210  IF (AC1(6,IB) - X3)  150,150,380
C
 220  IF (X3 - AC2(1,JB))  180,230,230
 230  IF (AC2(6,JB) - X3)   190,380,380
 240  WRITE OUTPUT TAPE 6,20
      CALL DUMP
C
 1500 REWIND 2
      READ TAPE 2
      READ TAPE 2,AC1,AC2,NN1,NN2
      GO TO 2000
C
 380  ITT = 0
 2000 RETURN
      END
```

```
      SUBROUTINE MOVE1 (IB,BB)                                          950JPP00
*     LABEL
 950JPP                                                                 950JPP
C                                                                       950JPP01
      DIMENSION XX3(10),BB(10,100)                                      950JPP02
      EQUIVALENCE (XX3(7),NPT3)                                         950JPP03
      IB = 0                                                            950JPP04
      DO 40 I=1,100                                                     950JPP05
      IB = IB+1                                                         950JPP06
      CALL DMOVE (XX3,BB(1,IB))                                         950JPP07
      IF (NPT3-12345) 40,50,40                                          950JPP08
 40   CONTINUE                                                          950JPP09
 50   RETURN                                                            950JPP10
      END
```

```
      SUBROUTINE SHOCK (N,M1,AA,XXA,XXB,XX1U,XX1,XX2,XX3U,XX3,XX5,C1,SW,950J2000
     1FSM)                                                              950JZ000
C                                                                       950JZ001
C        AA =  1.  FOR LEFT RUNNING SHOCKS.                             950JZ002
C        AA = -1.  FOR RIGHT RUNNING SHOCKS.                            950JZ003
C     N + FOR BOW WAVE, NEGATIVE FOR SHOCK WAVE IN FIELD.               950JZ004
C                                                                       950JZ005
      DIMENSION XXA(10),XXB(10),XX1U(10),XX1(10),XX2(10),XX3U(10),XX3(10950JZ006
     1          ),XX5(10)                                               950JZ007
C                                                                       950JZ008
 21   FORMAT (1P6E15.7,I15)                                             950JZ009
 22   FORMAT (28H  P3/R3 IS NEGATIVE OR ZERO.)                          950JZ010
 23   FORMAT (43H  RR2 OUT OF BOUNDS WHILE NPT2 IS NEGATIVE.)           950JZ011
 24   FORMAT (1H ///, 21H  SHOCK IS TOO WEAK. )                         950JZ012
 25   FORMAT (1P7E15.5)                                                 950JZ013
C                                                                       950JZ014
      R = 0.0                                                           950JZ015
      C2 = 1./(1.-C1)                                                   950JZ016
      C3 = C1/(C1-1.)                                                   950JZ017
      C4 = 2.*C1/(C1+1.)                                                950JZ018
      C5 = (C1-1.)/(C1+1.)                                              950JZ019
      C7 = (C1-1.)/C1                                                   950JZ020
      C10 = (C1-1.)/2.                                                  950JZ021
      C11 = (C1-1.)/(2.0*C1)                                            950JZ022
      C12 = 2./(1.-C1)                                                  950JZ023
      SFW = SW/2.                                                       950JZ024
      DW3 =0.0                                                          950JZ025
      X1U = XX1U(1)                                                     950JZ026
      Y1U = XX1U(2)                                                     950JZ027
      P1U = XX1U(3)                                                     950JZ028
      TH1U = XX1U(4)                                                    950JZ029
      ZMU1U = XX1U(5)                                                   950JZ030
      R1U = XX1U(6)                                                     950JZ031
      X1 = XX1(1)                                                       950JZ032
      Y1 = XX1(2)                                                       950JZ033
      P1 = XX1(3)                                                       950JZ034
      TH1 = XX1(4)                                                      950JZ035
      ZMU1 = XX1(5)                                                     950JZ036
      R1 = XX1(6)                                                       950JZ037
      W1 = ABSF(XX1(8))                                                 950JZ038
```

```
      X2 = XX2(1)                                                        950JZ039
      Y2 = XX2(2)                                                        950JZ040
      P2 = XX2(3)                                                        950JZ041
      TH2 = XX2(4)                                                       950JZ042
      ZMU2 = XX2(5)                                                      950JZ043
      R2 = XX2(6)                                                        950JZ044
      IF (N) 9011,9011,5                                                 950JZ045
5     ZM3A = FSM                                                         950JZ046
      ZM3B = FSM                                                         950JZ047
      TH3A = 0.0                                                         950JZ048
      TH3B = 0.0                                                         950JZ049
      R3A = 1.0                                                          950JZ050
      R3B = 1.0                                                          950JZ051
      FSM2 = FSM**2                                                      950JZ052
      P3A = (1.+C10*FSM2)**(-C3)                                         950JZ053
      P3B = P3A                                                          950JZ054
      ZMU3A = ATANF(SQRTF(1./(FSM2-1.)))                                 950JZ055
      X3 = X1+SW*COSF(W1)                                                950JZ056
      Y3 = Y1+SW*SINF(W1) *AA                                            950JZ057
      Y3B = Y3+SINF(-ZMU3A)*SFW *AA                                      950JZ058
      Y3A = Y3-SINF(-ZMU3A)*SFW *AA                                      950JZ059
      X3A = X3-COSF(-ZMU3A)*SFW                                          950JZ060
      X3B = X3+COSF(-ZMU3A)*SFW                                          950JZ061
      ZMU3B = ZMU3A                                                      950JZ062
      GO TO 783                                                          950JZ063
9011  X3A = XXA(1)                                                       950JZ064
      Y3A = XXA(2)                                                       950JZ065
      P3A = XXA(3)                                                       950JZ066
      TH3A = XXA(4)                                                      950JZ067
      ZMU3A = XXA(5)                                                     950JZ068
      R3A = XXA(6)                                                       950JZ069
      X3B = XXB(1)                                                       950JZ070
      Y3B = XXB(2)                                                       950JZ071
      P3B = XXB(3)                                                       950JZ072
      TH3B = XXB(4)                                                      950JZ073
      ZMU3B = XXB(5)                                                     950JZ074
      R3B = XXB(6)                                                       950JZ075
      XA = X3A                                                           950JZ076
      XB = X3B                                                           950JZ077
762   ZM3A = 1./SINF(ZMU3A)                                              950JZ078
      ZM3B = 1. / SINF(ZMU3B)                                            950JZ079
```

```
C                                                                          950JZ080
  783 NFLAG = XABSF(N)                                                     950JZ081
      W3 = W1                                                              950JZ082
  737 SLP1 =(Y3B-Y3A)/(X3B-X3A)                                            950JZ083
      T61  = P3B - P3A                                                     950JZ084
      T62  = TH3B -TH3A                                                    950JZ085
      T83 = ZMU3B - ZMU3A                                                  950JZ086
      T63  = ZM3B -ZM3A                                                    950JZ087
      T64  = R3B -R3A                                                      950JZ088
  700 RR2 = 0.5                                                            950JZ089
      P3LS = 1000.                                                         950JZ090
      KTR = 0                                                              950JZ091
      RR1=.5                                                               950JZ092
      SH1 = T62/2.                                                         950JZ093
      SH2 = (TH1U+TH3A)/2.                                                 950JZ094
      SH3 = 1./SLP1                                                        950JZ095
      SH4 = (Y3A-Y1)/(Y3B-Y3A)                                             950JZ096
      SH5 = (X3A-X1)/(X3B-X3A)                                             950JZ097
  701 SH6 =(AA*(W3+W1) + TH1U + TH3A)/2.                                   950JZ098
      DO 771 I=1,20                                                        950JZ099
      SH8 = SH6+RR1*SH1                                                    950JZ100
      SH9 = SINF(SH8)                                                      950JZ101
      SH10= COSF(SH8)                                                      950JZ102
      SH11= SH9/SH10                                                       950JZ103
      SH12= RR1+SH4-(RR1+SH5)*SH3*SH11                                     950JZ104
      SH13= 1. -SH3*(SH11+SH1*(RR1+SH5)/(SH10)**2)                         950JZ105
      IF (ABSF(SH13) - .00000001) 773,773,772                              950JZ106
  772 DRR1 = SH12 /SH13                                                    950JZ107
      RR1 = RR1 - DRR1                                                     950JZ108
      IF (ABSF(DRR1) - MAX1F(ABSF(RR1 * .000001) , .00001)) 773,773,771    950JZ109
  771 CONTINUE                                                             950JZ110
  773 X3 = X3A +RR1*(X3B-X3A)                                              950JZ111
      Y3 = Y3A +RR1*(Y3B-Y3A)                                              950JZ112
      P3U = P3A +RR1*T61                                                   950JZ113
      TH3U =TH3A + RR1*T62                                                 950JZ114
      ZMU3U = ZMU3A + T83* RR1                                             950JZ115
      ZM3U =ZM3A + RR1*T63                                                 950JZ116
      R3U = R3A +RR1*T64                                                   950JZ117
      T29 = SINF(2.0*W3)                                                   950JZ118
      T31 = SINF(W3)**2                                                    950JZ119
      T32 = ZM3U**2                                                        950JZ120
```

```
      DEL3=ATANF((T32*T29-2.*COSF(W3)/SINF(W3))/(T32*(C1+COSF(2.*W3))+2.950JZ121
     1))                                                                 950JZ122
      T28 = SINF(DEL3)**2                                                950JZ123
      TH3 = TH3U +AA*DEL3                                                950JZ124
      ERASB = C4*(T32*T31-C11)                                           950JZ125
      P3= P3U*ERASB                                                      950JZ126
      R3= ((T32*T31)/(C5*((T32*T31)-C12)))**C3*ERASB**C2*R3U             950JZ127
      T30 = P3/R3                                                        950JZ128
      IF (T30) 651,651,703                                               950JZ129
651    M1 = 2                                                            950JZ130
      WRITE OUTPUT TAPE 6,22                                             950JZ131
      GO TO 100                                                          950JZ132
703   T30 = C12*(1.-(T30)**(-C7))-1.                                     950JZ133
      IF (T30-.04) 651,651,705                                           950JZ134
705   ZMU3 = ATANF(SQRTF(1.0/T30))                                       950JZ135
778   IF (ABSF(P3-P3LS)-.001*P3) 780,780,715                             950JZ136
715   P3LS=P3                                                            950JZ137
      IF (KTR-100) 1019,1019,780                                         950JZ138
1019  KTR = KTR+1                                                        950JZ139
101   GO TO (776,740),NFLAG                                              950JZ140
776   X2=X3                                                              950JZ141
      Y2=Y3                                                              950JZ142
      P2=P3                                                              950JZ143
      TH2=TH3                                                            950JZ144
      ZMU2=ZMU3                                                          950JZ145
      R2=R3                                                              950JZ146
      NPT2=NPT3                                                          950JZ147
      XX2(1) = X2                                                        950JZ148
      XX2(2) = Y2                                                        950JZ149
      XX2(3) = P2                                                        950JZ150
      XX2(4) = TH2                                                       950JZ151
      XX2(5) = ZMU2                                                      950JZ152
      XX2(6) = R2                                                        950JZ153
10    CALL BODYPT (AA,XX1,XX2,XX3,C1,M1)                                 950JZ154
      X5 = XX3(1)                                                        950JZ155
      Y5 = XX3(2)                                                        950JZ156
      P5 = XX3(3)                                                        950JZ157
      TH5 = XX3(4)                                                       950JZ158
      ZMU5 = XX3(5)                                                      950JZ159
      R5 = XX3(6)                                                        950JZ160
      DO 1122 I=1,6                                                      950JZ161
```

```
      XX5(I) = XX3(I)                                                   950JZ162
 1122 CONTINUE                                                          950JZ163
      X3=X2                                                             950JZ164
      Y3=Y2                                                             950JZ165
      P3=P2                                                             950JZ166
      TH3=TH2                                                           950JZ167
      ZMU3=ZMU2                                                         950JZ168
      R3=R2                                                             950JZ169
      X2=X5                                                             950JZ170
      Y2=Y5                                                             950JZ171
      P2=P5                                                             950JZ172
      TH2=TH5                                                           950JZ173
      ZMU2=ZMU5                                                         950JZ174
      R2=R5                                                             950JZ175
 740  T42 = Y1 -Y3                                                      950JZ176
      T36 = X2 -X1                                                      950JZ177
      T37 = Y2 -Y1                                                      950JZ178
      T39 = (TH2 +AA*ZMU2)/2.                                           950JZ179
      T40 = (TH1 +AA*ZMU1)/2.                                           950JZ180
      T38 = P2- P1                                                      950JZ181
      T35 = TH2 -TH1                                                    950JZ182
      T33 = ZMU2 -ZMU1                                                  950JZ183
      T45 = T39 -T40                                                    950JZ184
      T46 = T37/T36                                                     950JZ185
      T43 = X1 -X3                                                      950JZ186
      T47 = T42/T36                                                     950JZ187
      T48 = T43/T36                                                     950JZ188
      T50 = (TH3 +AA*ZMU3)/2.                                           950JZ189
      T49 = T40 + T50                                                   950JZ190
      IF (TH2+AA*ZMU2-1.0) 3000,3000,3001                               950JZ191
 3001 DENOM = SQRTF(T36**2-T37**2)                                      950JZ192
      RR2A = .5                                                         950JZ193
      T501 = TH3+AA*ZMU3                                                950JZ194
      S2 = SINF(T501)/COSF(T501)                                        950JZ195
      DO 3010 I=1,20                                                    950JZ196
      X4 = X1+(T43-T42/S2)/(T46/S2-1.)                                  950JZ197
      Y4 = Y1+(X4-X1)*T46                                               950JZ198
      RR2 = SQRTF((X4-X1)**2+(Y4-Y1)**2)/DENOM                          950JZ199
      IF (ABSF(RR2A-RR2)-MAX1F(.00001*ABSF(RR2),.00001)) 711,711,3004   950JZ201
 3004 RR2A = RR2                                                        950JZ202
      TH4 = TH1+RR2*T35                                                 950JZ203
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      ZMU4 = ZMU1+RR2*T33                                              950JZ204
      T502 = (T501+TH4+AA*ZMU4)/2.                                     950JZ205
 3010 S2 = SINF(T502)/COSF(T502)                                       950JZ206
      GO TO 711                                                        950JZ207
 3000 RR2 = .5                                                         950JZ208
 706  DO 750 I=1,20                                                    950JZ209
      T51 = RR2*T45 +T49                                               950JZ210
      T52 = SINF(T51)                                                  950JZ211
      T53 =COSF(T51)                                                   950JZ212
      T54 =T52/T53                                                     950JZ213
      FR  =T47 +RR2*T46 -(RR2 +T48)*T54                                950JZ214
      FPR =T46 -T54 -(RR2 +T48)*T45/T53**2                             950JZ215
      IF (ABSF(FPR) - .00000001) 711,711, 751                          950JZ216
 751  DRR = FR/FPR                                                     950JZ217
      RR2= RR2 -DRR                                                    950JZ218
 708  CONTINUE                                                         950JZ219
 725  IF (ABSF(DRR) - MAX1F(.00001 * ABSF(RR2) , .00001)) 711, 711, 750 950JZ220
 750  CONTINUE                                                         950JZ221
 711  IF (ABSF(RR2-.5)-.5) 747,747,111                                 950JZ222
 111  IF (NPT2) 60,61,61                                               950JZ223
 60   IF (RR2 + .01)  1160,747,747                                     950JZ224
 1160 WRITE OUTPUT TAPE 6,23                                           950JZ225
 500  M1 = 3                                                           950JZ226
      GO TO 100                                                        950JZ227
C                                                                      950JZ228
 61   IF (RR2)  666,661,661                                            950JZ229
 666  IF (RR2 + .001)  670,747,747                                     950JZ230
 670  WRITE OUTPUT TAPE 6,25,X1,Y1,P1,TH1,ZMU1,W1                      950JZ231
      WRITE OUTPUT TAPE 6,25,X2,Y2,P2,TH2,ZMU2,W2                      950JZ232
      WRITE OUTPUT TAPE 6,25,X3,Y3,P3,TH3,ZMU3,W3                      950JZ233
      WRITE OUTPUT TAPE 6,25,X4,Y4,P4,TH4,ZMU4,W4                      950JZ234
      WRITE OUTPUT TAPE 6,25,RR2,DRR,DPDW,DTHDW,DW3,T30                950JZ235
      WRITE OUTPUT TAPE 6,25,X3A,Y3A,X3B,Y3B,                          950JZ236
 661  M1 = 5                                                           950JZ237
C                                                                      950JZ238
C       THE NEXT POINT MUST BE USED AS POINT 2.                        950JZ239
C                                                                      950JZ240
      GO TO 100                                                        950JZ241
C                                                                      950JZ242
 747  X4 = X1 +RR2*T36                                                 950JZ243
      Y4 = Y1 +RR2*T37                                                 950JZ244
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      P4 = P1 +RR2*T38                                                  950JZ245
      TH4 =TH1 +RR2*T35                                                 950JZ246
      ZMU4 =ZMU1+RR2*T33                                                950JZ247
      DPDW = P3U*C4*T32*T29                                             950JZ248
      DTHDW = (C1+1.0)*T28*T31*T32**2/(T32*T31-1.0)**2 - SINF(2.0*DEL3)/950JZ249
     1T29                                                               950JZ250
      T13 =(TH4 +TH3)/2.0                                               950JZ251
      T60 = (TH4 +AA*ZMU4)/2.                                           950JZ252
      T11 =(P4 +P3)/2.0                                                 950JZ253
      T12 =(ZMU4 +ZMU3)/2.0                                             950JZ254
      T34 = (Y4 +Y3)/2.0                                                950JZ255
      DW3 = -((P3-P4)/(C1*T11)+A*(TH3-TH4)/((COSF(T12))*(SINF(T12))))   950JZ256
 774  W3=W3+DW3/(DPDW/(C1*T11)+DTHDW/(SINF(T12)/COSF(T12)))             950JZ257
      GO TO 701                                                         950JZ258
 780  M1 = 1                                                            950JZ259
 765  IF (RR1) 763,763,1900                                             950JZ260
 1900 IF (RR1-1.0) 100,100,1904                                         950JZ261
C                                                                       950JZ262
 763  M1 = 6                                                            950JZ263
      GO TO 100                                                         950JZ264
C                                                                       950JZ265
C        NEW 3A AND 3B POINTS UPSTREAM MUST BE USED.                    950JZ266
C                                                                       950JZ267
 1904 M1 = 7                                                            950JZ268
C                                                                       950JZ269
C        NEW 3A AND 3B POINTS DOWNSTREAM MUST BE USED.                  950JZ270
C                                                                       950JZ271
 100  XX3U(1) = X3                                                      950JZ272
      XX3(1) = X3                                                       950JZ273
      XX3U(2) = Y3                                                      950JZ274
      XX3(2) = Y3                                                       950JZ275
      XX3U(3) = P3U                                                     950JZ276
      XX3U(4) = TH3U                                                    950JZ277
      XX3U(5) = ZMU3U                                                   950JZ278
      XX3U(6) = R3U                                                     950JZ279
      XX3(3) = P3                                                       950JZ280
      XX3(4) = TH3                                                      950JZ281
      XX3(5) = ZMU3                                                     950JZ282
      XX3(6) = R3                                                       950JZ283
      XX3(8) = SIGNF(W3,XX1(8))                                         950JZ284
      RETURN                                                            950JZ285
```