TECHNICAL NOTE R-116

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ANALYSIS OF AXIALLY SYMMETRIC DE LAVAL NOZZLES FOR ADIABATIC, STEADY, NONVISCOUS, ROTATIONAL, COMPRESSIBLE FLOW

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BROWN ENGINEERING COMPANY, INC.

HUNTSVILLE, ALABAMA

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October 1964

Prepared For

ENGINE SYSTEMS BRANCH
PROPULSION DIVISION
P&VE LABORATORY
GEORGE C. MARSHALL SPACE FLIGHT CENTER

By

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BROWN ENGINEERING COMPANY, INC.

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Prepared By

J. W. Littles

ABSTRACT

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This report describes the revisions which have been made to an existing FORTRAN IV computer program[1] in order to account for the rotational effects which are present downstream of a curved shock in a flow field which is originally irrotational. The revised program utilizes the axially symmetric method of characteristics for adiabatic, steady, nonviscous, rotational, supersonic, compressible flow. All of the capabilities of the original program have been preserved.

Author

Approved

C. E. Kaylor

C. E. Kaylor, Ph. D.
Director, Mechanics and
Propulsion Laboratories

Approved

R. C. Watson

R. C. Watson, Jr.
Director of Research

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LIST OF SYMBOLS

Mathematical	FORTRAN	Definition
A	A	Cross-sectional area
A	FMTRIX	Polynomial coefficient
C_f	CF	Thrust coefficient
c	C	Speed of sound
c_p		Specific heat at constant pressure
c_v		Specific heat at constant volume
H	H	Characteristic coefficient
k	G	Ratio of specific heats
M	FM	Mach number
M^*	FMS	Reference Mach number
$\dot{m}$	FLOW	Mass flow rate
P	P	Static pressure
P_o	PO	Total pressure
R	R	Radius of curvature of the throat contour
R_t	RT	Throat radius
$\overline{R}$		Universal gas constant
r	Y	r-coordinate, normal to the axis of symmetry
Sp Imp	SPIPLS	Specific impulse

LIST OF SYMBOLS (Continued)

Mathematical	FORTRAN	Definition
s	SS	Entropy
T	T	Static temperature
T_o		Total temperature
u		Velocity
v	V	Velocity
W	FMW	Molecular weight
x	X	x-coordinate, parallel to the axis of symmetry
Greek Symbols		
α	ALPHA	Mach number
β	BETA	Characteristic coefficient
Γ	PULSE	Thrust
Γ	PUSH	Thrust
$\bar{\gamma}$	GBAR	Average ratio of specific heat
δ	DEL	Defined in Appendix A, Subroutine SHOCK
ε	EPS	Density ratio, defined in Appendix A, SHOCK and SHOCK I
η	XETA	Defined in Appendix A, Cases 1, 2, 3, 4
θ	THETA	Velocity inclination angle
λ	FLAM	Characteristic coefficient

LIST OF SYMBOLS (Continued)

Mathematical	FORTRAN	Definition
μ	XMU	Shock angle
ρ	RHU	Mass density
ψ	Angle	Defined in Appendix A, Subroutine SHOCK
ω	W	Defined in Appendix A, Cases 1, 2, 3, 4

Subscripts

a	A	Ambient condition
c	C	Denotes chamber condition
e	EXIT	Denotes condition at the nozzle exit
ℓ	L	Denotes a point on a left-running characteristic
ℓ, n	LN	Average value of variable between points ℓ and n
n	N	Denotes a lattice point
r	R	Denotes a point on a right-running characteristic
r, n	RN	Average value of variable between points r and n
s	S	Denotes a point on the starting line
u		Denotes an upstream point on either the axis of symmetry or the wall
w	WALL	Denotes a point on the nozzle contour

INTRODUCTION

An IBM 7040 FORTRAN IV computer program which utilizes the axially symmetric method of characteristics for adiabatic, steady, non-viscous, rotational, compressible flow has been developed by the Fluid Mechanics Laboratory of Brown Engineering Company to analyze axially symmetric de Laval nozzles. The program was developed by revising an existing program[1] for irrotational flow. The revised program includes all of the capabilities of the original program.

This report describes the revisions and additions which have been made to the original program. A sample problem is presented with results for both irrotational and rotational flow.

A complete program listing is presented in Appendix B.

REVISION OF GOVERNING EQUATIONS

Discussion

The original program was written for steady, irrotational, frictionless, isentropic flow. For these conditions a single differential was derived and solutions were found. Downstream of a shock in the flow field the entropy varies from streamline to streamline and the isentropic equation used in the original analysis is not valid. The revised program accounts for this variation of entropy.

Derivation

The characteristic equations will be derived for a steady, axially symmetric, adiabatic, nonviscous, supersonic, rotational flow in which the stagnation enthalpy is the same for all points and in which the entropy is constant along a streamline before and after the shock, while there is a discontinuous increase in entropy on each streamline in crossing the shock. Such a flow field must satisfy the following equations.

The continuity equation for axially symmetric flow is

$$\frac{\rho v}{r} + \rho \frac{\partial v}{\partial r} + \rho \frac{\partial u}{\partial x} + v \frac{\partial \rho}{\partial r} + u \frac{\partial \rho}{\partial x} = 0 \quad . \tag{1}$$

Euler's equations are

$$u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial r} + \frac{1}{\rho} \frac{\partial p}{\partial x} = 0 \tag{2a}$$

and

$$u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial r} + \frac{1}{\rho} \frac{\partial p}{\partial r} = 0 \quad . \tag{2b}$$

Now dp must equal, by the definition of an exact differential,

$$dp = \left.\frac{\partial p}{\partial s}\right|_{\rho} ds + \left.\frac{\partial p}{\partial \rho}\right|_{s} d\rho \quad . \tag{3a}$$

For a perfect gas,

$$\frac{ds}{c_v} = \frac{dp}{p} - k\frac{d\rho}{\rho} \quad . \tag{3b}$$

By comparing Equations 3a and 3b, it can be seen that

$$\left.\frac{\partial p}{\partial s}\right|_{\rho} = \frac{p}{c_v} \quad .$$

We also know from the definition of the velocity of sound in a perfect gas that

$$\left.\frac{\partial p}{\partial \rho}\right|_{s} = \frac{kp}{\rho} = c^2 \quad .$$

Therefore, Equation 3a may be written as

$$dp = \left(\frac{\rho c^2}{k}\right) d\left(\frac{s}{c_v}\right) + c^2\, d\rho \quad .$$

Also,

$$\frac{\partial p}{\partial x} = \left(\frac{\rho c^2}{k}\right)\frac{\partial\left(\frac{s}{c_v}\right)}{\partial x} + c^2\,\frac{\partial \rho}{\partial x}$$

and

$$\frac{\partial \rho}{\partial r} = \frac{\rho c^2}{k}\,\frac{\partial\left(\frac{s}{c_v}\right)}{\partial r} + c^2\,\frac{\partial \rho}{\partial r} \quad .$$

Equations 2a and 2b may now be rewritten

$$u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial r} + \frac{c^2}{k} \frac{\partial \left(\frac{s}{c_v}\right)}{\partial x} + \frac{c^2}{\rho} \frac{\partial \rho}{\partial x} = 0 \tag{4a}$$

$$u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial r} + \frac{c^2}{k} \frac{\partial \left(\frac{s}{c_v}\right)}{\partial r} + \frac{c^2}{\rho} \frac{\partial \rho}{\partial r} = 0 \quad . \tag{4b}$$

By definition of an exact differential,

$$ds = \left.\frac{\partial s}{\partial x}\right|_r dx + \left.\frac{\partial s}{\partial r}\right|_x dr \quad .$$

From the definition of a streamline,

$$\frac{dr}{dx} = \frac{v}{u}$$

and along a streamline, $ds = 0$ (except through a shock wave). Therefore,

$$u \left(\frac{\partial s}{\partial x}\right) + v \left(\frac{\partial s}{\partial r}\right) = 0 \quad . \tag{5}$$

The other four equations required to solve for the eight unknowns

$$\frac{\partial s}{\partial r}, \frac{\partial s}{\partial x}, \frac{\partial v}{\partial x}, \frac{\partial v}{\partial r}, \frac{\partial u}{\partial x}, \frac{\partial u}{\partial r}, \frac{\partial \rho}{\partial x}, \text{ and } \frac{\partial \rho}{\partial r}$$

are given by

$$\left.\frac{\partial v}{\partial x}\right|_r dx + \left.\frac{\partial v}{\partial r}\right|_x dr = dv \tag{6}$$

$$\left.\frac{\partial \rho}{\partial x}\right|_r dx + \left.\frac{\partial \rho}{\partial r}\right|_x dr = d\rho \tag{7}$$

$$\left.\frac{\partial u}{\partial x}\right|_r dx + \left.\frac{\partial u}{\partial r}\right|_x dr = du \tag{8}$$

and

$$\left.\frac{\partial s}{\partial x}\right|_r dx + \left.\frac{\partial s}{\partial r}\right|_x dr = ds \quad . \tag{9}$$

We now have eight quantities connected by eight linear, nonhomogeneous, independent equations. These equations are numbers 1, 4a, 4b, 5, 6, 7, 8, and 9. The solution may be written symbolically in terms of the matrix of the equations.

$\frac{\partial u}{\partial x}$	$\frac{\partial u}{\partial r}$	$\frac{\partial v}{\partial x}$	$\frac{\partial v}{\partial r}$	$\frac{\partial \rho}{\partial x}$	$\frac{\partial \rho}{\partial r}$	$\frac{\partial\left(\frac{s}{c_v}\right)}{\partial x}$	$\frac{\partial \frac{s}{c_v}}{\partial r}$	$=$
ρ	0	0	ρ	u	v	0	0	$-\frac{\rho v}{r}$
0	0	0	0	0	0	u	v	0
u	v	0	0	$\frac{c^2}{\rho}$	0	$\frac{c^2}{k}$	0	0
0	0	u	v	0	$\frac{c^2}{\rho}$	0	$\frac{c^2}{k}$	0
dx	dr	0	0	0	0	0	0	du
0	0	dx	dr	0	0	0	0	dv
0	0	0	0	dx	dr	0	0	$d\rho$
0	0	0	0	0	0	dx	dr	$d\left(\frac{s}{c_v}\right)$

The characteristics curves are defined as those curves on which the derivatives of the velocity components and all fluid properties are discontinuous or indeterminate. By selecting any quantity and setting the numerator and denominator of the determinate solution equal to zero,

we can get the complete set of characteristics. After simplification, the resulting equations become[3]

$$u\,dr - v\,dx = 0 \tag{10}$$

$$c^2\,(dx^2 + dr^2) - (u\,dr - v\,dx)^2 = 0 \tag{11}$$

$$ds = 0 \tag{12}$$

$$u\,du + v\,dv + c^2\,\frac{d\rho}{\rho} = 0 \tag{13}$$

$$\begin{aligned}(u\,dr - v\,dx)\,(u\,dv - v\,du) + c^2 \left[\frac{d\rho}{\rho} + \frac{d\left(\frac{s}{c_v}\right)}{k}\right] (u\,dx + v\,dr) \\ + (u\,dr - v\,dx)^2\,\frac{v}{r} = 0 \quad .\end{aligned} \tag{14}$$

Equations 10 and 12 are equations of the streamlines and Equation 13 is Euler's equation for changes in state along a streamline. If Equation 11 is solved for $\frac{dr}{dx}$, the results are

$$\left.\frac{dr}{dx}\right|_{R,\,L} = \frac{-\frac{uv}{c^2} \pm \left(\frac{u^2 + v^2}{c^2} - 1\right)^{\frac{1}{2}}}{1 - \frac{u^2}{c^2}} \tag{15a}$$

This result may be simplified by using polar coordinates and letting $v = V \sin\theta$, $u = V \cos\theta$, and $M = \frac{1}{\sin\alpha}$, yielding

$$\left.\frac{dr}{dx}\right|_{R,\,L} = \tan(\theta \mp \alpha) \tag{15b}$$

where the minus sign is associated with the right running characteristics and the plus sign with the left running characteristics. This equation is the differential equation of the physical characteristics and is identical to the equation which was found for irrotational flow. The physical characteristics are inclined at the Mach angle to the velocity vector and are identical with the Mach lines of the flow.

Equation 15b may be substituted into Equation 14 yielding

$$[u \tan(\theta \mp \alpha) - v]\,(u\,dv - v\,du) + c^2 \left[\frac{d\rho}{\rho} + \frac{d\left(\frac{s}{c_v}\right)}{k}\right] [u + v \tan(\theta \mp \alpha)]$$

$$+ [u \tan(\theta \mp \alpha) - v]^2 \frac{v\,dr}{r \tan(\theta \mp \alpha)} = 0$$

The resulting equation may be simplified by the use of polar coordinates to give

$$\pm \frac{d\theta}{\sin\alpha \cos\alpha} + \frac{d\rho}{\rho} + \frac{d\left(\frac{s}{c_v}\right)}{k} + \frac{\sin\theta}{\cos\alpha \sin(\theta \pm \alpha)} \frac{dr}{r} = 0 \quad . \qquad (16)$$

Since we are dealing with the adiabatic case,

$$d\left(\frac{V^2}{2}\right) + c_p dT = 0$$

or

$$V\,dV + \left(\frac{2}{k-1}\right) c\,dc = 0 \quad .$$

Also,

$$T\,ds = c_v\,dT + p\,d\left(\frac{1}{\rho}\right)$$

and

$$\frac{ds}{c_v} = 2\frac{dc}{c} - (k-1)\frac{d\rho}{\rho} \quad .$$

Combining these relations,

$$\frac{d\rho}{\rho} = -\left(\frac{1}{k-1}\right) d\left(\frac{s}{c_v}\right) - \frac{V\,dV}{c^2} \quad . \tag{17}$$

Substitution of Equation 17 into 16 and rearranging yields

$$\begin{aligned}(d\theta)_{R,L} \pm \frac{\cot\alpha}{V}(dV)_{R,L} \mp \frac{\sin\theta\sin\alpha}{\sin(\theta\mp\alpha)}\frac{(dr)_{R,L}}{r} \\ \pm \frac{\sin\alpha\cos\alpha}{Rk}(ds)_{R,L} = 0 \quad .\end{aligned} \tag{18}$$

Comparison of this equation with the equation for irrotational flow shows that the rotational effects are included in the last term of the above equation.

Equations 15b and 18 may be written in finite difference form and may be solved simultaneously to construct the physical and hodograph characteristic nets for a particular problem with given boundary conditions.

REVISION OF SUBROUTINES

Discussion

The addition of the last term of Equation 18 has made necessary the revision of several subroutines. Corresponding changes were made in the main routine.

Subroutine SAUER. Statements were added to this subroutine to create an entropy field on the starting line. Since the flow is irrotational in the region of the starting line (this assumption was made in Sauer's analysis), the entropy field may be assigned a constant value. A value of 1.0 BTU/lb-°R was chosen and incorporated in the SAUER subroutine.

Subroutine CASE 1. Numerous changes were made to this subroutine as a result of the addition of the last term to Equation 18. As can be seen from Equation 18, the numerical values of the Mach number and flow angle at the new field point located by CASE 1 are now dependent upon the entropy change between the two known field points and the new field point. In order to be able to satisfy Equation 18, a set of equations to calculate the entropy at the view point has been included. The method presented in Reference 2 has been used.

In the adiabatic case which is being considered, the entropy remains constant on each streamline, but may be differed on different streamlines. Thus, we may write

$$ds\,|_{R,\,L} = \left(\frac{ds}{dn}\right) (dn)_{R,\,L} \tag{19}$$

where, as can be seen from Figure 1, n is the normal distance from the known field point under consideration to the streamline passing through the new field point.

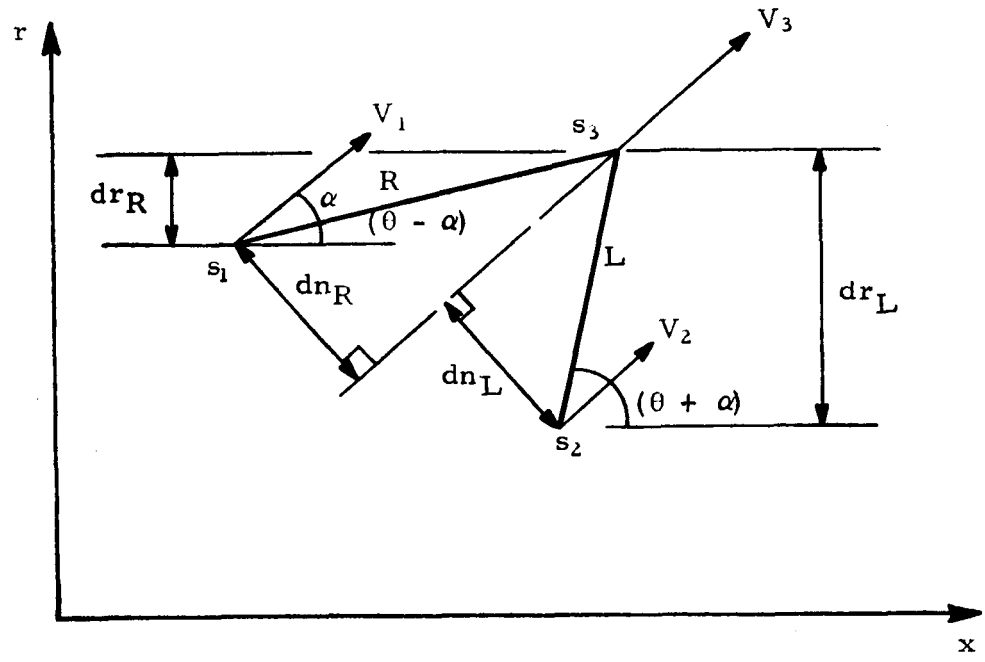

Figure 1

From Figure 1 it can be seen that

$$dn|_R = \frac{\sin \alpha}{\sin (\theta + \alpha)} (dr)_R \tag{20a}$$

and

$$dn|_L = \frac{\sin \alpha}{\sin (\theta - \alpha)} (dr)_L \quad . \tag{20b}$$

From the geometry of Figure 1 it can also be shown that

$$\frac{ds}{dn} \simeq \frac{s_1 - s_2}{(x_3 - x_2) \dfrac{\sin \alpha_2}{\cos (\theta_2 + \alpha_2)} + (x_3 - x_1) \dfrac{\sin \alpha_1}{\cos (\theta_1 - \alpha_1)}} \quad . \tag{21}$$

Substituting Equations 20a, 20b, and 21 into Equation 19 yields

$$ds|_{R,L} = \frac{(s_1 - s_2) \quad (dr)_{R,L}}{(x_3 - x_2) \dfrac{\sin \alpha_2}{\cos (\theta_2 + \alpha_2)} + (x_3 - x_1) \dfrac{\sin \alpha_1}{\cos (\theta_1 - \alpha_1)}} \left[\frac{\sin \alpha}{\sin (\theta \mp \alpha)} \right] \quad . \tag{22}$$

Equation 22 can now be used along with the revised finite-difference form of Equation 18 to solve the hodograph net in the same manner as for irrotational flow. A complete list of equations for CASE 1 is given in Appendix A.

Subroutine CASE 2. The revisions made to CASE 2 are almost identical to those in CASE 1. The single exception is found in the expression for $\frac{ds}{dn}$. Since one of the two known field points for this case lies on the axis of symmetry, $\theta_2 = 0$. The revised expression for $\frac{ds}{dn}$ is

$$\frac{ds}{dn} = \frac{s_1 - s_2}{(x_3 - x_2)\frac{\sin \alpha_2}{\cos \alpha_2} + (x_3 - x_1)\frac{\sin \alpha_1}{\cos (\theta_1 - \alpha_1)}} \quad . \tag{23}$$

A list of those equations from CASE 2 which have been revised, as well as those which have been added, is given in Appendix A.

Subroutine CASE 3. It was not necessary to calculate the entropy for the field point located by CASE 3. Since the axis of symmetry is a streamline, the entropy was assigned the value of the first upstream point on the axis. As in CASE 1 and CASE 2, the finite-difference forms of Equation 18 were revised to include the last term. The equations for CASE 3 are presented in Appendix A.

Subroutine CASE 4. Since the wall of the nozzle is a streamline, the entropy at the point located on the wall by CASE 4 can be assigned the value of the first upstream point on the wall. The finite-difference forms of Equation 18 were also revised for CASE 4. The equations for CASE 4 are presented in Appendix A.

Subroutine PROPTY. The original program used Subroutine PLTN and the thermodynamic table to calculate Mach number, pressure, and temperature. The values in the thermodynamic table are found from Subroutine THERMO by using the isentropic equations. It was necessary, therefore, to revise this subroutine and calculate pressure directly due to the change in stagnation pressure across the shock.

For a perfect gas,

$$s_3 - s_1 = R \ln \frac{P_{o_1}}{P_{o_3}} + c_p \ln \frac{T_{o_3}}{T_{o_1}} \quad . \tag{24}$$

The case being considered is adiabatic and

$$T_{o_3} = T_{o_1} \quad .$$

So,

$$s_3 - s_1 = R \ln \frac{P_{o_1}}{P_{o_3}} \quad . \tag{25}$$

In this equation, P_{o_1} corresponds to the chamber pressure, P_{o_c}, and s_1 corresponds to the chosen constant entropy upstream of the shock, 1 BTU/lb-°R. The new stagnation pressure is

$$P_{o_3} = \frac{P_{o_c}}{\exp\left(\frac{s_3 - 1}{R}\right)} \quad . \tag{26}$$

The pressure at the new field point can then be determined from the isentropic relation

$$p_3 = \frac{P_{o_3}}{\left(1 + \frac{k-1}{2} M^2\right)^{\frac{k}{k-1}}} \quad . \tag{27}$$

Subroutine SHOCK I and SHOCK. Subroutines to calculate the change in properties across adiabatic shocks which exist in the flow field are included in the program. The existence of shocks is determined by testing characteristics for intersection. The intersection of two characteristics of the same family is taken to be the initial point of an interior shock. Eastman's adaptation[4] of Moe and Troesch's method for calculation of an interior shock has been used in the program.

After it has been determined that the characteristics of the same family cross, the point with the larger value of r is chosen to be the initial shock point and the second point is ignored in further calculations. Since the shock is initially weak, the initial shock direction is approximated by the direction of the right running characteristic. The following procedure is used to calculate succeeding shock points. The points referred to are shown in Figure 2.

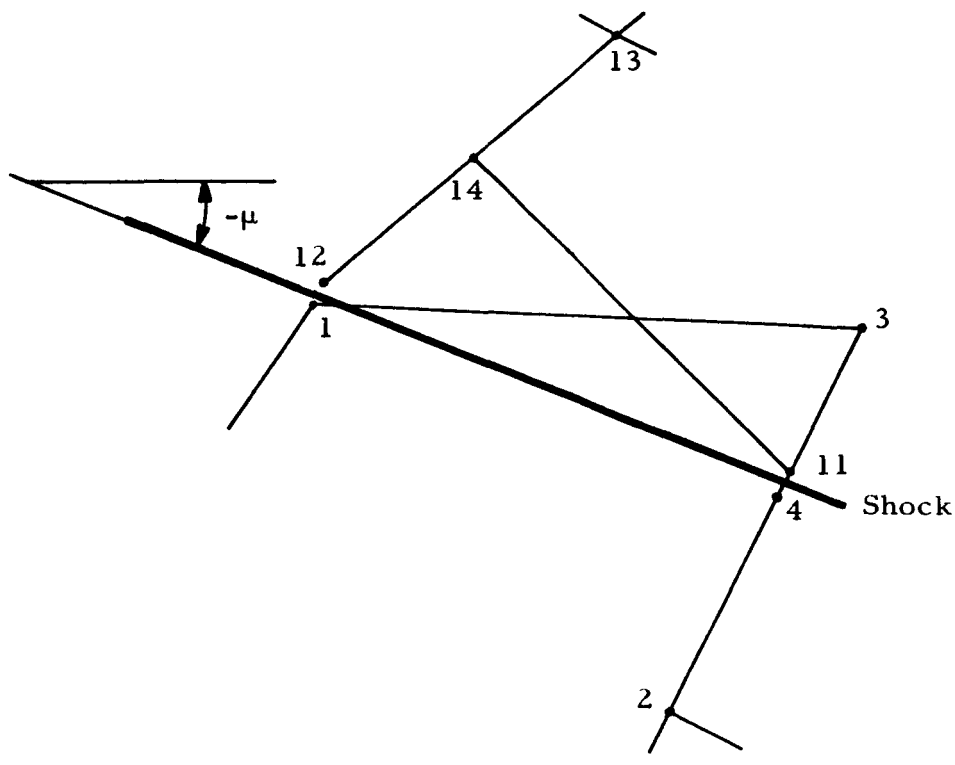

Figure 2. Shock Point Calculation Procedure

Points 1, 2, and 13 are known and have been determined by using the standard procedures. Point 12 is known and is the shock point upstream of the point being determined (point 11).

Point 3 is obtained by assuming that no interior shock is present. The location of this point is necessary in order to calculate point 4. After point 3 is established, points 14 and 4 are located by assuming a linear variation of flow properties between 12 and 13 to locate point 14 and assuming a linear variation of flow properties between 2 and 3 to calculate point 4.

The location of the desired point, point 11, is then established by an iteration procedure using the applicable Rankine-Hugoniot equations and the finite difference form of Equation 18. When the correct solution has been obtained, the flow direction at point 11 will be the same when calculated by the finite difference form of Equation 18 and by the Rankine-Hugoniot equations. The equations used are

$$\theta_{11} = \theta_{14} + \left(\frac{\cot \alpha}{M^*}\right)_{11,\,14} (M_{14}^* - M_{11}^*) - \left(\frac{\sin \theta \sin \alpha}{r \cos (\theta - \alpha)}\right)_{11,\,14} (x_{14} - x_4) + \left(\frac{\sin \alpha \cos \alpha}{R\,k}\right)_{11,\,14} (s_{14} - s_{11}) \tag{28}$$

and

$$\theta_{11} = \mu_4 + \delta_{11} \tag{29}$$

where δ_{11} is derived as follows (see Figure 3). $\tan \delta_{11} = \dfrac{V_{11N}}{V_{11T}}$, and from the Rankine-Hugoniot relations, $V_{11N} = V_4 \varepsilon \sin (\theta_4 - \mu_4)$, and $V_{11T} = V_4 \cos (\theta_4 - \mu_4)$. Therefore, $\tan \delta_{11} = \varepsilon \tan (\theta_4 - \mu_4)$, and $\delta_{11} = \tan^{-1} [\varepsilon \tan (\theta_4 - \mu_4)]$.

As suggested by Eastman, three values of the shock angle, μ_{11}, were assumed and the values of θ_{11} were calculated using Equations 28

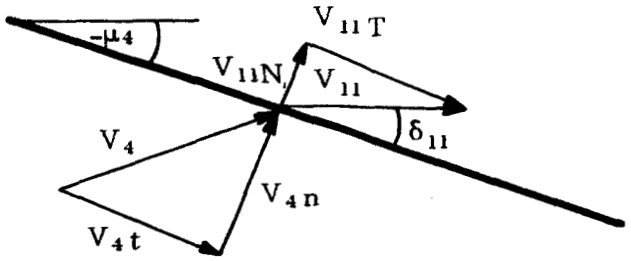

Figure 3

and 29. It was then assumed that θ_{11} varied parabolically with μ_{11}, and $\theta_{11} = a_1 + b_1 \mu_{11} + c_1 \mu_{11}^2$. After using the values obtained from Equations 28 and 29 to satisfy the coefficients of the above equation for each set of values, the final value of μ_{11} was calculated by setting the resulting equations equal and solving for μ_{11} . A complete set of the equations used in Subroutine SHOCK I and SHOCK is presented in Appendix A. The equations were written for irrotational flow and adapted to the original program by two of the authors of that program, E. H. Ingram and C. T. K. Young.

SAMPLE PROBLEM

A sample problem was run for both rotational and irrotational flow. The input data was identical for both cases. For the irrotational case, the subroutines for calculating the change in properties across shocks were used but no entropy gradient was permitted across the shock. The only difference between the two cases, therefore, was the consideration of rotational effects downstream of the shock. As can be seen by comparing the output data presented on following pages, including rotational effects caused a decrease of approximately 0.528 second in specific impulse (out of a total of approximately 325 seconds) and a decrease of approximately 2915 pounds in thrust (out of approximately 1,795,100 pounds). These changes indicate a decrease in performance of approximately 0.16 percent.

The computer output data are presented on following pages. Only a few sample planes are presented in each case. Since the input data was the same for both cases, it is only listed with the first case. The rotational case is presented first.

INPUT DATA ARE AS FOLLOWS

AMBIENT PRESSURE, PA = 4.2800000 PSIA

CHAMBER PRESSURE, PC =1075.0000000 PSIA

CHAMBER TEMPERATURE, TC =6535.7999878 DEGREE R

THROAT RADIUS, RT = 17.5000000 IN.

NOZZLE LENGTH, XNLTH = 141.6411839 IN.

AREA RATIO, AE/AT = 15.8973081

MAXIMUM MESH SIZE =1000.0000000 IN.

RADII OF THE NOZZLE WALL IN THE NEIGHBORHOOD OF THE THROAT, ASSUMING ALL THE CENTERS OF RADII LIE ON THE Y-AXIS, AND THEIR EFFECTIVE RANGES

RADIUS =27.5000000 IN. FOR X BETWEEN -2.0000000 IN. AND -1.0000000 IN.
RADIUS =27.5000000 IN. FOR X BETWEEN -1.0000000 IN. AND 0. IN.
RADIUS = 6.8628000 IN. FOR X BETWEEN 0. IN. AND -0. IN.
RADIUS = 6.8628000 IN. FOR X BETWEEN -0. IN. AND -0. IN.
RADIUS = 6.8628000 IN. FOR X BETWEEN -0. IN. AND -0. IN.

THERMODYNAMIC DATA

PRESSURE (PSIA)	TEMPERATURE (DEGREE R)	MOLECULAR WT (LB/LB-MOLE)	SPECIFIC HEAT RATIO	MACH NO	M*
619.2396317	6177.5999756	22.9480000	1.1426000	1.0000000	1.0000000
593.9226532	6150.5999756	22.9690001	1.1426000	1.0380000	1.0360000
590.6593399	6147.0000000	22.9710000	1.1426000	1.0430000	1.0400000
587.4316864	6143.4000244	22.9740000	1.1426000	1.0480000	1.0450000
584.2391281	6139.7999878	22.9770000	1.1426000	1.0530000	1.0490000
581.0810776	6136.2000122	22.9800000	1.1426000	1.0580000	1.0540000
577.9569931	6132.5999756	22.9820001	1.1426000	1.0630000	1.0580000
574.8663101	6130.7999878	22.9849999	1.1426000	1.0680000	1.0630000
571.8085098	6127.2000122	22.9879999	1.1426000	1.0720000	1.0670000
568.7830734	7743.5999756	22.9900000	1.1426000	1.0770000	1.0710000
565.7894669	6120.0000000	22.9930000	1.1426000	1.0820000	1.0750000
562.8272324	6116.4000244	22.9960001	1.1426000	1.0860000	1.0800000
559.8958282	6112.7999878	22.9979999	1.1426000	1.0910000	1.0840000
556.9948196	6109.2000122	23.0009999	1.1426000	1.0950000	1.0880000
554.1237106	6107.4000244	23.0030000	1.1426000	1.1000000	1.0920000
551.2820511	6103.7999878	23.0060000	1.1426000	1.1040000	1.0960000
548.4693909	6100.2000122	23.0079999	1.1426000	1.1090000	1.1000000
545.6852798	6096.5999756	23.0109999	1.1426000	1.1130000	1.1040000
542.9292908	6093.0000000	23.0130000	1.1426000	1.1170000	1.1080000
540.2010117	6091.2000122	23.0160000	1.1426000	1.1220000	1.1120000
537.5000000	6087.5999756	23.0179999	1.1426000	1.1260000	1.1160000
534.8258667	6084.0000000	23.0209999	1.1426000	1.1300000	1.1200000
532.1782227	6080.4000244	23.0230000	1.1426000	1.1340000	1.1240000
529.5566483	6078.5999756	23.0260000	1.1426000	1.1380000	1.1270000
524.3902435	6071.4000244	23.0300000	1.1426000	1.1470000	1.1350000
511.9047585	6057.0000000	23.0420001	1.1426000	1.1660000	1.1530000

THERMODYNAMIC DATA (CONT.)

PRESSURE (PSIA)	TEMPERATURE (DEGREE R)	MOLEDULAR WT (LB/LB-MOLE)	SPECIFIC HEAT RATIO	MACH NO	M^*
500.0000000	6042.5999756	23.0539999	1.1427000	1.1860000	1.1700000
488.6363602	6028.2000122	23.0650001	1.1427000	1.2040000	1.1870000
477.7777786	6013.7999878	23.0760000	1.1427000	1.2220000	1.2030000
467.3913002	5999.4000244	23.0860000	1.1428000	1.2390000	1.2180000
457.4468117	5986.7999878	23.0969999	1.1428000	1.2560000	1.2330000
447.9166718	5974.2000122	23.1070001	1.1428000	1.2720000	1.2470000
438.7755089	5959.7999878	23.1159999	1.1429000	1.2880000	1.2610000
430.0000000	5947.2000122	23.1259999	1.1429000	1.3030000	1.2740000
413.4615402	5923.7999878	23.1440001	1.1431000	1.3330000	1.3000000
398.1481514	5900.4000244	23.1619999	1.1432000	1.3600000	1.3240000
383.9285698	5877.0000000	23.1789999	1.1433000	1.3860000	1.3460000
370.6896591	5855.4000244	23.1949999	1.1434000	1.4110000	1.3670000
358.3333282	5835.5999756	23.2110000	1.1436000	1.4350000	1.3870000
346.7741890	5814.0000000	23.2260001	1.1437000	1.4580000	1.4070000
335.9375000	5794.2000122	23.2400000	1.1439000	1.4800000	1.4250000
325.7575798	5776.2000122	23.2539999	1.1440000	1.5000000	1.4420000
316.1764717	5758.2000122	23.2670000	1.1442000	1.5200000	1.4590000
307.1428604	5740.2000122	23.2800000	1.1444000	1.5400000	1.4750000
294.5205498	5713.2000122	23.2980001	1.1446000	1.5670000	1.4970000
286.6666718	5697.0000000	23.3099999	1.1448000	1.5850000	1.5120000
279.2207794	5680.7999878	23.3210001	1.1450000	1.6020000	1.5250000
272.1519012	5664.5999756	23.3320000	1.1452000	1.6180000	1.5390000
262.1951218	5643.0000000	23.3480000	1.1455000	1.6420000	1.5580000
250.0000000	5612.4000244	23.3680000	1.1429000	1.6720000	1.5810000
238.8888893	5585.4000244	23.3859999	1.1463000	1.7000000	1.6040000
228.7234001	5558.4000244	23.4040000	1.1467000	1.7260000	1.6240000
219.3877602	5533.2000122	23.4210000	1.1471000	1.7510000	1.6440000
210.7843094	5508.0000000	23.4370000	1.1475000	1.7750000	1.6630000
202.8301907	5484.5999756	23.4519999	1.1479000	1.7980000	1.6800000
195.4545498	5461.2000122	23.4660001	1.1484000	1.8200000	1.6970000
188.5964909	5439.5999756	23.4800000	1.1488000	1.8410000	1.7130000
182.2033901	5418.0000000	23.4930000	1.1492000	1.8610000	1.7280000
176.2295094	5398.2000122	23.5050001	1.1497000	1.8800000	1.7420000
170.6349201	5378.4000244	23.5170000	1.1501000	1.8990000	1.7560000
165.3846207	5358.5999756	23.5280001	1.1505000	1.9160000	1.7690000
160.4477596	5340.5999756	23.5390000	1.1510000	1.9340000	1.7820000
155.7971001	5320.7999878	23.5500000	1.1514000	1.9500000	1.7940000
151.4084492	5304.5999756	23.5599999	1.1519000	1.9660000	1.8050000
147.2602692	5286.5999756	23.5690000	1.1523000	1.9820000	1.8170000
143.3333302	5270.4000244	23.5780001	1.1527000	1.9970000	1.8270000
139.6103897	5254.2000122	23.5869999	1.1532000	2.0110000	1.8380000
136.0759506	5238.0000000	23.5960000	1.1536000	2.0250000	1.8480000
132.7160492	5221.7999878	23.6040001	1.1540000	2.0390000	1.8580000
129.5180702	5207.4000244	23.6120000	1.1544000	2.0520000	1.8670000
126.4705896	5191.2000122	23.6199999	1.1549000	2.0650000	1.8760000
123.5632200	5176.7999878	23.6270001	1.1553000	2.0780000	1.8850000
71.6666670	4831.2000122	23.7750001	1.1673000	2.3620000	2.0740000
43.0000000	4496.4000244	23.8680000	1.1807000	2.6170000	2.2250000
26.8750000	4185.0000000	23.9210000	1.1925000	2.8490000	2.3460000
17.9166670	3918.6000061	23.9470000	1.2008000	3.0520000	2.4400000
13.4375000	3735.0000000	23.9579999	1.2055000	3.1980000	2.5000000
10.7500000	3594.6000061	23.9630001	1.2089000	3.3390000	2.5540000
5.3750000	3186.0000000	23.9710000	1.2141000	3.6810000	2.6670000
3.5833333	2966.3999939	23.9730000	1.2157000	3.9030000	2.7290000

POINTS DEFINING THE NOZZLE CONTOUR

X (IN.)	Y (IN.)	X (IN.)	Y (IN.)	X (IN.)	Y (IN.)
0.	17.5000000	15.0000000	24.7488000	47.0000000	40.0945001
0.2500000	17.5046000	15.2500000	24.8813000	48.0000000	40.5183001
0.5000000	17.5181999	15.5000000	25.0137000	49.0000000	40.9386001
0.7500000	17.5411000	15.7500000	25.1459999	50.0000000	41.3554001
1.0000000	17.5732000	16.0000000	25.2780001	51.0000000	41.7687001
1.2500000	17.6148000	16.2500000	25.4098001	52.0000000	42.1785002
1.5000000	17.6659000	16.5000000	25.5415001	53.0000000	42.5848999
1.7500000	17.7269001	16.7500000	25.6730001	54.0000000	42.9878001
2.0000000	17.7979000	17.0000000	25.8041999	55.0000000	43.3871999
2.2500000	17.8793001	17.2500000	25.9353001	56.0000000	43.7831998
2.5000000	17.9716001	17.5000000	26.0662000	57.0000000	44.1757002
2.7500000	18.0750999	17.7500000	26.1970000	58.0000000	44.5647998
3.0000000	18.1903999	18.0000000	26.3275001	59.0000000	44.9505000
3.2500000	18.3183000	18.2500000	26.4577999	60.0000000	45.3326998
3.5000000	18.4577000	18.5000000	26.5880001	61.0000000	45.7115002
3.7500000	18.5983000	18.7500000	26.7179000	62.0000000	46.0869999
4.0000000	18.7386999	19.0000000	26.8477001	63.0000000	46.4590001
4.2500000	18.8789999	19.2500000	26.9772999	64.0000000	46.8277001
4.5000000	19.0191000	19.5000000	27.1066999	65.0000000	47.1929998
4.7500000	19.1589999	19.7500000	27.2358999	66.0000000	47.5549998
5.0000000	19.2988000	20.0000000	27.3649001	67.0000000	47.9137001
5.2500000	19.4384000	20.2000000	27.4937000	68.0000000	48.2690001
5.5000000	19.5778999	20.5000000	27.6222999	69.0000000	48.6210999
5.7500000	19.7172000	20.7500000	27.7507000	70.0000000	48.9699998
6.0000000	19.8563001	21.0000000	27.8789001	71.0000000	49.3155999
6.2500000	19.9951999	21.2500000	28.0070000	72.0000000	49.6578999
6.5000000	20.1340001	21.5000000	28.1348000	73.0000000	49.9970999
6.7500000	20.2725999	21.7500000	28.2623999	74.0000000	50.3330998
7.0000000	20.4110000	22.0000000	28.3900001	75.0000000	50.6659999
7.2500000	20.5493000	22.2500000	28.5171001	76.0000000	50.9956999
7.5000000	20.6874001	22.5000000	28.6442001	77.0000000	51.3223000
7.7500000	20.8253000	22.7500000	28.7709999	78.0000000	51.6458001
8.0000000	20.9631000	23.0000000	28.8977001	79.0000000	51.9663000
8.2500000	21.1006999	23.2500000	29.0242000	80.0000000	52.2838001
8.5000000	21.2381001	23.5000000	29.1503999	81.0000000	52.5983000
8.7500000	21.3752999	23.7500000	29.2765000	82.0000000	52.9098001
9.0000000	21.5123999	24.0000000	29.4024000	83.0000000	53.2182999
9.2500000	21.6493001	24.2500000	29.5280001	84.0000000	53.5240002
9.5000000	21.7860000	24.5000000	29.6535001	85.0000000	53.8267999
9.7500000	21.9224999	24.7500000	29.7788000	86.0000000	54.1266999
10.0000000	22.0589001	27.0000000	30.8972001	87.0000000	54.4236999
10.2500000	22.1951001	28.0000000	31.3889999	88.0000000	54.7179999
10.5000000	22.3311000	29.0000000	31.8776000	89.0000000	55.0095000
10.7500000	22.4669001	30.0000000	32.3628001	90.0000000	55.2982998
11.0000000	22.6026001	31.0000000	32.8448000	98.0000000	57.5491266
11.2500000	22.7381001	32.0000000	33.3234000	103.0000000	58.9498534
11.5000000	22.8734000	33.0000000	33.7986999	108.0000000	60.3505797
11.7500000	23.0085001	34.0000000	34.2705998	113.0000000	61.7513065
12.0000000	23.1435001	35.0000000	34.7392001	118.0000000	63.1520329
12.2500000	23.2781999	36.0000000	35.2042999	123.0000000	64.5527592
12.5000000	23.4128001	37.0000000	35.6661000	128.0000000	65.9534864
12.7500000	23.5472000	38.0000000	36.1244001	133.0000000	67.3542128
13.0000000	23.6815000	39.0000000	36.5794001	138.0000000	68.7549391
13.2500000	23.8155000	40.0000000	37.0309000	141.6411839	69.7749996
13.5000000	23.9493999	41.0000000	37.4789000	150.0000000	72.1166620
13.7500000	24.0831001	42.0000000	37.9235001		
14.0000000	24.2165999	43.0000000	38.3646998		
14.2500000	24.3499000	44.0000000	38.8023000		
14.5000000	24.4830000	45.0000000	39.2364998		
14.7500000	24.6159999	46.0000000	39.6673002		

POINTS ON THE STARTING LINE

X (IN.)	Y (IN.)	THETA (DEGREES)	M	ENTROPY (BTU/LB. DEG.R)
3.0054114	18.1931674	27.0943208	1.9312258	1.0000000
3.1015134	17.7308900	20.8704937	1.7602118	1.0000000
3.2713982	16.9618237	14.6752536	1.5867536	1.0000000
3.4363195	16.2152271	11.4836057	1.4887691	1.0000000
3.6006526	15.4712937	8.9932814	1.4126346	1.0000000
3.7763805	14.6757762	7.4038906	1.3539491	1.0000000
3.9559068	13.8630629	6.2143198	1.3066441	1.0000000
4.1367482	13.0443960	5.2233964	1.2667252	1.0000000
4.3179488	12.2241036	4.4007728	1.2328507	1.0000000
4.5010017	11.3954251	3.6856612	1.2041164	1.0000000
4.6855183	10.5601209	3.0571496	1.1804863	1.0000000
4.8711339	9.7198422	2.5000977	1.1592838	1.0000000
5.0581858	8.8730602	1.9883725	1.1424441	1.0000000
5.2519720	7.9957931	1.7157276	1.1332070	1.0000000
5.4490621	7.1035683	1.5507369	1.1290357	1.0000000
5.6477737	6.2040037	1.3786341	1.1267115	1.0000000
5.8467692	5.3031539	1.2049838	1.1257339	1.0000000
6.0456483	4.4028304	1.0206785	1.1262808	1.0000000
6.2441479	3.5042258	0.8120876	1.1288147	1.0000000
6.4408628	2.6137004	0.6102237	1.1335201	1.0000000
6.6358016	1.7312148	0.4873105	1.1448248	1.0000000
6.8282049	0.8602074	0.2627363	1.1534117	1.0000000
7.0182226	0.	0.0000001	1.1634541	1.0000000

CALCULATED POINTS ARRANGED ROW WISE

I	J	X (IN.)	Y (IN.)	M	M*	THETA (DEG)	T (DEG R)	P (PSIA)	V (FT/SEC)	DENSITY (LB/CU-FT)	TOLERANCE	ITERATION	S (BTU/LB.DEG.R)
2	1	3.3845508	18.1668022	1.9340160	1.7820120	27.2702057	5340.6	161.43	6971.1	0.066260	-0.0000000	4	1.00000
2	2	3.7116510	17.5834677	1.7650324	1.6551090	21.0922844	5518.5	215.12	6471.8	0.085053	-0.0000000	4	1.00000
2	3	3.8064660	16.7209282	1.5890500	1.5150971	14.9143544	5693.1	285.04	5926.5	0.108695	-0.0000000	4	1.00000
2	4	3.9304344	15.9232180	1.4922833	1.4354408	11.6267297	5783.1	329.86	5614.9	0.123487	-0.0000000	4	1.00000
2	5	4.0893683	15.1169655	1.4131289	1.3687741	9.2295856	5853.6	369.85	5354.2	0.136484	0.0000000	4	1.00000
2	6	4.2425879	14.2833332	1.3540278	1.3186914	7.6342361	5905.6	401.59	5156.7	0.146648	0.0000001	3	1.00000
2	7	4.3972904	13.4427243	1.3079848	1.2783202	6.3852140	5943.3	427.39	4999.8	0.154886	0.0000001	3	1.00000
2	8	4.5533672	12.6009592	1.2685973	1.2440227	5.3625013	5976.9	450.16	4865.2	0.162052	0.0000001	3	1.00000
2	9	4.7157911	11.7555773	1.2357536	1.2151355	4.4979907	6002.1	469.60	4751.3	0.168187	0.0000001	3	1.00000
2	10	4.8812695	10.9034226	1.2078626	1.1904334	3.7493579	6025.1	486.44	4654.5	0.173427	0.0000000	3	1.00000
2	11	5.0495618	10.0469812	1.1851153	1.1692480	3.0939404	6043.2	500.36	4575.1	0.177749	0.0000001	3	1.00000
2	12	5.2206390	9.1837574	1.1643648	1.1514509	2.5039856	6058.2	513.23	4501.6	0.181771	0.0000000	3	1.00000
2	13	5.4052963	8.2985538	1.1476454	1.1356114	1.9929360	6070.9	523.68	4442.6	0.185001	0.0000000	3	1.00000
2	14	5.5966847	7.3998398	1.1389291	1.1278258	1.7245293	6077.9	529.17	4411.7	0.186692	0.0000000	3	1.00000
2	15	5.7926399	6.4960924	1.1351528	1.1248646	1.5327178	6079.9	531.55	4398.1	0.187450	-0.0000000	3	1.00000
2	16	5.9895120	5.5903403	1.1333554	1.1233554	1.3434548	6081.0	532.68	4391.6	0.187806	0.0000000	3	1.00000
2	17	6.1874866	4.6854582	1.1334115	1.1234115	1.1458544	6080.9	532.65	4391.8	0.187796	-0.0000000	2	1.00000
2	18	6.3867333	3.7828303	1.1358260	1.1253695	0.9240680	6079.6	531.12	4400.5	0.187313	-0.0000000	3	1.00000
2	19	6.5847613	2.8873623	1.1399078	1.1286958	0.6883652	6077.1	528.55	4415.2	0.186502	0.0000000	3	1.00000
2	20	6.7834432	2.0006308	1.1461886	1.1342787	0.4534061	6072.0	524.60	4437.4	0.185284	0.0000000	3	1.00000
2	21	6.9833910	1.1312762	1.1577758	1.1452087	0.3050251	6063.2	517.34	4478.3	0.183042	-0.0000000	4	1.00000
2	22	7.1781759	0.2679312	1.1663428	1.1532914	0.0401718	6056.8	512.00	4508.5	0.181389	-0.0000000	5	1.00000
3	1	3.5905890	18.5085063	1.9952990	1.8258660	29.3246303	5272.2	144.97	7145.2	0.060373	-0.0000000	4	1.00000
3	2	4.0607004	18.1231956	1.9411474	1.7873606	27.4930737	5331.8	159.44	6990.9	0.065564	-0.0000000	4	1.00000
3	3	4.3138857	17.4416699	1.7693090	1.6584947	21.3361859	5514.0	213.60	6484.6	0.084533	-0.0000000	4	1.00000
3	4	4.3405930	16.4838142	1.5940801	1.5189436	15.0622058	5688.3	282.84	5942.5	0.107960	-0.0000000	4	1.00000
3	5	4.4524252	15.6181670	1.4938709	1.4367903	11.8665788	5781.7	329.09	5620.1	0.123235	-0.0000000	4	1.00000
3	6	4.5809569	14.7640038	1.4141412	1.3696177	9.4609663	5852.8	369.32	5357.6	0.136311	-0.0000000	4	1.00000
3	7	4.7059364	13.8967333	1.3560398	1.3204798	7.8065687	5903.8	400.48	5163.4	0.146296	0.0000001	3	1.00000
3	8	4.8340815	13.0304635	1.3105074	1.2805064	6.5258072	5941.3	425.95	5008.5	0.154426	0.0000001	3	1.00000
3	9	4.9702599	12.1614435	1.2720506	1.2470443	5.4618262	5974.2	448.14	4877.1	0.161414	0.0000001	3	1.00000
3	10	5.1144031	11.2912371	1.2399719	1.2188576	4.5644153	5998.7	467.08	4765.9	0.167398	0.0000001	3	1.00000
3	11	5.2626807	10.4161407	1.2126714	1.1947079	3.7901268	6021.3	483.52	4671.2	0.172518	0.0000000	3	1.00000
3	12	5.4167062	9.5371586	1.1905915	1.1743364	3.1017706	6038.9	496.99	4594.2	0.176704	0.0000000	3	1.00000
3	13	5.5846141	8.6349397	1.1700266	1.1564226	2.5143595	6054.1	509.71	4521.6	0.180673	0.0000000	3	1.00000
3	14	5.7617868	7.7191584	1.1527207	1.1404196	2.0030569	6067.1	520.50	4460.5	0.184019	-0.0000000	3	1.00000
3	15	5.9497371	6.8031168	1.1455820	1.1337395	1.7058815	6072.5	524.98	4435.3	0.185401	-0.0000000	3	1.00000
3	16	6.1435509	5.8913221	1.1431476	1.1315757	1.4971093	6074.5	526.51	4426.7	0.185873	-0.0000000	3	1.00000
3	17	6.3393242	4.9798177	1.1425852	1.1310757	1.2843016	6074.9	526.86	4424.7	0.185983	-0.0000000	2	1.00000
3	18	6.5377914	4.0705472	1.1441865	1.1324991	1.0505051	6073.7	525.86	4430.4	0.185672	-0.0000000	3	1.00000
3	19	6.7364190	3.1693867	1.1472397	1.1352271	0.8028983	6071.2	523.94	4441.1	0.185080	-0.0000000	3	1.00000
3	20	6.9355709	2.2751170	1.1515582	1.1393183	0.5340516	6067.9	521.23	4456.4	0.184244	-0.0000000	3	1.00000
3	21	7.1352263	1.3942980	1.1581076	1.1455230	0.2548786	6063.0	517.13	4479.5	0.182978	-0.0000000	3	1.00000
3	22	7.3402478	0.5369108	1.1703953	1.1567360	0.0985955	6053.8	509.48	4522.9	0.180602	-0.0000001	5	1.00000
3	23	7.3399575	0.	1.1695001	1.1559751	0.	6054.5	510.03	4519.7	0.180776	0.0000000	2	1.00000
4	1	4.2879227	18.5014267	2.0029128	1.8316458	29.5419378	5263.6	143.03	7166.6	0.059675	-0.0000000	3	1.00000
4	2	4.7273291	18.0843344	1.9476861	1.7922646	27.7350729	5323.7	157.63	7008.9	0.064930	-0.0000000	4	1.00000
4	3	4.9173648	17.3031399	1.7760799	1.6637982	21.4890018	5506.9	211.22	6504.9	0.083713	-0.0000001	4	1.00000
4	4	4.9030040	16.2378082	1.5972021	1.5213310	15.3031905	5685.4	281.47	5952.4	0.107505	0.0000000	4	1.00000
4	5	4.9775046	15.3149893	1.4959652	1.4385705	12.0997422	5779.8	328.07	5626.9	0.122902	-0.0000000	4	1.00000
4	6	5.0706232	14.4160691	1.4171065	1.3720888	9.6339207	5850.4	367.77	5367.5	0.135807	-0.0000000	4	1.00000
4	7	5.1650493	13.5173873	1.3591479	1.3232426	7.9479817	5901.1	398.77	5173.9	0.145752	0.0000001	3	1.00000

I	J	X (IN.)	Y (IN.)	M	M*	THETA (DEG)	T (DEG R)	P (PSIA)	V (FT/SEC)	DENSITY (LB/CU-FT)	TOLERANCE	ITERATION	S (BTU/LB.DEG.R)
4	8	5.2719977	12.6213058	1.3145478	1.2840081	6.6264529	5938.2	423.66	5022.4	0.153691	0.0000001	3	1.00000
4	9	5.3886318	11.7252336	1.2767682	1.2511722	5.5302235	5969.9	445.39	4893.2	0.160554	0.0000001	3	1.00000
4	10	5.5147274	10.8306656	1.2452151	1.2234839	4.6077912	5994.8	463.95	4784.2	0.166412	0.0000001	3	1.00000
4	11	5.6478337	9.9310871	1.2187309	1.2000941	3.8019976	6016.4	479.85	4692.3	0.171375	0.0000001	3	1.00000
4	12	5.7989375	9.0145659	1.1961892	1.1796231	3.1160320	6034.4	493.56	4613.8	0.175640	-0.0000001	2	1.00000
4	13	5.9585423	8.0813565	1.1761011	1.1615859	2.5297708	6049.7	505.93	4543.1	0.179494	0.0000000	3	1.00000
4	14	6.1268493	7.1371101	1.1591377	1.1464989	1.9861903	6062.2	516.49	4483.1	0.182780	0.0000000	3	1.00000
4	15	6.3104611	6.2075961	1.1528244	1.1405178	1.6698631	6067.0	520.44	4460.9	0.183999	0.0000000	3	1.00000
4	16	6.5031984	5.2884694	1.1515736	1.1393329	1.4377661	6067.9	521.22	4456.5	0.184241	0.0000001	2	1.00000
4	17	6.6995412	4.3707327	1.1524461	1.1401595	1.1897743	6067.3	520.67	4459.5	0.184072	0.0000000	3	1.00000
4	18	6.8969914	3.4613808	1.1547567	1.1423484	0.9314522	6065.5	519.23	4467.7	0.183626	-0.0000000	3	1.00000
4	19	7.0962313	2.5599207	1.1584345	1.1458327	0.6534727	6062.7	516.93	4480.7	0.182915	-0.0000000	3	1.00000
4	20	7.2950180	1.6687835	1.1632661	1.1504100	0.3452764	6059.1	513.91	4497.7	0.181983	-0.0000000	4	1.00000
4	21	7.4949538	0.7925936	1.1688090	1.1553876	0.0298014	6055.0	510.46	4517.3	0.180910	-0.0000000	5	1.00000
4	22	7.5043333	0.2694502	1.1740422	1.1598359	0.0583506	6051.2	507.21	4535.8	0.179894	-0.0000000	6	1.00000
5	1	4.6427577	19.0990107	2.0077260	1.8354276	29.2289109	5258.0	141.82	7180.1	0.059239	0.0000000	4	1.00000
5	2	4.9749615	18.4985895	2.0096909	1.8369714	29.7774146	5255.7	141.32	7185.6	0.059061	0.0000000	3	1.00000
5	3	5.3974694	18.0492275	1.9571972	1.7989481	27.8859892	5313.5	155.03	7036.4	0.063997	-0.0000000	4	1.00000
5	4	5.5501493	17.1617351	1.7815630	1.6678509	21.7302828	5501.3	209.30	6521.5	0.083051	-0.0000001	4	1.00000
5	5	5.4688247	15.9942358	1.6008761	1.5241406	15.5354637	5681.9	279.88	5964.1	0.106971	-0.0000000	4	1.00000
5	6	5.5016919	15.0160565	1.4998637	1.4418842	12.2740501	5776.3	326.19	5639.6	0.122285	0.0000000	4	1.00000
5	7	5.5565121	14.0746154	1.4211785	1.3754821	9.7751788	5847.0	365.65	5381.1	0.135117	-0.0000000	4	1.00000
5	8	5.6262558	13.1403551	1.3638473	1.3272554	8.0494521	5896.9	396.20	5189.6	0.144935	0.0000001	3	1.00000
5	9	5.7121868	12.2146363	1.3198055	1.2885648	6.6960136	5934.1	420.68	5040.5	0.152736	0.0000001	3	1.00000
5	10	5.8093468	11.2919260	1.2824767	1.2561671	5.5754061	5964.8	442.06	4912.7	0.159515	0.0000001	3	1.00000
5	11	5.9195975	10.3712306	1.2516641	1.2291742	4.6224822	5990.0	460.13	4806.6	0.165201	0.0000001	3	1.00000
5	12	6.0488796	9.4337870	1.2250811	1.2057186	3.8196254	6011.2	476.01	4714.3	0.170182	0.0000000	3	1.00000
5	13	6.1913574	8.4864833	1.2020318	1.1851411	3.1351355	6029.8	489.99	4634.2	0.174531	0.0000000	2	1.00000
5	14	6.3423541	7.5244271	1.1836211	1.1679780	2.5184469	6044.3	501.28	4569.8	0.178038	0.0000000	3	1.00000
5	15	6.4998524	6.5550036	1.1665180	1.1534403	1.9521367	6056.6	511.89	4509.2	0.181355	0.0000000	3	1.00000
5	16	6.6798730	5.6124108	1.1610761	1.1483352	1.6103896	6060.7	515.28	4490.0	0.182405	-0.0000000	3	1.00000
5	17	6.8732270	4.6852636	1.1611819	1.1484355	1.3439242	6060.7	515.21	4490.3	0.182385	-0.0000000	3	1.00000
5	18	7.0682616	3.7660510	1.1628534	1.1500190	1.0724165	6059.4	514.17	4496.2	0.182063	-0.0000000	3	1.00000
5	19	7.2660362	2.8551021	1.1659590	1.1529612	0.7861538	6057.0	512.24	4507.2	0.181464	-0.0000000	3	1.00000
5	20	7.4647703	1.9556935	1.1706199	1.1569269	0.4756435	6053.7	509.34	4523.7	0.180558	-0.0000001	3	1.00000
5	21	7.6623287	1.0676957	1.1746124	1.1603206	0.1539000	6050.8	506.86	4537.9	0.179783	-0.0000001	4	1.00000
5	22	7.6590989	0.5223015	1.1711739	1.1573978	-0.0344863	6053.3	508.99	4525.7	0.180450	-0.0000001	3	1.00000
5	23	7.6714119	0.	1.1785374	1.1636568	0.	6048.0	504.42	4551.8	0.179022	0.0000000	3	1.00000
6	1	5.3264409	19.0933216	2.0145100	1.8405072	29.4524183	5250.1	140.12	7199.0	0.058628	-0.0000000	3	1.00000
6	2	5.6668815	18.4996605	2.0194402	1.8440287	29.9226656	5244.4	138.90	7212.7	0.058188	0.0000000	3	1.00000
6	3	6.0980912	18.0167696	1.9652754	1.8045018	28.1215198	5305.3	152.85	7060.0	0.063208	-0.0000000	4	1.00000
6	4	6.1868590	17.0236580	1.7875844	1.6723015	21.9599702	5495.2	207.21	6539.6	0.082328	-0.0000001	4	1.00000
6	5	6.0350140	15.7543198	1.6058870	1.5284011	15.7077837	5676.9	277.71	5979.8	0.106251	-0.0000000	4	1.00000
6	6	6.0225603	14.7227228	1.5047826	1.4460652	12.4158858	5771.9	323.82	5655.6	0.121506	0.0000000	4	1.00000
6	7	6.0456648	13.7348301	1.4266714	1.3800595	9.8763853	5842.5	362.80	5399.5	0.134188	-0.0000000	4	1.00000
6	8	6.0906640	12.7650975	1.3697794	1.3322749	8.1197352	5891.6	392.97	5209.5	0.143908	0.0000001	3	1.00000
6	9	6.1554341	11.8100843	1.3260231	1.2939533	6.7421468	5929.2	417.17	5061.8	0.151611	0.0000001	3	1.00000
6	10	6.2355073	10.8588054	1.2893638	1.2621820	5.5920582	5958.7	438.07	4936.2	0.158265	0.0000001	3	1.00000
6	11	6.3411475	9.8998667	1.2584441	1.2351386	4.6422819	5984.9	456.12	4830.1	0.163935	0.0000001	3	1.00000
6	12	6.4607854	8.9311453	1.2317532	1.2116058	3.8411692	6005.5	472.00	4737.5	0.168934	0.0000001	3	1.00000
6	13	6.5944925	7.9533454	1.2094609	1.1918542	3.1283917	6023.8	485.46	4660.1	0.173125	0.0000000	2	1.00000
6	14	6.7349544	6.9667019	1.1915420	1.1752341	2.4897620	6038.2	496.41	4597.6	0.176523	0.0000000	3	1.00000
6	15	6.8824676	5.9722263	1.1758749	1.1613937	1.8951010	6049.9	506.07	4542.3	0.179538	-0.0000000	3	1.00000
6	16	7.0603339	5.0156003	1.1712487	1.1574614	1.5171145	6053.2	508.95	4525.9	0.180436	0.0000000	3	1.00000
6	17	7.2521068	4.0855364	1.1722397	1.1583038	1.2278483	6052.5	508.33	4529.5	0.180244	-0.0000000	3	1.00000
6	18	7.4473333	3.1635353	1.1749766	1.1606301	0.9301570	6050.5	506.63	4539.2	0.179712	0.0000000	3	1.00000

I	J	X (IN.)	Y (IN.)	M	Mθ	THETA (DEG)	T (DEG R)	P (PSIA)	V (FT/SEC)	DENSITY (LB/CU-FT)	TOLERANCE	ITERATION	S (BTU/LB.DEG.R)
59	3	46.0122147	37.6310153	2.5855369	2.2063689	22.7650237	4537.7	48.73	8636.5	0.023857	0.0000001	2	1.00042
59	4	47.1961651	36.9272246	2.6047968	2.2177738	22.2688086	4512.4	46.92	8679.0	0.023108	-0.0000000	3	1.00059
59	5	49.1402378	36.1834979	2.6366383	2.2352424	21.5459447	4470.0	44.17	8748.1	0.021965	0.0000000	3	1.00069
59	6	51.4528670	35.6554122	2.6738462	2.2546482	20.8188496	4420.1	41.20	8827.4	0.020729	0.0000000	3	1.00072
59	7	54.1545644	35.0654154	2.7171850	2.2772517	19.9568796	4361.9	38.02	8917.7	0.019394	0.0000001	3	1.00071
59	8	57.3369021	34.4475746	2.7672705	2.3033738	18.9842720	4294.7	34.67	9019.3	0.017970	-0.0000000	3	1.00068
59	9	60.3215256	33.1255546	2.8188703	2.3302858	17.9079683	4225.4	31.54	9120.9	0.016624	0.0000001	3	1.00064
59	10	64.0791874	31.7317812	2.8824464	2.3614875	16.6514356	4141.1	28.07	9242.2	0.015102	-0.0000000	4	1.00061
59	11	69.2566566	30.3876667	2.9727306	2.4032940	15.2096314	4022.6	23.78	9406.5	0.013179	-0.0000000	4	1.00061
59	12	75.7228136	28.4225690	3.0656784	2.4456213	13.0375791	3901.4	20.07	9565.8	0.011473	0.0000000	4	1.00064
59	13	86.5501947	26.0352683	3.2285122	2.5116855	10.1025795	3704.6	14.91	9834.7	0.008979	0.0000001	4	1.00076
59	14	101.7960157	22.4366376	3.4385495	2.5868921	6.3215405	3475.7	10.14	10161.9	0.006512	0.0000000	5	1.00117
59	15	89.1867094	17.4591589	3.2161716	2.5069593	1.1330808	3716.9	15.11	9812.2	0.009072	-0.0000001	2	1.00149
60	1	46.1467924	39.2021246	2.5805912	2.2034403	23.0851743	4544.2	49.36	8625.5	0.024129	0.0000001	2	1.00012
60	2	46.7606306	38.3920040	2.5919206	2.2101491	22.7416527	4529.3	48.20	8650.6	0.023644	0.0000001	2	1.00034
60	3	47.9003048	37.6266589	2.6105410	2.2211753	22.2475893	4504.9	46.45	8691.6	0.022917	-0.0000000	3	1.00053
60	4	49.8913054	36.9037247	2.6434623	2.2388014	21.5359087	4460.9	43.62	8762.8	0.021742	0.0000000	3	1.00066
60	5	51.9740534	36.1372638	2.6778938	2.2567593	20.8003869	4414.7	40.89	8835.9	0.020602	0.0000000	3	1.00071
60	6	54.7314410	35.5762124	2.7212647	2.2793795	19.9357500	4356.5	37.74	8926.1	0.019272	0.0000000	3	1.00071
60	7	57.9193587	34.9386382	2.7703199	2.3049642	18.9396758	4290.6	34.48	9025.4	0.017885	0.0000001	3	1.00068
60	8	61.7319016	34.2521791	2.8263594	2.3341917	17.8295388	4215.4	31.11	9135.4	0.016435	0.0000001	3	1.00065
60	9	65.5396070	32.8276525	2.8904918	2.3652129	16.5761647	4130.5	27.65	9257.2	0.014917	0.0000000	4	1.00062
60	10	70.5181351	31.2626488	2.9730445	2.4034393	14.9695138	4022.2	23.77	9407.1	0.013173	-0.0000000	4	1.00061
60	11	77.6609192	29.6379986	3.0828097	2.4526615	13.1821227	3879.9	19.45	9594.6	0.011183	-0.0000000	4	1.00063
60	12	88.1574831	26.8928223	3.2326373	2.5132654	9.9975020	3700.5	14.80	9842.1	0.008924	0.0000001	4	1.00075
60	13	103.6658306	23.2376392	3.4433409	2.5884752	6.2677050	3469.9	10.06	10167.9	0.006469	0.0000001	5	1.00113
60	14	101.9435005	22.4089811	3.4428444	2.5883112	6.2297347	3470.5	10.06	10167.3	0.006471	0.0000000	6	1.00117
61	1	47.0232000	40.1043591	2.5877332	2.2076695	23.0459096	4534.8	48.78	8641.3	0.023897	0.0000000	3	1.00000
61	2	47.5642190	39.2066379	2.5985229	2.2140587	22.7127085	4520.7	47.67	8665.2	0.023430	0.0000001	2	1.00025
61	3	48.6695538	38.3887267	2.6166790	2.2248099	22.2237041	4496.8	45.96	8705.0	0.022718	0.0000000	3	1.00047
61	4	50.6238923	37.6044297	2.6496250	2.2420156	21.5141475	4452.6	43.15	8776.0	0.021544	-0.0000000	3	1.00063
61	5	52.7567401	36.8593631	2.6843762	2.2601402	20.7896261	4406.0	40.41	8849.5	0.020400	0.0000001	3	1.00070
61	6	55.2769303	36.0583196	2.7250814	2.2813700	19.9167771	4351.3	37.47	8933.9	0.019159	0.0000000	3	1.00071
61	7	58.5261889	35.4491525	2.7741562	2.3069651	18.9180260	4285.5	34.23	9033.1	0.017780	0.0000001	3	1.00069
61	8	62.3450150	34.7401643	2.8291457	2.3356450	17.7840152	4211.6	30.95	9140.8	0.016365	0.0000001	3	1.00066
61	9	67.0388117	33.9471011	2.8981741	2.3687703	16.4957061	4120.5	27.26	9271.5	0.014742	0.	4	1.00063
61	10	72.0931835	32.3476467	2.9801990	2.4067523	14.8928393	4012.8	23.46	9419.7	0.013032	0.0000000	4	1.00061
61	11	78.9928885	30.4699628	3.0818087	2.4522502	12.9340334	3881.1	19.49	9592.9	0.011200	-0.0000000	4	1.00063
61	12	90.4625425	28.1209157	3.2495761	2.5197526	10.1558443	3683.6	14.36	9872.7	0.008695	0.0000001	4	1.00073
61	13	105.5198011	24.0281744	3.4457264	2.5892634	6.1655209	3467.1	10.02	10170.9	0.006450	-0.0000000	5	1.00109
61	14	103.8202829	23.2085936	3.4475938	2.5898804	6.1768578	3464.9	9.98	10173.3	0.006429	0.0000000	3	1.00113
62	1	48.4579172	40.1095686	2.6054782	2.2181773	22.6729400	4511.5	47.12	8680.5	0.023209	0.0000001	2	1.00013
62	2	49.4954672	39.2044516	2.6238416	2.2285682	22.1941788	4487.2	45.40	8720.5	0.022488	-0.0000000	3	1.00039
62	3	51.4242229	38.3678150	2.6562069	2.2454484	21.4898252	4443.8	42.64	8790.0	0.021337	0.0000000	3	1.00058
62	4	53.5192285	37.5611215	2.6901995	2.2631773	20.7671518	4398.1	39.99	8861.7	0.020222	0.0000000	3	1.00068
62	5	56.0973554	36.7819796	2.7312246	2.2845740	19.9054849	4343.1	37.05	8946.5	0.018981	0.	3	1.00071
62	6	59.1000137	35.9310427	2.7777445	2.3088366	18.8986216	4280.6	34.00	9040.2	0.017683	0.0000001	3	1.00069
62	7	62.9865155	35.2496791	2.8327326	2.3375157	17.7618175	4206.8	30.74	9147.7	0.016276	-0.0000000	4	1.00066
62	8	67.6887589	34.4306188	2.9009844	2.3700716	16.4492626	4116.8	27.12	9276.7	0.014679	-0.0000000	4	1.00063
62	9	73.7084951	33.4551125	2.9870114	2.4099067	14.8113304	4003.9	23.17	9431.6	0.012900	-0.0000000	4	1.00062
62	10	80.7128382	31.5366807	3.0886875	2.4550771	12.8555635	3872.5	19.25	9604.4	0.011086	0.0000000	4	1.00062
62	11	91.8938398	28.8806171	3.2465613	2.5185980	9.8982092	3686.6	14.44	9867.3	0.008737	0.0000001	4	1.00072
62	12	108.3858099	25.2499053	3.4634820	2.5951300	6.3573567	3445.9	9.71	10193.1	0.006289	-0.0000000	5	1.00104
62	13	105.6808033	23.9976366	3.4499384	2.5906551	6.0755295	3462.1	9.94	10176.2	0.006410	0.0000000	3	1.00109
63	1	49.4813399	41.1396422	2.6132572	2.2227837	22.6295650	4501.3	46.52	8697.5	0.022967	0.0000000	3	1.00000
63	2	50.4137850	40.1082401	2.6314328	2.2325274	22.1539121	4477.0	44.81	8736.9	0.022251	-0.0000000	3	1.00029

I	J	X (IN.)	Y (IN.)	M	M*	THETA (DEG)	T (DEG R)	P (PSIA)	V (FT/SEC)	DENSITY (LB/CU-FT)	TOLERANCE	ITERATION	S (BTU/LB.DEG.R)
63	3	52.2833791	39.1848559	2.6630026	2.2489927	21.4597590	4434.7	42.14	8804.4	0.021129	0.0000000	3	1.00053
63	4	54.3520398	38.3255892	2.6964122	2.2664176	20.7421417	4389.8	39.54	8874.7	0.020036	-0.0000000	3	1.00066
63	5	56.8954949	37.4843707	2.7367092	2.2874345	19.8824651	4335.7	36.68	8957.6	0.018823	0.0000000	3	1.00070
63	6	59.9645805	36.6557336	2.7835560	2.3118675	18.8869555	4272.8	33.64	9051.7	0.017526	0.0000001	3	1.00070
63	7	63.5931578	35.7306871	2.8360887	2.3392661	17.7419612	4202.3	30.55	9154.1	0.016193	0.0000001	3	1.00067
63	8	68.3724279	34.9381447	2.9047151	2.3717991	16.4266415	4111.9	26.93	9283.6	0.014596	0.0000000	4	1.00064
63	9	74.4062366	33.9317732	2.9894440	2.4110332	14.7642981	4000.7	23.07	9435.9	0.012853	-0.0000000	4	1.00062
63	10	82.4751253	32.6244183	3.0952101	2.4577576	12.7727894	3864.3	19.02	9615.2	0.010978	0.0000000	4	1.00062
63	11	93.8466187	29.9094932	3.2522324	2.5207699	9.8219264	3681.0	14.29	9877.5	0.008662	0.0000001	4	1.00070
63	12	109.9172020	25.9005628	3.4573175	2.5930932	6.0874411	3453.2	9.82	10185.4	0.006348	-0.0000000	5	1.00101
63	13	108.5588484	25.2179627	3.4676420	2.5965045	6.2689023	3440.9	9.64	10198.2	0.006251	0.0000000	3	1.00104
64	1	51.4656262	41.1393275	2.6399496	2.2369694	22.1101937	4465.6	44.17	8755.2	0.021991	-0.0000000	3	1.00017
64	2	53.2379661	40.0896025	2.6701525	2.2527218	21.4189377	4425.1	41.62	8819.6	0.020915	0.0000000	3	1.00045
64	3	55.2456155	39.1434989	2.7028140	2.2697564	20.7113993	4381.2	39.09	8888.0	0.019848	0.0000000	3	1.00062
64	4	57.7670431	38.2494550	2.7425506	2.2904812	19.8569448	4327.9	36.29	8969.5	0.018658	-0.0000000	3	1.00069
64	5	60.8043447	37.3581138	2.7887093	2.3145553	18.8635232	4265.9	33.32	9061.9	0.017389	0.0000001	3	1.00070
64	6	64.5090790	36.4556351	2.8415673	2.3421234	17.7299538	4195.0	30.24	9164.6	0.016059	-0.0000000	4	1.00067
64	7	69.0190706	35.4173522	2.9082087	2.3734168	16.4064896	4107.3	26.76	9290.1	0.014518	-0.0000000	4	1.00064
64	8	75.1450844	34.4354844	2.9928195	2.4125962	14.7417346	3996.3	22.92	9441.8	0.012788	-0.0000000	4	1.00062
64	9	83.2328520	33.0904126	3.0974505	2.4586783	12.7250266	3861.4	18.94	9618.9	0.010942	-0.0000001	4	1.00062
64	10	95.8444414	30.9572296	3.2575604	2.5228104	9.7418573	3675.7	14.16	9887.0	0.008592	0.0000000	4	1.00069
64	11	112.1956148	26.8609493	3.4615784	2.5945010	6.0211007	3448.2	9.75	10190.7	0.006311	-0.0000000	5	1.00098
64	12	110.0943146	25.8669083	3.4614423	2.5944561	5.9994380	3448.3	9.75	10190.6	0.006309	-0.0000000	3	1.00102
65	1	52.9102445	42.5485287	2.6511207	2.2427957	22.0481567	4450.6	43.35	8779.2	0.021657	0.0000001	3	1.00000
65	2	54.3312144	41.1218534	2.6781973	2.2569176	21.3747132	4414.3	41.05	8836.5	0.020680	0.0000000	3	1.00036
65	3	56.2377057	40.0486741	2.7095313	2.2732598	20.6698840	4372.2	38.63	8901.9	0.019656	-0.0000000	3	1.00057
65	4	58.7016649	39.0676923	2.7485518	2.2936110	19.8257151	4319.8	35.89	8981.7	0.018492	0.0000000	3	1.00067
65	5	61.7211318	38.1231070	2.7941880	2.3174127	18.8376396	4258.6	32.99	9072.7	0.017246	0.0000001	3	1.00070
65	6	65.3971348	37.1670926	2.8463903	2.3446389	17.7061181	4188.5	29.98	9173.8	0.015942	0.	4	1.00068
65	7	69.9980030	36.1415024	2.9139731	2.3760861	16.3944836	4099.7	26.48	9300.7	0.014391	-0.0000000	4	1.00065
65	8	75.8440104	34.9112020	2.9959858	2.4140624	14.7217185	3992.1	22.79	9447.3	0.012727	-0.0000000	4	1.00062
65	9	84.0424786	33.5873003	3.1007843	2.4600483	12.7026612	3857.3	18.83	9624.4	0.010887	0.0000000	4	1.00062
65	10	96.6972113	31.4028721	3.2592390	2.5234532	9.6947623	3674.0	14.11	9890.0	0.008571	0.0000001	4	1.00069
65	11	114.5220079	27.8373339	3.4654897	2.5957934	5.9513719	3443.5	9.69	10195.6	0.006278	0.0000000	5	1.00095
65	12	112.3807764	26.8256145	3.4656604	2.5958498	5.9340227	3443.3	9.68	10195.8	0.006273	0.0000000	3	1.00098
66	1	55.8320756	42.5323715	2.6888009	2.2624479	21.3121436	4400.0	40.32	8858.8	0.020380	0.0000000	3	1.00021
66	2	57.3738074	41.0815024	2.7171001	2.2772073	20.6250076	4362.0	38.12	8917.5	0.019445	0.0000000	3	1.00050
66	3	59.7384634	39.9726191	2.7548221	2.2968813	19.7837045	4311.4	35.49	8994.3	0.018322	0.	3	1.00064
66	4	62.7036743	38.9408674	2.7997965	2.3203378	18.8060796	4251.0	32.65	9083.7	0.017101	0.0000001	3	1.00069
66	5	66.3665705	37.9210787	2.8518247	2.3473080	17.6798129	4181.3	29.68	9184.2	0.015810	-0.0000000	4	1.00068
66	6	70.9452686	36.8407769	2.9190058	2.3784164	16.3705699	4093.1	26.23	9309.9	0.014281	-0.0000000	4	1.00065
66	7	76.9055138	35.6325045	3.0012895	2.4165183	14.7104306	3985.1	22.57	9456.4	0.012626	0.0000000	4	1.00063
66	8	84.8086023	34.0567274	3.1039201	2.4613370	12.6829603	3853.3	18.72	9629.6	0.010837	0.0000001	4	1.00062
66	9	97.6212759	31.8848174	3.2621345	2.5245622	9.6747583	3671.1	14.04	9895.2	0.008533	0.0000001	4	1.00068
66	10	115.5046520	28.2483597	3.4664485	2.5961102	5.9076378	3442.3	9.67	10196.7	0.006270	-0.0000000	5	1.00093
66	11	114.7152653	27.8002796	3.4695298	2.5971283	5.8651899	3438.7	9.62	10200.5	0.006241	-0.0000000	3	1.00095
67	1	58.0170360	44.5713782	2.7019168	2.2692885	21.1734698	4382.4	39.45	8886.1	0.020024	-0.	3	1.00000
67	2	58.9328942	42.4925523	2.7270990	2.2824223	20.5617313	4348.6	37.48	8938.0	0.019175	-0.0000001	3	1.00039
67	3	60.9256845	41.0052762	2.7618879	2.3005665	19.7384138	4301.9	35.05	9008.5	0.018135	-0.0000000	3	1.00060
67	4	63.7926292	39.8445692	2.8056255	2.3233779	18.7637320	4243.2	32.31	9095.1	0.016953	0.0000001	3	1.00068
67	5	67.4051008	38.7374125	2.8577012	2.3500291	17.6478109	4173.6	29.35	9195.4	0.015669	0.0000001	3	1.00068
67	6	71.9793110	37.6023765	2.9243375	2.3808853	16.3442054	4086.1	25.97	9319.7	0.014165	0.	4	1.00066
67	7	77.9299517	36.3272963	3.0058727	2.4186406	14.6870196	3979.1	22.38	9464.4	0.012540	-0.0000000	4	1.00063
67	8	85.9773026	34.7716594	3.1092900	2.4635438	12.6728889	3846.6	18.54	9638.4	0.010750	0.0000001	4	1.00062
67	9	98.4960699	32.3403935	3.2648715	2.5256104	9.6574244	3668.4	13.97	9900.0	0.008498	0.0000001	4	1.00068
67	10	116.5914974	28.7021451	3.4688815	2.5969141	5.8940896	3439.4	9.63	10199.7	0.006249	-0.0000000	5	1.00092

I	J	X (IN.)	Y (IN.)	M	M*	THETA (DEG)	T (DEG R)	P (PSIA)	V (FT/SEC)	DENSITY (LB/CU-FT)	TOLERANCE	ITERATION	S (BTU/LB.DEG.R)
67	21	115.7011967	28.2105377	3.4704713	2.5974393	5.8218061	3437.5	9.60	10201.7	0.006233	0.0000000	2	1.00093
68	1	61.1980371	44.5287209	2.7394571	2.2888677	20.4220328	4332.0	36.71	8963.2	0.018858	0.0000000	3	1.00020
68	2	62.5542531	42.4158187	2.7712218	2.3054346	19.6747506	4289.4	34.48	9027.2	0.017895	-0.0000000	3	1.00052
68	3	65.0395288	40.8759627	2.8121887	2.3268010	18.7182202	4234.4	31.93	9107.9	0.016789	0.0000000	3	1.00066
68	4	68.5551119	39.6387119	2.8637716	2.3528401	17.6050699	4165.6	29.03	9206.9	0.015524	0.0000001	3	1.00068
68	5	73.0863647	38.4157400	2.9297510	2.3833921	16.3120990	4079.0	25.71	9329.5	0.014049	-0.0000000	4	1.00066
68	6	79.0478649	37.0838823	3.0107258	2.4208878	14.6612988	3972.8	22.18	9472.7	0.012449	0.0000000	4	1.00063
68	7	87.1014853	35.4580808	3.1138647	2.4654239	12.6503946	3840.8	18.39	9645.9	0.010677	-0.0000001	4	1.00062
68	8	99.8394928	33.0390449	3.2697516	2.5274794	9.6521020	3663.6	13.85	9908.7	0.008435	-0.0000000	5	1.00067
68	9	117.6210794	29.1315122	3.4712034	2.5976813	5.8829960	3436.7	9.59	10202.6	0.006229	0.0000000	5	1.00091
68	10	116.7919006	28.6635756	3.4728864	2.5982373	5.8086678	3434.6	9.56	10204.6	0.006212	0.0000000	2	1.00092
69	1	63.6244698	46.6896095	2.7500381	2.2943862	20.2182305	4317.8	36.09	8984.7	0.018600	-0.	4	1.00000
69	2	64.9149141	44.4471436	2.7826837	2.3114126	19.5344427	4274.0	33.82	9050.0	0.017616	-0.0000000	3	1.00038
69	3	66.7492380	42.2844801	2.8208400	2.3313131	18.6544442	4222.8	31.44	9124.7	0.016580	0.0000000	3	1.00061
69	4	69.8721800	40.6675196	2.8705992	2.3560016	17.5593698	4156.7	28.67	9219.9	0.015365	0.0000001	3	1.00068
69	5	74.3107367	39.3127861	2.9353079	2.3859653	16.2692554	4071.7	25.45	9339.6	0.013931	0.	4	1.00067
69	6	80.2435446	37.8912368	3.0156343	2.4231607	14.6299001	3966.3	21.98	9481.1	0.012358	-0.0000000	4	1.00064
69	7	88.3279428	36.2053971	3.1187075	2.4674141	12.6258154	3834.7	18.22	9653.8	0.010600	-0.0000000	4	1.00062
69	8	101.1250982	33.7065716	3.2738039	2.5290313	9.6335464	3659.5	13.75	9915.9	0.008383	0.0000001	4	1.00067
69	9	119.2172470	29.7965295	3.4756680	2.5991564	5.8890502	3431.3	9.52	10208.0	0.006190	0.0000000	5	1.00089
69	10	117.8251343	29.0922430	3.4751916	2.5989990	5.7979565	3431.9	9.52	10207.4	0.006192	-0.0000000	2	1.00091
70	1	67.4369726	46.5977793	2.7924239	2.3164926	19.3299303	4260.9	33.29	9069.2	0.017394	-0.0000000	3	1.00021
70	2	69.2211313	44.3082166	2.8313309	2.3367847	18.5138438	4208.7	30.88	9145.0	0.016339	0.0000001	3	1.00052
70	3	71.6777115	42.0721474	2.8795665	2.3601539	17.4956591	4144.9	28.20	9236.8	0.015160	0.0000001	3	1.00066
70	4	75.7130194	40.3369503	2.9415558	2.3888583	16.2236404	4063.5	25.16	9350.9	0.013800	0.0000000	4	1.00067
70	5	81.5639496	38.7804675	3.0206363	2.4254769	14.5877970	3959.8	21.78	9489.7	0.012266	0.0000000	4	1.00064
70	6	89.6382904	37.0020251	3.1235821	2.4694173	12.5956699	3828.6	18.06	9661.7	0.010523	0.0000000	4	1.00063
70	7	102.5270128	34.4331608	3.2780931	2.5306740	9.6133442	3655.2	13.64	9923.5	0.008328	0.0000001	4	1.00067
70	8	120.7337084	30.4276783	3.4792032	2.6003245	5.8801023	3427.1	9.46	10212.3	0.006159	-0.0000000	5	1.00087
70	9	119.4270992	29.7562516	3.4796314	2.6004659	5.8046077	3426.6	9.45	10212.8	0.006154	-0.0000001	2	1.00089
71	1	70.4228706	49.1165347	2.8024829	2.3217389	19.0781777	4247.4	32.76	9089.0	0.017173	-0.	4	1.00000
71	2	71.8541384	46.4450169	2.8401015	2.3413590	18.3088942	4196.9	30.43	9161.8	0.016150	0.0000000	3	1.00038
71	3	74.2811203	44.0848055	2.8902380	2.3650954	17.3551385	4130.9	27.67	9256.7	0.014926	0.0000000	3	1.00060
71	4	77.6344070	41.7348423	2.9497308	2.3926438	16.1602571	4052.8	24.79	9365.6	0.013632	0.0000001	3	1.00066
71	5	83.0763578	39.7959871	3.0262652	2.4280834	14.5432420	3952.4	21.56	9499.3	0.012164	0.0000000	4	1.00065
71	6	91.0827465	37.8779140	3.1285024	2.4714393	12.5548935	3822.4	17.90	9669.7	0.010447	0.0000001	4	1.00063
71	7	104.0221691	35.2065239	3.2823737	2.5323133	9.5877496	3651.0	13.54	9931.0	0.008274	0.0000000	4	1.00066
71	8	122.3863411	31.1145761	3.4829425	2.6015599	5.8702907	3422.6	9.40	10216.9	0.006127	-0.0000000	5	1.00086
71	9	120.9489260	30.3864045	3.4831435	2.6016264	5.7961935	3422.4	9.39	10217.1	0.006124	-0.0000000	2	1.00087
72	1	74.9676933	48.9452233	2.8492057	2.3460952	18.0570259	4184.7	29.99	9179.2	0.015964	-0.0000000	3	1.00021
72	2	77.0453720	46.2031069	2.8989187	2.3691151	17.1502175	4119.5	27.26	9272.9	0.014746	0.0000000	3	1.00052
72	3	80.3950491	43.7312984	2.9592250	2.3970401	16.0198939	4040.4	24.37	9382.6	0.013443	0.0000000	3	1.00064
72	4	85.1474609	41.1816134	3.0336055	2.4314824	14.4815058	3942.7	21.27	9511.7	0.012032	0.0000000	4	1.00065
72	5	92.7377949	38.8785768	3.1340548	2.4737211	12.5121688	3815.4	17.72	9678.6	0.010360	0.0000000	4	1.00063
72	6	105.6656637	36.0546293	3.2866203	2.5339397	9.5516839	3646.8	13.44	9938.5	0.008221	0.0000000	4	1.00066
72	7	124.1445484	31.8442519	3.4866124	2.6027725	5.8553281	3418.2	9.34	10221.3	0.006096	0.0000000	5	1.00084
72	8	122.6073694	31.0722239	3.4868584	2.6028538	5.7869436	3417.9	9.33	10221.6	0.006092	-0.0000000	2	1.00086
73	1	78.6273031	51.8471866	2.8593301	2.3507834	17.7508278	4171.4	29.51	9198.5	0.015759	-0.	4	1.00000
73	2	80.3105621	48.6789765	2.9078603	2.3732555	16.8989363	4107.8	26.86	9289.4	0.014570	0.0000000	3	1.00039
73	3	83.3141413	45.8244343	2.9666434	2.4004753	15.8148129	4030.6	24.05	9395.8	0.013301	0.0000000	3	1.00060
73	4	88.1102142	43.1524563	3.0418630	2.4353060	14.3428637	3931.9	20.96	9525.6	0.011886	-0.0000000	4	1.00065
73	5	96.0030966	40.2433457	3.1412750	2.4766884	12.4532082	3806.3	17.49	9690.2	0.010250	-0.0000000	4	1.00064
73	6	107.5495672	37.0242233	3.2914440	2.5357871	9.5146608	3642.0	13.32	9947.0	0.008161	0.0000000	4	1.00066
73	7	126.0694666	32.6416287	3.4901280	2.6039341	5.8301779	3414.0	9.28	10225.5	0.006066	-0.0000000	5	1.00082
73	8	124.3716793	31.8007436	3.4905029	2.6040580	5.7725552	3413.6	9.27	10226.0	0.006061	-0.0000001	2	1.00084
74	1	84.1435909	51.5495143	2.9166865	2.3773425	16.5936365	4096.2	26.48	9305.7	0.014407	-0.0000001	3	1.00021

I	J	X (IN.)	Y (IN.)	M	M*	THETA (DEG)	T (DEG R)	P (PSIA)	V (FT/SEC)	DENSITY (LB/CU-FT)	TOLERANCE	ITERATION	S (BTU/LB.DEG.R)
74	2	86.7570105	48.2677913	2.9741706	2.4039608	15.5638306	4020.7	23.75	9409.1	0.013165	0.0000000	3	1.00052
74	3	91.2270060	45.2086830	3.0479428	2.4381213	14.1389341	3923.9	20.73	9535.8	0.011782	-0.0000000	4	1.00063
74	4	98.2259579	42.1740541	3.1490473	2.4798825	12.3175550	3796.6	17.24	9702.6	0.010132	-0.0000000	4	1.00064
74	5	110.1258163	38.3458996	3.2976981	2.5381822	9.4636015	3635.7	13.17	9957.9	0.008083	0.0000001	4	1.00065
74	6	128.2774315	33.5543017	3.4941748	2.6052712	5.8059009	3409.2	9.21	10230.4	0.006032	0.0000000	5	1.00081
74	7	126.3031578	32.5968318	3.4939913	2.6052106	5.7480026	3409.4	9.21	10230.1	0.006032	-0.0000000	2	1.00083
75	1	88.7227125	54.9289393	2.9250763	2.3812275	16.2184901	4085.2	26.14	9321.0	0.014262	-0.	4	1.00000
75	2	90.7917891	51.0965562	2.9814927	2.4073513	15.2593995	4011.1	23.47	9422.0	0.013042	-0.0000000	3	1.00039
75	3	94.8967142	47.6052399	3.0541768	2.4408946	13.8896821	3915.9	20.51	9546.3	0.011679	0.0000000	4	1.00059
75	4	101.5944357	44.1753922	3.1542564	2.4820232	12.1156806	3790.0	17.08	9710.8	0.010055	-0.0000000	4	1.00064
75	5	113.7594461	40.2001729	3.3038930	2.5405548	9.3368765	3629.6	13.02	9968.8	0.008007	0.0000000	4	1.00065
75	6	131.2932091	34.7976985	3.4993927	2.6069953	5.7719956	3403.0	9.13	10236.6	0.005988	0.0000000	5	1.00079
75	7	128.5186214	33.5080490	3.4980082	2.6065378	5.7243907	3404.6	9.15	10234.9	0.005998	-0.0000001	2	1.00081
76	1	95.6030493	54.4214234	2.9883460	2.4105247	14.8858486	4002.1	23.22	9434.0	0.012937	-0.0000000	3	1.00021
76	2	99.1894445	50.3749814	3.0604975	2.4434921	13.5876633	3907.9	20.29	9557.0	0.011580	0.0000001	3	1.00052
76	3	105.5524054	46.5032277	3.1591201	2.4840220	11.8692458	3783.9	16.94	9718.5	0.009984	-0.0000000	4	1.00062
76	4	117.5182533	42.1028824	3.3072188	2.5418285	9.1418499	3626.2	12.95	9974.5	0.007967	0.0000000	4	1.00065
76	5	135.4945774	36.5218730	3.5036631	2.6084062	5.6646724	3397.9	9.06	10241.6	0.005953	-0.0000000	5	1.00076
76	6	131.5445271	34.7494655	3.5031868	2.6082489	5.6913472	3398.4	9.07	10241.1	0.005955	0.0000000	3	1.00079
77	1	101.5769148	58.5515842	3.0344909	2.4318923	15.6393367	3941.6	21.41	9513.2	0.012111	0.0000000	4	1.00000
77	2	104.2977066	53.6238155	3.0661283	2.4458062	13.2176216	3900.8	20.11	9566.6	0.011499	-0.0000000	3	1.00039
77	3	110.1714611	49.1874485	3.1633078	2.4857429	11.5708224	3778.6	16.81	9725.1	0.009927	0.0000001	4	1.00059
77	4	121.9204826	44.3088465	3.3098793	2.5428474	8.9036543	3623.6	12.89	9979.2	0.007935	-0.0000000	4	1.00064
77	5	139.7764416	38.2654724	3.5044620	2.6086702	5.4845866	3396.9	9.05	10242.6	0.005947	-0.0000000	5	1.00074
77	6	135.7592545	36.4706650	3.5074037	2.6096421	5.5850891	3393.4	9.00	10246.0	0.005920	0.0000000	3	1.00077
78	1	110.9660072	57.8690381	3.1171531	2.4667753	13.9985492	3836.7	18.37	9651.3	0.010677	0.0000000	3	1.00022
78	2	115.6530495	52.3277431	3.1665424	2.4870722	11.2055836	3774.6	16.73	9730.2	0.009888	0.0000000	4	1.00052
78	3	127.0391636	46.8431492	3.3114977	2.5434672	8.6149937	3622.0	12.85	9982.0	0.007917	0.0000000	4	1.00063
78	4	144.7688026	40.2779255	3.5041267	2.6085594	5.2633825	3397.3	9.06	10242.2	0.005951	-0.0000000	5	1.00073
78	5	140.0537739	38.2109327	3.5081490	2.6098884	5.4059585	3392.5	8.99	10246.9	0.005915	-0.0000000	3	1.00075
79	1	119.7743349	63.6490464	3.2053830	2.5028275	15.6499591	3727.6	15.69	9792.4	0.009393	-0.0000000	4	1.00000
79	2	123.2750187	56.7059140	3.2176907	2.5075411	12.0248851	3715.4	15.27	9815.0	0.009171	0.0000000	4	1.00040
79	3	133.0894985	49.7959776	3.3116991	2.5435443	8.2614743	3621.8	12.85	9982.3	0.007917	0.0000000	4	1.00060
80	1	133.6569252	62.8764439	3.3114275	2.5434403	13.7353035	3622.1	12.92	9981.9	0.007957	0.0000001	3	1.00021
80	2	142.3323383	54.3307233	3.3673226	2.5633580	9.1530828	3560.8	11.63	10068.3	0.007288	-0.0000000	4	1.00053
81	1	147.2224159	71.3382568	3.4322698	2.5848172	15.6498010	3483.2	10.40	10153.9	0.006665	-0.	5	1.00000

PERFORMANCE BY INTEGRATING ALONG NOZZLE CONTOUR AT WALL POINTS

X (IN.)	Y (IN.)	THRUST (LBF.)	SP. IMPULSE (LBF-SEC/LBM)	CF
34.8529406	34.6704688	1542268.3906250	279.4009056	1.4911644
35.9380364	35.1755519	1548654.7031250	280.5578651	1.4973391
37.0509310	35.6895161	1555070.3281250	281.7201347	1.5035421
38.1100483	36.1746244	1561039.2968750	282.8014870	1.5093133
39.7026997	36.8970103	1569759.9843750	284.3813477	1.5177450
41.2778745	37.6027741	1578073.7656250	285.8874931	1.5257833
43.0156422	38.3715649	1586901.1250000	287.4866753	1.5343182
44.9019589	39.1940479	1596072.3125000	289.1481514	1.5431855
47.0232000	40.1043591	1605887.2656250	290.9262505	1.5526752
49.4813399	41.1396422	1616606.2812500	292.8681297	1.5630390
52.9102445	42.5485287	1630544.8593750	295.3932762	1.5765158
58.0170360	44.5713782	1649658.0937500	298.8558731	1.5949957
63.6244698	46.6896095	1668546.9375000	302.2778206	1.6132586
70.4228706	49.1165347	1688721.4218750	305.9326782	1.6327646
78.6273031	51.8471866	1709448.3750000	309.6876183	1.6528048
88.7227125	54.9289393	1730705.5937500	313.5386276	1.6733576
101.5769148	58.5515842	1752565.0468750	317.4987335	1.6944927
119.7743349	63.6490464	1775146.1875000	321.5895882	1.7163257
141.6411839	72.1166620	1792185.8125000	324.6765251	1.7328007

MASS FLOW RATE BY INTEGRATING ALONG THE STARTING LINE

FLOW RATE = 5519.9118652 LBM/SEC

POINTS ALONG THE SHOCK WAVE

X (IN.)	Y (IN.)	THETA (DEG)	M*	SHOCK ANGLE (DEG)	DENSITY RATIO	ENTROPY (BTU/LB.DEG.R)
0.24131142E 02	0.26748111E 02	0.16301758E 02	0.18540117E 01	-0.65555871E 01	0.65869477E 00	0.10012022E 01
0.25268517E 02	0.26620128E 02	0.16693800E 02	0.18737246E 01	-0.62847018E 01	0.66604798E 00	0.10011062E 01
0.26460458E 02	0.26492190E 02	0.16832236E 02	0.18956635E 01	-0.59681059E 01	0.67603195E 00	0.10009883E 01
0.27683125E 02	0.26367008E 02	0.16903341E 02	0.19164722E 01	-0.57234918E 01	0.68467489E 00	0.10008973E 01
0.28219492E 02	0.26313683E 02	0.16913156E 02	0.19251904E 01	-0.56316491E 01	0.68774953E 00	0.10008664E 01
0.28761440E 02	0.26260643E 02	0.16901653E 02	0.19339712E 01	-0.55475847E 01	0.69029090E 00	0.10008413E 01
0.29271032E 02	0.26211449E 02	0.16877149E 02	0.19421412E 01	-0.54806113E 01	0.69247947E 00	0.10008200E 01
0.30019339E 02	0.26140100E 02	0.16799837E 02	0.19543475E 01	-0.54123120E 01	0.69540047E 00	0.10007922E 01
0.30753173E 02	0.26070958E 02	0.16722912E 02	0.19657874E 01	-0.53527318E 01	0.69799966E 00	0.10007679E 01
0.31549865E 02	0.25996645E 02	0.16622316E 02	0.19779610E 01	-0.53051068E 01	0.70054507E 00	0.10007445E 01
0.32402087E 02	0.25917785E 02	0.16502277E 02	0.19906380E 01	-0.52685184E 01	0.70301040E 00	0.10007222E 01
0.33343506E 02	0.25831156E 02	0.16352583E 02	0.20043361E 01	-0.52464538E 01	0.70546029E 00	0.10007004E 01
0.34409510E 02	0.25733256E 02	0.16156127E 02	0.20196301E 01	-0.52480048E 01	0.70792984E 00	0.10006786E 01
0.35853139E 02	0.25600135E 02	0.15852800E 02	0.20399636E 01	-0.52890257E 01	0.71087647E 00	0.10006528E 01
0.37934691E 02	0.25405645E 02	0.15394414E 02	0.20678758E 01	-0.53868055E 01	0.71462037E 00	0.10006204E 01
0.40147183E 02	0.25194233E 02	0.14898571E 02	0.20956751E 01	-0.55296893E 01	0.71802299E 00	0.10005918E 01
0.42698536E 02	0.24942022E 02	0.14249500E 02	0.21266994E 01	-0.57613965E 01	0.71992335E 00	0.10005813E 01
0.45638467E 02	0.24637426E 02	0.13459527E 02	0.21606470E 01	-0.60687547E 01	0.71961381E 00	0.10005866E 01
0.49095623E 02	0.24257385E 02	0.12533535E 02	0.21978082E 01	-0.64776286E 01	0.71925785E 00	0.10005906E 01
0.53263294E 02	0.23764179E 02	0.11428502E 02	0.22391760E 01	-0.70201288E 01	0.71926561E 00	0.10005894E 01
0.58415786E 02	0.23094272E 02	0.99391849E 01	0.22878031E 01	-0.77948450E 01	0.71430944E 00	0.10006350E 01
0.65198502E 02	0.22102127E 02	0.80997558E 01	0.23440490E 01	-0.88476323E 01	0.70905980E 00	0.10006858E 01
0.75289487E 02	0.20373107E 02	0.51743711E 01	0.24199620E 01	-0.10593441E 02	0.68848235E 00	0.10008979E 01
0.89099372E 02	0.17479491E 02	0.12357926E 01	0.25053759E 01	-0.13063626E 02	0.64672871E 00	0.10014808E 01
0.89186709E 02	0.17459159E 02	0.11330808E 01	0.25069593E 01	-0.13145606E 02	0.64623535E 00	0.10014896E 01

CALCULATED POINTS ARRANGED ROW WISE

I	J	X (IN.)	Y (IN.)	M	M*	THETA (DEG)	T (DEG R)	P (PSIA)	V (FT/SEC)	DENSITY (LB/CU-FT)	TOLERANCE	ITERATION	S (BTU/LB.DEG.R)
2	1	3.3845508	18.1668022	1.9340160	1.7820120	27.2702048	5340.6	161.43	6971.1	0.066260	0.0000000	4	1.00000
2	2	3.7116510	17.5834677	1.7650324	1.6551090	21.0922840	5518.5	215.12	6471.8	0.085053	-0.0000000	4	1.00000
2	3	3.8064660	16.7209282	1.5890500	1.5150971	14.9143540	5693.1	285.04	5926.5	0.108695	-0.0000000	4	1.00000
2	4	3.9304344	15.9232180	1.4922833	1.4354408	11.6267295	5783.1	329.86	5614.9	0.123487	-0.0000000	4	1.00000
2	5	4.0893683	15.1169657	1.4131289	1.3687741	9.2295855	5853.6	369.85	5354.2	0.136484	0.0000000	4	1.00000
2	6	4.2425879	14.2833332	1.3540278	1.3186914	7.6342360	5905.6	401.59	5156.7	0.146648	0.0000001	3	1.00000
2	7	4.3972904	13.4427243	1.3079848	1.2783202	6.3852139	5943.3	427.39	4999.8	0.154886	0.0000001	3	1.00000
2	8	4.5533672	12.6009592	1.2685973	1.2440227	5.3625013	5976.9	450.16	4865.2	0.162052	0.0000001	3	1.00000
2	9	4.7157911	11.7555773	1.2357536	1.2151355	4.4979906	6002.1	469.60	4751.3	0.168187	0.0000001	3	1.00000
2	10	4.8812695	10.9034226	1.2078626	1.1904334	3.7493579	6025.1	486.44	4654.5	0.173427	0.0000000	3	1.00000
2	11	5.0495619	10.0469813	1.1851153	1.1692480	3.0939404	6043.2	500.36	4575.1	0.177749	0.0000001	3	1.00000
2	12	5.2206390	9.1837574	1.1643648	1.1514509	2.5039855	6058.2	513.23	4501.6	0.181771	0.0000000	3	1.00000
2	13	5.4052963	8.2985538	1.1476454	1.1356114	1.9929359	6070.9	523.68	4442.6	0.185001	0.0000000	3	1.00000
2	14	5.5966847	7.3998398	1.1389291	1.1278258	1.7245292	6077.9	529.17	4411.7	0.186692	0.0000000	3	1.00000
2	15	5.7926399	6.4960924	1.1351528	1.1248646	1.5327178	6079.9	531.55	4398.1	0.187450	-0.0000000	3	1.00000
2	16	5.9895120	5.5903403	1.1333554	1.1233554	1.3434548	6081.0	532.68	4391.6	0.187806	0.0000000	3	1.00000
2	17	6.1874866	4.6854582	1.1334115	1.1234115	1.1458544	6080.9	532.65	4391.8	0.187796	-0.0000000	2	1.00000
2	18	6.3867333	3.7828303	1.1358260	1.1253695	0.9240680	6079.6	531.12	4400.5	0.187313	-0.0000000	3	1.00000
2	19	6.5847613	2.8873623	1.1399078	1.1286958	0.6883652	6077.1	528.55	4415.2	0.186502	0.0000000	3	1.00000
2	20	6.7834432	2.0006308	1.1461886	1.1342787	0.4534061	6072.0	524.60	4437.4	0.185284	0.0000000	3	1.00000
2	21	6.9833910	1.1312762	1.1577758	1.1452087	0.3050251	6063.2	517.34	4478.3	0.183042	-0.0000000	4	1.00000
2	22	7.1781759	0.2679312	1.1663428	1.1532914	0.0401718	6056.8	512.00	4508.5	0.181389	-0.0000000	5	1.00000
3	1	3.5905892	18.5085065	1.9952990	1.8258660	29.3246303	5272.2	144.97	7145.2	0.060373	-0.0000000	4	1.00000
3	2	4.0607003	18.1231954	1.9411474	1.7873606	27.4930735	5331.8	159.44	6990.9	0.065564	-0.0000000	4	1.00000
3	3	4.3138856	17.4416699	1.7693090	1.6584947	21.3361857	5514.0	213.60	6484.6	0.084533	-0.0000000	4	1.00000
3	4	4.3405930	16.4838142	1.5940801	1.5189436	15.0622047	5688.3	282.84	5942.5	0.107960	-0.0000000	4	1.00000
3	5	4.4524253	15.6181672	1.4938709	1.4367903	11.8665786	5781.7	329.09	5620.1	0.123235	-0.0000000	4	1.00000
3	6	4.5809571	14.7640039	1.4141412	1.3696177	9.4609662	5852.8	369.32	5357.6	0.136311	-0.0000000	4	1.00000
3	7	4.7059363	13.8967332	1.3560398	1.3204798	7.8065684	5903.8	400.48	5163.4	0.146296	0.0000001	3	1.00000
3	8	4.8340815	13.0304635	1.3105074	1.2805064	6.5258071	5941.3	425.95	5008.5	0.154426	0.0000001	3	1.00000
3	9	4.9702599	12.1614435	1.2720506	1.2470443	5.4618262	5974.2	448.14	4877.1	0.161414	0.0000001	3	1.00000
3	10	5.1144031	11.2912371	1.2399719	1.2188576	4.5644153	5998.7	467.08	4765.9	0.167398	0.0000001	3	1.00000
3	11	5.2626806	10.4161406	1.2126714	1.1947079	3.7901268	6021.3	483.52	4671.2	0.172518	0.0000000	3	1.00000
3	12	5.4167063	9.5371587	1.1905915	1.1743364	3.1017705	6038.9	496.99	4594.2	0.176704	0.0000000	3	1.00000
3	13	5.5846141	8.6349397	1.1700266	1.1564226	2.5143594	6054.1	509.71	4521.6	0.180673	0.0000000	3	1.00000
3	14	5.7617868	7.7191584	1.1527207	1.1404196	2.0030569	6067.1	520.50	4460.5	0.184019	-0.0000000	3	1.00000
3	15	5.9497371	6.8031168	1.1455820	1.1337395	1.7058815	6072.5	524.98	4435.3	0.185401	-0.0000000	3	1.00000
3	16	6.1435509	5.8913221	1.1431476	1.1315757	1.4971089	6074.5	526.51	4426.7	0.185873	-0.0000000	3	1.00000
3	17	6.3393242	4.9798177	1.1425852	1.1310757	1.2843016	6074.9	526.86	4424.7	0.185983	-0.0000000	2	1.00000
3	18	6.5377914	4.0705472	1.1441865	1.1324991	1.0505051	6073.7	525.86	4430.4	0.185672	-0.0000000	3	1.00000
3	19	6.7364190	3.1693867	1.1472397	1.1352271	0.8028983	6071.2	523.94	4441.1	0.185080	-0.0000000	3	1.00000
3	20	6.9355709	2.2751170	1.1515582	1.1393183	0.5340516	6067.9	521.23	4456.4	0.184244	-0.0000000	3	1.00000
3	21	7.1352263	1.3942980	1.1581076	1.1455230	0.2548786	6063.0	517.13	4479.5	0.182978	-0.0000000	3	1.00000
3	22	7.3402478	0.5369108	1.1703953	1.1567360	0.0985955	6053.8	509.48	4522.9	0.180602	-0.0000001	5	1.00000
3	23	7.3399575	0.	1.1695001	1.1559751	0.	6054.5	510.03	4519.7	0.180776	0.0000000	2	1.00000
4	1	4.2879229	18.5014269	2.0029128	1.8316458	29.5419378	5263.6	143.03	7166.6	0.059675	0.	3	1.00000
4	2	4.7273290	18.0843341	1.9476861	1.7922646	27.7350712	5323.7	157.63	7008.9	0.064930	0.	4	1.00000
4	3	4.9173647	17.3031397	1.7760800	1.6637982	21.4890008	5506.9	211.22	6504.9	0.083713	-0.0000001	4	1.00000
4	4	4.9030039	16.2378082	1.5972021	1.5213310	15.3031898	5685.4	281.47	5952.4	0.107505	0.0000000	4	1.00000
4	5	4.9775046	15.3149892	1.4959652	1.4385704	12.0997422	5779.8	328.07	5626.9	0.122902	-0.0000000	4	1.00000
4	6	5.0706233	14.4160693	1.4171065	1.3720888	9.6339196	5850.4	367.77	5367.5	0.135807	-0.0000000	4	1.00000
4	7	5.1650492	13.5173872	1.3591479	1.3232426	7.9479817	5901.1	398.77	5173.9	0.145752	0.0000001	3	1.00000

I	J	X (IN.)	Y (IN.)	M	M*	THETA (DEG)	T (DEG R)	P (PSIA)	V (FT/SEC)	DENSITY (LB/CU-FT)	TOLERANCE	ITERATION	S (BTU/LB.DEG.R)
4	8	5.2719978	12.6213059	1.3145478	1.2840081	6.6264528	5938.2	423.66	5022.4	0.153691	0.0000001	3	1.00000
4	9	5.3886318	11.7252336	1.2767682	1.2511722	5.5302235	5969.9	445.39	4893.2	0.160554	0.0000001	3	1.00000
4	10	5.5147274	10.8306656	1.2452151	1.2234839	4.6077912	5994.8	463.95	4784.2	0.166412	0.0000001	3	1.00000
4	11	5.6478336	9.9310869	1.2187309	1.2000941	3.8019978	6016.4	479.85	4692.3	0.171375	0.0000000	3	1.00000
4	12	5.7989376	9.0145659	1.1961892	1.1796231	3.1160320	6034.4	493.56	4613.8	0.175640	-0.0000001	2	1.00000
4	13	5.9585423	8.0813565	1.1761011	1.1615859	2.5297707	6049.7	505.93	4543.1	0.179494	0.0000000	3	1.00000
4	14	6.1268493	7.1371101	1.1591377	1.1464989	1.9861902	6062.2	516.49	4483.1	0.182780	0.0000000	3	1.00000
4	15	6.3104611	6.2075961	1.1528244	1.1405178	1.6698631	6067.0	520.44	4460.9	0.183999	0.0000000	3	1.00000
4	16	6.5031984	5.2884696	1.1515736	1.1393328	1.4377653	6067.9	521.22	4456.5	0.184241	0.0000001	2	1.00000
4	17	6.6995412	4.3707327	1.1524461	1.1401595	1.1897743	6067.3	520.67	4459.5	0.184072	0.0000000	3	1.00000
4	18	6.8969914	3.4613808	1.1547567	1.1423484	0.9314522	6065.5	519.23	4467.7	0.183626	-0.0000000	3	1.00000
4	19	7.0962313	2.5599207	1.1584345	1.1458327	0.6534727	6062.7	516.93	4480.7	0.182915	-0.0000000	3	1.00000
4	20	7.2950180	1.6687835	1.1632661	1.1504100	0.3452764	6059.1	513.91	4497.7	0.181983	-0.0000000	4	1.00000
4	21	7.4949538	0.7925936	1.1688090	1.1553876	0.0298014	6055.0	510.46	4517.3	0.180910	-0.0000000	5	1.00000
4	22	7.5043333	0.2694502	1.1740422	1.1598359	0.0583506	6051.2	507.21	4535.8	0.179894	-0.0000000	6	1.00000
5	1	4.6427577	19.0990107	2.0077260	1.8354276	29.2289095	5258.0	141.82	7180.1	0.059239	-0.	4	1.00000
5	2	4.9749616	18.4985900	2.0096909	1.8369715	29.7774158	5255.7	141.32	7185.6	0.059061	-0.0000000	3	1.00000
5	3	5.3974693	18.0492272	1.9571972	1.7989481	27.8859868	5313.5	155.03	7036.4	0.063997	-0.0000000	4	1.00000
5	4	5.5501491	17.1617348	1.7815630	1.6678509	21.7302816	5501.3	209.30	6521.5	0.083051	-0.0000000	4	1.00000
5	5	5.4688248	15.9942358	1.6008761	1.5241406	15.5354636	5681.9	279.88	5964.1	0.106971	-0.0000000	4	1.00000
5	6	5.5016919	15.0160564	1.4998637	1.4418842	12.2740493	5776.3	326.19	5639.6	0.122285	0.0000000	4	1.00000
5	7	5.5565122	14.0746156	1.4211785	1.3754821	9.7751788	5847.0	365.65	5381.1	0.135117	-0.0000000	4	1.00000
5	8	5.6262557	13.1403551	1.3638473	1.3272554	8.0494521	5896.9	396.20	5189.6	0.144935	0.0000001	3	1.00000
5	9	5.7121868	12.2146364	1.3198055	1.2885648	6.6960136	5934.1	420.68	5040.5	0.152736	0.0000001	3	1.00000
5	10	5.8093468	11.2919260	1.2824767	1.2561671	5.5754061	5964.8	442.06	4912.7	0.159515	0.0000001	3	1.00000
5	11	5.9195975	10.3712305	1.2516641	1.2291742	4.6224822	5990.0	460.13	4806.6	0.165201	0.0000001	3	1.00000
5	12	6.0488796	9.4337867	1.2250810	1.2057186	3.8196255	6011.2	476.01	4714.3	0.170182	0.0000000	3	1.00000
5	13	6.1913574	8.4864833	1.2020318	1.1851411	3.1351354	6029.8	489.99	4634.2	0.174531	0.0000000	2	1.00000
5	14	6.3423541	7.5244271	1.1836211	1.1679780	2.5184469	6044.3	501.28	4569.8	0.178038	0.0000000	3	1.00000
5	15	6.4998524	6.5550036	1.1665180	1.1534403	1.9521367	6056.6	511.89	4509.2	0.181355	0.0000000	3	1.00000
5	16	6.6798730	5.6124110	1.1610761	1.1483353	1.6103897	6060.7	515.28	4490.0	0.182405	-0.0000000	3	1.00000
5	17	6.8732270	4.6852636	1.1611819	1.1484355	1.3439233	6060.7	515.21	4490.3	0.182385	-0.0000000	3	1.00000
5	18	7.0682616	3.7660510	1.1628534	1.1500190	1.0724165	6059.4	514.17	4496.2	0.182063	-0.0000000	3	1.00000
5	19	7.2660362	2.8551021	1.1659590	1.1529612	0.7861538	6057.0	512.24	4507.2	0.181464	-0.0000000	3	1.00000
5	20	7.4647703	1.9556935	1.1706199	1.1569269	0.4756435	6053.7	509.34	4523.7	0.180558	-0.0000001	3	1.00000
5	21	7.6623287	1.0676957	1.1746124	1.1603206	0.1539000	6050.8	506.86	4537.9	0.179783	-0.0000001	4	1.00000
5	22	7.6590989	0.5223015	1.1711739	1.1573978	-0.0344863	6053.3	508.99	4525.7	0.180450	-0.0000001	3	1.00000
5	23	7.6714119	0.	1.1785374	1.1636568	0.	6048.0	504.42	4551.8	0.179022	0.0000000	3	1.00000
6	1	5.3264408	19.0933216	2.0145100	1.8405072	29.4524167	5250.1	140.12	7199.0	0.058628	0.0000000	3	1.00000
6	2	5.6668819	18.4996610	2.0194403	1.8440288	29.9226656	5244.4	138.90	7212.7	0.058188	0.0000000	3	1.00000
6	3	6.0980911	18.0167692	1.9652754	1.8045018	28.1215169	5305.3	152.85	7060.0	0.063208	-0.0000000	4	1.00000
6	4	6.1868589	17.0236580	1.7875844	1.6723015	21.9599707	5495.2	207.21	6539.6	0.082328	-0.0000001	4	1.00000
6	5	6.0350141	15.7543198	1.6058870	1.5284011	15.7077829	5676.9	277.71	5979.8	0.106251	-0.0000000	4	1.00000
6	6	6.0225603	14.7227228	1.5047826	1.4460652	12.4158859	5771.9	323.82	5655.6	0.121506	0.0000000	4	1.00000
6	7	6.0456649	13.7348304	1.4266714	1.3800595	9.8763852	5842.5	362.80	5399.5	0.134188	-0.0000000	4	1.00000
6	8	6.0906640	12.7650975	1.3697794	1.3322749	8.1197355	5891.6	392.97	5209.5	0.143908	0.0000001	3	1.00000
6	9	6.1554343	11.8100845	1.3260231	1.2939533	6.7421467	5929.2	417.17	5061.8	0.151611	0.0000001	3	1.00000
6	10	6.2355074	10.8588054	1.2893638	1.2621820	5.5920582	5958.7	438.07	4936.2	0.158265	0.0000001	3	1.00000
6	11	6.3411476	9.8998666	1.2584441	1.2351386	4.6422829	5984.9	456.12	4830.1	0.163935	0.0000001	3	1.00000
6	12	6.4607853	8.9311451	1.2317532	1.2116058	3.8411688	6005.5	472.00	4737.5	0.168934	0.0000001	3	1.00000
6	13	6.5944925	7.9533454	1.2094609	1.1918542	3.1283917	6023.8	485.46	4660.1	0.173125	0.0000000	2	1.00000
6	14	6.7349544	6.9867019	1.1915420	1.1752341	2.4897620	6038.2	496.41	4597.6	0.176523	0.0000000	3	1.00000
6	15	6.8824676	5.9722263	1.1758749	1.1613937	1.8951007	6049.9	506.07	4542.3	0.179538	0.0000000	3	1.00000
6	16	7.0603339	5.0156004	1.1712487	1.1574614	1.5171145	6053.2	508.95	4525.9	0.180436	0.0000000	3	1.00000
6	17	7.2521068	4.0855365	1.1722397	1.1583038	1.2278474	6052.5	508.33	4529.5	0.180244	-0.0000000	3	1.00000
6	18	7.4473333	3.1635353	1.1749766	1.1606301	0.9301570	6050.5	506.63	4539.2	0.179712	0.0000000	3	1.00000

I	J	X (IN.)	Y (IN.)	M	M*	THETA (DEG)	T (DEG R)	P (PSIA)	V (FT/SEC)	DENSITY (LB/CU-FT)	TOLERANCE	ITERATION	S (BTU/LB.DEG.R)
59	3	46.0015850	37.6223111	2.5839903	2.2054531	22.7587252	4539.7	49.12	8633.0	0.024037	0.	3	1.00000
59	4	47.1847811	36.9167404	2.6041618	2.2173978	22.2579596	4513.3	47.31	8677.6	0.023294	-0.0000000	3	1.00000
59	5	49.1269126	36.1708488	2.6365726	2.2352081	21.5294137	4470.1	44.54	8748.0	0.022151	0.0000000	3	1.00000
59	6	51.4373760	35.6407266	2.6739522	2.2547035	20.7978511	4420.0	41.55	8827.6	0.020906	0.0000000	3	1.00000
59	7	54.1348844	35.0480270	2.7171402	2.2772283	19.9323864	4362.0	38.35	8917.6	0.019561	0.0000001	3	1.00000
59	8	57.3097067	34.4260478	2.7668577	2.3031585	18.9566355	4295.3	34.98	9018.5	0.018129	0.0000001	3	1.00000
59	9	60.2800288	33.0954652	2.8178914	2.3297752	17.8717666	4226.8	31.84	9119.0	0.016778	0.0000001	3	1.00000
59	10	64.0121346	31.6860456	2.8805270	2.3605987	16.6003985	4143.6	28.38	9238.6	0.015258	0.	4	1.00000
59	11	69.0978289	30.2859695	2.9684761	2.4013239	15.1090273	4028.2	24.14	9399.0	0.013361	-0.0000000	4	1.00000
59	12	75.8399277	28.5065489	3.0694477	2.4471703	13.1237593	3896.7	20.09	9572.2	0.011496	0.0000000	4	1.00000
59	13	86.7236242	26.1408319	3.2329843	2.5133983	10.2107062	3700.2	14.92	9842.8	0.009000	0.0000001	2	1.00000
59	14	102.0754175	22.5770690	3.4453999	2.5891555	6.4826935	3467.5	10.16	10170.5	0.006538	0.0000000	5	1.00000
59	15	89.2722197	17.4966540	3.2210442	2.5088254	1.2432131	3712.1	15.25	9821.1	0.009167	-0.0000000	2	1.00000
60	1	46.1367903	39.1965737	2.5773918	2.2015457	23.0849304	4548.4	49.73	8618.4	0.024285	0.0000000	2	1.00000
60	2	46.7509179	38.3845239	2.5899814	2.2090007	22.7375474	4531.9	48.57	8646.3	0.023813	0.0000001	2	1.00000
60	3	47.8901653	37.6173391	2.6096754	2.2206627	22.2388983	4506.0	46.83	8689.7	0.023095	-0.0000000	3	1.00000
60	4	49.8798361	36.8924975	2.6433184	2.2387264	21.5222173	4461.1	43.98	8762.5	0.021920	0.0000000	3	1.00000
60	5	51.9602261	36.1237593	2.6780363	2.2568336	20.7813756	4414.5	41.24	8836.2	0.020775	0.0000000	3	1.00000
60	6	54.7139983	35.5603857	2.7213222	2.2794094	19.9138265	4356.4	38.06	8926.2	0.019436	0.0000000	3	1.00000
60	7	57.8957314	34.9197154	2.7700709	2.3048344	18.9157910	4290.9	34.78	9024.9	0.018040	0.0000000	3	1.00000
60	8	61.6996737	34.2284451	2.8257503	2.3338740	17.8018191	4216.2	31.39	9134.2	0.016580	0.0000001	3	1.00000
60	9	65.4902802	32.7939286	2.8892154	2.3646219	16.5397794	4132.2	27.93	9254.8	0.015058	-0.0000000	4	1.00000
60	10	70.4339895	31.2109320	2.9709406	2.4024651	14.9209132	4025.0	24.04	9403.4	0.013311	-0.0000000	4	1.00000
60	11	77.4578285	29.5210373	3.0779147	2.4506499	13.0821393	3886.0	19.78	9586.4	0.011351	0.0000000	4	1.00000
60	12	88.3237524	26.9975083	3.2369585	2.5149203	10.1039782	3696.2	14.82	9850.0	0.008944	0.0000001	4	1.00000
60	13	103.9333525	23.3778012	3.4498207	2.5906162	6.4247799	3462.2	10.08	10176.1	0.006496	-0.0000000	5	1.00000
60	14	102.2241716	22.5497019	3.4496705	2.5905666	6.3921820	3462.4	10.08	10175.9	0.006498	-0.0000000	5	1.00000
61	1	47.0135918	40.1002660	2.5839122	2.2054068	23.0474946	4539.8	49.13	8632.8	0.024040	0.0000000	3	1.00000
61	2	47.5552711	39.2004132	2.5961087	2.2126291	22.7103927	4523.8	48.02	8659.8	0.023587	0.0000001	2	1.00000
61	3	48.6605678	38.3805928	2.6155132	2.2241196	22.2172101	4498.4	46.32	8702.4	0.022887	0.0000000	3	1.00000
61	4	50.6139312	37.5943813	2.6493442	2.2418692	21.5026157	4453.0	43.49	8775.4	0.021717	0.0000000	3	1.00000
61	5	52.7450962	36.8473949	2.6845356	2.2602233	20.7734900	4405.8	40.74	8849.8	0.020567	0.0000000	3	1.00000
61	6	55.2613850	36.0438004	2.7252134	2.2814389	19.8968623	4351.2	37.78	8934.2	0.019320	0.0000000	3	1.00000
61	7	58.5051174	35.4319973	2.7740265	2.3068974	18.8967440	4285.6	34.52	9032.8	0.017932	0.0000000	3	1.00000
61	8	62.3169789	34.7193837	2.8287014	2.3354132	17.7601128	4212.2	31.22	9139.9	0.016506	-0.0000000	4	1.00000
61	9	67.0005283	33.9206295	2.8972996	2.3683653	16.4679675	4121.6	27.51	9269.9	0.014874	-0.0000000	4	1.00000
61	10	72.0308113	32.3097463	2.9787196	2.4060672	14.8592665	4014.8	23.70	9417.1	0.013157	-0.0000000	4	1.00000
61	11	78.8855925	30.4111147	3.0793631	2.4512451	12.8877991	3884.2	19.73	9588.8	0.011327	0.0000000	4	1.00000
61	12	90.1769218	27.9852672	3.2442893	2.5177278	10.0644671	3688.9	14.62	9863.2	0.008844	0.0000001	4	1.00000
61	13	105.7749548	24.1677649	3.4518982	2.5913026	6.3195309	3459.7	10.04	10178.7	0.006477	-0.0000000	5	1.00000
61	14	104.0889320	23.3490789	3.4540499	2.5920136	6.3351820	3457.1	10.00	10181.4	0.006456	0.0000000	3	1.00000
62	1	48.4495897	40.1047068	2.6024976	2.2164123	22.6724596	4515.4	47.46	8673.9	0.023354	-0.0000000	3	1.00000
62	2	49.4874249	39.1974669	2.6220843	2.2276517	22.1894948	4489.6	45.76	8716.7	0.022654	-0.0000000	3	1.00000
62	3	51.4156914	38.3589406	2.6557235	2.2451963	21.4804833	4444.4	42.98	8789.0	0.021503	0.0000000	3	1.00000
62	4	53.5093651	37.5503917	2.6903222	2.2632413	20.7531955	4398.0	40.31	8862.0	0.020385	0.0000000	3	1.00000
62	5	56.0843239	36.7691693	2.7314418	2.2846873	19.8884742	4342.8	37.35	8946.9	0.019137	0.	3	1.00000
62	6	59.0810914	35.9153562	2.7777091	2.3088181	18.8793752	4280.7	34.29	9040.1	0.017832	0.0000000	3	1.00000
62	7	62.9614635	35.2309079	2.8324108	2.3373479	17.7405565	4207.3	31.01	9147.0	0.016414	0.0000001	3	1.00000
62	8	67.6554813	34.4075146	2.9002903	2.3697502	16.4254136	4117.7	27.36	9275.4	0.014807	0.	4	1.00000
62	9	73.6595297	33.4255543	2.9859121	2.4093978	14.7866189	4005.3	23.39	9429.7	0.013017	0.0000000	4	1.00000
62	10	80.6331930	31.4939227	3.0869280	2.4543540	12.8248595	3874.7	19.46	9601.5	0.011199	-0.0000000	4	1.00000
62	11	91.7420359	28.8145881	3.2439225	2.5175873	9.8639427	3689.3	14.63	9862.5	0.008849	0.0000001	4	1.00000
62	12	107.9621058	25.1019945	3.4579771	2.5933111	6.2904460	3452.5	9.93	10186.3	0.006419	-0.0000001	5	1.00000
62	13	105.9369431	24.1375821	3.4560869	2.5926866	6.2307479	3454.7	9.96	10183.9	0.006437	0.0000000	3	1.00000
63	1	49.4734983	41.1363735	2.6096024	2.2206194	22.6309044	4506.1	46.83	8689.5	0.023098	0.0000000	3	1.00000
63	2	50.4065475	40.1025023	2.6291361	2.2313296	22.1510262	4480.1	45.16	8732.0	0.022408	-0.0000000	3	1.00000

I	J	X (IN.)	Y (IN.)	M	M*	THETA (DEG)	T (DEG R)	P (PSIA)	V (FT/SEC)	DENSITY (LB/CU-FT)	TOLERANCE	ITERATION	S (BTU/LB.DEG.R)
63	3	52.2760291	39.1770210	2.6622326	2.2485911	21.4522564	4435.7	42.47	8802.8	0.021288	-0.0000000	3	1.00000
63	4	54.3438907	38.3160696	2.6964487	2.2664366	20.7303870	4389.8	39.85	8874.7	0.020193	0.0000000	3	1.00000
63	5	56.8845010	37.4729109	2.7369656	2.2875682	19.8676546	4335.4	36.97	8958.2	0.018976	0.0000000	3	1.00000
63	6	59.9485202	36.6419826	2.7836450	2.3119140	18.8706474	4272.7	33.92	9051.9	0.017671	0.0000000	3	1.00000
63	7	63.5705967	35.7135773	2.8358668	2.3391504	17.7227778	4202.6	30.81	9153.7	0.016329	-0.0000000	4	1.00000
63	8	68.3426952	34.9173379	2.9041542	2.3715394	16.4054937	4112.6	27.17	9282.6	0.014720	0.0000000	4	1.00000
63	9	74.3633595	33.9060893	2.9885164	2.4106036	14.7435675	4001.9	23.28	9434.3	0.012966	0.0000001	4	1.00000
63	10	82.4123335	32.5913653	3.0938542	2.4572003	12.7512417	3866.0	19.21	9613.0	0.011084	-0.0000000	4	1.00000
63	11	93.7325697	29.8627803	3.2502873	2.5200249	9.8040667	3682.9	14.46	9874.0	0.008762	0.0000001	4	1.00000
63	12	109.6916599	25.8362985	3.4548873	2.5922903	6.0839584	3456.1	9.99	10182.4	0.006448	0.0000000	5	1.00000
63	13	108.1321573	25.0703149	3.4621219	2.5946806	6.2026619	3447.5	9.86	10191.4	0.006381	0.0000000	3	1.00000
64	1	51.4590678	41.1350288	2.6369801	2.2354206	22.1090620	4469.6	44.51	8748.9	0.022137	-0.0000000	3	1.00000
64	2	53.2317438	40.0828915	2.6689980	2.2521197	21.4132259	4426.6	41.93	8817.1	0.021067	0.0000000	3	1.00000
64	3	55.2389150	39.1350045	2.7026939	2.2696938	20.7014937	4381.4	39.39	8887.7	0.020000	0.0000000	3	1.00000
64	4	57.7580252	38.2393022	2.7428141	2.2906186	19.8443530	4327.5	36.57	8970.1	0.018807	0.0000000	3	1.00000
64	5	60.7905798	37.3458772	2.7888846	2.3146467	18.8494418	4265.7	33.59	9062.3	0.017531	0.0000001	3	1.00000
64	6	64.4898558	36.4407353	2.8414852	2.3420806	17.7137523	4195.1	30.49	9164.4	0.016191	0.0000000	3	1.00000
64	7	68.9922800	35.3984375	2.9077571	2.3732077	16.3874631	4107.9	26.99	9289.2	0.014640	-0.0000000	4	1.00000
64	8	75.1064692	34.4124503	2.9920154	2.4122239	14.7237686	3997.3	23.13	9440.4	0.012899	-0.0000000	4	1.00000
64	9	83.1777344	33.0618677	3.0962771	2.4581961	12.7075868	3862.9	19.13	9617.0	0.011043	0.0000000	4	1.00000
64	10	95.7529030	30.9221830	3.2560003	2.5222129	9.7336090	3677.2	14.31	9884.2	0.008685	0.0000000	4	1.00000
64	11	112.0237389	26.8200657	3.4598418	2.5939273	6.0354191	3450.2	9.90	10188.6	0.006402	-0.0000000	5	1.00000
64	12	109.8668842	25.8029540	3.4589946	2.5936473	5.9967697	3451.2	9.91	10187.5	0.006410	0.0000000	3	1.00000
65	1	52.9039392	42.5459757	2.6472003	2.2407510	22.0492120	4455.9	43.67	8770.8	0.021789	0.0000000	3	1.00000
65	2	54.3260412	41.1163983	2.6765286	2.2560472	21.3707440	4416.5	41.35	8833.0	0.020823	-0.0000000	3	1.00000
65	3	56.2324185	40.0412464	2.7091732	2.2730731	20.6617708	4372.7	38.92	8901.1	0.019802	0.0000000	3	1.00000
65	4	58.6943207	39.0586114	2.7487689	2.2937243	19.8149817	4319.5	36.17	8982.1	0.018636	0.	3	1.00000
65	5	61.7095952	38.1123319	2.7944327	2.3175403	18.8257964	4258.2	33.25	9073.2	0.017384	0.0000001	3	1.00000
65	6	65.3805695	37.1439171	2.8464159	2.3446523	17.6921735	4188.5	30.22	9173.8	0.016072	0.0000001	3	1.00000
65	7	69.9751816	36.1251307	2.9136779	2.3759494	16.3785009	4100.1	26.70	9300.1	0.014510	-0.0000000	4	1.00000
65	8	75.8088999	34.8903427	2.9952824	2.4137367	14.7059267	3993.0	22.99	9446.0	0.012836	0.0000000	4	1.00000
65	9	83.9926777	33.5618420	3.0997378	2.4596183	12.6880710	3858.6	19.01	9622.7	0.010987	0.0000001	4	1.00000
65	10	96.6159601	31.3732448	3.2578552	2.5229233	9.6908280	3675.4	14.27	9887.5	0.008661	0.0000001	4	1.00000
65	11	114.3808956	27.8106806	3.4640848	2.5953292	5.9758803	3445.2	9.82	10193.8	0.006363	-0.0000000	5	1.00000
65	12	112.2072515	26.7850664	3.4639054	2.5952699	5.9491847	3445.4	9.83	10193.6	0.006364	0.0000000	3	1.00000
66	1	55.8276715	42.5283704	2.6863394	2.2611641	21.3103359	4403.3	40.61	8853.6	0.020510	0.0000000	3	1.00000
66	2	57.3698869	41.0752158	2.7163908	2.2768375	20.6186295	4363.0	38.41	8916.0	0.019584	0.0000000	3	1.00000
66	3	59.7327614	39.9646149	2.7549334	2.2969394	19.7747672	4311.3	35.76	8994.5	0.018461	0.	3	1.00000
66	4	62.6940098	38.9312739	2.8000734	2.3204822	18.7961030	4250.7	32.91	9084.3	0.017236	0.0000001	3	1.00000
66	5	66.3525972	37.9095764	2.8519682	2.3473744	17.6681404	4181.1	29.91	9184.4	0.015937	0.0000001	3	1.00000
66	6	70.9255905	36.8263884	2.9188355	2.3783376	16.3568993	4093.4	26.45	9309.6	0.014397	-0.0000000	4	1.00000
66	7	76.8751469	35.6145973	3.0007312	2.4162598	14.6977500	3985.9	22.76	9455.5	0.012733	-0.0000000	4	1.00000
66	8	84.7631359	34.0337920	3.1029748	2.4609486	12.6706116	3854.5	18.90	9628.0	0.010934	0.0000000	4	1.00000
66	9	97.5469618	31.8589127	3.2608639	2.5240755	9.6737839	3672.4	14.19	9892.9	0.008621	0.0000001	4	1.00000
66	10	115.3777027	28.2283134	3.4652025	2.5956985	5.9367276	3443.8	9.80	10195.2	0.006352	0.0000000	5	1.00000
66	11	114.5726080	27.7739851	3.4681061	2.5966579	5.8905498	3440.4	9.75	10198.8	0.006325	0.0000000	3	1.00000
67	1	58.0135336	44.5700259	2.6982714	2.2673872	21.1740642	4387.3	39.72	8878.5	0.020137	-0.0000000	3	1.00000
67	2	58.9301739	42.4875035	2.7257927	2.2817410	20.5574942	4350.4	37.74	8935.4	0.019303	0.0000000	3	1.00000
67	3	60.9215865	40.9983687	2.7618065	2.3005241	19.7312028	4302.0	35.31	9008.4	0.018269	0.0000000	3	1.00000
67	4	63.7847943	39.8361335	2.8058970	2.3235196	18.7555609	4242.9	32.55	9095.7	0.017085	0.0000000	3	1.00000
67	5	67.3932981	38.7272601	2.8579315	2.3501358	17.6380339	4173.3	29.58	9195.8	0.015792	0.0000001	3	1.00000
67	6	71.9627123	37.5899286	2.9242920	2.3808643	16.3328571	4086.2	26.18	9319.6	0.014279	-0.0000000	4	1.00000
67	7	77.9032984	36.3116946	3.0054306	2.4184359	14.6767029	3979.7	22.57	9463.6	0.012644	-0.0000000	4	1.00000
67	8	85.9377346	34.7521839	3.1084905	2.4632153	12.6637409	3847.6	18.71	9637.1	0.010844	-0.0000000	4	1.00000
67	9	98.4273138	32.3175225	3.2636879	2.5251571	9.6587659	3669.6	14.12	9897.9	0.008583	0.0000001	4	1.00000
67	10	116.4735718	28.6866889	3.4677143	2.5965284	5.9262198	3440.8	9.76	10198.3	0.006329	-0.0000000	5	1.00000

I	J	X (IN.)	Y (IN.)	M	M*	THETA (DEG)	T (DEG R)	P (PSIA)	V (FT/SEC)	DENSITY (LB/CU-FT)	TOLERANCE	ITERATION	S (BTU/LB.DEG.R)
67	11	115.5727539	28.1908612	3.4692062	2.5970213	5.8517523	3439.0	9.73	10200.1	0.006315	0.0000000	2	1.00000
68	1	61.1968737	44.5259175	2.7371460	2.2876624	20.4201667	4335.1	36.96	8958.5	0.018970	-0.0000000	3	1.00000
68	2	62.5516553	42.4100127	2.7707577	2.3051926	19.6696560	4290.0	34.73	9026.3	0.018021	0.0000000	3	1.00000
68	3	65.0334711	40.8686604	2.8123969	2.3269096	18.7117712	4234.1	32.17	9108.3	0.016918	0.0000000	3	1.00000
68	4	68.5454235	39.6298656	2.8640671	2.3529769	17.5971243	4165.2	29.25	9207.5	0.015645	0.0000001	3	1.00000
68	5	73.0723333	38.4048672	2.9298118	2.3834203	16.3026836	4078.9	25.92	9329.6	0.014160	-0.0000000	4	1.00000
68	6	79.0248480	37.0705543	3.0104023	2.4207380	14.6533517	3973.2	22.37	9472.2	0.012551	-0.0000000	4	1.00000
68	7	87.0664921	35.4413099	3.1131793	2.4651422	12.6436751	3841.7	18.55	9644.8	0.010769	0.0000000	4	1.00000
68	8	99.7782879	33.0203800	3.2686926	2.5270738	9.6567359	3664.6	13.99	9906.8	0.008517	0.0000001	4	1.00000
68	9	117.5101528	29.1198027	3.4700882	2.5973128	5.9174634	3438.0	9.72	10201.2	0.006307	0.0000000	5	1.00000
68	10	116.6724987	28.6485000	3.4716996	2.5978452	5.8416559	3436.1	9.69	10203.2	0.006293	-0.0000000	2	1.00000
69	1	63.6245918	46.6896544	2.7466254	2.2926063	20.2182112	4322.4	36.32	8977.8	0.018697	-0.	4	1.00000
69	2	64.9143124	44.4432497	2.7814725	2.3107809	19.5316641	4275.6	34.05	9047.6	0.017730	-0.0000000	3	1.00000
69	3	66.7448683	42.2782531	2.8208599	2.3313235	18.6500876	4222.8	31.67	9124.8	0.016703	0.0000000	3	1.00000
69	4	69.8645334	40.6599202	2.8709231	2.3561516	17.5531578	4156.2	28.88	9220.5	0.015483	0.0000001	3	1.00000
69	5	74.2991943	39.3034320	2.9354666	2.3860387	16.2617037	4071.5	25.65	9339.9	0.014040	-0.0000000	4	1.00000
69	6	80.2235203	37.8797727	3.0154150	2.4230592	14.6239245	3966.6	22.16	9480.8	0.012458	-0.0000000	4	1.00000
69	7	88.2974377	36.1913137	3.1181390	2.4671804	12.6215304	3835.4	18.38	9652.9	0.010689	0.0000001	4	1.00000
69	8	101.0696211	33.6912117	3.2728373	2.5286611	9.6406699	3660.5	13.88	9914.2	0.008463	0.0000001	4	1.00000
69	9	119.1156874	29.7900867	3.4746245	2.5988116	5.9268045	3432.6	9.64	10206.8	0.006266	-0.0000000	5	1.00000
69	10	117.7127352	29.0809224	3.4740567	2.5986240	5.8332819	3433.2	9.65	10206.1	0.006271	0.0000000	2	1.00000
70	1	67.4381704	46.5962796	2.7902906	2.3153800	19.3289435	4263.8	33.50	9065.0	0.017494	0.0000000	3	1.00000
70	2	69.2189894	44.3036981	2.8308817	2.3365504	18.5117455	4209.3	31.09	9144.1	0.016452	0.0000000	3	1.00000
70	3	71.6720362	42.0657067	2.8798454	2.3602831	17.4915423	4144.5	28.41	9237.3	0.015274	0.0000000	3	1.00000
70	4	75.7038593	40.3290324	2.9417964	2.3889697	16.2178485	4063.2	25.35	9351.3	0.013907	0.	4	1.00000
70	5	81.5467978	38.7708068	3.0205193	2.4254227	14.5837115	3959.9	21.96	9489.5	0.012364	-0.0000000	4	1.00000
70	6	89.6114454	36.9901652	3.1231148	2.4692253	12.5934063	3829.2	18.22	9660.9	0.010611	-0.0000000	4	1.00000
70	7	102.4771166	34.4211149	3.2772201	2.5303396	9.6229500	3656.1	13.77	9921.9	0.008407	0.0000000	4	1.00000
70	8	120.6389093	30.4254229	3.4782006	2.5999932	5.9202765	3428.3	9.58	10211.1	0.006233	-0.0000000	5	1.00000
70	9	119.3240728	29.7502139	3.4785678	2.6001145	5.8432143	3427.9	9.57	10211.6	0.006230	-0.0000000	2	1.00000
71	1	70.4242268	49.1170034	2.7992091	2.3200314	19.0779483	4251.8	32.96	9082.6	0.017259	-0.	4	1.00000
71	2	71.8540592	46.4425325	2.8389806	2.3407743	18.3085175	4198.4	30.63	9159.6	0.016252	0.0000000	3	1.00000
71	3	74.2779655	44.0800123	2.8902666	2.3651087	17.3532441	4130.8	27.87	9256.8	0.015034	0.0000001	3	1.00000
71	4	77.6275759	41.7282782	2.9500308	2.3927827	16.1565895	4052.4	24.97	9366.1	0.013736	0.	4	1.00000
71	5	83.0619097	39.7880368	3.0262463	2.4280747	14.5409430	3952.4	21.73	9499.2	0.012259	-0.0000000	4	1.00000
71	6	91.0593948	37.8682165	3.1281358	2.4712887	12.5545617	3822.9	18.05	9669.1	0.010532	0.0000000	4	1.00000
71	7	103.9766674	35.1972585	3.2815766	2.5320081	9.5993874	3651.8	13.67	9929.6	0.008351	0.0000000	4	1.00000
71	8	122.2979841	31.1165683	3.4819801	2.6012420	5.9128496	3423.8	9.51	10215.7	0.006199	-0.0000000	5	1.00000
71	9	120.8526545	30.3845694	3.4821208	2.6012884	5.8372176	3423.6	9.51	10215.9	0.006198	-0.0000000	2	1.00000
72	1	74.9679489	48.9440899	2.8471082	2.3450134	18.0573068	4187.5	30.18	9175.2	0.016055	-0.0000000	3	1.00000
72	2	77.0445147	46.2001028	2.8984891	2.3689161	17.1499681	4120.1	27.45	9272.1	0.014847	0.0000000	3	1.00000
72	3	80.3910866	43.7264786	2.9594784	2.3971575	16.0184424	4040.0	24.55	9383.0	0.013542	0.0000000	3	1.00000
72	4	85.1356344	41.1753411	3.0336916	2.4315223	14.4813445	3942.6	21.44	9511.8	0.012125	0.0000000	4	1.00000
72	5	92.7176924	38.8709440	3.1337882	2.4736116	12.5136594	3815.7	17.87	9678.2	0.010444	-0.0000000	4	1.00000
72	6	105.6242628	36.0480933	3.2858975	2.5336629	9.5652534	3647.5	13.56	9937.3	0.008295	0.0000001	4	1.00000
72	7	124.0607882	31.8498905	3.4856682	2.6024606	5.8997604	3419.4	9.45	10220.1	0.006166	-0.0000000	5	1.00000
72	8	122.5175276	31.0746527	3.4858754	2.6025290	5.8303486	3419.1	9.44	10220.4	0.006164	-0.0000000	2	1.00000
73	1	78.6253443	51.8465595	2.8557059	2.3491052	17.7511339	4176.2	29.71	9191.6	0.015846	-0.	4	1.00000
73	2	80.3100443	48.6767607	2.9066535	2.3726967	16.8992057	4109.3	27.04	9287.2	0.014665	0.0000000	3	1.00000
73	3	83.3127232	45.8213067	2.9666937	2.4004986	15.8149680	4030.5	24.22	9395.9	0.013396	0.0000000	3	1.00000
73	4	88.1014414	43.1482263	3.0420192	2.4353784	14.3449087	3931.7	21.12	9525.9	0.011977	0.0000000	4	1.00000
73	5	94.9861717	40.2378349	3.1411281	2.4766280	12.4568751	3806.5	17.63	9689.9	0.010331	-0.0000001	4	1.00000
73	6	107.5118179	37.0203290	3.2907932	2.5355378	9.5300294	3642.6	13.44	9945.9	0.008233	0.0000001	4	1.00000
73	7	125.9897223	32.6509004	3.4891976	2.6036267	5.8763464	3415.2	9.39	10224.4	0.006135	0.0000000	5	1.00000
73	8	124.2864065	31.8068349	3.4895379	2.6037391	5.8178278	3414.7	9.38	10224.8	0.006132	-0.0000000	2	1.00000
74	1	84.1407175	51.5468636	2.9144128	2.3762897	16.5938480	4099.2	26.66	9301.5	0.014493	-0.0000001	3	1.00000

I	J	X (IN.)	Y (IN.)	M	M*	THETA (DEG)	T (DEG R)	P (PSIA)	V (FT/SEC)	DENSITY (LB/CU-FT)	TOLERANCE	ITERATION	S (BTU/LB.DEG.R)
74	2	86.7558718	48.2650094	2.9737517	2.4037668	15.5644166	4021.3	23.91	9408.3	0.013256	0.0000000	3	1.00000
74	3	91.2207708	45.2062750	3.0480713	2.4381808	14.1425430	3923.8	20.89	9536.0	0.011870	-0.0000000	4	1.00000
74	4	98.2125492	42.1710558	3.1490207	2.4798715	12.3234403	3796.6	17.38	9702.5	0.010211	0.0000000	4	1.00000
74	5	110.0914736	38.3448787	3.2971360	2.5379670	9.4810967	3636.3	13.29	9957.0	0.008154	0.0000000	4	1.00000
74	6	128.2007580	33.5671701	3.4932494	2.6049654	5.8536187	3410.3	9.32	10229.3	0.006099	-0.0000000	5	1.00000
74	7	126.2218695	32.6065755	3.4930398	2.6048962	5.7950063	3410.6	9.32	10229.0	0.006101	-0.0000000	2	1.00000
75	1	88.7180748	54.9275908	2.9215688	2.3796033	16.2191744	4089.8	26.31	9314.6	0.014338	-0.	4	1.00000
75	2	90.7880507	51.0925775	2.9803126	2.4068048	15.2597978	4012.7	23.63	9419.9	0.013126	0.0000000	3	1.00000
75	3	94.8901777	47.6029692	3.0540800	2.4408548	13.8936071	3916.0	20.66	9546.1	0.011765	0.0000001	3	1.00000
75	4	101.5837412	44.1745338	3.1542919	2.4820378	12.1231111	3790.0	17.21	9710.9	0.010132	-0.0000000	4	1.00000
75	5	113.7284164	40.2025542	3.3034284	2.5403768	9.3564892	3630.0	13.14	9967.9	0.008076	0.0000000	4	1.00000
75	6	131.2186699	34.8147216	3.4984733	2.6066915	5.8214773	3404.1	9.23	10235.5	0.006053	-0.0000000	5	1.00000
75	7	128.4403572	33.5214105	3.4970613	2.6062249	5.7729344	3405.8	9.26	10233.8	0.006065	-0.0000001	2	1.00000
76	1	95.5976725	54.4178057	2.9861591	2.4095121	14.8865861	4005.0	23.38	9430.1	0.013012	-0.0000001	3	1.00000
76	2	99.1792269	50.3709717	3.0598984	2.4432459	13.5912429	3908.7	20.44	9556.0	0.011662	0.0000001	3	1.00000
76	3	105.5407419	46.5024981	3.1590895	2.4840094	11.8768855	3783.9	17.06	9718.5	0.010060	0.0000000	4	1.00000
76	4	117.4892406	42.1081553	3.3068222	2.5416766	9.1628633	3626.6	13.06	9973.9	0.008034	0.0000000	4	1.00000
76	5	135.4208431	36.5439215	3.5027408	2.6081015	5.7157484	3399.0	9.16	10240.5	0.006016	-0.0000000	5	1.00000
76	6	131.4683323	34.7670126	3.5022455	2.6079378	5.7416410	3399.6	9.17	10240.0	0.006020	0.0000000	3	1.00000
77	1	101.5695248	58.5495157	3.0310921	2.4303185	15.6394093	3946.0	21.54	9507.4	0.012172	-0.	4	1.00000
77	2	104.2848997	53.6194096	3.0647614	2.4452444	13.2213449	3902.6	20.26	9564.2	0.011577	-0.0000000	3	1.00000
77	3	110.1547127	49.1846542	3.1630463	2.4856355	11.5779525	3779.0	16.94	9724.7	0.010002	0.0000000	4	1.00000
77	4	121.8881731	44.3146963	3.3094702	2.5426907	8.9246202	3624.0	13.00	9978.5	0.008002	-0.0000000	4	1.00000
77	5	139.7015305	38.2919250	3.5035236	2.6083601	5.5365333	3398.0	9.15	10241.5	0.006009	-0.0000001	5	1.00000
77	6	135.6837578	36.4932785	3.5064588	2.6093300	5.6369655	3394.5	9.10	10244.9	0.005984	0.0000000	3	1.00000
78	1	110.9494133	57.8647213	3.1146578	2.4657498	14.0010135	3839.8	18.50	9647.2	0.010745	0.0000000	3	1.00000
78	2	115.6324787	52.3240185	3.1658691	2.4867955	11.2126650	3775.4	16.86	9729.1	0.009960	-0.0000000	4	1.00000
78	3	126.9980135	46.8471818	3.3109896	2.5432726	8.6350932	3622.5	12.96	9981.1	0.007983	-0.0000000	4	1.00000
78	4	144.6845379	40.3063059	3.5031014	2.6082206	5.3145494	3398.5	9.16	10241.0	0.006013	-0.0000000	5	1.00000
78	5	139.9769859	38.2379918	3.5071875	2.6095707	5.4586875	3393.7	9.09	10245.8	0.005977	-0.0000001	3	1.00000
79	1	119.7445040	63.6406908	3.2012627	2.5012495	15.6499591	3731.8	15.81	9784.8	0.009453	-0.0000001	4	1.00000
79	2	123.2479992	56.7007518	3.2161183	2.5069389	12.0302106	3717.0	15.39	9812.1	0.009238	0.0000000	4	1.00000
79	3	133.0407028	49.7993016	3.3110164	2.5432829	8.2811334	3622.5	12.96	9981.1	0.007983	-0.0000000	4	1.00000
80	1	133.6117439	62.8644023	3.3086340	2.5423705	13.7374362	3624.8	13.01	9977.0	0.008012	0.0000001	3	1.00000
80	2	142.2681103	54.3312387	3.3659706	2.5629113	9.1701839	3562.4	11.73	10066.5	0.007349	0.0000000	4	1.00000
81	1	147.1556435	71.3195572	3.4275731	2.5832654	15.6498022	3488.8	10.49	10147.9	0.006711	-0.0000001	4	1.00000

PERFORMANCE BY INTEGRATING ALONG NOZZLE CONTOUR AT WALL POINTS

X (IN.)	Y (IN.)	THRUST (LBF.)	SP. IMPULSE (LBF-SEC/LBM)	CF
34.8319898	34.6606760	1542852.8906250	279.5067978	1.4917295
35.9186945	35.1665859	1549313.1406250	280.6771507	1.4979757
37.0327692	35.6811576	1555799.0625000	281.8521538	1.5042467
38.0930319	36.1668611	1561833.4375000	282.9453545	1.5100811
39.6871653	36.8900080	1570647.8750000	284.5421982	1.5186035
41.2637424	37.5964808	1579050.7187500	286.0644798	1.5267279
43.0029531	38.3659887	1587972.4843750	287.6807671	1.5353541
44.8907747	39.1892076	1597242.3281250	289.3601112	1.5443167
47.0135918	40.1002660	1607163.7812500	291.1575050	1.5539094
49.4734983	41.1363735	1618001.4375000	293.1208801	1.5643880
52.9039392	42.5459757	1632076.5781250	295.6707649	1.5779967
58.0135336	44.5700259	1651336.0156250	299.1598511	1.5966180
63.6245918	46.6896544	1670385.9218750	302.6109734	1.6150367
70.4242268	49.1170034	1690733.3125000	306.2971535	1.6347098
78.6253443	51.8465595	1711624.0000000	310.0817604	1.6549083
88.7180748	54.9275908	1733031.6875000	313.9600258	1.6756066
101.5695248	58.5495157	1755082.5937500	317.9548187	1.6969269
119.7445040	63.6406908	1777870.0312500	322.0830460	1.7189592
141.6411839	72.1166620	1795101.0156250	325.2046509	1.7356193

MASS FLOW RATE BY INTEGRATING ALONG THE STARTING LINE

FLOW RATE = 5519.9118652 LBM/SEC

POINTS ALONG THE SHOCK WAVE

X (IN.)	Y (IN.)	THETA (DEG)	M*	SHOCK ANGLE (DEG)	DENSITY RATIO	ENTROPY (BTU/LB.DEG.R)
0.24131794E 02	0.26748973E 02	0.16485010E 02	0.18561693E 01	-0.64661492E 01	0.66157845E 00	0.10000000E 01
0.25270593E 02	0.26622767E 02	0.16820466E 02	0.18762308E 01	-0.61816069E 01	0.66950512E 00	0.10000000E 01
0.26464056E 02	0.26496674E 02	0.16940397E 02	0.18978196E 01	-0.58805267E 01	0.67911542E 00	0.10000000E 01
0.27688114E 02	0.26373102E 02	0.16998833E 02	0.19183277E 01	-0.56486602E 01	0.68739991E 00	0.10000000E 01
0.28225051E 02	0.26320410E 02	0.17003400E 02	0.19269570E 01	-0.55607316E 01	0.69036258E 00	0.10000000E 01
0.28767557E 02	0.26267978E 02	0.16987758E 02	0.19356577E 01	-0.54801038E 01	0.69280801E 00	0.10000000E 01
0.29277658E 02	0.26219327E 02	0.16959639E 02	0.19437613E 01	-0.54159867E 01	0.69491711E 00	0.10000000E 01
0.30026707E 02	0.26148736E 02	0.16877657E 02	0.19558794E 01	-0.53514875E 01	0.69773212E 00	0.10000000E 01
0.30761245E 02	0.26080292E 02	0.16796696E 02	0.19672420E 01	-0.52952563E 01	0.70023698E 00	0.10000000E 01
0.31558681E 02	0.26006694E 02	0.16692213E 02	0.19793411E 01	-0.52508664E 01	0.70269104E 00	0.10000000E 01
0.32411682E 02	0.25928553E 02	0.16568468E 02	0.19919472E 01	-0.52173592E 01	0.70506918E 00	0.10000000E 01
0.33353938E 02	0.25842671E 02	0.16415148E 02	0.20055761E 01	-0.51983016E 01	0.70743415E 00	0.10000000E 01
0.34420891E 02	0.25745559E 02	0.16215079E 02	0.20208013E 01	-0.52028549E 01	0.70981921E 00	0.10000000E 01
0.35865768E 02	0.25613426E 02	0.15907525E 02	0.20410537E 01	-0.52474207E 01	0.71266692E 00	0.10000000E 01
0.37949081E 02	0.25420218E 02	0.15444103E 02	0.20688638E 01	-0.53495818E 01	0.71628164E 00	0.10000000E 01
0.40163380E 02	0.25209998E 02	0.14943405E 02	0.20965753E 01	-0.54968754E 01	0.71959012E 00	0.10000000E 01
0.42716810E 02	0.24959006E 02	0.14291378E 02	0.21275507E 01	-0.57309269E 01	0.72143352E 00	0.10000000E 01
0.45659167E 02	0.24655706E 02	0.13500863E 02	0.21614695E 01	-0.60395604E 01	0.72112151E 00	0.10000000E 01
0.49119281E 02	0.24277091E 02	0.12573736E 02	0.21986068E 01	-0.64495109E 01	0.72078086E 00	0.10000000E 01
0.53290647E 02	0.23785463E 02	0.11467189E 02	0.22399369E 01	-0.69936777E 01	0.72078920E 00	0.10000000E 01
0.58448139E 02	0.23117375E 02	0.99808410E 01	0.22885990E 01	-0.77673292E 01	0.71599195E 00	0.10000000E 01
0.65238209E 02	0.22127582E 02	0.81446431E 01	0.23448837E 01	-0.88185186E 01	0.71094901E 00	0.10000000E 01
0.75343260E 02	0.20402500E 02	0.52362760E 01	0.24210581E 01	-0.10552701E 02	0.69115699E 00	0.10000000E 01
0.89184373E 02	0.17516983E 02	0.13445878E 01	0.25072404E 01	-0.12988569E 02	0.65138731E 00	0.10000000E 01
0.89272220E 02	0.17496654E 02	0.12432131E 01	0.25088254E 01	-0.13070334E 02	0.65090290E 00	0.10000000E 01

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APPENDIX A

EQUATIONS FOR THE REVISED AND ADDED SUBROUTINES

CASE 1, Calculation of a General Field Point

CASE 1 allows the calculation of properties at a field point n by use of the known properties of field points r and ℓ (see Figure A-1).

The flow properties at the new point n are calculated by the following relations:

1. Obtain M_ℓ^* and M_r^* from the thermodynamic table (M_ℓ and M_r as inputs)

2. $\alpha_\ell = \sin^{-1} \dfrac{1}{M_\ell}$

3. $\alpha_r = \sin^{-1} \dfrac{1}{M_r}$

4. $\lambda_\ell = \tan(\theta_\ell + \alpha_\ell)$

5. $\lambda_r = \tan(\theta_r - \alpha_r)$

6. $H_\ell = \dfrac{\cot \alpha_\ell}{M_\ell^*}$

7. $H_r = \dfrac{\cot \alpha_r}{M_r^*}$

8. $\beta_\ell = \dfrac{\sin \theta_\ell \sin \alpha_\ell}{r_\ell \sin(\theta_\ell + \alpha_\ell)}$

9. $\beta_r = \dfrac{\sin \theta_r \sin \alpha_r}{r_r \cos(\theta_r - \alpha_r)}$

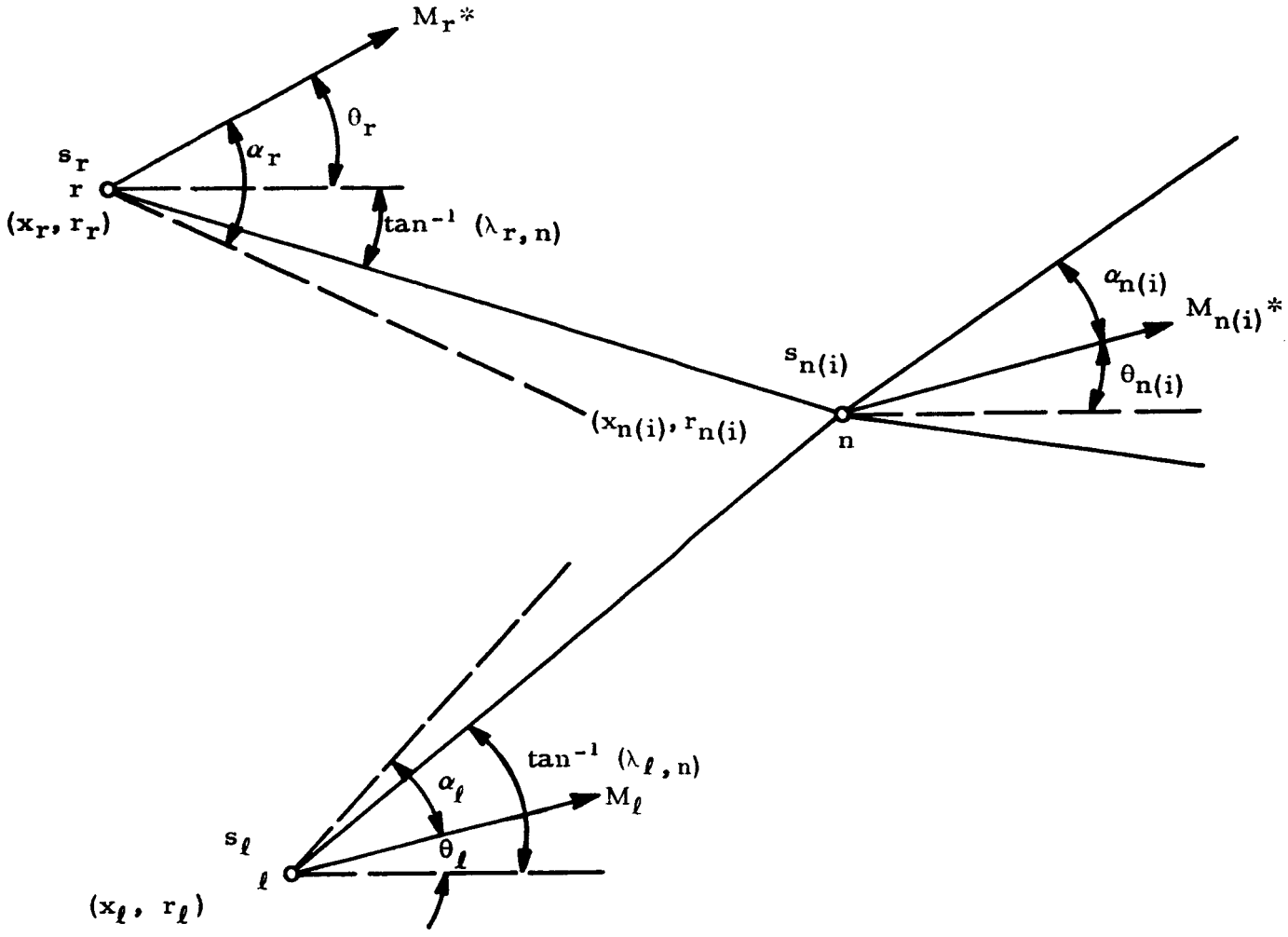

Figure A-1. Field Point Unit Process

10. $$x_n = \frac{(\lambda_r x_r - \lambda_\ell x_\ell) + r_\ell - r_r}{\lambda_r - \lambda_\ell}$$

11. $$r_n = r_\ell - \lambda_\ell (x_\ell - x_n)$$

12. Obtain k_ℓ, k_r, W_ℓ and W_r from the thermodynamic table ($M_\ell{}^*$ and $M_r{}^*$ as input)

13. $$\omega_\ell = \frac{\sin \alpha_\ell \cos \alpha_\ell}{\left(\frac{\bar{R}}{W_\ell}\right) k_\ell}$$

14. $$\omega_r = \frac{\sin \alpha_r \cos \alpha_r}{\left(\frac{\bar{R}}{W_r}\right) k_r}$$

15. $$\eta_\ell = \frac{\sin \alpha_\ell}{\cos (\theta_\ell + \alpha_\ell)}$$

16. $$\eta_r = \frac{\sin \alpha_r}{\cos (\theta_r - \alpha_r)}$$

17. $$DN = \frac{(x_n - x_r) \sin \alpha_r}{\cos (\theta_r - \alpha_r)}$$

18. $$DW = \frac{(s_r - s_\ell)}{\eta_\ell (x_n - x_\ell) + \eta_r (x_n - x_r)}$$

19. $$s_n = s_r - (DW)(DN)$$

20. $$M_n{}^* = \frac{\theta_r - \theta_\ell + H_\ell M_\ell{}^* + H_r M_r{}^* - \beta_r (x_r - x_n) - \beta_\ell (r_\ell - r_n)}{H_\ell + H_r}$$

$$+ \frac{\omega_r (s_r - s_n) + \omega_\ell (s_\ell - s_n)}{H_\ell + H_r}$$

21. $$\theta_n = \theta_\ell - H_\ell (M_\ell{}^* - M_n{}^*) + \beta_\ell (r_\ell - r_n) - \omega_\ell (s_\ell - s_n)$$

22. Obtain M_n from thermodynamic table (M_n^* as input)

23. $\alpha_n = \sin^{-1} \frac{1}{M_n}$

24. $\lambda_n = \tan(\theta_n + \alpha_n)$

25. $\lambda_n' = \tan(\theta_n - \alpha_n)$

26. $H_n = \frac{\cot \alpha_n}{M_n^*}$

27. $\beta_n = \frac{\sin \theta_n \sin \alpha_n}{r_n \sin(\theta_n + \alpha_n)}$

28. $\beta_n' = \frac{\sin \theta_n \sin \alpha_n}{r_n \cos(\theta_n - \alpha_n)}$

29. $\lambda_{\ell, n} = \frac{\lambda_\ell + \lambda_n}{2}$

30. $\lambda_{r, n} = \frac{\lambda_r + \lambda_n}{2}$

31. $H_{\ell, n} = \frac{H_\ell + H_n}{2}$

32. $H_{r, n} = \frac{H_r + H_n}{2}$

33. $\beta_{\ell, n} = \frac{\beta_\ell + \beta_n}{2}$

34. $\beta_{r, n} = \frac{\beta_r + \beta_n'}{2}$

35. $x_{n(i)} = \frac{\lambda_{r, n} x_r - \lambda_{\ell, n} x_\ell + r_\ell - r_r}{\lambda_{r, n} - \lambda_{\ell, n}}$

36. $r_{n(i)} = r_\ell - \lambda_{\ell, n} (x_\ell - x_{n(i)})$

37. $\eta_n = \dfrac{\sin \alpha_n}{\cos (\theta_n + \alpha_n)}$

38. $\eta_n' = \dfrac{\sin \alpha_n}{\cos (\theta_n - \alpha_n)}$

39. $\eta_{n, \ell} = \dfrac{(\eta_\ell + \eta_n)}{2}$

40. $\eta_{n, r} = \dfrac{(\eta_r + \eta_n')}{2}$

41. Obtain k_n and W_n from the thermodynamic table (M_n^* as input).

42. $\omega_n = \dfrac{\sin \alpha_n \cos \alpha_n}{\left(\dfrac{\overline{R}}{W_n}\right) k_n}$

43. $\omega_{n, \ell} = \dfrac{(\omega_\ell + \omega_n)}{2}$

44. $\omega_{n, r} = \dfrac{(\omega_r + \omega_n)}{2}$

45. $DN_n = (x_n - x_r)\ \eta_{n, r}$

46. $DW_n = \dfrac{(s_r - s_\ell)}{(x_n - x_\ell)\ \eta_{n, \ell} + (x_n - x_r)\ \eta_{n, r}}$

47. $s_{n(i)} = s_n - (DW_n)\ (DN_n)$

48. $$M_{n(i)}^* = \frac{\theta_r - \theta_\ell + H_{\ell, n} M_\ell^* + H_{r, n} M_r^* - \beta_{r, n} (x_r - x_{n(i)}) - \beta_{\ell, n} (r_\ell - r_{n(i)})}{H_{\ell, n} + H_{r, n}}$$

$$+ \frac{\omega_{n, r} (s_r - s_{n(i)}) + \omega_{n, \ell} (s_\ell - s_{n(i)})}{H_{\ell, n} + H_{r, n}}$$

49. $\theta_{n(i)} = \theta_\ell - H_{\ell,n}(M_\ell^* - M_{n(i)}^*) + \beta_{\ell,n}(r_\ell - r_{n(i)}) - \omega_{n,\ell}(s_\ell - s_{n(i)})$

50. If either $|\theta_{n(i)} - \theta_n| \leq 10^{-7}$ or the number of iterations exceeds 50, return to the main program; otherwise, set $\theta_n = \theta_{n(i)}$, $M_n^* = M_{n(i)}^*$, $x_n = x_{n(i)}$, and $r_n = r_{n(i)}$, increment the iteration counter by 1 and return to step 22.

CASE 2, Calculation of a Field Point Adjacent to the Axis

Given the flow properties at a point on the axis of symmetry and at the field point adjacent to the axis, a point adjacent to the axis is calculated. The unit process for CASE 2 is the same as the one for CASE 1 except that $\theta_\ell = 0$ and $r_\ell = 0$ (see Figure A-1). However, because of several indeterminate forms which result for $\theta_\ell = 0$ and $r_\ell = 0$, formulas 8, 15, 20, 21, 33, 48 and 49 listed under CASE 1 must be replaced by the following relations:

8'. $\beta_L = 0$

15'. $\eta_\ell = \dfrac{\sin \alpha_\ell}{\cos \alpha_\ell}$

20'. $M_n^* = \dfrac{2\,\theta_r + H_\ell\, M_\ell^* + 2\, H_r\, M_r^* + 2\,\beta_r (x_n - x_r) + (s_\ell - s_n)\,\omega_\ell + 2\,\omega_r (s_r - s_n)}{H_\ell + 2\, H_r}$

21'. $\theta_n = \dfrac{H_\ell\,(M_n^* - M_\ell^*) - \omega_\ell\,(s_\ell - s_n)}{2}$

33'. $\beta_{\ell,n} = \dfrac{(\sin \theta_n)/r_n + \beta_n}{2}$

48'. $M_{n(i)}^* = \dfrac{\theta_r + H_{r,n}\, M_r^* + H_{\ell,n}\, M_\ell^* + \beta_{\ell,n}\, r_{n(i)}}{H_{\ell,n} + H_{r,n}}$

$$- \frac{\beta_{r,n}(x_r - x_{n(i)}) + \omega_{r,n}(s_r - s_{n(i)}) + \omega_{\ell,n}(s_\ell - s_{n(i)})}{H_{\ell,n} + H_{r,n}}$$

49'. $\theta_{n(i)} = H_{\ell,n}(M_{n(i)}^* - M_\ell^*) - \beta_{\ell,n}\, r_{n(i)} - \omega_{\ell,n}(s_\ell - s_{n(i)})$

CASE 3, Calculation of a Point on the Axis of Symmetry

Given the flow properties at point r, the properties at point $n(r_n = 0,\ \theta_n = 0)$ are to be determined. This unit process is illustrated in Figure A-2.

The flow properties at point n are calculated by the following relations:

1. Obtain M_r^* from the thermodynamic table using the known value of M_r.

2. $\alpha_r = \sin^{-1}\dfrac{1}{M_r}$

3. $\lambda_r = \tan(\theta_r - \alpha_r)$

4. $H_r = \dfrac{\cot \alpha_r}{M_r^*}$

5. $\beta_r = \dfrac{\sin\theta_r \sin\alpha_r}{r_r \cos(\theta_r - \alpha_r)}$

6. $x_n = x_r - r_r/\lambda_r$

7. Obtain k_r and W_r from the thermodynamic table (M_r^* as input)

8. $\omega_r = \dfrac{\sin\alpha_r \cos\alpha_r}{\left(\dfrac{\bar{R}}{W_r}\right) k_r}$

9. $s_n = s_u$

10. $M_n^* = \dfrac{\theta_r + H_r M_r^* + \beta_r(x_n - x_r) + \omega_r(s_r - s_n)}{H_r}$

11. Obtain M_n from thermodynamic table by entering M_n^*

12. $\alpha_n = \sin^{-1}\dfrac{1}{M_n}$

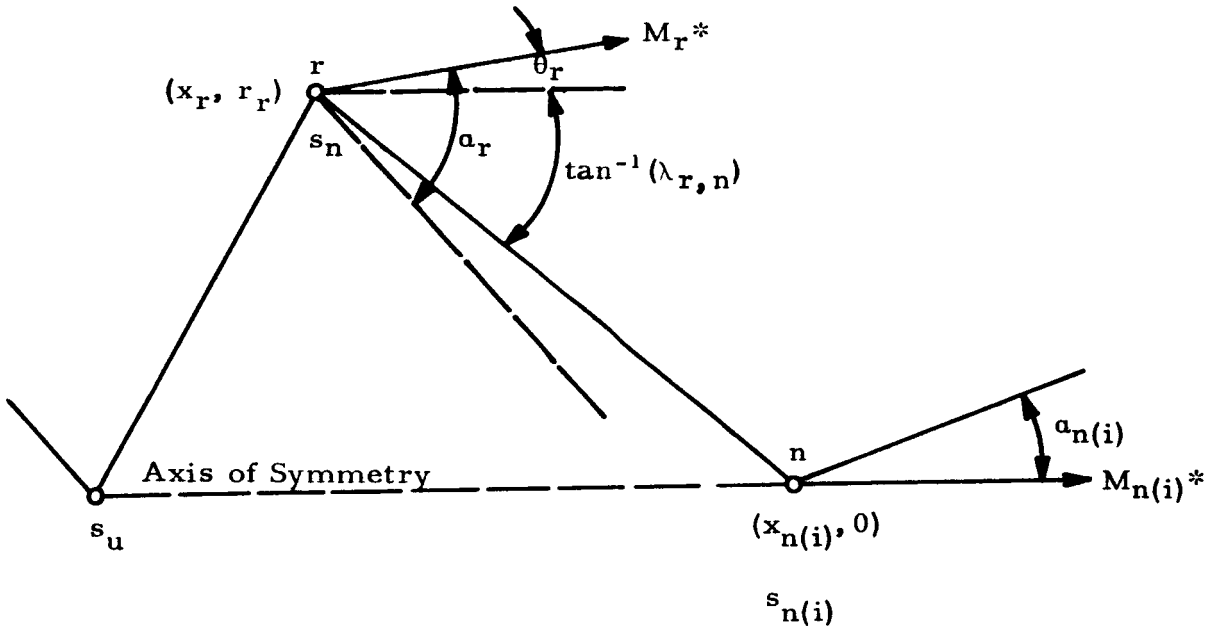

Figure A-2. Unit Process for Point on Axis of Symmetry

13. $\lambda_n = \tan(\theta_n - \alpha_n)$

14. $H_n = \dfrac{\cot \alpha_n}{M_n^*}$

15. $\lambda_{r,n} \dfrac{\lambda_r + \lambda_n}{2}$

16. $H_{r,n} = \dfrac{H_r + H_n}{2}$

17. $\beta_n = \tan \alpha_n \left(\dfrac{\theta_r}{r_r}\right)$

18. $\beta_{r,n} = \dfrac{\beta_r + \beta_n}{2}$

19. $x_{n(i)} = x_r - r_r/\lambda_{r,n}$

20. Obtain k_n and W_n from the thermodynamic table (M_n^* as input)

21. $\omega_n = \dfrac{\sin \alpha_n \cos \alpha_n}{\left(\dfrac{\bar{R}}{W_n}\right) k_n}$

22. $\omega_{n,n} = \dfrac{(\omega_n + \omega_n)}{2}$

23. $s_{n(i)} = s_u$

24. $M_{n(i)}^* = \dfrac{\theta_r + H_{r,n} M_r^* + \beta_{r,n}(x_{n(i)} - x_r) + \omega_{r,n}(s_r - s_{n(i)})}{H_{r,n}}$

25. If either $|M_{n(i)}^* - M_n^*| \leqq 10^{-7}$ or the number of iterations exceeds 50, return to the main program; otherwise, set $x_n = x_{n(i)}$, $M_n^* = M_{n(i)}^*$, increment the iteration counter by 1 and go to step 11.

CASE 4, Calculation of a point on the Contour

Given the flow properties at a point ℓ, the properties at point n are to be determined. The unit process for a boundary point is illustrated in Figure A-3.

The properties at point n are determined by the following relations:

1. Obtain M_ℓ^* from the thermodynamic table using M_ℓ as input.

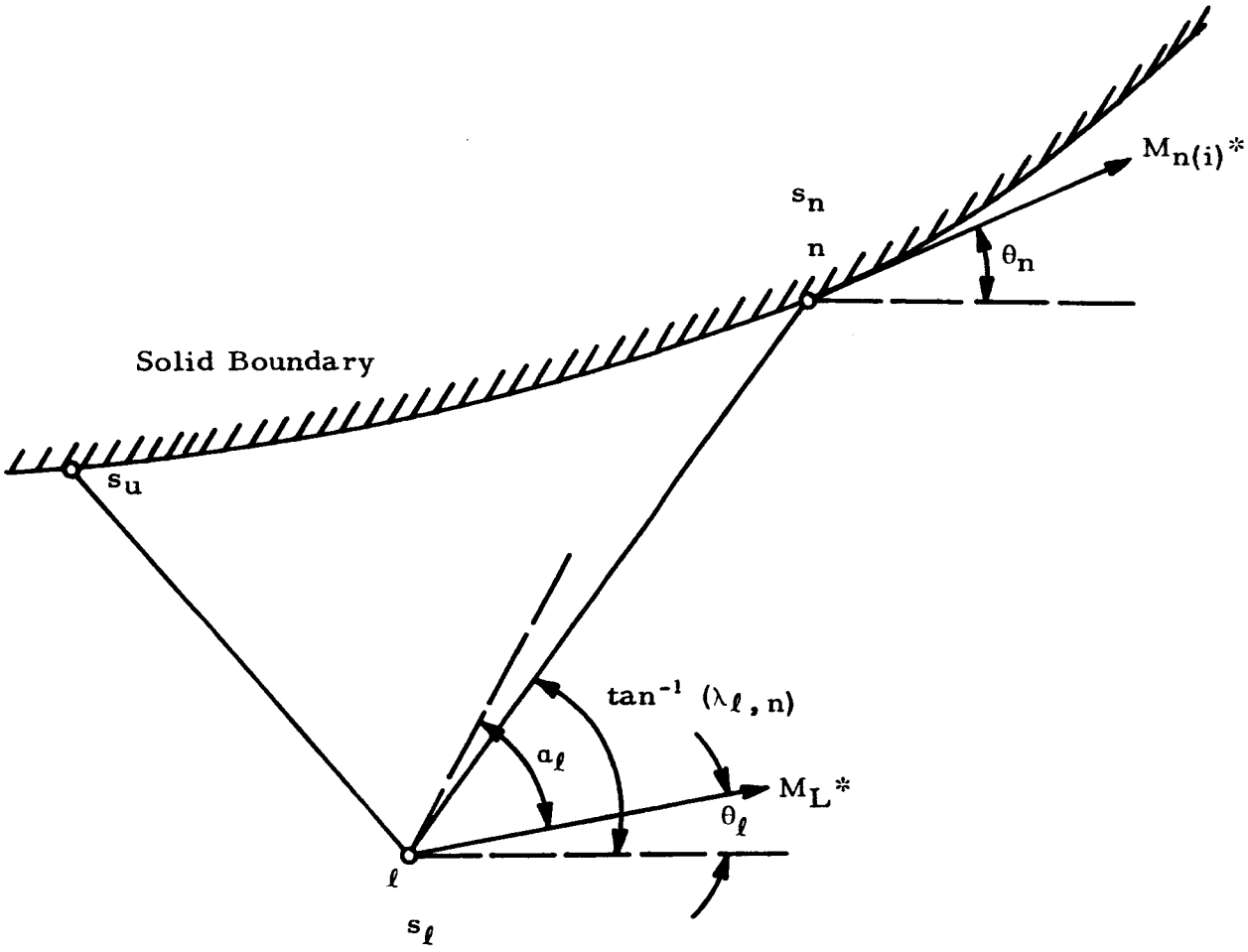

Figure A-3. Unit Process for Point on a Solid Boundary

2. $\alpha = \sin^{-1} \frac{1}{M_\ell}$

3. $\beta_\ell = \frac{\sin \theta_\ell \sin \alpha_\ell}{r_\ell \sin(\theta_\ell + \alpha_\ell)}$

4. $H_\ell \frac{\cot \alpha_\ell}{M_\ell *}$

5. $\lambda_\ell = \tan(\theta_\ell + \alpha_\ell)$

6. $\beta_{\ell,n} = \beta_\ell$

7. $H_{\ell,n} = H_\ell$

8. $\lambda_{\ell,n} = \lambda_\ell$

9. Obtain k_ℓ and W_ℓ from the thermodynamic table ($M_\ell *$ as input)

10. $s_n = s_u$

11. $\omega_\ell = \frac{\sin \alpha_\ell \cos \alpha_\ell}{\left(\frac{\bar{R}}{W_\ell}\right) k_\ell}$

12. $\omega_{\ell,n} = \omega_\ell$

13. Find x_n, r_n, and θ_n by solving the intersection of the left running characteristic with the contour.

14. $M_{n(i)}* = \frac{\theta_n - \theta_\ell - \beta_{\ell,n}(r_\ell - r_n)}{H_{\ell,n}} + M_\ell * + \frac{\omega_{\ell,n}(s_\ell - s_n)}{H_{\ell,n}}$

15. If either $|M_{n(i)}* - M_n*| \leqq 10^{-7}$ or number of iterations exceed 50, return to the main program; otherwise, set $M_n* = M_{n(i)}*$ and go to step 16.

16. Obtain M_n from thermodynamic table using M_n* as input.

17. $\alpha_n = \sin^{-1} \frac{1}{M_n}$

18. $\lambda_n = \tan(\theta_n + \alpha_n)$

19. $H_n = \dfrac{\cot \alpha_n}{M_n^*}$

20. $\beta_n = \dfrac{\sin \theta_n \sin \alpha_n}{r_n \sin(\theta_n + \alpha_n)}$

21. $H_{\ell,n} = \dfrac{H_\ell + H_n}{2}$

22. $\lambda_{\ell,n} = \dfrac{\lambda_\ell + \lambda_n}{2}$

23. $\beta_{\ell,n} = \dfrac{\beta_\ell + \beta_n}{2}$

24. Obtain k_n and W_n from the thermodynamic table (M_n^* as input)

25. $s_{n(i)} = s_n$

26. $\omega_n = \dfrac{\sin \alpha_n \cos \alpha_n}{\left(\dfrac{\bar{R}}{W_n}\right) k_n}$

27. $\omega_{\ell,n} = \dfrac{\omega_\ell + \omega_n}{2}$

28. Go to Step 13.

Subroutines SHOCK I and SHOCK.

Subroutines SHOCK I and SHOCK use the following sets of equations to calculate the change in properties across adiabatic shocks. (See Figure 2). Flow properties are known at points 1, 2, 12 and 13.

Subroutine SHOCK

1. Determine P_4, V_4, and ρ_4 from Subroutine PROPTY.

2. Obtain k_4 and W_4 from the thermodynamic table using M_4^* as input.

3. $\psi = \theta_4 - \mu_4$

4. $P_{11} = P_4 + \rho_1 V_4^2 (1 - \epsilon_1) \sin^2(\psi)$

5. Obtain k_{11} from the thermodynamic table using P_{11} as input

6. $\varepsilon_2 = \left(\frac{k_{11} + 1}{k_{11} - 1} + \frac{P_{11}}{P_4}\right) \Big/ \left[\frac{(k_{11} + 1)\, P_{11}}{(k_{11} - 1)\, P_4} + 1\right]$

7. If $|\varepsilon_2 - \varepsilon_1| < 10^{-5}$ continue; otherwise, set $\varepsilon_1 = \varepsilon_2$ and return to step 4

8. $VN_{11} = V_4\ \varepsilon_2\ \sin\psi$

9. $VT_{11} = V_4 \cos\psi$

10. $V_{11} = \left[(VN_{11})^2 + (VT_{11})^2\right]^{\frac{1}{2}}$

11. $M_{11}{}^* = \frac{V_{11}}{c^*}$

12. $\psi_{11} = \tan^{-1}(\varepsilon_2 \tan\psi)$

13. $\theta_{11} = \mu_4 + \psi_{11}$

14. $EDD = M_4^2 \sin^2\psi$

15. $PAR = \frac{\overline{R}}{W}$

16. $R_1 = \frac{2}{(k_4 + 1)\, EDD} + \frac{k_4 - 1}{k_4 + 1}$

17. $R_2 = \frac{2k_4}{k_4 + 1}\, EDD - \frac{k_4 - 1}{k_4 + 1}$

18. $s_{11} = s_4 + PAR\left[\left(\frac{k_4}{k_4 - 1}\right) \ln R_1 + \left(\frac{1}{k_4 - 1}\right) \ln R_2\right]$

Subroutine SHOCK I

1. DEL = 2/57.3
2. Properties at points 1, 2, 12, and 13 are recalled from storage. If the point being calculated is the first calculated point on the shock wave, $\mu_1 = \theta_1 - \alpha_1$ where $\alpha_1 = \tan^{-1}\left[\frac{1}{M_1^2 - 1}\right]^{\frac{1}{2}}$; otherwise, $\mu_1 = \mu_{11}$, the angle of the first upstream shock point.
3. $\mu_1 = \mu_1 + DEL$
4. $\mu_1 = \mu_1 - DEL$
5. $\mu_{4(1)} = \mu_1$

6. $\mu_4(2) = \mu_1 - DEL$

7. $\mu_4(3) = \mu_{42} - DEL$

8. $N = 3$

9. Repeat steps 10 through 41 for D = 1 through N.

10. $x\mu_4 = \mu_4(D)$

11. $F = \dfrac{\tan \mu_1 + \tan x\mu_4}{2}$

12. $B = \dfrac{(r_1 - r_2) - (x_1 - x_2)F}{(r_3 - r_2) - (x_3 - x_2)F}$

13. $x_4 = x_2 + B(x_3 - x_2)$

14. $r_4 = r_2 + B(r_3 - r_2)$

15. $s_4 = s_2 + B(s_3 - s_2)$

16. $\theta_4 = \theta_2 + B(\theta_3 - \theta_2)$

17. $M_4* = M_2* + B(M_3* - M_2*)$

18. $x_{11} = x_4$

19. $r_{11} = r_4$

20. Use Subroutine SHOCK to obtain $M_{11}*$, θ_{11}, and s_{11}

21. Obtain M_{11} from the thermodynamic table using $M_{11}*$ as input

22. $\alpha_{11} = \tan^{-1}\left[\dfrac{1}{M_{11}^2 - 1}\right]^{\frac{1}{2}}$

23. $\theta_{11}(D) = \theta_{11}$

24. $\theta_{14}(1) = \theta_{11}$

25. $\alpha_{14} = \alpha_{11}$

26. $ETA = \dfrac{\tan(\theta_{14}(1) - \alpha_{14}) + \tan(\theta_{11} - \alpha_{11})}{2}$

27. $G = \dfrac{(r_{11} - r_{12}) - (x_{11} - x_{12})\,ETA}{(r_{13} - r_{12}) - (x_{13} - x_{12})\,ETA}$

28. $x_{14} = x_{12} + G(x_{13} - x_{12})$

29. $r_{14} = r_{12} + G(r_{13} - r_{12})$

30. $s_{14} = s_{12} + G(s_{13} - s_{12})$

31. $\theta_{14} = \theta_{12} + G(\theta_{13} - \theta_{12})$

32. $M_{14}* = M_{12}* + G(M_{13}* - M_{12}*)$

33. If $|\theta_{14} - \theta_{14(1)}| \leqq 10^{-5}$, proceed to step 34; otherwise, set $\theta_{14(1)} = \theta_{14}$, find M_{14} from the thermodynamic table, find $\alpha_{14} = \tan^{-1}\left[\frac{1}{M_{14}^2 - 1}\right]^{\frac{1}{2}}$ and return to step 26. If after 25 loops of steps 26 through 33 the condition $|\theta_{14} - \theta_{14(1)}| \leqq 10^{-5}$ still has not been met, and if D = 1, set $\mu_1 = \mu_1 - 1/57.3$ and return to step 5.

34. $\theta_{11} = \theta_{14}$

35. $H_{11} = 0.5\left(\frac{1}{M_{11}* \tan \alpha_{11}} + \frac{1}{M_{14}* \tan \alpha_{14}}\right)$

36. $B_{11} = 0.5\left[\left(\frac{\sin \alpha_{11} \sin \theta_{11}}{r_{11} \cos(\theta_{11} - \alpha_{11})}\right) + \left(\frac{\sin \alpha_{14} \sin \theta_{14}}{r_{14} \cos(\theta_{14} - \alpha_{14})}\right)\right]$

37. Obtain k_{11}, k_{14}, W_{11}, and W_{14} from the thermodynamic table ($M_{11}*$ and $M_{14}*$ as input)

38. $\omega_{11} = 0.5 \frac{\sin \alpha_{11} \cos \alpha_{11}}{\frac{\bar{R}}{W_{11}} k_{11}} + \frac{\sin \alpha_{14} \cos \alpha_{14}}{\frac{\bar{R}}{W_{11}} k_{14}}$

39. $\theta_{11}(D) = \theta_{14} + B_{11}(x_{11} - x_{14}) - H_{11}(M_{11}* - M_{14}*) - \omega_{11}(s_{11} - s_{14})$

40. If $|\theta_{11}(D) - \theta_{11}| < 10^{-6}$ continue the calculations; otherwise, set $\theta_{11} = \theta_{11}(D)$ and return to step 35.

41. If N = 1 the values established for point 11 are the final values.

42. Using Subroutine POLY, create two parabolic equations with the two sets of values of μ_4 and θ_{11}. Solve these two equations for μ_{11}, set $\mu_{4\,(1)} = \mu_{11}$, N = 1, and return to step 9 to establish the final values of the properties at point 11.

APPENDIX B

LISTING OF FORTRAN PROGRAM

```
C
C     PROGRAMMED BY CARL T.K. YOUNG , MODIFIED BY JERRY DANIEL
C
C     PROGRAM SP-37M  IBM 7040 COMPUTER SYSTEM   SEPTEMBER, 1964
C     A FORTRAN IV COMPUTER PROGRAM TO CALCULATE FLOW PATTERN AND
C     PERFORMANCE PARAMETERS FOR AXIALLY SYMMETRIC NOZZLE (BASED ON
C     METHOD OF CHARACTERISTICS AND UTILIZIES SC-4020 PLOTTER TO
C     CONSTRUCT PLOTS OF THE CHARACTERISTIC NETWORK AND STREAMLINES.
C     FLOW ASSUMED TO BE SUPERSONIC, STEADY,   ROTATIONAL, AND COMPRESS-
C     IBLE. THE CHEMICAL COMPOSITION IS ASSUMED TO BE FROZEN
C     OR IN CHEMICAL EQUILIBRIUM.
C
C     DEVELOPED BY THE GASDYNAMICS/THERMOCHEMISTRY LABORATORY OF
C     BROWN ENGINEERING COMPANY, INC.
C
C
C
C
      COMMON FMVEC,FMSTAR,SFIELD,SSHOCK
      COMMON/WAYN/ FMW,GAMMA
      COMMON /XJR/ NSONE
      COMMON/CAL/ KENTRO
      DIMENSION P(80),T(80),FMW(80),GAMMA(80),FMVEC(80),FMSTAR(80),
     1 XWALL(250),YWALL(250),PWALL(250),FMWALL(250),XSAUER(60),
     2 YSAUER(60),THETAS(60),FMSAUR(60),XFIELD(3,60),YFIELD(3,60),
```

```
    3 FMSFLD(3,60),THETAV(3,60),XCWALL(250),YCWALL(250),XX(2),YY(2),
    4 XM(2),XT(2),XSTR(60),YSTR(60),THSTR(60),NROW(3),IN(3,60),
    5 DEL(3,60),SSHOCK(100),SSX(2),SFIELD(3,60),SSAUER(60)
      DIMENSION XSHOCK(100), YSHOCK(100), FMSHOK(100), TSHOCK(100),
    1 XMUSHK(100), EPS(100),SSCWAL(250)
      DIMENSION CM( 6), NPTCM( 6), XCM( 6,120), YCM( 6,120)
      TAN(X) = SIN(X)/COS(X)
      PI = 3.1415925636
      REWIND 2
C
C     READ IN NUMBER OF CASES TO BE RUN
C
      READ (5,553) NDATA
  553 FORMAT (5I5)
      WRITE (2,553) NDATA
      NCASE = 1
C
C     KT CONTROLS INPUT OF THERMODYNAMIC DATA.   KT = 1 FOR BEING
C     READ IN.   KT = 0 FOR ADIABATIC FLOW, WITH CONSTANT MOLECULAR
C     WEIGHT AND SPECIFIC HEATS RATIO TO BE READ IN.  KT = 2 FOR USING
C     THE SAME THERMODYNAMIC DATA AS THE PREVIOUS RUN
C
C     KC CONTROLS INPUT OF CONTOUR POINTS.   KC = 1 FOR BEING READ IN.
C     KC = 0 FOR USING THE SAME CONTOUR AS THE PREVIOUS RUN
C
```

```
C     KS CONTROLS STARTING LINE.   KS = 1 FOR BEING READ IN.   KS = 0
C     FOR BEING CALCULATED BY SUBROUTINE SAUER.    KS = 2 FOR USING THE
C     SAME STARTING LINE AS THE PREVIOUS RUN
C
C     KSHOCK CONTROLS THE OPTION OF COMPUTING SHOCK WAVES.  KSHOCK = 0
C     FOR NOT COMPUTING.   KSHOCK = 1 FOR COMPUTING
C
   93 READ (5,553) KT, KC, KS, KSHOCK
C
C     READ NUMBER OF INPUT POINTS OF THERMODYNAMIC DATA, ON THE
C     NOZZLE CONTOUR, ON THE STARTING LINE AND THE ORDER OF POLYNOMIAL
C     TO BE DESCRIBED FOR THE NOZZLE CONTOUR, AND NUMBER OF CONSTANT
C     MACH NUMBER LINES TO BE PLOTTED
C
C     KENTRO CONTROLS OPTION OF COMPUTING ENTROPY CHANGE ACROSS SHOCK
C     KENTRO=0 FOR COMPUTING . KENTRO=1 FOR NO CHANGE
      READ(5,553)KENTRO
      READ (5,553) NTABLE, NCT, NSONE, N, NCM
C
C     READ AMBIENT PRESSURE, CHAMBER PRESSURE AND TEMPERATURE
C
      READ (5,552) PA, PC, TC
  552 FORMAT (8F10.7)
C
C     READ THERMODYNAMIC DATA
```

```
C
      IF (KT - 1) 754, 753, 735
  753 DO 97 I = 1, NTABLE
   97 READ (5,552) P(I), T(I), FMW(I), GAMMA(I), FMVEC(I), FMSTAR(I)
      G = GAMMA(1)
      T1 = PLTN(1.0,T,FMVEC,NTABLE)
      FMW1 = PLTN(1.0,FMW,FMVEC,NTABLE)
      G1 = PLTN(1.0,GAMMA,FMVEC,NTABLE)
      CSTAR = SQRT(32.174*1546.336*G1*T1/FMW1)
      GO TO 735
C
C     READ SPECIFIC HEATS RATIO AND MOLECULAR WEIGHT (FOR FROZEN FLOW)
C
  754 READ (5,552) G, W
      CALL THERMO(NTABLE,G,W,PC,TC,P,T,FMW,GAMMA,FMVEC,FMSTAR,CSTAR)
  735 CONTINUE
C
C     READ SYMBOL AND SCALES OF COORDINATES TO BE USED FOR S-C 4020
C     PLOTTER
C
      READ (5,511) ISYM, XCL, XCR, YCB, YCT
  511 FORMAT (I10,4F10.5)
C
C     READ DIFFERENT RADII AND THEIR RANGES OF THE NOZZLE WALL
C     IN THE NEIGHBORHOOD OF THE THROAT
```

```
C
      READ (5,552) RNX1, RNX2, RPX1, RPX2, RPX3
      READ (5,552)  XN1,  XN2,  XP1,  XP2,  XP3
C
C     READ THROAT RADIUS, AREA RATIO, NOZZLE LENGTH, X COORDINATE OF
C     THE ROTATED NEW STARTING LINE ON THE CONTOUR, MAXIMUM ALLOWABLE
C     MESH SIZE, AND A SPECIAL FACTOR WHICH DECIDES THE CUT-OFF POINT
C     ON THE AXIS OF SYMMETRY
C
      READ (5,552) RT, ARATIO, XNLTH, XC, DMAX, ANL
C
C     READ MACH NUMBERS FOR CONSTRUCTING CONSTANT MACH NUMBER LINES.
C
      READ (5,552) (CM(I), I = 1, NCM)
C
C     READ POINTS ON THE NOZZLE CONTOUR
C
  921 IF (KS - 1) 734, 733, 742
  734 CALL SAUER(RNX2,RT,G,NSONE,XSAUER,YSAUER,THETAS,FMSAUR,SSAUER)
      GO TO 742
  733 DO 704 J = 1, NSONE
      READ (5,552) XSAUER(J), YSAUER(J), THETAS(J), FMSAUR(J),SSAUER(J)
      THETAS(J) = THETAS(J) * PI / 180.
  704 CONTINUE
  742 FMSUER = FMSAUR(1)
```

```
      IS = 1
      IF (XC .LE. XSAUER(1)) GO TO 2400
      IS = 0
      ISTART = 0
      R = RPX3
      IF (XC .GT. XP1 .AND. XC .LE. XP2) R = RPX2
      IF (XC .LE. XP1) R = RPX1
      YC = RT + R - SQRT(R*R - XC*XC)
      XA = XSAUER(NSONE)
      YA = YSAUER(NSONE)
      SB = (YC-YA)/(XC-XA)
 2400 YEXIT = RT * SQRT(ARATIO)
      FXT = 0.
      IF(KC.EQ.0)GO TO 2323
      DO 705 I=1,NCT
  705 READ (5,552)  XWALL(I),YWALL(I)
 2323 YEXIT=YWALL(NCT)
C
C     PRINT INPUT DATA
C
      WRITE (6,600)
  600 FORMAT (1H1,5X,25HINPUT DATA ARE AS FOLLOWS//)
      WRITE (6,601) PA
  601 FORMAT (1H0,10X,22HAMBIENT PRESSURE, PA =,F12.7,5H PSIA)
      WRITE (6,602) PC
```

```
602 FORMAT (1H0,10X,22HCHAMBER PRESSURE, PC =,F12.7,5H PSIA)
    WRITE (6,675) TC
675 FORMAT (1H0,7X,25HCHAMBER TEMPERATURE, TC =,F12.7,9H DEGREE R)
    WRITE (6,603) RT
603 FORMAT (1H0,13X,19HTHROAT RADIUS, RT =,F12.7,4H IN.)
    WRITE (6,617) XNLTH
617 FORMAT (1H0,10X,22HNOZZLE LENGTH, XNLTH =,F12.7,4H IN.)
    WRITE (6,604) ARATIO
604 FORMAT (1H0,13X,19HAREA RATIO, AE/AT =,F12.7)
    WRITE (6,629) DMAX
629 FORMAT (1H0,13X,19HMAXIMUM MESH SIZE =,F12.7,4H IN.)
    WRITE (6,605)
605 FORMAT (1H0,10X,44HRADII OF THE NOZZLE WALL IN THE NEIGHBORHOOD,
   1 24H OF THE THROAT, ASSUMING/11X,24HALL THE CENTERS OF RADII,
   2 46H LIE ON THE Y-AXIS, AND THEIR EFFECTIVE RANGES//)
    WRITE (6,606) RNX1, XN1, XN2
    WRITE (6,606) RNX2, XN2, FXT
    WRITE (6,606) RPX1, FXT, XP1
    WRITE (6,606) RPX2, XP1, XP2
    WRITE (6,606) RPX3, XP2, XP3
606 FORMAT (11X,8HRADIUS =,F10.7,1X,3HIN.,1X,13HFOR X BETWEEN,F12.7,
   1 1X,3HIN.,1X,3HAND,3X,F10.7,4H IN.)
    WRITE (6,609)
609 FORMAT (1H1,7X,18HTHERMODYNAMIC DATA///16X,8HPRESSURE,5X,
   1 11HTEMPERATURE,3X,12HMOLECULAR WT,5X,8HSPECIFIC,6X,7HMACH NO,
```

```
    2 9X,2HM*/17X,6H(PSIA),7X,10H(DEGREE R),3X,12H(LB/LB-MORE),3X,
    3 11HHEATS RATIO//)
      J = 1
      DO 95 I = 1, NTABLE
      IF (I - 50 * J) 95, 95, 331
  331 WRITE (6,662)
      J = J + 1
   95 WRITE (6,610) P(I), T(I), FMW(I), GAMMA(I), FMVEC(I), FMSTAR(I)
  610 FORMAT (11X,F14.7,F15.7,4F14.7)
  662 FORMAT (1H1)
      WRITE (6,619) CSTAR
  619 FORMAT (///10X,29HCRITICAL SONIC VELOCITY, C* =,F14.7,7H FT/SEC)
      WRITE (6,607)
  607 FORMAT (1H1,7X,34HPOINTS DEFINING THE NOZZLE CONTOUR //1H0,17X,
     1 1HX,11X,1HY/16X,5H(IN.),7X,5H(IN.)/)
      DO 94 I = 1, NCT
   94 WRITE (6,608) XWALL(I), YWALL(I)
  608 FORMAT (11X,2F12.7)
C
C     CREATE ARRAYS FOR CHARACTERISTIC NETWORK CONSTRUCTION
C
   85 DO 96 J = 1, NSONE
      FMSN = PLTN(FMSAUR(J),FMSTAR,FMVEC,NTABLE)
      DO 96 I = 1, 2
      XFIELD(I,J) = XSAUER(J)
```

```
      YFIELD(I,J) = YSAUER(J)
      SFIELD(I,J)=SSAUER(J)
      THETAV(I,J) = THETAS(J)
   96 FMSFLD(I,J) = FMSN
      WRITE (6,611)
  611 FORMAT (1H1,7X,27HPOINTS ON THE STARTING LINE/)
      IF (FMSAUR(1) - FMSAUR(NSONE)) 743, 744, 743
  744 CONTINUE
      FMSSER = PLTN(FMSUER,FMSTAR,FMVEC,NTABLE)
      PSAUER = PLTN(FMSUER,P,FMVEC,NTABLE)
      TSAUER = PLTN(FMSUER,T,FMVEC,NTABLE)
      FMWS=PLTN(FMSUER,FMW,FMVEC,NTABLE)
      GSAUER = PLTN(FMSUER,GAMMA,FMVEC,NTABLE)
      CSAUER = SQRT(32.174*1546.336*GSAUER*TSAUER/FMWS)
      VSAUER = CSAUER * FMSUER
      RHU = 144.0 * PSAUER * FMWS / (1546.336 * TSAUER)
      WRITE (6,612) FMSUER
  612 FORMAT (1H0,21X,10HMACH NO. =,F14.7)
      WRITE (6,681) FMSSER
  681 FORMAT (28X,4HM* =,F14.7)
      WRITE (6,614) GSAUER
  614 FORMAT (11X,21HSPECIFIC HEAT RATIO =,F14.7)
      WRITE (6,613) PSAUER
  613 FORMAT (22X,10HPRESSURE =,F14.7,5H PSIA)
      WRITE (6,684) TSAUER
```

```
684 FORMAT (19X,13HTEMPERATURE =,F14.7,9H DEGREE R)
    WRITE (6,682) CSAUER
682 FORMAT (16X,16HSONIC VELOCITY =,F14.7,7H FT/SEC)
    WRITE (6,683) VSAUER
683 FORMAT (22X,10HVELOCITY =,F14.7,7H FT/SEC)
    WRITE (6,689) RHO
689 FORMAT (23X,9HDENSITY =,F14.7,10H LBM/CU-FT)
    WRITE (6,685) FMWS
685 FORMAT (14X,18HMOLECULAR WEIGHT =,F14.7,12H LBM/LB-MOLE)
    WRITE(6,999)SSAUER(1)
    WRITE (6,615)
999 FORMAT(21X,9HENTROPY =,F14.7,16HBTU/LB. DEGREE R)
615 FORMAT (//1H0,18X,1HX,11X,1HY,9X,5HTHETA/17X,5H(IN.),7X,5H(IN.),
   1 5X,9H(DEGREES)/)
    DO 32 J = 1, NSONE
    THETAS(J) = THETAS(J) * 180. / PI
    WRITE (6,616) XSAUER(J), YSAUER(J), THETAS(J),SSAUER(J)
 32 THETAS(J) = THETAS(J) * PI / 180.
616 FORMAT (12X,5F12.7)
    GO TO 747
743 CONTINUE
    WRITE (6,6115)
6115 FORMAT (1H0,18X,1HX,11X,1HY,9X,5HTHETA,9X,1HM
   1,10X,7HENTROPY/17X,5H(IN.),7X,5H(IN.),5X9H(DEGREES),15X,15H(BTU/LB
   2. DEG.R)/)
```

```
      DO 31 J = 1, NSONE
      THETAS(J) = THETAS(J) * 180. / PI
      WRITE (6,616) XSAUER(J), YSAUER(J), THETAS(J), FMSAUR(J),SSAUER(J)
   31 THETAS(J) = THETAS(J) * PI / 180.
  747 CONTINUE
      NMONE = NSONE - 1
      DO 241 J = 2, NMONE
      XSTR(J) = XSAUER(J)
      YSTR(J) = YSAUER(J)
  241 THSTR(J) = THETAS(J)
      IF (IS .EQ. 0) GO TO 277
      WRITE (2,511) ISYM, XCL, XCR, YCB, YCT
      WRITE (2,276) NSONE, (XSAUER(J), YSAUER(J),SSAUER(J),J=1,NSONE)
  276 FORMAT (I10/(12F10.6))
  277 WRITE (6,671)
  671 FORMAT (1H1,1X,35HCALCULATED POINTS ARRANGED ROW WISE//
     1 3X,1HI,2X,1HJ,7X,1HX,10X,1HY,10X,1HM,10X,2HM*,7X,5HTHETA,8X,1HT,
     2 8X,1HP,8X,1HV,5X,7HDENSITY,3X,9HTOLERANCE,2X,9HITERATION,4X,1HS/
     3 12X,5H(IN.),6X,5H(IN.),28X,5H(DEG),5X,7H(DEG R),2X,
     4 6H(PSIA),2X,8H(FT/SEC),1X,10H(LB/CU-FT),12X,14H(BTU/LB.DEG.R)//)
C
C     CALCULATE FIELD POINTS
C
      REWIND 1
      REWIND 3
```

```
      I = 1
      IEXT = 0
      ISHOCK = 0
      JLAST = 1
      KCHECK = 1
      L1 = 1
      L2 = 1
      M = 1
      NPRINT = 0
      NTOTAL = 0
      DO 13 J = 1, NCM
   13 NPTCM(J) = 0
      NROW(1) = NSONE
      NROW(2) = NSONE
      NROW(3) = NSONE - 1
      DO 78 J = 1, NSONE
   78 FMSFLD(3,J) = 0.
   45 JEND = NROW(2) - 1
      JK = (I/2)*2 - I + 1
      IF (ISHOCK .EQ. 0) GO TO 26
      J2 = J2 + JK
      J3 = J3 - JK + 1
      J11 = J11 + JK
      J13 = J13 + JK
   26 II = JK
```

```
      DO 20 J = 1, JEND
      J1 = JK + J
      IF (FMSFLD(2,J+1) .EQ. 0. .OR. FMSFLD(2,J) .EQ. 0.) GO TO 1002
      XR = XFIELD(2,J)
      YR = YFIELD(2,J)
      SSR=SFIELD(2,J)
      FMSR = FMSFLD(2,J)
      FMR = PLTN(FMSR,FMVEC,FMSTAR,NTABLE)
      THETAR = THETAV(2,J)
      XL = XFIELD(2,J+1)
      YL = YFIELD(2,J+1)
      SSL=SFIELD(2,J+1)
      FMSL = FMSFLD(2,J+1)
      FML= PLTN(FMSL,FMVEC,FMSTAR,NTABLE)
      THETAL = THETAV(2,J+1)
      IF (ISHOCK .GT. 0 .AND. J1 .EQ. J11 .AND. ITEST .LT. 3) GO TO 321
      IF (XL - XNLTH) 303, 303, 322
  303 IF (XR - XNLTH) 302, 302, 1002
  322 IF (J - 1) 302, 302, 1002
  302 IF (YL) 5, 5, 10
   10 CALL CASE1(XR,YR,FMR,THETAR,XL,YL,FML,THETAL,
     1 NTABLE,XN,YN,FMSN,THETAN,DELTA,ICOUNT,SSN,SSL,SSR)
      GO TO 306
    5 CALL CASE2(XR,YR,FMR,THETAR,XL,YL,FML,THETAL,
     1 NTABLE,XN,YN,FMSN,THETAN,DELTA,ICOUNT,SSN,SSL,SSR)
```

```
  306 FMN = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
      IF (IS .EQ. 1) GO TO 79
      SA = (YL-YN)/(XL-XN)
      XXT= (YC-YN+SA*XN-SB*XC)/(SA-SB)
      IF (XN .LT. XXT) GO TO 3200
      II = II + 1
      IF (XL - XXT .GT. 1.E-05) GO TO 71
C
C     OBTAIN NEW POINT ON THE ROTATED NEW STARTING LINE
C
      ISTART = ISTART + 1
      XSAUER(ISTART) = XXT
      SSAUER(ISTART)=SSN
      YSAUER(ISTART) = YN + SA * (XXT- XN)
      IF (I .EQ. 1 .AND. J+1 .EQ. NSONE) YSAUER(ISTART) = 0.
      THETAS(ISTART) = THETAL + (THETAN-THETAL) *(XXT-XL) / (XN-XL)
      FMS = FMSL + (FMSN-FMSL) *(XXT-XL) / (XN-XL)
      FMSAUR(ISTART) = PLTN(FMS,FMVEC,FMSTAR,NTABLE)
      GO TO 71
   79 IF (I .EQ. 1 .OR. ISHOCK .GT. 0 .OR. KSHOCK .EQ. 0) GO TO 3200
C
C     TEST IF CHARACTERISTICS OF SAME FAMILIES CROSS
C
      XP = XFIELD(1,J1)
      YP = YFIELD(1,J1)
```

```
      CALL TEST(XR,YR,XL,YL,XN,YN,XP,YP,ITEST)
      IF (ITEST .EQ. 1) GO TO 321
 3200 IF (IS .EQ. 0) GO TO 71
      WRITE (2,552) XR, YR, XN, YN,SSN,SSR
      WRITE (2,552) XL, YL, XN, YN,SSN,SSL
      CALL CMLINE(XR,YR,FMR,XN,YN,FMN,CM,NPTCM,XCM,YCM)
      CALL CMLINE(XL,YL,FML,XN,YN,FMN,CM,NPTCM,XCM,YCM)
   71 FMSFLD(3,J1) = FMSN
 1002 XFIELD(3,J1) = XN
      YFIELD(3,J1) = YN
      SFIELD(3,J1)=SSN
      THETAV(3,J1) = THETAN
      IN(3,J1) = ICOUNT
      DEL(3,J1) = DELTA
      GO TO 20
C
C     CALCULATE POINT DESCRIBING THE SHOCK WAVE
C
  321 CALL SHOCKI(P,T,FMW,GAMMA, PC,          NTABLE,CSTAR,XFIELD,
     1 YFIELD,FMSFLD,THETAV,NROW,J,J1,J2,J3,J11,J13,ITEST,ISHOCK,XSHOCK,
     2 YSHOCK,FMSHCK,TSHOCK,XMUSHK,EPS)
      IF (J+2 .GT. NROW(2) .OR. FMSFLD(2,J+2) .EQ. 0.) ITEST = 3
      IF (ITEST .EQ. 3) GO TO 24
      FMN = PLTN(FMSFLD(3,J1),FMVEC,FMSTAR,NTABLE)
      CALL CMLINE(XR,YR,FMR,XFIELD(3,J1),YFIELD(3,J1),FMN,CM,NPTCM,
```

```
     1 XCM,YCM)
       CALL CMLINE(XL,YL,FML,XFIELD(3,J1),YFIELD(3,J1),FMN,CM,NPTCM,
     1 XCM,YCM)
       IN(3,J1) = IN(3,J1) + 120
    20 CONTINUE
    24 IF (I - (I/2)*2) 59, 59, 2100
  2100 K = 0
       GO TO 2009
    59 NN = NROW(3)
       IF (IS .EQ. 0 .AND. II .EQ. NN) GO TO 40
       IF (IS .EQ. 0) GO TO 2009
       IF (KCHECK .EQ. 2) GO TO 313
       IF (FMSFLD(2,JEND+1) .EQ. 0. .OR.  XL .GE. XNLTH) GO TO 313
       CALL CASE3(XL,YL,FML,THETAL,              XN,YN,FMSN,THETAN,NTABLE,
     1 DELTA,ICOUNT,SSN,SSL)
       SR = SQRT((XL-XN)**2 + (YL-YN)**2)
       IF (SR .LE. DMAX) GO TO 902
C
C      CREATE NEW CHARACTERISTICS FROM THE AXIS OF SYMMETRY
C
       DO 903 KK = 1, 2
       NN = NROW(KK)
       XX(KK) = XFIELD(KK,NN)
       YY(KK) = YFIELD(KK,NN)
       SSX(KK)=SFIELD(KK,NN)
```

```
      XM(KK) = PLTN(FMSFLD(KK,NN),FMVEC,FMSTAR,NTABLE)
  903 XT(KK) = THETAV(KK,NN)
      CALL EXTRA3(XX,YY,XM,XT,                NTABLE,NROW,XFIELD,YFIELD,
     1 FMSFLD,THETAV,DMAX,DEL,IN,IEXT,CM,NPTCM,XCM,YCM,SSX)
      NN = NROW(3)
      GO TO 901
  902 WRITE (2,552) XL, YL, XN, YN,SSN
      FMN = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
      CALL CMLINE(XL,YL,FML,XN,YN,FMN,CM,NPTCM,XCM,YCM)
      FMSFLD(3,NN) = FMSN
  313 XFIELD(3,NN) = XN
      YFIELD(3,NN) = YN
      SFIELD(3,NN)=SSN
      THETAV(3,NN) = THETAN
      IN(3,NN) = ICOUNT
      DEL(3,NN) = DELTA
  901 IF (KCHECK .EQ. 2 .AND. X .GT. XNLTH) DEL(3,NN) = 100.
      X = 0.
      IF (FMSFLD(3,NN) .EQ. 0.) GO TO 911
      FMN = PLTN(FMSFLD(3,NN),FMVEC,FMSTAR,NTABLE)
      X = YEXIT * SQRT(FMN*FMN-1.) + XFIELD(3,NN)
      IF (X .GE. ANL * XNLTH) KCHECK = 2
  911 K = 1
 2009 I = I + 1
      IF (IS .EQ. 0) GO TO 74
```

```
C
C     CONSTRUCT PORTIONS OF STREAMLINES
C
      CALL STREAM(XFIELD,YFIELD,FMSFLD,THETAV,K,NSONE,XSTR,YSTR,THSTR,
     1 NTOTAL,NROW)
   74 DO 2004 KK = 1, 2
      NN = NROW(KK+1)
      NROW(KK) = NN
      DO 2004 J = 1, NN
      XFIELD(KK,J) = XFIELD(KK+1,J)
      YFIELD(KK,J) = YFIELD(KK+1,J)
      FMSFLD(KK,J) = FMSFLD(KK+1,J)
      THETAV(KK,J) = THETAV(KK+1,J)
      SFIELD(KK,J)=SFIELD(KK+1,J)
      IN(KK,J) = IN(KK+1,J)
      DEL(KK,J) = DEL(KK+1,J)
      IF (KK .NE. 2) GO TO 2004
      FMSFLD(3,J) = 0.
 2004 CONTINUE
      FMSFLD(3,NN+1) = 0.
      NROW(3) = NROW(2) + 1 - 2*(I - (I/2)*2)
      IF (IS .EQ. 0) NROW(3) = NROW(3) - 1 + I - (I/2)*2
      IF (ITEST .NE. 3) GO TO 2016
      ITEST = 4
      NROW(3) = J1 - 1
```

```
 2016 IF (IEXT .EQ. 0) GO TO 2014
C
C     PRINT EXTRA MESH POINTS CREATED DURING MESH SIZE CONTROL PROCESS
C
      REWIND 3
      DO 2011 J = 1, IEXT
      READ (3) XN, YN, FMN, FMSN, THETAN, II,SSN
      NPRINT = NPRINT + 1
      THETAN = THETAN * 180. / PI
      IF (NPRINT - 52) 821, 821, 822
  822 NDEL = NPRINT - 53 - 56*((NPRINT-52)/56)
      IF (NDEL) 821, 823, 821
  823 WRITE (6,686)
  821 WRITE (6,669) XN, YN, FMN, FMSN, THETAN, II,SSN
 2011 CONTINUE
  686 FORMAT (1H1,
     1 3X,1HI,2X,1HJ,7X,1HX,10X,1HY,10X,1HM,10X,2HM*,7X,5HTHETA,8X,1HT,
     2 8X,1HP,8X,1HV,5X,7HDENSITY,3X,9HTOLERANCE,2X,9HITERATION,4X,1HS/
     3 12X,5H(IN.),6X,5H(IN.),28X,5H(DEG),5X,7H(DEG R),2X,
     4 6H(PSIA),2X,8H(FT/SEC),1X,10H(LB/CU-FT),12X,14H(BTU/LB.DEG.R)//)
  669 FORMAT (7X,F12.7,3F11.7,F12.7,3X,28H-----   EXTRA POINT CREATED ,
     1 29HWHILE CALLING SUBROUTINE CASE,I1)
      IEXT = 0
      REWIND 3
 2014 IF (I .EQ. 2) GO TO 2015
```

```
C
C     PRINT MESH POINTS OF THE CHARACTERISTIC NETWORK
C
      DO 2012 M = L1, L2
      NN = NROW(M)
      I1 = I - 2 + M
      DO 2012 J = 1, NN
      IF (FMSFLD(M,J) .EQ. 0.) GO TO 2050
      FMSN = FMSFLD(M,J)
      SSN=SFIELD(M,J)
      CALL PROPTY(FMSN,  T,FMW,GAMMA,              NTABLE,PN,TN,VN,
     1 RHUN,FMN,SSN,PC,PON)
  814 THETAV(M,J) = THETAV(M,J) * 180. / PI
      NPRINT = NPRINT + 1
      IF (NPRINT - 52) 811, 811, 812
  812 NDEL = NPRINT - 53 - 56*((NPRINT-52)/56)
      IF (NDEL) 811, 813, 811
  813 WRITE (6,686)
  811 IF (IN(M,J) .GE. 120) GO TO 2032
      IF (IN(M,J) .GE. 60) GO TO 2013
      WRITE (6,670) I1,J,XFIELD(M,J),YFIELD(M,J),FMN,FMSFLD(M,J),
     1 THETAV(M,J),TN,PN,VN,RHUN,DEL(M,J),IN(M,J),SFIELD(M,J)
      GO TO 2018
 2032 WRITE (6,663) I1,J,XFIELD(M,J),YFIELD(M,J),FMN,FMSFLD(M,J),
     1 THETAV(M,J),TN,PN,VN,RHUN,DEL(M,J),SFIELD(M,J)
```

```
      IF (ITEST .NE. 4) GO TO 2018
      WRITE (6,6123)
      ITEST = 2
 6123 FORMAT (1H0,10X,27HEND OF RIGHT INCLINED SHOCK/)
      GO TO 2018
 2013 IN(M,J) = IN(M,J) - 60
      WRITE (6,668) I1,J,XFIELD(M,J),YFIELD(M,J),FMN,FMSFLD(M,J),
     1 THETAV(M,J),TN,PN,VN,RHUN,DEL(M,J),IN(M,J),SFIELD(M,J)
 2018 THETAV(M,J) = THETAV(M,J) * PI / 180.
 2050 IF (DEL(M,J) .GT. 50.) WRITE (6,664)
 2012 CONTINUE
  663 FORMAT (1X,2I3,F12.7,3F11.7,F12.7,F9.1,F8.2,F9.1,F11.6,F11.7,
     1  5X,F11.7,1HS)
  664 FORMAT (1H0,10X,40HCHARACTERISTIC CUT-OFF HAS BEEN EXECUTED/)
  668 FORMAT (1X,2I3,F12.7,3F11.7,F12.7,F9.1,F8.2,F9.1,F11.6,F11.7,
     1 I7,8X,1HE)
  670 FORMAT (1X,2I3,F12.7,3F11.7,F12.7,F9.1,F8.2,F9.1,F11.6,F11.7,I7
     1,F10.5)
      IF (IS .EQ. 0 .AND. M .GT. 2) GO TO 82
 2015 IF (M .GT. 2) GO TO 42
      IF (I .GT. (I/2)*2) GO TO 45
      IF (FMSFLD(2,1) .EQ. 0.) GO TO 40
      XL = XFIELD(2,1)
      YL = YFIELD(2,1)
      SSL=SFIELD(2,1)
```

```
      FMSL = FMSFLD(2,1)
      FML = PLTN(FMSL,FMVEC,FMSTAR,NTABLE)
      THETAL = THETAV(2,1)
      CALL CASE4(XL,YL,FML,THETAL,NCT,              XWALL,YWALL,RT,
     1 NTABLE,RNX1,XN1,RNX2,XN2,RPX1,XP1,RPX2,XP2,RPX3,XP3,N,XN,YN,
     2 FMSN,THETAN,DELTA,ICOUNT,SSN,SSL)
      IF (IS .EQ. 0) GO TO 905
      SL = SQRT((XL-XN)**2 + (YL-YN)**2)
      IF (SL .LE. DMAX) GO TO 905
C
C     CREATE NEW CHARACTERISTICS FROM THE NOZZLE CONTOUR
C
      DO 906 KK = 1, 2
      XX(KK) = XFIELD(KK,1)
      SSX(KK)=SFIELD(KK,1)
      YY(KK) = YFIELD(KK,1)
      XM(KK) = PLTN(FMSFLD(KK,1),FMVEC,FMSTAR,NTABLE)
  906 XT(KK) = THETAV(KK,1)
      CALL EXTRA4(XX,YY,XM,XT,              NCT,XWALL,YWALL,NTABLE,
     1 RT,RNX1,XN1,RNX2,XN2,RPX1,XP1,RPX2,XP2,RPX3,XP3,N,NROW,XFIELD,
     2 YFIELD,FMSFLD,THETAV,DMAX,DEL,IN,IEXT,CM,NPTCM,XCM,YCM,        SSX
     1)
      JK = IEXT / 3
      J2 = J2 + JK
      J3 = J3 + JK
```

```
      J11 = J11 + JK
      J13 = J13 + JK
      GO TO 904
  905 XFIELD(3,1) = XN
      YFIELD(3,1) = YN
      SFIELD(3,1)=SSN
      FMSFLD(3,1) = FMSN
      THETAV(3,1) = THETAN
      IN(3,1) = ICOUNT
      DEL(3,1) = DELTA
      FMN = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
      IF (IS .EQ. 1) CALL CMLINE(XL,YL,FML,XN,YN,FMN,CM,NPTCM,XCM,YCM)
      IF (IS .EQ. 1 .OR. XN .LT. XC) GO TO 11
      IF (JLAST .EQ. 2) GO TO 29
      IF (ABS(XN-XC) .LE. 1.E-03 .AND. ABS(YN-YC) .LE. 1.E-03) GO TO 12
      SA = (YL-YN)/(XL-XN)
      XXT= (YC-YN+SA*XN-SB*XC)/(SA-SB)
      IF (XL .GE. XXT) GO TO 12
      ISTART = ISTART + 1
      SSAUER(ISTART)=SSN
      XSAUER(ISTART) = XXT
      YSAUER(ISTART) = YN + SA * (XXT- XN)
      THETAS(ISTART) = THETAL + (THETAN-THETAL) *(XXT-XL) / (XN-XL)
      FMS = FMSL + (FMSN-FMSL) *(XXT-XL) / (XN-XL)
      FMSAUR(ISTART) = PLTN(FMS,FMVEC,FMSTAR,NTABLE)
```

```
C
C     OBTAIN THE TOP MOST POINT ON THE ROTATED NEW STARTING LINE BY
C     FALSE POSITION METHOD
C
   12 XL = XFIELD(1,1)
      YL = YFIELD(1,1)
      SSL=SFIELD(1,1)
      FMSL = FMSFLD(1,1)
      FML = PLTN(FMSL,FMVEC,FMSTAR,NTABLE)
      THETAL = THETAV(1,1)
      XR = XFIELD(2,1)
      YR = YFIELD(2,1)
      SSR=SFIELD(2,1)
      FMSR = FMSFLD(2,1)
      FMR = PLTN(FMSR,FMVEC,FMSTAR,NTABLE)
      THETAR = THETAV(2,1)
      IK = 0
   81 XP = (XL + XR) / 2.
      YP = (YL + YR) / 2.
      SSP=(SSL+SSR)/2.
      FMP = (FML + FMR)/  2.
      THETAP = (THETAL + THETAR) / 2.
      IK = IK + 1
      CALL CASE4(XP,YP,FMP,THETAP,NCT,              XWALL,YWALL,RT,
     1 NTABLE,RNX1,XN1,RNX2,XN2,RPX1,XP1,RPX2,XP2,RPX3,XP3,N,XN,YN,
```

```
  2 FMSN,THETAN,DELTA,ICOUNT,SSN,SSP)
    IF (ABS(XC-XN) .LT. 1.E-06 .OR. IK .GE. 10) GO TO 77
    IF (XN .GT. XC) GO TO 80
    XL = XP
    YL = YP
    SSL=SSP
    FML = FMP
    THETAL = THETAP
    GO TO 81
 80 XR = XP
    YR = YP
    SSR=SSP
    FMR = FMP
    THETAR = THETAP
    GO TO 81
 77 ISTART = ISTART + 1
    XSAUER(ISTART) = XN
    YSAUER(ISTART) = YN
    SSAUER(ISTART)=SSN
    THETAS(ISTART) = THETAN
    FMSAUR(ISTART)= PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
    JLAST = 2
 29 IF (NROW(3) .EQ. 1) GO TO 40
    GO TO 45
 11 IF (IS .EQ. 0) GO TO 45
```

```
      WRITE (2,552) XL, YL, XN, YN,SSN,SSL
  904 JLAST = JLAST + 1
      XCWALL(JLAST) = XFIELD(3,1)
      YCWALL(JLAST) = YFIELD(3,1)
      SSCWAL(JLAST)=SFIELD(3,1)
      FMWALL(JLAST) = PLTN(FMSFLD(3,1),FMVEC,FMSTAR,NTABLE)
      PWALL(JLAST) = PLTN(FMSFLD(3,1),P,FMSTAR,NTABLE)
      IF (XFIELD(3,1) .LT. XNLTH) GO TO 45
   40 L1 = 2
      L2 = 3
      GO TO 2016
   42 XCWALL(1) = XSAUER(1)
      YCWALL(1) = YSAUER(1)
      SSCWAL(1)=SSAUER(1)
      FMWALL(1) = FMSAUR(1)
      PWALL(1) = PLTN(FMWALL(1),P,FMVEC,NTABLE)
      CALL PERFOR(XSAUER,YSAUER,FMSAUR,THETAS,XCWALL,YCWALL,PWALL,
     1 P,T,GAMMA,FMW,       NTABLE,NSONE,JLAST,N,PA,PC,RT,XNLTH,YEXIT)
      WRITE (2,552) XN, YN, XN, YN,SSN
      IF (ISHOCK .EQ. 0) GO TO 14
      WRITE (6,677)
  677 FORMAT (1H1,10X,27HPOINTS ALONG THE SHOCK WAVE//20X,1HX,15X,1HY,
     1 13X,5HTHETA,13X,2HM*,8X,11HSHOCK ANGLE,5X,13HDENSITY RATIO,
     17X,7HENTROPY/
     2 18X,5H(IN.),11X,5H(IN.),11X,5H(DEG),26X,5H(DEG)
```

```
     4,23X,14H(BTU/LB.DEG.R)/)
      DO 57 I = 1, ISHOCK
      TSHOCK(I) = TSHOCK(I) * 180. / PI
      XMUSHK(I) = XMUSHK(I) * 180. / PI
   57 WRITE (6,678) XSHOCK(I), YSHOCK(I), TSHOCK(I), FMSHOK(I),
     1 XMUSHK(I), EPS(I),SSHOCK(I)
  678 FORMAT (1H0,10X,7E16.8)
C
C     WRITE ALL INFORMATION ABOUT FIELD POINTS AND STREAMLINES ON
C     TAPE 2 TO FEED THE SC-4020 PLOTTER
C
   14 WRITE (2,276) JLAST, (XCWALL(J), YCWALL(J), J = 1, JLAST)
      WRITE (2,553) NTOTAL
      REWIND 1
      NPOINT = 0
  244 READ (1) XL, YL, XR, YR
      WRITE (2,552) XL, YL, XR, YR
      NPOINT = NPOINT + 1
      IF (NPOINT - NTOTAL) 244, 245, 245
C
C     SORT POINTS ON EACH OF THE CONSTANT MACH NUMBER LINES IN
C     DECENDING ORDER ALONG THE Y-AXIS AND WRITE ON TAPE 2
C
  245 NCP = NCM
      DO 17 I = 1, NCM
```

```
      IF (NPTCM(I) .LE. 1) NCP = NCM - 1
   17 CONTINUE
      WRITE (2,553) NCP
      WRITE (6,631) NCP
  631 FORMAT (1H1,5X,33HCALCULATED POINTS ON EACH OF THE ,I2,
     1 39H CONSTANT PROPERTY LINES ARE AS FOLLOWS/)
      ICP = 0
      DO 15 I = 1, NCM
      IF (NPTCM(I) .LE. 1) GO TO 15
      NPT = NPTCM(I)
      NMONE = NPT - 1
      DO 16 J = 1, NMONE
      NN = NPT - J + 1
      DO 16 K = 2, NN
      IF (YCM(I,K) .LE. YCM(I,K-1)) GO TO 16
      TEMP = XCM(I,K)
      XCM(I,K) = XCM(I,K-1)
      XCM(I,K-1) = TEMP
      TEMP = YCM(I,K)
      YCM(I,K) = YCM(I,K-1)
      YCM(I,K-1) = TEMP
   16 CONTINUE
      WRITE (2,276) NPT, (XCM(I,K), YCM(I,K), K = 1, NPT)
      FMSCP = PLTN(CM(I),FMSTAR,FMVEC,NTABLE)
      ALPHA = ATAN(SQRT(1./(CM(I)*CM(I)-1.))) * 180. / 3.1415926536
```

```
      TCP = PLTN(CM(I),T,FMVEC,NTABLE)
      PCP = PLTN(CM(I),P,FMVEC,NTABLE)
      GCP = PLTN(CM(I),GAMMA,FMVEC,NTABLE)
      FMWCP = PLTN(CM(I),FMW,FMVEC,NTABLE)
      CCP = SQRT(32.174*1546.336*GCP*TCP/FMWCP)
      VCP = CCP * CM(I)
      RHU = 144. * PCP * FMWCP / (1546.336 * TCP)
      ICP = ICP + 1
      WRITE (6,632) ICP,CM(I),FMSCP,ALPHA,TCP,PCP,GCP,FMWCP,VCP,RHU
  632 FORMAT (////7X,I2,2H. ,37HPOINTS ON THE CONSTANT PROPERTY LINE ,
     1 4HWITH//20X13HMACH NUMBER =,F12.5,20X,23HREFERENCE MACH NUMBER =,
     2 F12.5/21X,12HMACH ANGLE =,F12.5,8H DEGREES,22X,13HTEMPERATURE =,
     3 F12.5,9H DEGREE R/23X,10HPRESSURE =,F12.5,5H PSIA,16X,
     4 22HSPECIFIC HEATS RATIO =,F12.5/15X,18HMOLECULAR WEIGHT =,F12.5,
     5 12H LBM/LB-MOLE,21X,10HVELOCITY =,F12.5,7H FT/SEC/24X,9HDENSITY =
     6 F12.5,10H LBM/CU-FT//)
      N3 = 0
  952 N1 = N3 + 1
      DO 951 J = N1, NPT
      N3 = N1 + 7
      IF (N3 .GT. NPT) N3 = NPT
      WRITE (6,633) (XCM(I,J),J=N1,N3)
  633 FORMAT (11X,3HX =,8F12.5)
      WRITE (6,634) (YCM(I,J),J=N1,N3)
  634 FORMAT (11X,3HY =,8F12.5/)
```

```
      IF(N3.LT.NPT)  GO TO 952
  951 CONTINUE
   15 CONTINUE
      WRITE (6,622)
  622 FORMAT (//////25X,25H****** END OF CASE ******)
      IF (NCASE - NDATA) 751, 752, 752
  751 NCASE = NCASE + 1
      GO TO 93
  752 CONTINUE
      REWIND 2
      PAUSE 77777
      CALL EXIT
C
C     SORT POINTS ON THE ROTATED NEW STARTING LINE IN DECENDING
C     ORDER ALONG THE Y-AXIS
C
   82 NSONE = ISTART
      NMONE = NSONE - 1
      DO 84 I = 1, NMONE
      NN = NSONE - I + 1
      DO 84 J = 2, NN
      IF (YSAUER(J) .LE. YSAUER(J-1)) GO TO 84
      TEMP = XSAUER(J)
      XSAUER(J) = XSAUER(J-1)
      XSAUER(J-1) = TEMP
```

```
      TEMP = YSAUER(J)
      YSAUER(J) = YSAUER(J-1)
      YSAUER(J-1) = TEMP
      TEMP=SSAUER(J)
      SSAUER(J)=SSAUER(J-1)
      SSAUER(J-1)=TEMP
      TEMP = THETAS(J)
      THETAS(J) = THETAS(J-1)
      THETAS(J-1) = TEMP
      TEMP = FMSAUR(J)
      FMSAUR(J) = FMSAUR(J-1)
      FMSAUR(J-1) = TEMP
   84 CONTINUE
      IS = 1
      GO TO 85
      END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE CASE 1

```
C
C     SUBROUTINE TO CALCULATE A NEW FIELD POINT WITH BOTH INPUT POINTS
C     LOCATED IN THE CENTER FIELD
C
      SUBROUTINE CASE1(XXR,YYR,FFMR,THETAP,XXL,YYL,FFML,THETAQ,
     1        NTABLE,XN,YN,FMSN,THETAN,DELTA,ICOUNT ,SSN,SSL,SSR)
      COMMON FMVEC,FMSTAR
      COMMON/WAYN/ FMW,GAMMA
      DIMENSION FMW(80),GAMMA(80)
      DIMENSION FMVEC(80), FMSTAR(80)
      TAN(X) = SIN(X)/COS(X)
      ICOUNT = 1
      DELT = 0.
      XR = XXR
      YR = YYR
      FMR = FFMR
      THETAR = THETAP
      XL = XXL
      YL = YYL
      FML = FFML
      THETAL = THETAQ
      IF (FML .GT. 1.0 .OR. FMR .GT. 1.0) GO TO 103
      WRITE (6,666) XR, YR, FMR, XL, YL, FML,SSR,SSL
  666 FORMAT (1H1,10X,46HERROR MESSAGE, EITHER FMR OR FML IS LESS THAN
     1  3HONE//11X,8F12.7)
```

```
      GO TO 801
  103 FMSL = PLTN(FML,FMSTAR,FMVEC,NTABLE)
      FMSR = PLTN(FMR,FMSTAR,FMVEC,NTABLE)
      ALPHAL = ATAN(SQRT(1./(FML*FML-1.)))
      ALPHAR = ATAN(SQRT(1./(FMR*FMR-1.)))
      FLAMDL = TAN(THETAL+ALPHAL)
      FLAMDR = TAN(THETAR-ALPHAR)
      HL = 1./(TAN(ALPHAL)*FMSL)
      HR = 1./(TAN(ALPHAR)*FMSR)
      BETAL = SIN(THETAL)*SIN(ALPHAL)/(YL*SIN(THETAL+ALPHAL))
      BETAR = SIN(THETAR)*SIN(ALPHAR)/(YR*COS(THETAR-ALPHAR))
      XN=((FLAMDR*XR-FLAMDL*XL)+YL-YR)/(FLAMDR-FLAMDL)
      YN = YL - FLAMDL*(XL-XN)
      GL=PLTN(FMSL,GAMMA,FMSTAR,NTABLE)
      FMWL=PLTN(FMSL,FMW,FMSTAR,NTABLE)
      WL=(SIN(ALPHAL)*COS(ALPHAL))/(1546.336/(FMWL*778.)*GL)
      GR=PLTN(FMSR,GAMMA,FMSTAR,NTABLE)
      FMWR=PLTN(FMSR,FMW,FMSTAR,NTABLE)
      WR=(SIN(ALPHAR)*COS(ALPHAR))/(1546.336/(FMWR*778.)*GR)
      XETAL=SIN  (ALPHAL)/COS  (THETAL+ALPHAL)
      XETAR=SIN  (ALPHAR)/COS  (THETAR-ALPHAR)
      DN=((XN-XR)*SIN  (ALPHAR))/COS  (THETAR-ALPHAR)
      DW =(SSR-SSL)/((XN-XL)*XETAL+(XN-XR)*XETAR)
      SSN=SSR-DW*DN
      FMSN  = (THETAR-THETAL+HL*FMSL+HR*FMSR-BETAR*(XR-XN)-BETAL*(YL-YN
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE CASE 1

```
1 ))/(HL+HR)+(WR*(SSR-SSN)+WL*(SSL-SSN))/(HL+HR)
  THETAN = THETAL-HL*(FMSL-FMSN)+BETAL*(YL-YN)-WL*(SSL-SSN)
  IF (FMSN .GT. 1.0) GO TO 30
  IF (FMSR .GT. FMSL) GO TO 31
  FMSN = FMSL
  THETAN = THETAL
  GO TO 30
31 FMSN = FMSR
  THETAN = THETAR
30 IF (FMSN .GT. FMSTAR(NTABLE) .OR. FMSN .LE. 1.) GO TO 104
  FMN = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
  ALPHAN = ATAN(SQRT(1./(FMN*FMN-1.)))
  FLAMN = TAN(THETAN+ALPHAN)
  FLAMNP= TAN(THETAN-ALPHAN)
  HN = 1./(TAN(ALPHAN)*FMSN)
  BETAN = SIN(THETAN)*SIN(ALPHAN)/(YN*SIN(THETAN+ALPHAN))
  BETANP= SIN(THETAN)*SIN(ALPHAN)/(YN*COS(THETAN-ALPHAN))
  FLAMRN = (FLAMDR + FLAMNP)/2.
  FLAMLN = (FLAMDL + FLAMN)/2.
  HLN = (HL + HN)/2.
  HRN = (HR + HN)/2.
  BETARN = (BETAR + BETANP)/2.
  BETALN = (BETAL + BETAN)/2.
  XN = ((FLAMRN*XR-FLAMLN*XL)+YL-YR)/(FLAMRN-FLAMLN)
  YN = YL - FLAMLN*(XL-XN)
```

```
      XETAN=SIN  (ALPHAN)/COS (THETAN+ALPHAN)
      XETANP=SIN (ALPHAN)/COS (THETAN-ALPHAN)
      XETANL=(XETAL+XETAN)/2.
      XETANR=(XETAR+XETANP)/2.
      GN=PLTN(FMSN,GAMMA,FMSTAR,NTABLE)
      FMWN=PLTN(FMSN,FMW,FMSTAR,NTABLE)
      WN=(SIN (ALPHAN)*COS (ALPHAN))/(1546.336/(FMWN*778.)*GN)
      WLN=(WL+WN)/2.
      WRN=(WR+WN)/2.
      DNN=(XN-XR)*XETANR
      DWN= (SSR-SSL)/((XN-XL)*XETANL+(XN-XR)*XETANR)
      SSN=SSR-DWN*DNN
      FMSN = (THETAR-THETAL+HLN*FMSL+HRN*FMSR-BETARN*(XR-XN)-BETALN*
     1 (YL-YN))/(HLN+HRN)+(WRN*(SSR-SSN)+WLN*(SSL-SSN))/(HLN+HRN)
      THETA = THETAL-HLN*(FMSL-FMSN)+BETALN*(YL-YN)-WLN*(SSL-SSN)
      DELTA = THETA - THETAN
      IF (ABS(DELTA) .LE. 1.E-07) GO TO 10
      IF (ICOUNT .LE. 1) GO TO 60
      IF (ABS(DELTA) .GE. ABS(DELT)) GO TO 70
   60 XT = XN
      YT = YN
      SST=SSN
      THETAT = THETAN
      FMSNT = FMSN
      DELT = DELTA
```

```
 70 THETAN = THETA
    IF (ICOUNT .GE. 50) GO TO 104
    ICOUNT = ICOUNT + 1
    GO TO 30
104 XN = XT
    YN = YT
    SSN=SST
    THETAN = THETAT
    FMSN = FMSNT
    DELTA = DELT
 10 RETURN
801 CALL DUMP
    END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE CASE 2

```
C
C     SUBROUTINE TO CALCULATE A NEW FIELD POINT WITH ONE OF THE INPUT
C     POINTS ON THE AXIS OF SYMMETRY
C
      SUBROUTINE CASE2(XXR,YYR,FFMR,THETAP,XXL,YYL,FFML,THETAQ,
     1        NTABLE,XN,YN,FMSN,THETAN,DELTA,ICOUNT ,SSN,SSL,SSR )
      COMMON FMVEC,FMSTAR
      COMMON/WAYN/ FMW,GAMMA
      DIMENSION FMW(80),GAMMA(80)
      DIMENSION FMVEC(80), FMSTAR(80)
      TAN(X) = SIN(X)/COS(X)
      ICOUNT = 1
      DELT = 0.
      XR = XXR
      YR = YYR
      FMR = FFMR
      THETAR = THETAP
      XL = XXL
      YL = YYL
      FML = FFML
      THETAL = THETAQ
      IF (FML .GT. 1.0 .OR. FMR .GT. 1.0) GO TO 103
      WRITE (6,666) XR, YR, FMR, XL, YL, FML,SSR,SSL
  666 FORMAT (1H1,10X,46HERROR MESSAGE, EITHER FMR OR FML IS LESS THAN
     1  3HONE//11X,8F12.7)
```

```
      GO TO 802
  103 FMSL = PLTN(FML,FMSTAR,FMVEC,NTABLE)
      FMSR = PLTN(FMR,FMSTAR,FMVEC,NTABLE)
      ALPHAL = ATAN(SQRT(1./(FML*FML-1.)))
      ALPHAR = ATAN(SQRT(1./(FMR*FMR-1.)))
      FLAMDL = TAN(ALPHAL)
      FLAMDR = TAN(THETAR-ALPHAR)
      BETAR = SIN (THETAR)*SIN (ALPHAR)/(YR*COS (THETAR-ALPHAR))
      HL = 1./(TAN(ALPHAL)*FMSL)
      HR = 1./(TAN(ALPHAR)*FMSR)
      XN = (YR+FLAMDL*XL-FLAMDR*XR)/(FLAMDL-FLAMDR)
      YN = FLAMDL*(XN-XL)
      GL=PLTN(FMSL,GAMMA,FMSTAR,NTABLE)
      FMWL=PLTN(FMSL,FMW,FMSTAR,NTABLE)
      WL=(SIN(ALPHAL)*COS(ALPHAL))/(1546.336/(FMWL*778.)*GL)
      GR=PLTN(FMSR,GAMMA,FMSTAR,NTABLE)
      FMWR=PLTN(FMSR,FMW,FMSTAR,NTABLE)
      WR=(SIN(ALPHAR)*COS(ALPHAR))/(1546.336/(FMWR*778.)*GR)
      XETAL=SIN (ALPHAL)/COS (ALPHAL)
      XETAR=SIN  (ALPHAR)/COS  (THETAR-ALPHAR)
      DN=((XN-XR)*SIN  (ALPHAR))/COS  (THETAR-ALPHAR)
      DW =(SSR-SSL)/((XN-XL)*XETAL+(XN-XR)*XETAR)
      SSN=SSR-DW*DN
      FMSN = (2.*THETAR+HL*FMSL+2.*HR*FMSR+2.*BETAR*(XN-XR))/(HL+2.*HR)
     1+ ((SSL-SSN)*WL+2.*WR*(SSR-SSN))/(HL+2.*HR)
```

```
      THETAN = HL*(FMSN-FMSL)/2.-WL*(SSL-SSN)/2.
      IF (FMSN .GT. 1.0) GO TO 30
      IF (FMSR .GT. FMSL) GO TO 31
      FMSN = FMSL
      THETAN = THETAL
      GO TO 30
   31 FMSN = FMSR
      THETAN = THETAR
   30 IF (FMSN .GT. FMSTAR(NTABLE) .OR. FMSN .LE. 1.) GO TO 104
      FMN = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
      ALPHAN = ATAN(SQRT(1./(FMN*FMN-1.)))
      FLAMN = TAN(THETAN+ALPHAN)
      FLAMNP= TAN(THETAN-ALPHAN)
      HN = 1./(TAN(ALPHAN)*FMSN)
      BETAN = SIN(THETAN)*SIN(ALPHAN)/(YN*SIN(THETAN+ALPHAN))
      BETANP= SIN(THETAN)*SIN(ALPHAN)/(YN*COS(THETAN-ALPHAN))
      FLAMLN = (FLAMDL + FLAMN)/2.
      FLAMRN = (FLAMDR + FLAMNP)/2.
      HLN = (HL + HN)/2.
      HRN = (HR + HN)/2.
      BETALN = (THETAN/YN + BETAN) / 2.
      BETARN = (BETAR + BETANP)/2.
      XN = (YR+FLAMLN*XL-FLAMRN*XR)/(FLAMLN-FLAMRN)
      YN = FLAMLN*(XN-XL)
      XETAN=SIN  (ALPHAN)/COS (THETAN+ALPHAN)
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE CASE 2

```
      XETANP=SIN (ALPHAN)/COS (THETAN-ALPHAN)
      XETANL=(XETAL+XETAN)/2.
      XETANR=(XETAR+XETANP)/2.
      GN=PLTN(FMSN,GAMMA,FMSTAR,NTABLE)
      FMWN=PLTN(FMSN,FMW,FMSTAR,NTABLE)
      WN=(SIN (ALPHAN)*COS (ALPHAN))/(1546.336/(FMWN*778.)*GN)
      WLN=(WL+WN)/2.
      WRN=(WR+WN)/2.
      DNN=(XN-XR)*XETANR
      DWN= (SSR-SSL)/((XN-XL)*XETANL+(XN-XR)*XETANR)
      SSN=SSR-DWN*DNN
      FMSN = (THETAR+HLN*FMSL+HRN*FMSR-BETARN*(XR-XN)+BETALN*YN)/
     1 (HLN+HRN)+(WRN*(SSR-SSN)+WLN*(SSL-SSN))/(HLN+HRN)
      THETA = HLN*(FMSN-FMSL) - BETALN*YN-WLN*(SSL-SSN)
      DELTA = THETA - THETAN
      IF (ABS(DELTA) .LE. 1.E-07) GO TO 10
      IF (ICOUNT .LE. 1) GO TO 60
      IF (ABS(DELTA) .GE. ABS(DELT)) GO TO 70
   60 XT = XN
      YT = YN
      SST=SSN
      THETAT = THETAN
      FMSNT = FMSN
      DELT = DELTA
   70 THETAN = THETA
```

```
      IF (ICOUNT .GE. 50) GO TO 104
      ICOUNT = ICOUNT + 1
      GO TO 30
  104 XN = XT
      YN = YT
      SSN=SST
      THETAN = THETAT
      FMSN = FMSNT
      DELTA = DELT
   10 RETURN
  802 CALL DUMP
      END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE CASE 3

```
C
C     SUBROUTINE TO CALCULATE A NEW POINT ON THE AXIS OF SYMMETRY
C
      SUBROUTINE CASE3(XR,YR,FMR,THETAR,                XN,YN,FMSN,THETAN,
     1 NTABLE,DELMN,ICOUNT,SSN,SSR)
      COMMON FMVEC,FMSTAR,SFIELD
      COMMON/WAYN/ FMW,GAMMA
      COMMON /XJR/ NSONE
      DIMENSION FMW(80),GAMMA(80)
      DIMENSION FMVEC(80), FMSTAR(80) ,SFIELD(3,60)
      TAN(X) = SIN(X)/COS(X)
      ICOUNT = 1
      DELT = 0.
      YN = 0.
      THETAN = 0.
      IF (FMR .GT. 1.0) GO TO 32
      WRITE (6,666) XR, YR, FMR,SSR
  666 FORMAT (1H1,10X,35HERROR MESSAGE, FMR IS LESS THAN ONE//
     1 11X,4F12.7)
      GO TO 803
   32 FMSR = PLTN(FMR,FMSTAR,FMVEC,NTABLE)
      ALPHAR = ATAN(SQRT(1./(FMR*FMR-1.)))
      FLAMDR = TAN(THETAR-ALPHAR)
      HR = 1./(TAN(ALPHAR)*FMSR)
      BETAR = SIN(THETAR)*SIN(ALPHAR)/(YR*COS(THETAR-ALPHAR))
```

```
      XN = XR - YR/FLAMDR
      GR=PLTN(FMSR,GAMMA,FMSTAR,NTABLE)
      FMWR=PLTN(FMSR,FMW,FMSTAR,NTABLE)
      WR=(SIN (ALPHAR)*COS (ALPHAR))/(1546.336/(FMWR*778.)*GR)
      SSN=SFIELD(1,NSONE)
      FMSN=(THETAR+HR*FMSR+BETAR*(XN-XR))/HR+WR*(SSR-SSN)/HR
   30 IF (FMSN .GT. FMSTAR(NTABLE) .OR. FMSN .LE. 1.) GO TO 104
      FMN = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
      ALPHAN = ATAN(SQRT(1./(FMN*FMN-1.)))
      FLAMNP = TAN(THETAN-ALPHAN)
      HN = 1./(TAN(ALPHAN)*FMSN)
      FLAMRN = (FLAMDR + FLAMNP)/2.
      HRN = (HR + HN)/2.
      BETAN = TAN(ALPHAN)*THETAR/YR
      BETARN = (BETAR + BETAN)/2.
      XN = XR - YR/FLAMRN
      GN=PLTN(FMSN,GAMMA,FMSTAR,NTABLE)
      FMWN=PLTN(FMSN,FMW,FMSTAR,NTABLE)
      WN=(SIN (ALPHAN)*COS (ALPHAN))/(1546.336/(FMWN*778.)*GN)
      WRN=(WR+WN)/2.
      SSN=SFIELD(1,NSONE)
      FMSNS=((THETAR+HRN*FMSR+BETARN*(XN-XR))/HRN)+WRN*(SSR-SSN)/HRN
      DELMN = FMSNS - FMSN
      IF (ABS(DELMN) .LE. 1.E-07) GO TO 10
      IF (ICOUNT .LE. 1) GO TO 60
```

```
      IF (ABS(DELMN) .GE. ABS(DELT)) GO TO 70
   60 XT = XN
      YT = YN
      SST=SSN
      THETAT = THETAN
      FMSNT = FMSN
      DELT = DELMN
   70 FMSN = FMSNS
      IF (ICOUNT .GE. 50) GO TO 104
      ICOUNT = ICOUNT + 1
      GO TO 30
  104 XN = XT
      YN = YT
      SSN=SST
      THETAN = THETAT
      FMSN = FMSNT
      DELMN = DELT
   10 RETURN
  803 CALL DUMP
      END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE CASE 4

```
C
C     SUBROUTINE TO CALCULATE A NEW POINT ON THE NOZZLE CONTOUR
C
      SUBROUTINE CASE4(XL,YL,FML,THETAL,NCT,                XC,YC,RT,
     1 NTABLE,RNX1,XN1,RNX2,XN2,RPX1,XP1,RPX2,XP2,RPX3,XP3,N,
     2 XN,YN,FMSN,THETAN,DELMN,ICOUNT,SSN,SSL)
      COMMON FMVEC,FMSTAR,SFIELD
      COMMON/WAYN/ FMW,GAMMA
      DIMENSION FMW(80),GAMMA(80)
      DIMENSION FMVEC(80), FMSTAR(80), XC(250), YC(250), FMTRIX(8,9)
     1,SFIELD(3,60)
      TAN(X) = SIN(X)/COS(X)
      NP1 = N + 1
      NP2 = N + 2
      ICOUNT = 1
      FMSNT = 50.0
      IF (FML .GT. 1.0) GO TO 102
      WRITE (6,666) XL, YL, FML,SSL
  666 FORMAT (1H1,10X,35HERROR MESSAGE, FML IS LESS THAN ONE//
     1 11X,4F12.7)
      GO TO 804
  102 ALPHAL = ATAN(SQRT(1./(FML*FML-1.)))
      BETAL = SIN(THETAL)*SIN(ALPHAL)/(YL*SIN(THETAL+ALPHAL))
      FMSL = PLTN(FML,FMSTAR,FMVEC,NTABLE)
      HL = 1./(TAN(ALPHAL)*FMSL)
```

```
      HLN = HL
      BETALN = BETAL
      FLAML = TAN(THETAL+ALPHAL)
      FLAMLN = FLAML
      SSN=SFIELD(1,1)
      GL=PLTN(FMSL,GAMMA,FMSTAR,NTABLE)
      FMWL=PLTN(FMSL,FMW,FMSTAR,NTABLE)
      WL=(SIN (ALPHAL)*COS (ALPHAL))/(1546.336/(FMWL*778.)*GL)
      WLN=WL
  155 AS = FLAMLN
      BS = - 1.
      CS = YL - XL*FLAMLN
      KR = 1
  245 GO TO (205,215,225,235,240), KR
  205 RC = RNX1
      CXL = XN1
      CXR = XN2
      GO TO 250
  215 RC = RNX2
      CXL = XN2
      CXR = 0.
      GO TO 250
  225 RC = RPX1
      CXL = 0.
      CXR = XP1
```

```
      GO TO 250
  235 RC = RPX2
      CXL = XP1
      CXR = XP2
      GO TO 250
  240 RC = RPX3
      CXL = XP2
      CXR = XP3
  250 Y1 = RT + RC
      A1 = AS*AS + BS*BS
      B1 = 2.*(BS*CS - Y1*AS*AS)
      C1 = AS*AS*Y1*Y1 + CS*CS - AS*AS*RC*RC
      IF (B1*B1-4.*A1*C1) 255, 10, 15
   10 YN = -B1/(2.*A1)
      XN = -(BS*YN + CS)/AS
      GO TO 270
   15 YN = (-B1 - SQRT(B1*B1-4.*A1*C1))/(2.*A1)
      XN = -(BS*YN + CS)/AS
  270 IF (XN-CXL) 271, 140, 260
  260 IF (XN-CXR) 140, 140, 255
  255 IF (KR-5) 265, 5, 5
  265 KR = KR + 1
      GO TO 245
    5 NC = NCT -1
      DO 30  I = 1, NC
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE CASE 4

```
      SLOPE = (YC(I+1)-YC(I))/(XC(I+1)-XC(I))
      XN = -(BS*YC(I)-SLOPE*BS*XC(I)+CS)/(AS+BS*SLOPE)
      IF (XN - XC(I+1)) 35, 40, 30
   35 IF (XN - XC(I)) 30, 45, 57
   40 XN = XC(I+1)
      YN = YC(I+1)
      K = 0
      GO TO 50
   45 XN = XC(I)
      YN = YC(I)
      K = 0
      GO TO 50
   30 CONTINUE
      I = NC
   57 K = 1
   50 CALL POLY(XC,YC,I,N,NCT,FMTRIX)
      IF (K) 198, 198, 73
   73 X = XC(I)
      IK = 0
  130 KCOUNT = NP1
      YN = FMTRIX(NP1,NP2)
   83 KCOUNT = KCOUNT - 1
      IF (KCOUNT) 81, 81, 82
   82 YN = YN + FMTRIX(KCOUNT,NP2) * X**(NP1-KCOUNT)
      GO TO 83
```

```
 81 XN = -(BS*YN + CS) / AS
    IF (XN - 1.) 246, 246, 247
246 DELTAX = XN - X
    GO TO 248
247 DELTAX = (XN - X)/XN
248 IF (ABS(DELTAX) .LE.1.E-06.OR.IK.GE.10)  GO TO 198
    X = XN
    IK = IK + 1
    GO TO 130
198 KCOUNT = N
    SLOPE = FMTRIX(N,NP2)
 86 KCOUNT = KCOUNT - 1
    IF (KCOUNT) 84, 84, 85
 85 SLOPE = SLOPE + FLOAT(NP1-KCOUNT) * FMTRIX(KCOUNT,NP2) *
   1 XN**(N-KCOUNT)
    GO TO 86
 84 THETAN = ATAN(SLOPE)
    GO TO 193
140 THETAN = ATAN(XN/(Y1-YN))
193 FMSN = (THETAN - THETAL-BETALN*(YL-YN))/HLN+FMSL+(WLN*(SSL-SSN))/H
   1LN
    IF (FMSN .GT. FMSTAR(NTABLE) .OR. FMSN .LE. 1.0) GO TO 160
    FMN = PLTN(FMSN ,FMVEC,FMSTAR,NTABLE)
    ALPHAN = ATAN(SQRT(1./(FMN*FMN-1.)))
    FLAMN = TAN(THETAN + ALPHAN)
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE CASE 4

```
      HN = 1./(TAN(ALPHAN)*FMSN)
      BETAN = SIN(THETAN)*SIN(ALPHAN)/(YN*SIN(THETAN+ALPHAN))
      FLAMLN = (FLAML+FLAMN)/2.
      HLN = (HL + HN)/2.
      BETALN = (BETAL+BETAN)/2.
      GN=PLTN(FMSN,GAMMA,FMSTAR,NTABLE)
      FMWN=PLTN(FMSN,FMW,FMSTAR,NTABLE)
      SSN=SFIELD(1,1)
      WN=( SIN (ALPHAN)* COS(ALPHAN))/(1546.336/(FMWN*778.)*GN)
      WLN=(WL+WN)/2.
      DELMN = FMSN - FMSNT
      IF (ABS(DELMN) .LE. 1.E-07 .OR. ICOUNT .GE. 50) GO TO 160
      ICOUNT = ICOUNT + 1
      FMSNT = FMSN
      GO TO 155
  160 RETURN
  271 WRITE (6,698)
  698 FORMAT (1H1,10X,43HTHE X-COORDINATE OF THE IMPUT POINT IS TOO ,
     1 18HSMALL---DATA ERROR)
  804 CALL DUMP
      END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE PERFOR

```
C
C     SUBROUTINE FOR CALCULATING NOZZLE PERFORMANCE BY INTEGRATING
C     ALONG STARTING LINE AND NOZZLE CONTOUR
C
      SUBROUTINE PERFOR(XSAUER,YSAUER,FMSAUR,THETAS,XWALL,YWALL,PWALL,
     1 P,T,GAMMA,FMW,       NTABLE,NSONE,JLAST,N,PA,PC,RT,XNLTH,YEXIT)
      COMMON FMVEC
      DIMENSION XSAUER(60), YSAUER(60), THETAS(60), FMSAUR(60),
     1 XWALL(250), YWALL(250), PWALL(250), P(80), T(80), FMW(80),
     2 GAMMA(80), FMVEC(80), FMTRIX(8,9), PUSHSW(250)
      PI = 3.1415926536
      NP2 = N + 2
      NSMONE = NSONE - 1
C
C     INTEGRATING ALONG THE INITIAL VALUE CURVE
C
      FLOW = 0.
      PUSH = 0.
      DO 5 I = 1, NSMONE
      THETAV = (THETAS(I)+THETAS(I+1))/2.
      THETAN = ATAN ((XSAUER(I)-XSAUER(I+1))/(YSAUER(I+1)-YSAUER(I)))
      THETAT = THETAN - THETAV
      P1 = PLTN(FMSAUR(I),P,FMVEC,NTABLE)
      P2 = PLTN(FMSAUR(I+1),P,FMVEC,NTABLE)
      PS = (P1 + P2)/2.
```

```
      T1 = PLTN(P1,T,P,NTABLE)
      T2 = PLTN(P2,T,P,NTABLE)
      TS = (T1 + T2)/2.
      G1 = PLTN(P1,GAMMA,P,NTABLE)
      G2 = PLTN(P2,GAMMA,P,NTABLE)
      GS = (G1 + G2)/2.
      FMW1 = PLTN(P1,FMW,P,NTABLE)
      FMW2 = PLTN(P2,FMW,P,NTABLE)
      FMWS = (FMW1 + FMW2)/2.
      CS = SQRT (32.174*GS*1546.336*TS/FMWS)
      VS = CS * (FMSAUR(I)+FMSAUR(I+1))/2.
      RHU = 144.0 * PS * FMWS /(1546.336 * TS)
      DA = PI * (YSAUER(I+1)**2 - YSAUER(I)**2) / COS(THETAN)
      DA = ABS(DA)
      VN = VS * COS(THETAT)
      FLOW = FLOW + DA*RHU*VN / 144.0
      PUSH = PUSH + DA*(PS*COS(THETAN) + RHU*VN*VS*COS(THETAV)/
     1 (144.0*32.174))
    5 CONTINUE
      PUSH = ABS(PUSH)
      FLOW = ABS(FLOW)
C
C     INTEGRATING ALONG THE NOZZLE CONTOUR
C
      PULSE = 0.
```

```
      DO 104 J = 2, JLAST
      I = J - 1
      CALL POLY(YWALL,PWALL,I,N,JLAST,FMTRIX)
      KCOUNT = NP2
  130 KCOUNT = KCOUNT - 1
      POWER = NP2 - KCOUNT + 1
      IF (KCOUNT) 112, 112, 132
  132 PULSE = PULSE + FMTRIX(KCOUNT,NP2) * (YWALL(J)**POWER -
     1 YWALL(J-1)**POWER) / POWER
      GO TO 130
  112 PUSHSW(J) = 2.*PI*PULSE + PUSH - PA*PI*YWALL(J)*YWALL(J)
  104 CONTINUE
      IF (XWALL(JLAST)-XNLTH) 116, 116, 117
  117 PUSHSW(JLAST) = PUSHSW(JLAST-1) + (PUSHSW(JLAST)-PUSHSW(JLAST-1))
     1 *(XNLTH-XWALL(JLAST-1))/(XWALL(JLAST)-XWALL(JLAST-1))
      XWALL(JLAST) = XNLTH
      YWALL(JLAST) = YEXIT
  116 WRITE (6,641)
  641 FORMAT (1H1,10X,47HPERFORMANCE BY INTEGRATING ALONG NOZZLE CONTOUR
     1 15H AT WALL POINTS//19X,1HX,12X,1HY,12X,6HTHRUST,7X,
     2 11HSP. IMPULSE,9X,2HCF/17X,5H(IN.),8X,5H(IN.),10X,6H(LBF.),6X,
     3 13H(LBF-SEC/LBM)//)
      DO 151 J = NSONE, JLAST
      SPIPLS = PUSHSW(J) / FLOW
      CF = PUSHSW(J)/(PC*PI*RT*RT)
```

```
151 WRITE (6,642) XWALL(J), YWALL(J), PUSHSW(J), SPIPLS, CF
642 FORMAT (1H0,10X,2F13.7,F18.7,2F14.7)
    WRITE (6,636) FLOW
636 FORMAT (//1H0,10X,39HMASS FLOW RATE BY INTEGRATING ALONG THE
   1 14H STARTING LINE//12X,11HFLOW RATE =,F13.7,8H LBM/SEC)
    WRITE (6,637)
637 FORMAT (1H0)
    RETURN
    END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE SAUER

```
      SUBROUTINE SAUER(RNX2,RT,G,NSONE,XSAUER,YSAUER,THETAS,FMSAUR,
     1SSAUER)
      DIMENSION XSAUER(60), YSAUER(60), THETAS(60), FMSAUR(60),SSAUER(60
     1)
      R = RNX2/RT
      SIGMA = SQRT(2./((G+1.)*R))
      EPS = 0.125 * SQRT(2.*(G+1.)/R)
      FMS = 1. - SIGMA * EPS + 0.25*(G+1.)*SIGMA*SIGMA
      FMSAUR(1) = SQRT((2.0*FMS*FMS/(G+1.))/(1.-(G-1.)*FMS*FMS/(G+1.)))
      ALPHA = ATAN(SQRT(1./(FMSAUR(1)*FMSAUR(1)-1.)))
      PHI = 3.1415926536/2. - ALPHA
      DELU = 0.15
   16 XO = DELU/SIGMA + EPS
      BETA = ATAN(XO)
      IF (PHI .GT. BETA) GO TO 14
      DELU = DELU - 0.01
      WRITE(6,600)XO,FMS, FMSAUR(1),ALPHA,PHI,BETA
      IF(DELU-0.11)15,16,16
   14 XSAUER(1) = 0.
      YSAUER(1) = 1.
      THETAS(1) = 0.
      SSAUER(1)=1.
      DELY = 1./(FLOAT(NSONE)-1.)
      DO 20 I = 2, NSONE
      YSAUER(I) = 1. -(FLOAT(I)-1.)*DELY
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE SAUER

```
      XSAUER(I) = XO*(1.-YSAUER(I))
      U = SIGMA*(XSAUER(I)-EPS) + 0.25*(G+1.)*SIGMA*SIGMA*YSAUER(I)**2
      V = 0.5*(G+1.)*SIGMA*SIGMA*(XSAUER(I)-EPS)*YSAUER(I) +
     1 (G+1.)*(G+1.)*SIGMA*SIGMA*SIGMA*YSAUER(I)*YSAUER(I)**2/16.
      XMS = SQRT((1.+U)*(1.+U)+V*V)
      FMSAUR(I) = SQRT((2.0*XMS*XMS/(G+1.))/(1.-(G-1.)*XMS*XMS/(G+1.)))
      THETAS(I) = ATAN(V/(1.+U))
      SSAUER(I)=1.
   20 CONTINUE
      YSAUER(NSONE) = 0.
      THETAS(NSONE) = 0.
      DO 25 I = 1, NSONE
      XSAUER(I) = XSAUER(I) * RT
      YSAUER(I) = YSAUER(I) * RT
   25 CONTINUE
      RETURN
   15 WRITE (6,600) XO,FMS,FMSAUR(1),ALPHA,PHI,BETA
  600 FORMAT (1H0,10X,6F12.7)
      CALL EXIT
      END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE PROPTY

```
C
C     SUBROUTINE TO CALCULATE DIFFERENT THERMODYNAMIC PROPERTIES
C
      SUBROUTINE PROPTY(FMSN,  T,FMW,GAMMA,              NTABLE,PN,TN,
     1 VN,RHUN,FMN,SSN,PC,PON)
      COMMON FMVEC,FMSTAR
      DIMENSION P(80), T(80), FMW(80), GAMMA(80), FMVEC(80), FMSTAR(80)
      TN = PLTN(FMSN,T,FMSTAR,NTABLE)
      FMN = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
      GN = PLTN(FMSN,GAMMA,FMSTAR,NTABLE)
      FMWN = PLTN(FMSN,FMW,FMSTAR,NTABLE)
      PON= PC/ EXP((SSN-1.)/(1546.336/(FMWN*778.)))
      PN= PON/( 1.+(GN-1.)/2.*FMN*FMN)**(GN/(GN-1.))
      CN = SQRT(32.174*1546.336*GN*TN/FMWN)
      VN = CN * FMN
      RHUN = 144.0 * PN * FMWN / (1546.336 * TN)
      RETURN
      END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE THERMO

```
C
C     SUBROUTINE FOR CALCULATING THERMODYNAMIC DATA FOR FROZEN FLOW
C
      SUBROUTINE THERMO(NTABLE,G,W,PC,TC,P,T,FMW,GAMMA,FMVEC,FMSTAR,
     1 CSTAR)
      DIMENSION P(80), T(80), FMVEC(80),FMSTAR(80), FMW(80), GAMMA(80)
      DELM = 0.1
      DO 92 I = 1, NTABLE
      FI = I
      FMVEC(I) = 1.0 + DELM * (FI-1.)
      FMSTAR(I) = SQRT(0.5*(G+1.)*FMVEC(I)*FMVEC(I)/(1.+0.5*(G-1.)*
     1 FMVEC(I)*FMVEC(I)))
      T(I) = TC / (1.+0.5*(G-1.)*FMVEC(I)*FMVEC(I))
      P(I) = PC / (1.+0.5*(G-1.)*FMVEC(I)*FMVEC(I))**(G/(G-1.))
      GAMMA(I) = G
      FMW(I) = W
   92 CONTINUE
      CSTAR = SQRT(32.174*1546.336*G*T(1)/W)
      RETURN
      END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE PLTN

```
C
C     SUBROUTINE TO PERFORM LINEAR INTERPOLATION BETWEEN THERMODYNAMIC
C     DATA
C
      FUNCTION PLTN(FM,FM1,FM2,NTABLE)
      DIMENSION FM1(80), FM2(80)
      IF (FM2(1)-FM2(NTABLE)) 230, 230, 235
  235 DO 240 I = 1, NTABLE
      IF (FM2(I) - FM) 35, 30, 240
  240 CONTINUE
      I = NTABLE
   50 WRITE (6,600) FM, FM1(2), FM2(2)
  600 FORMAT (    6X,44HVALUE BEYOND TABLE LIMITS, EXTRAPOLATION WAS,
     1 15H PERFORMED --- ,3F15.7)
      GO TO 30
  230 DO 10 I = 1, NTABLE
      IF (FM2(I) - FM) 10, 30, 35
   10 CONTINUE
      I = NTABLE
      GO TO 50
   35 IF (I - 1) 45, 45, 30
   45 I = 2
      GO TO 50
   30 PLTN = (FM1(I)-FM1(I-1))*(FM-FM2(I-1))/(FM2(I)-FM2(I-1))+FM1(I-1)
   40 RETURN
      END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE STREAM

```
C     SUBROUTINE FOR CALCULATING STREAM LINES TO FEED INTO SC-4020
C     PLOTTER
C
      SUBROUTINE STREAM(XFIELD,YFIELD,FMSFLD,THETAV,K,NSONE,XSTR,YSTR,
     1 THSTR,NTOTAL,NROW)
      DIMENSION XFIELD(3,60), YFIELD(3,60), FMSFLD(3,60), THETAV(3,60),
     1 XSTR(60), YSTR(60), THSTR(60), NROW(3)
      TAN (X) = SIN (X)/COS (X)
      YTEST = 10. * YFIELD(3,1)
      N = NROW(3) - 1
      JSTART = 1
      NMONE = NSONE - 1
      KI = -1
      DO 5 J = 2, NMONE
      IF (XSTR(J) + YSTR(J) + THSTR(J)) 29, 28, 29
   29 IF (K) 10, 10, 25
   10 IF (KI) 20, 25, 45
   20 YNEW = YSTR(J) + TAN (THSTR(J))*(XFIELD(3,1)-XSTR(J))
      IF (YNEW - YFIELD(3,1)) 30, 30, 35
   35 WRITE (1) XSTR(J), YSTR(J), XFIELD(3,1), YNEW
      NTOTAL = NTOTAL + 1
      XSTR(J) = XFIELD(3,1)
      YSTR(J) = YNEW
      THSTR(J) = THETAV(3,1)
      YTEST = YNEW
```

```
      GO TO 5
   30 K1 = 0
   25 DO 50 J1 = JSTART, N
      IF (FMSFLD(3,J1+1)) 28, 28, 7
    7 XNEW =((YSTR(J)-YFIELD(3,J1)-XSTR(J)*TAN (THSTR(J)))*
     1 (XFIELD(3,J1+1)-XFIELD(3,J1))+XFIELD(3,J1)*(YFIELD(3,J1+1)-
     2 YFIELD(3,J1)))/(YFIELD(3,J1+1)-YFIELD(3,J1)-TAN(THSTR(J))*
     3 (XFIELD(3,J1+1)-XFIELD(3,J1)))
      YNEW = YSTR(J) + TAN (THSTR(J))*(XNEW-XSTR(J))
      IF (YNEW - YFIELD(3,J1)) 8, 9, 19
    8 IF (YNEW - YFIELD(3,J1+1)) 50, 9, 9
    9 IF (YNEW - YTEST) 16, 19, 19
   16 WRITE (1) XSTR(J), YSTR(J), XNEW, YNEW
      NTOTAL = NTOTAL + 1
      XSTR(J) = XNEW
      YSTR(J) = YNEW
      YTEST = YNEW
      THSTR(J) = THETAV(3,J1+1) + (THETAV(3,J1)-THETAV(3,J1+1))*(YNEW-
     1 YFIELD(3,J1+1))/(YFIELD(3,J1)-YFIELD(3,J1+1))
      GO TO 12
   50 CONTINUE
      KI = 1
      IF (K) 45, 45, 51
   12 JSTART = J1
      GO TO 5
```

```
 45 YNEW = YSTR(J) + TAN (THSTR(J))*(XFIELD(3,N+1)-XSTR(J))
    IF (YNEW) 46, 47, 48
 48 WRITE (1) XSTR(J), YSTR(J), XFIELD(3,N+1), YNEW
    NTOTAL = NTOTAL + 1
    XSTR(J) = XFIELD(3,N+1)
    YSTR(J) = YNEW
    THSTR(J) = THETAV(3,N+1)
    YTEST = YNEW
  5 CONTINUE
    RETURN
 19 JU = J + 1
    WRITE (6,603)J, JU
603 FORMAT (1H ,3X,I2,5H AND ,I2,26H TH STREAMLINES CROSS OVER)
 28 DO 21 I = J, NMONE
    XSTR(I) = 0.
    YSTR(I) = 0.
 21 THSTR(I) = 0.
    RETURN
 46 WRITE(6,601)
601 FORMAT (1H ,10X,36HSTREAM LINE CROSSES AXIS OF SYMMETRY)
    RETURN
 47 WRITE(6,602)
602 FORMAT (1H ,10X,20HSTREAM LINES OVERLAP)
 51 RETURN
    END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE POLY

```
C
C     SUBROUTINE TO FIT AN NTH ORDER POLYNOMIAL.  N = 1 TO 7
C
      SUBROUTINE POLY(XC,YC,L,N,NCT,FMTRIX)
      DIMENSION XC(250), YC(250), FMTRIX(8,9)
      NP1 = N + 1
      NP2 = N + 2
C
C     PICK UP PROPER POINTS FOR CURVE FITTING
C
      IF (L .GT. N/2) GO TO 60
      NI = 1
      GO TO 145
   60 IF (L .GE. NCT + (N-1)/2) GO TO 65
      NI = L - N/2
      GO TO 145
   65 NI = NCT - N
C
C     DEFINE COEFFICIENTS OF THE SIMULTANEOUS EQUATIONS
C
  145 DO 100 I = 1, NP1
      DO 105 J = 1, N
  105 FMTRIX(I,J) = XC(NI)**(NP1-J)
      FMTRIX(I,NP1) = 1.
      FMTRIX(I,NP2) = YC(NI)
```

```
  100 NI = NI + 1
C
C     TEST IF ANY COEFFICIENT ON THE PRINCIPAL DIAGONAL IS ZERU
C
      DO 5 I = 1, N
      IF (FMTRIX(I,I) .EQ. 0.) GO TO 10
    5 CONTINUE
      GO TO 15
C
C     INTERCHANGE THE EQUATION WHERE THE COEFFICIENT ON THE PRINCIPAL
C     DIAGONAL IS ZERO WITH THE LAST EQUATION
C
   10 DO 20 J = 1, NP2
      TEMP = FMTRIX(I,J)
      FMTRIX(I,J) = FMTRIX(NP1,J)
      FMTRIX(NP1,J) = TEMP
   20 CONTINUE
C
C     USE JORDANS ELIMINATION METHOD TO SOLVE THE SIMULTANEOUS EQUATIONS
C
   15 DO 110 K = 1, NP1
      K1 = K + 1
      DO 115 J = K1, NP2
  115 FMTRIX(K,J) = FMTRIX(K,J)/FMTRIX(K,K)
      FMTRIX(K,K) = 1.
```

```
      DO 110 I = 1, NP1
      IF (I - K) 130, 110, 130
  130 DO 120 J = K1, NP2
  120 FMTRIX(I,J) = FMTRIX(I,J)-FMTRIX(I,K)*FMTRIX(K,J)
      FMTRIX(I,K) = 0.
  110 CONTINUE
      RETURN
      END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE TEST

```
      SUBROUTINE TEST(XR,YR,XL,YL,XN,YN,XP,YP,ITEST)
      DIMENSION X(4), Y(4)
      ITEST = 0
      X(1) = XP
      Y(1) = YP
      X(4) = XN
      Y(4) = YN
      IF (YN .GT. YL) GO TO 5
      IF (XN .LE. XL) GO TO 15
      GO TO 10
    5 IF (YN .LT. YR) GO TO 10
      IF (XN .LE. XR) GO TO 20
      GO TO 10
   15 WRITE (6,600)
  600 FORMAT (4X,39HTWO RIGHT RUNNING CHARACTERISTICS CROSS)
      ITEST = 1
      X(2) = XL
      Y(2) = YL
      X(3) = XR
      Y(3) = YR
      GO TO 25
   20 WRITE (6,605)
  605 FORMAT (4X,38HTWO LEFT RUNNING CHARACTERISTICS CROSS)
      ITEST = 2
      X(2) = XR
```

```
      Y(2) = YR
      X(3) = XL
      Y(3) = YL
   25 SLOPE1= (Y(2)-Y(1))/(X(2)-X(1))
      SLOPE2 = (Y(4)-Y(3))/(X(4)-X(3))
      XS = (Y(1)-Y(3)-SLOPE1*X(1)+SLOPE2*X(3))/(SLOPE2-SLOPE1)
      YS = Y(1) + SLOPE1 * (XS-X(1))
      WRITE (6,610) XP, YP, XR, YR, XL, YL, XN, YN
  610 FORMAT (3X,4HXP =,F10.5,2X,4HYP =,F10.5,2X,4HXR =,F10.5,2X,
     1 4HYR =,F10.5,2X,4HXL =,F10.5,2X,4HYL =,F10.5,2X,4HXN =,F10.5,
     2 2X,4HYN =,F10.5)
   10 RETURN
      END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE SHOCKI

```
C
C     SUBROUTINE FOR COMPUTING SHOCK WAVES.
C
      SUBROUTINE SHOCKI(P,T,FMW,GAMMA,PC,          NTABLE,CSTAR,XFIELD,
     1 YFIELD,FMSFLD,THETAV,NROW,J,J1,J2,J3,J11,J13,ITEST,ISHOCK,XSHOCK,
     2 YSHOCK,FMSHOK,TSHOCK,XMUSHK,EPS)
      COMMON FMVEC,FMSTAR,SSS,SSHOCK
      COMMON/CAL/ KENTRO
      DIMENSION XFIELD(3,60), YFIELD(3,60), FMSFLD(3,60), THETAV(3,60),
     1 NROW(3), P(80), T(80), FMW(80), GAMMA(80), FMVEC(80), FMSTAR(80),
     2 THB11(3), T11(3), XMU4(3), FMTRIX(8,9), XSHOCK(100), YSHOCK(100),
     3 TSHOCK(100), FMSHOK(100), XMUSHK(100), EPS(100)
     1,SSS(3,60),SSHOCK(100)
      TAN(X) = SIN(X)/COS(X)
      DELTA = 2. / 57.3
      IF (ISHOCK .GT. 0) GO TO 10
      X1 = XFIELD(1,J1)
      Y1 = YFIELD(1,J1)
      SS1=SSS(1,J1)
      FMS1 = FMSFLD(1,J1)
      FM1 = PLTN(FMS1,FMVEC,FMSTAR,NTABLE)
      TH1 = THETAV(1,J1)
      ALP1 = ATAN(SQRT(1./(FM1*FM1-1.)))
      XMU1 = TH1 - ALP1
      J2 = J1 + 1
```

```
      J3 = J + 1
      J11 = J1
      J13 = J1 - 1
      X12 = XFIELD(2,J)
      Y12 = YFIELD(2,J)
      SS12=SSS(2,J)
      FMS12 = FMSFLD(2,J)
      TH12 = THETAV(2,J)
      EPS1 = 0.9
      GO TO 15
   10 X1 = XSHOCK(ISHOCK)
      Y1 = YSHOCK(ISHOCK)
      SS1=SSHOCK(ISHOCK)
      FMS1 = FMSHOK(ISHOCK)
      FM1 = PLTN(FMS1,FMVEC,FMSTAR,NTABLE)
      TH1 = TSHOCK(ISHOCK)
      XMU1 = XMUSHK(ISHOCK)
      X12 = X1
      Y12 = Y1
      SS12=SS1
      FMS12 = FMS1
      TH12 = TH1
      EPS1 = EPS(ISHOCK)
   15 X2 = XFIELD(1,J2)
      Y2 = YFIELD(1,J2)
```

```
      SS2=SSS(1,J2)
      IF (Y2 .EQ. 0.) GO TO 60
      FMS2 = FMSFLD(1,J2)
      TH2 = THETAV(1,J2)
      X3 = XFIELD(2,J3)
      Y3 = YFIELD(2,J3)
      SS3=SSS(2,J3)
      FMS3 = FMSFLD(2,J3)
      TH3 = THETAV(2,J3)
      X13 = XFIELD(3,J13)
      Y13 = YFIELD(3,J13)
      SS13=SSS(3,J13)
      FMS13 = FMSFLD(3,J13)
      TH13 = THETAV(3,J13)
      FM12 = PLTN(FMS12,FMVEC,FMSTAR,NTABLE)
      ALP12 = ATAN(SQRT(1./(FM12*FM12-1.)))
      WRITE (6,601) X12,Y12,TH12,FMS12,X13,Y13,TH13,FMS13,SS12,SS13
      IF (FMS2 .EQ. 0. .OR. FMS3 .EQ. 0. .OR. FMS13 .EQ. 0.) GO TO 60
      XMU1 = XMU1 + DELTA
   72 XMU1 = XMU1 - DELTA
   71 XMU4(1)= XMU1
      XMU4(2)= XMU1 - DELTA
      XMU4(3) = XMU4(2) - DELTA
      N = 3
   50 DO 20 K = 1, N
```

```
      FMU4 = XMU4(K)
      FLAM = (TAN(XMU1) + TAN(FMU4))/2.
      B = ((Y1-Y2)-(X1-X2)*FLAM)/((Y3-Y2)-(X3-X2)*FLAM)
      X4 = X2 + B*(X3-X2)
      Y4 = Y2 + B*(Y3-Y2)
      SS4=SS2+B*(SS3-SS2)
      TH4 = TH2 + B*(TH3-TH2)
      FMS4 = FMS2 + B*(FMS3-FMS2)
      X11 = X4
      Y11 = Y4
      CALL SHOCK(P,T,FMW,GAMMA,PC,          NTABLE,FMS4,TH4,FMU4,EPS1,
     1 EPS11,FMS11,TH11,CSTAR,SS4,SS11)
      FM11 = PLTN(FMS11,FMVEC,FMSTAR,NTABLE)
      ALP11 = ATAN(SQRT(1./(FM11*FM11-1.)))
      T11(K) = TH11
      WRITE (6,601) X4, Y4, TH4, FMS4, FMS11, FM11, ALP11, EPS11,SS4
      TH141 = TH11
      ALP14 = ALP11
      DO 25 I = 1, 25
      ETA = (TAN(TH141-ALP14)+TAN(TH11-ALP11))/2.
      G = ((Y11-Y12)-(X11-X12)*ETA)/((Y13-Y12)-(X13-X12)*ETA)
      X14 = X12 + G * (X13-X12)
      Y14 = Y12 + G * (Y13-Y12)
      SS14=SS12+G*(SS13-SS12)
      TH14 = TH12 + G * (TH13-TH12)
```

```
      FMS14 = FMS12 + G * (FMS13-FMS12)
      DEL = TH14 - TH141
      IF (ABS(DEL) .LE. 1.E-05) GO TO 30
      TH141 = TH14
      FM14 = PLTN(FMS14,FMVEC,FMSTAR,NTABLE)
      ALP14 = ATAN(SQRT(1./(FM14*FM14-1.)))
   25 WRITE (6,601) X14,Y14,TH14,FMS14,ALP14,ETA,G,DEL,SS14
      IF(K.GT.1)  GO TO 30
      XMU1 = XMU1 - 1./57.3
      GO TO 71
   30 TH11 = TH14
      DO 73 I = 1,25
   40 H1114 = 0.5*(1./(FMS11*TAN(ALP11))+1./(FMS14*TAN(ALP14)))
      B1114 = 0.5*(SIN(ALP11)*SIN(TH11)/(Y11*COS(TH11-ALP11)) +
     1 SIN(ALP14)*SIN(TH14)/(Y14*COS(TH14-ALP14)))
      FMW11= PLTN(FMS11,FMW,FMSTAR,NTABLE)
      FMW14=PLTN(FMS14,FMW,FMSTAR,NTABLE)
      G11=PLTN(FMS11,GAMMA,FMSTAR,NTABLE)
      G14=PLTN(FMS14,GAMMA,FMSTAR,NTABLE)
      W114= .5  *((SIN(ALP11)*COS(ALP11))/(1546.336/(FMW11*778.)*G11)
     1+ (SIN(ALP14)*COS(ALP14))/(1546.336/(FMW14*778.)*G14))
      THB11(K)=TH14+ B1114*(X11-X14) - H1114*(FMS11-FMS14)
     1-W114*(SS11-SS14)
      IF (ABS(THB11(K)-TH11) .LE. 1.E-06) GO TO 65
      TH11 = THB11(K)
```

```
73 CONTINUE
   IF( K.GT.1)  GO TO 65
   XMU1 = XMU1 - 1./57.3
   GO TO 71
65 IF (N .EQ. 1) GO TO 45
20 CONTINUE
   CALL POLY(XMU4,T11,1,2,3,FMTRIX)
   A1 = FMTRIX(3,4)
   B1 = FMTRIX(2,4)
   C1 = FMTRIX(1,4)
   CALL POLY(XMU4,THB11,1,2,3,FMTRIX)
   A2 = FMTRIX(3,4)
   B2 = FMTRIX(2,4)
   C2 = FMTRIX(1,4)
   ROOT =       (B1-B2)*(B1-B2) -4.*(C1-C2)*(A1-A2)
   WRITE (6,601) A1, B1, C1, A2, B2, C2, XMU4
   WRITE (6,601) T11, THB11, ROOT
   IF (ROOT .LT. 0.) GO TO 72
   ROOT = SQRT(ROOT)
   XMUP =     (0.5*((B2-B1)+ROOT)/(C1-C2))
   XMUM =     (0.5*((B2-B1)-ROOT)/(C1-C2))
   XMU11 = AMIN1(XMUP,XMUM)
   IF (XMUP.LT. 0. .AND. XMUM .LT. 0.) XMU11 = AMAX1(XMUP,XMUM)
   XMU4(1) = XMU11
   N = 1
```

```
      GO TO 50
   45 ISHOCK = ISHOCK + 1
      XSHOCK(ISHOCK) = X4
      YSHOCK(ISHOCK) = Y4
      SSHOCK(ISHOCK)=SS11
      TSHOCK(ISHOCK) = TH11
      FMSHOK(ISHOCK) = FMS11
      XMUSHK(ISHOCK) = XMU4(1)
      EPS(ISHOCK) = EPS11
      XFIELD(3,J1) = X4
      YFIELD(3,J1) = Y4
      SSS(3,J1)=SS11
      THETAV(3,J1) = TH11
      FMSFLD(3,J1) = FMS11
      WRITE (6,601) XMUP, XMUM, A1, B1, C1, A2, B2, C2
      WRITE (6,601) EPS11,FMU4,X2,Y2,X3,Y3,X13,Y13,T11(1),THB11(1)
     1,SS2,SS3
  601 FORMAT (7X,10F12.7)
      RETURN
   60 ITEST = 3
      RETURN
      END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE SHOCK

```
C
C     SUBROUTINE FOR COMPUTING PROPERTIES ACROSS A SHOCK WAVE.
C
      SUBROUTINE SHOCK(P,T,FMW,GAMMA,PC,          NTABLE,FMS4,THETA4,
     1 XMU4,EPS,EPS2,FMS11,THE11,CSTAR,SS4,SS11)
      COMMON FMVEC,FMSTAR
      COMMON/CAL/ KENTRO
      DIMENSION P(80), T(80), FMW(80), GAMMA(80), FMVEC(80), FMSTAR(80)
      CALL PROPTY(FMS4,  T,FMW,GAMMA,              NTABLE,P4,T4,V4,RHU4,
     1 FM4,SS4,PC,PON)
      G4 = PLTN(FMS4,GAMMA,FMSTAR,NTABLE)
      FMW4 = PLTN(FMS4,FMW,FMSTAR,NTABLE)
      ANGLE = THETA4 - XMU4
      EPS1 = EPS
    2 P11 = P4 + RHU4*V4*V4*(1.-EPS1)*SIN(ANGLE)**2/(32.174*144.)
      G11 = PLTN(P11,GAMMA,P,NTABLE)
      EPS2 = ((G11+1.)/(G11-1.)+P11/P4)/((G11+1.)*P11/((G11-1.)*P4)+1.)
      DEL = EPS2 - EPS1
      IF (ABS(DEL) .LT. 1.E-05) GO TO 12
      EPS1 = EPS2
      GO TO 2
   12 VN11 = V4 * EPS2 * SIN(ANGLE)
      VT11 = V4 * COS(ANGLE)
      V11 = SQRT(VN11*VN11 + VT11*VT11)
      FMS11 = V11 / CSTAR
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE SHOCK

```
      DEL11 = ATAN(EPS2*SIN(ANGLE)/COS(ANGLE))
      THE11  = XMU4 + DEL11
      EDD1=FM4 *FM4 *SIN (ANGLE)*SIN (ANGLE)
      PAR1=1546.336/(FMW4*778.)
      RIP1= (2./((G4+1.)*EDD1))+(G4-1.)/(G4+1.)
      RIP2 =(2.*G4)/(G4+1.)*EDD1-(G4-1.)/(G4+1.)
      IF(KENTRO.EQ.0)
     1SS11= SS4+PAR1*(G4/(G4-1.)*ALOG(RIP1)+1./(G4-1.)*ALOG(RIP2))
      IF(KENTRO.NE.0)SS11=SS4
      IF(SS11.LT.SS4)SS11=SS4
      RETURN
      END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE EXTRA4

```
C
C     SUBROUTINE FOR CONTROLING MESH SIZES BY GENERATING NEW RIGHT
C     RUNNING CHARACTERISTICS FROM THE NOZZLE WALL.
C
      SUBROUTINE EXTRA4(XX,YY,XM,XT,                NCT,XWALL,YWALL,NTABLE,
     1 RT,RNX1,XN1,RNX2,XN2,RPX1,XP1,RPX2,XP2,RPX3,XP3,N,NROW,XFIELD,
     2 YFIELD,FMSFLD,THETAV,DMAX,DEL,IN,IEXT,CM,NPTCM,XCM,YCM,     SSX)
      COMMON FMVEC,FMSTAR,SSS
      COMMON/WAYN/ FMW,GAMMA
      DIMENSION FMW(80),GAMMA(80)
      DIMENSION XFIELD(3,60), YFIELD(3,60), FMSFLD(3,60), THETAV(3,60),
     1 XX(2), YY(2), XM(2), XT(2), FMVEC(80), FMSTAR(80), XWALL(250),
     2 YWALL(250), IN(3,60), DEL(3,60), EXTRAX(2),
     3 EXTRAY(2), EXTRAM(2), EXTRAT(2), NROW(3)
     4,SSS(3,60),SSX(2),EXTRAS(2)
      DIMENSION CM( 6), NPTCM( 6), XCM( 6,120), YCM( 6,120)
      II = 4
   15 DO 5 I = 1, 2
      FI = FLOAT(I)
      EXTRAS(I)=SSX(1)+(FI*(SSX(2)-SSX(1)))/4.
      EXTRAX(I)  =  XX(1) +  FI  *   (XX(2)-XX(1))/4.
      EXTRAY(I)  =  YY(1) +  FI  *   (YY(2)-YY(1))/4.
      EXTRAM(I)  =  XM(1) +  FI  *   (XM(2)-XM(1))/4.
      EXTRAT(I)  =  XT(1) +  FI  *   (XT(2)-XT(1))/4.
      FMSN = PLTN(EXTRAM(I),FMSTAR,FMVEC,NTABLE)
```

```
  5 WRITE (3) EXTRAX(I),EXTRAY(I),EXTRAM(I),FMSN,EXTRAT(I),II
   1,EXTRAS(I)
    NROW(1) = NROW(1) + 1
    NN = NROW(1) + 1
 35 NN = NN - 1
    XFIELD(1,NN) = XFIELD(1,NN-1)
    YFIELD(1,NN) = YFIELD(1,NN-1)
    SSS(1,NN)=SSS(1,NN-1)
    THETAV(1,NN) = THETAV(1,NN-1)
    FMSFLD(1,NN) = FMSFLD(1,NN-1)
    IF (NN .GT. 3) GO TO 35
    CALL CASE4(EXTRAX(1),EXTRAY(1),EXTRAM(1),EXTRAT(1),NCT,
   1        XWALL,YWALL,RT,NTABLE,RNX1,XN1,RNX2,XN2,RPX1,XP1,RPX2,XP2,
   2 RPX3,XP3,N,XN,YN,FMSN,THETAN,DELTA,ICOUNT,SSN,EXTRAS(1))
    XX(1)      = XN
    YY(1)      = YN
    SSX(1)=SSN
    XM(1)      = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
    XT(1)      = THETAN
    WRITE (2,552) EXTRAX(1), EXTRAY(1), XN, YN,SSN,EXTRAS(1)
552 FORMAT (6F10.7)
    WRITE (3) XN, YN, XM(1), FMSN, XT(1), II,SSN
    CALL CASE1(XX(1),YY(1),XM(1),XT(1),EXTRAX(2),EXTRAY(2),EXTRAM(2),
   1 EXTRAT(2),              NTABLE,XN,YN,FMSN,THETAN,DELTA,ICOUNT,
   1SSN,EXTRAS(2),SSX(1))
```

```
      XX(2) = XN
      YY(2) = YN
      SSX(2)=SSN
      XM(2) = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
      XT(2) = THETAN
      WRITE (2,552) EXTRAX(2), EXTRAY(2), XN, YN,SSN,EXTRAS(2)
      WRITE (2,552) XX(1), YY(1), XN, YN ,SSN,SSX(1)
      CALL CMLINE(XX(1),YY(1),XM(1),XN,YN,XM(2),CM,NPTCM,XCM,YCM)
      CALL CMLINE(EXTRAX(2),EXTRAY(2),EXTRAM(2),XN,YN,XM(2),CM,NPTCM,
     1 XCM,YCM)
      IEXT = IEXT + 3
      NROW(2) = NROW(2) + 1
      NROW(3) = NROW(3) + 1
      I = NROW(3)
      FMSFLD(3,I) = 0.
      I = NROW(2) + 1
   25 I = I - 1
      XFIELD(2,I) = XFIELD(2,I-1)
      SSS(2,I)=SSS(2,I-1)
      YFIELD(2,I) = YFIELD(2,I-1)
      FMSFLD(2,I) = FMSFLD(2,I-1)
      THETAV(2,I) = THETAV(2,I-1)
      IN(2,I) = IN(2,I-1)
      DEL(2,I) = DEL(2,I-1)
      IF (I .GT. 2) GO TO 25
```

```
      XFIELD(2,1) = XN
      YFIELD(2,1) = YN
      SSS(2,1)=SSN
      FMSFLD(2,1) = FMSN
      THETAV(2,1) = THETAN
      IN(2,1) = ICOUNT + 60
      DEL(2,1) = DELTA
      CALL CASE4(XX(2),YY(2),XM(2),XT(2),NCT,                XWALL,YWALL,
     1 RT,NTABLE,RNX1,XN1,RNX2,XN2,RPX1,XP1,RPX2,XP2,RPX3,XP3,N,XN,YN,
     2 FMSN,THETAN,DELTA,ICOUNT,SSN,SSX(2))
      SL = (XX(2)-XN)**2 + (YY(2)-YN)**2
      IF (SL .GT. DMAX) GO TO 15
      WRITE (2,552) XX(2), YY(2), XN, YN ,SSN,SSX(2)
      FMN = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
      CALL CMLINE(XX(2),YY(2),XM(2),XN,YN,FMN,CM,NPTCM,XCM,YCM)
      XFIELD(3,1) = XN
      YFIELD(3,1) = YN
      SSS(3,1)=SSN
      FMSFLD(3,1) = FMSN
      THETAV(3,1) = THETAN
      IN(3,1) = ICOUNT
      DEL(3,1) = DELTA
      RETURN
      END
```

```
C
C     SUBROUTINE FOR CONTROLING MESH SIZES BY GENERATING NEW LEFT
C     RUNNING CHARACTERISTICS FROM THE AXIS OF SYMMETRY.
C
      SUBROUTINE EXTRA3(XX,YY,XM,XT,                NTABLE,NROW,XFIELD,
     1 YFIELD,FMSFLD,THETAV,DMAX,DEL,IN,IEXT,CM,NPTCM,XCM,YCM,SSX)
      COMMON FMVEC,FMSTAR,SSS
      COMMON/WAYN/ FMW,GAMMA
      COMMON /XJR/ NSONE
      DIMENSION FMW(80),GAMMA(80)
      DIMENSION XFIELD(3,60), YFIELD(3,60), FMSFLD(3,60), THETAV(3,60),
     1 IN(3,60), DEL(3,60), FMVEC(80), FMSTAR(80),
     2 XX(2), YY(2), XM(2), XT(2), EXTRAX(2), EXTRAY(2), EXTRAM(2),
     3 EXTRAT(2), NROW(3)
     4,SSS(3,60),EXTRAS(2),SSX(2)
      DIMENSION CM( 6), NPTCM( 6), XCM( 6,120), YCM( 6,120)
      II = 3
   15 DO 5 I = 1, 2
      FI = FLOAT(I)
      EXTRAS(I)=SSX(1)+(FI*(SSX(2)-SSX(1)))/4.
      EXTRAX(I)  =  XX(1) +  FI  *   (XX(2)-XX(1))/4.
      EXTRAY(I)  =  YY(1) +  FI  *   (YY(2)-YY(1))/4.
      EXTRAM(I)  =  XM(1) +  FI  *   (XM(2)-XM(1))/4.
      EXTRAT(I)  =  XT(1) +  FI  *   (XT(2)-XT(1))/4.
      FMSN = PLTN(EXTRAM(I),FMSTAR,FMVEC,NTABLE)
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE EXTRA3

```
  5 WRITE (3) EXTRAX(I),EXTRAY(I),EXTRAM(I),FMSN,EXTRAT(I),II
   1,EXTRAS(I)
    CALL CASE3(EXTRAX(1),EXTRAY(1),EXTRAM(1),EXTRAT(1),
   1 XN,YN,FMSN,THETAN,NTABLE,DELTA,ICOUNT,SSN,EXTRAS(1))
    XX(1)      = XN
    YY(1)      = YN
    SSX(1)=SSN
    XM(1)      = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
    XT(1)      = THETAN
    WRITE (2,552) EXTRAX(1), EXTRAY(1), XN, YN ,SSN,EXTRAS(1)
552 FORMAT (6F10.7)
    WRITE (3) XN, YN, XM(1), FMSN, XT(1), II,SSN
    CALL CASE2(EXTRAX(2),EXTRAY(2),EXTRAM(2),EXTRAT(2),XX(1),YY(1),
   1 XM(1),XT(1),              NTABLE,XN,YN,FMSN,THETAN,DELTA,ICOUNT,
   2SSN,SSX(1),EXTRAS(2))
    XX(2) = XN
    YY(2) = YN
    SSX(2)=SSN
    XM(2) = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
    XT(2) = THETAN
    WRITE (2,552) EXTRAX(2), EXTRAY(2), XN, YN,SSN,EXTRAS(2)
    WRITE (2,552) XX(1), YY(1), XN, YN,SSX(1),SSN
    CALL CMLINE(EXTRAX(2),EXTRAY(2),EXTRAM(2),XN,YN,XM(2),CM,NPTCM,
   1 XCM,YCM)
    CALL CMLINE(XX(1),YY(1),XM(1),XN,YN,XM(2),CM,NPTCM,XCM,YCM)
```

```
      IEXT = IEXT + 3
      NROW(2) = NROW(2) + 1
      NROW(3) = NROW(3) + 1
      NN = NROW(2)
      XFIELD(2,NN) = XN
      YFIELD(2,NN) = YN
      SSS(2,NN)=SSN
      FMSFLD(2,NN) = FMSN
      THETAV(2,NN) = THETAN
      IN(2,NN) = ICOUNT + 60
      DEL(2,NN) = DELTA
      FMR = PLTN(FMSFLD(2,NN-1),FMVEC,FMSTAR,NTABLE)
      FML = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
      CALL CASE1(XFIELD(2,NN-1),YFIELD(2,NN-1),FMR,THETAV(2,NN-1),
     1 XFIELD(2,NN),YFIELD(2,NN),FML,THETAV(2,NN),              NTABLE,
     2 XN,YN,FMSN,THETAN,DELTA,ICOUNT ,SSN,SSS(2,NN),SSS(2,NN-1))
      WRITE (2,552) XFIELD(2,NN), YFIELD(2,NN), XN, YN,SSN,SSS(2,NN)
      WRITE (2,552) XFIELD(2,NN-1), YFIELD(2,NN-1), XN, YN
     1,SSN,SSS(2,NN-1)
      FMN = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
      CALL CMLINE(XFIELD(2,NN-1),YFIELD(2,NN-1),FMR,XN,YN,FMN,
     1 CM,NPTCM,XCM,YCM)
      CALL CMLINE(XFIELD(2,NN),YFIELD(2,NN),FML,XN,YN,FMN,CM,NPTCM,
     1 XCM,YCM)
      NN = NROW(3)
```

```
      XFIELD(3,NN-1) = XN
      YFIELD(3,NN-1) = YN
      SSS(3,NN-1)=SSN
      FMSFLD(3,NN-1) = FMSN
      THETAV(3,NN-1) = THETAN
      IN(3,NN-1) = ICOUNT
      DEL(3,NN-1) = DELTA
      CALL CASE3(XX(2),YY(2),XM(2),XT(2),                XN,YN,FMSN,
     1 THETAN,NTABLE,DELTA,ICOUNT,SSN,SSX(2))
      SR = (XX(2)-XN)**2 + (YY(2)-YN)**2
      IF (SR .GT. DMAX) GO TO 15
      WRITE (2,552) XX(2), YY(2), XN, YN,SSN,SSX(2)
      FMN = PLTN(FMSN,FMVEC,FMSTAR,NTABLE)
      CALL CMLINE(XX(2),YY(2),XM(2),XN,YN,FMN,CM,NPTCM,XCM,YCM)
      XFIELD(3,NN) = XN
      YFIELD(3,NN) = YN
      SSS(3,NN)=SSN
      FMSFLD(3,NN) = FMSN
      THETAV(3,NN) = THETAN
      IN(3,NN) = ICOUNT
      DEL(3,NN) = DELTA
      RETURN
      END
```

FORTRAN IV PROGRAM LISTING OF SUBROUTINE CMLINE

```
C
C     SUBROUTINE FOR LOCATING POINT ON CERTAIN CONSTANT MACH NUMBER LINE
C
      SUBROUTINE CMLINE(X,Y,FM,XN,YN,FMN,CM,NPTCM,XCM,YCM)
      DIMENSION CM( 6), NPTCM( 6), XCM( 6,120), YCM( 6,120)
      DO 10 I = 1, 6
      IF (CM(I) .LT. FM .OR. CM(I) .GT. FMN) GO TO 10
      NPTCM(I) = NPTCM(I) + 1
      J = NPTCM(I)
      TEMP = (CM(I)-FM) / (FMN-FM)
      XCM(I,J) = X + (XN-X) * TEMP
      YCM(I,J) = Y + (YN-Y) * TEMP
   10 CONTINUE
      RETURN
      END
```