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INVISCID ANALYSIS OF THE PLUME CREATED BY MULTIPLE ROCKET ENGINES

Part II

Description of the Computer Programs

by

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ABSTRACT

In this second part, the computer programs for the calculation of the single jet and the five-jet interaction regions are discussed in detail. Input and running instructions are given and coarse grained flow charts are presented. Complete listings of the programs are also given.

The program for the two-jet interaction problem is discussed only as it deviates from the five-jet program.

1. INTRODUCTION

The basic method used to calculate the single jet and the interaction regions of two-and five jets has been described in Part I of this report. Sample calculations have also been reported.

In this second part, the programs are discussed and running instructions are provided.

In Section 2, the program for calculating the single jet is presented. A general description of the program is followed by specific input and running instructions and by coarse grained flow charts. A listing of the program is given in Appendix A.

In Section 3, the same information is furnished for the five-jet interaction program. The program listing is given in Appendix B.

Finally, in Section 4, the deviations of the two-jet from the five-jet interaction program are enumerated. For the two-jet program only input instructions and a program listing (Appendix C) are given since the basic program is essentially the same as that described in Section 3.

2. SINGLE JET PROGRAM

2.1 DESCRIPTION OF PROGRAM

2.1.1 THE DEPENDENT VARIABLES. As is described in Part I, the dependent variables are represented by a column vector W with three elements. While this notation is convenient for analytical treatment, for numerical work one has to distinguish between the elements. Thus we write the transpose of W in the form

$$W^T = \{W_1, W_2, W_3\}$$

For computational purposes it is still more advantageous to use arguments as follows:

$$W(M, J) \qquad J = 1, 2, 3$$

where the first argument denotes the position along the arc (see Fig. 1) and the second distinguishes the element.

2.1.2 CALCULATION PROCEDURE. Given the W vector at all points M along the line L the values at L + 1 are calculated. In order to evaluate the values at M, L + 1 we need the properties at L, M ± 1 and M, as indicated by the shaded area in Figure 1.

The calculation starts near the boundary and proceeds towards decreasing M, i.e., towards the axis. Referring to Figure 1 we notice that in general the point M = MO, L + 1 cannot be calculated with the same procedures since the jet boundary point is located at a different distance from the point L, MO. The procedure chosen was as follows: First, the values of W at two points L + 1, MO-1 and MO-2 were evaluated. Next, the new boundary

point at L + 1 was calculated according to the method described in Part I, Appendix 2. Then the values of W at MO were obtained by quadratic interpolation.

On the axis all elements of W are zero (see Part I, Appendix 1). The gas dynamic variables at these points we obtained by quadratic interpolation using the appropriate symmetry conditions.

2.1.3 **CALCULATION OF THE JET-BOUNDARY.** The method used for the calculation of the jet boundary has been discussed in Appendix 2 of Part I. In order to calculate the pressure gradient normal to the jet boundary, the pressure at a number of mesh points has to be available. Thus, these values were stored along the six rays closest to the boundary and along five arcs L, L - 1, L - 2, etc. In addition the values of P on L + 1, MO - 1 and MO - 2 are available. From these values the pressures along the normals to the boundary are interpolated and the pressure gradient calculated.

2.1.4 **REFINEMENT OF MESH.** The polar coordinate system is chosen such that the jet boundary diverges less rapidly than the coordinates θ = constant. Therefore, mesh points are continuously lost on the boundary. Also, the distance between the mesh points increases and the resolution is consequently decreased. Therefore, whenever the number of points along an arc decreases below forty, rays are filled in halfway between the existing rays. Thus the angle increment $\Delta\theta$ is divided by two. The values of W at these new mesh points are obtained by linear interpolation.

Care has been taken to take this subdivision into account in the storage of the pressures near the boundary as described in the last section. This necessarily complicates the program logic for this portion of the program.

2.2 INPUT DATA

The following data have to be given as input:

GAM constant ratio of specific heats.

DØ angle increment between polar rays.

BK initial polar angle, measured from the axis to the boundary, divided by DØ.

SR radius of the initial data arc.

XO distance of the nozzle exit from the origin of the polar coordinate system.

LAM1 relative step size $\Delta r/\Delta s$ for the first step. At subsequent steps this value is calculated.

FACTOR This is the safety factor for the step size; a value of 0.9 to 1.0 yields stable calculation. If FACTOR is put equal to zero the calculation uses the constant value LAM1 for the step size.

LL total number of arcs to be calculated.

ALP factor to weight the radii of curvature R^o and R^1. It has to lie between 0.5 and 1.0, a value of 0.6 yields good accuracy. The following data govern the output print (see also Section 2.3):

IPRINT If this quantity is one, results are printed out in cylindrical coordinates. If it is two the print out is in polar coordinates.

DELPNT interval between planes or arcs printed out.

FF ratio of DX/DY for print out in cylindrical coordinates.

In addition to these input constants the initial data have to be read into the program. This input consist of the following properties:

i) Flow angle with respect to the polar coordinate system.

ii) Total velocity.

iii) Pressure.

2.3 OUTPUT DATA

There are two options for the output: if IPRINT is put equal to one, properties are interpolated on mesh points of a cylindrical coordinate system. This data is printed and stored on tape for use in conjunction with the jet interaction programs. On the other hand, if IPRINT is equal to two, the gas dynamic properties are printed and stored on tape for the actually calculated polar coordinates.

For print out in cylindrical coordinates the number of mesh points across the jet width must lie between forty and eighty. The program automatically determines the increment DY such that there are between 40 and 80 mesh points and the DY is a "reasonable" number, in the sense that it contains a minimum number of digits. If the jet boundary diverges such that more than 80 points would be needed in a cross plane, the program automatically drops every second point and increased DY by a factor of two.

2.4 LIST OF PRINCIPLE SYMBOLS USED IN THE PROGRAM.

Dimensions used are indicated wherever applicable.

ALP	averaging factor for radius of curvature.
ALPHA	angle between line parallel to axis and boundary at L.
AN (30)	storage array for Dϕ values.
B (30)	storage array for BK values.
BETA	alpha for plane L + 1.
DELPNT	print interval.
Dϕ	angular separation of rays in degrees.
DX	distance between cylindrical planes.

DY	mesh distance in cylindrical plane.
ENT	entropy.
F	the F functions of W.
FACTOR	safety factor, used in determining LAM1.
FF	ratio between DX and DY.
FM (3)	$F^{+\frac{1}{2}}_{-\frac{1}{2}}$
FPL (3)	$F^{+\frac{1}{2}}_{+\frac{1}{2}}$
GAM	constant ratio of specific heats.
IFLAG	current polar arc being computed.
II	number of jet planes stored.
IPRINT	determines output in cylindrical or polar coordinates.
LAM1	relative step size $\Delta r/\Delta s$.
LL	number of polar arcs to be calculated.
M	grid point on jet arc.
MAX	numer of points on plane in cylindrical coordinates.
MN (30)	storage array of MO values.
MO	no. of rays plus two from axis to boundary.
MOR (3)	stores: Mach No., tan B2 and density respectively.
MR	reference quantity for pressure locations.
ϕ	angular distance from ray to axis.
P_2	pressure value on normal vector.
P_3	pressure value on normal vector.
P(6,10)	storage array for pressure values.
PL(6)	radii of arcs where pressure is stored.
PN	pressure gradient on normal to boundary.

Pr	boundary pressure value.
Q(3)	the Q functions of W.
Q1	total velocity.
QM (3)	$Q_{-\frac{1}{2}}^{+\frac{1}{2}}$
QPL (3)	$Q_{+\frac{1}{2}}^{\frac{1}{2}}$
R	density at boundary.
R1	density.
R2	distance from boundary to location of pressure P_2.
R3	distance from boundary to location of pressure P_3.
RH (30)	storage array of RR values.
RHØ	distance of point from axis in cylindrical coordinates.
RR	distance of polar arc to vertex.
RS	radius of curvature of jet boundary.
S	center of difference scheme.
SR	radius of initial data arc.
THETA	angle between axis and boundary point.
THETC	Theta plus angle between axis and pivot point.
U	boundary velocity in direction of jet axis.
U1	velocity component in direction of axis.
UM	angle that determinates variable LAM1.
UVP (3)	stores U, V velocities and pressure.
V	boundary velocity perpendicular to jet axis.
V1	velocity component normal to jet axis.
W3D(3, 80)	W storage array for cylindrical values.
WJ(100,3)	storage of jet W values.

WJET (30, 100,3) storage array for WJ values.

WM (3) $W^{\frac{1}{2}}_{-\frac{1}{2}}$

WP (3) $W^{\frac{1}{2}}_{+\frac{1}{2}}$

XO distance from origin of polar coordinates to nozzle exit.

XB distance of plane in cylindrical coordinates.

YB jet radius.

YH (30) storage array of jet radius values.

Note: All lengths are made dimensionless with the nozzle exit radius.

2.5 OPERATING INSTRUCTIONS

The following instructions apply to the IBM 7094 - 7044 DCS computer configuration.

2.5.1 **RUN REQUEST.** This request will in general contain the following information

i) Name of operator, date, etc.

ii) Identifying name for output tape.

iii) Time estimate. This depends on the number of polar arcs calculated. As a rough estimate, one can assume that 75 arcs are calculated per minute.

iv) Number of lines printed. As a guide, about 2500 lines may be assumed to be printed for every minute of calculation.

2.5.2 **CONTROL CARDS**

i) One SETUP card is required for writing the output tape. The tape drive used to load the tape must be specified on this card.

ii) An ATEND card will give a post-mortem dump if the run is terminated by unusual conditions.

iii) The EXECUTE IBJØB card selects the IBSYS monitoring system for loading the binary deck.

iv) The IBJØB card uses ALTIØ, a version 13 option, which requires fewer cells for the I/O package.

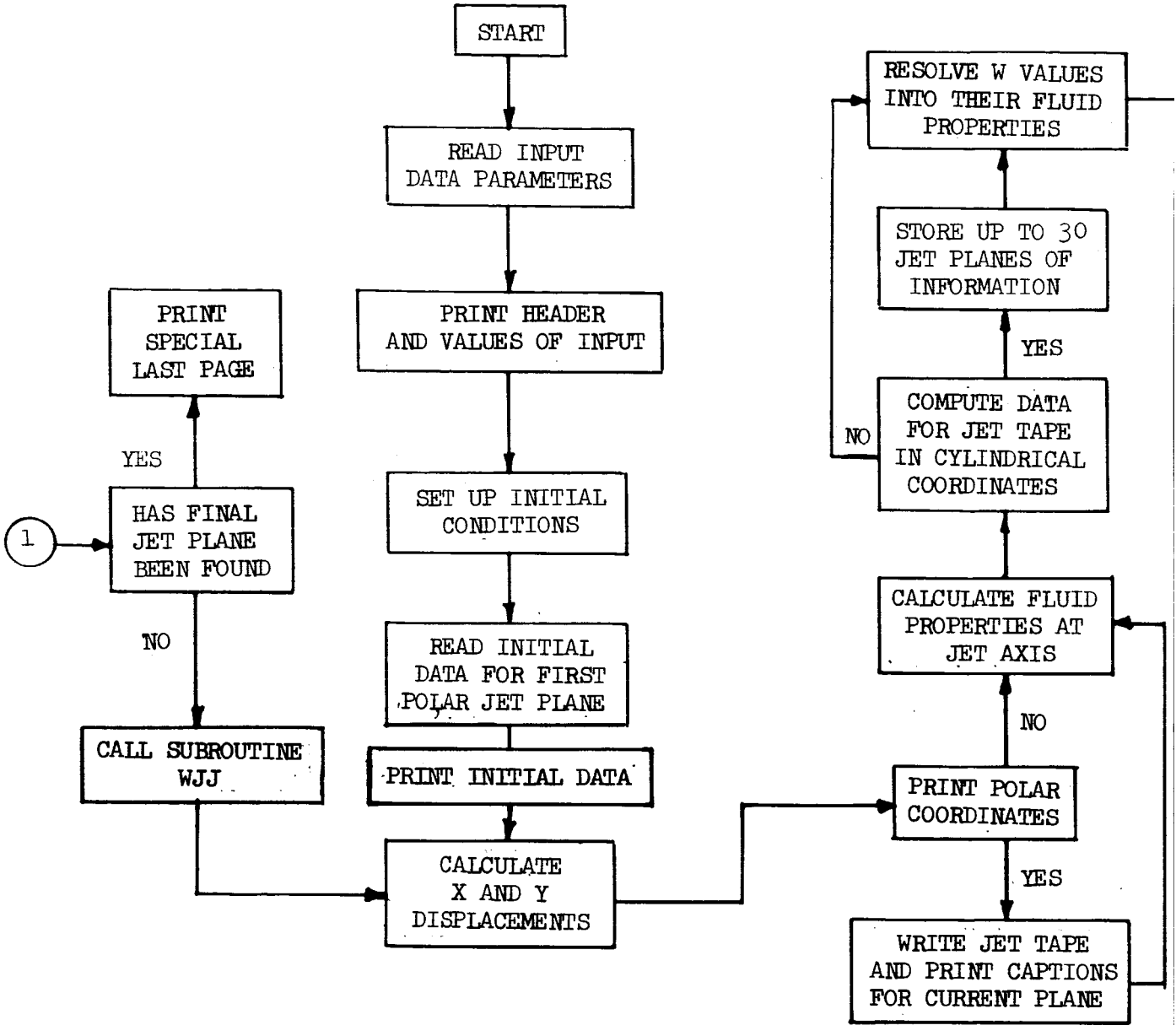
2.5.3 BINARY DECK. The binary deck consists of the main program (MAIN) and the following subroutines: WJJ, PRES, PROPWJ, WJET, PROP3D, JET, POLATE and FILES. These names appear in the appropriate binary deck, starting in column 72.

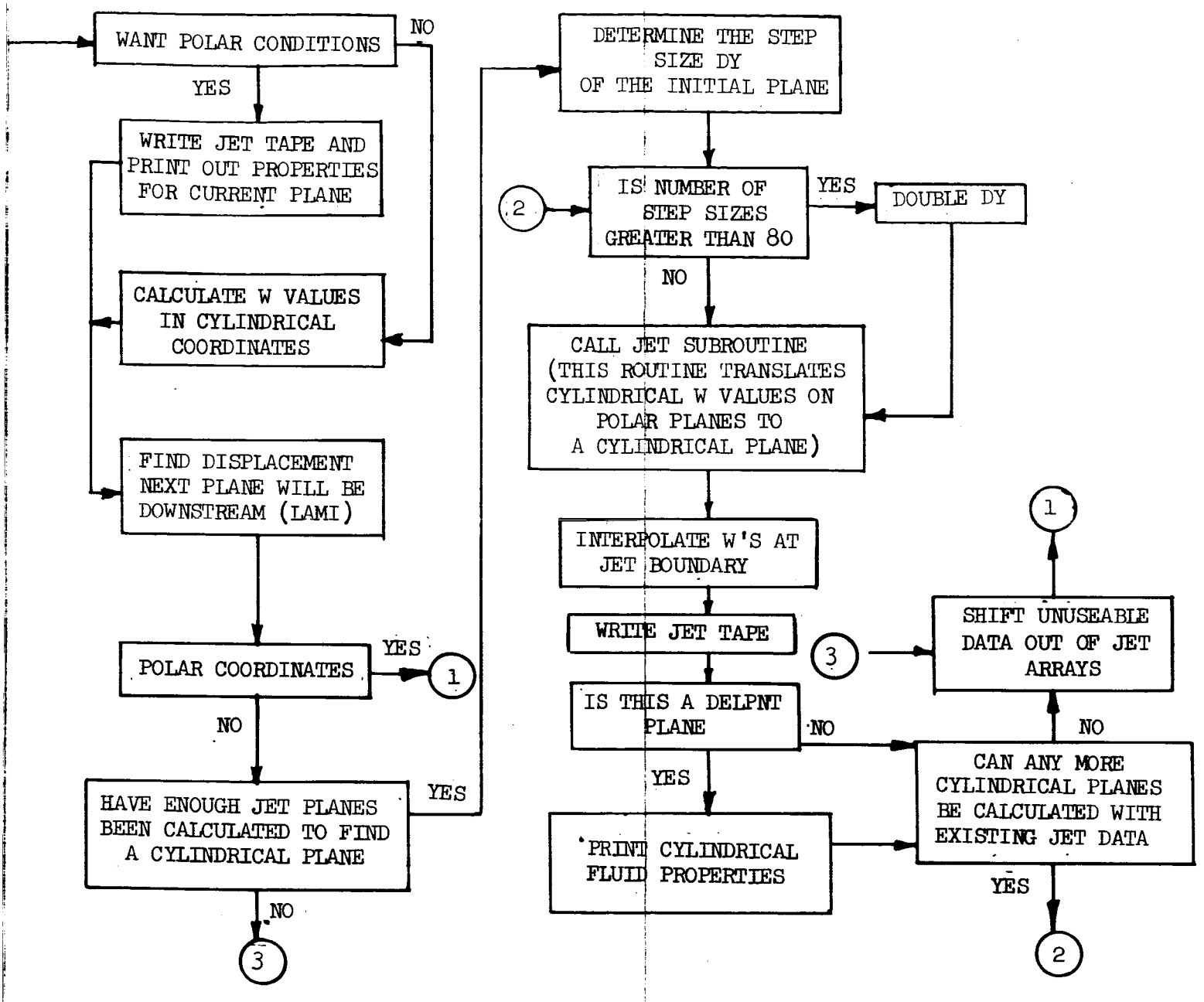
2.5.4 DATA CARDS

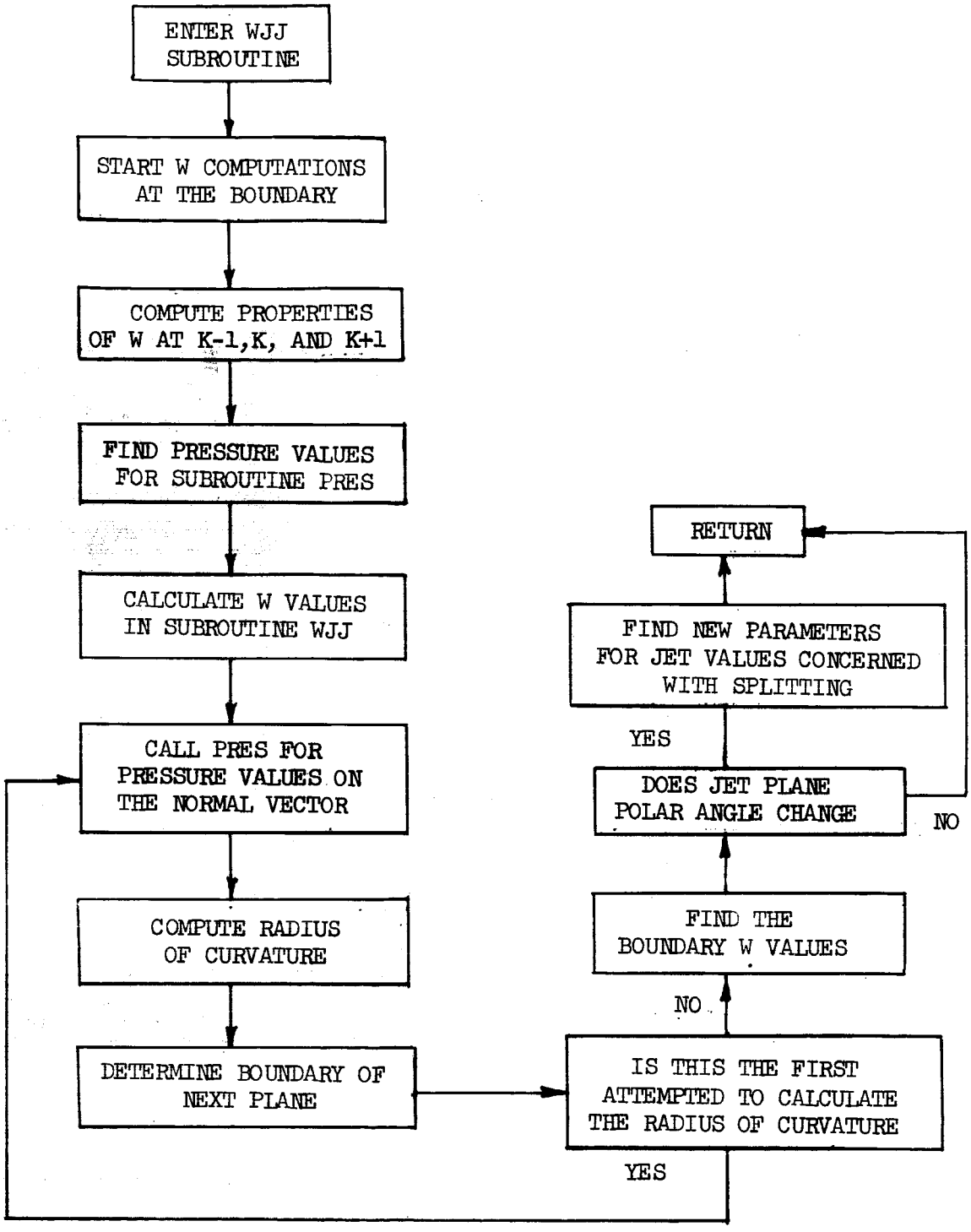
i) An end of file card, with a 7 and 8 punch in column one, or a $ DATA card (starting in column one) separates the binary deck from the data cards.

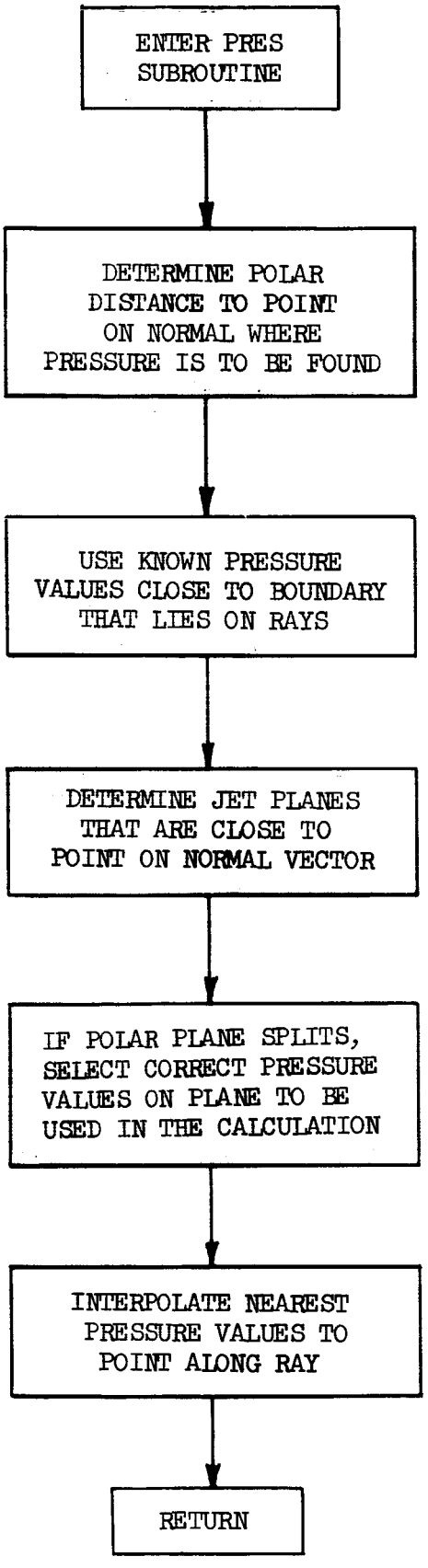
ii) Two input cards (see Appendix A) are read as input, followed by the initial data cards.

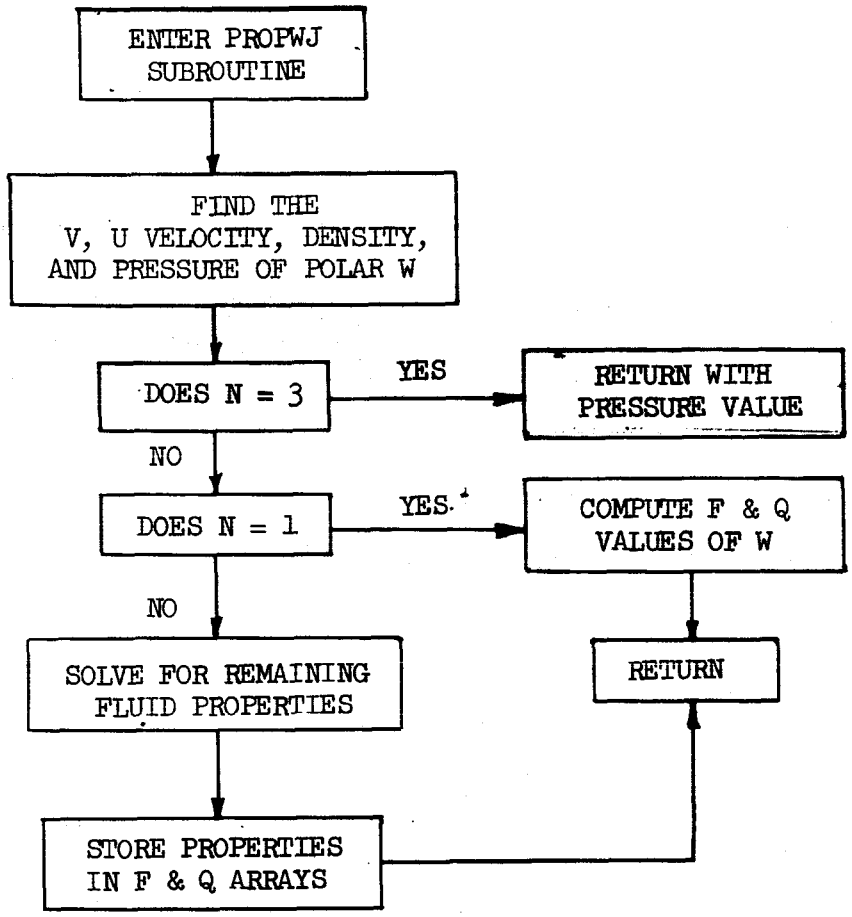
2.6 FLOW CHARTS FOR SINGLE JET PROGRAM

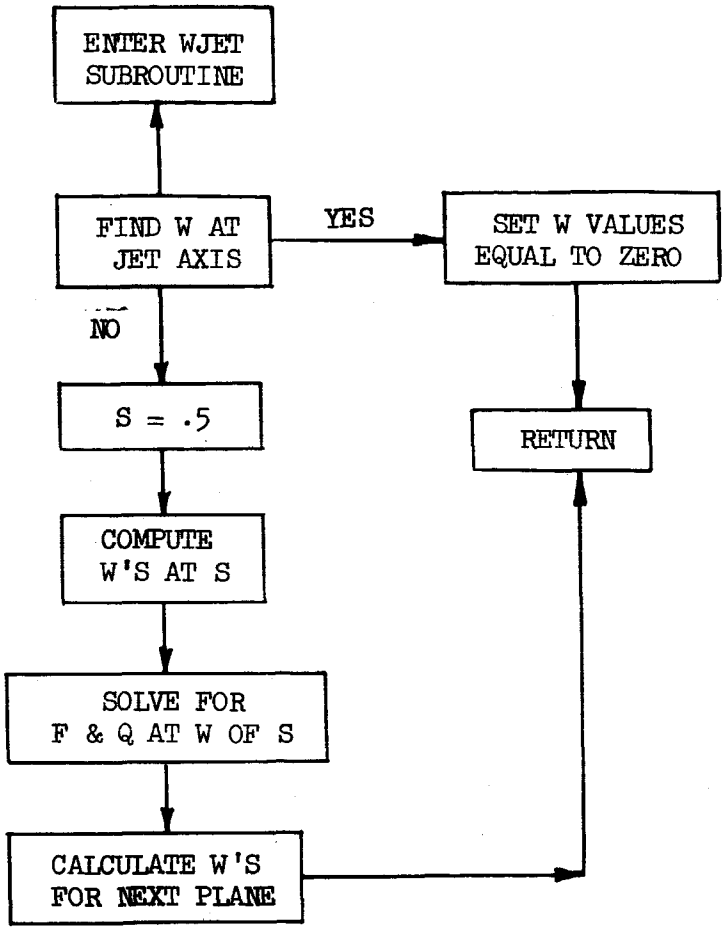


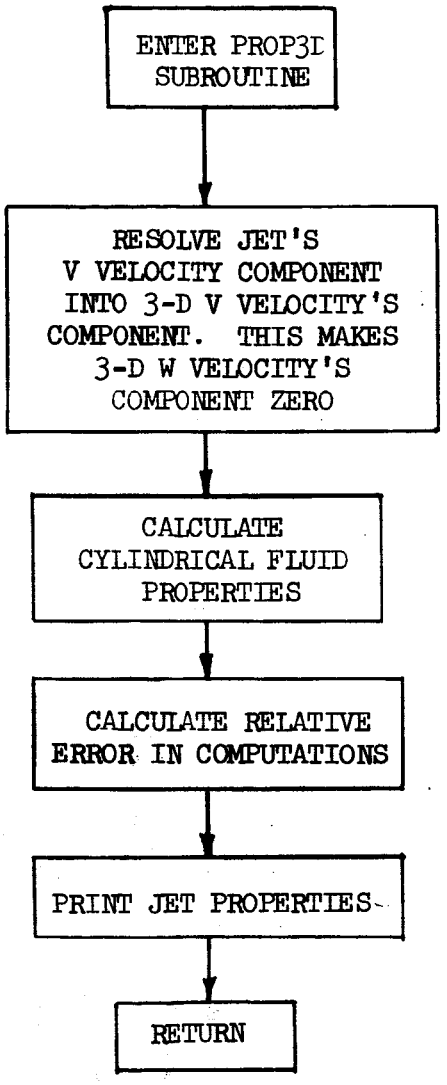

WANT POLAR CONDITIONS
NO
YES
WRITE JET TAPE AND PRINT OUT PROPERTIES FOR CURRENT PLANE
CALCULATE W VALUES IN CYLINDRICAL COORDINATES
FIND DISPLACEMENT NEXT PLANE WILL BE DOWNSTREAM (LAMI)
POLAR COORDINATES
YES
1
NO
HAVE ENOUGH JET PLANES BEEN CALCULATED TO FIND A CYLINDRICAL PLANE
YES
NO
3
DETERMINE THE STEP SIZE DY OF THE INITIAL PLANE
2
IS NUMBER OF STEP SIZES GREATER THAN 80
YES
DOUBLE DY
NO
CALL JET SUBROUTINE (THIS ROUTINE TRANSLATES CYLINDRICAL W VALUES ON POLAR PLANES TO A CYLINDRICAL PLANE)
INTERPOLATE W'S AT JET BOUNDARY
WRITE JET TAPE
IS THIS A DELPNT PLANE
NO
YES
PRINT CYLINDRICAL FLUID PROPERTIES
3
SHIFT UNUSEABLE DATA OUT OF JET ARRAYS
1
NO
CAN ANY MORE CYLINDRICAL PLANES BE CALCULATED WITH EXISTING JET DATA
YES
2

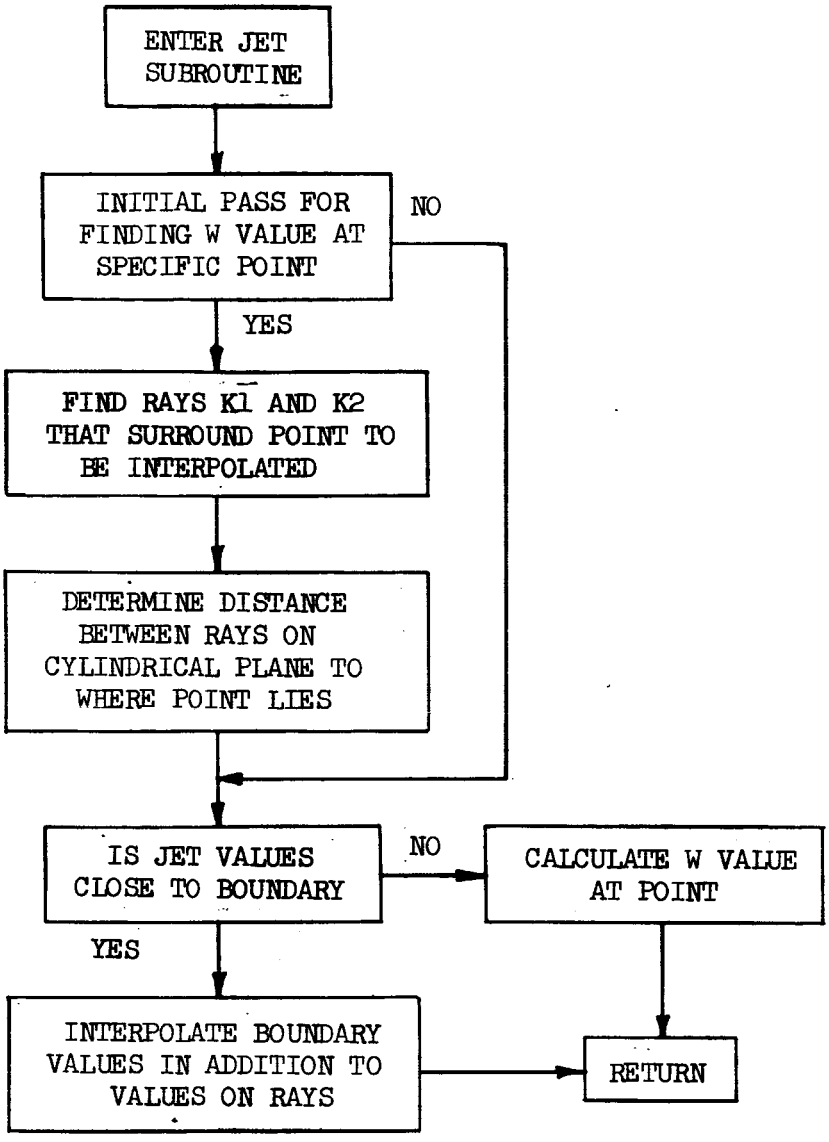

ENTER WJJ SUBROUTINE
START W COMPUTATIONS AT THE BOUNDARY
COMPUTE PROPERTIES OF W AT K-1,K, AND K+1
FIND PRESSURE VALUES FOR SUBROUTINE PRES
CALCULATE W VALUES IN SUBROUTINE WJJ
CALL PRES FOR PRESSURE VALUES ON THE NORMAL VECTOR
COMPUTE RADIUS OF CURVATURE
DETERMINE BOUNDARY OF NEXT PLANE
IS THIS THE FIRST ATTEMPTED TO CALCULATE THE RADIUS OF CURVATURE
YES
NO
FIND THE BOUNDARY W VALUES
DOES JET PLANE POLAR ANGLE CHANGE
NO
YES
FIND NEW PARAMETERS FOR JET VALUES CONCERNED WITH SPLITTING
RETURN

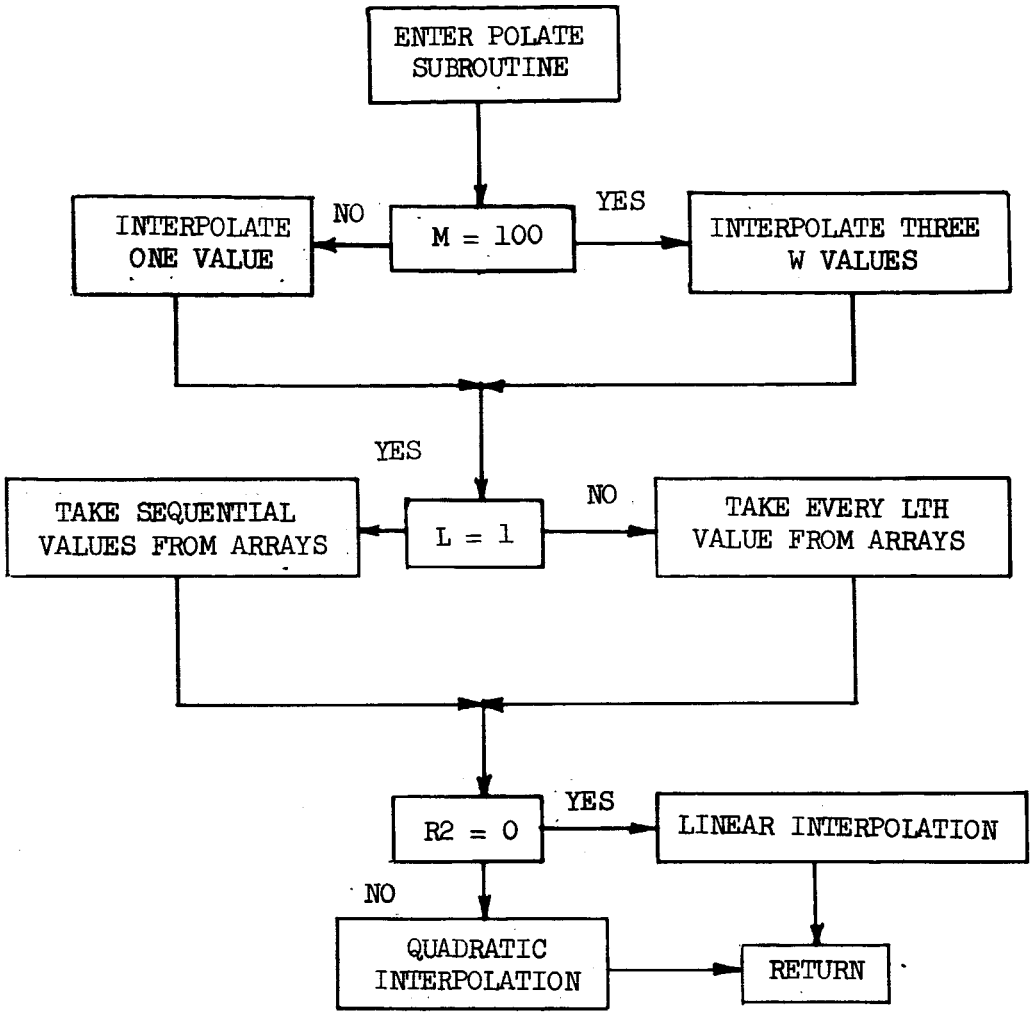

ENTER PRES SUBROUTINE
DETERMINE POLAR DISTANCE TO POINT ON NORMAL WHERE PRESSURE IS TO BE FOUND
USE KNOWN PRESSURE VALUES CLOSE TO BOUNDARY THAT LIES ON RAYS
DETERMINE JET PLANES THAT ARE CLOSE TO POINT ON NORMAL VECTOR
IF POLAR PLANE SPLITS, SELECT CORRECT PRESSURE VALUES ON PLANE TO BE USED IN THE CALCULATION
INTERPOLATE NEAREST PRESSURE VALUES TO POINT ALONG RAY
RETURN


ENTER PROPWJ SUBROUTINE
FIND THE V, U VELOCITY, DENSITY, AND PRESSURE OF POLAR W
DOES N = 3
YES
RETURN WITH PRESSURE VALUE
NO
DOES N = 1
YES
COMPUTE F & Q VALUES OF W
NO
SOLVE FOR REMAINING FLUID PROPERTIES
RETURN
STORE PROPERTIES IN F & Q ARRAYS


ENTER WJET SUBROUTINE
FIND W AT JET AXIS
YES
SET W VALUES EQUAL TO ZERO
NO
S = .5
RETURN
COMPUTE W'S AT S
SOLVE FOR F & Q AT W OF S
CALCULATE W'S FOR NEXT PLANE


ENTER PROP3D SUBROUTINE
RESOLVE JET'S V VELOCITY COMPONENT INTO 3-D V VELOCITY'S COMPONENT. THIS MAKES 3-D W VELOCITY'S COMPONENT ZERO
CALCULATE CYLINDRICAL FLUID PROPERTIES
CALCULATE RELATIVE ERROR IN COMPUTATIONS
PRINT JET PROPERTIES
RETURN


ENTER JET SUBROUTINE
INITIAL PASS FOR FINDING W VALUE AT SPECIFIC POINT
NO
YES
FIND RAYS K1 AND K2 THAT SURROUND POINT TO BE INTERPOLATED
DETERMINE DISTANCE BETWEEN RAYS ON CYLINDRICAL PLANE TO WHERE POINT LIES
IS JET VALUES CLOSE TO BOUNDARY
NO
CALCULATE W VALUE AT POINT
YES
INTERPOLATE BOUNDARY VALUES IN ADDITION TO VALUES ON RAYS
RETURN


ENTER POLATE SUBROUTINE
M = 100
NO
YES
INTERPOLATE ONE VALUE
INTERPOLATE THREE W VALUES
YES
NO
L = 1
TAKE SEQUENTIAL VALUES FROM ARRAYS
TAKE EVERY LTH VALUE FROM ARRAYS
R2 = 0
YES
NO
LINEAR INTERPOLATION
QUADRATIC INTERPOLATION
RETURN

3. FIVE-JET INTERACTION PROGRAM

3.1 DESCRIPTION OF PROGRAM

3.1.1 THE DEPENDENT VARIABLES AND THEIR STORAGE. The dependent variables are represented by the elements of the column vector W as given in Part I, Appendix 1. For the three-dimensional flowfield, W has 4 components. Thus, using the notation of Section 2, we use subscripts to distinguish these elements and write the transpose of W as

$$W^T = \{W_1, W_2, W_3, W_4\}$$

The basic grid in a cross plane x = constant is shown in Figure 2A. At each point M, N we have to store the four elements. Hence, similar to the discussion in Section 2, we could use the three-dimensional array

$$W(J, M, N) \quad J = 1, 2, 3, 4$$

However, since only an octant of the x = constant plane is calculated, this would result in very inefficient use of available core storage. Therefore, the vector W is stored as indicated in Figure 2B in two two-dimensional arrays as follows:

$$W_1(M, N) = W13(M, N)$$
$$W_2(M, N) = W24(M, N)$$
$$W_3(M, N) = W13(N, M)$$
$$W_4(M, N) = W24(N, M)$$

Thus, the first two elements are stored in two triangular regions of core storage which are an exact image of the physical plane except for a

translation (see below). The last two elements, on the other hand, are stored in the triangular region symmetric about the diagonal in the core storage. Every point in the physical plane has thus two image points in the core storage. In particular, this also applies to the auxiliary points necessary for the application of the boundary conditions as discussed in Part I. This necessitates a translation of the field as indicated in Figure 2B. The axis of the center engine ($y = z = 0$) is located at $M = 5$, $N = 2$. Only the small region $M \leq 3$, $N \leq 3$ and the diagonal $M = N$ are unused in the storage.

The interaction plane, $y = D$, during the two-jet interaction phase is divided into M_o intervals. Hence, this plane translates into $m' = M_o + 5$ in the core storage.

3.1.2 EXPANSION OF THE THREE-DIMENSIONAL REGION. The two nearest jets start to interact at the point $M = M'$, $N = 2$ when the jets just touch each other. As the single jets expand, the intersection of the jet boundaries wanders along the line M' towards increasing N. This process governs the expansion of the three-dimensional region in z-direction. The program tests at each step whether a new mesh point will be swallowed by the three dimensional flowfield in the step about to be calculated. If this is the case the area is enlarged such that all the necessary auxiliary points are available for the calculation in a manner described in Part I.

The three-dimensional region also grows in y-direction from the interaction plane towards the center line of the center engine. This growth is determined by comparing the values calculated with the three-dimensional program with those obtained by interpolation of the single jet values at the corresponding points. If the two values differ by more than a small

percentage C_1 the point is considered to be inside the three-dimensional region and a new row M = constant is added as auxiliary (or boundary) points with values obtained by interpolation from the single jet results.

When the three-dimensional region reaches the diagonal z = y, five-jet interaction begins. At that moment the flow remains no longer symmetric about M'. Therefore, the three-dimensional region is extended into the region $M > M'$ by reflection. The three-dimensional region then is allowed to grow in direction of increasing as well as decreasing M. The growth towards increasing M is again governed by testing the calculated three-dimensional values against interpolated single jet values. The tolerance for this growth, C_2, can be chosen different from C_1.

No provisions have been made in the program to allow the jet boundaries to contract. If the calculations are carried too far downstream that the single jet boundary starts to converge towards the axis, the calculation stops.

3.1.3 REFINEMENT OF THE MESH SIZE. It may be desirable to use a smaller mesh size in the early stages of the two-jet interaction zone. This can be done by simply specifying the number of planes to be calculated with the refined mesh. The number of these planes is denoted by JUMP1. If JUMP1 is given a nonzero input value, the program proceeds as follows: The mesh size $\Delta y = \Delta z$ is divided by two by shifting the interaction plane in the core storage from $M' = M_o + 5$ to $M'' = M' + M_o$ as indicated in Figure 3. However, in the print out the values along the interaction plane are still labeled as $M = M'$ and N. Those at $y = D - \Delta y/2$ are labeled as $M' - 1$, N, etc. Thus there is a one-to-one correspondence between core storage and grid points, independent of the refinement. However, the actual step size used is

printed at the top of each plane print out.

If the specified number of planes has been calculated with the refined mesh, the program automatically drops every second point and shifts the values to the appropriate locations corresponding to the unrefined input data.

If the number of planes JUMP1 is chosen so large that the interaction region reaches the diagonal before the specified number of planes is calculated, the program automatically enlarges the mesh as discussed above. Subsequently it reflects the flowfield about the interaction plane as discussed in Section 3.1.2.

Finally, the maximum number of M is 80; thus $M_o \leq 74$. Now, if M_o is chosen close to that value and still a refined mesh is to be used, then clearly the shifting in core storage described above is not possible. In this case the program calculates the two-jet interaction region in the same fashion as with the regular mesh size but with $\Delta y = \Delta z$ half the regular value. In this case, however, the calculation must be terminated when the three-dimensional region reaches the diagonal.

3.1.4 CHOICE OF DIFFERENCE SCHEMES. Three different damping mechanisms are incorporated in the program. These will now be considered separately.

3.1.4.1 Gradient Damping. This method was described in Part I, Section 3.3 and 3.5.1. The difference scheme is centered at $S = \frac{1}{2} + O(\Delta x)$ and s is calculated as follows:

$$S = \frac{1}{2}\left\{1 + ASO\left(\frac{\lambda_e}{\lambda} - 1\right) + AS1 \cdot \frac{\lambda}{W_i}\left[F_{i_{+1,o}} - F^{\ell}_{i_{-1,o}}\right]\right.$$

$$\left. + AS2 \cdot \frac{\lambda}{W_i}\left[G^{\ell}_{i_{o,+1}} - G^{\ell}_{i_{o,-1}}\right]\right\}$$

Here W_i denotes the element of the vector W used to calculate S and F_i and G_i are the corresponding elements of the vector valued function F and G.

If AS1 = AS2 = 0 and AS0 = 1, then

$$S = \frac{\lambda_\ell}{2\lambda} = \frac{\Delta x_\ell}{2\Delta x}$$

i.e., the scheme is centered halfway between the initial plane and the furthest point that could be reached without violating the Courant-Friedrichs-Lewy condition. This means that the region of influence approaches that of the characteristics as close as possible. The situation is shown in Figure 4A for the two dimensional case. According to the local stability condition, the maximum allowed step size is Δx_ℓ, i.e., the point P could be calculated. Choosing S as given in the last expression in effect means calculating W at the point P and then interpolating linearly for $W(x + \Delta x, y)$ between $W(x, y)$ and $W(x + \Delta x_\ell, y)$. The accuracy of this scheme is, therefore, only of first order.

If AS0 = 0 but AS1 and AS2 are different from zero, the scheme is of second order accuracy as long as the damping factors are of order one. This is the actual gradient damping method discussed in Part I, 3.3. Usually, the first or second element of W is chosen (i = 1,2) since these vary strongly in marching direction and are anti-symmetric about the interaction plane.

3.1.4.2 Artificial Viscosity Damping. This method is also discussed in Part I, 3.3. With $D_\lambda \neq 1$ the accuracy of the scheme is only of first order. This scheme has only very recently been tested and requires additional investigations.

3.1.4.3 Laterally Uncentered Difference Scheme. The principle of this scheme is graphically shown in Figure 4B for the two-dimensional case. In the first step, values at $x + \Delta x/2$, $y \pm TT\ \Delta y$. The second step is similar to that for the basic scheme.

It was hoped that this scheme would yield better results in the case where the theoretical shock location was close to the interaction plane. However, the contrary was observed; choosing $TT < \frac{1}{2}$ resulted in smaller gradients. Consequently, this scheme has subsequently been used only after imposing shock jump conditions in the early stages of the two-jet interaction regions, where it prevents overshoots after the discontinuous jumps.

3.2 INPUT DATA

Data to be given as input and their meaning are given here.

GAM — is the ratio of specific heats, assumed constant.

RDJ — is half the separation distance of the centerlines of the two nearest jets in exit radii, i.e., D.

MO — is the number of grid intervals chosen for D. It can be at most 74.

LMIN — the number of the initial plane. It is one for the first run, for for a continuation run it is the previous LMAX plus one.

LMAX — Last plane to be calculated for given run.

DPRNT — This property governs the output print. If it is set equal to zero, every calculated plane is printed out. If it is given a finite value, results are printed out roughly at x-intervals specified by the number. Since Δx is variable, the program prints out the next plane downstream of each interval.

LAMO is the ratio $\Delta z/\Delta y$ and has the value one.

The following data pertain to the single jet calculations:

CN is the radius of the initial data line for the jet calculation in exit radii.

CXR is the distance of the center of the polar coordinate system from the nozzle exit plane.

The following tolerances are used.

CC is the tolerance on entropy undershoot. A value of 0.95 is satisfactory.

FACTOR is $\sqrt{3}/8$ multiplied by a safety factor for stability considerations. The safety factor can be of the order of 0.9 to 1.0

C1,C2 tolerances, determining the lateral spreading of the three-dimensional regions. Values of 0.05 to 0.10 are reasonable.

The following data govern the calculation of the first few interaction points:

IFLG is the number of points at which shock conditions are initially imposed. This will usually be zero or two.

ALF is the fraction of Δx by which the calculation is receded from the interaction point, as discussed in Part I, 3.5.4.

IDIV is the number of intervals in which this element is divided.

JUMP1 is the number of planes calculated with a refined mesh.

JUMP is the number of planes calculated with laterally uncentered difference scheme.

TS, TT give the fraction of uncentering for this scheme (see 3.1.4).

Finally, the following damping factors are used:

ASO is used for centering the difference scheme according to the locally allowable step size (see 3.1.4).

AS1,AS2 are the damping factors in centering the difference scheme according to the local gradients (see 3.1.4).

IJL determines which element of W is used in the damping factor. It is either 1 or 2 (see 3.1.4).

DL,CL is the artificial viscosity term discussed in 3.1.4.

3.3 OUTPUT DATA

The first information printed after the input data is the distance from the nozzle exit at which the interaction begins.

On top of each printed plane the following data are printed.

L, the number of computed planes. L = 1 is the initial plane. LAM1 and LAM2, the relative step sizes $\Delta x/\Delta y$ and $\Delta x/\Delta z$. For the five jet program the values are identical. X, the distance of the plane from the nozzle exit. Z1, the coordinate of the jet boundary intersection with the interaction plane, and DY the mesh size in the cross plane.

Below this heading, the calculated values of density, pressure, temperature, entropy, velocity components, speed and Mach number are printed for each M and N. In the last column a symbol indicates how the values were obtained. A point calculated in normal fashion by the difference scheme has the symbol N. If the values were obtained by interpolation from the single jet values, they are distinguished by the letter J. Finally, those points that were calculated in the jet region with the difference scheme traversing the jet shock in the "wrong" direction and were subsequently replaced by jet values are characterized by the symbol E.

3.4 SUBROUTINES

Various subroutines and their function will be briefly discussed.

3.4.1 AUXILIARY POINTS SUBROUTINE (AUXPTS). This subroutine allocates the values of W corresponding to the auxiliary points to the proper storage locations. These values are obtained from those of the regular mesh points by using the reflection principle to satisfy the boundary conditions.

3.4.2 PROPERTIES SUBROUTINE (PRØP). This subroutine calculates a variety of thermodynamic data from the basic dependent variables, W_i. Given the total enthalpy H,

$$H = \frac{1}{2} \frac{\gamma + 1}{\gamma - 1}$$

the density, R, is evaluated from

$$R = a \left\{1 - \sqrt{1 - (b/a)}\right\}$$

where:

$$a = \frac{\gamma}{\gamma - 1} \; W_2(2H - V^2 - W^2)^{-1}$$

$$b = \frac{\gamma + 1}{\gamma} \; W_1^2/W_2$$

and where the lateral velocity components are given by

$$V = W_3/W_1 \quad W = W_4/W_1$$

Subsequently we have

$$U = W_1/R$$

$$P = W_2 - (W_1^2/R)$$

$$M^2 = (U^2 + V^2 + W^2)\ R/(\gamma P)$$

There are six input options to this routine, selected according to the last of the input variables, as follows:

Option one computes the elements of both F and G.

Options two and three calculates respectively the elements of F only or G only.

The fourth option is used for print out. It calculates the variables R, P, T, S, U, V, W, Q and M. Also it allocates M and N and the index (N, J or E) indicating the method used in obtaining the data.

The fifth option calculates only those thermodynamic properties used in the main program. Thus the calculation of the temperature is by-passed.

Finally, the sixth option is used to transform the axisymmetric data interpolated from the jet program to the appropriate values for the three - dimensional region, i.e., it splits up the velocity component normal to the marching direction into the V and W components.

3.4.3 JET SUBROUTINE (JET). This subroutine interpolates the W values from the jet tape onto a particular cross plane for the five-jet program. There are two options: If the last argument in this subroutine is one, then boundary points are interpolated. If the argument is two, interior points are interpolated. The two interpolation procedures are slightly different.

The interpolation proceeds first in x-direction to the prescribed plane position and subsequently within the plane along the radius through

the desired point. Once the W values are interpolated, the density, pressure and cylindrical velocity components are calculated and returned to the main program.

3.4.3 INTERPOLATION SUBROUTINE (INTRP). This subroutine interpolates or extrapolates either linearly or quadratically.

The first argument gives the three coordinates of the pivotal points. If the first and third coordinates are equal, interpolation is linear.

The second argument gives the desired interpolation coordinate.

The third argument gives the ordinates corresponding to the pivotal points and the fourth argument denotes the interpolated ordinates.

3.4.5 FILE SUBROUTINES. There are three symbolic FILE subroutines for the five-jet program, each concerned with the I/O tape usage.

Subroutine FILE 1 sets up the jet tape correctly for input into the five-jet program.

Subroutines FILE 2 and FILE 3 handle the I/O for contination runs. FILE 2 is needed for the input tape, FILE 3 for the output tape.

3.5 LIST OF PRINCIPLE SYMBOLS USED IN THE FIVE JET PROGRAM

ADIV	floating point variable of IDIV
ALF	input coefficient to initial LAMI
ANB	the Y distance of interaction wall
ASO	damping factor
AS1	damping factor
AS2	damping factor
BCD	tells how W value is determined: N, J or E
C1	tolerance in 3-D expansion toward center jet
C2	tolerance in 3-D expansion away from center jet
CC	tolerance on reference entropy
CN	radius of initial data line for jet calculation
CXR	distance of polar vertex to nozzle exit
DPRNT	interval between printed planes
DR(3)	step size of jet plane
DX	distance between cross planes
DY	step size in Y direction
ENTH	reference entropy
F(4,80,3)	F functions of W
F1(4)	$F^{s}_{+\frac{1}{2},\ 0}$
F2(4)	$F^{s}_{-\frac{1}{2},\ 0}$
FACTOR	coefficient for LAMI
G(4,80,3)	G functions of W
G1(4)	$G^{s}_{0,\ +\frac{1}{2}}$
G2(4)	$G^{s}_{0,\ -\frac{1}{2}}$
GAM	constant ratio of specific heats

ICNT	number of points calculated using jet values
IDIV	Integer value by which LAMI is divided until first interaction occurs
IFLG	selects conditions for shock points
IJL	index of element of W used for damping
IPAGE	determines when caption should be printed
JJ	determines when point is being tested or being filled
JJJ	used for calculating jet points
JUMP	number of planes calculated with laterally uncentered difference scheme
JUMP 1	number of planes calculated with refined mesh
K1	test left line for 3-D expansion
K2	test right line for 3-D expansion
LAMO	ratio between DY and DZ (value 1 for 5-jet)
LAM1	ratio of DX/DY
LAM2	ratio of LAM1/LAMO
LMAX	last plane computed
LMIN	starting plane for run
LPLANE	current cross plane being computed
M	grid point Y direction
M2	center of outside jet on Y axis
MA	left boundary line for W values
MA3D	left boundary for 3-D region
MAX1(3)	location where jet boundary values are stored
MB	location of the interaction plane
MBC	= MB until expansion occurs to right, then = MC
MBD	right boundary of 3-D region

MC	last line to right with W values
MO	number of intervals between center jet and interaction plane
N	location of grid point in Z direction
NB	boundary of 3-D region in Z-direction
NBB	NB value for previous plane
NBP	top boundary line in Z direction with W values
NJE(3,300)	contains location and BCD value
PJB	jet pressure value at boundary
Q	total speed
RDJ	half separation distance of initial interaction
RJB	jet density value at boundary
RR	distance from polar vertex to 3-D plane
RUVP(4)	contains density, U and V velocities and pressure
RWVP(4)	contains density, W, V velocities and pressure
RX(3)	location of jet plane from polar vertex
S	center of the difference scheme
TS	parameter for laterally uncentered scheme; Z direction
TT	parameter for laterally uncentered scheme; Y direction
UM	angle which determines LAM1
UQM(4)	contains U velocity, total velocity, Mach No. and entropy
W13(80,80)	first and third element of W
W24(80,80)	second and fourth element of W
W3D(3,80,2)	jet values of W
YBD	radius of jet

NOTE: All length dimensions are referred to the nozzle exit radius.

3.6 OPERATING INSTRUCTIONS

The following operating instructions refer to the IBM 7094-7044 DCS computer systems.

3.6.1 RUN REQUEST. The following information will in general be included in this request.

i) Operator's name, date, identifying run number, etc.

ii) Tape request. Two input tapes and one output tape must be requested.

iii) The time estimate depends on the number of points calculated. For an initial time guess, two minutes should be sufficient to calculate 20 planes with a value of MO of 25.

iv) As line estimate roughly 2,600 lines will suffice to print out the results under the same condition as in iii). Note that the number of lines printed as well as the execution time increase as the calculation proceeds downstream.

3.6.2 CONTROL CARDS.

i) Three SETUP cards are required for specifying the tape drives and the I/O operations. Currently, the single jet tape is being setup on B(1), the tape read in a continuation run on B(2) and the results of the present run on B(3). For an initial run a tape B(2) will have to be set up although it is not used.

ii) An ATEND card will give a post-mortem dump if the run is terminated by unusual conditions.

iii) The EXECUTE IBJØB card places the deck under the IBSYS monitoring system.

iv) The IBJØB card uses ALTIØ, a version 13 option, which requires fewer cells for the I/O package.

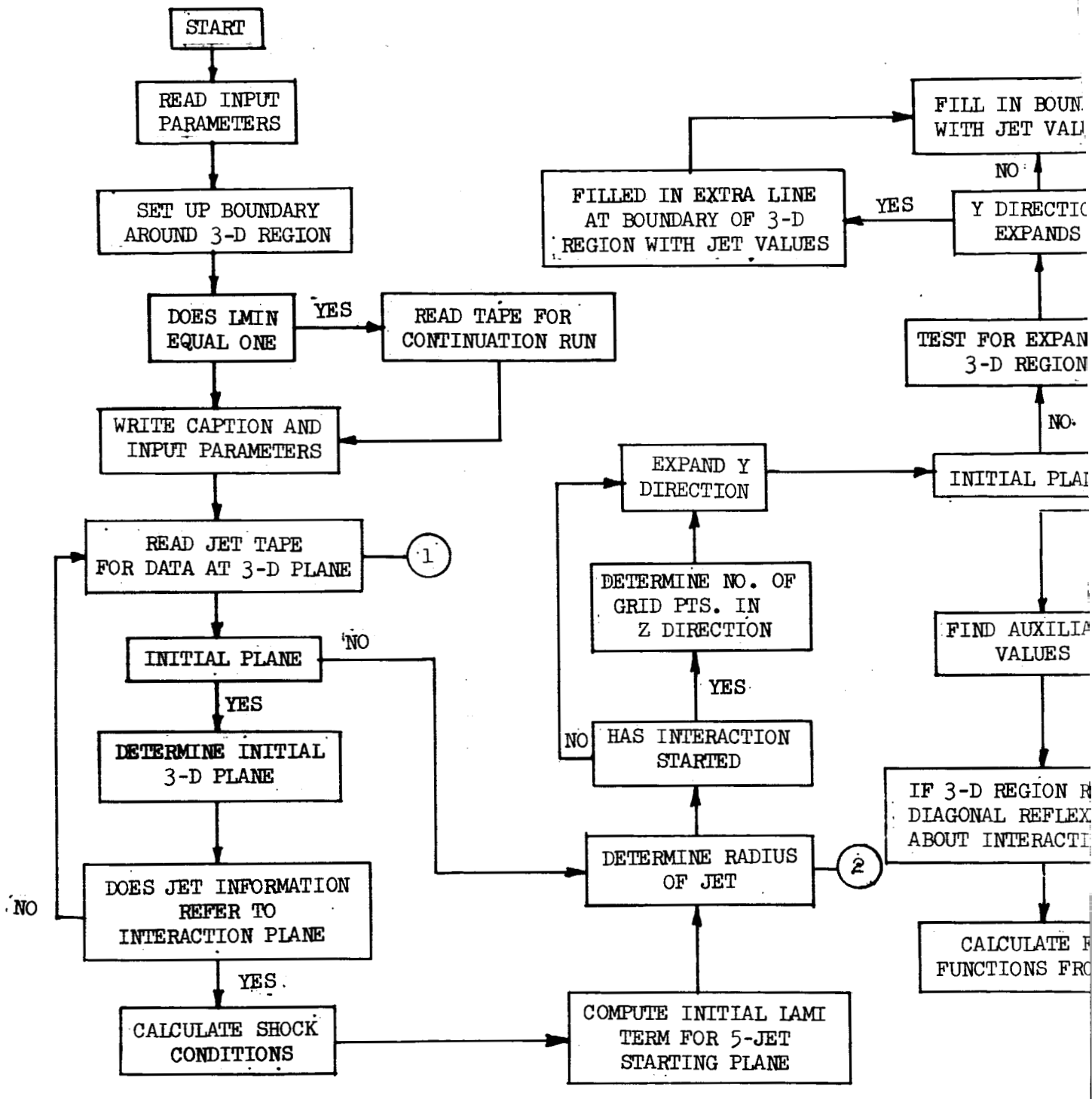
3.6.3 BINARY DECK. The binary deck consists of the MAIN program and the following subroutines: PRØP, WRITES, INTRP, AUXPT and FILE. These names appear in Column 72 ff of the binary deck.

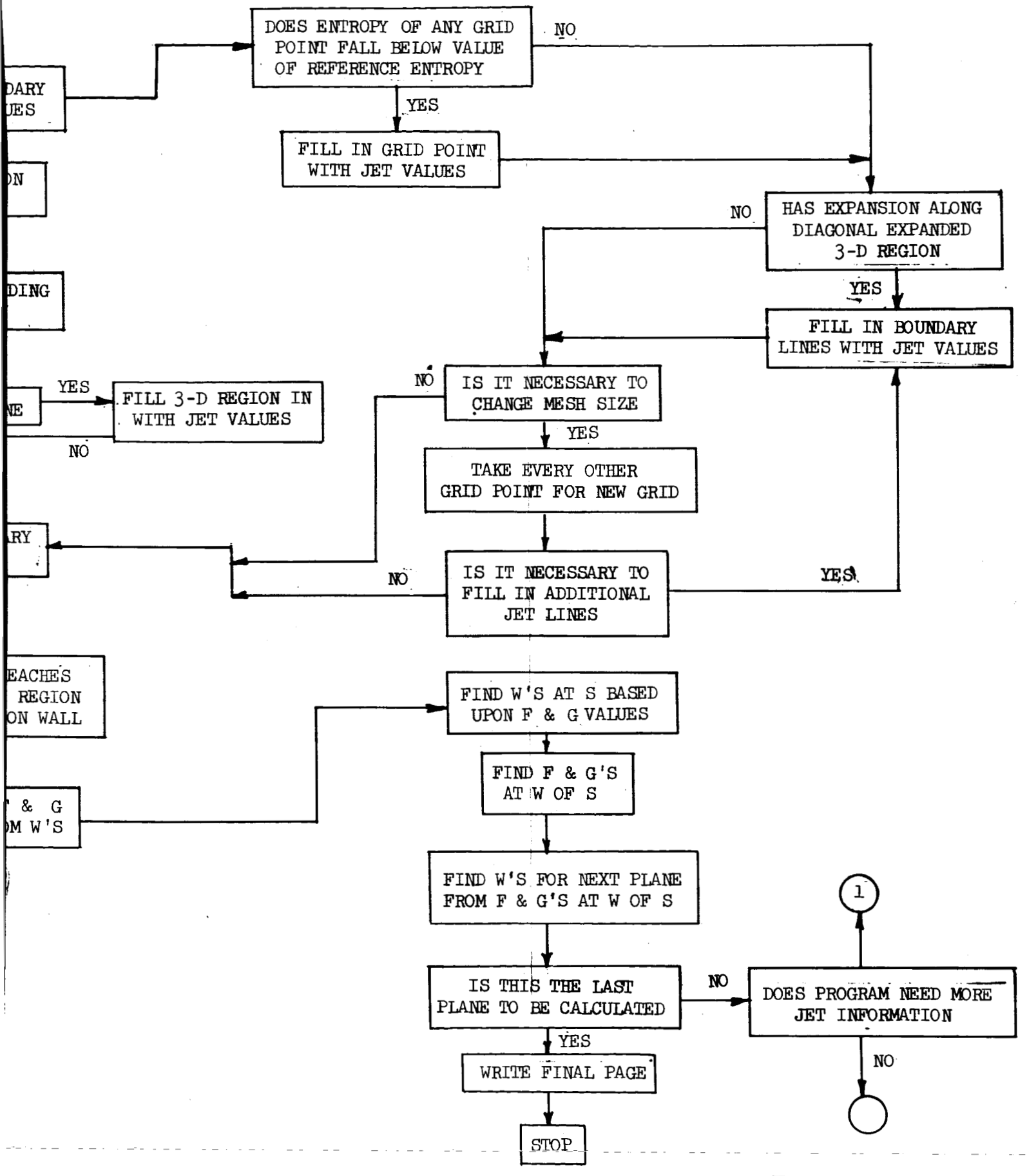
3.6.4 INPUT DATA

i) An end of file card separates the binary deck from the input cards. This card has a 7 and 8 punch in Column one or a $ DATA punched starting in Column one.

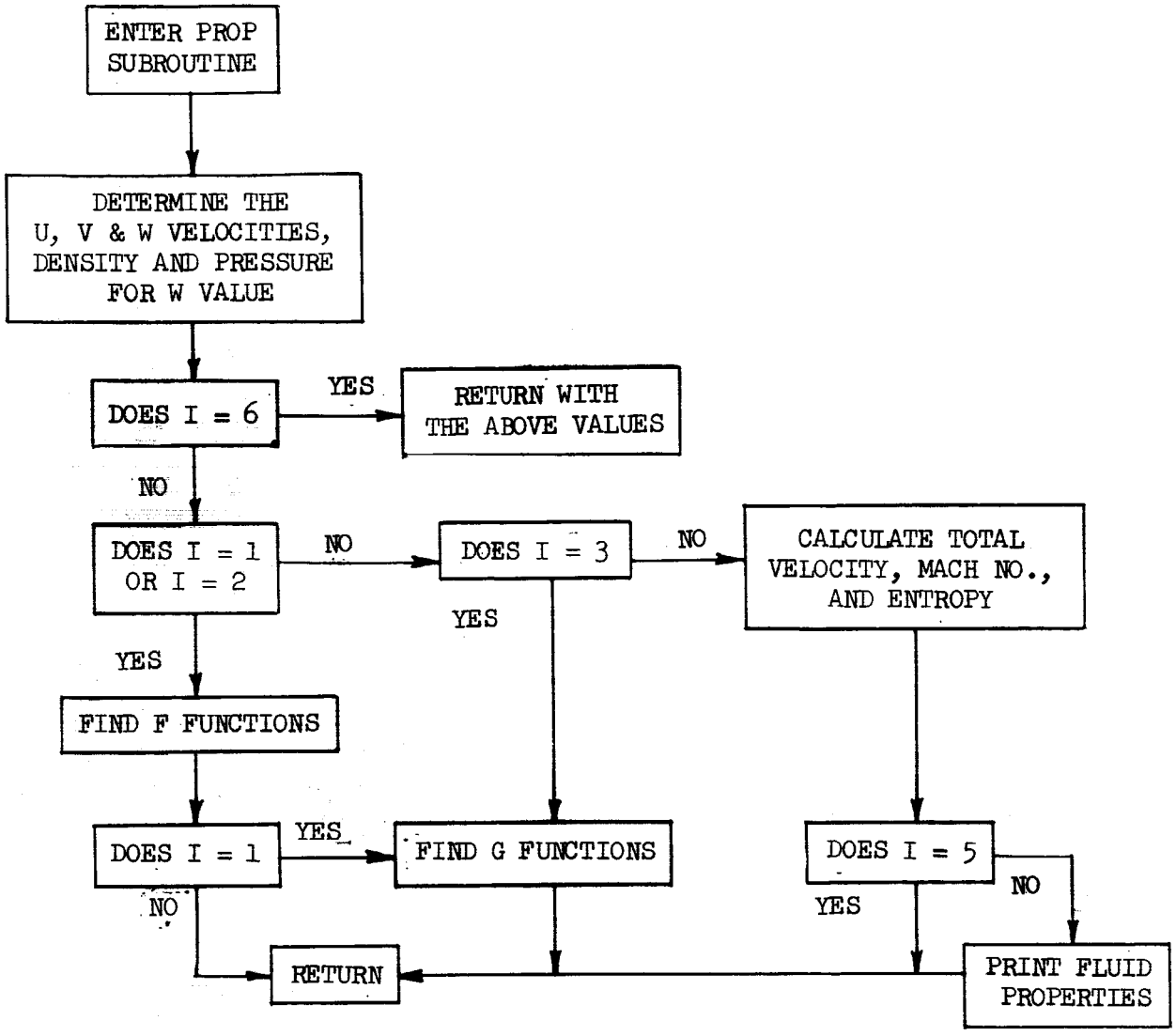
ii) Four cards are read as input to the program (see Appendix B)

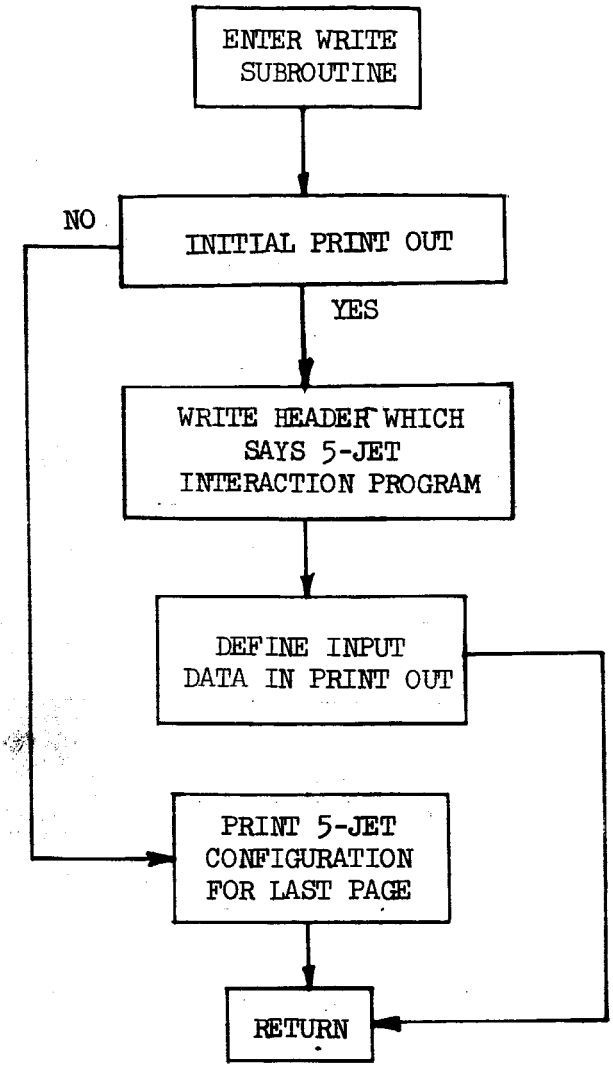
3.7 FLOW CHARTS FOR FIVE-JET INTERACTION PROGRAM

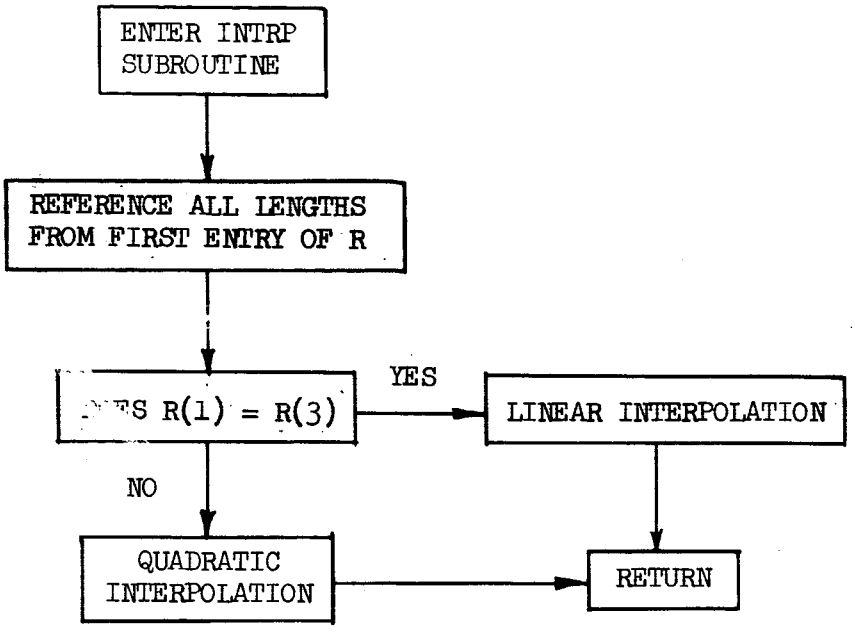


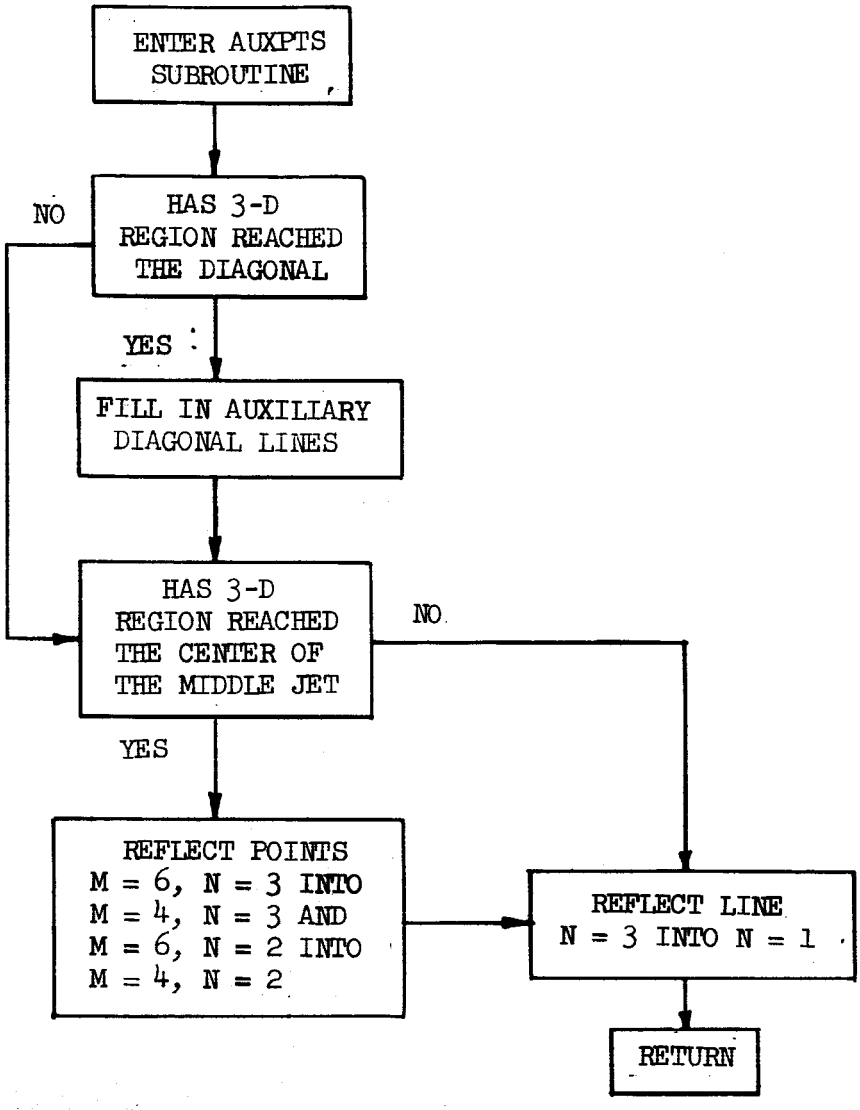

DOES ENTROPY OF ANY GRID POINT FALL BELOW VALUE OF REFERENCE ENTROPY
NO
YES
FILL IN GRID POINT WITH JET VALUES
HAS EXPANSION ALONG DIAGONAL EXPANDED 3-D REGION
NO
YES
FILL IN BOUNDARY LINES WITH JET VALUES
IS IT NECESSARY TO CHANGE MESH SIZE
NO
YES
TAKE EVERY OTHER GRID POINT FOR NEW GRID
IS IT NECESSARY TO FILL IN ADDITIONAL JET LINES
NO
YES
FILL 3-D REGION IN WITH JET VALUES
YES
NO
FIND W'S AT S BASED UPON F & G VALUES
FIND F & G'S AT W OF S
FIND W'S FOR NEXT PLANE FROM F & G'S AT W OF S
IS THIS THE LAST PLANE TO BE CALCULATED
NO
YES
DOES PROGRAM NEED MORE JET INFORMATION
NO
1
WRITE FINAL PAGE
STOP

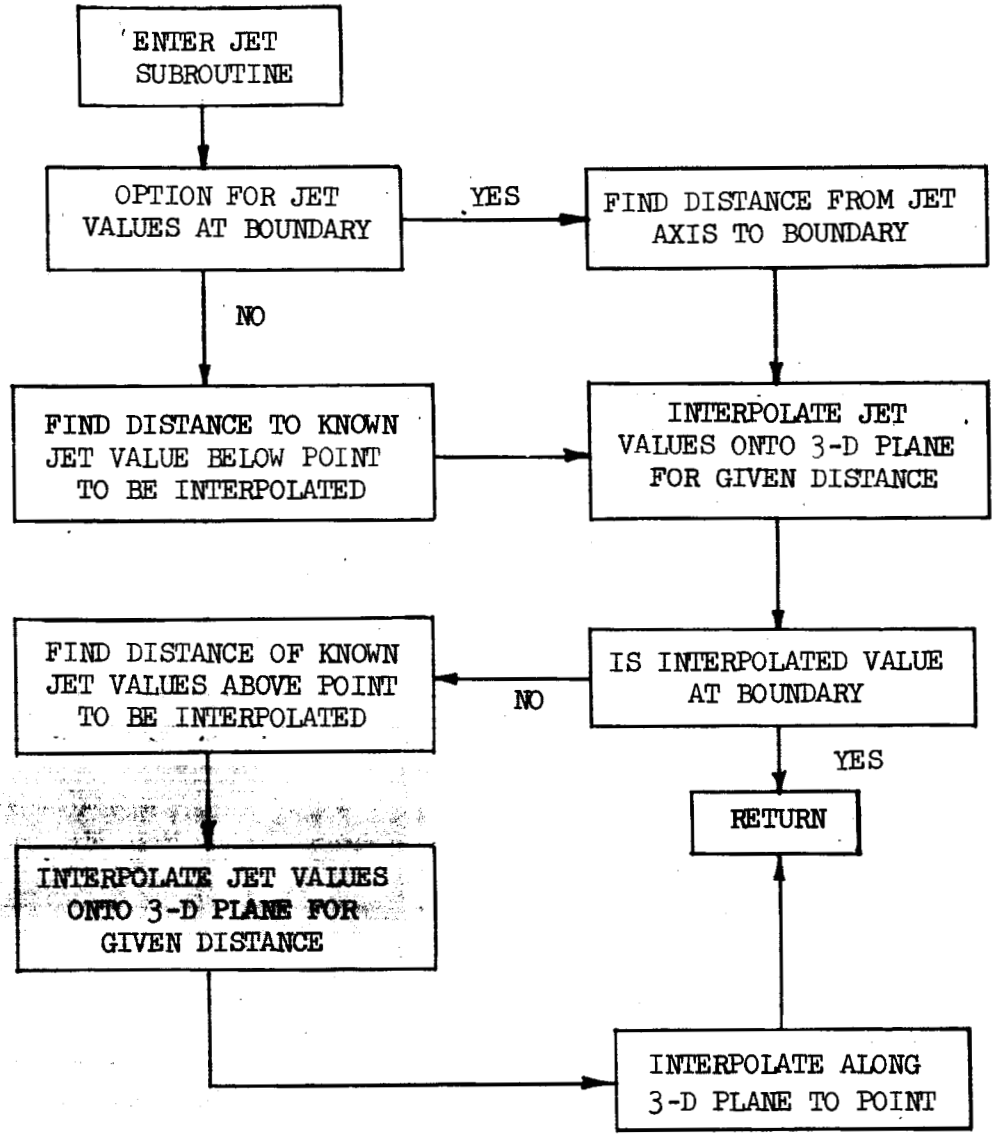
35-2


ENTER PROP SUBROUTINE
DETERMINE THE U, V & W VELOCITIES, DENSITY AND PRESSURE FOR W VALUE
DOES I = 6
YES
RETURN WITH THE ABOVE VALUES
NO
DOES I = 1 OR I = 2
NO
DOES I = 3
NO
CALCULATE TOTAL VELOCITY, MACH NO., AND ENTROPY
YES
YES
FIND F FUNCTIONS
DOES I = 1
YES
FIND G FUNCTIONS
DOES I = 5
NO
NO
YES
RETURN
PRINT FLUID PROPERTIES


ENTER WRITE SUBROUTINE
NO
INITIAL PRINT OUT
YES
WRITE HEADER WHICH SAYS 5-JET INTERACTION PROGRAM
DEFINE INPUT DATA IN PRINT OUT
PRINT 5-JET CONFIGURATION FOR LAST PAGE
RETURN


ENTER INTRP SUBROUTINE
REFERENCE ALL LENGTHS FROM FIRST ENTRY OF R
R(1) = R(3)
YES
LINEAR INTERPOLATION
NO
QUADRATIC INTERPOLATION
RETURN


ENTER AUXPTS SUBROUTINE
HAS 3-D REGION REACHED THE DIAGONAL
NO
YES
FILL IN AUXILIARY DIAGONAL LINES
HAS 3-D REGION REACHED THE CENTER OF THE MIDDLE JET
NO
YES
REFLECT POINTS M = 6, N = 3 INTO M = 4, N = 3 AND M = 6, N = 2 INTO M = 4, N = 2
REFLECT LINE N = 3 INTO N = 1
RETURN


ENTER JET SUBROUTINE
OPTION FOR JET VALUES AT BOUNDARY
YES
FIND DISTANCE FROM JET AXIS TO BOUNDARY
NO
FIND DISTANCE TO KNOWN JET VALUE BELOW POINT TO BE INTERPOLATED
INTERPOLATE JET VALUES ONTO 3-D PLANE FOR GIVEN DISTANCE
FIND DISTANCE OF KNOWN JET VALUES ABOVE POINT TO BE INTERPOLATED
NO
IS INTERPOLATED VALUE AT BOUNDARY
YES
RETURN
INTERPOLATE JET VALUES ONTO 3-D PLANE FOR GIVEN DISTANCE
INTERPOLATE ALONG 3-D PLANE TO POINT

4. THE TWO-JET INTERACTION PROGRAM

4.1 GENERAL DESCRIPTION

The main difference between the two-jet and the five-jet interaction program is the fact that the diagonal $y = \pm z$ is no longer a symmetry axis. Consequently, the storage of the dependent variables, the vector W, is different. Since the basic grid is rectangular, the elements of W are stored in the three-dimensional array

$$W(J, M, N) \qquad J = 1, 2, 3, 4.$$

The rest of the program logic is the same as for the five-jet program except that, of course, the reflection about the diagonal and the growth of the three-dimensional region in direction of increasing y are omitted.

4.2 INPUT DATA

The input data are the same in the two programs except that there is only one tolerance C which governs the growth of the three-dimensional region.

APPENDIX A

SINGLE JET PROGRAM

Input Cards Format

FORTRAN Listing

W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8
±	±	±	±	±	±	±	±
THE FIRST CARD ENTRIES OCCUPY 10 SPACES. EACH ENTER THE VALUE AND ITS EXPONENT							
CARD 1							
GAM	LAM1	DØ	BK	FACTOR	ALP	FF	XO
E10.5	E10.5	E10.5	E10.5	E10.5	E10.5	E10.5	E10.5
EACH ENTRY ON THE CARD BELOW OCCUPIES 10 SPACES. THE FIRST ENTRY USES THE ABOVE FORMAT. THE LAST THREE ENTRIES ARE RIGHT ADJUSTED INTEGER VALUES.							
CARD 2							
SR	IPRINT	LL	DELPNT				
E10.5	I10	I10	I10				
ENTRIES BELOW ARE SUPPLIED BY AN EXISTING PROGRAM WHICH PUNCHES THE INPUT CARDS							
REMAINING CARDS							
Z	Q	P					
E10.5	E10.5	E10.5					
LOAD FROM AXIS TO BOUNDARY							

Input Cards Format

```
$IBJOB JETT     MAP,LOGIC
$IBFTC MAIN     LIST                                                    JET   10
C                                                                       JET   20
C                                                                       JET   30
C                                                                       JET   40
C     THE JET PROGRAM                                                   JET   50
C                                                                       JET   60
C                                                                       JET   70
C                                                                       JET   80
      COMMON /ALL/ DO,RR                                                JET   90
      COMMON /WJ1234/ WJ(100,3)                                         JET  100
      COMMON /INPWJ/ MO,LAM1,BK,R,U,V,PR,IFLAG,MR,ALP                   JET  110
      COMMON /INPJET/ RH(30),AN(30),B(30),YH(30),MN(30)                 JET  120
      COMMON /INPPRO/ GAM1,GAM2,GAM                                     JET  130
      DIMENSION W1(3),UVP(3),MOR(3),UVP3(3),UVP4(3)                     JET  140
      DIMENSION WJET(30,100,3),W3D(3,80),RX(3),YY(3),WW(3)              JET  150
      REAL LAM1,MOR                                                     JET  160
      INTEGER DELPNT                                                    JET  170
      PI = 3.14159265                                                   JET  180
C                                                                       JET  190
C     READ INPUT PARAMETERS                                             JET  200
C                                                                       JET  210
      READ (5,10) GAM,LAM1,DO,BK,FACTOR,ALP,FF,X0,SR,IPRINT,LL,DELPNT   JET  220
   10 FORMAT (8E10.5/ L10.5,3I10)                                       JET  230
C     IF FACTOR IS ZERO LAM1 = CONSTANT                                 JET  240
C     IF FACTOR IS NON-ZERO LAM1 = VARIABLE                             JET  250
C                                                                       JET  260
C     PRINT INPUT DATA DEFINITIONS                                      JET  270
C                                                                       JET  280
      WRITE (6,20)                                                      JET  290
   20 FORMAT (1H1,26(/),26X3H*  7H*****  7(1H*),10X5(1H*),3X5(1H*),2X2(8JET  300
     *H  ****  ),6H *****4X4H****3X1H*5X,1H*/26X,4H*  *,9X,1H*,13X,1H*,6JET  310
     *(4X,4H*  *),1H*,3X2H**/26X,4H*  *,9X,1H*13X1H*,3(4X,4H*  *),7X1H*2JET  320
     *(4X,4H*  *),3(2H *)/26X1H*2X4H****6X,1H*,13X,2(5(1H*),3X),1H*,4X,4JET  330
     *H*  *,7X,5(1H*),3X,6(1H*),3(3H  *)/26X,4H*  *,9X,1H*,13X,1H*,7X,3HJET  340
     ** *,5X,1H*,4X,9H*  *  ***,2X,3H* *,5X,1H*,4X,4H*  *,5X,1H*/22X,1H*JET  350
     *,3X,4H*  *,9X,1H*,13X,1H*,7X,4H*  *,4X,1H*,2(4X,4H*  *),3H  *,2(4XJET  360
     *,1H*),2X,2(1H*,5X)/23X,3H***,3X,5(1H*),5X,1H*,13X,1H*,7X1H*3X1H*4XJET  370
     *,4H****,4X,4H****,3(3X,1H*),4X,4H*  *,5X,1H*/1H1)                 JET  380
      WRITE (6,30)                                                      JET  390
   30 FORMAT (36X,2(1H*,2X),4H *  ,4(1H*),2(3X,1H*),2X,5(1H*),7X,4(1H*),JET  400
     *4X,3H***,3X,5(1H*),3X,3H***/36X,5H*  **,2(2X,1H*),1X,2(2X,1H*),3X,JET  410
     *2(1H*,4X),2X,2(3X,1H*),2X,2(1H*,3X),3H * ,2(3X,1H*)/10X,5(2H* ),14JET  420
     *X,2(2X,1H*),2(2H *),2X,4(1H*),2(3X,1H*),4X,1H*,6X,2(3X,1H*),2X,5(1JET  430
     *H*),4X,1H*,4X,5(1H*),16X,5(2H *)/34X,3(3H  *),2(3H*  ),4X,2(1H*,3XJET  440
     *),2H *,6X,2(3X,1H*),2X,2(1H*,3X),3H * ,2(3X,1H*)/34X,2(3H  *),1X,2JET  450
     *(3H  *),7X,3H***,5X,1H*,9X,4H****,2(3X,1H*),2(4X,1H*),3X,1H*/////)JET  460
      WRITE (6,40) GAM                                                  JET  470
   40 FORMAT (48X,30HRATIO OF SPECIFIC HEATS GAM = ,F6.2/78X,6(1H-)//)  JET  480
      WRITE (6,50) BK                                                   JET  490
   50 FORMAT (23X,77HINITIAL POLAR ANGLE DIVIDED BY DO MEASURED FROM JETJET  500
     * AXIS TO BOUNDARY IS BK = ,F8.3/100X,8(1H-)//)                    JET  510
      WRITE (6,60) SR                                                   JET  520
   60 FORMAT (37X,5HSR = ,F7.3,46H IS THE POLAR DISTANCE OF THE INITIAL JET  530
     *DATA ARC/42X,7(1H-)//)                                            JET  540
```

```
      WRITE (6,70) X0                                                   JET  550
   70 FORMAT (31X,64HDISTANCE BETWEEN NOZZLE EXIT AND ORIGIN OF POLAR SYJET  560
     *STEM IS X0 = ,F7.3/95X,7(1H-)//)                                  JET  570
      WRITE (6,80) DO                                                   JET  580
   80 FORMAT (34X,49HTHE ANGULAR STEP SIZE BETWEEN POLAR RAYS IS DO = ,FJET  590
     *7.4,8H DEGREES/83X,7(1H-)//)                                      JET  600
      WRITE (6,90) LL                                                   JET  610
   90 FORMAT (43X,46HTHE MAXIMUM NUMBER OF ARCS CALCULATED IS LL = ,I5/8JET  620
     *9X,5(1H-)//)                                                      JET  630
      IF (FACTOR.EQ.0.0) WRITE (6,100) FACTOR                           JET  640
  100 FORMAT (41X51HFACTOR = 0 MAKES LAM1 CONSTANT FOR ALL COMPUTATIONS/JET  650
     *//)                                                               JET  660
      IF (FACTOR.NE.0.0) WRITE (6,110) FACTOR                           JET  670
  110 FORMAT (31X,61HCONSTANT MULTIPLIER FACTOR TO VARIABLE LAM1 TERM ISJET  680
     * FACTOR = ,F8.4/92X,8(1H-)//)                                     JET  690
      WRITE (6,120) ALP                                                 JET  700
  120 FORMAT (30X,66HTHE WEIGHTED AVERAGING FACTOR FOR THE RADIUS OF CURJET  710
     *VATURE IS ALP= ,F7.3/96X,7(1H-)//)                                JET  720
      WRITE (6,130) LAM1                                                JET  730
  130 FORMAT (38X,49HINITIAL RATIO OF GRID STEP SIZES DR/DS IS LAM1 = ,FJET  740
     *6.4/87X,8(1H-)///59X,13HOUTPUT FORMAT///)                         JET  750
      IF (IPRINT.EQ.1) WRITE (6,140) IPRINT                             JET  760
  140 FORMAT (40X,9HIPRINT = ,I2,41H PRINTS VALUES IN CYLINDRICAL COORDIJET  770
     *NATES/50X,1H-//)                                                  JET  780
      IF (IPRINT.EQ.2) WRITE (6,150) IPRINT                             JET  790
  150 FORMAT (43X,9HIPRINT = ,I2,35H PRINTS VALUES IN POLAR COORDINATES/JET  800
     *53X,1H-//)                                                        JET  810
      WRITE (6,160) DELPNT                                              JET  820
  160 FORMAT (40X,6HEVERY ,I3,53H TH CYLINDRICAL PLANE OR ARC WILL BE PRJET  830
     *INTED (DELPNT)/46X,3H---//)                                       JET  840
      IF (IPRINT.EQ.1) WRITE (6,170) FF                                 JET  850
  170 FORMAT (30X,6H FF = ,F7.3,59H IS THE RATIO OF DX/DY ON THE CYLINDRJET  860
     *ICAL COORDINATE SYSTEM/36X,7(1H-)//)                              JET  870
      JUMP = DELPNT-1                                                   JET  880
      DO = DO*PI/180.                                                   JET  890
      RR = 1.0                                                          JET  900
      II = 0                                                            JET  910
      L1 = 0                                                            JET  920
      DY = 0.0                                                          JET  930
      RX(1) = 0.0                                                       JET  940
      RX(2) = 0.0                                                       JET  950
      XX = RR                                                           JET  960
      GAM1 = GAM/(GAM-1.0)                                              JET  970
      GAM2 = (GAM+1.0)/(GAM-1.0)                                        JET  980
      H = .5*GAM2                                                       JET  990
      M0 = BK                                                           JET 1000
C                                                                       JET 1010
C     AXIS OF JET CORRESPONDS TO K=2 GRID LINE                          JET 1020
C                                                                       JET 1030
      M3 = M0+2                                                         JET 1040
      MR = 100-M3                                                       JET 1050
C                                                                       JET 1060
C     M3 IS A GRID POINT ON OR JUST ABOVE JET BOUNDARY                  JET 1070
C                                                                       JET 1080
      IF (BK.NE.FLOAT(M0)) M3 = M3+1                                    JET 1090
```

```
      DO 180 K=2,M3                                                     JET 1100
      READ (5,10) Z,Q,P                                                 JET 1110
      O = FLOAT(K-2)*DO                                                 JET 1120
      IF(K.EQ.M3) O = BK*DO                                             JET 1130
      U = Q*COS(Z-O)                                                    JET 1140
      V = Q*SIN(Z-O)                                                    JET 1150
      R = GAM1*P/(H-.5*(U**2+V**2))                                     JET 1160
C                                                                       JET 1170
C     CALCULATE W INITIAL VALUES                                        JET 1180
C                                                                       JET 1190
      WJ(K,1) = R*U*RR**2*SIN(O)                                        JET 1200
      WJ(K,2) = (P+R*U**2)*RR**2*SIN(O)                                 JET 1210
  180 WJ(K,3) = R*U*V*RR**3*SIN(O)                                      JET 1220
C                                                                       JET 1230
C     LAST FLUID PROPERTIES CALCULATED IN ABOVE LOOP ARE BOUNDARY VALUESJET 1240
C                                                                       JET 1250
      PR = P                                                            JET 1260
      IFLAG = 0                                                         JET 1270
      GO TO 200                                                         JET 1280
  190 CALL WJJ                                                          JET 1290
      M3 = M0+2                                                         JET 1300
      IF (BK.GT.FLOAT(M0))M3 = M3+1                                     JET 1310
  200 IFLAG = IFLAG+1                                                   JET 1320
      DD = DO*180./PI                                                   JET 1330
C                                                                       JET 1340
C     THE X AND Y VALUES ARE CALCULATED IN REFERENCE TO THE NOZZLE EXIT JET 1350
C                                                                       JET 1360
      XB = RR*SR*COS(BK*DO)-X0                                          JET 1370
      YB = RR*SR*SIN(BK*DO)                                             JET 1380
      IF (IPRINT.NE.2) GO TO 240                                        JET 1390
C                                                                       JET 1400
C     PRINT POLAR VALUES AND HEADERS                                    JET 1410
C                                                                       JET 1420
      WRITE(8) IFLAG,RR,LAM1,BK,DO,XB,YB                                JET 1430
      JUMP = JUMP +1                                                    JET 1440
      JUMP = MOD(JUMP,DELPNT)                                           JET 1450
      IF (JUMP.NE.0) GO TO 240                                          JET 1460
      WRITE (6,210)                                                     JET 1470
  210 FORMAT (1H1)                                                      JET 1480
      WRITE (6,220) IFLAG,RR,DD,LAM1,XB,YB                              JET 1490
  220 FORMAT (7X,10HPLANE  L =,I3,5X,11HR(L)/R(1) =,F10.5,5X,4HDO =,F10.JET 1500
     *5,5X,6HLAM1 =,F10.6,5X,4HXB =,F10.5,5X,4HYB =,F10.5///)           JET 1510
      WRITE (6,230)                                                     JET 1520
  230 FORMAT (11X,7HDENSITY,8X,8HPRESSURE,5X,11HTEMPERATURE,6X,7HENTROPYJET 1530
     *,8X,3(8HVELOCITY,7X),8HMACH NO./4X,1HM,9X,1HR,14X,1HP,14X,1HT,14X,JET 1540
     *1HE,14X,1HU,14X,1HV,14X,1HQ,14X,1HM//)                            JET 1550
C                                                                       JET 1560
C     EXTRAPOLATE FLUID PROPERTIES FROM K=3 AND 4 LINES TO AXIS         JET 1570
C                                                                       JET 1580
  240 CALL PROPWJ (WJ,3,MOR,UVP3,2,100,3)                               JET 1590
      CALL PROPWJ (WJ,4,MOR,UVP4,2,100,4)                               JET 1600
      U1 = (4.0*UVP3(1)-UVP4(1))/3.0                                    JET 1610
      V1 = 0.0                                                          JET 1620
      P1 = (4.0*UVP3(3)-UVP4(3))/3.0                                    JET 1630
      R1 = GAM1*P1/(H-.5*U1**2)                                         JET 1640
```

```
      AM = U1/SQRT(GAM*P1/R1)                                           JET 1650
      ANG = 0.0                                                         JET 1660
      IF (FACTOR.NE.0.0) UM = ATAN2(1.0,SQRT(AM**2-1.0))                JET 1670
      IF (IPRINT.EQ.2) GO TO 270                                        JET 1680
      II = II+1                                                         JET 1690
C                                                                       JET 1700
C     A MAXIMUM OF 30 JET PLANES ARE USED TO CALCULATE ONE CYLINDRICAL  JET 1710
C     PLANE                                                             JET 1720
C                                                                       JET 1730
      IF (II.LE.30) GO TO 260                                           JET 1740
      WRITE (6,250)                                                     JET 1750
  250 FORMAT (55HTOO MANY JET PLANES ARE REQUIRED TO CALCULATE 3-D PLANEJET 1760
     *)                                                                 JET 1770
      STOP                                                              JET 1780
C                                                                       JET 1790
C     PARAMETERS OF JET PLANE ARE STORED IN THE FOLLOWING ARRAYS FOR USEJET 1800
C     IN COMPUTING CYLINDRICAL PLANES                                   JET 1810
C                                                                       JET 1820
  260 RH(II) = RR                                                       JET 1830
      YH(II) = YB/SR                                                    JET 1840
      MN(II) = M3                                                       JET 1850
      B(II) = BK                                                        JET 1860
      AN(II) = DO                                                       JET 1870
C                                                                       JET 1880
C     L1 REPRESENTS JET PLANE THOSE DO VALUE CHANGES                    JET 1890
C                                                                       JET 1900
      IF (II.NE.1.AND.AN(II).NE.AN(II-1)) L1 = II                       JET 1910
      THETA = 0.0                                                       JET 1920
  270 DO 320 K=2,M3                                                     JET 1930
      L = K                                                             JET 1940
      IF (K.EQ.2) GO TO 290                                             JET 1950
      IF (K.NE.M3) GO TO 280                                            JET 1960
      IF (BK.EQ.FLOAT(M0)) GO TO 280                                    JET 1970
C                                                                       JET 1980
C     BOUNDARY VALUES PRINTED OUT                                       JET 1990
C                                                                       JET 2000
      U1 = U                                                            JET 2010
      V1 = V                                                            JET 2020
      P1 = PR                                                           JET 2030
      R1 = R                                                            JET 2040
      ANG = ATAN2(V,U)*180./PI                                          JET 2050
      AM = SQRT((U1**2+V1**2)/(GAM*P1/R1))                              JET 2060
C                                                                       JET 2070
C     BOUNDARY L IS GRID POINT POSITION MULTIPLIED BY 100               JET 2080
C                                                                       JET 2090
      L = (BK+2.005)*100.0                                              JET 2100
      CK = M0                                                           JET 2110
      THETA = BK*DO                                                     JET 2120
      GO TO 290                                                         JET 2130
C                                                                       JET 2140
C     CALCULATE FLUID PROERTIES FOR PRINT OUT                           JET 2150
C                                                                       JET 2160
  280 CALL PROPWJ (WJ,K,MOR,UVP,2,100,K)                                JET 2170
      U1 = UVP(1)                                                       JET 2180
      V1 = UVP(2)                                                       JET 2190
```

```
      P1 = UVP(3)                                                       JET 2200
      AM = MOR(1)                                                       JET 2210
      ANG = MOR(2)                                                      JET 2220
      R1 = MOR(3)                                                       JET 2230
      THETA = FLOAT(K-2)*DO                                             JET 2240
  290 Q1 = SQRT(U1**2+V1**2)                                            JET 2250
C                                                                       JET 2260
C     ENT IS THE ENTROPY                                                JET 2270
C                                                                       JET 2280
      ENT = P1/(R1**GAM)                                                JET 2290
      TEM = GAM*P1/R1                                                   JET 2300
      ANGL = ANG*PI/180.0                                               JET 2310
      IF (FACTOR.NE.0.0) UM = AMAX1 (UM,ATAN2(1.0,SQRT(AM**2-1.0))+ABS( JET 2320
     *ANGL))                                                            JET 2330
      IF (IPRINT.EQ.2) GO TO 300                                        JET 2340
      THETA = THETA+ANGL                                                JET 2350
C                                                                       JET 2360
C     CONVERT POLAR COORDINATE W'S INTO CYLINDRICAL COORDINATES         JET 2370
C                                                                       JET 2380
      UU = COS(THETA)*Q1                                                JET 2390
      VV = SIN(THETA)*Q1                                                JET 2400
      WJET(II,K,1) = R1*UU                                              JET 2410
      WJET(II,K,2) = R1*UU**2+P1                                        JET 2420
      WJET(II,K,3) = R1*UU*VV                                           JET 2430
      GO TO 320                                                         JET 2440
C                                                                       JET 2450
C     WRITE POLAR JET TAPE AND PRINT POLAR VALUES                       JET 2460
C                                                                       JET 2470
  300 WRITE (8) R1,P1,U1,V1,Q1,AM,ANGL                                  JET 2480
      IF (JUMP.NE.0) GO TO 320                                          JET 2490
      WRITE (6,310) L,R1,P1,TEM,ENT,U1,V1,Q1,AM                         JET 2500
  310 FORMAT (I5,8E15.5)                                                JET 2510
  320 CONTINUE                                                          JET 2520
C                                                                       JET 2530
C     CALCULATE LAM1 FOR NEXT PLANE                                     JET 2540
C                                                                       JET 2550
      IF (FACTOR.NE.0.0) LAM1 = FACTOR/TAN(UM)                          JET 2560
      IF (IPRINT.EQ.2) GO TO 480                                        JET 2570
C                                                                       JET 2580
C     BELOW CYLINDRICAL W PLANES ARE DETERMINED                         JET 2590
C                                                                       JET 2600
      LP = II                                                           JET 2610
      RX(3) = RX(2)                                                     JET 2620
      RX(2) = RX(1)                                                     JET 2630
      RX(1) = RR*COS(BK*DO)                                             JET 2640
  330 IF (RX(2).LT.XX) GO TO 440                                        JET 2650
C                                                                       JET 2660
C     LP REPRESENTS THE NUMBER OF JET PLANES NECESSARY TO FILL IN A 3-D JET 2670
C                                                                       JET 2680
      CALL POLATE (YH(LP-2),Y,0,RX(3),RX(2),RX(1),XX,1)                 JET 2690
      IF (DY.NE.0.0) GO TO 360                                          JET 2700
C                                                                       JET 2710
C     FIND THE GRID SIZE OF CYLINDRICAL PLANES VALUE OF Y/DY BETWEEN 40 JET 2720
C     AND 80                                                            JET 2730
C                                                                       JET 2740
```

```
      DY1 = Y/40.0                                                      JET 2750
      DO 340 I=1,10                                                     JET 2760
      DY1 = DY1*10.0                                                    JET 2770
      DY = FLOAT(IFIX(DY1))/10.0**I                                     JET 2780
  340 IF (Y/DY.GE.40.0.AND.Y/DY.LE.77.0) GO TO 350                      JET 2790
  350 DX = FF*DY                                                        JET 2800
  360 RHO = -DY                                                         JET 2810
      MAX = Y/DY+2.0                                                    JET 2820
      IF (MAX.LE.79) GO TO 370                                          JET 2830
C                                                                       JET 2840
C     IF TOO MANY GRID POINTS ARE NEEDED DY CHANGES SIZE TO REDUCE THE  JET 2850
C     NUMBER OF POINTS                                                  JET 2860
C                                                                       JET 2870
      DY = 2.0*DY                                                       JET 2880
      GO TO 360                                                         JET 2890
  370 MAX1 = MAX+1                                                      JET 2900
      DO 380 M=2,MAX                                                    JET 2910
      RHO = RHO+DY                                                      JET 2920
      I = 1                                                             JET 2930
C                                                                       JET 2940
C     L1 REPRESENTS THE JET PLANE WHOSE RESOLUTION HAS DOUBLED          JET 2950
C     WJET (PLANE,POSITION,PROPERTY)                                    JET 2960
C                                                                       JET 2970
C     INTERPOLATE W VALUES AT CYLINDRICAL GRID POINTS                   JET 2980
C                                                                       JET 2990
      CALL JET (WJET(1,1,1),W3D(1,M),I,RHO,L1,LP,XX)                    JET 3000
      CALL JET (WJET(1,1,2),W3D(2,M),I,RHO,L1,LP,XX)                    JET 3010
  380 CALL JET (WJET(1,1,3),W3D(3,M),I,RHO,L1,LP,XX)                    JET 3020
      DO 400 I=1,3                                                      JET 3030
      DO 390 J=1,3                                                      JET 3040
      M = LP+J-3                                                        JET 3050
C                                                                       JET 3060
C     MN REPRESENTS THE POSITION WHERE BOUNDARY IS TO BE STORED         JET 3070
C                                                                       JET 3080
      NM = MN(M)                                                        JET 3090
  390 WW(J) = WJET (M,NM,I)                                             JET 3100
C                                                                       JET 3110
C     INTERPOLATE W'S AT JET BOUNDARY                                   JET 3120
C                                                                       JET 3130
  400 CALL POLATE (WW,W3D(I,MAX1),0,RX(3),RX(2),RX(1),XX,1)             JET 3140
      XD = XX+DX                                                        JET 3150
C                                                                       JET 3160
C     WRITE CYLINDRICAL JET TAPE                                        JET 3170
C                                                                       JET 3180
      WRITE(8) XD,XX,DX,Y,DY,MAX1,W3D                                   JET 3190
      XP = SR*XX-X0                                                     JET 3200
      YP = Y*SR                                                         JET 3210
      DYP = DY*SR                                                       JET 3220
      JUMP = JUMP +1                                                    JET 3230
      JUMP = MOD(JUMP,DELPNT)                                           JET 3240
C                                                                       JET 3250
C     PRINT EVERY DELPNT PLANE                                          JET 3260
C                                                                       JET 3270
      IF (JUMP.NE.0) GO TO 430                                          JET 3280
C                                                                       JET 3290
```

```
C     WRITE HEADERS AND PRINT CYLINDRICAL JET FLUID PROPERTIES
C
      WRITE (6,410) XP,YP,DYP,DY
  410 FORMAT (1H1,24X,3HX =,F10.5,10X,3HY =,F10.5,10X,4HDY =,F10.5,10X
     *,4HDR =,F10.5////13X,7HDENSITY,5X,8HPRESSURE,4X,11HTEMPERATURE,4X,
     *7HENTROPY6X3(8HVELOCITY5X),1X,5HERROR,7X,8HMACH NO./8X,1HM,7X,1HR,
     *12X,1HP,12X,1HT,12X,1HS,12X,1HU,12X,1HV,12X,1HQ,12X,1HE,12X,1HM//)
      DO 420 M=2,MAX
  420 CALL PROP3D (W3D(1,M),M)
      CALL PROP3D (W3D(1,MAX1),IFIX((Y/DY+2.005)*100.0))
  430 XX = XD
C
C     SEE IF ANY MORE CYLINDRICAL PLANES ARE POSSIBLE TO CALCULATED WITH
C     THE EXITING INFORMATION
C
      GO TO 330
  440 DO 450 I=1,LP
      K = I
  450 IF (RH(I).GT.XX) GO TO 460
  460 K = K-2
      IF (K.LE.1) GO TO 480
C
C     SHIFT OUT UNUSEABLE DATA IN ORDER TO MAKE ROOM FOR MORE JET DATA
C     ALL USEFUL DATA WILL BEGIN WITH FIRST LOCATION OF ANY JET ARRAY UP
C     TO LP - LAST JET INFORMATION
C
      DO 470 I=K,LP
      II = I-K+1
      RH(II) = RH(I)
      YH(II) = YH(I)
      MN(II) = MN(I)
      B(II) = B(I)
      AN(II) = AN(I)
      NM = MN(I)
      DO 470 J=1,3
      DO 470 M=2,NM
  470 WJET(II,M,J) = WJET(I,M,J)
C
C     SHIFT LOCATION OF PLANE CONTAINING NEW DO
C
      L1 = L1-(K-1)
C
C     CALCULATE IFLAG NUMBER OF POLAR JET PLANES
C
  480 IF (IFLAG.NE.LL) GO TO 190
      WRITE (6,490)
  490 FORMAT (1H1,20(/),18X,4H****,4X,3H***,3X,5H*****,3X,3H***,9X,3H***
     *,2(3X,1H*),10X,7H*  ****,2X,5(1H*),7X,5(1H*),3X,3H***,3X,4H****,3X
     *4H****/18X1H*3X4H*  *3X2(1H*4X),1H*3X1H*4X2(3X1H*),2X2H**3H  *10X,
     *4H*  *,7X,1H*,11X,1H*4X,1H*,2(3X,4H*  *)/18X,1H*,3X,8H*  *****,4X
     *,1H*,4X,5(1H*),7X,1H*,3X,1H*,2X,3(2H* ),9X,6H*  ***,5X,1H*,11X,1H*
     *4X,5(1H*),2X,4H****,3X,3H***/18X,1H*,3X,4H*  *,3X,2(1H*,4X),2(1H*,
     *3X),1X,2(3X1H*),3H  *,2X,2H**,5X,3(3H  *),7X,1H*,11X,1H*,4X,1H*,3X
     *1H*2X1H*6X1H*/18X4H****3X1H*,3X,1H*,2(4X,1H*),3X,1H*,8X,3H***,2(3X
     *,1H*),8X,2H**,3X,4H****,4X,1H*,11X,1H*,4X,1H*,3X,1H*,2X,1H*,6X,4H*
```

```
   ****)                                                                JET 3850
    WRITE (6,500)                                                       JET 3860
500 FORMAT (//27X,1H*,3X,3H***,7X2(1H*,3X),3H***2X2(4H****,2X),6X,4H* JET 3870
   * *,3X,1H*,7X,5(1H*),3(3H  *),3H***/27X,4H*  *,7X,2(3X,1H*),2X,1H*,JET 3880
   *2(5X,1H*),3X,1H*,7X,8H*  **  *, 9X,1H*,4X,3(3H*  )/27X,1H*,3X,2H**JET 3890
   *,8X,2(4H*   ),2H**,3X,3H***,2(3X,1H*),7X,2H* ,3(2H *), 9X,1H*,4X,4JET 3900
   *H****,2X,3H***/27X,1H*,5X,1H*,7X,2(1H*,3X),2(2X,1H*),5X2(4H*   ),4JET 3910
   *X,2(3H*  ),2H**, 9X1H*4X3(3H*  )/27X,6H*  ***,9X,2(3H***,3X),2(4H*JET 3920
   ****,2X),6X,2(3H*  ),2H * 9X,1H*,4X,2(3H*  ),4H****)                JET 3930
    WRITE (6,510)                                                       JET 3940
510 FORMAT (//3X,2(3H*  ),4H *  ,5(1H*),2(2X,4H****),2(4X,3H***),2X,5(JET 3950
   *1H*),2X,1H*,3X,3H***,2(3X,1H*),7X,2(4H****,3X),4H ***,2X,2(2X,4H**JET 3960
   ***),4X,3H***3(3X,1H*),2H**/3X,5H*  **,2X,3(1H*,4X),2H *,2(3X,4H*  JET 3970
   **),7X,1H*,4X,2(3H*  ), 9H *  **  *,7X,3(1H*,3X,3H*  ),1H*,6X, 2(1HJET 3980
   **,3X,3H*  ),8H** **  */3X,3H*  ,3(2H* ),3X,1H*,4X,3H***,3X,4H****,JET 3990
   *3X,5H*****,2X,1H*,7X,1H*,4X,2(3H*  ),3H * ,3(2H *),7X,2(4H****,3X)JET 4000
   *,1H*,3X,1H*,7H  * ***,2X,4H****,3X,5(1H*),2X,3(2H* ),4H  **/3X,2(3JET 4010
   *H*  ),2H**,2(4X,1H*),5X,2(2H* ),2(3X,1H*),2X,1H*,7X,1H*,4X,1H*,2X,JET 4020
   *1H*,3X,2(3H*  ),3H** ,2(6X,1H*),2H *,4X,1H*,3X,1H*,2X,1H*,3X,1H*,2JET 4030
   *X,4H* * ,2(3X,1H*),2X,2(1H*,3X),3H  */3X,2(3H*  ),1X,2(1H*,4X),4H*JET 4040
   ****,2(3H  *),2(3X,1H*),3X,3H***,2(4X,1H*),3X,3H***,2(3X,1H*),1X2(6JET 4050
   *X,1H*),3H  *,4X,3H***,4X,4H*** ,2(3H  *),2(3X,1H*),2X,1H*,3X,6H*  JET 4060
   ****)                                                                JET 4070
    STOP                                                                JET 4080
    END                                                                 JET 4090
```

```
$IBFTC WJJ      LIST                                                    WJJ   10
      SUBROUTINE WJJ                                                    WJJ   20
      COMMON /ALL/ DO,RR                                                WJJ   30
      COMMON /WJ1234/ WJ(100,3)                                         WJJ   40
      COMMON /INPWJ/ M0,LAM1,BK,R,U,V,PR,IFLAG,MR,ALP                   WJJ   50
      COMMON /WJJPRE/ ALPHA,THETA,LL(6),PL(6),P(10,6)                   WJJ   60
      DIMENSION F(3,3),Q(3,3),PRS(2)                                    WJJ   70
      REAL LAM1                                                         WJJ   80
      CK = M0                                                           WJJ   90
      CC = (BK-CK)*DO                                                   WJJ  100
      M2 = M0+2                                                         WJJ  110
      M1 = M2-1                                                         WJJ  120
C                                                                       WJJ  130
C     FIND F AND Q'S AT K,K+1                                           WJJ  140
C                                                                       WJJ  150
      CALL PROPWJ(WJ,M2,F(1,3),Q(1,3),1,100,M2)                         WJJ  160
      CALL PROPWJ(WJ,M1,F(1,2),Q(1,2),1,100,M1)                         WJJ  170
C                                                                       WJJ  180
C     LL GIVES UPPER RAY                                                WJJ  190
C     PL GIVES DISTANCE FROM VERTEX TO PRESSURE VALUES                  WJJ  200
C     P IS PRESSURE VALUES THAT ARE SAVED                               WJJ  210
C                                                                       WJJ  220
      IF (IFLAG.GT.1) GO TO 20                                          WJJ  230
      DO 10 L=1,4                                                       WJJ  240
      LL(L) = 0.0                                                       WJJ  250
      PL(L) = 0.0                                                       WJJ  260
      DO 10 K=1,6                                                       WJJ  270
   10 P(K,L) = 0.0                                                      WJJ  280
      THETA = BK*DO                                                     WJJ  290
C                                                                       WJJ  300
C     INITIAL ALPHA FOR BOUNDARY                                        WJJ  310
C                                                                       WJJ  320
      ALPHA =-ATAN2(U*SIN(THETA)+V*COS(THETA),U*COS(THETA)-V*SIN(THETA))WJJ  330
      CC = CC+DO                                                        WJJ  340
      IPN = 1                                                           WJJ  350
      GO TO 40                                                          WJJ  360
C                                                                       WJJ  370
C     THE PRESSURE INFORMATION IS SAVE FOR THE CURRENT SIX POLAR PLANES WJJ  380
C                                                                       WJJ  390
   20 DO 30 L=1,4                                                       WJJ  400
      LL(L) = LL(L+1)                                                   WJJ  410
      PL(L) = PL(L+1)                                                   WJJ  420
      DO 30 K=1,6                                                       WJJ  430
   30 P(K,L) = P(K,L+1)                                                 WJJ  440
C                                                                       WJJ  450
C     MR IS USED AS A REFERENCE MARK IN ORDER TO DISTINGUISH ONE RAY    WJJ  460
C     FROM ANOTHER (FOR PRESSURE PURPOSES ONLY)                         WJJ  470
C                                                                       WJJ  480
   40 LL(5) = MR+M2                                                     WJJ  490
      PL(5) = RR                                                        WJJ  500
      DO 50 N=1,6                                                       WJJ  510
      K = M2+1-N                                                        WJJ  520
C                                                                       WJJ  530
C     FIND THE 6 PRESSURE VALUES CLOSE TO THE BOUNDARY OF CURRENT PLANE WJJ  540
C                                                                       WJJ  550
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```
   50 CALL PROPWJ (WJ,K,X,P(N,5),3,100,K)                              WJJ  560
      DO 90 N=2,M1                                                     WJJ  570
      K = M1+2-N                                                       WJJ  580
      IF (K.EQ.2) GO TO 80                                             WJJ  590
      IF (K.NE.3) GO TO 70                                             WJJ  600
C                                                                      WJJ  610
C     F AND Q VALUES AT K=2 ARE ZERO EXCEPT Q(3,1)                     WJJ  620
C                                                                      WJJ  630
      DO 60 J=1,3                                                      WJJ  640
      F(J,1) = 0.0                                                     WJJ  650
   60 Q(J,1) = 0.0                                                     WJJ  660
      CALL PROPWJ (WJ,K+1,X,PRS(2),3,100,K+1)                          WJJ  670
      CALL PROPWJ (WJ,K,X,PRS(1),3,100,K)                              WJJ  680
C                                                                      WJJ  690
C     EXTRAPOLATE Q(3,1) FROM K=3 AND 4                                WJJ  700
C                                                                      WJJ  710
      Q(3,1) = (4.0*PRS(1)-PRS(2))/3.0*RR**3                           WJJ  720
      GO TO 80                                                         WJJ  730
C                                                                      WJJ  740
C     FIND F AND Q AT K=1                                              WJJ  750
C                                                                      WJJ  760
   70 CALL PROPWJ(WJ,K-1,F(1,1),Q(1,1),1,100,K-1)                      WJJ  770
C                                                                      WJJ  780
C     FIND W'S FOR NEXT PLANE                                          WJJ  790
C                                                                      WJJ  800
   80 CALL WJET (F,Q,WJ,WJ(K+1,1),LAM1,K)                              WJJ  810
      DO 90 I=1,2                                                      WJJ  820
      II = -I+3                                                        WJJ  830
      DO 90 J=1,3                                                      WJJ  840
      F(J,II+1) = F(J,II)                                              WJJ  850
   90 Q(J,II+1) = Q(J,II)                                              WJJ  860
C                                                                      WJJ  870
C     STORE W'S CORRECTLY                                              WJJ  880
C                                                                      WJJ  890
      DO 100 K=2,M1                                                    WJJ  900
      DO 100 J=1,3                                                     WJJ  910
  100 WJ(K,J) = WJ(K+1,J)                                              WJJ  920
C                                                                      WJJ  930
C                                                                      WJJ  940
C     THE POLAR JET BOUNDARY IS HANDLED BELOW                          WJJ  950
C                                                                      WJJ  960
C                                                                      WJJ  970
      LL(6) = MR+M1                                                    WJJ  980
C                                                                      WJJ  990
C     FIND THE NEXT PLANE'S DISTANCE FROM JET VERTEX                   WJJ 1000
C                                                                      WJJ 1010
      PL(6) = RR*(1.+LAM1*DO)                                          WJJ 1020
      RP = RR                                                          WJJ 1030
      RR = PL(6)                                                       WJJ 1040
C                                                                      WJJ 1050
C     SOLVE FOR KNOWN PRESSURES AT PLANE L+1, (6)                      WJJ 1060
C                                                                      WJJ 1070
      DO 110 N=1,6                                                     WJJ 1080
      K = M2-N                                                         WJJ 1090
  110 CALL PROPWJ (WJ,K,X,P(N,6),3,100,K)                              WJJ 1100
```

```
      RR = RP                                                           WJJ 1110
      ALPHA1 = ALPHA                                                    WJJ 1120
      JJ = 1                                                            WJJ 1130
C                                                                       WJJ 1140
C     MA IS HIGHEST REFERENCED RAY                                      WJJ 1150
C                                                                       WJJ 1160
      MA = M2+MR                                                        WJJ 1170
      IF (IFLAG.NE.1) GO TO 130                                         WJJ 1180
C                                                                       WJJ 1190
C     FIND PRESSURE ON NORMAL VECTOR AT PLANE L ON RAY M1               WJJ 1200
C                                                                       WJJ 1210
  120 IF (IPN.EQ.0) GO TO 130                                           WJJ 1220
C                                                                       WJJ 1230
C     FIND PRESSURE ON NORMAL VECTOR AT PLANE L ON RAY M1-1             WJJ 1240
C                                                                       WJJ 1250
      CALL PRES (MA-1,M1,IFLAG,P2,RA,1)                                 WJJ 1260
      CALL PRES (MA-2,M1-1,IFLAG,P3,RB,2)                               WJJ 1270
      GO TO 140                                                         WJJ 1280
  130 CALL PRES (MA,M2,IFLAG,P2,RA,1)                                   WJJ 1290
      CALL PRES (MA-1,M2-1,IFLAG,P3,RB,2)                               WJJ 1300
  140 P1 = PR                                                           WJJ 1310
C                                                                       WJJ 1320
C     CALCULATE R2 AND R3 DISTANCE MEASURED FROM PRESSURES P2 AND P3 ON WJJ 1330
C     NORMAL TO BOUNDARY ALONG NORMAL                                   WJJ 1340
C                                                                       WJJ 1350
      IF (CC.EQ.0.0) CC = DO                                            WJJ 1360
      R2 = RR*SIN(CC)/COS(THETA+ALPHA-CC)                               WJJ 1370
      IF (IPN.EQ.0.OR.R2.LT.CC*RR/2.0) GO TO 150                        WJJ 1380
C                                                                       WJJ 1390
C     LINEARLY INTERPOLATE PRESSURE GRADIENT                            WJJ 1400
C                                                                       WJJ 1410
      PN = (P2-P1)/R2                                                   WJJ 1420
      GO TO 160                                                         WJJ 1430
  150 CC = CC+DO                                                        WJJ 1440
      R3 = RR*SIN(CC)/COS(THETA+ALPHA-CC)                               WJJ 1450
C                                                                       WJJ 1460
C     USE THREE POINT INTERPOLATION FOR PRESSURE GRADIENT               WJJ 1470
C                                                                       WJJ 1480
      PN = (P2+P3-2.0*P1)/(R2+R3)                                       WJJ 1490
  160 UV = U**2+V**2                                                    WJJ 1500
C                                                                       WJJ 1510
C     FIND THE RADIUS OF CURVATURE                                      WJJ 1520
C                                                                       WJJ 1530
      RS = -R*UV/(PN)                                                   WJJ 1540
C                                                                       WJJ 1550
C     AVERAGE TWO RADIUS OF CURVATURES                                  WJJ 1560
C                                                                       WJJ 1570
      IF (JJ.EQ.2) RS = (1.0-ALP)*RT+ALP*RS                             WJJ 1580
      RC = SQRT(RR**2+RS**2-2.0*RR*RS*SIN(THETA+ALPHA))                 WJJ 1590
      OC = THETA-ACOS((RC**2+RR**2-RS**2)/(2.*RR*RC))                   WJJ 1600
      RR = PL(6)                                                        WJJ 1610
      THETC = ACOS((RR**2+RC**2-RS**2)/(2.*RR*RC))                      WJJ 1620
      THETA = THETC+OC                                                  WJJ 1630
      BETA = ATAN2(RC*COS(OC)-RR*COS(THETA),RR*SIN(THETA)-RC*SIN(OC))   WJJ 1640
      ALPHA = -BETA                                                     WJJ 1650
```

```
      UV = SQRT(UV)                                                     WJJ 1660
      UB = UV*COS(BETA)                                                 WJJ 1670
      VB = UV*SIN(BETA)                                                 WJJ 1680
      U = UB*COS(THETA)+VB*SIN(THETA)                                   WJJ 1690
      V =-UB*SIN(THETA)+VB*COS(THETA)                                   WJJ 1700
      BK = THETA/DO                                                     WJJ 1710
      BB = RR**2*SIN(THETA)                                             WJJ 1720
C                                                                       WJJ 1730
C     CALCULATE BOUNDARY W'S                                            WJJ 1740
C                                                                       WJJ 1750
      WJ(M2,1)= R*U*BB                                                  WJJ 1760
      WJ(M2,2) = (PR+R*U**2)*BB                                         WJJ 1770
      WJ(M2,3) = R*U*V*RR*BB                                            WJJ 1780
      M0 = BK                                                           WJJ 1790
      CK = M0                                                           WJJ 1800
      M3 = M0+2                                                         WJJ 1810
      IF (M3.LT.M2) GO TO 210                                           WJJ 1820
C                                                                       WJJ 1830
C     INTERPOLATE EXTRA POINT AT M2                                     WJJ 1840
C                                                                       WJJ 1850
      IF (BK.EQ.FLOAT(M0)) GO TO 210                                    WJJ 1860
C                                                                       WJJ 1870
C     IF BK FALLS ON A GRID POINT IT IS NOT INTERPOLATED                WJJ 1880
C                                                                       WJJ 1890
      K = M2                                                            WJJ 1900
      DO 170 J=1,3                                                      WJJ 1910
  170 WJ(K+1,J) = WJ(K,J)                                               WJJ 1920
      R1 = BK-CK                                                        WJJ 1930
      IF (R1+1.0-10.0*R1) 190,180,180                                   WJJ 1940
C                                                                       WJJ 1950
C     LINEARLY INTERPOLATE FILL IN W'S FOR NEXT PLANE                   WJJ 1960
C                                                                       WJJ 1970
  180 CALL POLATE (WJ(K-1,1),WJ(K,1),0,R1+1.0,0.,0.,R1,100)             WJJ 1980
      GO TO 200                                                         WJJ 1990
C                                                                       WJJ 2000
C     QUADRATICLY INTERPOLATE FILL IN W'S FOR NEXT PLANE                WJJ 2010
C                                                                       WJJ 2020
  190 CALL POLATE (WJ(K-2,1),WJ(K,1),0,R1+2.,R1+1.,0.,R1,100)           WJJ 2030
  200 M4 = M3+1                                                         WJJ 2040
      IPN = 0                                                           WJJ 2050
      GO TO 220                                                         WJJ 2060
C                                                                       WJJ 2070
C     NO W VALUES NEED TO BE FILLED IN BETWEEN BOUNDARY AND GRID POINT  WJJ 2080
C     CLOSES TO BOUNDARY                                                WJJ 2090
C                                                                       WJJ 2100
  210 M4 = M2                                                           WJJ 2110
      IPN = 1                                                           WJJ 2120
  220 IF (JJ.EQ.2) GO TO 230                                            WJJ 2130
      JJ = 2                                                            WJJ 2140
      CC = (THETA/DO-FLOAT(IFIX(THETA/DO)))*DO                          WJJ 2150
      RT = RS                                                           WJJ 2160
C                                                                       WJJ 2170
C     CALCULATE RADIUS OF CURVATURE AGAIN (FOR AVERAGING)               WJJ 2180
C                                                                       WJJ 2190
      GO TO 120                                                         WJJ 2200
```

```
  230 CONTINUE                                                          WJJ 2210
C                                                                       WJJ 2220
C     BK.GT.42, DO REMAINS CONSTANT                                     WJJ 2230
C                                                                       WJJ 2240
      IF (BK.GT.42.0) GO TO 350                                         WJJ 2250
C                                                                       WJJ 2260
C     DO MUST BECOME TWICE AS SMALL SINCE TOO MANY RAYS HAVE BEEN LOST  WJJ 2270
C                                                                       WJJ 2280
      DO 260 L=2,5                                                      WJJ 2290
      DO 240 N=1,5                                                      WJJ 2300
      K = 6-N                                                           WJJ 2310
C                                                                       WJJ 2320
C     DOUBLE THE NUMBER OF PRESSURE VALUES                              WJJ 2330
C                                                                       WJJ 2340
  240 P(2*K,L) = P(K,L)                                                 WJJ 2350
      DO 250 K=1,3                                                      WJJ 2360
  250 CALL POLATE (P(2*K,L),P(2*K+1,L),1,4.,2.,0.,3.,1)                 WJJ 2370
      DO 260 K=2,7                                                      WJJ 2380
  260 P(K-1,L) = P(K,L)                                                 WJJ 2390
C                                                                       WJJ 2400
C     THE ABOVE ASSUMES THAT A LINE BETWEEN BOUNDARY AND RAY WILL NOT BEWJJ 2410
C                                                                       WJJ 2420
      NN = M0+2                                                         WJJ 2430
      MM = 2*(NN-1)                                                     WJJ 2440
      NM = MM+2                                                         WJJ 2450
      DO 270 J=1,3                                                      WJJ 2460
  270 WJ(NM,J) = WJ(M4,J)                                               WJJ 2470
      DO 280 N=2,NN                                                     WJJ 2480
      K = NN+2-N                                                        WJJ 2490
      DO 280 J=1,3                                                      WJJ 2500
  280 WJ(2*K-2,J) = WJ(K,J)                                             WJJ 2510
C                                                                       WJJ 2520
C     CHANGE PARAMETERS TO COMPENSATE FOR SPITTING                      WJJ 2530
C                                                                       WJJ 2540
      DO 290 L=2,5                                                      WJJ 2550
  290 LL(L) = 2*LL(L)-2-MR                                              WJJ 2560
      BK = 2.0*BK                                                       WJJ 2570
      DO = DO/2.0                                                       WJJ 2580
      M0 = BK                                                           WJJ 2590
      CK = M0                                                           WJJ 2600
      IF (M0+2.EQ.MM.OR.BK.EQ.CK) GO TO 330                             WJJ 2610
C                                                                       WJJ 2620
C     EXTRA RAY MUST BE ADDED BETWEEN BOUNDARY AND UPPER RAY            WJJ 2630
C                                                                       WJJ 2640
      CK = BK-CK                                                        WJJ 2650
      CALL POLATE (WJ(NM-4,1),WJ(NM-1,1),1,3.+CK,1.+CK,0.,CK,100)       WJJ 2660
      DO 320 L=2,5                                                      WJJ 2670
      DO 300 N=1,5                                                      WJJ 2680
      K = 6-N                                                           WJJ 2690
  300 P(K+1,L) = P(K,L)                                                 WJJ 2700
      LL(L) = LL(L)+1                                                   WJJ 2710
      IF (L.NE.5) GO TO 310                                             WJJ 2720
      P(1,L) = PR                                                       WJJ 2730
      CALL POLATE (P(1,L),P(1,L),1,CK+3.,2.,0.,3.,1)                    WJJ 2740
      GO TO 320                                                         WJJ 2750
```

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310 CALL POLATE (P(2,L),P(1,L),0,2.,1.,0.,3.,1)                    WJJ 2760
320 CONTINUE                                                       WJJ 2770
330 NM = MM-2                                                      WJJ 2780
    DO 340 K=2,NM,2                                                WJJ 2790
340 CALL POLATE (WJ(K,1),WJ(K+1,1),1,2.,0.,0.,1.,100)              WJJ 2800
350 RETURN                                                         WJJ 2810
    END                                                            WJJ 2820
```

```
$IBFTC PRES     LIST
      SUBROUTINE PRES (M,N,II,PP,R,KK)
C
C     R IS DISTANCE FROM VERTEX TO PRESSURE ON NORMAL VECTOR
C
      COMMON /WJJPRE/ ALPHA,THETA,LL(6),PL(6),P(10,6)
      COMMON /ALL/ DO,RR
      DIMENSION PR(6)
      R = RR*COS(THETA+ALPHA)/COS(FLOAT(N-2)*DO+ALPHA)
      DO 10 I=1,6
      L = I
   10 IF (R.LT.PL(I)) GO TO 20
C
C     L IS THE PLANE TO THE RIGHT OF THE POINT ON THE NORMAL
C
   20 DO 30 I=1,6
      K = LL(I)+1-M
   30 PR(I) = P(K,I)
      IF (KK.NE.1.OR.II.NE.2) GO TO 40
      L = 4
      GO TO 80
C
C     NOT ALL PRESSURE VALUES ARE KNOWN UNTIL FIRST FIVE PLANES HAVE
C     BEEN COMPUTED
C
   40 IF (II.GE.5.AND.L.NE.1) GO TO 100
      IF (II.LT.5.AND.L.GT.6-II) GO TO 100
C
C     EXTRAPOLATION IS NECESSARY BELOW
C
      K = LL(L)+1-M
      IF (K.LE.6) GO TO 70
   50 WRITE (6,60)
   60 FORMAT (1H1,32HNOT ENOUGH PRESSURE VALUES GIVEN)
      STOP
   70 IF (L+2.LE.6) GO TO 90
   80 CALL POLATE (PR(L),PP,0,PL(L)-PL(L+1),0.,0.,R-PL(L+1),1)
      GO TO 180
   90 CALL POLATE (PR(L),PP,0,PL(L)-PL(L+2),PL(L+1)-PL(L+2),0.,R-PL(L+2)
     *,1)
      GO TO 180
  100 IF (((L.LT.6.OR.PL(6).GT.R).AND.K.EQ.2).OR.(K.EQ.1.AND.PL(5).GT.R)
     1) GO TO 140
C
C     EXTRAPOLATE TO RIGHT
C
      IF (KK.EQ.1) GO TO 120
      IF (II.GT.1) GO TO 130
  110 CALL POLATE (PR(5),PP,0,PL(5)-PL(6),0.,0.,R-PL(6),1)
      GO TO 180
  120 L = 5
  130 CALL POLATE (PR(L-2),PP,0,PL(L-2)-R,PL(L-1)-R,PL(L)-R,0.,1)
      GO TO 180
  140 IF (II.EQ.1) GO TO 110
C
```

```
C     INTERPOLATE BELOW                                                 PRES 560
C                                                                       PRES 570
      IF (KK.EQ.1.AND.L.EQ.6) L = 5                                     PRES 580
      IF (PL(L)-R.GT.R-PL(L-1)) GO TO 160                               PRES 590
      IF (L+1.GT.6.OR.(KK.EQ.1.AND.L+1.GT.5)) GO TO 170                 PRES 600
  150 K = LL(L-1)+1-M                                                   PRES 610
C                                                                       PRES 620
C     USE L-1,L,L+1                                                     PRES 630
C                                                                       PRES 640
      IF (K.GT.6) GO TO 50                                              PRES 650
      CALL POLATE (PR(L-1),PP,0,PL(L-1)-PL(L+1),PL(L)-PL(L+1),0.,R-PL(L+PRES 660
     *1),1)                                                             PRES 670
      GO TO 180                                                         PRES 680
  160 IF (L-2.LT.1.OR.(L-2.LT.6-II.AND.II.LT.5)) GO TO 150              PRES 690
C                                                                       PRES 700
C     USE L-2,L-1,L                                                     PRES 710
C                                                                       PRES 720
  170 K= LL(L-2)+1-M                                                    PRES 730
      IF (K.GT.6) GO TO 50                                              PRES 740
      CALL POLATE (PR(L-2),PP,0,PL(L-2)-PL(L),PL(L-1)-PL(L),0.,R-PL(L),1PRES 750
     *)                                                                 PRES 760
  180 RETURN                                                            PRES 770
      END                                                               PRES 780
```

```
$IBFTC PROP3D  LIST                                                     PR3D  10
      SUBROUTINE PROP3D (W,M)                                           PR3D  20
      COMMON /INPPRO/ GAM1,GAM2,GAM                                     PR3D  30
      DIMENSION W(4),F(4),G(4)                                          PR3D  40
C                                                                       PR3D  50
C     CALCULATE FLUID PROPERTIES FOR PRINT OUT IN CYLINDRICAL COORDINATEPR3D  60
C                                                                       PR3D  70
      XXX =W(4)                                                         PR3D  80
C                                                                       PR3D  90
C     NOTE W(4)'S VELOCITY IS DISTRIBUTED TO W(3)                       PR3D 100
C                                                                       PR3D 110
      W(4) = 0.0                                                        PR3D 120
      G(3) = W(3)/W(1)                                                  PR3D 130
      G(2) = W(4)/W(1)                                                  PR3D 140
      A = GAM1*W(2)/(GAM2-G(3)**2-G(2)**2)                              PR3D 150
      B = GAM2*W(1)**2/(GAM1*W(2))                                      PR3D 160
      G(1) = A*(1.0-SQRT(1.0-B/A))                                      PR3D 170
      F(1) = W(1)/G(1)                                                  PR3D 180
      G(4) = W(2)-F(1)*W(1)                                             PR3D 190
      F(2) = SQRT(F(1)**2+G(3)**2+G(2)**2)                              PR3D 200
      F(3) = F(2)/SQRT(GAM*G(4)/G(1))                                   PR3D 210
      F(4) = G(4)/(G(1)**GAM)                                           PR3D 220
      T = GAM*G(4)/G(1)                                                 PR3D 230
C                                                                       PR3D 240
C     SHOWS THE RELATIVE ERROR IN THIS PROCEDURE                        PR3D 250
C                                                                       PR3D 260
      ERR = .5*GAM2-(.5*F(2)**2+GAM1*G(4)/G(1))                         PR3D 270
      WRITE (6,10) M,G(1),G(4),T,F(4),F(1),G(3),F(2),ERR,F(3)           PR3D 280
   10 FORMAT (I9,1X,9E13.6)                                             PR3D 290
      W(4) = XXX                                                        PR3D 300
      RETURN                                                            PR3D 310
      END                                                               PR3D 320
```

```
$IBFTC PROPWJ  LIST
      SUBROUTINE PROPWJ (WJ,K,F,Q,N,L,I)
      COMMON /ALL/ DO,RR
      COMMON /INPPRO/ GAM1,GAM2,GAM
      DIMENSION WJ(L,3),F(1),Q(1)
      REAL M
C
C     COMPUTES FLUID PROPERTIES OF JET
C
      O = FLOAT(I-2)*DO
      B = RR**2*SIN(O)
      V = WJ(K,3)/(RR*WJ(K,1))
      A = GAM1*WJ(K,2)/(GAM2-V**2)
      C = GAM2*WJ(K,1)**2/(GAM1*WJ(K,2))
      RB = A*(1.-SQRT(1.-C/A))
      PB = WJ(K,2)-WJ(K,1)**2/RB
      P = PB/B
      G(1) = P
C
C     IF N=3 RETURN WITH PRESSURE
C
      GO TO (10,20,30), N
C
C     SOLVES FOR F FUNCTIONS OF W
C
   10 F(1) = -RB*V
      F(2) = -WJ(K,1)*V
      F(3) = -RR*(PB+RB*V**2)
C
C     SOLVES FOR Q FUNCTIONS OF W
C
      Q(1) = 0.0
      Q(2) = 2.*PB+RB*V**2
      Q(3) = RR**3*P*COS(O)
      GO TO 30
C
C     RETURNS WITH ALL OF THE FLUID PROPERTIES
C
   20 U = WJ(K,1)/RB
      R = RB/B
      M = SQRT((U**2+V**2)/(GAM*P/R))
      F(1) = M
      F(2) = ATAN2(V,U)*180./3.14159265
      F(3) = R
      G(1) = U
      G(2) = V
      G(3) = P
   30 RETURN
      END
```

```
$IBFTC WJET     LIST
      SUBROUTINE WJET (F,Q,WJ,WJS,LAM1,K)
      COMMON /ALL/ DO,RR
      DIMENSION WJ(100,3),WJS(1)
      DIMENSION F(3,3),Q(3,3),FM(3),FPL(3),QM(3),QPL(3),WM(3),WP(3)
      REAL LAM1
      IF (K.NE.2) GO TO 20
      DO 10 J=1,3
      I = 100*(J-1)+1
   10 WJS(I) = 0.0
C
C     W'S AT AXIS ARE ZERO, BECAUSE RR IS ZERO
C
      GO TO 50
C
C     COMPUTE W'S AT S=.5
C
   20 DO 30 J=1,3
      WP(J) = .5*(WJ(K+1,J)+WJ(K,J) +  LAM1*(F(J,3)-F(J,2)+.5*DO*(Q(J,3)
     *+Q(J,2))))
   30 WM(J) = .5*(WJ(K-1,J)+WJ(K,J) +  LAM1*(F(J,2)-F(J,1)+.5*DO*(Q(J,2)
     *+Q(J,1))))
C
C     FIND F AND Q'S OF W AT S
C
      CALL PROPWJ (WP,1,FPL,QPL,1,1,K)
      CALL PROPWJ (WM,1,FM,QM,1,1,K)
      DO 40 J=1,3
C
C     STORE VALUES IN DECREMENTS OF 100, BECAUSE DIMENSIONS OF W
C
      I = 100*(J-1)+1
C
C     CALCULATE W'S FOR NEXT POLAR PLANE
C
   40 WJS(I) = WJ(K,J)+LAM1*(FPL(J)-FM(J)+.5*DO*(QPL(J)+QM(J)))/(1.+.5*L
     *AM1*DO)
   50 RETURN
      END
```

```
$IBFTC JETS     LIST                                                    JETS  10
      SUBROUTINE JET (P,ANS,LL,RHO,J1,J2,RR)                            JETS  20
      COMMON /INPJET/ R(30),ANGL(30),B(30),Y(30),MN(30)                 JETS  30
      DIMENSION P(30,100),PP(3),PS(3),BA(4)                             JETS  40
C                                                                       JETS  50
C     INTERPOLATES ONE W VALUE AT A TIME                                JETS  60
C                                                                       JETS  70
      GO TO (10,50), LL                                                 JETS  80
C                                                                       JETS  90
C     S IS THE DISTANCE FROM THE POLAR CENTER (VERTEX) TO A POINT ON THEJETS 100
C     CYLINDRICAL PLANE                                                 JETS 110
C                                                                       JETS 120
   10 S = SQRT(RR**2+RHO**2)                                            JETS 130
C                                                                       JETS 140
C     ANG IS THE ANGLE BETWEEN THE POLAR AXIS AND THE GRID POINT        JETS 150
C                                                                       JETS 160
      ANG = ATAN2(RHO,RR)                                               JETS 170
      DO 20 I=1,J2                                                      JETS 180
   20 IF (S.LT.R(I)) GO TO 30                                           JETS 190
   30 L = I-1                                                           JETS 200
C                                                                       JETS 210
C     L IS POLAR PLANE JUST UP STREAM OF GRID POINT                     JETS 220
C     I IS POLAR PLANE JUST DOWN STREAM OF GRID POINT                   JETS 230
C                                                                       JETS 240
      I1 = I+1                                                          JETS 250
      DO = ANGL(L)                                                      JETS 260
      C = ANG/DO+2.0                                                    JETS 270
C                                                                       JETS 280
C     K IS POLAR RAY JUST BELOW GRID POINT                              JETS 290
C                                                                       JETS 300
      K = C                                                             JETS 310
C                                                                       JETS 320
C     C IS FRACTION OF ANGLE TO GRID POINTS MEASURED FROM K             JETS 330
C                                                                       JETS 340
      C = C-FLOAT(K)                                                    JETS 350
      L1 = 0                                                            JETS 360
      L2 = 1                                                            JETS 370
      IF (1.NE.J1) GO TO 40                                             JETS 380
C                                                                       JETS 390
C     STEP SIZES ON PLANE L WILL BE HALF AS LARGE AS I SINCE POLAR JET  JETS 400
C     ANGLE ,DO, CHANGES                                                JETS 410
C                                                                       JETS 420
      L1 = 1                                                            JETS 430
      L2 = 2                                                            JETS 440
   40 LL = 2                                                            JETS 450
C                                                                       JETS 460
C     K1 IS RAY BELOW GRID POINT ON CYLINDRICAL PLANE                   JETS 470
C                                                                       JETS 480
      K1 = K                                                            JETS 490
C                                                                       JETS 500
C     K2 IS RAY ABOVE GRID POINT ON CYLINDRICAL PLANE                   JETS 510
C                                                                       JETS 520
      K2 = K+1                                                          JETS 530
   50 DO 60 K=K1,K2                                                     JETS 540
C                                                                       JETS 550
```

```
C     IF STEP SIZES ARE DIFFERENT BETWEEN L AND I ARRAY K PASSING THRU  JETS 560
C     L MAPS INTO 2(K-1) IN I                                           JETS 570
C                                                                       JETS 580
      N = K1+3-K                                                        JETS 590
      K3 = L2*(K-L1)                                                    JETS 600
      IF (IFIX(B(I))+2.LT.K3) GO TO 80                                  JETS 610
      PP(1) = P(I,K3)                                                   JETS 620
      PP(2) = P(L,K)                                                    JETS 630
C                                                                       JETS 640
C     LINEARLY INTERPOLATE VALUES ON RAYS TO CYLINDRICAL PLANE          JETS 650
C                                                                       JETS 660
   60 CALL POLATE (PP,PP(N),0,R(I)-R(L),0.0,0.0,S-R(L),1)               JETS 670
C                                                                       JETS 680
C     LINEARLY INTERPOLATE BETWEEN ARRAYS ON CYLINDRICAL PLANE TO GRID  JETS 690
C     POINT                                                             JETS 700
C                                                                       JETS 710
   70 CALL POLATE (PP(2),ANS,0,1.0,0.0,0.0,C,1)                         JETS 720
      RETURN                                                            JETS 730
C                                                                       JETS 740
C     TREAT INTERPOLATION CLOSE TO BOUNDARY                             JETS 750
C                                                                       JETS 760
   80 BA(1) = B(L-1)*ANGL(L-1)                                          JETS 770
      DO 90 J=L,I1                                                      JETS 780
      K=J-L+1                                                           JETS 790
      BA(K+1) = B(J)*ANGL(J)                                            JETS 800
      NM = MN(J)                                                        JETS 810
C                                                                       JETS 820
C     PS IS W VALUE LOCATED FROM L-1 PLANE TO I1 PLANE AT BOUNDARY      JETS 830
C                                                                       JETS 840
   90 PS(K)=P(J,NM)                                                     JETS 850
      IF (K.EQ.K2) GO TO 100                                            JETS 860
C                                                                       JETS 870
C     K1 RAY IS CLOSE TO BOUNDARY                                       JETS 880
C                                                                       JETS 890
      ANG = FLOAT(K1-2)*DO                                              JETS 900
C                                                                       JETS 910
C     INTERPOLATE DISTANCE BETWEEN BOUNDARY OF JET AND AXIS OF JET AT   JETS 920
C     THE CYLINDRICAL PLANE BASED UPON ANGULAR VALUES                   JETS 930
C                                                                       JETS 940
      CALL POLATE (Y(L),ANS,0,BA(2),BA(3),BA(4),ANG,1)                  JETS 950
C                                                                       JETS 960
C     SS IS LENGTH OF RAY FROM PLANE L TO BOUNDARY AND PP(1) IS BOUNDARYJETS 970
C     VALUE ON RAY K1                                                   JETS 980
C                                                                       JETS 990
      SS = ANS/SIN(ANG)-R(L)                                            JETS1000
      CALL POLATE (PS,PP(1),0,BA(2),BA(3),BA(4),ANG,1)                  JETS1010
      PP(2) = P(L,K1)                                                   JETS1020
      CALL POLATE (PP,PP(3),0,SS,0.0,0.0,S-R(L),1)                      JETS1030
C                                                                       JETS1040
C     K2 RAY IS CLOSE TO BOUNDARY                                       JETS1050
C                                                                       JETS1060
  100 ANG = FLOAT(K2-2)*DO                                              JETS1070
      CALL POLATE (Y(L-1),ANS,0,BA(1),BA(2),BA(3),ANG,1)                JETS1080
      SS = ANS/SIN(ANG)                                                 JETS1090
      IF (SS.LT.S) GO TO 110                                            JETS1100
```

```
C                                                                       JETS1110
C     REPEAT ABOVE PROCEDURE BELOW FOR RAY K2                           JETS1120
C                                                                       JETS1130
      CALL POLATE (PS,PP,0,BA(2),BA(3),BA(4),ANG,1)                     JETS1140
      PP(2) = P(L,K2)                                                   JETS1150
      CALL POLATE (PP,PP(2),0,SS-R(L),0.0,0.0,S-R(L),1)                 JETS1160
      GO TO 70                                                          JETS1170
  110 PP(1) = B(I)+2.0-FLOAT(K1)                                        JETS1180
      PP(2) = B(L)+2.0-FLOAT(K1)                                        JETS1190
C                                                                       JETS1200
C     DETERMINE DISPLACEMENT GRID POINT IS FROM RAY K1                  JETS1210
C                                                                       JETS1220
      CALL POLATE (PP,ANS,0,R(I)-R(L),0.0,0.0,S-R(L),1)                 JETS1230
C                                                                       JETS1240
C     FIND BOUDARY VALUE S DISTANCE FROM POLAR CENTER                   JETS1250
C                                                                       JETS1260
      CALL POLATE (PS,PP(2),0,R(L),R(I),R(I+1),S,1)                     JETS1270
C                                                                       JETS1280
C     INTERPOLATE VALUE FROM BOUNDARY VALUE AND RAY K1 VALUE ON         JETS1290
C     CYLINDRICAL PLANE                                                 JETS1300
C                                                                       JETS1310
      CALL POLATE (PP(2),ANS,0,ANS,0.0,0.0,C,1)                         JETS1320
      RETURN                                                            JETS1330
      END                                                               JETS1340
```

```
$IBFTC POLATE  LIST                                                     POLA  10
      SUBROUTINE POLATE (W,ANS,L,R1,R2,R3,R,M)                          POLA  20
      DIMENSION W(1),ANS(1)                                             POLA  30
C                                                                       POLA  40
C     THIS ROUTINE DOES BOTH LINEAR AND QUADRATIC INTERPOLATION OR      POLA  50
C     EXTRAPOLATION                                                     POLA  60
C                                                                       POLA  70
      NN = 1                                                            POLA  80
C                                                                       POLA  90
C     M=100 IS FOR SELECTION AND STORAGE OF THREE W VALUES              POLA 100
C                                                                       POLA 110
      IF (M.EQ.100) NN = 3                                              POLA 120
      C = 0.0                                                           POLA 130
      DO 20 N=1,NN                                                      POLA 140
      K1 = M*(N-1)+1                                                    POLA 150
C                                                                       POLA 160
C     L IS THE INCREMENT OF THE SUBSCRIPT FROM WHERE SEQUENTIAL VALUES  POLA 170
C     WILL BE PROCURED                                                  POLA 180
C                                                                       POLA 190
      K2 = K1+1+L                                                       POLA 200
      K3 = K1+2*(1+L)                                                   POLA 210
C                                                                       POLA 220
C     IF R2 = 0. INTERPOLATION IS LINEAR                                POLA 230
C                                                                       POLA 240
      IF (R2.EQ.0.0) GO TO 10                                           POLA 250
      C = ((W(K1)-W(K2))*(R1-R3)-(W(K1)-W(K3))*(R1-R2))/((R1-R2)*(R1-R3)POLA 260
     **(R2-R3))                                                         POLA 270
   10 B = (W(K1)-W(K2)-C*(R1**2-R2**2))/(R1-R2)                         POLA 280
      A = W(K1)-B*R1-C*R1**2                                            POLA 290
   20 ANS(K1) = A+B*R+C*R**2                                            POLA 300
      RETURN                                                            POLA 310
      END                                                               POLA 320
$IBMAP FILES
       ENTRY    .UN08.
*     SETS UP JET TAPE FOR OUTPUT
.UN08. PZE      UNIT08
UNIT08 FILE     ,B(1),RLADY,BIN,BLK=256,INOUT,HOLD,HIGH
       END
```

APPENDIX B

FIVE-JET INTERACTION PROGRAM

Input Cards Format

FORTRAN Listing

W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8
±	±	±	±	±	±	±	±
CARD 1							
LMIN	LMAX	MO	IJL	IFLG	IDIV	JUMP	JUMPI
I10	I10	I10	I10	I10	I10	I10	I10
EACH OF THE ABOVE ENTRIES OCCUPY 10 SPACES. ENTER AN INTEGER VALUE RIGHT ADJUSTED IN EACH FIELD							
EACH OF THE ENTRIES BELOW OCCUPIES 10 SPACES. ENTER THE VALUE AND ITS EXPONENT							
CARD 2							
LAMO	GAM	ASO	AS1	AS2	FACTOR	RDJ	C1
E10.5	E10.5	E10.5	E10.5	E10.5	E10.5	E10.5	E10.5
CARD 3							
C2	CC	ALF	TT	TS	DPRNT	CN	CXR
E10.5	E10.5	E10.5	E10.5	E10.5	E10.5	E10.5	E10.5
CARD 4							
DL1	CL1						
E10.5	E10.5						

Input Cards Format

```
$IBFTC MAIN    LIST                                                     5JET  10
C                                                                       5JET  20
C                                                                       5JET  30
C                                                                       5JET  40
C     5 - JET PROGRAM                                                   5JET  50
C                                                                       5JET  60
C                                                                       5JET  70
C                                                                       5JET  80
      COMMON /INPROP/ GAM,GAM1,GAM2,MM,N,BCD                            5JET  90
      COMMON /INOUT/ LMIN,LMAX,MI,IJL,IFLG,IDIV,JUMP,JUMP1,LAM0,GAM3,AS05JET 100
     *,AS1,AS2,FACTOR,RDJ,C1,C2,CC,ALF,TT,TS,DPRNT,CN,CXR,DL1,CL1       5JET 110
      DIMENSION   WW(4,5), W3D(3,80,2),RX(3),DR(3),MAX1(3),XX(20),YY(3) 5JET 120
     *,F(4,80,3),G(4,80,3),W1(4),W2(4),W3(4),W4(4),F1(4),F2(4),G1(4),G2(5JET 130
     *4),UQM(4),RWVP(4),RUVP(4),Y(3),W5(4),W13(80,80),W24(80,80),W(4)   5JET 140
     *,NE(3),NJE(3,300)                                                 5JET 150
      REAL LAM0,LAM1,LAM2                                               5JET 160
      DATA BCD1/1HN/,BCD2/1HJ/,BCD3/1HE/                                5JET 170
C                                                                       5JET 180
C                                                                       5JET 190
C      READ INITIAL CONDITIONS OR DATA PARAMETERS FOR CONTINUATION RUN  5JET 200
C                                                                       5JET 210
C                                                                       5JET 220
      READ (5,10) LMIN,LMAX,M0,IJL,IFLG,IDIV,JUMP,JUMP1,LAM0,GAM,AS0,AS15JET 230
     1,AS2,FACTOR,RDJ,C1,C2,CC,ALF,TT,TS,DPRNT,CN,CXR,DL1,CL1           5JET 240
   10 FORMAT (8I10/(8F10.5))                                            5JET 250
C                                                                       5JET 260
C     ADIV DIVIDES INTO LAM1 UNTIL INTERACTION STARTS                   5JET 270
C                                                                       5JET 280
      ADIV = IDIV                                                       5JET 290
      IF (IDIV.EQ.0) ADIV = 1.0                                         5JET 300
      LMAX = LMAX+1                                                     5JET 310
C                                                                       5JET 320
C     AXIS OF CENTER JET TO ACTUAL INTERACTION PLANE CREATES A TEMPORARY5JET 330
C     FINER MESH                                                        5JET 340
C     IJK = 0, A SIMULATED MESH CHANGE DOES NOT OCCUR                   5JET 350
C     IJK =1, DY/2 CREATES A TEMPORARY FINE MESH SIZE                   5JET 360
C     IJK = 2, A SIMULATED MESH CHANGE DOES NOT OCCUR                   5JET 370
C     IJK =3, RELOCATION OF WALL BY DOUBLING THE NO. OF INTERVALS FROM  5JET 380
C                                                                       5JET 390
      IJK = 0                                                           5JET 400
      IF (2*M0+6.LE.80) IJK = 2                                         5JET 410
      IF (JUMP1.GT.LMIN) IJK=IJK+1                                      5JET 420
      MI = M0                                                           5JET 430
      IF (IJK.EQ.3) M0 = 2*M0                                           5JET 440
      RDJ = RDJ/CN                                                      5JET 450
      RR = RDJ                                                          5JET 460
      DY = RDJ/FLOAT(M0)                                                5JET 470
      DYY = DY                                                          5JET 480
      IF (IJK.EQ.1) DY = DY/2.0                                         5JET 490
      CONST = (DL1+1.0)/2.0*(CL1-0.5)/0.5+(DL1-1.0)/2.0                 5JET 500
      ITEST = 1                                                         5JET 510
C                                                                       5JET 520
C     MB REPRESENTS INTERACTION WALL MIDWAY BETWEEN M=5 AND M=M2        5JET 530
C                                                                       5JET 540
      MB = M0+5                                                         5JET 550
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C                                                                       5JET 560
C     ONE JET'S CENTER IS AT M=5, THE OTHER IS AT M=M2                  5JET 570
C                                                                       5JET 580
      M2 = 2*MB-5                                                       5JET 590
      MBC = MB                                                          5JET 600
      MBD = MBC                                                         5JET 610
C                                                                       5JET 620
C     MC IS AUXILIARY GRID LINE TO RIGHT OF 3-D REGION                  5JET 630
C                                                                       5JET 640
      MC = MB+1                                                         5JET 650
C                                                                       5JET 660
C     MA IS AUXILIARY GRID LINE TO LEFT OF 3-D REGION                   5JET 670
C                                                                       5JET 680
      MA = MB                                                           5JET 690
C                                                                       5JET 700
C     NB IS MAXIMUM 3-D CALCULATED GRID LINE IN Z DIRECTION             5JET 710
C                                                                       5JET 720
      NB = 2                                                            5JET 730
C                                                                       5JET 740
C     NBP IS AUXILIARY GRID LINE ABOVE NB IT IS FILLED IN WITH JET VALUE5JET 750
C                                                                       5JET 760
      NBP = NB                                                          5JET 770
      ANB = 0.0                                                         5JET 780
      ICNT = 0                                                          5JET 790
      PHY = .7853982                                                    5JET 800
C                                                                       5JET 810
C                                                                       5JET 820
C     IF CONTINUATION RUN IS MADE, INFORMATION FROM PREVIOUS RUN IS     5JET 830
C     OBTAIN HERE                                                       5JET 840
C                                                                       5JET 850
C                                                                       5JET 860
      IF (LMIN.NE.1) READ(2) LAM0,LAM1,GAM,M0,RR,NB,NBP,MA,ENTH,W13,W24,5JET 870
     *LPLANE,MBC,MC,NX                                                  5JET 880
      GAM3 = GAM                                                        5JET 890
C                                                                       5JET 900
C     PRINT TITLE PAGE                                                  5JET 910
C     WRITE HEADER AND INPUT CONDITIONS                                 5JET 920
C                                                                       5JET 930
      CALL WRITES (1)                                                   5JET 940
      MA3D = MA-1                                                       5JET 950
      GAM1 = GAM/(GAM-1.0)                                              5JET 960
      GAM2 = (GAM+1.0)/(GAM-1.0)                                        5JET 970
      H = .5*GAM2                                                       5JET 980
      XDIST = 0.0                                                       5JET 990
      LPLANE = LMIN                                                     5JET1000
C                                                                       5JET1010
C                                                                       5JET1020
C     JET TAPE IS READ BELOW                                            5JET1030
C                                                                       5JET1040
C                                                                       5JET1050
      DO 20 I=1,19                                                      5JET1060
      XX(I) = 0.0                                                       5JET1070
   20 IF (I.LT.3) YY(I) = 0.0                                           5JET1080
      GO TO 50                                                          5JET1090
   30 RX(3) = RX(2)                                                     5JET1100
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```
      Y(3) = Y(2)                                                       5JET1110
      DR(3) = DR(2)                                                     5JET1120
      MAX1(3) = MAX1(2)                                                 5JET1130
      MAXX = MAX1(3)                                                    5JET1140
      DO 40 M=2,MAXX                                                    5JET1150
      DO 40 I=1,3                                                       5JET1160
   40 W3D(I,M,2) = W3D(I,M,1)                                           5JET1170
   50 READ (1) XD,RX(2),DX,Y(2),DR(2),MAX1(2),((W3D(I,J,1),I=1,3),J=1,80 5JET1180
     *)                                                                 5JET1190
      IF (RR.NE.RDJ) GO TO 110                                          5JET1200
      DO 60 I=1,19                                                      5JET1210
      J = 20-I                                                          5JET1220
      XX(J+1) = XX(J)                                                   5JET1230
   60 IF (J.LT.3) YY(J+1) = YY(J)                                       5JET1240
      XX(1) = RX(2)                                                     5JET1250
      YY(1) = Y(2)                                                      5JET1260
C                                                                       5JET1270
C     IF PLUME OF JET IS LESS THAN INTERACTION DISTANCE CONTINUE TO READ5JET1280
C     JET TAPE                                                          5JET1290
C                                                                       5JET1300
      IF (Y(2).LE.RDJ) GO TO 50                                         5JET1310
      CALL INTRP (YY,RDJ,XX,RR)                                         5JET1320
C                                                                       5JET1330
C     RRDJ IS DISTANCE FROM NOZZLE EXIT INTERACTION OCCURS              5JET1340
C                                                                       5JET1350
      RRDJ = RR                                                         5JET1360
      RXP = CN*RR-CXR                                                   5JET1370
      WRITE (6,70) RXP                                                  5JET1380
   70 FORMAT (36X,22HINTERACTION WILL OCCUR,F10.5,28H EXIT RADII FROM NO5JET1390
     *ZZLE EXIT/////)                                                   5JET1400
C                                                                       5JET1410
C                                                                       5JET1420
C     CALCULATE SHOCK PROPERTIES BELOW                                  5JET1430
C                                                                       5JET1440
C                                                                       5JET1450
      NX = 1                                                            5JET1460
   80 MM = MAX1(2)                                                      5JET1470
C                                                                       5JET1480
C     FIRST SHOCK PROPERTIES DETERMINED ARE USED IN THE REGION OF M=MB  5JET1490
C     AND N=MB-3                                                        5JET1500
C                                                                       5JET1510
      IF (NX.EQ.2) NX = MB-4                                            5JET1520
      NX = NX+1                                                         5JET1530
      W1(1) = W3D(1,MM,1)                                               5JET1540
      W1(2) = W3D(2,MM,1)                                               5JET1550
      W1(3) = W3D(3,MM,1)                                               5JET1560
      W1(4) = 0.0                                                       5JET1570
      CALL PROP (W1,UQM,RWVP,5)                                         5JET1580
      TNB = (RWVP(3)/UQM(1))**2                                         5JET1590
      SNB = TNB/(1.+TNB)                                                5JET1600
      P =(-(UQM(3)**2+2.)/UQM(3)**2-GAM*SNB)/3.                         5JET1610
      Q = (2.*UQM(3)**2+1.)/UQM(3)**4+((GAM+1.)**2/4.+(GAM-1.)/UQM(3)**25JET1620
     *)*SNB                                                             5JET1630
      R = (SNB-1.)/UQM(3)**4                                            5JET1640
      A = Q-3.*P**2                                                     5JET1650
```

```
      B = R-P*Q-2.*ABS(P)**3.                                           5JET1660
      PHI =(ACOS(-.5*B/(ABS(A)/3.)**1.5))/3.                            5JET1670
      AA = 2.*SQRT(-A/3.)                                               5JET1680
      PI3 = 2.0943952                                                   5JET1690
      YY(1) = AA*COS(PHI)-P                                             5JET1700
      YY(2) = AA*COS(PHI+PI3)-P                                         5JET1710
      YY(3) = AA*COS(PHI+2.*PI3)-P                                      5JET1720
      B = AMAX1 (YY(1),YY(2))                                           5JET1730
      IF (YY(3).LT.B) B = AMAX1(YY(3),AMIN1(YY(1),YY(2)))               5JET1740
      AM = UQM(3)**2*B                                                  5JET1750
      PPP = (2.*GAM*AM-GAM+1.)/(GAM+1.)                                 5JET1760
      RRR = (GAM+1.)*AM/((GAM-1.)*AM+2.)                                5JET1770
      B = AM*(GAM+1.)**2                                                5JET1780
      PR = PPP/RRR                                                      5JET1790
      AM2 = (UQM(3)**2*B-4.*(AM-1.)*(GAM*AM+1.))/(B*PR)                 5JET1800
      RJB = RWVP(1)                                                     5JET1810
      U3D = UQM(1)                                                      5JET1820
      QB  = RWVP(3)                                                     5JET1830
      PJB = RWVP(4)                                                     5JET1840
      Q2 = SQRT(U3D**2+QB**2-GAM1*PJB/RJB*2.0*(PPP/RRR-1.0))            5JET1850
      W13(MB,NX) = Q2*RJB*RRR                                           5JET1860
      W24(MB,NX) = Q2**2*RJB*RRR+PJB*PPP                                5JET1870
      W13(NX,MB) = 0.0                                                  5JET1880
      W24(NX,MB) = 0.0                                                  5JET1890
      IF (NX.NE.MB-3) GO TO 90                                          5JET1900
      W13(MB+1,NX+1) = W13(MB,NX)                                       5JET1910
      W24(MB+1,NX+1) = W24(MB,NX)                                       5JET1920
      W13(NX+1,MB+1) = W13(NX,MB)                                       5JET1930
      W24(NX+1,MB+1) = W24(NX,MB)                                       5JET1940
      GO TO 290                                                         5JET1950
   90 LAM1 = FACTOR*SQRT(AM2-1.0) * ALF                                 5JET1960
C                                                                       5JET1970
C                                                                       5JET1980
C     DETERMINE ACTUAL STARTING DISTANCE FROM NOZZLE EXIT               5JET1990
C                                                                       5JET2000
      RR = RR-LAM1*DY                                                   5JET2010
C                                                                       5JET2020
C     CALCULATE INITIAL LAM1                                            5JET2030
C                                                                       5JET2040
      LAM1 = LAM1/ADIV                                                  5JET2050
      BACKSPACE 1                                                       5JET2060
      DO 100 I=1,20                                                     5JET2070
  100 IF (XX(I).GT.RR) BACKSPACE 1                                      5JET2080
      GO TO 50                                                          5JET2090
  110 IF (RX(2).LT.RR) GO TO 30                                         5JET2100
      READ (1) K,RX(1),K,Y(1),DR(1),MAX1(1)                             5JET2110
      BACKSPACE 1                                                       5JET2120
C                                                                       5JET2130
C     FIND RADIUS OF JET AT GIVEN DISTANCE FROM NOZZLE EXIT             5JET2140
C                                                                       5JET2150
  120 CALL INTRP (RX,RR,Y,YBD)                                          5JET2160
      JJ = 0                                                            5JET2170
      K1 = 1                                                            5JET2180
      K2 = 1                                                            5JET2190
      JKL = 0                                                           5JET2200
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      JJJ = 1                                                           5JET2210
      NBB = NB                                                          5JET2220
      IF (RR.LT.RRDJ) GO TO 140                                         5JET2230
C                                                                       5JET2240
C     COMPUTE 3-D REGION IN Z DIRECTION                                 5JET2250
C                                                                       5JET2260
      ANB = 2.0+SQRT((YBD/(LAM0*DY))**2-(DYY/DY*FLOAT(MB-5)/LAM0)**2)   5JET2270
      NB = ANB+1.0                                                      5JET2280
      IF (NB.LE.MB-3) GO TO 130                                         5JET2290
      DL = FLOAT (M2-5) *DY                                             5JET2300
      DLL = DL*COS(PHY)                                                 5JET2310
      ANB = DLL*(1.0+SQRT(1.0+(YBD**2-DL**2)/DLL**2))*SIN(PHY)/(LAM0*DY)5JET2320
     *+2.0                                                              5JET2330
      NB = ANB+1.0                                                      5JET2340
  130 ANB = (ANB-2.0)*LAM0*DY*CN                                        5JET2350
      NBP = NB+1                                                        5JET2360
      IF (NBP.GT.80) CALL DUMP                                          5JET2370
  140 J = 0                                                             5JET2380
  150 J = J+1                                                           5JET2390
      JJ = JJ+1                                                         5JET2400
C                                                                       5JET2410
C     EXPAND 3-D REGION IN Y DIRECTION IF K1 AND/OR K2 = 1              5JET2420
C                                                                       5JET2430
      IF (MBC.NE.MB.AND.K2.EQ.1) MBC = MBC+1                            5JET2440
      IF (MBC.GT.80) CALL DUMP                                          5JET2450
      IF (K1.EQ.1) MA = MA -1                                           5JET2460
      IF (MA.LT.4) MA = 4                                               5JET2470
      MAA = MA                                                          5JET2480
      MAX = MA                                                          5JET2490
      NJ = 1                                                            5JET2500
      IF (LPLANE.EQ.1) GO TO 160                                        5JET2510
      K1 = 2                                                            5JET2520
      K2 = 2                                                            5JET2530
  160 NPB = NBP                                                         5JET2540
      IF (JJ.EQ.1) NPB = NBB                                            5JET2550
C                                                                       5JET2560
C                                                                       5JET2570
C                                                                       5JET2580
C     BELOW JET VALUES ARE CALCULATED AND ARE FILLED INTO THE MESH WHEN 5JET2590
C     IT IS NECESSARY                                                   5JET2600
C                                                                       5JET2610
C                                                                       5JET2620
C                                                                       5JET2630
      DO 270 N=2,NPB,NJ                                                 5JET2640
      IF (JJJ.NE.1.AND.N.NE.NN) GO TO 270                               5JET2650
      MJ = 1                                                            5JET2660
C                                                                       5JET2670
C     THE FOLLOWING TWO STRINGS OF IF STATEMENTS DETERMINE WHICH POINTS 5JET2680
C     MAY NEED JET VALUES                                               5JET2690
C                                                                       5JET2700
      IF ((N.LE.NBB.OR.J.EQ.1).AND.MBC.NE.MB) MJ = MBC-MA               5JET2710
      IF (JJJ.GE.2) MJ = MM-MA                                          5JET2720
      IF (MJ.EQ.0.OR.MA.NE.MAA) MJ = 1                                  5JET2730
      IF (LPLANE.EQ.1.AND.JJ.EQ.1.AND.IFLG.EQ.0) MAX = MB               5JET2740
      IF (N.GT.NBB.AND.J.EQ.2.AND.MBC.EQ.MB) MAX = MB                   5JET2750
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      IF (MBC.NE.MB) MAX = MBC                                          5JET2760
      DO 260 M=MA,MAX,MJ                                                5JET2770
      IF (N.GT.M-3) GO TO 240                                           5JET2780
      IF (JJJ.NE.1.AND.M.NE.MM) GO TO 260                               5JET2790
      IF (LPLANE.EQ.1.OR.JJ.NE.1) GO TO 170                             5JET2800
      IF (K1.EQ.1.AND.M.EQ.MA) GO TO 240                                5JET2810
      IF (K2.EQ.1.AND.M.EQ.MAX) GO TO 260                               5JET2820
C                                                                       5JET2830
C     AN IS Z DISTANCE OF GRID POINT FROM CENTER JET                    5JET2840
C                                                                       5JET2850
  170 AN = FLOAT(N-2)*LAM0                                              5JET2860
C                                                                       5JET2870
C     AM IS Y DISTANCE OF GRID POINT TO CENTER JET OR M=M2,WHICH EVER   5JET2880
C     JET CENTER IS CLOSES                                              5JET2890
C                                                                       5JET2900
      AM = IFIX(DYY/DY)*(MB-5)+M-MB                                     5JET2910
      IF (M.GT.MB) AM = IFIX(DYY/DY)*(MB-M2)+M-MB                       5JET2920
C                                                                       5JET2930
C     RHO IS ACTUAL DISTANCE FROM GRID POINT TO CENTER JET OR M=M2 JET  5JET2940
C                                                                       5JET2950
      RHO = DY*SQRT(AN**2+AM**2)                                        5JET2960
      IF (RHO.GE.YBD) GO TO 180                                         5JET2970
      IF (M.NE.MB.OR.N.LT.NB.OR.N.LE.NBB) GO TO 190                     5JET2980
C                                                                       5JET2990
C     CALCULATE JET PROPERTIES FOR PARTICULAR MESH POINT                5JET3000
C                                                                       5JET3010
  180 CALL JET (W3D,RUVP,YBD,DR,MAX1,Y,RX,RR,1)                         5JET3020
C                                                                       5JET3030
C     COMPUTE REFERENCE ENTROPY                                         5JET3040
C                                                                       5JET3050
      IF (LPLANE.EQ.1) ENTH = CC*RUVP(4)/(RUVP(1)**GAM)                 5JET3060
      GO TO 200                                                         5JET3070
  190 CALL JET (W3D,RUVP,RHO,DR,MAX1,Y,RX,RR,2)                         5JET3080
  200 RJB = RUVP(1)                                                     5JET3090
      U3D = RUVP(2)                                                     5JET3100
      QB  = RUVP(3)                                                     5JET3110
      PJB = RUVP(4)                                                     5JET3120
      IF (AM.EQ.0.0.AND.AN.EQ.0.0) QB = 0.0                             5JET3130
      ANG3 = 1.5707963                                                  5JET3140
      IF (AM.NE.0.0) ANG3 = ATAN2(AN,AM)                                5JET3150
      IF (AN.EQ.0.0) ANG3 = 0.0                                         5JET3160
C                                                                       5JET3170
C     BELOW IS DETERMINED THE COMPONENT OF VELOCITY IN THE PLANE V3D,W3D5JET3180
C                                                                       5JET3190
      IF (N.NE.M-3.OR.N.LE.NBB.OR.MBC.EQ.MB) GO TO 210                  5JET3200
      ANG2 = ATAN2(AN,FLOAT(M-5))                                       5JET3210
      VB = QB*COS(ANG3-ANG2)                                            5JET3220
      V3D = VB*COS(ANG2)                                                5JET3230
      W3D = VB*SIN(ANG2)                                                5JET3240
      GO TO 220                                                         5JET3250
  210 V3D = QB*COS(ANG3)                                                5JET3260
      IF (N.EQ.2.AND.M.GT.MB.AND.M.LT.M2) V3D = -V3D                    5JET3270
      W3D = QB*SIN(ANG3)                                                5JET3280
  220 IF (M.EQ.MB.AND.N.LT.M-3) V3D = 0.0                               5JET3290
      W1(1) = W13(M,N)                                                  5JET3300
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      W1(2) = W24(M,N)                                                  5JET3310
      W1(3) = W13(N,M)                                                  5JET3320
      W1(4) = W24(N,M)                                                  5JET3330
      IF (JJ.NE.1.OR.LPLANE.EQ.1) GO TO 250                             5JET3340
      CALL PROP (W1,W2,RWVP,5)                                          5JET3350
C                                                                       5JET3360
C     C1 IS TOLERANCE APPLING TO MA EXPANSION                           5JET3370
C                                                                       5JET3380
      C = C1                                                            5JET3390
C                                                                       5JET3400
C     C2 IS TOLERANCE APPLING TO MBC EXPANSION                          5JET3410
C                                                                       5JET3420
      IF (M.EQ.MBC) C = C2                                              5JET3430
C                                                                       5JET3440
C     IF ANY OF THE FOLLOWING FOUR TEST TRANSFERS TO 230 THE 3-D REGION 5JET3450
C     WILL EXPAND                                                       5JET3460
C                                                                       5JET3470
      IF (ABS(QB-SQRT(RWVP(2)**2+RWVP(3)**2)).GT.C*QB) GO TO 230        5JET3480
      IF (ABS(U3D-W2(1)).GT.C*U3D) GO TO 230                            5JET3490
      IF (ABS(RJB-RWVP(1)).GT.C*RJB) GO TO 230                          5JET3500
      IF (ABS(PJB-RWVP(4)).GT.C*PJB) GO TO 230                          5JET3510
      GO TO 240                                                         5JET3520
  230 IF (M.EQ.MA) K1 = 1                                               5JET3530
      IF (M.EQ.MBC) K2 = 1                                              5JET3540
      IF (K1.EQ.1.AND.MA.EQ.MAX) GO TO 140                              5JET3550
      IF (K1.EQ.1.AND.K2.EQ.1) GO TO 140                                5JET3560
  240 IF (M.EQ.MAX.AND.N.EQ.NPB.AND.(K1.EQ.1.OR.K2.EQ.1)) GO TO 140     5JET3570
      IF (N.EQ.MA-3.AND.K2.EQ.1) GO TO 140                              5JET3580
      GO TO 260                                                         5JET3590
C                                                                       5JET3600
C                                                                       5JET3610
C     A TRIANGULAR STORAGE MATRIX STORES HALF THE W PROPERTIES IN THE   5JET3620
C     LOWER RIGHT HAND TRIANGLE AND THE OTHER HALF OF W'S IN THE UPPER  5JET3630
C     LEFT HAND PART OF THE MATRIX                                      5JET3640
C                                                                       5JET3650
C                                                                       5JET3660
  250 W13(M,N) = RJB*U3D                                                5JET3670
      W24(M,N) = RJB*U3D**2+PJB                                         5JET3680
      W13(N,M) = RJB*U3D*V3D                                            5JET3690
      W24(N,M) = RJB*U3D*W3D                                            5JET3700
C                                                                       5JET3710
C     CLASSIFY EACH JET GRID POINT                                      5JET3720
C     NJE = 1, PRINT J FOR AUXILIARY JET POINT                          5JET3730
C     NJE = 2, PRINT E FOR JET PROPERTIES DUE TO 3-D ENTROPY VALUE BEING5JET3740
C     LESS THAN REFERENCE ENTROPY                                       5JET3750
C                                                                       5JET3760
      ICNT = ICNT +1                                                    5JET3770
      IF (ICNT.GT.300) CALL DUMP                                        5JET3780
      NJE(1,ICNT) = N                                                   5JET3790
      NJE(2,ICNT) = M                                                   5JET3800
      NJE(3,ICNT) = 1                                                   5JET3810
      IF (JJJ.EQ.2) NJE(3,ICNT) = 2                                     5JET3820
  260 CONTINUE                                                          5JET3830
C                                                                       5JET3840
C     JJJ=1, FOR AUXILIARY JET POINTS                                   5JET3850
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C     JJJ=2, FOR ENTROPY JET POINTS                                     5JET3860
C     JJJ=3,4, AND 5 FOR AUXILIARY FILL IN JET POINTS WHEN MESH CHANGES 5JET3870
C     SIZES                                                             5JET3880
C                                                                       5JET3890
      GO TO (270,320,380,360,360), JJJ                                  5JET3900
  270 CONTINUE                                                          5JET3910
C                                                                       5JET3920
C                                                                       5JET3930
C                                                                       5JET3940
C     THIS ENDS THE CALCULATION OF JET POINTS                           5JET3950
C                                                                       5JET3960
C                                                                       5JET3970
C                                                                       5JET3980
      K1 = 1                                                            5JET3990
      K2 = 1                                                            5JET4000
      IF (NBP.EQ.NB) NBP = NB+2                                         5JET4010
      IF (J.EQ.1) GO TO 150                                             5JET4020
      IF (NB.EQ.2) NB = 3                                               5JET4030
      IF (MBC.GE.NBP+3) GO TO 280                                       5JET4040
C                                                                       5JET4050
C     IF N IS LARGER THAN M-3,ADDITIONAL AUXILIARY JET GRID LINES MUST  5JET4060
C     BE ADDED TO MBC                                                   5JET4070
C                                                                       5JET4080
      MAA = MA                                                          5JET4090
      J = 2                                                             5JET4100
      JJ = 2                                                            5JET4110
      MA = MBC+1                                                        5JET4120
      MBC = NBP+3                                                       5JET4130
      GO TO 160                                                         5JET4140
  280 MA = MAA                                                          5JET4150
C                                                                       5JET4160
C     CALCULATE SHOCK POINTS                                            5JET4170
C                                                                       5JET4180
      IF (NX.EQ.2.AND.NB.GE.MB-3.AND.IFLG.NE.0) GO TO 80                5JET4190
      IF (LPLANE.NE.1) GO TO 290                                        5JET4200
      IF (IFLG.EQ.0) GO TO 330                                          5JET4210
      W13(MB,3) = W13(MB,2)                                             5JET4220
      W24(MB,3) = W24(MB,2)                                             5JET4230
      W13(3,MB) = W13(2,MB)                                             5JET4240
      W24(3,MB) = W24(2,MB)                                             5JET4250
      GO TO 330                                                         5JET4260
  290 NN = NBB + 1                                                      5JET4270
  300 NN = NN - 1                                                       5JET4280
      MM = MC                                                           5JET4290
      IF (MB.NE.MBC) MM = MBC+1                                         5JET4300
  310 MM = MM-1                                                         5JET4310
      IF (NN.GT.MM-3) GO TO 300                                         5JET4320
      W(1) = W13(MM,NN)                                                 5JET4330
      W(2) = W24(MM,NN)                                                 5JET4340
      W(3) = W13(NN,MM)                                                 5JET4350
      W(4) = W24(NN,MM)                                                 5JET4360
      CALL PROP (W,UQM,RWVP,5)                                          5JET4370
C                                                                       5JET4380
C     COMPARE THE ENTROPY AT EACH 3-D MESH POINT WITH THE REFERENCE     5JET4390
C     ENTROPY                                                           5JET4400
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C                                                                       5JET4410
      IF (UQM(4).GT.ENTH) GO TO 320                                     5JET4420
C                                                                       5JET4430
C     REPLACE 3-D VALUES WITH JET VALUES                                5JET4440
C                                                                       5JET4450
      J = 2                                                             5JET4460
      JJ = 2                                                            5JET4470
      JJJ = 2                                                           5JET4480
      NJ = NN-2                                                         5JET4490
      IF (NJ.EQ.0) NJ = 1                                               5JET4500
      GO TO 160                                                         5JET4510
  320 UU = ATAN2 (1.0,SQRT(UQM(3)**2-1.0))                              5JET4520
      UM1 = ABS(ATAN2(ABS(RWVP(3)),UQM(1))-UU)                          5JET4530
      UM = ABS(ATAN2(ABS(RWVP(2)),UQM(1))+UU)                           5JET4540
      IF (UM1.GT.UM) UM = UM1                                           5JET4550
      IF (MM.EQ.MBC.AND.NN.EQ.NBB) UN = UM                              5JET4560
      UN = AMAX1 (UN,UM)                                                5JET4570
      IF (MM.GT.MA3D) GO TO 310                                         5JET4580
      IF (NN.GT.2) GO TO 300                                            5JET4590
C                                                                       5JET4600
C     FIND MINIMUM LAM1                                                 5JET4610
C                                                                       5JET4620
      LAM1 = FACTOR/TAN(UN)                                             5JET4630
      IF (RR.LT.RRDJ) LAM1 = LAM1/ADIV                                  5JET4640
C                                                                       5JET4650
C     LAM2 IS LAM1 FOR 5-JET CONFIGURATION                              5JET4660
C                                                                       5JET4670
  330 LAM2 = LAM1/LAM0                                                  5JET4680
      IF (LPLANE.NE.JUMP1) GO TO 410                                    5JET4690
C                                                                       5JET4700
C                                                                       5JET4710
C     DOUBLING MESH SIZE OCCURS BELOW                                   5JET4720
C                                                                       5JET4730
C                                                                       5JET4740
  340 JJJ = 2                                                           5JET4750
      IF (ITEST.EQ.2) GO TO 410                                         5JET4760
      ITEST = 2                                                         5JET4770
      IF (MOD(NBP,2).EQ.1) JJJ = 4                                      5JET4780
      NB = (NBP+1)/2                                                    5JET4790
      NN = 2                                                            5JET4800
      NBP = NB+1                                                        5JET4810
      IF (JJJ.EQ.4) NN = NBP                                            5JET4820
      MM = MB-MA                                                        5JET4830
      IF (MOD(MM,2).EQ.1) JJJ = JJJ+1                                   5JET4840
      MA = (MA+MB+1)/2                                                  5JET4850
C                                                                       5JET4860
C     STORE EVERY OTHER GRID POINT BACK INTO ORIGINAL MATRIX            5JET4870
C                                                                       5JET4880
      DO 350 N=2,NB                                                     5JET4890
      DO 350 I=MA,MB                                                    5JET4900
      M = MB+MA-I                                                       5JET4910
      K = 2*M-MB                                                        5JET4920
      W13(M,N) = W13(K,2*N-2)                                           5JET4930
      W24(M,N) = W24(K,2*N-2)                                           5JET4940
      W13(N,M) = W13(2*N-2,K)                                           5JET4950
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  350 W24(N,M) = W24(2*N-2,K)                                          5JET4960
      IF (MOD(JJJ,2).NE.0) MA = MA-1                                   5JET4970
      DY = 2.0*DY                                                      5JET4980
      DYY = DY                                                         5JET4990
      MM = MA                                                          5JET5000
      MMM = MM                                                         5JET5010
      MT = MM                                                          5JET5020
C                                                                      5JET5030
C     FILL IN AUXILIARY JET GRID LINES IF NEEDED                       5JET5040
C                                                                      5JET5050
      IF (JJJ.EQ.2) GO TO 390                                          5JET5060
      NJ = NBP-2                                                       5JET5070
      IF (NJ.EQ.0) NJ = 1                                              5JET5080
      MAX = MBC                                                        5JET5090
      GO TO 160                                                        5JET5100
  360 MM = MM+1                                                        5JET5110
      IF (MT.GE.MB) IF (JJJ-4) 370,390,370                             5JET5120
      MT = MM                                                          5JET5130
      GO TO 160                                                        5JET5140
  370 MM = MMM                                                         5JET5150
      NN = 2                                                           5JET5160
      JJJ = 3                                                          5JET5170
      GO TO 160                                                        5JET5180
  380 NN = NN+1                                                        5JET5190
      NJ = NBP-2                                                       5JET5200
      IF (NN.GT.NBP) GO TO 390                                         5JET5210
      GO TO 160                                                        5JET5220
  390 CONTINUE                                                         5JET5230
      IF (IJK.NE.3) GO TO 410                                          5JET5240
C                                                                      5JET5250
C     SHIFT SIMULATED POSITION OF INTERACTION WALL TO ACTUAL LOCATION OF5JET5260
C     WALL                                                             5JET5270
C                                                                      5JET5280
      IJK =0                                                           5JET5290
      MO = MO/2                                                        5JET5300
      DO 400 N=2,NBP                                                   5JET5310
      DO 400 I=MA,MBC                                                  5JET5320
      M = I-MO                                                         5JET5330
      W13(M,N) = W13(I,N)                                              5JET5340
      W24(M,N) = W24(I,N)                                              5JET5350
      W13(N,M) = W13(N,I)                                              5JET5360
  400 W24(N,M) = W24(N,I)                                              5JET5370
      MA = MA-MO                                                       5JET5380
      MB = MB-MO                                                       5JET5390
      MBC = MBC-MO                                                     5JET5400
      MBD = MBC-1                                                      5JET5410
      MC = MC-MO                                                       5JET5420
      M2 = 2*MB-5                                                      5JET5430
  410 MA3D = MA+1                                                      5JET5440
      IN = 1                                                           5JET5450
      NI = 0                                                           5JET5460
      IF (IJK.NE.3) GO TO 420                                          5JET5470
      IN = 2                                                           5JET5480
      NI = MO/2                                                        5JET5490
  420 IF (NBP.LT.IN*(MA-NI-3).OR.MC.NE.MB+1) GO TO 450                 5JET5500
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      JKL = JKL+1                                                       5JET5510
      IF (LPLANE.LT.JUMP1) GO TO (340,430), JKL                         5JET5520
C                                                                       5JET5530
C     WHEN NBP HITS DIAGONAL 3-D REGION EXPANDS FROM MC TO MBC          5JET5540
C                                                                       5JET5550
  430 MBC = 2*MB-MA                                                     5JET5560
      DO 440 N=1,NBP                                                    5JET5570
      DO 440 M=MA,MB                                                    5JET5580
      MM = MBC+MA-M                                                     5JET5590
      W13(MM,N) = W13(M,N)                                              5JET5600
      W24(MM,N) = W24(M,N)                                              5JET5610
      W13(N,MM) =-W13(N,M)                                              5JET5620
  440 W24(N,MM) = W24(N,M)                                              5JET5630
  450 IF (MBC.NE.MB) GO TO 470                                          5JET5640
C                                                                       5JET5650
C     IF NBP HAS NOT REACHED DIAGONAL MB-1, IT IS REFLECTED INTO MC     5JET5660
C                                                                       5JET5670
      DO 460 N=2,NBP                                                    5JET5680
      W13(MC,N) = W13(MB-1,N)                                           5JET5690
      W24(MC,N) = W24(MB-1,N)                                           5JET5700
      W13(N,MC) =-W13(N,MB-1)                                           5JET5710
  460 W24(N,MC) = W24(N,MB-1)                                           5JET5720
C                                                                       5JET5730
C     REFLECTION POINTS ARE FILLED IN                                   5JET5740
C                                                                       5JET5750
  470 CALL AUXPTS (W13,W24,MA,NBP+3,MBC)                                5JET5760
      IF (MBC.NE.MB) MC = MBC                                           5JET5770
      IF (MC.EQ.MBC) MBD = MBC-1                                        5JET5780
C                                                                       5JET5790
C     PRINT EVERY DPRNT INTERVAL                                        5JET5800
C                                                                       5JET5810
      IF (RR.LT.XDIST) GO TO 610                                        5JET5820
      XDIST = RR+DPRNT/CN                                               5JET5830
C                                                                       5JET5840
C     WRITE HEADER FOR OUTPUT                                           5JET5850
C                                                                       5JET5860
      IF (LPLANE.NE.LMIN) WRITE (6,480)                                 5JET5870
  480 FORMAT (1H1)                                                      5JET5880
      RXP = CN*RR-CXR                                                   5JET5890
      WRITE (6,490) LPLANE,LAM1,LAM2,RXP,ANB,DY                         5JET5900
  490 FORMAT (      1X,3HL =,I5, 9X,7HLAM 1 =,F10.5,10X,7HLAM 2 =,F10.5, 5JET5910
     *10X,3HX =,F10.5,10X,4HZI =,F10.5,8X,4HDY =,F7.4///)               5JET5920
      WRITE (6,500)                                                     5JET5930
  500 FORMAT (13X,7HDENSITY,5X,8HPRESSURE,4X,11HTEMPERATURE,4X,7HENTROPY5JET5940
     *,6X                ,4(8HVELOCITY,5X),8HMACH NO.)                  5JET5950
      IPAGE = 6                                                         5JET5960
      IF (LPLANE.EQ.1) IPAGE = 12                                       5JET5970
      WRITE (6,510)                                                     5JET5980
  510 FORMAT (3X,1HM,4X,1HN,7X,1HR,12X,1HP,12X,1HT,12X,1HS,12X,1HU,12X,15JET5990
     *HV,12X,1HW,12X,1HQ,12X,1HM//)                                     5JET6000
      ICNT1 = ICNT-1                                                    5JET6010
C                                                                       5JET6020
C                                                                       5JET6030
C     DETERMINE BELOW WHETHER A GRID POINT IS CALCULATED BY JET, ENTROPY5JET6040
C     , OR 3-D PROCEDURE                                                5JET6050
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C                                                                       5JET6060
C                                                                       5JET6070
      DO 550 I=1,ICNT1                                                  5JET6080
      NN = NJE(1,I)                                                     5JET6090
      MM = NJE(2,I)                                                     5JET6100
      L = I+1                                                           5JET6110
      DO 520 K=L,ICNT                                                   5JET6120
      IF (NN.LT.NJE(1,K)) GO TO 520                                     5JET6130
      NN = NJE(1,K)                                                     5JET6140
      MM = NJE(2,K)                                                     5JET6150
  520 CONTINUE                                                          5JET6160
      DO 530 K=I,ICNT                                                   5JET6170
      IF (NJE(1,K).NE.NN) GO TO 530                                     5JET6180
      IF (NJE(2,K).GT.MM) GO TO 530                                     5JET6190
      MM = NJE(2,K)                                                     5JET6200
      M = K                                                             5JET6210
  530 CONTINUE                                                          5JET6220
      IF (M.EQ.I) GO TO 550                                             5JET6230
      DO 540 J=1,3                                                      5JET6240
      NE(J) = NJE(J,I)                                                  5JET6250
      NJE(J,I) = NJE(J,M)                                               5JET6260
  540 NJE(J,M) = NE(J)                                                  5JET6270
  550 CONTINUE                                                          5JET6280
      I = 1                                                             5JET6290
      DO 600 N=2,NB                                                     5JET6300
      WRITE (6,560)                                                     5JET6310
  560 FORMAT (1H )                                                      5JET6320
      IPAGE = IPAGE+1                                                   5JET6330
      MBE = MB                                                          5JET6340
      IF (MB.NE.MBC) MBE = MBD                                          5JET6350
      DO 600 M=MA,MBC                                                   5JET6360
      IF (N.GT.M-3) GO TO 600                                           5JET6370
      W(1) = W13(M,N)                                                   5JET6380
      W(2) = W24(M,N)                                                   5JET6390
      W(3) = W13(N,M)                                                   5JET6400
      W(4) = W24(N,M)                                                   5JET6410
      BCD = BCD1                                                        5JET6420
      MM = M                                                            5JET6430
      IF (IJK.EQ.3) MM = M-M0/2                                         5JET6440
  570 IF (I.GT.ICNT) GO TO 580                                          5JET6450
      IF (NJE(1,I).NE.N.OR.NJE(2,I).NE.M) GO TO 580                     5JET6460
      BCD = BCD2                                                        5JET6470
      IF (NJE(3,I).EQ.2) BCD = BCD3                                     5JET6480
      I = I+1                                                           5JET6490
      GO TO 570                                                         5JET6500
C                                                                       5JET6510
C     KEEP LINE COUNT FOR HEADING AT TOP OF EACH PAGE                   5JET6520
C                                                                       5JET6530
  580 IF (M.EQ.MA.OR.M.GT.MBE) GO TO 600                                5JET6540
      IPAGE = IPAGE+1                                                   5JET6550
      IF (IPAGE.LT.60) GO TO 590                                        5JET6560
      IPAGE = 2                                                         5JET6570
      WRITE (6,510)                                                     5JET6580
C                                                                       5JET6590
C                                                                       5JET6600
```

```
C     COMPUTE AND PRINT W PROPERTIES                                    5JET6610
C                                                                       5JET6620
C                                                                       5JET6630
  590 CALL PROP (W,W1,W2,4)                                             5JET6640
  600 CONTINUE                                                          5JET6650
  610 ICNT = 0                                                          5JET6660
C                                                                       5JET6670
C     SOLVE FOR X DISPLACEMENT FROM NOZZLE EXIT FOR NEXT PLANE          5JET6680
C                                                                       5JET6690
      RR = RR+LAM1*DY                                                   5JET6700
      LPLANE = LPLANE+1                                                 5JET6710
C                                                                       5JET6720
C     COMPUTATION TERMINATES IF RADIUS OF JET FROM AXIS TO BOUNDARY IS  5JET6730
C     DECREASING                                                        5JET6740
C                                                                       5JET6750
      CALL INTRP (RX,RR,Y,YYBD)                                         5JET6760
      IF (YYBD.GE.YBD) GO TO 630                                        5JET6770
      WRITE (6,620)                                                     5JET6780
  620 FORMAT (5(/),44X,46HRADIUS OF JET IS DECREASING, COMPUTATION STOPS5JET6790
     *)                                                                 5JET6800
      STOP                                                              5JET6810
C                                                                       5JET6820
C                                                                       5JET6830
C     COMPUTE F AND G FUNCTIONS OF W TAKING ONE GRID LINE AT A TIME     5JET6840
C     WHILE HOLDING N CONSTANT                                          5JET6850
C                                                                       5JET6860
C                                                                       5JET6870
  630 DO 740 N=2,NB                                                     5JET6880
      DO 670 M=MA,MC                                                    5JET6890
      IF (N.GT.M-1) GO TO 670                                           5JET6900
      IF (N.NE.2) GO TO 640                                             5JET6910
      W(1) = W13(M,N)                                                   5JET6920
      W(2) = W24(M,N)                                                   5JET6930
      W(3) = W13(N,M)                                                   5JET6940
      W(4) = W24(N,M)                                                   5JET6950
C                                                                       5JET6960
C     THIRD SUBSCRIPT OF F AND G POSITIONS GRID POINT IN Z DIRECTION    5JET6970
C                                                                       5JET6980
C                                                                       5JET6990
      IF SUBSCRIPT = 2, N                                               5JET7000
C                                                                       5JET7010
      CALL PROP (W,F(1,M,2),G(1,M,2),1)                                 5JET7020
      W(1) = W13(M,N-1)                                                 5JET7030
      W(2) = W24(M,N-1)                                                 5JET7040
      W(3) = W13(N-1,M)                                                 5JET7050
      W(4) = W24(N-1,M)                                                 5JET7060
C                                                                       5JET7070
C     IF SUBSCRIPT = 3, N-1                                             5JET7080
C                                                                       5JET7090
      CALL PROP (W,F(1,M,3),G(1,M,3),1)                                 5JET7100
      GO TO 660                                                         5JET7110
C                                                                       5JET7120
C     WHEN N INCREASED BY ONE F AND G SUBSCRIPTS 1 AND 2 INCREASE BY ONE5JET7130
C                                                                       5JET7140
  640 DO 650 I=1,2                                                      5JET7150
```

```
      K = 4-I                                                           5JET7160
      DO 650 J=1,4                                                      5JET7170
      F(J,M,K) = F(J,M,K-1)                                             5JET7180
  650 G(J,M,K) = G(J,M,K-1)                                             5JET7190
  660 W(1) = W13(M,N+1)                                                 5JET7200
      W(2) = W24(M,N+1)                                                 5JET7210
      W(3) = W13(N+1,M)                                                 5JET7220
      W(4) = W24(N+1,M)                                                 5JET7230
C                                                                       5JET7240
C     IF SUBSCRIPT = 1, N+1                                             5JET7250
C                                                                       5JET7260
      CALL PROP (W,F(1,M,1),G(1,M,1),1)                                 5JET7270
  670 CONTINUE                                                          5JET7280
C                                                                       5JET7290
C                                                                       5JET7300
C                                                                       5JET7310
C     BELOW W VALUES ARE COMPUTED FOR NEXT PLANE                        5JET7320
C                                                                       5JET7330
C                                                                       5JET7340
C                                                                       5JET7350
      DO 740 M=MA3D,MBD                                                 5JET7360
      IF (N.GT.M-3) GO TO 740                                           5JET7370
      W(1) = W13(M,N)                                                   5JET7380
      W(2) = W24(M,N)                                                   5JET7390
      W(3) = W13(N,M)                                                   5JET7400
      W(4) = W24(N,M)                                                   5JET7410
      CALL PROP (W,UQM,RWVP,5)                                          5JET7420
      UU = ATAN2 (1.0,SQRT(UQM(3)**2-1.0))                              5JET7430
      UM1 = ABS(ATAN2(ABS(RWVP(3)),UQM(1))-UU)                          5JET7440
      UM = ABS(ATAN2(ABS(RWVP(2)),UQM(1))+UU)                           5JET7450
      IF (UM1.GT.UM) UM = UM1                                           5JET7460
C                                                                       5JET7470
C                                                                       5JET7480
C     DISTANCE OF FIRST STEP OF TWO STEP METHOD IS FOUND                5JET7490
C                                                                       5JET7500
C                                                                       5JET7510
      S =.5*(1.0+AS0*(FACTOR/LAM1/TAN(UM)-1.0)+AS1*LAM1*(F(IJL,M+1,2)-F(5JET7520
     *IJL,M-1,2))/W(IJL)+AS2*LAM2*(G(IJL,M,1)-G(IJL,M,3))/W(IJL))       5JET7530
      NN1 = N-1                                                         5JET7540
      NN2 = N+1                                                         5JET7550
      MM1 = M-1                                                         5JET7560
      MM2 = M+1                                                         5JET7570
      I = 0                                                             5JET7580
C                                                                       5JET7590
C     W'S THAT ARE NEEDED FOR COMPUTING W OF PLANE L+1 ARE ARRANGED     5JET7600
C                                                                       5JET7610
      DO 680 NN=NN1,NN2                                                 5JET7620
      DO 680 MM=MM1,MM2                                                 5JET7630
      IF (NN.NE.N.AND.MM.NE.M) GO TO 680                                5JET7640
      I = I+1                                                           5JET7650
      WW(1,I) = W13(MM,NN)                                              5JET7660
      WW(2,I) = W24(MM,NN)                                              5JET7670
      WW(3,I) = W13(NN,MM)                                              5JET7680
      WW(4,I) = W24(NN,MM)                                              5JET7690
  680 CONTINUE                                                          5JET7700
```

```
      IF (M.EQ.MB.AND.LPLANE.LE.JUMP) GO TO 700                         5JET7710
C                                                                       5JET7720
C     STANDARD PROCEDURE FOR CALCULATION W'S AT S                       5JET7730
C                                                                       5JET7740
      DO 690 J=1,4                                                      5JET7750
      W1(J) = .5*(WW(J,4)+WW(J,3))+S*LAM1*(F(J,M+1,2)-F(J,M,2))+.25*    5JET7760
     *S*LAM2*(G(J,M,1)-G(J,M,3)+G(J,M+1,1)-G(J,M+1,3))                  5JET7770
      W2(J) = .5*(WW(J,2)+WW(J,3))+S*LAM1*(F(J,M,2)-F(J,M-1,2))+.25*    5JET7780
     *S*LAM2*(G(J,M,1)-G(J,M,3)+G(J,M-1,1)-G(J,M-1,3))                  5JET7790
      W3(J) = .5*(WW(J,3)+WW(J,5))+.25*S*LAM1*(F(J,M+1,1)-F(J,M-1,1)    5JET7800
     *+F(J,M+1,2)-F(J,M-1,2))+S*LAM2*(G(J,M,1)-G(J,M,2))                5JET7810
  690 W4(J) = .5*(WW(J,3)+WW(J,1))+.25*S*LAM1*(F(J,M+1,3)-F(J,M-1,3)    5JET7820
     *+F(J,M+1,2)-F(J,M-1,2))+S*LAM2*(G(J,M,2)-G(J,M,3))                5JET7830
      GO TO 720                                                         5JET7840
C                                                                       5JET7850
C     SPECIAL PROCEDURE FOR FINDING W'S AT M=MB AND S                   5JET7860
C                                                                       5JET7870
  700 DO 710 J=1,4                                                      5JET7880
      W1(J) = WW(J,3)+.5*TT*(WW(J,4)-WW(J,2))+.5*TT**2*(WW(J,4)+WW(J,2)-5JET7890
     *2.0*WW(J,3))+.5*S*LAM1*(F(J,M+1,2)-F(J,M-1,2))+.5*S*LAM2*(G(J,M,1)5JET7900
     *-G(J,M,3))+S*LAM1*TT*(F(J,M+1,2)+F(J,M-1,2)-2.*F(J,M,2))+.25*S*TT*5JET7910
     *LAM2*(G(J,M+1,1)-G(J,M+1,3)-G(J,M-1,1)+G(J,M-1,3))                5JET7920
      W2(J) = WW(J,3)-.5*TT*(WW(J,4)-WW(J,2))+.5*TT**2*(WW(J,4)+WW(J,2)-5JET7930
     *2.0*WW(J,3))+.5*S*LAM1*(F(J,M+1,2)-F(J,M-1,2))+.5*S*LAM2*(G(J,M,1)5JET7940
     *-G(J,M,3))-S*LAM1*TT*(F(J,M+1,2)+F(J,M-1,2)-2.*F(J,M,2))-.25*S*TT*5JET7950
     *LAM2*(G(J,M+1,1)-G(J,M+1,3)-G(J,M-1,1)+G(J,M-1,3))                5JET7960
      W3(J) = WW(J,3)+.5*TS*(WW(J,5)-WW(J,1))+.5*TS**2*(WW(J,5)+WW(J,1)-5JET7970
     *2.0*WW(J,3))+.5*S*LAM1*(F(J,M+1,2)-F(J,M-1,2))+.5*S*LAM2*(G(J,M,1)5JET7980
     *-G(J,M,3))+.25*S*LAM1*TS*(F(J,M+1,1)-F(J,M-1,1)-F(J,M+1,3)+F(J,M-15JET7990
     *,3))+S*LAM2*TS*(G(J,M,1)+G(J,M,3)-2.0*G(J,M,2))                   5JET8000
  710 W4(J) = WW(J,3)-.5*TS*(WW(J,5)-WW(J,1))+.5*TS**2*(WW(J,5)+WW(J,1)-5JET8010
     *2.0*WW(J,3))+.5*S*LAM1*(F(J,M+1,2)-F(J,M-1,2))+.5*S*LAM2*(G(J,M,1)5JET8020
     *-G(J,M,3))-.25*S*LAM1*TS*(F(J,M+1,1)-F(J,M-1,1)-F(J,M+1,3)+F(J,M-15JET8030
     *,3))-S*LAM2*TS*(G(J,M,1)+G(J,M,3)-2.0*G(J,M,2))                   5JET8040
C                                                                       5JET8050
C     DETERMINE F AND G PROPERTIES OF W AT S                            5JET8060
C                                                                       5JET8070
  720 CALL PROP (W1(1),F1(1),UQM,2)                                     5JET8080
      CALL PROP (W2(1),F2(1),UQM,2)                                     5JET8090
      CALL PROP (W3(1),UQM,G1(1),3)                                     5JET8100
      CALL PROP (W4(1),UQM,G2(1),3)                                     5JET8110
C                                                                       5JET8120
C     STORE RESULTS OF W IN TEMPORARY UNUSED SECTION OF W MATRIX        5JET8130
C                                                                       5JET8140
      DO 730 J=1,4                                                      5JET8150
  730 W1(J) = (DL1+1.0)/2.0*CL1*(LAM1*(F1(J)-F2(J))+LAM2*(G1(J)-G2(J)))+5JET8160
     *(.25*(1.0-(CL1-0.5)/0.5)*(DL1+1.0)/2.0-0.5*(DL1-1.0)/2.0)*(W1(J)+W5JET8170
     *2(J)+W3(J)+W4(J))                                                 5JET8180
      W13(M-1,N-1) = CONST*W13(M,N)+W1(1)                               5JET8190
      W24(M-1,N-1) = CONST*W24(M,N)+W1(2)                               5JET8200
      W13(N-1,M-1) = CONST*W13(N,M)+W1(3)                               5JET8210
      W24(N-1,M-1) = CONST*W24(N,M)+W1(4)                               5JET8220
  740 CONTINUE                                                          5JET8230
C                                                                       5JET8240
C     RESTORE W VALUE CORRECTLY                                         5JET8250
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C                                                                       5JET8260
      DO 750 I=2,NB                                                     5JET8270
      N = NB+2-I                                                        5JET8280
      DO 750 M=MA3D,MBD                                                 5JET8290
      IF (N.GT.M-3) GO TO 750                                           5JET8300
      W13(M,N) = W13(M-1,N-1)                                           5JET8310
      W24(M,N) = W24(M-1,N-1)                                           5JET8320
      W13(N,M) = W13(N-1,M-1)                                           5JET8330
      W24(N,M) = W24(N-1,M-1)                                           5JET8340
  750 CONTINUE                                                          5JET8350
C                                                                       5JET8360
C                                                                       5JET8370
C                                                                       5JET8380
      MA = MA+2                                                         5JET8390
      IF (MBC.NE.MB) MBC = MBC-2                                        5JET8400
      IF (LPLANE.LT.LMAX) GO TO 760                                     5JET8410
C                                                                       5JET8420
C                                                                       5JET8430
C     STORE INFORMATION FOR CONTINUATION RUN                            5JET8440
C                                                                       5JET8450
C                                                                       5JET8460
      WRITE(3) LAM0,LAM1,GAM,M0,RR,NB,NBP,MA,ENTH,W13,W24,LPLANE,MBC,MC,5JET8470
     *NX                                                                5JET8480
C                                                                       5JET8490
C     WRITE OUT LAST PAGE                                               5JET8500
C                                                                       5JET8510
      CALL WRITES (2)                                                   5JET8520
      STOP                                                              5JET8530
C                                                                       5JET8540
C     IF NO MORE JET INFORMATION IS NEEDED GO AND FILL IN AUXILIARY JET 5JET8550
C     PROPERTIES                                                        5JET8560
C                                                                       5JET8570
  760 IF (RR.LT.RX(2)) GO TO 120                                        5JET8580
C                                                                       5JET8590
C     MORE JET INFORMATION IS NEEDED IN ORDER TO CONTINUE               5JET8600
C                                                                       5JET8610
      GO TO 30                                                          5JET8620
      END                                                               5JET8630
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$IBFTC WRITE1  LIST                                                     WRIT  10
      SUBROUTINE WRITES(I)                                              WRIT  20
C                                                                       WRIT  30
C                                                                       WRIT  40
C     OUTPUT SUBROUTINE                                                 WRIT  50
C                                                                       WRIT  60
C                                                                       WRIT  70
      COMMON /INOUT/ LMIN,LMAX,MI,IJL,IFLG,IDIV,JUMP,JUMP1,LAMO,GAM ,ASOWRIT  80
     *,AS1,AS2,FACTOR,RDJ,C1,C2,CC,ALF,TT,TS,DPRNT,CN,CXR,DL1,CL1       WRIT  90
      REAL LAMO                                                         WRIT 100
      IF (I.EQ.2) GO TO 250                                             WRIT 110
C                                                                       WRIT 120
C     PRINT DATA CAPTION                                                WRIT 130
C                                                                       WRIT 140
      WRITE (6,10)                                                      WRIT 150
   10 FORMAT (1H1,17(/),43X,5(1H*),25X,1H*,2X,5(1H*),2X,7(1H*)/43X,1H*,2WRIT 160
     *9X,2(1H*,2X),7X,1H*/43X4(1H*),26X2(1H*,2X),7X,1H*/47X,  1H*,     8WRIT 170
     *X,5(1H*),12X,1H*,2X,4(1H*),6X,1H*/47X,1H*,25X,2(1H*,2X),7X,1H*/43XWRIT 180
     *,2(1H*,3X),15X,2(3X,1H*),2X,2(1H*,9X),/44X,3(1H*),23X,3(1H*),3X,5(WRIT 190
     *1H*),5X,1H*///25X,2(1H*,2X),3X,1H*,2X,7(1H*),2X,5(1H*),2X,5(1H*),4WRIT 200
     *X,4(1H*),4X,4(1H*),3X,7(1H*),2X,1H*,3X,4(1H*),3X,2(1H*,5X)/25X,1H*WRIT 210
     *,2X,2H**,4X,1H*,5X,1H*,5X,1H*,6X1H*4X1H*,2X,1H*,4X,1H*,2X,1H*,4X,1WRIT 220
     *H*,5X,1H*,5X,1H*,2X,1H*,4X,1H*,2X,2H**,4X,1H*/25X,1H*,2X,3H* *,3X,WRIT 230
     *1H*,5X,1H*,5X,1H*,6X,1H*,4X,1H*,2X,1H*,4X,1H*,2X,1H*,10X,1H*,5X,1HWRIT 240
     **,2X,1H*,4X,1H*,2X,3H* *,3X,1H*/25X,4(1H*,2X),3X,1H*,5X,4(1H*),3X,WRIT 250
     *5(1H*),3X,6(1H*),2X,1H*,10X,1H*,5X,1H*,2X,1H*,4X,4(1H*,2X),/25X,9HWRIT 260
     **  *   * ,3(1H*,5X),2(1X,1H*),1X2(4X,1H*),2X1H*5X,2(5X,1H*),2X,1H*WRIT 270
     *,2X,2(2X,1H*),3X,3H* */25X,2(3H*  ),3H  *3(1H*,5X),5H *  *,2(4X,1HWRIT 280
     **),2X,1H*,4X,1H*,2(5X,1H*),2X,1H*,4X,2(1H*,2X),4H  **/25X3H*  ,3(1WRIT 290
     *H*,5X),5(1H*),2X,1H*,2(3X,1H*),4X,1H*,3X,4(1H*),1X,2(5X,1H*),3X,4(WRIT 300
     *1H*),3X,2(1H*,5X),///39X,2(5(1H*),3X),5H ****,4X,4(1H*),3X,5(1H*),WRIT 310
     *4X4(1H*),3X2(1H*,5X),/39X6(1H*,4X,3H*  ),2(2H**,3X),/39X6(1H*4X3H*WRIT 320
     *  ),4(2H* ),/39X2(5(1H*),3X),1H*,4X,4H*  *,7X,5(1H*),3X,6(1H*),3(2WRIT 330
     *X,1H*),/32X,2(7X,1H*),3H  *,2(4X,1H*),2X,12H*  ***  * * 2(4X,1H*),WRIT 340
     *2X,1H*,5X,1H*)                                                    WRIT 350
      WRITE (6,20)                                                      WRIT 360
   20 FORMAT (39X,1H*,7X,1H*,3X,1H*,3X,1H*,4X,1H*,2X,1H*,4X,1H*,2X,1H*,2WRIT 370
     *X,1H*,2(4X,1H*),2X,2(1H*,5X)/                                     WRIT 380
     *        32X,2(7X,1H*),4X,1H*,3X,4H****,4X,4H****,3(3X,1H*),4X,4H* WRIT 390
     * *,5X,1H*/1H1)                                                    WRIT 400
C                                                                       WRIT 410
C     PRINT INPUT DATA DEFINITIONS                                      WRIT 420
C                                                                       WRIT 430
      WRITE (6,30)                                                      WRIT 440
   30 FORMAT (36X,2(1H*,2X),4H *  ,4(1H*),2(3X,1H*),2X,5(1H*),7X,4(1H*),WRIT 450
     *4X,3H***,3X,5(1H*),3X,3H***/36X,5H*  **,2(2X,1H*),1X,2(2X,1H*),3X,WRIT 460
     *2(1H*,4X),2X,2(3X,1H*),2X,2(1H*,3X),3H * ,2(3X,1H*)/10X,5(2H* ),14WRIT 470
     *X,2(2X,1H*),2(2H *),2X,4(1H*),2(3X,1H*),4X,1H*,6X,2(3X,1H*),2X,5(1WRIT 480
     *H*),4X,1H*,4X,5(1H*),16X,5(2H *)/34X,3(3H  *),2(3H*  ),4X,2(1H*,3XWRIT 490
     *),2H *,6X,2(3X,1H*),2X,2(1H*,3X),3H * ,2(3X,1H*)/34X,2(3H  *),1X,2WRIT 500
     *(3H  *),7X,3H***,5X,1H*,9X,4H****,2(3X,1H*),2(4X,1H*),3X,1H*/////)WRIT 510
      WRITE (6,40) GAM                                                  WRIT 520
   40 FORMAT (48X,30HRATIO OF SPECIFIC HEATS GAM = ,F6.2/78X,6(1H-)/)   WRIT 530
      RDJJ = RDJ*CN                                                     WRIT 540
      WRITE (6,50) RDJJ                                                 WRIT 550
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 50 FORMAT (32X,74HHALF THE SEPARATION DISTANCE OF THE AXIS OF THE TWOWRIT 560
   * NEAREST JETS IS RDJ = ,F7.3/108X,7(1H-)/)                        WRIT 570
    WRITE (6,60) CN                                                   WRIT 580
 60 FORMAT (31X,63HTHE RADIUS OF THE INITIAL DATA LINE FOR THE SINGLE WRIT 590
   *JET IS CN = ,F6.3/94X,6(1H-)/)                                    WRIT 600
    WRITE (6,70) CXR                                                  WRIT 610
 70 FORMAT (21X,84HTHE DISTANCE BETWEEN NOZZLE EXIT AND ORIGIN OF THE WRIT 620
   *POLAR COORDINATE SYSTEM IS CXR = ,F6.3/105X,6(1H-)/)              WRIT 630
    WRITE (6,80) MI                                                   WRIT 640
 80 FORMAT (18X,94HTHE NUMBER OF GRID INTERVALS BETWEEN THE AXIS OF CEWRIT 650
   *NTER JET AND THE INTERACTION PLANE IS MO = ,I3/112X,3H---/)       WRIT 660
    WRITE (6,90) LAMO                                                 WRIT 670
 90 FORMAT (37X,52HRATIO OF GRID CROSS PLANE STEP SIZES DZ/DY IS LAMO=WRIT 680
   * ,F6.3/89X,6(1H-)/)                                               WRIT 690
    LL = LMAX-LMIN                                                    WRIT 700
    LMAX1 = LMAX-1                                                    WRIT 710
    WRITE (6,100) LL,LMIN,LMAX1                                       WRIT 720
100 FORMAT (29X,22HTHIS RUN WILL COMPUTE ,I4,26H CROSS PLANES FROM LMIWRIT 730
   *N = ,I4,6H THRU ,8H LMAX = ,I4/51X,4H----,26X,4H----,14X,4H----/) WRIT 740
    IF (DPRNT.EQ.0.0) WRITE (6,110)                                   WRIT 750
110 FORMAT (42X,48HPRINTING OCCURS FOR EVERY CALCULATED CROSS PLANE//)WRIT 760
    IF (DPRNT.NE.0.0) WRITE (6,120) DPRNT                             WRIT 770
120 FORMAT (37X,26HPRINT INTERVAL IS DPRNT = ,F7.4,25H NOZZLE RADII DOWRIT 780
   *WN STREAM/63X,7(1H-)/)                                            WRIT 790
    WRITE (6,130) JUMP1                                               WRIT 800
130 FORMAT (28X,52HTWICE AS MANY GRID INTERVALS ARE USED FOR THE FIRSTWRIT 810
   * ,I2,21H CROSS PLANES (JUMP1)/80X,2H--/)                          WRIT 820
    WRITE (6,140) IFLG                                                WRIT 830
140 FORMAT (46X,16HTHERE ARE IFLG =,I2,23H SHOCK POINTS INITIALLY/63X,WRIT 840
   *1H-/)                                                             WRIT 850
    WRITE (6,150) ALF                                                 WRIT 860
150 FORMAT (44X,39HTHE FACTOR ALF FOR THE INITIAL STEP IS ,F8.4/83X,8(WRIT 870
   *1H-)/)                                                            WRIT 880
    WRITE (6,160) IDIV                                                WRIT 890
160 FORMAT (36X,24HDX IS DIVIDED BY IDIV = ,I2,33H UNTIL INITIAL INTERWRIT 900
   *ACTION OCCURS/60X,2H--/)                                          WRIT 910
    WRITE (6,170) JUMP                                                WRIT 920
170 FORMAT (30X,17HTHERE ARE JUMP = ,I4,51H PLANES CALCULATED WITH LATWRIT 930
   *ERALLY UNCENTERED SCHEME/47X,4H----/)                             WRIT 940
    WRITE (6,180) TT,TS                                               WRIT 950
180 FORMAT (11X,85HVALUES OF THE UNCENTERED DISTANCES FOR THE SCHEME AWRIT 960
   *T THE INTERACTION PLANE ARE TT =  ,F7.4,10H AND TS = ,F7.4/96X,7(1WRIT 970
   *H-),10X,7(1H-)/)                                                  WRIT 980
    WRITE (6,190) CC                                                  WRIT 990
190 FORMAT (41X,42HTOLERANCE ON THE VALUE OF ENTROPY IS CC = ,F9.4/83XWRIT1000
   *,9(1H-)/)                                                         WRIT1010
    WRITE (6,200) C1,C2                                               WRIT1020
200 FORMAT (11X,71HTOLERANCES THAT CONTROL THE LATERAL SPREADING OF 3-WRIT1030
   *D REGION ARE - C1 = ,F5.3,19H TO THE RIGHT C2 = F5.3/82X,5(1H-),1 WRIT1040
   *9X,5(1H-)/)                                                       WRIT1050
    WRITE (6,210) FACTOR                                              WRIT1060
210 FORMAT (35X,52HCONSTANT MULTIPLIER FACTOR TO LAM1 TERM IS FACTOR =WRIT1070
   * ,F7.4/87X,7(1H-)/)                                               WRIT1080
    WRITE (6,220) AS0,AS1,AS2                                         WRIT1090
220 FORMAT (33X,30HTHE DAMPING FACTORS ARE AS0 = ,F7.3,7H AS1 = ,F7.3,WRIT1100
```

```
     *7H AS2 = ,F7.3/63X,3(6(1H-),8X)/)                                 WRIT1110
      WRITE (6,230) IJL                                                 WRIT1120
  230 FORMAT (43X,19HTHE ELEMENTS IJL = ,I2,25H OF W IS USED FOR DAMPINGWRIT1130
     */62X,2H--/)                                                       WRIT1140
      WRITE (6,240) DL1,CL1                                             WRIT1150
  240 FORMAT (31X,47HTHE ARTIFICIAL VISCOSITY COEFFICIENTS ARE DL = ,F7.WRIT1160
     *3,10H AND CL = ,F7.3/78X,7(1H-),10X,7(1H-)/1H1)                   WRIT1170
      GO TO 270                                                         WRIT1180
C                                                                       WRIT1190
C     PRINT FINAL PAGE                                                  WRIT1200
C                                                                       WRIT1210
  250 WRITE (6,260)                                                     WRIT1220
  260 FORMAT                                                            WRIT1230
     *(1H1/64X1H*/62X,3(2H* )/57X,3(1H*,6X)/55X,3(1H*,8X)/64X,8H*  .....WRIT1240
     */53X,1H*,10X,1H*,5X,1H.,4X,1H*/64X,1H*,4X,1H./52X,1H*,11X1H*3X1H.7WRIT1250
     *X,1H*/64X,1H*,2X,5(1H.)/52X,3(1H*,11X)/64X,1H*/53X,3(1H*,10X)/64X,WRIT1260
     *1H*/55X,3(1H*,8X)/57X,3(1H*,6X)/62X,3(2H* )/5(64X,1H*/),28X,1H*,3XWRIT1270
     *,1H*,29X,3(2H* ),28X,1H*,3X,1H*/23X,1H*,13X,1H*,19X,3(1H*,6X),13X,WRIT1280
     *1H*,13X,1H*/21X,1H*,17X,1H*,15X,3(1H*,8X),7X,1H*,17X,1H*/64X,1H*/1WRIT1290
     *9X,1H*,21X,1H*,11X,3(1H*,10X),2H *,21X,1H*/64X,1H*/18X,1H*,23X,1H*WRIT1300
     *,9X,2(1H*,11X),1H*,9X,1H*,23X,1H*,2(3X,1H.)/12X,51(2H* ),2(2H .)/1WRIT1310
     *8X,1H*,23X,1H*,9X,2(1H*,11X),1H*,9X,1H*,23X,1H*,5X,1H./61X,4H*  *,WRIT1320
     *50X,1H./19X,1H*,21X,1H*,11X,3(1H*,10X),2H *,21X,1H*,4X,1H./58X,2(1WRIT1330
     *H*,5X)/21X,1H*,17X,1H*,15X,3(1H*,8X),7X,1H*,17X,1H*/23X,1H*,13X,1HWRIT1340
     **,17X,2H*  ,3(1H*,6X),13X,1H*,13X,1H*/28X,1H*,3X,1H*,29X,3(2H* ),2WRIT1350
     *8X,1H*,3X,1H*/52X,2(1H*,11X)/64X,1H*/49X,2(1H*,14X)/64X,1H*/46X,2(WRIT1360
     *1H*,17X)/62X,3(2H* )/43X,1H*,13X,3(1H*,6X)/55X,3(1H*,8X)/40X,1H*,2WRIT1370
     *3X,1H*/53X,3(1H*,10X)/37X,1H*,26X,1H*/52X,3(1H*,11X)/23X,1H.,3X,1HWRIT1380
     *.,6X,1H*,29X,1H*/24X,3H. .,25X,3(1H*,11X)/25X,1H.,5X,1H*,32X,1H*/2WRIT1390
     *4X,3H. .,26X,3(1H*,10X)/23X,1H.,3X,1H.,36X,1H*/55X,3(1H*,8X)/57X,3WRIT1400
     *(1H*,6X)/62X,3(2H* )/64X,1H*)                                     WRIT1410
  270 RETURN                                                            WRIT1420
      END                                                               WRIT1430
```

```
$IBFTC PROPS   LIST                                                     PROP  10
      SUBROUTINE PROP (W,F,G,I)                                         PROP  20
      COMMON /INPROP/ GAM,GAM1,GAM2,M,N,BCD                             PROP  30
      DIMENSION W(4),F(1),G(1)                                          PROP  40
C     V = G(3)                                                          PROP  50
C     W = G(2)                                                          PROP  60
C     R = G(1)                                                          PROP  70
C     U = F(1)                                                          PROP  80
C     P = G(4)                                                          PROP  90
C     Q = F(2)                                                          PROP 100
C     M = F(3)                                                          PROP 110
C     S = F(4)                                                          PROP 120
      G(3) = W(3)/W(1)                                                  PROP 130
      G(2) = W(4)/W(1)                                                  PROP 140
      IF (I.EQ.6) G(2) = 0.0                                            PROP 150
      A = GAM1*W(2)/(GAM2-G(3)**2-G(2)**2)                              PROP 160
      B = GAM2*W(1)**2/(GAM1*W(2))                                      PROP 170
      G(1) = A*(1.0-SQRT(1.0-B/A))                                      PROP 180
      F(1) = W(1)/G(1)                                                  PROP 190
      G(4) = W(2)-F(1)*W(1)                                             PROP 200
      GO TO (20,20,30,10,10,60), I                                      PROP 210
   10 F(2) = SQRT(F(1)**2+G(3)**2+G(2)**2)                              PROP 220
      F(3) = F(2)/SQRT(GAM*G(4)/G(1))                                   PROP 230
      F(4) = G(4)/(G(1)**GAM)                                           PROP 240
      IF (I-4) 60,40,60                                                 PROP 250
C     SOLVE FOR F FUNCTIONS                                             PROP 260
   20 F(1) = -G(1)*G(3)                                                 PROP 270
      F(2) = -W(3)                                                      PROP 280
      F(3) = G(3)*F(1)-G(4)                                             PROP 290
      F(4) = G(2)*F(1)                                                  PROP 300
      GO TO (30,60), I                                                  PROP 310
C     COMPUTE G FUNCTIONS                                               PROP 320
   30 G(1) = -G(1)*G(2)                                                 PROP 330
      G(3) = G(3)*G(1)                                                  PROP 340
      G(4) = G(2)*G(1)-G(4)                                             PROP 350
      G(2) = -W(4)                                                      PROP 360
      GO TO 60                                                          PROP 370
   40 T = GAM*G(4)/G(1)                                                 PROP 380
C     PRINT FLUID PROPERTIES                                            PROP 390
      WRITE (6,50) M,N,G(1),G(4),T,F(4),F(1),G(3),G(2),F(2),F(3),BCD    PROP 400
   50 FORMAT (I4,I5,1X,9E13.6,3X,A1)                                    PROP 410
   60 RETURN                                                            PROP 420
      END                                                               PROP 430
```

```
$IBFTC JETS    LIST                                                     JET   10
      SUBROUTINE JET (w,RUVP,RHO,DR,MAX1,Y,RX,RR,I)                     JET   20
      DIMENSION W(3,80,2),RUVP(4),DR(3),MAX1(3),RX(3),X(3),W1(2),W2(3,2)JET   30
     *,Y(3),W3(2),W4(3)                                                 JET   40
C     X(1) LIES TO LEFT OF CROSS PLANE                                  JET   50
C     X(2) LIES DOWN STREAM OF CROSS PLANE                              JET   60
      X(1) = RX(3)                                                      JET   70
      X(2) = RX(2)                                                      JET   80
      X(3) = RX(3)                                                      JET   90
C     I=1 CALCULATE JET VALUES CLOSE TO BOUNDARY OF JET                 JET  100
C     I=2 CALCULATE INTERIOR JET VALUES                                 JET  110
      GO TO (20,10), I                                                  JET  120
C     STEP SIZES CAN BE DIFFERENT FOR ANY TWO JET PLANES                JET  130
   10 K1 = RHO/DR(3)+2.0                                                JET  140
      IF (K1.GT.MAX1(3)) K1 = MAX1(3)                                   JET  150
      K2 = RHO/DR(2)+2.0                                                JET  160
      IF (K2.GT.MAX1(2)) K2 = MAX1(2)                                   JET  170
       IF (FLOAT(K1-1)*DR(3).EQ.FLOAT(K2)*DR(2)) K1 = K1-1              JET  180
      GO TO 30                                                          JET  190
   20 K1 = MAX1(3)                                                      JET  200
      K2= MAX1(2)                                                       JET  210
      W2(1,2) = 0.0                                                     JET  220
   30 DO 40 J=1,3                                                       JET  230
C     W HERE IS W VALUES OF JET CROSS PLANE                             JET  240
C     J IS THE W PROPERTY                                               JET  250
C     K1 IS THE W POSITION                                              JET  260
C     1 OR 2 IS THE W CROSS PLANE CORRESPONDING TO X                    JET  270
      W1(1) = W(J,K1,2)                                                 JET  280
      W1(2) = W(J,K2,1)                                                 JET  290
   40 CALL INTRP (X,RR,W1,W2(J,I))                                      JET  300
      IF (W2(1,2).EQ.0.0) GO TO 90                                      JET  310
      IF (I.EQ.1) GO TO 50                                              JET  320
      I = 1                                                             JET  330
C     W3 GIVES DISTANCE FROM AXIS TO INTEGER DISTANCE BELOW RHO         JET  340
      W3(1) = FLOAT(K1-2)*DR(3)                                         JET  350
      IF (K1.GE.MAX1(3)) W3(1) = Y(3)                                   JET  360
      K1 = K1+1                                                         JET  370
      W3(2) = FLOAT(K2-2)*DR(2)                                         JET  380
      IF (K2.GE.MAX1(2)) W3(2) = Y(2)                                   JET  390
      K2 = K2+1                                                         JET  400
      IF (DR(2).NE.DR(3)) K1 = K1+1                                     JET  410
      IF (K2.GT.MAX1(2)) K2 = MAX1(2)                                   JET  420
      IF (K1.GT.MAX1(3)) K1 = MAX1(3)                                   JET  430
      GO TO 30                                                          JET  440
   50 I = 2                                                             JET  450
C     W1 SAME AS W3 EXCEPT DISTANCE IS ABOVE RHO                        JET  460
      W1(1) = DR(3)*FLOAT(K1-2)                                         JET  470
      IF (K1.EQ.MAX1(3)) W1(1) = Y(3)                                   JET  480
      W1(2) = DR(2)*FLOAT(K2-2)                                         JET  490
      IF (K2.EQ.MAX1(3)) W1(2) = Y(2)                                   JET  500
      CALL INTRP (X,RR,W1,RH)                                           JET  510
      IF (W3(1).NE.W3(2)) CALL INTRP (X,RR,W3,W3(1))                    JET  520
C     X(2) IS Y DISTANCE ON 3-D PLANE ABOVE RHO                         JET  530
C     X(3) IS Y DISTANCE BELOW RHO                                      JET  540
      X(2) = W3(1)                                                      JET  550
```

```
      X(3) = RH                                                         JET  560
      X(1) = RH                                                         JET  570
      DO 60 J=1,3                                                       JET  580
      W1(1) = W2(J,1)                                                   JET  590
      W1(2) = W2(J,2)                                                   JET  600
   60 CALL INTRP (X,RHO,W1,W4(J))                                       JET  610
      CALL PROP (W4,RH,RUVP,6)                                          JET  620
   70 RUVP(2) = RH                                                      JET  630
   80 FORMAT (8E16.8)                                                   JET  640
C     W IS INTERPOLATED W VALUES AT RHO                                 JET  650
      RETURN                                                            JET  660
C     I = 1                                                             JET  670
   90 CALL PROP (W2,RH,RUVP,6)                                          JET  680
      GO TO 70                                                          JET  690
      END                                                               JET  700
```

```
$IBFTC INTRPS  LIST                                                    INTP  10
      SUBROUTINE INTRP (R,S,P,ANS)                                     INTP  20
      DIMENSION R(3),P(3)                                              INTP  30
C     R    X ARRAY, THREE ENTRIES                                      INTP  40
C     P    Y ARRAY, THREE ENTRIES                                      INTP  50
C     S VALUE TO BE INTERPOLATED                                       INTP  60
C     P    INTERPOLATED VALUE                                          INTP  70
C     X    DISTANCES ARE REFERENCED TO R(1)                            INTP  80
      Q1 = S-R(1)                                                      INTP  90
      Q2 = R(2)-R(1)                                                   INTP 100
      Q3 = R(3)-R(1)                                                   INTP 110
      C = ((P(2)-P(1))*Q3+(P(1)-P(3))*Q2)/(Q2*Q3*(Q2-Q3))              INTP 120
C     IF C=0 LINEAR INTERPOLATION                                      INTP 130
      IF (Q3.EQ.0.0) C = 0.0                                           INTP 140
      B = (P(2)-P(1)-C*Q2**2)/Q2                                       INTP 150
      ANS = P(1)+B*Q1+C*Q1**2                                          INTP 160
      RETURN                                                           INTP 170
      END                                                              INTP 180
```

```
$IBFTC AUXPT   LIST                                                    AXPT  10
      SUBROUTINE AUXPTS (W13,W24,MA,MAX,MBC)                           AXPT  20
      DIMENSION W13(80,80),W24(80,80)                                  AXPT  30
      MBB = MBC+1                                                      AXPT  40
      IF (MAX.LE.MA) GO TO 20                                          AXPT  50
C     FILL IN DIAGONAL REFLECTION POINTS                               AXPT  60
      MMAX = MAX-1                                                     AXPT  70
      DO 10 I=MA,MMAX                                                  AXPT  80
      L = I-3                                                          AXPT  90
      DO 10 J=1,2                                                      AXPT 100
      LL = I-J                                                         AXPT 110
      K = I+3-J                                                        AXPT 120
      W13(I,LL) = W13(K,L)                                             AXPT 130
      W24(I,LL) = W24(K,L)                                             AXPT 140
      W13(LL,I) = W24(L,K)                                             AXPT 150
   10 W24(LL,I) = W13(L,K)                                             AXPT 160
   20 IF (MA.GE.5) GO TO 30                                            AXPT 170
C     FILL IN REFLECTION POINTS AT CENTER ENGINE REGION                AXPT 180
      W13(4,3) = W13(6,3)                                              AXPT 190
      W24(4,3) = W24(6,3)                                              AXPT 200
      W13(3,4) =-W13(3,6)                                              AXPT 210
      W24(3,4) = W24(3,6)                                              AXPT 220
      W13(4,2) = W13(6,2)                                              AXPT 230
      W24(4,2) = W24(6,2)                                              AXPT 240
      W13(2,4) =-W13(2,6)                                              AXPT 250
      W24(2,4) = W24(2,6)                                              AXPT 260
   30 DO 40 I=MA,MBB                                                   AXPT 270
C     REFLECT VALUES OF N=3 INTO N=1 LINE                              AXPT 280
      W13(I,1) = W13(I,3)                                              AXPT 290
      W24(I,1) = W24(I,3)                                              AXPT 300
      W13(1,I) = W13(3,I)                                              AXPT 310
   40 W24(1,I) =-W24(3,I)                                              AXPT 320
      RETURN                                                           AXPT 330
      END                                                              AXPT 340
```

```
$IBMAP FILE1
*      JET TAPE INPUT
       ENTRY    .UN01.
.UN01. PZE      UNIT01
UNIT01 FILE     ,B(1),READY,BIN,BLK=256,INOUT,HOLD,HIGH
       END
$IBMAP FILE2
*      CONTINUATION RUN INPUT
       ENTRY    .UN02.
.UN02. PZE      UNIT02
UNIT02 FILE     ,B(2),READY,BIN,BLK=256,INOUT,HOLD,HIGH
       END
$IBMAP FILE3
*      CONTINUATION RUN OUTPUT
       ENTRY    .UN03.
.UN03. PZE      UNIT03
UNIT03 FILE     ,B(3),READY,BIN,BLK=256,INOUT,HOLD,HIGH
       END
```

APPENDIX C

TWO-JET INTERACTION PROGRAM

Input Cards Format

FORTRAN Listing

W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8
±	±	±	±	±	±	±	±
THE FIRST CARD CONSISTS OF FIX POINT INTEGER ENTRIES. ALL INTEGER VALUES ARE RIGHT ADJUSTED IN THEIR FIELDS.							
THE FIRST SEVEN ENTRIES OCCUPY TEN SPACES AND THE LAST TWO ENTRIES FIVE SPACES.							
CARD 1							
LMIN	LMAX	MO	IJL	IFLG	IDIV	JUMP 1	JUMP
I10	I10	I10	I10	I10	I10	I10	I10
THE REMAINING CARDS ARE FLOATING POINT ENTRIES. EACH ENTRY OCCUPIES TEN SPACES							
CARD 2							
LAMO	GAM	ASO	AS1	AS2	FACTOR	RDJ	C
E10.5	E10.5	E10.5	E10.5	E10.5	E10.5	E10.5	E10.5
CARD 3							
CC	ALF	TT	TS	DPRNT	CL	CXR	DL
E10.5	E10.5	E10.5	E10.5	E10.5	E10.5	E10.5	E10.5

Input Cards Format

```
$IBFTC MAIN    LIST                                                     2JET  10
C                                                                       2JET  20
C                                                                       2JET  30
C                                                                       2JET  40
C                                                                       2JET  50
C     2 - JET PROGRAM                                                   2JET  60
C                                                                       2JET  70
C                                                                       2JET  80
C                                                                       2JET  90
C                                                                       2JET 100
      COMMON /INPROP/ GAM,GAM1,GAM2,M,N                                 2JET 110
      DIMENSION W(4,56,56),W3D(3,80,2),RX(3),DR(3),MAX1(3),XX(20),YY(3) 2JET 120
     *,F(4,56,3),G(4,56,3),W1(4),W2(4),W3(4),W4(4),F1(4),F2(4),G1(4),G2(2JET 130
     *4),UQM(4),RWVP(4),RUVP(4),Y(3),W5(4)                              2JET 140
      REAL LAM0,LAM1,LAM2                                               2JET 150
C                                                                       2JET 160
C      READ INITIAL CONDITIONS OR DATA PARAMETERS FOR CONTINUATION RUN  2JET 170
C                                                                       2JET 180
      READ (5,10) LMIN,LMAX,M0,IJL,IFLG,IDIV,JUMP,JUMP1,LAM0,GAM,       2JET 190
     1AS0,AS1,AS2,FACTOR,RDJ,C,CC,ALF,TT,TS,DPRNT,CN,CXR,DL,CL          2JET 200
   10 FORMAT (8I10/(8F10.5))                                            2JET 210
      RDJ = RDJ/CN                                                      2JET 220
C     ADIV DIVIDES INTO LAM1 UNTIL INTERACTION STARTS                   2JET 230
C                                                                       2JET 240
      ADIV = IDIV                                                       2JET 250
      IF (IDIV.EQ.0) ADIV = 1.0                                         2JET 260
      LMAX = LMAX+1                                                     2JET 270
      RR = RDJ                                                          2JET 280
      DY = RDJ/FLOAT(M0)                                                2JET 290
      DYY = DY                                                          2JET 300
      IF (JUMP1.GT.LMIN) DY = DY/2.0                                    2JET 310
C                                                                       2JET 320
C     ONE JET'S CENTER IS AT M=5                                        2JET 330
C                                                                       2JET 340
      MB = M0+5                                                         2JET 350
C                                                                       2JET 360
C     MC IS AUXILIARY GRID LINE TO RIGHT OF 3-D REGION                  2JET 370
C                                                                       2JET 380
      MC = MB+1                                                         2JET 390
C                                                                       2JET 400
C     MA IS AUXILIARY GRID LINE TO LEFT OF 3-D REGION                   2JET 410
C                                                                       2JET 420
      MA = MB                                                           2JET 430
C                                                                       2JET 440
C     NB IS MAXIMUM 3-D CALCULATED GRID LINE IN Z DIRECTION             2JET 450
C                                                                       2JET 460
      NB = 2                                                            2JET 470
C                                                                       2JET 480
C     NBP IS AUXILIARY GRID LINE ABOVE NB IT IS FILLED IN WITH JET VALUE2JET 490
C                                                                       2JET 500
      NBP = NB                                                          2JET 510
      ANB = 0.0                                                         2JET 520
C                                                                       2JET 530
C     IF CONTINUATION RUN IS MADE, INFORMATION FROM PREVIOUS RUN IS     2JET 540
C     OBTAIN HERE                                                       2JET 550
```

```
C                                                                       2JET 560
      IF (LMIN.NE.1) READ (2) W,LAM0,LAM1,GAM,M0,FACTOR,RR,NB,NBP,MA,ENT2JET 570
     *H                                                                 2JET 580
C                                                                       2JET 590
C     PRINT DATA CAPTION                                                2JET 600
C                                                                       2JET 610
      WRITE (6,20)                                                      2JET 620
   20 FORMAT (1H1,17(/),43X,5(1H*),25X,1H*2X5(1H*),2X7(1H*)/42X1H*5X1H*22JET 630
     *4X,2(1H*,2X),7X,1H*/48X, 1H* ,24X2(1H*,2X),7X,1H*/47X,  1H*,     82JET 640
     *X,5(1H*),12X,1H*,2X,4(1H*),6X,1H*/45X,1H*,27X,2(1H*,2X),7X,1H*/43X2JET 650
     *,  1H*    ,22X,2(3X,1H*),2X,2(1H*,9X),/42X,7(1H*),21X,3(1H*),3X,5(2JET 660
     *1H*),5X,1H*///25X,2(1H*,2X),3X,1H*,2X,7(1H*),2X,5(1H*),2X,5(1H*),42JET 670
     *X,4(1H*),4X,4(1H*),3X,7(1H*),2X,1H*,3X,4(1H*),3X,2(1H*,5X)/25X,1H*2JET 680
     *,2X,2H**,4X,1H*,5X,1H*,5X,1H*,6X1H*4X1H*,2X,1H*,4X,1H*,2X,1H*,4X,12JET 690
     *H*,5X,1H*,5X,1H*,2X,1H*,4X,1H*,2X,2H**,4X,1H*/25X,1H*,2X,3H* *,3X,2JET 700
     *1H*,5X,1H*,5X,1H*,6X,1H*,4X,1H*,2X,1H*,4X,1H*,2X,1H*,10X,1H*,5X,1H2JET 710
     **,2X,1H*,4X,1H*,2X,3H* *,3X,1H*/25X,4(1H*,2X),3X,1H*,5X,4(1H*),3X,2JET 720
     *5(1H*),3X,6(1H*),2X,1H*,10X,1H*,5X,1H*,2X,1H*,4X,4(1H*,2X),/25X,9H2JET 730
     **  *   * ,3(1H*,5X),2(1X,1H*),1X2(4X,1H*),2X1H*5X,2(5X,1H*),2X,1H*2JET 740
     *,2X,2(2X,1H*),3X,3H* */25X,2(3H*  ),3H  *3(1H*,5X),5H *  *,2(4X,1H2JET 750
     **),2X,1H*,4X,1H*,2(5X,1H*),2X,1H*,4X,2(1H*,2X),4H  **/25X3H*  ,3(12JET 760
     *H*,5X),5(1H*),2X,1H*,2(3X,1H*),4X,1H*,3X,4(1H*),1X,2(5X,1H*),3X,4(2JET 770
     *1H*),3X,2(1H*,5X),///39X,2(5(1H*),3X),5H ****,4X,4(1H*),3X,5(1H*),2JET 780
     *4X4(1H*),3X2(1H*,5X),/39X6(1H*,4X,3H*  ),2(2H**,3X),/39X6(1H*4X3H*2JET 790
     *  ),4(2H* ),/39X2(5(1H*),3X),1H*,4X,4H*  *,7X,5(1H*),3X,6(1H*),3(22JET 800
     *X,1H*),/32X,2(7X,1H*),3H  *,2(4X,1H*),2X,12H*  ***  * * 2(4X,1H*),2JET 810
     *2X,1H*,5X,1H*)                                                    2JET 820
      WRITE (6,30)                                                      2JET 830
   30 FORMAT (39X,1H*,7X,1H*,3X,1H*,3X,1H*,4X,1H*,2X,1H*,4X,1H*,2X,1H*,22JET 840
     *X,1H*,2(4X,1H*),2X,2(1H*,5X)/                                     2JET 850
     *         32X,2(7X,1H*),4X,1H*,3X,4H****,4X,4H****,3(3X,1H*),4X,4H* 2JET 860
     * *,5X,1H*/1H1)                                                    2JET 870
C                                                                       2JET 880
C     PRINT INPUT DATA DEFINITIONS                                      2JET 890
C                                                                       2JET 900
      WRITE (6,40)                                                      2JET 910
   40 FORMAT (36X,2(1H*,2X),4H *  ,4(1H*),2(3X,1H*),2X,5(1H*),7X,4(1H*),2JET 920
     *4X,3H***,3X,5(1H*),3X,3H***/36X,5H*  **,2(2X,1H*),1X,2(2X,1H*),3X,2JET 930
     *2(1H*,4X),2X,2(3X,1H*),2X,2(1H*,3X),3H * ,2(3X,1H*)/10X,5(2H* ),142JET 940
     *X,2(2X,1H*),2(2H *),2X,4(1H*),2(3X,1H*),4X,1H*,6X,2(3X,1H*),2X,5(12JET 950
     *H*),4X,1H*,4X,5(1H*),16X,5(2H *)/34X,3(3H  *),2(3H*  ),4X,2(1H*,3X2JET 960
     *),2H *,6X,2(3X,1H*),2X,2(1H*,3X),3H * ,2(3X,1H*)/34X,2(3H  *),1X,22JET 970
     *(3H  *),7X,3H***,5X,1H*,9X,4H****,2(3X,1H*),2(4X,1H*),3X,1H*/////)2JET 980
      WRITE (6,50) GAM                                                  2JET 990
   50 FORMAT (48X,30HRATIO OF SPECIFIC HEATS GAM = ,F6.2/78X,6(1H-)/)   2JET1000
      RDJJ = RDJ*CN                                                     2JET1010
      WRITE (6,60) RDJJ                                                 2JET1020
   60 FORMAT (26X,74HHALF THE SEPARATION DISTANCE OF THE AXIS OF THE TWO2JET1030
     * NEAREST JETS IS RDJ = ,F7.3/100X,7(1H-)/)                        2JET1040
      WRITE (6,70) CN                                                   2JET1050
   70 FORMAT (31X,63HTHE RADIUS OF THE INITIAL DATA LINE FOR THE SINGLE 2JET1060
     *JET IS CN = ,F6.3/94X,6(1H-)/)                                    2JET1070
      WRITE (6,80) CXR                                                  2JET1080
   80 FORMAT (21X,84HTHE DISTANCE BETWEEN NOZZLE EXIT AND ORIGIN OF THE 2JET1090
     *POLAR COORDINATE SYSTEM IS CXR = ,F6.3/105X,6(1H-)/)              2JET1100
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      WRITE (6,90) MO                                                   2JET1110
   90 FORMAT (18X,94HTHE NUMBER OF GRID INTERVALS BETWEEN THE AXIS OF CE2JET1120
     *NTER JET AND THE INTERACTION PLANE IS MO = ,I3/112X,3H---/)       2JET1130
      WRITE (6,100) LAMO                                                2JET1140
  100 FORMAT (37X,52HRATIO OF GRID CROSS PLANE STEP SIZES DZ/DY IS LAMO=2JET1150
     * ,F6.3/89X,6(1H-)/)                                               2JET1160
      LL = LMAX-LMIN                                                    2JET1170
      LMAX1 = LMAX-1                                                    2JET1180
      WRITE (6,110) LL,LMIN,LMAX1                                       2JET1190
  110 FORMAT (29X,22HTHIS RUN WILL COMPUTE ,I4,26H CROSS PLANES FROM LMI2JET1200
     *N = ,I4,6H THRU ,8H LMAX = ,I4/51X,4H----,26X,4H----,14X,4H----/) 2JET1210
      IF (DPRNT.EQ.0.0) WRITE (6,120)                                   2JET1220
  120 FORMAT (42X,48HPRINTING OCCURS FOR EVERY CALCULATED CROSS PLANE//)2JET1230
      IF (DPRNT.NE.0.0) WRITE (6,130) DPRNT                             2JET1240
  130 FORMAT (37X,26HPRINT INTERVAL IS DPRNT = ,F7.4,25H NOZZLE RADII DO2JET1250
     *WN STREAM/63X,7(1H-)/)                                            2JET1260
      WRITE (6,140) JUMP1                                               2JET1270
  140 FORMAT (28X,52HTWICE AS MANY GRID INTERVALS ARE USED FOR THE FIRST2JET1280
     * ,I2,21H CROSS PLANES (JUMP1)/80X,2H--/)                          2JET1290
      WRITE (6,150) IFLG                                                2JET1300
  150 FORMAT (46X,16HTHERE ARE IFLG =,I2,23H SHOCK POINTS INITIALLY/63X,2JET1310
     *1H-/)                                                             2JET1320
      WRITE (6,160) ALF                                                 2JET1330
  160 FORMAT (44X,39HTHE FACTOR ALF FOR THE INITIAL STEP IS ,F8.4/83X,8(2JET1340
     *1H-)/)                                                            2JET1350
      WRITE (6,170) IDIV                                                2JET1360
  170 FORMAT (36X,24HDX IS DIVIDED BY IDIV = ,I2,33H UNTIL INITIAL INTER2JET1370
     *ACTION OCCURS/60X,2H--/)                                          2JET1380
      WRITE (6,180) JUMP                                                2JET1390
  180 FORMAT (30X,17HTHERE ARE JUMP = ,I4,51H PLANES CALCULATED WITH LAT2JET1400
     *ERALLY UNCENTERED SCHEME/47X,4H----/)                             2JET1410
      WRITE (6,190) TT,TS                                               2JET1420
  190 FORMAT (11X,85HVALUES OF THE UNCENTERED DISTANCES FOR THE SCHEME A2JET1430
     *T THE INTERACTION PLANE ARE TT =  ,F7.4,10H AND TS = ,F7.4/96X,7(12JET1440
     *H-),10X,7(1H-)/)                                                  2JET1450
      WRITE (6,200) CC                                                  2JET1460
  200 FORMAT (41X,42HTOLERANCE ON THE VALUE OF ENTROPY IS CC = ,F9.4/83X2JET1470
     *,9(1H-)/)                                                         2JET1480
      WRITE (6,210) C                                                   2JET1490
  210 FORMAT (29X,68HTOLERANCES THAT CONTROL THE LATERAL SPREADING OF 3-2JET1500
     *D REGION IS  C =  F5.3/97X,5(1H-)/)                               2JET1510
      WRITE (6,220) FACTOR                                              2JET1520
  220 FORMAT (35X,52HCONSTANT MULTIPLIER FACTOR TO LAM1 TERM IS FACTOR =2JET1530
     * ,F7.4/87X,7(1H- /)                                               2JET1540
      WRITE (6,230) AS0,AS1,AS2                                         2JET1550
  230 FORMAT (33X,30HTHE DAMPING FACTORS ARE AS0 = ,F7.3,7H AS1 = ,F7.3,2JET1560
     *7H AS2 = ,F7.3 53X,3(6(1H-),8X)/)                                 2JET1570
      WRITE (6,240) JL                                                  2JET1580
  240 FORMAT (43X,19HTHE ELEMENTS IJL = ,I2,25H OF W IS USED FOR DAMPING2JET1590
     */62X,2H--/)                                                       2JET1600
      WRITE (6,250) DL,CL                                               2JET1610
  250 FORMAT (31X,47HTHE ARTIFICIAL VISCOSITY COEFFICIENTS ARE DL = ,F7.2JET1620
     *3,10H AND CL = ,F7.3/78X,7(1H-),10X,7(1H-)/1H1)                   2JET1630
      MA3D = MA-1                                                       2JET1640
      GAM1 = GAM/(GAM-1.0)                                              2JET1650
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      GAM2 = (GAM+1.0)/(GAM-1.0)                                        2JET1660
      H = .5*GAM2                                                       2JET1670
      XDIST = 0.0                                                       2JET1680
      LPLANE = LMIN                                                     2JET1690
C                                                                       2JET1700
C                                                                       2JET1710
C     JET TAPE IS READ BELOW                                            2JET1720
C                                                                       2JET1730
C                                                                       2JET1740
      DO 260 I=1,19                                                     2JET1750
      XX(I) = 0.0                                                       2JET1760
  260 IF (I.LT.3) YY(I) = 0.0                                           2JET1770
      GO TO 290                                                         2JET1780
  270 RX(3) = RX(2)                                                     2JET1790
      Y(3) = Y(2)                                                       2JET1800
      DR(3) = DR(2)                                                     2JET1810
      MAX1(3) = MAX1(2)                                                 2JET1820
      MAXX = MAX1(3)                                                    2JET1830
      DO 280 M=2,MAXX                                                   2JET1840
      DO 280 I=1,3                                                      2JET1850
  280 W3D(I,M,2) = W3D(I,M,1)                                           2JET1860
  290 READ (1) XD,RX(2),DX,Y(2),DR(2),MAX1(2),((W3D(I,J,1),I=1,3),J=1,80 2JET1870
     *)                                                                 2JET1880
      IF (RR.NE.RDJ) GO TO 330                                          2JET1890
      DO 300 I=1,19                                                     2JET1900
      J = 20-I                                                          2JET1910
      XX(J+1) = XX(J)                                                   2JET1920
  300 IF (J.LT.3) YY(J+1) = YY(J)                                       2JET1930
      XX(1) = RX(2)                                                     2JET1940
      YY(1) = Y(2)                                                      2JET1950
C                                                                       2JET1960
C     IF PLUME OF JET IS LESS THAN INTERACTION DISTANCE CONTINUE TO READ2JET1970
C     JET TAPE                                                          2JET1980
C                                                                       2JET1990
      IF (Y(2).LE.RDJ) GO TO 290                                        2JET2000
      CALL INTRP (YY,RDJ,XX,RR)                                         2JET2010
C                                                                       2JET2020
C     RRDJ IS DISTANCE FROM NOZZLE EXIT INTERACTION OCCURS              2JET2030
C                                                                       2JET2040
      RRDJ = RR                                                         2JET2050
      RXP = CN*RR-CXR                                                   2JET2060
      WRITE (6,310) RXP                                                 2JET2070
  310 FORMAT (36X,22HINTERACTION WILL OCCUR,F10.5,28H EXIT RADII FROM NO2JET2080
     *ZZLE EXIT/////)                                                   2JET2090
C                                                                       2JET2100
C                                                                       2JET2110
C                                                                       2JET2120
C     CALCULATE SHOCK PROPERTIES BELOW                                  2JET2130
C     FIRST SHOCK PROPERTIES DETERMINED ARE USED IN THE REGION OF M=MB  2JET2140
C                                                                       2JET2150
C                                                                       2JET2160
C                                                                       2JET2170
      MM = MAX1(2)                                                      2JET2180
      W1(1) = W3D(1,MM,1)                                               2JET2190
      W1(2) = W3D(2,MM,1)                                               2JET2200
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      W1(3) = W3D(3,MM,1)                                               2JET2210
      W1(4) = 0.0                                                       2JET2220
      CALL PROP (W1,UQM,RWVP,5)                                         2JET2230
      TNB = (RWVP(3)/UQM(1))**2                                         2JET2240
      SNB = TNB/(1.+TNB)                                                2JET2250
      P =(-(UQM(3)**2+2.)/UQM(3)**2-GAM*SNB)/3.                         2JET2260
      Q = (2.*UQM(3)**2+1.)/UQM(3)**4+((GAM+1.)**2/4.+(GAM-1.)/UQM(3)**22JET2270
     *)*SNB                                                             2JET2280
      R = (SNB-1.)/UQM(3)**4                                            2JET2290
      A = Q-3.*P**2                                                     2JET2300
      B = R-P*Q-2.*ABS(P)**3.                                           2JET2310
      PHI =(ACOS(-.5*B/(ABS(A)/3.)**1.5))/3.                            2JET2320
      AA = 2.*SQRT(-A/3.)                                               2JET2330
      PI3 = 2.0943952                                                   2JET2340
      YY(1) = AA*COS(PHI)-P                                             2JET2350
      YY(2) = AA*COS(PHI+PI3)-P                                         2JET2360
      YY(3) = AA*COS(PHI+2.*PI3)-P                                      2JET2370
      B = AMAX1 (YY(1),YY(2))                                           2JET2380
      IF (YY(3).LT.B) B = AMAX1(YY(3),AMIN1(YY(1),YY(2)))               2JET2390
      AM = UQM(3)**2*B                                                  2JET2400
      PPP = (2.*GAM*AM-GAM+1.)/(GAM+1.)                                 2JET2410
      RRR = (GAM+1.)*AM/((GAM-1.)*AM+2.)                                2JET2420
      B = AM*(GAM+1.)**2                                                2JET2430
      PR = PPP/RRR                                                      2JET2440
      AM2 = (UQM(3)**2*B-4.*(AM-1.)*(GAM*AM+1.))/(B*PR)                 2JET2450
C                                                                       2JET2460
C     CALCULATE INITIAL LAM1                                            2JET2470
C                                                                       2JET2480
      LAM1 = FACTOR*SQRT(AM2-1.0) * ALF                                 2JET2490
      RJB = RWVP(1)                                                     2JET2500
      U3D = UQM(1)                                                      2JET2510
      QB  = RWVP(3)                                                     2JET2520
      PJB = RWVP(4)                                                     2JET2530
      Q2 = SQRT(U3D**2+QB**2-GAM1*PJB/RJB*2.0*(PPP/RRR-1.0))            2JET2540
      W(1,MB,2) = Q2*RJB*RRR                                            2JET2550
      W(2,MB,2) = Q2**2*RJB*RRR+PJB*PPP                                 2JET2560
      W(3,MB,2) = 0.0                                                   2JET2570
      W(4,MB,2) = 0.0                                                   2JET2580
C                                                                       2JET2590
C     DETERMINE ACTUAL STARTING DISTANCE FROM NOZZLE EXIT               2JET2600
C                                                                       2JET2610
      RR = RR-LAM1*DY                                                   2JET2620
      LAM1 = LAM1/ADIV                                                  2JET2630
      BACKSPACE 1                                                       2JET2640
      DO 320 I=1,20                                                     2JET2650
  320 IF (XX(I).GT.RR) BACKSPACE 1                                      2JET2660
      GO TO 290                                                         2JET2670
  330 IF (RX(2).LT.RR) GO TO 270                                        2JET2680
      READ (1) K,RX(1),K,Y(1),DR(1),MAX1(1)                             2JET2690
      BACKSPACE 1                                                       2JET2700
C                                                                       2JET2710
C     FIND RADIUS OF JET AT GIVEN DISTANCE FROM NOZZLE EXIT             2JET2720
C                                                                       2JET2730
  340 CALL INTRP (RX,RR,Y,YBD)                                          2JET2740
      JJ = 0                                                            2JET2750
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      JJJ = 1                                                           2JET2760
      NBB = NB                                                          2JET2770
      IF (RR.LT.RRDJ) GO TO 350                                         2JET2780
C                                                                       2JET2790
C     COMPUTE 3-D REGION IN Z DIRECTION                                 2JET2800
C                                                                       2JET2810
      ANB = 2.0+SQRT((YBD/(LAM0*DY))**2-(DYY/DY*FLOAT(MB-5)/LAM0)**2)   2JET2820
      NB = ANB+1.0                                                      2JET2830
      IF (NB.GT.55) CALL DUMP                                           2JET2840
      ANB = (ANB-2.0)*LAM0*DY*CN                                        2JET2850
      NBP = NB+1                                                        2JET2860
  350 J = 0                                                             2JET2870
  360 J = J+1                                                           2JET2880
      JJ = JJ+1                                                         2JET2890
C     EXPAND 3-D REGION IN Y DIRECTION                                  2JET2900
      MA = MA -1                                                        2JET2910
      MAX = MA                                                          2JET2920
C                                                                       2JET2930
C                                                                       2JET2940
C                                                                       2JET2950
C     BELOW JET VALUES ARE CALCULATED AND ARE FILLED INTO THE MESH WHEN 2JET2960
C     IT IS NECESSARY                                                   2JET2970
C                                                                       2JET2980
C                                                                       2JET2990
C                                                                       2JET3000
  370 DO 450 N=2,NBP                                                    2JET3010
C                                                                       2JET3020
C     THE FOLLOWING TWO STRINGS OF IF STATEMENTS DETERMINE WHICH POINTS 2JET3030
C     MAY NEED JET VALUES                                               2JET3040
C                                                                       2JET3050
      IF (JJ.EQ.1.AND.N.GT.2) GO TO 450                                 2JET3060
      IF (JJJ.NE.1.AND.N.NE.NN) GO TO 450                               2JET3070
      IF (N.GT.NBB.AND.J.EQ.2) MAX = MB                                 2JET3080
      IF (LPLANE.EQ.1.AND.JJ.EQ.1.AND.IFLG.EQ.0) MAX = MB               2JET3090
      DO 440 M=MA,MAX                                                   2JET3100
      IF (JJJ.NE.1.AND.M.NE.MM) GO TO 440                               2JET3110
C                                                                       2JET3120
C     AN IS Z DISTANCE OF GRID POINT FROM CENTER JET                    2JET3130
C                                                                       2JET3140
      AN = FLOAT(N-2)*LAM0                                              2JET3150
C                                                                       2JET3160
C     AM IS Y DISTANCE OF GRID POINT TO CENTER JET                      2JET3170
C                                                                       2JET3180
      AM = IFIX(DYY/DY)*(MB-5)+M-MB                                     2JET3190
C                                                                       2JET3200
C     RHO IS ACTUAL DISTANCE FROM GRID POINT TO CENTER JET OR M=M2 JET  2JET3210
C                                                                       2JET3220
      RHO = DY*SQRT(AN**2+AM**2)                                        2JET3230
      IF (RHO.GE.YBD) GO TO 380                                         2JET3240
      IF (M.NE.MB.OR.N.LT.NB.OR.N.LE.NBB) GO TO 390                     2JET3250
C                                                                       2JET3260
C     CALCULATE JET PROPERTIES FOR PARTICULAR MESH POINT                2JET3270
C                                                                       2JET3280
  380 CALL JET (W3D,RUVP,YBD,DR,MAX1,Y,RX,RR,1)                         2JET3290
C                                                                       2JET3300
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C     COMPUTE REFERENCE ENTROPY                                         2JET3310
C                                                                       2JET3320
      IF (LPLANE.EQ.1) ENTH = CC*RUVP(4)/(RUVP(1)**GAM)                 2JET3330
      GO TO 400                                                         2JET3340
  390 CALL JET (W3D,RUVP,RHO,DR,MAX1,Y,RX,RR,2)                         2JET3350
  400 RJB = RUVP(1)                                                     2JET3360
      U3D = RUVP(2)                                                     2JET3370
      QB  = RUVP(3)                                                     2JET3380
      PJB = RUVP(4)                                                     2JET3390
C                                                                       2JET3400
C     BELOW IS DETERMINED THE COMPONENT OF VELOCITY IN THE PLANE V3D,W3D2JET3410
C                                                                       2JET3420
      ANG3 = ATAN2(AN,AM)                                               2JET3430
      V3D = QB*COS(ANG3)                                                2JET3440
      W3D = QB*SIN(ANG3)                                                2JET3450
      IF (M.EQ.MB ) V3D = 0.0                                           2JET3460
  410 DO 420 K=1,4                                                      2JET3470
  420 W1(K) = W(K,M,N)                                                  2JET3480
      IF (JJ.NE.1.OR.LPLANE.EQ.1) GO TO 430                             2JET3490
      CALL PROP (W1,W2,RWVP,5)                                          2JET3500
C                                                                       2JET3510
C     C IS TOLERANCE APPLING TO MA EXPANSION                            2JET3520
C                                                                       2JET3530
C                                                                       2JET3540
C     IF ANY OF THE FOLLOWING FOUR TEST TRANSFERS TO 350 THE 3-D REGION 2JET3550
C     WILL EXPAND                                                       2JET3560
C                                                                       2JET3570
      IF (ABS(QB-SQRT(RWVP(2)**2+RWVP(3)**2)).GT.C*QB) GO TO 350        2JET3580
      IF (ABS(U3D-W2(1)).GT.C*U3D) GO TO 350                            2JET3590
      IF (ABS(RJB-RWVP(1)).GT.C*RJB) GO TO 350                          2JET3600
      IF (ABS(PJB-RWVP(4)).GT.C*PJB) GO TO 350                          2JET3610
      GO TO 440                                                         2JET3620
  430 W(1,M,N) = RJB*U3D                                                2JET3630
      W(2,M,N) = RJB*U3D**2+PJB                                         2JET3640
      W(3,M,N) = RJB*U3D*V3D                                            2JET3650
      W(4,M,N) = RJB*U3D*W3D                                            2JET3660
  440 CONTINUE                                                          2JET3670
C                                                                       2JET3680
C     JJJ=1, FOR AUXILIARY JET POINTS                                   2JET3690
C     JJJ=2, FOR ENTROPY JET POINTS                                     2JET3700
C     JJJ=3,4, AND 5 FOR AUXILIARY FILL IN JET POINTS WHEN MESH CHANGES 2JET3710
C     SIZES                                                             2JET3720
C                                                                       2JET3730
      GO TO (450,510,560,540,540), JJJ                                  2JET3740
  450 CONTINUE                                                          2JET3750
C                                                                       2JET3760
C                                                                       2JET3770
C                                                                       2JET3780
C     THIS ENDS THE CALCULATION OF JET POINTS                           2JET3790
C                                                                       2JET3800
C                                                                       2JET3810
C                                                                       2JET3820
      IF (NBP.EQ.NB) NBP = NB+2                                         2JET3830
      IF (J.EQ.1) GO TO 360                                             2JET3840
      IF (NB.EQ.2) NB = 3                                               2JET3850
```

```
      IF (MA.EQ.5) STOP                                                 2JET3860
      IF (LPLANE.NE.1) GO TO 470                                        2JET3870
      IF (IFLG.NE.2) GO TO 520                                          2JET3880
C                                                                       2JET3890
C     CALCULATE SHOCK POINTS                                            2JET3900
C                                                                       2JET3910
      DO 460 J=1,4                                                      2JET3920
  460 W(J,MB,3) = W(J,MB,2)                                             2JET3930
      GO TO 520                                                         2JET3940
C                                                                       2JET3950
C     COMPARE THE ENTROPY AT EACH 3-D MESH POINT WITH THE REFERENCE     2JET3960
C     ENTROPY                                                           2JET3970
C                                                                       2JET3980
  470 NN = NBB + 1                                                      2JET3990
  480 NN = NN - 1                                                       2JET4000
      MM = MC                                                           2JET4010
  490 MM = MM-1                                                         2JET4020
  500 CALL PROP (W(1,MM,NN),UQM,RWVP,5)                                 2JET4030
      IF (UQM(4).GT.ENTH) GO TO 510                                     2JET4040
      J = 2                                                             2JET4050
      JJ = 2                                                            2JET4060
      JJJ = 2                                                           2JET4070
C                                                                       2JET4080
C     REPLACE 3-D VALUES WITH JET VALUES                                2JET4090
C                                                                       2JET4100
      GO TO 370                                                         2JET4110
  510 UU = ATAN2 (1.0,SQRT(UQM(3)**2-1.0))                              2JET4120
C                                                                       2JET4130
C     FIND MINIMUM LAM1                                                 2JET4140
C                                                                       2JET4150
      UM = ABS(ATAN2(ABS(RWVP(2)),UQM(1))+UU)                           2JET4160
      UM1 = ABS(ATAN2(ABS(RWVP(3)),UQM(1))-UU)                          2JET4170
      IF (UM1.GT.UM) UM = UM1                                           2JET4180
      IF (MM.EQ.MB.AND.NN.EQ.NBB) UN = UM                               2JET4190
      UN = AMAX1 (UN,UM)                                                2JET4200
      IF (MM.GT.MA3D) GO TO 490                                         2JET4210
      IF (NN.GT.2) GO TO 480                                            2JET4220
      LAM1 = FACTOR/TAN(UN)                                             2JET4230
      IF (RR.LT.RRDJ) LAM1 = LAM1/ADIV                                  2JET4240
C                                                                       2JET4250
C     LAM2 IS LAM1 FOR 2-JET CONNFIGURATION                             2JET4260
C                                                                       2JET4270
  520 LAM2 = LAM1/LAM0                                                  2JET4280
C                                                                       2JET4290
C                                                                       2JET4300
C     DOUBLING MESH SIZE OCCURS BELOW                                   2JET4310
C                                                                       2JET4320
C                                                                       2JET4330
      IF (LPLANE.NE.JUMP1) GO TO 570                                    2JET4340
      JJJ = 2                                                           2JET4350
      IF (MOD(NBP,2).EQ.1) JJJ = 4                                      2JET4360
      NB = (NBP+1)/2                                                    2JET4370
      NN = 2                                                            2JET4380
      NBP = NB+1                                                        2JET4390
      IF (JJJ.EQ.4) NN = NBP                                            2JET4400
```

```
      MM = MB-MA                                                        2JET4410
      IF (MOD(MM,2).EQ.1) JJJ = JJJ+1                                   2JET4420
      MA = (MA+MB+1)/2                                                  2JET4430
C                                                                       2JET4440
C     STORE EVERY OTHER GRID POINT BACK INTO ORIGINAL MATRIX            2JET4450
C                                                                       2JET4460
      DO 530 N=2,NB                                                     2JET4470
      DO 530 I=MA,MB                                                    2JET4480
      M = MB+MA-I                                                       2JET4490
      K = 2*M-MB                                                        2JET4500
      DO 530 J=1,4                                                      2JET4510
  530 W(J,M,N) = W(J,K,2*N-2)                                           2JET4520
      IF(MOD(JJJ,2).NE.0) MA = MA-1                                     2JET4530
      DY = 2.0*DY                                                       2JET4540
      MM = MA                                                           2JET4550
      MMM = MM                                                          2JET4560
      MT = MM                                                           2JET4570
      IF (JJJ.EQ.2) GO TO 570                                           2JET4580
C                                                                       2JET4590
C     FILL IN AUXILIARY JET GRID LINES IF NEEDED                        2JET4600
C                                                                       2JET4610
C                                                                       2JET4620
      GO TO 370                                                         2JET4630
  540 MM = MM+1                                                         2JET4640
      IF (MT.GE.MB) IF (JJJ-4) 550,570,550                              2JET4650
      MT = MM                                                           2JET4660
      GO TO 370                                                         2JET4670
  550 MM = MMM                                                          2JET4680
      NN = 2                                                            2JET4690
      JJJ = 3                                                           2JET4700
      GO TO 370                                                         2JET4710
  560 NN = NN+1                                                         2JET4720
      IF (NN.GT.NBP) GO TO 570                                          2JET4730
      GO TO 370                                                         2JET4740
  570 CONTINUE                                                          2JET4750
      MA3D = MA+1                                                       2JET4760
C                                                                       2JET4770
C     REFLECTION POINTS ARE FILLED IN                                   2JET4780
C                                                                       2JET4790
      DO 580 N=2,NBP                                                    2JET4800
      DO 580 J=1,4                                                      2JET4810
  580 W(J,MC,N) = W(J,MB-1,N)*FLOAT((J-1)*(J-2)*(J-4)+1)                2JET4820
      DO 590 M=MA,MC                                                    2JET4830
      DO 590 J=1,4                                                      2JET4840
  590 W(J,M,1) = W(J,M,3)*FLOAT((1-J)*(2-J)*(3-J)/3+1)                  2JET4850
C                                                                       2JET4860
C     PRINT EVERY DPRNT INTERVAL                                        2JET4870
C                                                                       2JET4880
      IF (RR.LT.XDIST) GO TO 670                                        2JET4890
      XDIST = RR+DPRNT/CN                                               2JET4900
C                                                                       2JET4910
C     WRITE HEADER FOR OUTPUT                                           2JET4920
C                                                                       2JET4930
      IF (LPLANE.NE.LMIN) WRITE (6,600)                                 2JET4940
  600 FORMAT (1H1)                                                      2JET4950
```

```
      RXP = CN*RR-CXR                                                   2JET4960
      WRITE (6,610) LPLANE,LAM1,LAM2,RXP,ANB,DY                         2JET4970
  610 FORMAT (      1X,3HL =,I5, 9X,7HLAM 1 =,F10.5,10X,7HLAM 2 =,F10.5, 2JET4980
     *10X,3HX =,F10.5,10X,4HZI =,F10.5,8X,4HDY =,F7.4///)               2JET4990
      WRITE (6,620)                                                     2JET5000
  620 FORMAT (13X,7HDENSITY,5X,8HPRESSURE,4X,11HTEMPERATURE,4X,7HENTROPY2JET5010
     *,6X                ,4(8HVELOCITY,5X),8HMACH NO.)                  2JET5020
      IPAGE = 6                                                         2JET5030
      IF (LPLANE.EQ.1) IPAGE = 12                                       2JET5040
      WRITE (6,630)                                                     2JET5050
  630 FORMAT (3X,1HM,4X,1HN,7X,1HR,12X,1HP,12X,1HT,12X,1HS,12X,1HU,12X,12JET5060
     *HV,12X,1HW,12X,1HQ,12X,1HM//)                                     2JET5070
      DO 660 N=2,NB                                                     2JET5080
      WRITE (6,640)                                                     2JET5090
  640 FORMAT (1H )                                                      2JET5100
      IPAGE = IPAGE+1                                                   2JET5110
      DO 660 M=MA3D,MB                                                  2JET5120
      IPAGE = IPAGE+1                                                   2JET5130
C                                                                       2JET5140
C     KEEP LINE COUNT FOR HEADING AT TOP OF EACH PAGE                   2JET5150
C                                                                       2JET5160
      IF (IPAGE.LT.60) GO TO 650                                        2JET5170
      IPAGE = 2                                                         2JET5180
      WRITE (6,630)                                                     2JET5190
C                                                                       2JET5200
C     COMPUTE AND PRINT W PROPERTIES                                    2JET5210
C                                                                       2JET5220
  650 CALL PROP (W(1,M,N),W1,W2,4)                                      2JET5230
  660 CONTINUE                                                          2JET5240
C                                                                       2JET5250
C     SOLVE FOR X DISPLACEMENT FROM NOZZLE EXIT FOR NEXT PLANE          2JET5260
C                                                                       2JET5270
  670 RR = RR+LAM1*DY                                                   2JET5280
      LPLANE = LPLANE+1                                                 2JET5290
      CALL INTRP (RX,RR,Y,YYBD)                                         2JET5300
C                                                                       2JET5310
C     COMPUTATION TERMINATES IF RADIUS OF JET FROM AXIS TO BOUNDARY IS  2JET5320
C     DECREASING                                                        2JET5330
C                                                                       2JET5340
      IF (YYBD.LT.YBD) STOP                                             2JET5350
C                                                                       2JET5360
C                                                                       2JET5370
C     COMPUTE F AND G FUNCTIONS OF W TAKING ONE GRID LINE AT A TIME     2JET5380
C     WHILE HOLDING N CONSTANT                                          2JET5390
C                                                                       2JET5400
C                                                                       2JET5410
      DO 750 N=2,NB                                                     2JET5420
      DO 700 M=MA,MC                                                    2JET5430
      IF (N.NE.2) GO TO 680                                             2JET5440
C                                                                       2JET5450
C     THIRD SUBSCRIPT OF F AND G POSITIONS GRID POINT IN Z DIRECTION    2JET5460
C                                                                       2JET5470
C                                                                       2JET5480
C     IF SUBSCRIPT = 2, N                                               2JET5490
C                                                                       2JET5500
```

```
      CALL PROP (W(1,M,N),F(1,M,2),G(1,M,2),1)                          2JET5510
C                                                                       2JET5520
C     IF SUBSCRIPT = 3, N-1                                             2JET5530
C                                                                       2JET5540
      CALL PROP (W(1,M,N-1),F(1,M,3),G(1,M,3),1)                        2JET5550
      GO TO 700                                                         2JET5560
C                                                                       2JET5570
C     WHEN N INCREASED BY ONE F AND G SUBSCRIPTS 1 AND 2 INCREASE BY ONE2JET5580
C                                                                       2JET5590
  680 DO 690 I=1,2                                                      2JET5600
      K = 4-I                                                           2JET5610
      DO 690 J=1,4                                                      2JET5620
      F(J,M,K) = F(J,M,K-1)                                             2JET5630
  690 G(J,M,K) = G(J,M,K-1)                                             2JET5640
C                                                                       2JET5650
C     IF SUBSCRIPT = 1, N+1                                             2JET5660
C                                                                       2JET5670
  700 CALL PROP (W(1,M,N+1),F(1,M,1),G(1,M,1),1)                        2JET5680
C                                                                       2JET5690
C                                                                       2JET5700
C                                                                       2JET5710
C     BELOW W VALUES ARE COMPUTED FOR NEXT PLANE                        2JET5720
C                                                                       2JET5730
C                                                                       2JET5740
C                                                                       2JET5750
      DO 750 M=MA3D,MB                                                  2JET5760
      CALL PROP (W(1,M,N),UQM,RWVP,5)                                   2JET5770
      UU = ATAN2 (1.0,SQRT(UQM(3)**2-1.0))                              2JET5780
      UM = ABS(ATAN2(ABS(RWVP(2)),UQM(1))+UU)                           2JET5790
      UM1 = ABS(ATAN2(ABS(RWVP(3)),UQM(1))-UU)                          2JET5800
      IF (UM1.GT.UM) UM = UM1                                           2JET5810
C                                                                       2JET5820
C     DISTANCE OF FIRST STEP OF TWO STEP METHOD IS FOUND                2JET5830
C                                                                       2JET5840
      S =.5*(1.0+AS0*(FACTOR/LAM1/TAN(UM)-1.0)+AS1*LAM1*(F(IJL,M+1,2)-F(2JET5850
     *IJL,M-1,2))/W(IJL,M,N)+AS2*LAM2*(G(IJL,M,1)-G(IJL,M,3))/W(IJL,M,N)2JET5860
     *)                                                                 2JET5870
      IF (M.EQ.MB.AND.LPLANE.LE.JUMP) GO TO 720                         2JET5880
C                                                                       2JET5890
C     STANDARD PROCEDURE FOR CALCULATION W'S AT S                       2JET5900
C                                                                       2JET5910
      DO 710 J=1,4                                                      2JET5920
      W1(J) = .5*(W(J,M+1,N)+W(J,M,N))+S*LAM1*(F(J,M+1,2)-F(J,M,2))+.25*2JET5930
     *S*LAM2*(G(J,M,1)-G(J,M,3)+G(J,M+1,1)-G(J,M+1,3))                  2JET5940
      W2(J) = .5*(W(J,M-1,N)+W(J,M,N))+S*LAM1*(F(J,M,2)-F(J,M-1,2))+.25*2JET5950
     *S*LAM2*(G(J,M,1)-G(J,M,3)+G(J,M-1,1)-G(J,M-1,3))                  2JET5960
      W3(J) = .5*(W(J,M,N)+W(J,M,N+1))+.25*S*LAM1*(F(J,M+1,1)-F(J,M-1,1)2JET5970
     *+F(J,M+1,2)-F(J,M-1,2))+S*LAM2*(G(J,M,1)-G(J,M,2))                2JET5980
  710 W4(J) = .5*(W(J,M,N)+W(J,M,N-1))+.25*S*LAM1*(F(J,M+1,3)-F(J,M-1,3)2JET5990
     *+F(J,M+1,2)-F(J,M-1,2))+S*LAM2*(G(J,M,2)-G(J,M,3))                2JET6000
      GO TO 740                                                         2JET6010
C                                                                       2JET6020
C     SPECIAL PROCEDURE FOR FINDING W'S AT M=MB AND S                   2JET6030
C                                                                       2JET6040
  720 DO 730 J=1,4                                                      2JET6050
```

```
      W1(J) = W(J,M,N)+.5*TT*(W(J,M+1,N)-W(J,M-1,N))+.5*TT**2*(W(J,M+1,N2JET6060
     *)+W(J,M-1,N)-2.0*W(J,M,N))+.5*S*LAM1*(F(J,M+1,2)-F(J,M-1,2))+.5*S*2JET6070
     *LAM2*(G(J,M,1)-G(J,M,3))+S*LAM1*TT*(F(J,M+1,2)+F(J,M-1,2)-2.*F(J,M2JET6080
     *,2))+.25*S*TT*LAM2*(G(J,M+1,1)-G(J,M+1,3)-G(J,M-1,1)+G(J,M-1,3))  2JET6090
      W2(J) = W(J,M,N)-.5*TT*(W(J,M+1,N)-W(J,M-1,N))+.5*TT**2*(W(J,M+1,N2JET6100
     *)+W(J,M-1,N)-2.0*W(J,M,N))+.5*S*LAM1*(F(J,M+1,2)-F(J,M-1,2))+.5*S*2JET6110
     *LAM2*(G(J,M,1)-G(J,M,3))-S*LAM1*TT*(F(J,M+1,2)+F(J,M-1,2)-2.*F(J,M2JET6120
     *,2))-.25*S*TT*LAM2*(G(J,M+1,1)-G(J,M+1,3)-G(J,M-1,1)+G(J,M-1,3))  2JET6130
      W3(J) = W(J,M,N)+.5*TS*(W(J,M,N+1)-W(J,M,N-1))+.5*TS**2*(W(J,M,N+12JET6140
     *)+W(J,M,N-1)-2.0*W(J,M,N))+.5*S*LAM1*(F(J,M+1,2)-F(J,M-1,2))+.5*S*2JET6150
     *LAM2*(G(J,M,1)-G(J,M,3))+.25*S*LAM1*TS*(F(J,M+1,1)-F(J,M-1,1)-F(J,2JET6160
     *M+1,3)+F(J,M-1,3))+S*LAM2*TS*(G(J,M,1)+G(J,M,3)-2.0*G(J,M,2))     2JET6170
  730 W4(J) = W(J,M,N)-.5*TS*(W(J,M,N+1)-W(J,M,N-1))+.5*TS**2*(W(J,M,N+12JET6180
     *)+W(J,M,N-1)-2.0*W(J,M,N))+.5*S*LAM1*(F(J,M+1,2)-F(J,M-1,2))+.5*S*2JET6190
     *LAM2*(G(J,M,1)-G(J,M,3))-.25*S*LAM1*TS*(F(J,M+1,1)-F(J,M-1,1)-F(J,2JET6200
     *M+1,3)+F(J,M-1,3))-S*LAM2*TS*(G(J,M,1)+G(J,M,3)-2.0*G(J,M,2))     2JET6210
C                                                                       2JET6220
C     DETERMINE F AND G PROPERTIES OF W AT S                            2JET6230
C                                                                       2JET6240
  740 CALL PROP (W1(1),F1(1),UQM,2)                                     2JET6250
      CALL PROP (W2(1),F2(1),UQM,2)                                     2JET6260
      CALL PROP (W3(1),UQM,G1(1),3)                                     2JET6270
      CALL PROP (W4(1),UQM,G2(1),3)                                     2JET6280
C                                                                       2JET6290
C     STORE RESULTS OF W IN TEMPORARY UNUSED SECTION OF W MATRIX        2JET6300
C                                                                       2JET6310
      DO 750 J=1,4                                                      2JET6320
  750 W(J,M-1,N-1) = ((DL+1.0)/2.0*(CL-0.5)/0.5+(DL-1.0)/2.0)*W(J,M,N)+ 2JET6330
     *(DL+1.0)/2.0*CL*(LAM1*(F1(J)-F2(J))+LAM2*(G1(J)-G2(J)))+(.25*(1.0-2JET6340
     *(CL-0.5)/0.5)*(DL+1.0)/2.0-0.5*(DL-1.0)/2.0)*(W1(J)+W2(J)+W3(J)+W42JET6350
     *(J))                                                              2JET6360
C                                                                       2JET6370
C     RESTORE W VALUE CORRECTLY                                         2JET6380
C                                                                       2JET6390
      DO 760 I=2,NB                                                     2JET6400
      N = NB+2-I                                                        2JET6410
      DO 760 M=MA3D,MC                                                  2JET6420
      DO 760 J=1,4                                                      2JET6430
  760 W(J,M,N) = W(J,M-1,N-1)                                           2JET6440
C                                                                       2JET6450
C                                                                       2JET6460
C                                                                       2JET6470
      MA = MA+2                                                         2JET6480
      IF (LPLANE.LT.LMAX) GO TO 780                                     2JET6490
C                                                                       2JET6500
C     STORE INFORMATION FOR CONTINUATION RUN                            2JET6510
C                                                                       2JET6520
C                                                                       2JET6530
      WRITE (3) W,LAM0,LAM1,GAM,M0,FACTOR,RR,NB,NBP,MA,ENTH             2JET6540
C                                                                       2JET6550
C     WRITE OUT LAST PAGE                                               2JET6560
C                                                                       2JET6570
      WRITE (6,770)                                                     2JET6580
  770 FORMAT (1H1,8(/),2(65X,1H*/),65X,1H*,3X,5(1H.)/65X,1H*,6X,1H./65X,2JET6590
     *1H*,5X,1H./65X,1H*,4X,1H./ 65X,1H*,3X,5(1H.)/6(65X,1H*/),45X,3(2H*2JET6600
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     * ),14X,1H*,14X,3(2H *)/40X,1H*,13X,1H*,10X,1H*,10X,1H*,13X,1H*/38X2JET6610
     *,1H*,17X,1H*,8X,1H*,8X,1H*,17X,1H*/65X,1H*/36X,1H*,21X,1H*,6X,1H*,2JET6620
     *6X,1H*,21X,1H*/65X,1H*/35X,1H*,23X,1H*,5X,1H*,5X,1H*,23X,1H*/25X,42JET6630
     *1(2H* )/35X,1H*,23X,1H*,5X,1H*,5X,1H*,23X,1H*/62X,4H*  *,33X,1H.,32JET6640
     *X,1H./36X,1H*,21X,1H*,6X,1H*,6X,1H*,21X,1H*,5X,2(2H. )/59X,1H*,5X,2JET6650
     *1H*,35X,1H./38X,1H*,17X,1H*,8X,1H*,8X,1H*,17X,1H*,8X,1H./40X,1H*,12JET6660
     *3X,2(2H* ),7X,1H*,10X,1H*,13X,1H*,10X,1H./45X,3(2H* ),14X,1H*,14X,2JET6670
     *3(2H *)/53X,1H*,11X,1H*/65X,1H*/ 50X,1H*,14X,1H*/65X,1H*/47X,1H*,12JET6680
     *7X,1H*/65X,1H*/44X1H*20X1H*/65X1H*/28X,2(1H.,3X),5X,1H*,23X,1H*/292JET6690
     *X,2(2H. ),33X,1H*/30X,1H.,7X,1H*,26X,1H*/29X,2(2H. ),32X,1H*/28X,12JET6700
     *H.,3X,1H.,32X,1H*)                                                2JET6710
      STOP                                                              2JET6720
C                                                                       2JET6730
C     IF NO MORE JET INFORMATION IS NEEDED GO AND FILL IN AUXILIARY JET 2JET6740
C     PROPERTIES                                                        2JET6750
C                                                                       2JET6760
  780 IF (RR.LT.RX(2)) GO TO 340                                        2JET6770
C                                                                       2JET6780
C     MORE JET INFORMATION IS NEEDED IN ORDER TO CONTINUE               2JET6790
C                                                                       2JET6800
      GO TO 270                                                         2JET6810
      END                                                               2JET6820
```

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$IBFTC PROPS   LIST                                                     PROP  10
      SUBROUTINE PROP (W,F,G,I)                                         PROP  20
      COMMON /INPROP/ GAM,GAM1,GAM2,M,N,BCD                             PROP  30
      DIMENSION W(4),F(1),G(1)                                          PROP  40
C     V = G(3)                                                          PROP  50
C     W = G(2)                                                          PROP  60
C     R = G(1)                                                          PROP  70
C     U = F(1)                                                          PROP  80
C     P = G(4)                                                          PROP  90
C     Q = F(2)                                                          PROP 100
C     M = F(3)                                                          PROP 110
C     S = F(4)                                                          PROP 120
      G(3) = W(3)/W(1)                                                  PROP 130
      G(2) = W(4)/W(1)                                                  PROP 140
      IF (I.EQ.6) G(2) = 0.0                                            PROP 150
      A = GAM1*W(2)/(GAM2-G(3)**2-G(2)**2)                              PROP 160
      B = GAM2*W(1)**2/(GAM1*W(2))                                      PROP 170
      G(1) = A*(1.0-SQRT(1.0-B/A))                                      PROP 180
      F(1) = W(1)/G(1)                                                  PROP 190
      G(4) = W(2)-F(1)*W(1)                                             PROP 200
      GO TO (20,20,30,10,10,60), I                                      PROP 210
   10 F(2) = SQRT(F(1)**2+G(3)**2+G(2)**2)                              PROP 220
      F(3) = F(2)/SQRT(GAM*G(4)/G(1))                                   PROP 230
      F(4) = G(4)/(G(1)**GAM)                                           PROP 240
      IF (I-4) 60,40,60                                                 PROP 250
C     SOLVE FOR F FUNCTIONS                                             PROP 260
   20 F(1) = -G(1)*G(3)                                                 PROP 270
      F(2) = -W(3)                                                      PROP 280
      F(3) = G(3)*F(1)-G(4)                                             PROP 290
      F(4) = G(2)*F(1)                                                  PROP 300
      GO TO (30,60), I                                                  PROP 310
C     COMPUTE G FUNCTIONS                                               PROP 320
   30 G(1) = -G(1)*G(2)                                                 PROP 330
      G(3) = G(3)*G(1)                                                  PROP 340
      G(4) = G(2)*G(1)-G(4)                                             PROP 350
      G(2) = -W(4)                                                      PROP 360
      GO TO 60                                                          PROP 370
   40 T = GAM*G(4)/G(1)                                                 PROP 380
C     PRINT FLUID PROPERTIES                                            PROP 390
      WRITE (6,50) M,N,G(1),G(4),T,F(4),F(1),G(3),G(2),F(2),F(3),BCD    PROP 400
      WRITE (6,50) M,N,G(1),G(4),T,F(4),F(1),G(3),G(2),F(2),F(3)        PROP 400
   50 FORMAT (I4,I5,1X,9E13.6,3X)                                       PROP 410
   60 RETURN                                                            PROP 420
      END                                                               PROP 430
```
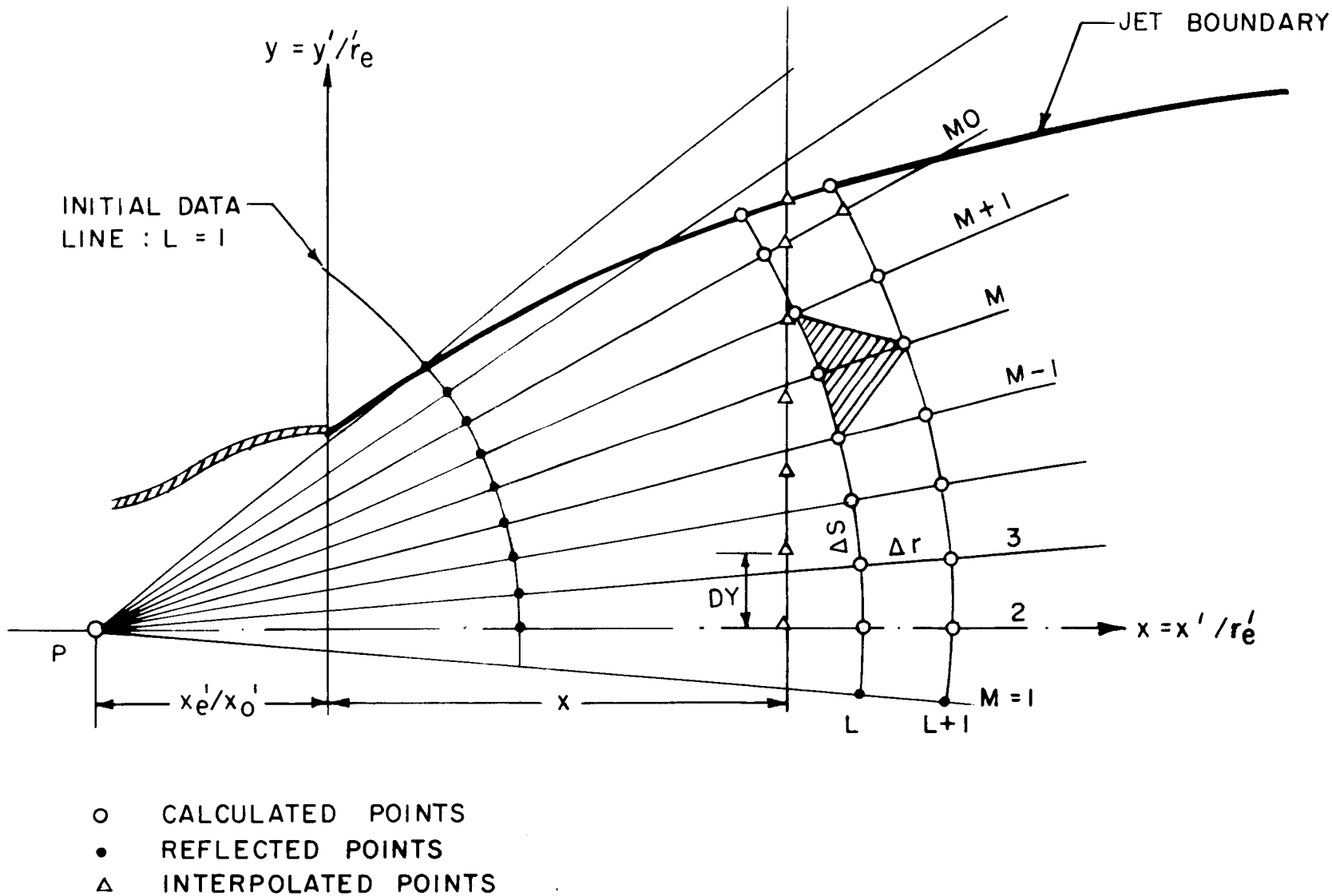

```
$IBFTC JETS    LIST                                                     JET   10
      SUBROUTINE JET (W,RUVP,RHO,DR,MAX1,Y,RX,RR,I)                     JET   20
      DIMENSION W(3,80,2),RUVP(4),DR(3),MAX1(3),RX(3),X(3),W1(2),W2(3,2)JET   30
     *,Y(3),W3(2),W4(3)                                                 JET   40
C     X(1) LIES TO LEFT OF CROSS PLANE                                  JET   50
C     X(2) LIES DOWN STREAM OF CROSS PLANE                              JET   60
      X(1) = RX(3)                                                      JET   70
      X(2) = RX(2)                                                      JET   80
      X(3) = RX(3)                                                      JET   90
C     I=1 CALCULATE JET VALUES CLOSE TO BOUNDARY OF JET                 JET  100
C     I=2 CALCULATE INTERIOR JET VALUES                                 JET  110
      GO TO (20,10), I                                                  JET  120
C     STEP SIZES CAN BE DIFFERENT FOR ANY TWO JET PLANES                JET  130
   10 K1 = RHO/DR(3)+2.0                                                JET  140
      IF (K1.GT.MAX1(3)) K1 = MAX1(3)                                   JET  150
      K2 = RHO/DR(2)+2.0                                                JET  160
      IF (K2.GT.MAX1(2)) K2 = MAX1(2)                                   JET  170
       IF (FLOAT(K1-1)*DR(3).EQ.FLOAT(K2)*DR(2)) K1 = K1-1              JET  180
      GO TO 30                                                          JET  190
   20 K1 = MAX1(3)                                                      JET  200
      K2= MAX1(2)                                                       JET  210
      W2(1,2) = 0.0                                                     JET  220
   30 DO 40 J=1,3                                                       JET  230
C     W HERE IS W VALUES OF JET CROSS PLANE                             JET  240
C     J IS THE W PROPERTY                                               JET  250
C     K1 IS THE W POSITION                                              JET  260
C     1 OR 2 IS THE W CROSS PLANE CORRESPONDING TO X                    JET  270
      W1(1) = W(J,K1,2)                                                 JET  280
      W1(2) = W(J,K2,1)                                                 JET  290
   40 CALL INTRP (X,RR,W1,W2(J,I))                                      JET  300
      IF (W2(1,2).EQ.0.0) GO TO 90                                      JET  310
      IF (I.EQ.1) GO TO 50                                              JET  320
      I = 1                                                             JET  330
C     W3 GIVES DISTANCE FROM AXIS TO INTEGER DISTANCE BELOW RHO         JET  340
      W3(1) = FLOAT(K1-2)*DR(3)                                         JET  350
      IF (K1.GE.MAX1(3)) W3(1) = Y(3)                                   JET  360
      K1 = K1+1                                                         JET  370
      W3(2) = FLOAT(K2-2)*DR(2)                                         JET  380
      IF (K2.GE.MAX1(2)) W3(2) = Y(2)                                   JET  390
      K2 = K2+1                                                         JET  400
      IF (DR(2).NE.DR(3)) K1 = K1+1                                     JET  410
      IF (K2.GT.MAX1(2)) K2 = MAX1(2)                                   JET  420
      IF (K1.GT.MAX1(3)) K1 = MAX1(3)                                   JET  430
      GO TO 30                                                          JET  440
   50 I = 2                                                             JET  450
C     W1 SAME AS W3 EXCEPT DISTANCE IS ABOVE RHO                        JET  460
      W1(1) = DR(3)*FLOAT(K1-2)                                         JET  470
      IF (K1.EQ.MAX1(3)) W1(1) = Y(3)                                   JET  480
      W1(2) = DR(2)*FLOAT(K2-2)                                         JET  490
      IF (K2.EQ.MAX1(3)) W1(2) = Y(2)                                   JET  500
      CALL INTRP (X,RR,W1,RH)                                           JET  510
      IF (W3(1).NE.W3(2)) CALL INTRP (X,RR,W3,W3(1))                    JET  520
C     X(2) IS Y DISTANCE ON 3-D PLANE ABOVE RHO                         JET  530
C     X(3) IS Y DISTANCE BELOW RHO                                      JET  540
      X(2) = W3(1)                                                      JET  550
```

```
      X(3) = RH                                                         JET  560
      X(1) = RH                                                         JET  570
      DO 60 J=1,3                                                       JET  580
      W1(1) = W2(J,1)                                                   JET  590
      W1(2) = W2(J,2)                                                   JET  600
   60 CALL INTRP (X,RHO,W1,W4(J))                                       JET  610
      CALL PROP (W4,RH,RUVP,6)                                          JET  620
   70 RUVP(2) = RH                                                      JET  630
   80 FORMAT (8E16.8)                                                   JET  640
C     W IS INTERPOLATED W VALUES AT RHO                                 JET  650
      RETURN                                                            JET  660
C     I = 1                                                             JET  670
   90 CALL PROP (W2,RH,RUVP,6)                                          JET  680
      GO TO 70                                                          JET  690
      END                                                               JET  700
```

```
$IBFTC INTRPS  LIST                                                    INTP  10
      SUBROUTINE INTRP (R,S,P,ANS)                                     INTP  20
      DIMENSION R(3),P(3)                                              INTP  30
C     R    X ARRAY, THREE ENTRIES                                      INTP  40
C     P    Y ARRAY, THREE ENTRIES                                      INTP  50
C     S VALUE TO BE INTERPOLATED                                       INTP  60
C     P    INTERPOLATED VALUE                                          INTP  70
C     X    DISTANCES ARE REFERENCED TO R(1)                            INTP  80
      Q1 = S-R(1)                                                      INTP  90
      Q2 = R(2)-R(1)                                                   INTP 100
      Q3 = R(3)-R(1)                                                   INTP 110
      C = ((P(2)-P(1))*Q3+(P(1)-P(3))*Q2)/(Q2*Q3*(Q2-Q3))              INTP 120
C     IF C=0 LINEAR INTERPOLATION                                      INTP 130
      IF (Q3.EQ.0.0) C = 0.0                                           INTP 140
      B = (P(2)-P(1)-C*Q2**2)/Q2                                       INTP 150
      ANS = P(1)+B*Q1+C*Q1**2                                          INTP 160
      RETURN                                                           INTP 170
      END                                                              INTP 180
```

```
$IBMAP FILE1
*      JET TAPE INPUT
       ENTRY    .UN01.
.UN01. PZE      UNIT01
UNIT01 FILE     ,B(1),READY,BIN,BLK=256,INOUT,HOLD,HIGH
       END
$IBMAP FILE2
*      CONTINUATION RUN INPUT
       ENTRY    .UN02.
.UN02. PZE      UNIT02
UNIT02 FILE     ,B(2),READY,BIN,BLK=256,INOUT,HOLD,HIGH
       END
$IBMAP FILE3
*      CONTINUATION RUN OUTPUT
       ENTRY    .UN03.
.UN03. PZE      UNIT03
UNIT03 FILE     ,B(3),READY,BIN,BLK=256,INOUT,HOLD,HIGH
       END
```



○ CALCULATED POINTS
● REFLECTED POINTS
△ INTERPOLATED POINTS

FIG. 1 : SKETCH OF THE FLOW FIELD OF A SINGLE JET

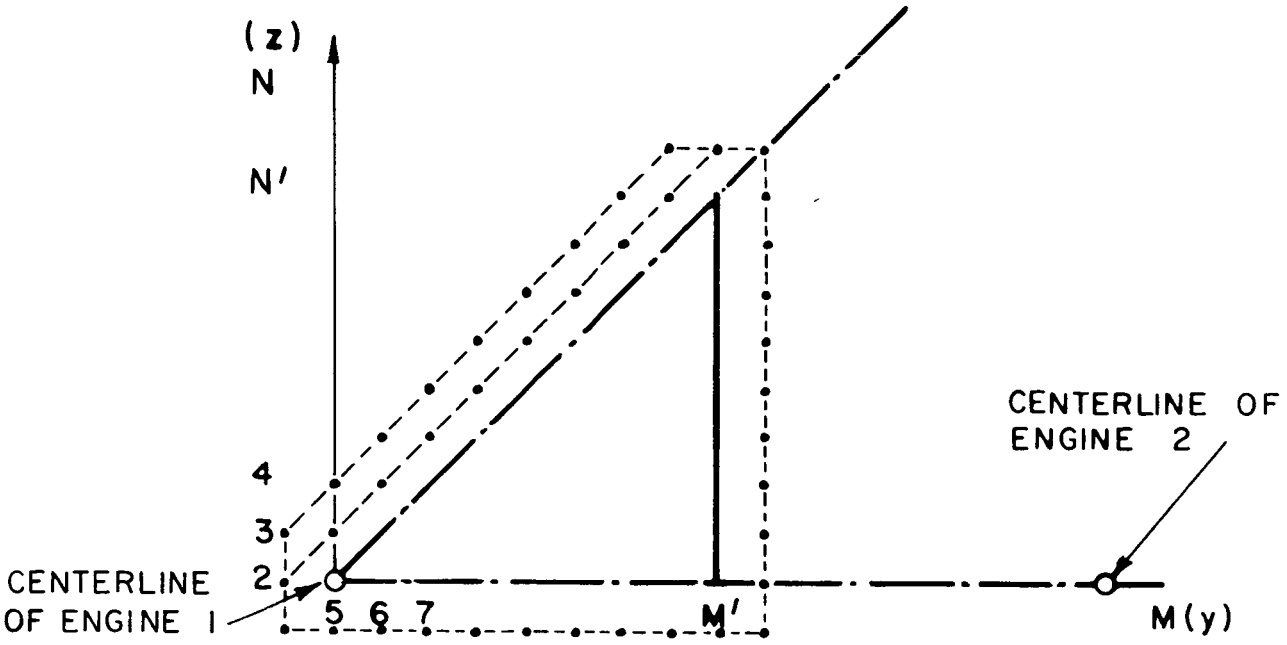


FIG 2 A: PHYSICAL PLANE, REGULAR MESH SIZE

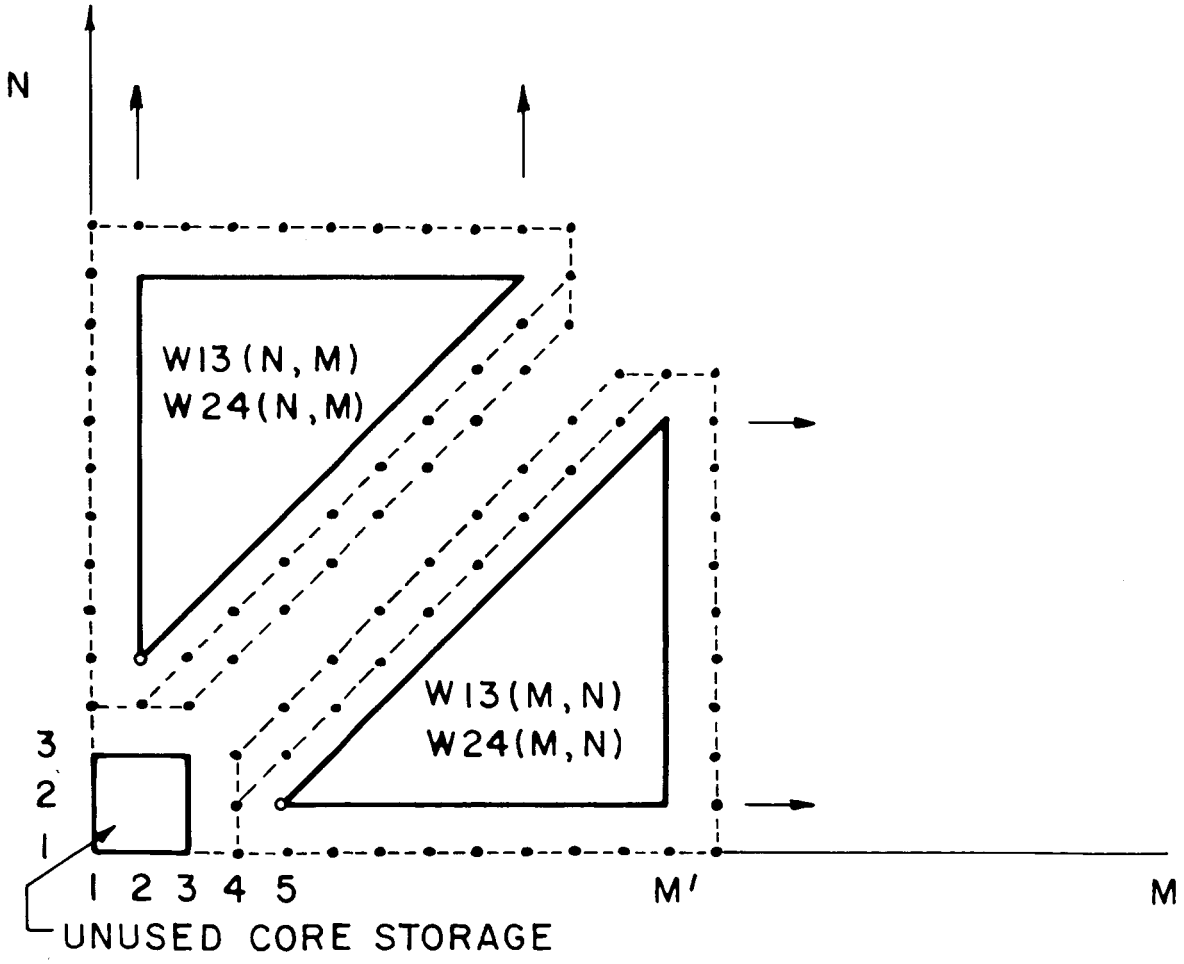


FIG. 2 B: CORE STORAGE FOR REGULAR MESH SIZE DURING 2-JET INTERACTION

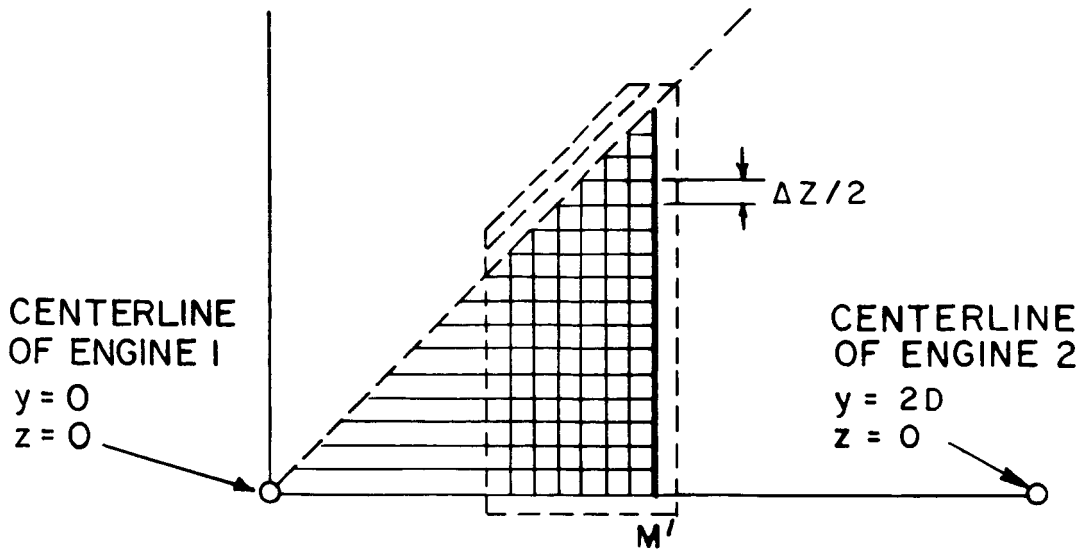


FIG 3 A: PHYSICAL PLANE, REFINED MESH SIZE

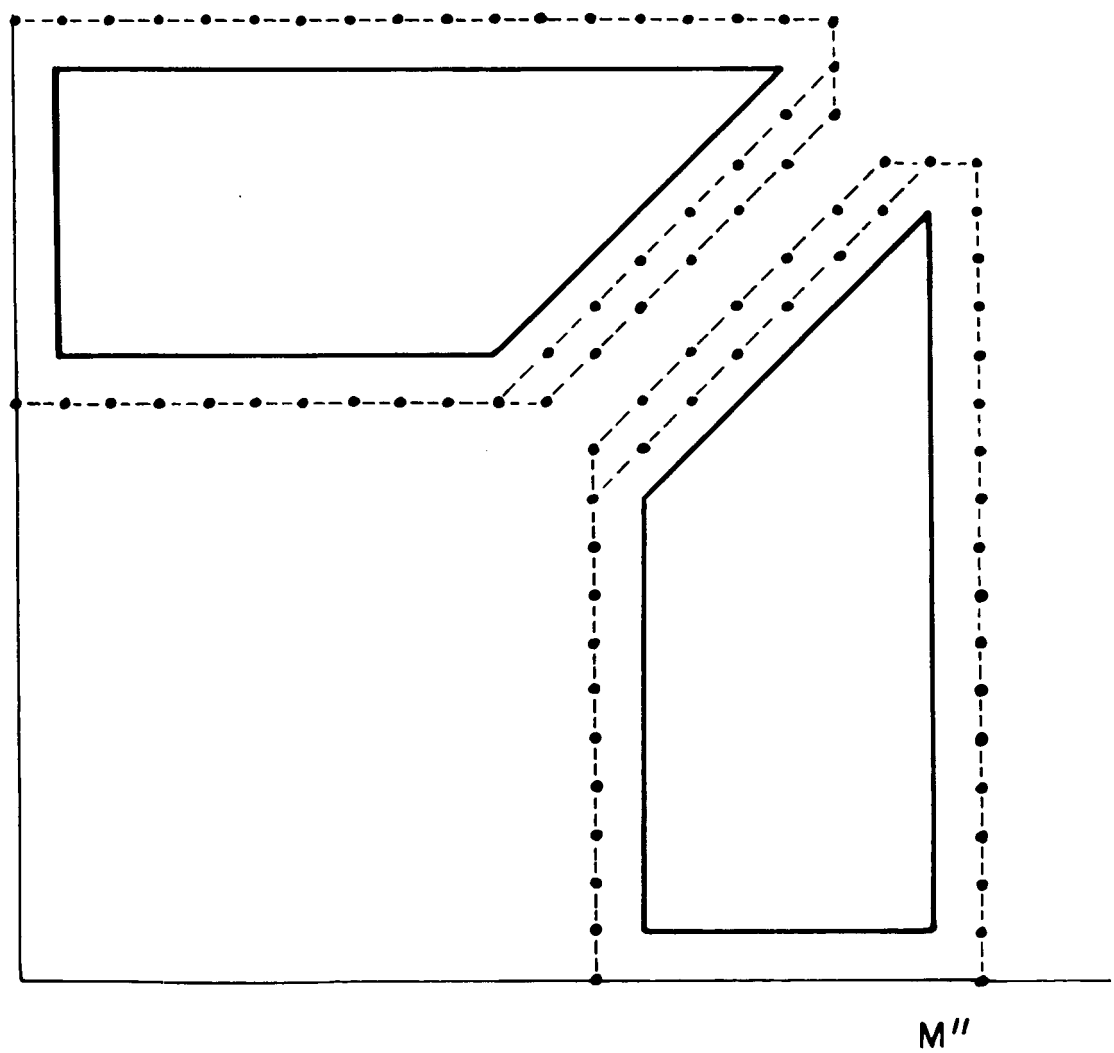


FIG 3 B: CORE STORAGE FOR REFINED MESH DURING 2 - JET INTERACTION

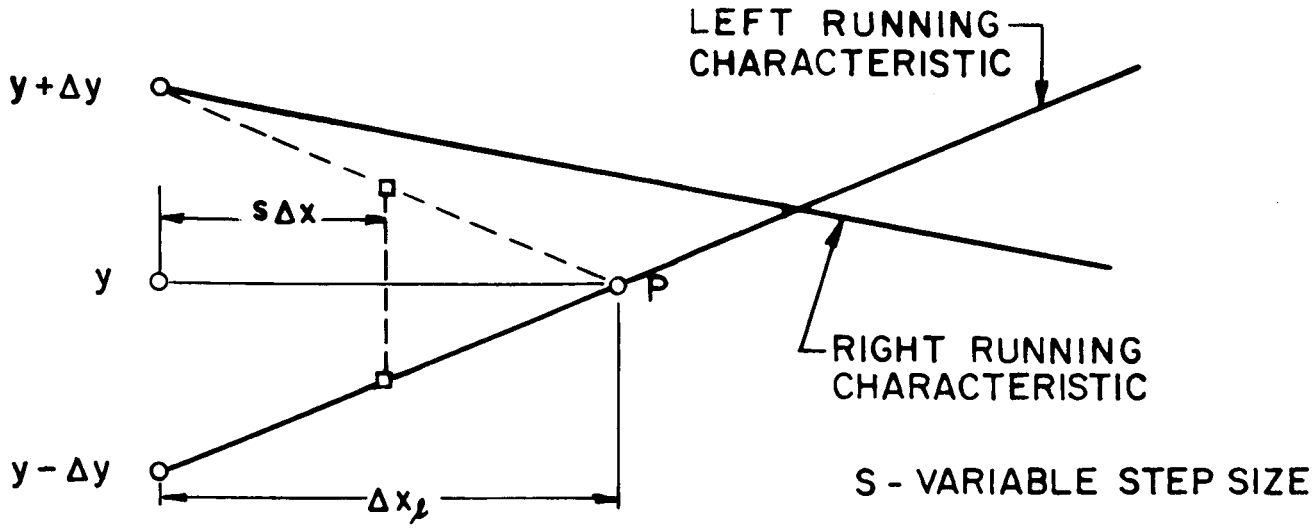


FIG. 4 A : DAMPING PARAMETER ASO

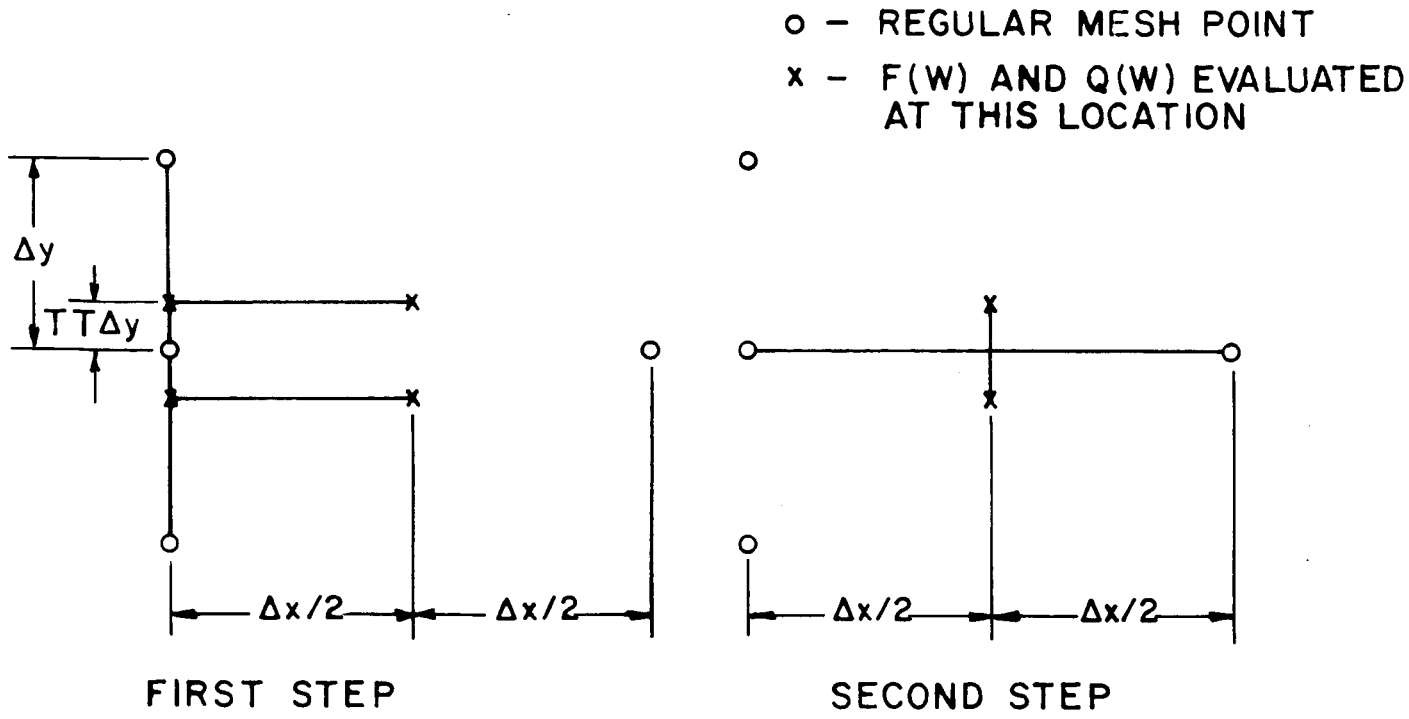


FIG. 4 B LATERALLY UNCENTERED DIFFERENCE SCHEME