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A COMPUTER PROGRAM FOR THE CALCULATION OF THE FLOW FIELD INCLUDING BOUNDARY LAYER EFFECTS FOR SUPERSONIC MIXED-COMPRESSION INLETS AT ANGLE OF ATTACK

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A COMPUTER PROGRAM FOR THE CALCULATION OF THE FLOW FIELD INCLUDING BOUNDARY LAYER EFFECTS FOR SUPERSONIC MIXED-COMPRESSION INLETS AT ANGLE OF ATTACK

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SUMMARY

A computer program has been developed which is capable of calculating the flow field including the boundary layer for the supersonic portion of a mixed-compression aircraft inlet operating at angle of attack. The calculation procedure is based on using a zonal solution algorithm. The supersonic core flow is determined using the method of characteristics for steady three-dimensional flow. The bow shock wave and the internal shock wave system are computed using a discrete shock wave fitting procedure. The boundary layer flow adjacent to both the forebody/centerbody and the cowl is determined using an implicit finite difference algorithm. The flow in a shock wave-boundary layer interaction region is computed using an integral analysis.

The computer program has the capability to compute the internal flow field with or without the discrete fitting of the internal shock wave system. The option in which the internal shock wave system is not fitted can be employed in situations in which the strength of the internal shock wave system is weak, and thereby an acceptable solution can be obtained by smearing the internal discontinuities.

The influence of molecular transport can be included in the computation of the external flow about the forebody, and in the computation of the internal flow in which the shock waves are not discretely fitted. This is accomplished by treating the viscous and thermal diffusion terms in the governing partial differential equations as forcing functions, or correction terms, in the method of characteristics scheme.

The boundary layer computation allows for the specification of the wall temperature or normal temperature gradient at the wall. Moreover, distributed wall bleed effects can be accounted for in the analysis. Laminar, transitional, or fully turbulent boundary layer flows can be calculated.

The thermodynamic model, molecular transport properties, and turbulence model employed in the computer program are contained in a separate group of subroutines. The assumed thermodynamic model is that of a thermally and calorically perfect gas. Dynamic viscosity is represented by Sutherland's law. Thermal conductivity is represented in terms of the dynamic viscosity and the laminar Prandtl number. Turbulent closure is achieved by use of a two layer eddy viscosity formulation based on mixing length and velocity defect concepts. Alternative formulations may be employed by modifying the existing subroutines or by replacing them.

The contours of the centerbody and the cowl are represented by a separate subroutine. The existing subroutine has the capability to describe a variety of axisymmetric contours. Other geometries, such as those having elliptic or super-elliptic cross-sections, may be described by suitably modifying the existing subroutine or by replacing it.

A major assumption of the present analysis is that the cowl lip is contained in a given axial station. Moreover, it is assumed that both the centerbody contour and the cowl contour are smooth and have continuous first partial derivatives.

The computer program cannot:

1. compute a subsonic core flow,
2. compute the external flow field about the forebody if the bow shock wave does not exist entirely around the forebody, or
3. compute the internal flow field if the bow shock wave is ingested into the annulus.

The computer program is written in Fortran IV for CDC 6000 Series, 7000 Series, and CYBER computer systems. The program can be easily modified to be compatible with other computers.

SECTION I

INTRODUCTION

A computer program has been developed for calculating the flow field including boundary layer effects for the supersonic portion of a mixed-compression aircraft inlet operating at angle of attack. The general features of the inlet geometry and the flow field are illustrated in Figure 1. The theoretical analysis on which the computer program is based is presented by Vadyak and Hoffman (1). The present study represents an extension of an earlier investigation [(2), (3)] which was concerned solely with the computation of the supersonic core flow.

This report presents a discussion of the computer program organization, descriptions of the subroutines, a discussion of the input parameters, a brief interpretation of the output information, and sample cases to illustrate the application of the analysis.

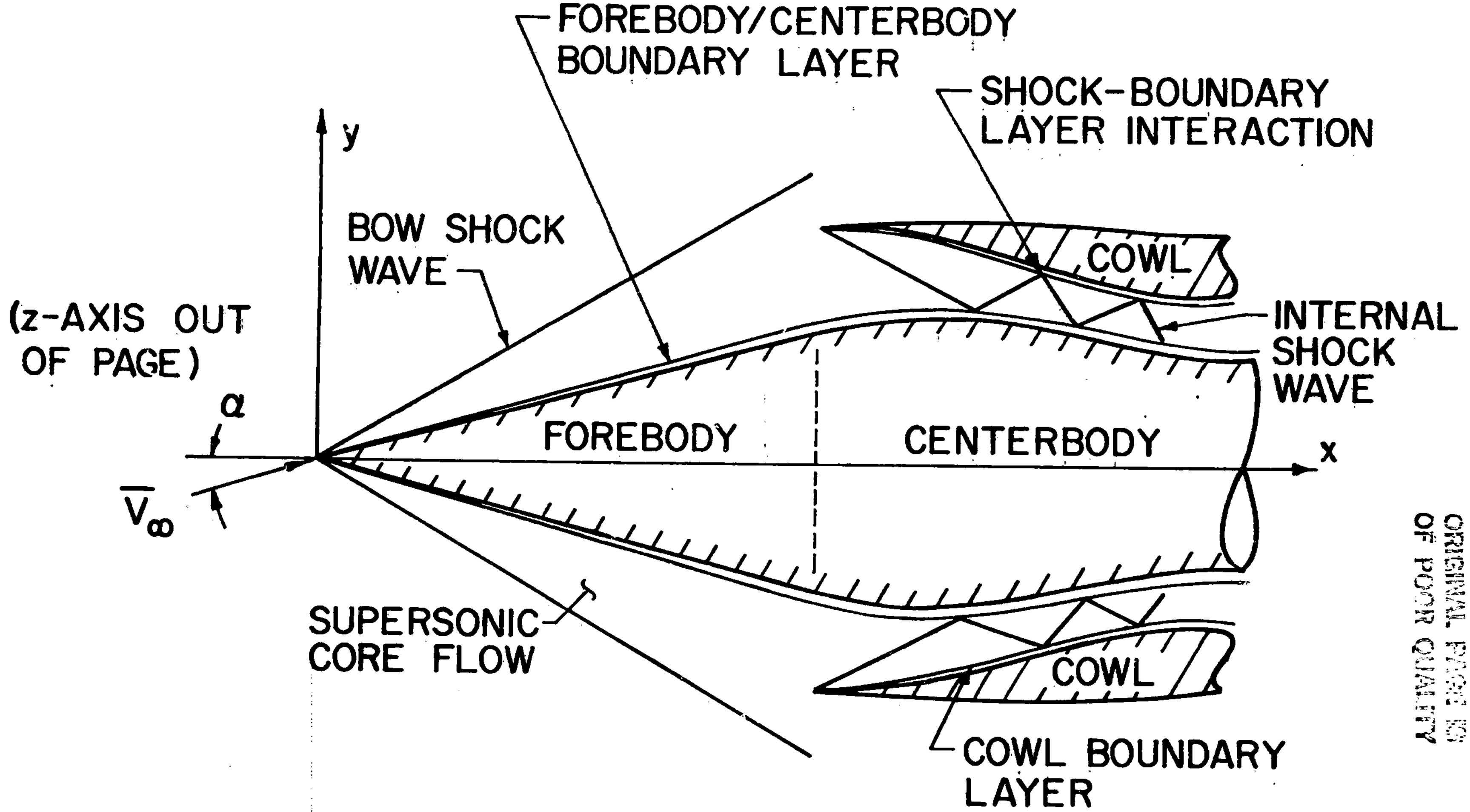


FIGURE I. MIXED-COMPRESSION AIRCRAFT INLET.

SECTION II

PROGRAM ORGANIZATION

1. INTRODUCTION

In this section, the program overlay structure is presented, and some general comments concerning program input and parameter initialization are made. The subroutines are identified which contain the thermodynamic model, the transport property representations, the turbulence model, and the formulations used for representing the centerbody and the cowl contours. The flow field integration options are briefly discussed, and some comments concerning program output are presented.

2. INTEGRATION OPTIONS

The computational flow regime is divided into two subregimes: the external flow field and the internal flow field (see Figure 1). If desired, only the external flow field may be computed. Alternatively, if the solution is known at the axial station of the cowl lip, the internal flow field may be determined without employing the forebody flow integration option.

The program has the capability to compute the internal flow field with or without the discrete fitting of the internal shock wave system in the supersonic core flow solution. The option in which shock waves are not discretely fitted might be employed if the strength of the internal shock wave system is relatively weak, and thereby an acceptable solution can be obtained by smearing all internal discontinuities.

The program can be executed with or without invoking the three-dimensional boundary layer calculation. The boundary layer calculation allows for the specification of distributed wall bleed and prescribed wall temperature or normal temperature gradient. Laminar, transitional, and fully turbient boundary layer flows may be computed.

The analysis includes the influence of molecular transport in the computation of the supersonic core flow by treating the viscous and thermal diffusion terms in the governing partial differential equations as forcing functions, or correction terms, in the method of characteristics scheme. At present, the program has the capability to include the influence of molecular transport in the computation of the external flow field about the forebody, and in the computation of the internal flow field in which the shock waves are not discretely fitted. The program option in which the internal shock waves are discretely fitted does not have the capability to include the influence of molecular transport in the computation, but rather assumes the flow to be inviscid and adiabatic.

3. PROGRAM ØVERLAY STRUCTURE

The overall program consists of 121 routines (16 program routines and 105 subroutines). The program is too large to be stored continuously in computer memory; hence an overlay scheme is employed. The overlay structure is presented in Figure 2. Three overlay levels are used: the resident overlay level, the primary overlay level, and the secondary overlay level.

ØVERLAY (0,0)* is the resident overlay and controls the overall execution of the program. ØVERLAY (0,0) calls the primary level overlays, ØVERLAY (1,0), ØVERLAY (2,0), ØVERLAY (3,0), and ØVERLAY (4,0). ØVERLAY (1,0) is used for data input and parameter initialization. ØVERLAY (1,0) calls the four secondary level overlays, ØVERLAY (1,1), ØVERLAY (1,2), ØVERLAY (1,3), and ØVERLAY (1,4). ØVERLAY (1,1) is used for the internal generation of the supersonic core flow initial data using an approximate integration technique. ØVERLAY (1,2) is employed for converting the output from ØVERLAY (2,0) which generates the supersonic core flow initial data using the Jones algorithm (4). ØVERLAY (1,3) is used to generate the three-dimensional boundary layer initial data for the forebody/centerbody geometry using the Adams finite difference algorithm (5). ØVERLAY (1,4) is employed for the initialization of the boundary layer computational parameters.

The supersonic core flow solution is computed using the primary level overlay, ØVERLAY (3,0), and the secondary level overlays, ØVERLAY (3,1), ØVERLAY (3,2), and ØVERLAY (3,3). ØVERLAY (3,0) contains the preponderance of the unit processes and the interpolation schemes. ØVERLAY (3,1) contains the control logic used in performing the integration for the external flow field about the forebody. ØVERLAY (3,2) contains the control logic used in determining the internal flow field in which shock waves are discretely fitted. ØVERLAY (3,3) contains the control logic used in determining the internal flow field in which shock waves are not discretely fitted.

The three-dimensional boundary layer solution is computed using the primary level overlay, ØVERLAY (4,0), and the four secondary level overlays, ØVERLAY (4,1), ØVERLAY (4,2), ØVERLAY (4,3), and ØVERLAY (4,4). ØVERLAY (4,0) contains the overall control logic for the boundary layer computation. ØVERLAY (4,1) contains the routines used for the attachment line flow solution and the three-dimensional flow solution. ØVERLAY (4,2) is used for the computation of the three-dimensional shock wave-boundary layer interaction region. ØVERLAY (4,3) is employed to account for boundary layer growth. ØVERLAY (4,4) initializes the boundary layer solution on the cowl boundary using an approximate technique.

The computer program has a restart capability in which an internally generated restart file is retrieved from tape. When the restart option is used, control is returned to the integration control secondary level overlay which was in use at the time the initial execution was terminated [e.g., if the forebody flow was being computed, control is returned to ØVERLAY (3,1)].

*Throughout the text, Ø denotes the letter O.

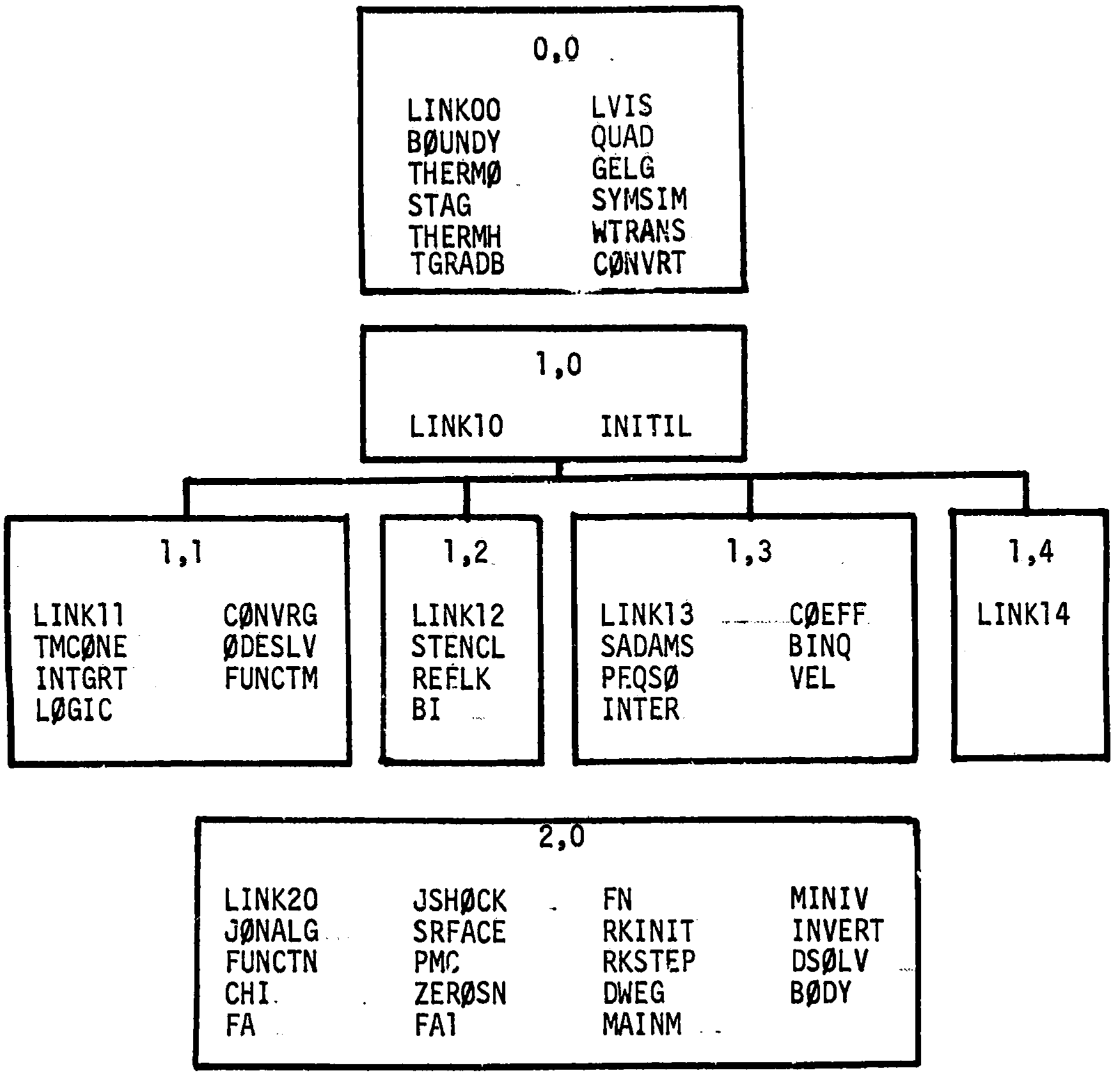


Figure 2. Program ØVERLAY Structure.

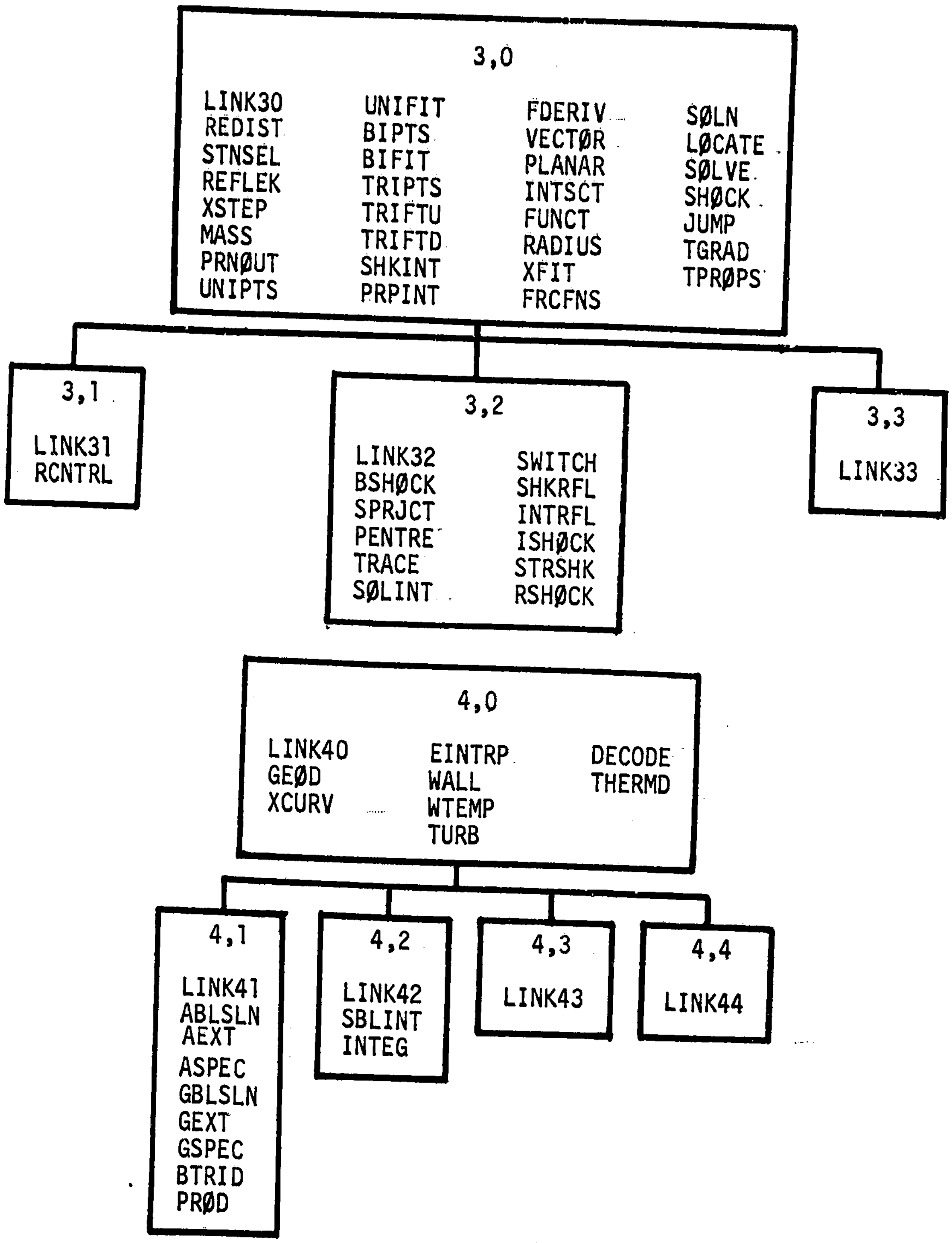


Figure 2. Concluded.

4. DATA INPUT

The input data are entered through both namelist input and formatted read statements. Eleven namelists must always be specified: namelists LIST1 to LIST11. Namelist LIST1 contains the input parameters which specify the flow field integration options, the number of planes of symmetry, the output options, etc. Namelist LIST2 contains the parameters which specify the free-stream conditions, the vehicle orientation, and parameters associated with the specification of the initial-value plane. Namelist LIST3 specifies the number of circumferential and radial stations used in the computational mesh of the supersonic core flow solution. Namelist LIST4 specifies the thermodynamic model and the molecular transport properties. Namelist LIST5 contains the parameters which specify the centerbody and the cowl contours. Namelist LIST6 contains the parameters which specify the boundary layer computational mesh. Namelist LIST7 contains the input parameters which specify the wall temperature or its normal gradient for use in the boundary layer computation. Namelist LIST8 contains the parameters used for the specification of distributed wall bleed. Namelist LIST9 is used for specification of the turbulence model and transition criteria. Namelist LIST10 is used for specification of all convergence tolerances and iteration limits. Namelist LIST11 specifies the parameters used for debug output.

In addition to the namelist input, the two-dimensional initial-value plane for the supersonic core flow can be input by formatted read statements. Alternatively, if the forebody is conical ahead of the axial location of the initial-value plane, the initial data may be generated internally in the computer program by one of two techniques.

The initial data for the boundary layer calculation can be input by formatted read statements. Alternatively, for conical forebody flows, the boundary layer initial data for the forebody/centerbody geometry can be generated internally in the computer program by a finite difference calculation. The cowl boundary layer initial data can also be generated internally using an approximate technique.

All input data are read in within routine LINK10. After the data have been entered, selected input parameters are checked for errors and consistency. If any errors are detected, appropriate messages are printed and the execution of the program is aborted. The input parameters are tested in subroutine INITIL.

It should be noted that many input parameters have default values and do not have to be specified. The default values for most of the input parameters are specified in LINK00.

After all input parameters and data have been entered, parameter initialization (for most of the subroutines) is performed in subroutine INITIL.

5. INITIAL DATA SPECIFICATION

The initial data for the supersonic core flow must be specified on a spacelike plane of constant x (see Figure 1). The flow must be supersonic at every point specified. The x-coordinate axis constitutes the longitudinal axis of the centerbody and the cowl. Moreover, the mean flow direction is assumed to be in the x-coordinate direction.

If the forebody flow field is to be determined, the initial-value plane must be specified at an axial (x) station that is upstream of the forebody computational flow regime (see Figure 1). The solution is then found along the streamlines that pass through the data points specified on the initial-value plane, although some streamline addition and deletion are performed on the ensuing solution planes. The axial location of the last solution plane of the forebody flow field is adjusted to lie at the axial station of the cowl lip, and constitutes the initial-value plane for the internal flow field computation.

If only the internal flow field is to be determined, the initial-value plane must be specified at the axial station which corresponds to the x-position of the cowl lip (see Figure 1). The cowl lip is assumed to be contained in a plane of constant x. For the internal flow field integration, a point redistribution is performed on the initial-value plane. This point redistribution is required to define streamlines which lie in the stream surface formed by the cowl boundary. The solution is then found along the streamlines that pass through the redistributed points on the plane at the cowl lip axial station. It should be noted that the internal flow field cannot be computed if the bow shock wave is ingested into the annulus.

The supersonic core flow initial data may be specified externally by the user. The user supplied data are entered by a formatted read of the file ITAP1.

Alternatively, if the forebody is conical ahead of the axial location of the initial-value plane, the supersonic flow property field on the initial-value plane can be generated internally in the computer program by one of two methods. One method of internally generating the initial-value plane is by using an approximate technique which employs the Taylor-Maccoll solution for the flow about a circular cone at zero incidence. A superposition procedure is used to obtain an approximation to the flow about a circular cone at nonzero angle of attack by neglecting the cross flow effects. This superposition procedure effectively amounts to computing the flow turning angle in the meridional plane of the given solution point, and then obtaining the flow properties at that point by applying the Taylor-Maccoll solution for a cone half-angle equal to the flow turning angle. It must be emphasized that this is only an approximate technique, giving the well accepted Taylor-Maccoll solution at zero incidence, but becoming increasingly less accurate as the angle of attack is increased. Subroutines LINK11, TMCØNE, INTGRT, LØGIC, CØNVRG, ØDESLV, and FUNCTM are used to generate internally the supersonic core flow initial-value plane property field.

The other method of internally generating the supersonic flow initial data is based on the numerical integration algorithm developed by Jones (4). The solution obtained by Jones for the flow about a circular cone at nonzero incidence has been well substantiated. For situations in which the forebody is conical up to the axial station where the initial-value plane is located, the Jones program is the recommended source for the initial data. The Jones algorithm has been incorporated into the present computer program in ØVERLAY (2,0). Routines LINK20, JØNALG, FUNCTN, CHI, FA, JSHØCK, SRFACE, PMC, ZERØSN, FA1, FN, RKINIT, RKSTEP, DWEG, MAINM, MINIV, INVERT, DSØLV, and BODY comprise the Jones algorithm and are used to internally generate the supersonic core flow initial-value plane property field. To make the output of the Jones algorithm compatible with the bicharacteristic scheme developed herein, data conversion is performed in subroutines LINK12, STENCL, REFLK, and BI.

If the boundary layer flow is to be computed, then the initial data must be specified for the forebody flow if the external flow is to be determined, and for the forebody/centerbody flow and the cowl flow if the internal flow is to be determined. Data for the boundary layer computation must be specified on a body normal grid. This grid will, in general, not coincide with a plane of constant x. The axial location for specification of the forebody/centerbody boundary layer initial data coincides with the axial location used for the supersonic core flow initial data specification. The axial location for specification of the cowl boundary layer initial data is always at the first computational station inside the annulus since the cowl boundary layer thickness is identically zero at the cowl lip.

The boundary layer flow initial data may be specified externally by the user. The user supplied data is entered by a formatted read of the file ITAP2 for input of the forebody/centerbody initial data, and by a formatted read of file ITAP3 for input of the cowl initial data.

Alternatively, if the forebody is conical ahead of the axial station of the initial-data plane, the forebody/centerbody boundary initial data may be generated internally in the computer program by using the finite difference algorithm developed by Adams (5). Laminar or turbulent flows may be determined using the Adams analysis. The Adams algorithm has been incorporated into the present computer program in ØVERLAY (1,3). Subroutines LINK13, SADAMS, PEQSØ, INTER, CØEFF, BINQ, and VEL comprise the Adams algorithm and are used to generate internally the forebody/centerbody boundary layer initial data. Routine LINK14 is used to initialize the appropriate parameters for the forebody/centerbody boundary layer computation.

The cowl boundary layer initial data may also be generated internally using the approximate analysis contained in routine LINK44.

6. THERMODYNAMIC MODEL

The assumed thermodynamic model is that of a thermally and calorically perfect gas. Other thermodynamic models can be incorporated into the computer program by suitably modifying or replacing subroutines THERMØ, STAG, TGRAD, JUMP, TMCØNE, LØGIC, FUNCTM, THERMH, TGRADB, and THERMD. The initial-data generation routines contained in ØVERLAY (1,3) and ØVERLAY (2,0) also require modification.

7. MOLECULAR TRANSPORT PROPERTIES

Both the dynamic viscosity and the thermal conductivity are assumed to be functions of the temperature only. The assumed functional form for the dynamic viscosity is given by Sutherland's law (6). The assumed functional form for the thermal conductivity is expressed in terms of the dynamic viscosity through use of the laminar Prandtl number. Other representations for the dynamic viscosity and the thermal conductivity can be incorporated into the analysis by suitably modifying or replacing subroutines TPRØPS and LVIS. The initial-data generation routines in ØVERLAY (1,3) also require modification.

8. TURBULENCE MODEL

A two-layer eddy viscosity formulation has been incorporated into the computer program in order to achieve mathematical closure (7). The model is based on a mixing length formulation for the inner region and a velocity defect formulation for the outer region. The model assumes isotropic turbulence and accounts for mass transfer at the wall. The turbulent eddy thermal conductivity is expressed in terms of the eddy viscosity and the turbulent Prandtl number. Alternate turbulence models may be incorporated into the analysis by suitably modifying or replacing subroutine TURB.

9. CENTERBODY AND COWL CONTOURS

The computer program developed in the present investigation assumes that both the centerbody contour and the cowl contour are axisymmetric. For the purposes of geometry description, the axial (x) domain is divided into a number of intervals. In any interval, the body radius may be specified by either tabular input, or by supplying the coefficients of a cubic polynomial written as a function of x. It is assumed that both the centerbody contour and the cowl contour are smooth and have continuous first derivatives. More arbitrary geometries, such as those having elliptic or super-elliptic cross-sections, can be incorporated into the analysis by suitably modifying or replacing subroutines BØUNDY, GEØD, and XCURV. The initial-data generation subroutines in ØVERLAY (1,1), ØVERLAY (1,2), ØVERLAY (1,3), and ØVERLAY (2,0) also require modification for noncircular cross-sections.

10. FLOW SYMMETRY

Four flow symmetry options have been incorporated into the computer program for cases in which the boundary layer computation is not invoked. The most general case is when no planes of symmetry exist. This option is used to compute the flow field for fully three-dimensional inlets at incidence. The second case is when one plane of symmetry exists. This option is used for computing the flow field for axisymmetric inlets at incidence. The third case is when two planes of flow symmetry exist. This option is used to compute the flow field for three-dimensional inlets with two planes of geometric symmetry at zero angle of attack. The final option is when the flow is axisymmetric. This option is used to compute the flow field in axisymmetric inlets at zero incidence.

One flow symmetry option has been incorporated into the computer program for cases in which the boundary layer is to be determined. This option is for the case of one plane of flow symmetry.

11. OUTPUT

Preliminary information is printed by LINK10. The initial-value plane for the supersonic core flow and all subsequent solution planes are printed by subroutine PRNØUT. The solution points on the space curves defined by the intersection of the internal shock wave with the solid boundaries are output by subroutine SHKRFL. In addition to the position of and the dependent variables at a solution point, the Mach number, static temperature, velocity magnitude, stagnation pressure, and stagnation temperature are also printed. The mass flow rate across every solution plane, calculated by trapezoidal rule integration in subroutine MASS, is also printed.

The initial data and subsequent solution surfaces for the boundary layer calculation are printed by subroutine DECØDE. The output consists of position, velocity components, pressure, density, temperature, velocity magnitude, stagnation pressure, stagnation temperature, bleed rate, and certain integral parameters.

SECTION III

SUBROUTINE DESCRIPTIONS

1. INTRODUCTION

In this section, a brief description is given of the function of each subroutine in the computer program. This information supplements the information available in the form of comment statements within the program.

2. ØVERLAY (0,0)

LINKOO. This program routine is the main control routine in ØVERLAY (0,0), the resident overlay. LINKOO first calls ØVERLAY (1,0) for data input, parameter initialization, and, if desired, internal generation of the initial data. LINKOO then calls ØVERLAY (3,0) and ØVERLAY (4,0) to perform the flow field integration. Most of the program constants and input parameters have their default values specified in LINKOO. Moreover, the reader and printer call numbers, denoted by IRE and IWR, respectively, are initialized in LINKOO.

BØUNDY. This subroutine is used for the specification of both the forebody/centerbody and cowl geometries. The version of BØUNDY supplied with the program assumes that both the forebody/centerbody and the cowl are axisymmetric. More arbitrary geometries can be described by suitably modifying or replacing this subroutine. If BØUNDY is replaced, the subroutine argument list must be identical to the existing list. The parameters in the argument list are defined as follows.

XABS	x-coordinate
Y	y-coordinate
Z	z-coordinate
ALPHA	polar angle defined by $\tan^{-1}(z/y)$
RBØDY	radius of either forebody/centerbody or cowl
BNX	x-component of outward body normal unit vector to forebody/centerbody or cowl
BNY	y-component of outward body normal unit vector to forebody/centerbody or cowl
BNZ	z-component of outward body normal unit vector to forebody/centerbody or cowl
J	If J=1, forebody/centerbody geometry is to be specified. If J=2, cowl geometry is to be specified.

K If K=0, read in XABS and ALPHA, and compute RBØDY and the corresponding Y and Z. If K=1, read in XABS and ALPHA, and compute RBØDY, Y, Z, BNX, BNY, and BNZ. If K=2, read in XABS, Y, and Z (coordinates of a point not on the body), and compute RBØDY, ALPHA, Y, Z, BNX, BNY, and BNZ at the point on the body where the projection of the body normal in the (y,z)-plane passes through the originally specified point.

THERMØ. This subroutine computes the temperature, sonic speed, and the thermodynamic parameter ξ. The assumed thermodynamic model is that of a thermally and calorically perfect gas. Other thermodynamic models may be incorporated into the analysis by suitably modifying or replacing this subroutine. If subroutine THERMØ is replaced, the argument list must be identical to the existing list. The parameters in the argument list are defined as follows.

- P pressure (p)
- RØ density (ρ)
- T temperature (t)
- A sonic speed (a)
- CØEFF $\xi=(1/\rho t)(\partial p/\partial s)_\rho$, where s is the entropy per unit mass
- KT If KT=1, compute T. If KT≠1, do not compute T.
- KA If KA=1, compute A. If KA≠1, do not compute A.
- KC If KC=1, compute CØEFF. If KC≠1, do not compute CØEFF.

Thermodynamic property information is supplied to subroutine THERMØ through the named common block GAS1. This common block contains the following parameters: RUNIV (universal gas constant), TDT (temperature data array), WTMØL (molecular weight data array), CP (specific heat data array), NGAS1 (an integer to denote the number of elements in the TDT, WTMØL, and CP arrays), and KGAS1 (an integer to denote which gas model is to be used). These parameters are included for modifying subroutine THERMØ to include real gas effects.

STAG. This subroutine computes the Mach number, the stagnation pressure, and the stagnation temperature. The assumed thermodynamic model is that of a thermally and calorically perfect gas. Other thermodynamic models may be incorporated into the analysis by suitably modifying or replacing this subroutine. If STAG is replaced, the argument list must be identical to the existing list. The parameters in the argument list are defined as follows.

- P static pressure
- RØ static density
- T static temperature
- A sonic speed
- Q velocity magnitude
- XM Mach number

PT stagnation pressure

TT stagnation temperature

Thermodynamic property information is supplied to subroutine STAG through the named common block GAS1.

THERMH. This subroutine computes the pressure, density, temperature, and specific enthalpy. Any two variables may be computed given the remaining two. The assumed thermodynamic model is that of a thermally and calorically perfect gas. Other thermodynamic models may be incorporated into the analysis by suitably modifying or replacing this subroutine. If subroutine THERMH is replaced, the argument list must be identical to the existing list. The parameters in the argument list are defined as follows.

P pressure

RØ density

T temperature

H specific static enthalpy

KØPT If KØPT=1, compute RØ and T given P and H.
If KØPT=2, compute T and H given P and RØ.
If KØPT=3, compute RØ and H given P and T.
If KØPT=4, compute H given P and T.
If KØPT=5, compute RØ and T given H and P.

Thermodynamic property information is supplied to subroutine THERMH through the named common block GAS1.

TGRADB. This sburoutine computes the spatial gradients of temperature by using an analytically differentiated form of the thermal equation of state so that temperature derivatives can be expressed in terms of the derivatives of pressure and density. The assumed thermodynamic model is that of a thermally perfect gas. Other thermodynamic models may be incorporated into the analysis by suitably modifying or replacing this subroutine. If TGRADB is replaced, the argument list must be identical to the existing list. The parameters in the argument list are defined as follows.

P pressure

RØ density

DPY first partial spatial derivative of pressure

DRØY first partial spatial derivative of density

DTY first partial spatial derivative of temperature

Thermodynamic property information is supplied to subroutine TGRADB through the named common block GAS1.

LVIS. This subroutine computes the dynamic viscosity and its spatial gradient. The assumed functional form for dynamic viscosity is given by Sutherland's Law (6). Other transport property formulations may be incorporated into the analysis by suitably modifying or replacing this subroutine. If LVIS is replaced, the argument list must be identical to the existing list. The parameters in the argument list are defined as follows.

T	static temperature
P	static pressure
VIS	dynamic viscosity
DTY	first partial spatial derivative of temperature
DPY	first partial spatial derivative of pressure
DVISY	first partial spatial derivative of viscosity
KØPT	If KØPT=1, compute VIS. If KØPT=2, compute DVISY.

Transport property information is supplied to subroutine LVIS through the named common block GAS2. The common block GAS2 contains the following parameters: TDL (temperature data array), VISD (viscosity data array), CØND (thermal conductivity data array), NGAS2 (an integer to denote the number of elements in the TDL, VISD, and CØND arrays), and KGAS2 (an integer to denote which transport property model is to be used). These parameters are included for modifying LVIS to use tabular data.

QUAD. This subroutine determines the three coefficients in the univariate quadratic interpolation polynomial.

GELG. This subroutine is used for solving a system of simultaneous linear equations. The system is solved using Gaussian elimination with complete pivoting. This subroutine is IBM library subroutine GELG.

SYMSIM. This subroutine solves a system of simultaneous linear equations with a symmetric coefficient matrix. The system is solved using Gaussian elimination with pivoting in the main diagonal. This subroutine is a modified version of IBM library subroutine GELS.

WTRANS. This subroutine determines the wall transpiration/suction parameters for use in the computation.

CØNVRT. This subroutine obtains the base axial coordinate of a point on the body given the streamwise curvilinear coordinate.

3. ØVERLAY (1,0)

LINK10. This program routine is the main control routine in ØVERLAY (1,0). All input parameters and initial data are entered in LINK10. In all cases, the eleven namelists LIST1 to LIST11 are entered. If the flow property field on the initial-value plane is externally specified, a formatted read is used to enter this information. After the input data have been entered, subroutine

INITIL is called for testing for input errors and performing parameter initialization. If the flow property field on the initial-value plane is to be internally generated, the appropriate subroutines are then called from subroutine INITIL. After subroutine INITIL has been called, preliminary output is printed by LINK10.

INITIL. This subroutine is called from routine LINK10, and is used to test for errors on selected input parameters and to perform parameter initialization. If an input parameter error is found, an appropriate message is generated and the program execution is aborted. After the selected input parameters have been tested, parameter initialization is performed. If the flow property field on the initial-value plane is to be internally generated, the appropriate subroutines are then called.

4. ØVERLAY (1,1)

LINK11. This program routine is the main control routine in ØVERLAY (1,1), and is used in conjunction with subroutines TMCØNE, INTGRT, LØGIC, CØNVRG, ØDESLV, and FUNCTM to internally generate the supersonic flow property field on the initial-value plane if the forebody is conical ahead of the initial-value plane. The internally generated initial-value plane is obtained by an approximate technique which employs the Taylor-Maccoll solution for the flow about a circular cone at zero incidence. A superposition procedure is used to obtain an approximation to the flow about a circular cone at nonzero angle of attack by neglecting the cross flow effects. This superposition procedure effectively amounts to computing the flow turning angle in the meridional plane of the given solution point, and then obtaining the flow properties at that point by applying the Taylor-Maccoll solution for a cone half-angle equal to the flow turning angle. The shock wave angle is then measured from the original streamline direction in the appropriate meridional plane. It must be emphasized that this is only an approximate technique, giving the well accepted Taylor-Maccoll solution at zero angle of attack, but becoming increasingly less accurate as the angle of attack is increased.

TMCØNE. This subroutine is one of the subroutines used for the internal generation of the initial-value plane. TMCØNE is called from routine LINK11 and performs initialization and post calculation storage of the Taylor-Maccoll solution used in computing the initial-value plane supersonic flow property field. Ths assumed thermodynamic model is that of a thermally and calorically perfect gas. Other thermodynamic models may be incorporated into the analysis by suitably modifying this subroutine. Thermodynamic property information is supplied to subroutine TMCØNE through the named common block GAS1.

INTGRT. This subroutine is one of the subroutines used in internally generating the supersonic flow property field on the initial-value plane. INTGRT integrates the Taylor-Maccoll equation inward towards the forebody until a point is reached where the normal component of velocity is sufficiently small.

LØGIC. This subroutine is one of the subroutines used in internally generating the supersonic flow property field on the initial-value palne. LØGIC is used to control the computation of the Taylor-Maccoll solution in a particular meridional plane. The assumed thermodynamic model is that of a thermally and calorically perfect gas. Other thermodynamic models may be incorporated into the analysis by suitably modifying this subroutine. Thermodynamic property information is supplied to subroutine LØGIC through the named common block GAS1.

CØNVRG. This subroutine is one of the subroutines used in internally generating the supersonic flow property field on the initial-value plane. CØNVRG is used in testing if the normal component of velocity has vanished at the body in the external flow field integration.

ØDESLV. This subroutine is one of the subroutines used in internally generating the supersonic flow property field on the initial-value plane. ØDESLV integrates the Taylor-Maccoll equation by employing a fourth-order Runge-Kutta method.

FUNCTM. This function is used in internally generating the supersonic flow property field on the initial-value plane. FUNCTM evaluates the Taylor-Maccoll equation. The assumed thermodynamic model is that of a thermally and calorically perfect gas. Other thermodynamic models may be incorporated into the analysis by suitably modifying this function. Thermodynamic property information is supplied to FUNCTM through the named common block GAS1.

5. ØVERLAY (1,2)

LINK12. This program routine is the main control routine in ØVERLAY (1,2) and is used in conjunction with subroutines STENCL, REFLK, and BI in converting the output of the Jones algorithm into a format which is compatible with the bicharacteristic algorithm. The Jones algorithm is contained in ØVERLAY (2,0) and is used to internally generate the supersonic flow property field on the initial-value plane. The assumed thermodynamic model employed in LINK12 is that of a thermally and calorically perfect gas. Other thermodynamic models may be incorporated into the analysis by suitably modifying this routine. Thermodynamic property information is supplied to routine LINK12 through the named common block GAS1.

STENCL. This subroutine is one of the subroutines used for conversion of the Jones algorithm output so that it can be used as initial data for the supersonic flow solution. STENCL determines the stencil of field points to be used in the bivariate interpolation of the initial data.

REFLK. This subroutine is one of the subroutines used for conversion of the Jones algorithm output so that it can be used as initial data for the supersonic flow solution. REFLK performs field point reflections about the plane of flow symmetry.

BI. This subroutine is one of the subroutines used for conversion of the Jones algorithm output so that it can be used as initial data for the supersonic flow solution. BI determines the coefficients of the least squares quadratic bivariate polynomial used for interpolation of the initial data. The system of normal equations which determines the polynomial coefficients is solved by calling subroutine SYMSIM.

6. ØVERLAY (1,3)

LINK13. This program routine is the main control routine in ØVERLAY (1,3) and is used in conjunction with subroutines SADAMS, PEQSØ, INTER, CØEFF, BINQ, and VEL to internally generate the initial data for the forebody/centerbody boundary layer computation. The initial data generation is accomplished by using the Adams finite-difference algorithm (5), which is incorporated into the computer program in ØVERLAY (1,3). The Adams algorithm generates the initial data at a specified axial location, assuming that the forebody/centerbody geometry is conical ahead of that location. It is also assumed in the analysis that the wall temperature is a specified constant, that the thermodynamic model is that of a thermally and calorically perfect gas, and that dynamic viscosity is given by Sutherland's Law (6). Other thermodynamic and molecualr transport models may be incorporated into the analysis by suitably modifying the subroutines in ØVERLAY (1,3). Thermodynamic and molecular transport property information is supplied to routine LINK13 through the named common blocks GAS1 and GAS2.

SADAMS. This subroutine is one of the subroutines used for the internal generation of the forebody/centerbody boundary layer initial data. SADAMS is the main control routine in the Adams finite-difference algorithm.

PEQSØ. This subroutine is one of the subroutines used for the internal generation of the forebody/centerbody boundary layer initial data. PEQSØ solves the system of parabolic differential equations generated in the analysis.

INTER. This subroutine is one of the subroutines used for the internal generation of the forebody/centerbody boundary layer initial data. INTER is used to perform Lagrangian interpolation.

CØEFF. This subroutine is one of the subroutines used for the internal generation of the forebody/centerbody boundary layer initial data. CØEFF is used to obtain the surface properties given the surface pressure distribution.

BINQ. This subroutine is one of the subroutines used for the internal generation of the forebody/centerbody boundary layer initial data. BINQ solves the system of simultaneous linear equations used in the Newton iteration scheme.

VEL. This subroutine is one of the subroutines used for the internal generation of the forebody/centerbody boundary layer initial data. VEL is used to interpolate the surface properties determined by subroutine CØEFF.

7. ØVERLAY (1,4)

LINK14. This program routine is the main control routine in ØVERLAY (1,4) and is used to initialize the transformed variables used in the boundary layer computations.

8. ØVERLAY (2,0)

LINK20. This program routine is the main control routine in ØVERLAY (2,0) and is used in conjunction with subroutines JØNALG, FUNCTN, CHI, FA, JSHØCK, SRFACE, PMC ZERØSN, FA1, FN, RKINIT, RKSTEP, DWEG, MAINM, MINIV, INVERT, DSØLV, and BØDY to internally generate the supersonic property field on the initial-value plane if the forebody is conical ahead of the initial-value plane. The internally generated initial-value plane is obtained by using the Jones finite difference algorithm (4). The Jones algorithm has been incorporated into the computer program in ØVERLAY (2,0). It is assumed that the thermodynamic model is that of a thermally and calorically perfect gas. Other thermodynamic models may be incorporated into the analysis by suitably modifying the subroutines in ØVERLAY (2,0). Thermodynamic property information is supplied to routine LINK20 through the named common block GAS1. All of the subroutines in ØVERLAY (2,0) are used for the internal generation of the supersonic flow initial data.

JØNALG. JØNALG is the main control routine for the Jones algorithm.

FUNCTN. FUNCTN computes the surface residual mass flow functions which are to be minimized.

CHI. CHI computes certain output parameters.

FA. FA computes gradient parameters that are used in subroutine PMC.

JSHØCK. JSHØCK computes the flow properties immediately downstream of the bow shock wave.

SRFACE. SRFACE finds the initial approximation to the surface solution.

PMC. PMC is used for numerically integrating the governing differential equations.

ZERØSN. ZERØSN is used to calculate the solution for a circular cone at zero incidence.

FA1. FA1 computes the derivatives used in the Runge-Kutta integration for the zero incidence solution.

FN. FN controls the Runge-Kutta integration for the zero incidence solution.

RKINIT. RKINIT computes functions used in the zero incidence solution.

RKSTEP. RKSTEP performs one Runge-Kutta integration step for the zero incidnece solution.

DWEG. DWEG is used for computing zeros of an equation.

MAINM. MAINM performs functional minimization applied for obtaining a minimum normal velocity at the body surface.

MINIV. MINIV is used for functional minimization.

INVERT. INVERT is used to perform matrix inversion.

DSØLV. DSØLV uses Gaussian elimination for solving systems of linear equations.

BØDY. BØDY is used to define conical geometries.

9. ØVERLAY (3,0)

LINK30. This program routine is the main control routine in ØVERLAY (3,0). LINK30 calls the supersonic flow integration control overlays, ØVERLAY (3,1), ØVERLAY (3,2), and ØVERLAY (3,3). If a program restart is specified, the last secondary level overlay that was in use at the time the initial execution was terminated is called.

REDIST. This subroutine is used to perform point redistribution on the solution plane at the axial station of the cowl lip. This point redistribution is required to obtain a uniform point distribution and to obtain streamlines which lie in the stream surface formed by the cowl boundary. The redistributed points are arranged symmetrically in the computed sector. These points lie on rays which have equal angular increments from one another, with the points on each ray being spaced at equal radial increments. The flow properties at these points are obtained by bivariate interpolation. If the viscous flow option is specified and the internal flow field integration option in which shock waves are not discretely fitted is specified, point redistribution is also performed on the forebody flow field solution plane immediately upstream of the solution plane located at the cowl lip axial station.

STNSEL. This subroutine is employed to determine the solution point on a given solution plane that is nearest to an arbitrary point whose coordinates are supplied in the argument list. After the proper solution point has been determined by a search of the computed sector, it is used as the base point of the nine point stencil used in formulating the quadratic bivariate interpolation polynomial. STNSEL calls subroutine BIPTS in the course of determining the proper solution point and in formulating the interpolation polynomial coefficients.

REFLEK. This subroutine performs reflections, about the coordinate axes, of the solution points in the computed sector on a given solution plane when flow symmetry exists. The solution point reflections are required to obtain the appropriate fit point stencils used in formulating the univariate, bivariate, and trivariate interpolation polynomials. REFLEK is used to reflect points for the case of one plane of flow symmetry, the case of two planes of flow symmetry, and the axisymmetric flow case. Both streamline and shock wave points are reflected in REFLEK.

XSTEP. This subroutine determines the axial marching step allowed by the Courant-Friedrichs-Lewy (CFL) stability criterion. Except in the vicinity of an internal shock wave intersection with a solid boundary, the marching step computed by XSTEP is that used to regulate the distance between successive solution planes. In the vicinity of an internal shock wave-solid boundary intersection, special constraints are used to determine the marching step. XSTEP applies the CFL stability criterion to all streamline points in the computed sector. The acutal marching step is taken as the allowable x-step at the most restrictive point. The stability criterion is not applied to the shock wave points. Moreover, the internal flow field shock wave points are ignored in defining the convex hull of the finite difference network when application of the stability criterion is made to a streamline point.

MASS. This subroutine is used to compute the mass flow rate across a given solution plane. The mass flow rate is numerically ascertained by a trapezoidal rule integration procedure in which the incremental mass flow rate is computed through an elemental triangle formed by three adjacent points. The sum of these incremental mass flow rates is the total mass flow rate. If flow symmetry exists, only the mass flow rate in the computed sector is found by integration. The mass flow rate across the entire plane is then obtained by use of an appropriate multiplier. Special logic is used to trace the internal shock wave in the integration procedure when the mass flow rate across an internal flow field solution plane is being computed.

PRNØUT. This subroutine is used to print the supersonic flow integration results for all solution planes. Both the external flow field and the internal flow field solution planes are printed by PRNØUT. In addition, the initial-value plane, the redistributed data plane at the cowl lip axial station, and the restart plane are output by PRNØUT. Three print options (specified in the input by the input parameter KPRINT) are available: body streamline points and shock wave points, all solution points, and all solution points and shock wave parameters (incident normal Mach number and shock wave surface normal unit vector components). The solution points along the space curves formed by the intersections of the internal shock wave with the solid boundaries are not printed by subroutine PRNØUT. They are printed by subroutine SHKRFL.

UNIPT. This subroutine selects the fit points used in formulating the univariate interpolation polynomials that are used to describe the shock wave radius and the shock wave angle along the curve defined by the intersection of the shock wave with a given solution plane. Three adjacent shock wave solution points constitute the fit point stencil in regions that are away from an internal shock wave-solid boundary intersection. In the region of an intersection, the fit point stencil may be appropriately expanded to be in accord with the Courant-Friedrichs-Lewy (CFL) stability criterion.

UNIFIT. This subroutine is used to determine the coefficients in the quadratic univariate interpolation polynomial. The three coefficients in this polynomial are determined by a fit to three data points which are supplied to UNIFIT through the call statement. Subroutine GELG is called to solve the system of simultaneous linear equations that determines the coefficients.

BIPTS. This subroutine selects the fit points used in formulating the quadratic bivariate interpolation polynomials that are used for intraplanar flow property determination. A base point and its eight immediate neighbors constitute the fit point array. Two types of fit point stencils are used: interior point and boundary point. A boundary point stencil is employed when the interpolation base point (the fit point nearest to the interpolated point) is on the shock wave. Special logic is used to ensure that no point stencil bridges the shock wave.

BIFIT. This subroutine is used to determine the coefficients in the quadratic bivariate interpolation polynomial. The six coefficients in this polynomial are determined by a least squares fit of nine data points which are supplied to BIFIT through the named common block FITPTS. Subroutine SYMSIM is called to solve the system of simultaneous linear equations (normal equations) which determines the coefficients in the interpolation polynomial. This system of linear equations has a symmetric coefficient matrix.

TRIPTS. This subroutine selects the fit points used in formulating both the linear trivariate interpolation polynomial and the quadratic trivariate interpolation polynomial. Four solution points are used in formulating the linear trivariate interpolation polynomial. Fourteen solution points are used in formulating the quadratic trivariate interpolation polynomial. The linear polynomial is used for flow property interpolation on the upstream side of the shock wave surface. The quadratic polynomial is used for flow property interpolation on both the downstream side of the shock wave surface and on the stream surface formed by a solid boundary.

TRIFTU. This subroutine is used to determine the coefficients in the linear trivariate interpolation polynomial. The four coefficients in this polynomial are determined by a fit to four data points which are supplied to TRIFTU through the named common block FITPTS. Subroutine GELG is called to solve the system of simultaneous linear equations which determine the coefficients.

TRIFTD. This subroutine is used to determine the coefficients in the quadratic trivariate interpolation polynomial. The eight coefficients in this polynomial are determined by a least squares fit of fourteen data points which are supplied to TRIFTD through the named common block FITPTS. Subroutine SYMSIM is called to solve the system of simultaneous linear equations (normal equations) which determines the coefficients. This system of equations has a symmetric coefficient matrix.

SHKINT. This subroutine is used to evaluate the univariate interpolation polynomials that are employed in describing the shock wave radius and the shock wave angle along the curve that is defined by the intersection of the shock wave with a given solution plane. The interpolation polynomial coefficients are supplied to SHKINT through the named common block SINTRP. The independent variable is the polar angle THETA, which is transmitted through the subroutine call statement.

PRPINT. This subroutine is used to evaluate the bivariate and trivariate interpolation polynomials that are used for flow property determination on solution planes, shock waves, and solid boundary stream surfaces. The interpolation polynomial coefficients are supplied to PRPINT through the named common block INTRP. The independent variables are the three position coordinates XA, Y, and Z, which are transmitted through the subroutine call statement.

FDERIV. This subroutine is used to compute the first partial derivatives of the flow properties on a solution plane, a shock wave, or a solid boundary stream surface. The derivatives are obtained by evaluating an analytically differentiated form of the appropriate interpolation polynomial. The interpolation polynomial coefficients are transmitted to FDERIV through the named common block INTRP. The independent variables are the three position coordinates XA, Y, and Z, which are transmitted through the subroutine call statement.

VECTØR. This subroutine is used in conjunction with subroutine SHØCK to determine the components of the unit vector $\hat{\beta}$ which is used in the parameterization of the wave surface compatibility relation. The unit vector $\hat{\beta}$ is orthogonal to the velocity vector that is downstream of the shock wave at the shock wave solution point, and has its projection on the (y,z)-plane lie in the meridional plane which passes through the shock wave solution point.

PLANAR. This subroutine is used to compute the parameters employed in the formulation that represents the shock wave surface. This formulation is then used in determining the intersection point of either a streamline or a bicharacteristic with the shock wave surface. Additionally, PLANAR initializes some parameters used in determining the intersection point of a bicharacteristic with the stream surface formed by a solid boundary.

INTSCT. This subroutine is used to compute the intersection point of either a streamline with the shock wave surface, or the intersection point of a bicharacteristic with either the shock wave surface or the stream surface formed by a solid boundary. The determination of the intersection point coordinates is performed in an iteration loop which uses the secant method to relax the difference in the radius of the point of intersection obtained from integration of the equation for a streamline or bicharacteristic and that obtained from the appropriate surface formulation.

FUNCT. This subroutine is used in conjunction with subroutine INTSCT to determine a streamline-shock wave intersection point, or the intersection point of a bicharacteristic with either a shock wave or a solid boundary. The axial position of the assumed intersection point is supplied to FUNCT through the subroutine call statement. From the given axial position, FUNCT computes the corresponding y and z coordinates of the assumed intersection point by both integrating the equation for a streamline or bicharacteristic, and by evaluating the appropriate surface formulation. The difference in the radius obtained from the streamline or bicharacteristic equation integration and that obtained from the surface formulation is reduced to within a specified tolerance of zero by the iteration method used in subroutine INTSCT.

RADIUS. This subroutine is used to compute the radius of a point on the shock wave surface or on the stream surface formed by a solid boundary. The axial position and the polar angle of the point are supplied to RADIUS through the subroutine call statement. To obtain the shock wave radius at the desired point, a linear interpolation is performed in the meridional plane of the point between two space curves which are defined by either a shock-wave solution plane intersection or by a shock wave-solid boundary intersection. To obtain the body radius at the desired point, subroutine BØUNDY is called.

XFIT. This subroutine is used to curve fit, as a function of the polar angle, the axial (x) position of an internal shock wave-solid boundary intersection. A quadratic polynomial expressed in terms of the polar angle is used for this representation.

FRCFNS. This subroutine is used to compute the molecular transport forcing terms used in both the governing equations and the compatibility relations. FRCFNS is called by subroutines SØLVE and SHØCK. The molecular transport terms can be included in the computation of the external flow field about the forebody or in the computation of the internal flow field in which shock waves are not discretely fitted. The program option in which internal shock waves are discretely fitted does not have the capability to include the influence of molecular-diffusion in the computation, but rather assumes the flow to be inviscid and adiabatic.

SØLN. This subroutine calls subroutines LØCATE and SØLVE for computing either a solid boundary solution point or an interior solution point.

LØCATE. This subroutine is used to compute the locations of and the flow properties at the streamline and bicharacteristic intersection points for the standard interior point, standard solid boundary point, shock-modified interior point, and shock-modified solid boundary point unit processes. The point locations and flow properties at these points are transmitted to subroutine SØLVE through the named common blocks RELAY1 and RELAY2. Subroutine SØLVE then solves the system of compatibility relations to obtain the position of and the flow properties at the solution point.

SØLVE. This subroutine is used to solve the system of compatibility equations for the standard interior point, standard solid boundary point, shock-modified interior point, and shock-modified solid boundary point unit processes. If the viscous and thermal diffusion terms are to be included in the computation, SØLVE calls subroutine FRCFNS. The system of five compatibility relations is solved by calling subroutine GELG.

SHØCK. This subroutine is used to compute the solution for all field-shock wave points. For the bow shock wave points, the free-stream flow conditions are used for the upstream flow properties. For the internal flow field shock wave points, an interior or solid boundary point unit process is applied to obtain the upstream flow properties. Body solution points on the downstream side of the cowl lip shock wave or on the downstream side of a reflected internal shock wave are computed using the solid boundary-shock wave point unit process (subroutine BSHØCK).

JUMP. This subroutine employs the Rankine-Hugoniot relations to compute the downstream flow properties at a shock wave solution point. The shock wave surface normal unit vector components and the flow properties upstream of the shock wave are entered in the argument list. The computed downstream flow properties are also transmitted in the argument list. The assumed thermodynamic model is that of a thermally and calorically perfect gas. Other thermodynamic models may be incorporated into the analysis by suitably modifying this subroutine. Thermodynamic property information is supplied to subroutine JUMP through the named common block GAS1.

TGRAD. This subroutine computes the spatial gradients of temperature by using an analytically differentiated form of the thermal equation of state so that temperature derivatives can be expressed in terms of the derivatives of pressure and density. The assumed thermodynamic model is that of a thermally perfect gas. Other thermodynamic models may be incorporated into the analysis by suitably modifying or replacing this subroutine. If TGRAD is replaced, the argument list must be identical to the existing list. The parameters in the argument list are defined as follows.

T	temperature
P	pressure
RØ	density
DPX,DPY,DPZ	first partial derivatives of pressure with respect to x, y, and z, respectively
DPXX,DPYY,DPZZ	second partial derivatives of pressure with respect to x, y, and z, respectively
DRØX,DRØY,DRØZ	first partial derivatives of density with respect to x, y, and z, respectively
DRØXX,DRØYY,DRØZZ	second partial derivatives of density with respect to x, y, and z, respectively
DTX,DTY,DTZ	first partial derivatives of temperature with respect to x, y, and z, respectively
DTXX,DTYY,DTZZ	second partial derivatives of temperature with respect to x, y, and z, respectively

Thermodynamic property information is supplied to subroutine TGRAD through the the named common block GAS1.

TPRØPS. This subroutine computes the dynamic viscosity, the thermal conductivity, and their spatial gradients. The assumed functional form for dynamic viscosity is given by Sutherland's Law (6). The assumed functional form for thermal conductivity is expressed in terms of the dynamic viscosity and laminar Prandtl number. Other transport property formulations may be incorporated into the analysis by suitably modifying or replacing this subroutine. If TPRØPS is replaced, the argument list must be identical to the existing list. The parameters in the argument list are defined as follows.

T	static temperature
P	static pressure
VIS	dynamic viscosity
CØN	thermal conductivity
DTX,DTY,DTZ	first partial derivatives of temperature with respect to x, y, and z, respectively
DPX,DPY,DPZ	first partial derivatives of pressure with respect to x, y, and z, respectively
DVISX,DVISY,DVISZ	first partial derivatives of viscosity with respect to x, y, and z, respectively
DCØNX,DCØNY,DCØNZ	first partial derivatives of thermal conductivity with respect to x, y, and z, respectively

Transport property information is supplied to subroutine TPRØPS through the named common block GAS2.

10. ØVERLAY (3,1)

LINK31. This program routine contains the control logic used in the computation of the supersonic external flow field about the forebody. LINK31 is the main control routine in ØVERLAY (3,1). ØVERLAY (3,1) is a secondary level overlay which is called from routine LINK30.

RCNTRL. This subroutine is used to control the number of radial stations on successive solution planes in the forebody flow field integration. If a sufficient influx of mass across the bow shock wave has occured between the current solution plane and the last solution plane where point addition or deletion was performed, a new ring of interior field points is added between the ring of shock wave points and the outermost ring of existing interior field points. If, after a number of successive point additions, a specified number of radial stations has been reached, point deletion is performed. Here, selected interior field points are deleted from the storage arrays while the bow shock wave points and the body streamline points are retained.

11. ØVERLAY (3,2)

LINK32. This program routine contains the control logic used in the computation of the supersonic internal flow field in which shock waves are discretely fitted. LINK32 is the main control routine in ØVERLAY (3,2). ØVERLAY (3,2) is a secondary level overlay which is called from routine LINK30.

BSHØCK. This subroutine is used to compute the flow properties at a point on the body that is downstream of either the cowl lip shock wave or an internal reflected shock wave (solid body-shock wave point unit process). This subroutine is used only in the option where the internal flow field integration in which shock waves are discretely fitted is employed.

SPRJCT. This subroutine is used in the internal flow field integration to project the internal shock wave from the current initial-value plane to the current solution plane. The projected intersection of the internal shock wave with the solution plane is then used to determine which streamlines do and do not penetrate the shock wave.

PENTRE. This subroutine is used in the internal flow field integration to control the computation of an interior field point when the streamline has penetrated the internal shock wave. If the streamline-shock wave intersection point is sufficiently close to the current solution plane, an interior point unit process on the downstream side of the shock wave is not performed. Instead, in this case, a streamline projection onto the solution plane and subsequent flow property interpolation in this plane is performed. Alternatively, if the streamline-shock wave intersection point is sufficiently far from the solution plane, an interior point unit process is performed on the downstream side of the shock wave.

TRACE. This subroutine is used in conjunction with subroutine INTSCT to compute the intersection point of a streamline with an internal shock wave. With the intersection point coordinates detemined, the trivariate interpolation polynomials are evaluated to obtain the flow properties at the intersection point.

SØLINT. This subroutine is used in the internal flow field integration to determine the intersection point coordinates of and the flow properties at an interior field point when the streamline penetrates an internal shock wave with the intersection point being sufficiently close to the current solution plane. SØLINT is called from subroutine PENTRE.

SWITCH. This subroutine is used in the internal flow field integration to perform the post computation interchange of indices when a streamline which initially appeared to intersect the internal shock wave ultimately did not. Consequently, a standard interior point unit process is used for this point instead of a shock-modified interior point unit process performed on the downstream side of the shock wave.

SHKRFL. This subroutine contains the control logic used for calculating an internal shock wave-solid boundary intersection.

INTRFL. This subroutine performs the necessary point reflections when flow symmetry exists for the solution points on the space curve defined by the intersection of the internal shock wave with a solid boundary.

ISHØCK. This subroutine is used in the internal flow field integration to compute the incident shock wave upstream and downstream flow properties at a point where the incident shock wave intersects a solid boundary.

STRSHK. This subroutine is used to compute the position of and the flow properties at the intersection point of a body streamline with the space curve defined by the intersection of the incident shock wave with a solid boundary.

RSHØCK. This subroutine is used with subroutine BSHØCK to compute the flow properties on the body downstream of an internal reflected shock wave.

12. ØVERLAY (3,3)

LINK33. This program routine contains the control logic used in the computation of the supersonic internal flow field in which shock waves are not discretely fitted. LINK33 is the main control routine in ØVERLAY (3,3). ØVERLAY (3,3) is a secondary level overlay which is called from routine LINK30.

13. ØVERLAY (4,0)

LINK40. This program routine is the main control routine in ØVERLAY (4,0). LINK40 controls the boundary layer computation on both the forebody/centerbody and the cowl. LINK40 calls the secondary level overlays, ØVERLAY (4,1), ØVERLAY (4,2), ØVERLAY (4,3), and ØVERLAY (4,4).

GEØD. This subroutine computes the metric coefficients and geodesic curvature terms used in the boundary layer computation. The version of GEØD supplied with the program assumes that both the forebody/centerbody and cowl are axisymmetric. More arbitrary geometries can be described by suitably modifying or replacing this subroutine. If GEØD is replaced, the subroutine argument list must be identical to the existing list. The parameters in the argument list are defined as follows.

KBØDY	If KBØDY=1, forebody/centerbody geometry is to be specified. If KBØDY=2, cowl geometry is to be supplied.
KPLANE	If KPLANE=1, axial location is for current initial-value plane. If KPLANE=2, axial location is for current solution plane.
XBASEI	Base axial coordinate of the current initial-value plane.
XBASES	Base axial coordinate of the current solution plane.

XCURV. This subroutine computes the $\tilde{x}$ curvilinear coordinate given the x base coordinate. The version of XCURV supplied with the program assumes that both the forebody/centerbody and cowl are axisymmetric. More arbitrary geometries can be described by suitably modifying or replacing this subroutine. If XCURV is replaced, the argument list must be identical to the existing list. The parameters in the argument list are defined as follows.

KBØDY	If KBØDY=1, forebody/centerbody geometry is to be specified. If KBØDY=2, cowl geometry is to be specified.
XBASEI	Base axial coordiante of the current initial-value plane.
XBASES	Base axial coordiante of the current solution plane.

EINTRP. This subroutine determines the external flow properties for the boundary layer computation by interpolation of the supersonic core flow solution.

WALL. This subroutine calculates the wall condition parameters for computation of the boundary layer.

WTEMP. This subroutine determines the wall temperature boundary condition for use in the boundary layer computation. Both temperature and normal temperature gradient boundary conditions can be specified. Subroutine WTEMP is called from subroutine WALL.

TURB. This subroutine computes the turbulent eddy viscosity and turbulent eddy thermal conductivity for use in the boundary layer computation. The version of TURB supplied with the program employs an isotropic two-layer eddy diffusitivity model(7). The turbulent thermal conductivity is expressed in terms of the eddy viscosity by use of the turbulent Prandtl number. Other turbulence models may be incorporated into the analysis by suitably modifying or replacing this subroutine. If TURB is replaced, the argument list must be identical to the existing list. The parameters in the argument list are defined as follows.

KBØDY	If KBØDY=1, forebody/centerbody boundary layer is specified. If KBØDY=2, cowl boundary layer is specified.
KPLANE	If KPLANE=1, initial-value surface is specified. If KPLANE=2, solution surface is specified.
I	Circumferential index of solution point.
J	Radial index of solution point.
ETX	Eddy viscosity for streamwise momentum equation.
ETZ	Eddy viscosity for cross-flow momentum equation.
ETE	Eddy thermal conductivity.

DECØDE. This subroutine is used to decode the boundary layer transformed variables into physical variables and then to print both the forebody/centerbody and cowl boundary layer solutions.

THERMD. This subroutine is used to compute the spatial gradient of the static enthalpy. The assumed thermodynamic model is that of a thermally and calorically perfect gas. Other thermodynamic models may be incorporated into the analysis by suitably modifying or replacing this subroutine. If subroutine THERMD is replaced, the argument list must be identical to the existing list. The parameters in the argument list are defined as follows.

T	temperature
P	pressure
DTDY	first partial spatial derivative of temperature
DPDY	first partial spatial derivative of pressure
DHDY	first partial spatial derivative of static enthalpy.

Thermodynamic property information is supplied to subroutine THERMD through the named common block GAS1.

14. ØVERLAY (4,1)

<u>LINK41</u>. This program routine is the main control routine in ØVERLAY (4,1) and is used to control the integration of the boundary layer differential equations.

<u>ABLSLN</u>. This subroutine computes the flow properties across the boundary layer at a circumferential station that is on the plane of symmetry. The transformed governing differential equations are solved implicitly using the matrix solution algorithm in subroutine BTRID.

<u>AEXT</u>. This subroutine calculates the edge condition parameters for the computation of a plane of symmetry boundary layer station. Subroutine AEXT is called from subroutine ABLSLN.

<u>ASPEC</u>. This subroutine determines certain parameters which are used in the plane of symmetry boundary layer computation. Subroutine ASPEC is called from subroutine ABLSLN.

<u>GBLSLN</u>. This subroutine computes the properties across the boundary layer at a circumferential station that is not on a plane of flow symmetry. The transformed governing equations are solved implicitly using the matrix solution algorithm in subroutine BTRID.

<u>GEXT</u>. This subroutine calculates the edge condition parameters for the computation of a boundary layer station that is not on the plane of flow symmetry. Subroutine GEXT is called from subroutine GBLSLN.

<u>GSPEC</u>. This subroutine determines certain parameters which are used in the boundary layer computation for stations not on the plane of flow symmetry. Subroutine GSPEC is called from subroutine GBLSLN.

<u>BTRID</u>. This subroutine solves a system of simultaneous linear equations with a block tridiagonal coefficient matrix. A direct factorization procedure employing triangular decomposition is used to obtain the solution vector.

PRØD. This subroutine is used to perform matrix multiplication. Subroutine PRØD is called from subroutine BTRID.

15. ØVERLAY (4,2)

LINK42. This program routine is the main control routine in ØVERLAY (4,2) and is used to determine the boundary layer properties downstream of a shock wave-boundary layer interaction region. An integral formulation is used to obtain the solution.

SBLINT. This subroutine determines the downstream boundary layer thickness and velocity profile exponents in the shock wave-boundary layer interaction analysis.

INTEG. This subroutine is used to numerically evaluate certain integral parameters involved in the shock wave-boundary layer interaction analysis.

16. ØVERLAY (4,3)

LINK43. This program routine is the main control routine in ØVERLAY (4,3) and is used for mesh alteration in the boundary layer computation to account for boundary layer growth.

17. ØVERLAY (4,4)

LINK44. This program routine is the main control routine in ØVERLAY (4,4) and is used for the internal generation of the cowl boundary layer initial data.

SECTION IV

INPUT PARAMETERS

1. INTRODUCTION

The input data required for execution of the computer program are entered by both namelist input and formatted read statements. In all cases, the eleven namelists LIST1 to LIST11 are entered. For cases in which the user selects to specify the flow property field on the initial-value plane, that information is entered by a formatted read of files ITAP1, ITAP2, and ITAP3.

In general, only those parameters and data pertinent to the particular problem being considered must be entered. Many input parameters have default values and do not need to be specified unless values other than the default values are to be entered.

In this section, each input parameter is defined. Where applicable, both the default value and a typical value of the input parameter are given.

2. TITLE CARD

The first card of each data deck is a title card on which 72 alphanumeric characters (any standard Fortran characters) of identifying information may be specified. This card must be the first card of the data deck even if no information is listed on it. The format of the card is (12A6).

3. NAMELIST LIST1

The parameters entered in namelist LIST1 control the overall execution of the program.

KUNIT An integer variable denoting whether English absolute units or SI units are to be used in the computation. If KUNIT = 1, English absolute units are employed. If KUNIT = 0, SI units are employed. A default value of 1 is specified for KUNIT.

KCALL A one-dimensional integer variable array consisting of three elements. Each element of KCALL specifies whether or not a particular supersonic flow field integration option is to be performed. If KCALL(I) = 1 (I=1,2,3), then the corresponding flow field integration option is performed. If KCALL(I) = 0, the integration option is not performed. The elements of KCALL control the flow field integration options and have specified default values as listed below.

KCALL(I)	Flow Field Integration Option	Default Value
KCALL(1)	forebody supersonic flow field	1
KCALL(2)	internal supersonic flow field with discrete shock wave fitting	1
KCALL(3)	internal supersonic flow field without discrete shock wave fitting	0

Specifying KCALL(2) = 1 and KCALL(3) = 1 simultaneously will cause an error message to be printed and the program execution to be aborted.

XEND

A one-dimensional real variable array consisting of three elements. XEND(I) (I=1,2,3) denotes the x-position, in either feet or meters, at which the supersonic flow field integration specified by the corresponding element of KCALL is to be terminated. Each element of XEND denotes a flow field integration option termination point and has a default value as follows.

XEND(I)	Termination Point for	Default Value
XEND(1)	forebody supersonic flow field integration	2.0 ft
XEND(2)	internal supersonic flow field integration with discrete shock wave fitting	3.5 ft
XEND(3)	internal supersonic flow field integration without discrete shock wave fitting	3.5 ft

If any element of XEND exceeds the x-position to which the centerbody geometry is specified, or if XEND(2) or XEND(3) exceeds the x-position to which the cowl geometry is specified, appropriate error messages are printed and the program execution is aborted. Each element of XEND must be positive. It should be noted that if KCALL(I) = 0, XEND(I) does not have to be specified.

KTRANS

An integer variable denoting whether or not distributed wall bleed effects are to be included in the supersonic core flow computation. If KTRANS = 1, bleed effects are included in the computation. If KTRANS = 0, bleed effects are not included in the computation. The wall bleed distribution is specified by the parameters entered in namelist LIST8. A default value of 1 is specified for KTRANS.

KBLAY

An integer variable denoting whether or not the boundary layer computation is to be performed. If KBLAY = 1, the boundary layer computation is performed. If KBLAY = 0, the boundary layer computation is not performed. A default value of 1 is specified for KBLAY.

RCAVG A positive real variable denoting the estimated average radius, in either feet or meters, of the bow shock wave at XEND(1). The specified value of RCAVG is used in estimating the captured mass flow rate at XEND(1). This mass flow rate is used in determining if point addition is to be performed in the forebody flow field integration. RCAVG must be specified only if the supersonic fore-body flow field integration option is used [KCALL(1) = 1]. RCAVG must be specified even if the forebody integration option is the only integration option used [KCALL(2) = KCALL(3) = 0]. The cowl lip radius may be used for RCAVG. A default value of 0.8 ft is specified for RCAVG.

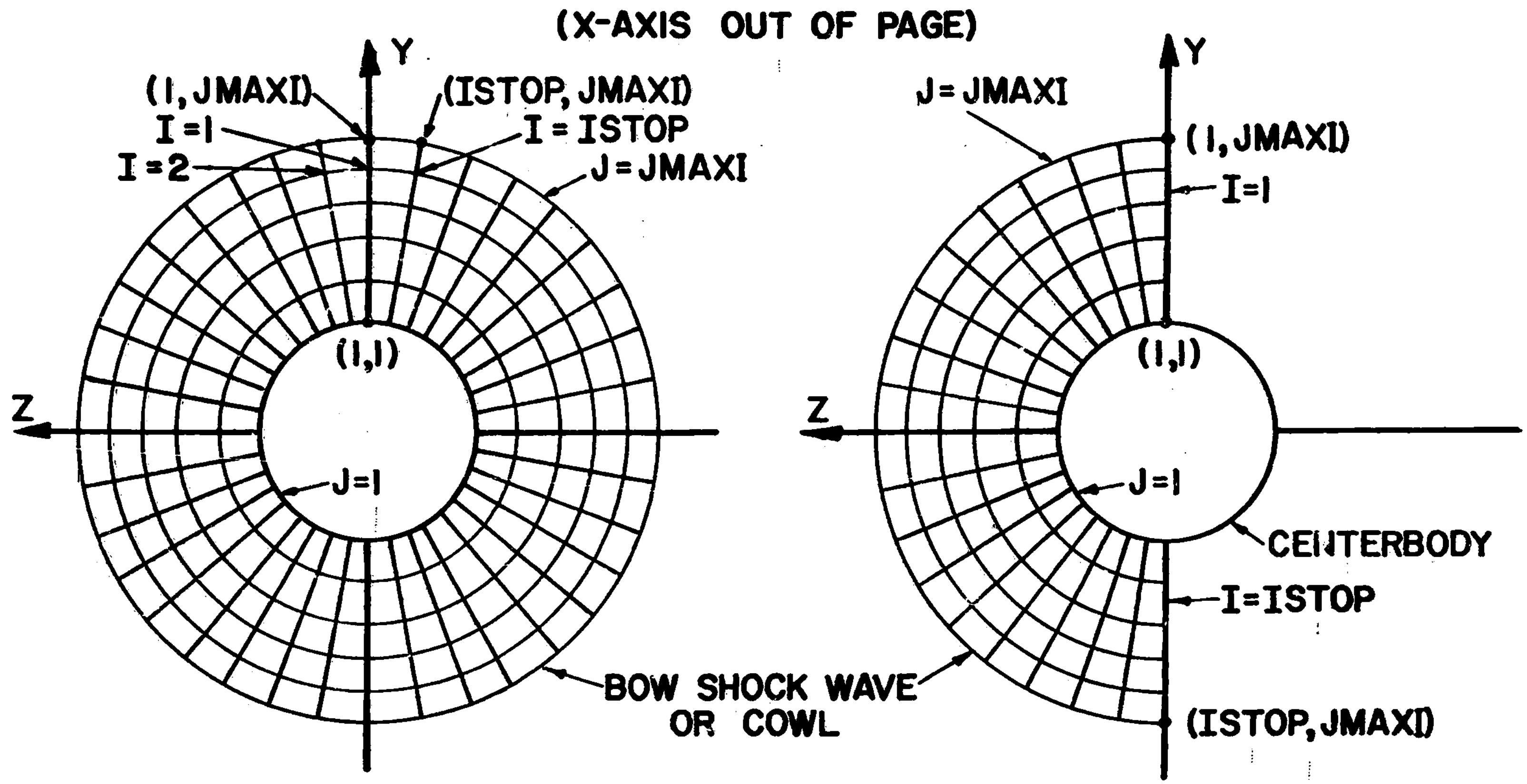
KVISCY An integer variable denoting whether or not the viscous and thermal diffusion terms are to be included in the computation of the fore-body supersonic flow field or the internal supersonic flow field in which shock waves are not discretely fitted. If KVISCY = 1, these terms are included in the computation. If KVISCY = 0, these terms are not included in the computation. A default value of 0 is speci-fied for KVISCY.

KSYM An integer variable denoting the flow symmetry option to be employed in the computation. If the boundary layer computation is not employ-ed (KBLAY = 0), KSYM can have the values 0, 1, 2, and 3 corresponding to:

KSYM	Flow Symmetry Option
0	no planes of symmetry - computed sector is the entire solution plane
1	one plane of symmetry - computed sector is the half-plane bounded by the y-axis and containing the +z-axis
2	two planes of symmetry - computed sector is the quadrant bounded by the +y-axis and the +z-axis
3	axisymmetric flow - computed sector is the single circumferential station on the +y-axis

If the boundary layer computation is employed (KBLAY = 1), then the allowable value of KSYM is 1. The supersonic flow networks for the flow symmetry options are illustrated in Figure 3. A default value of 1 is specified for KSYM.

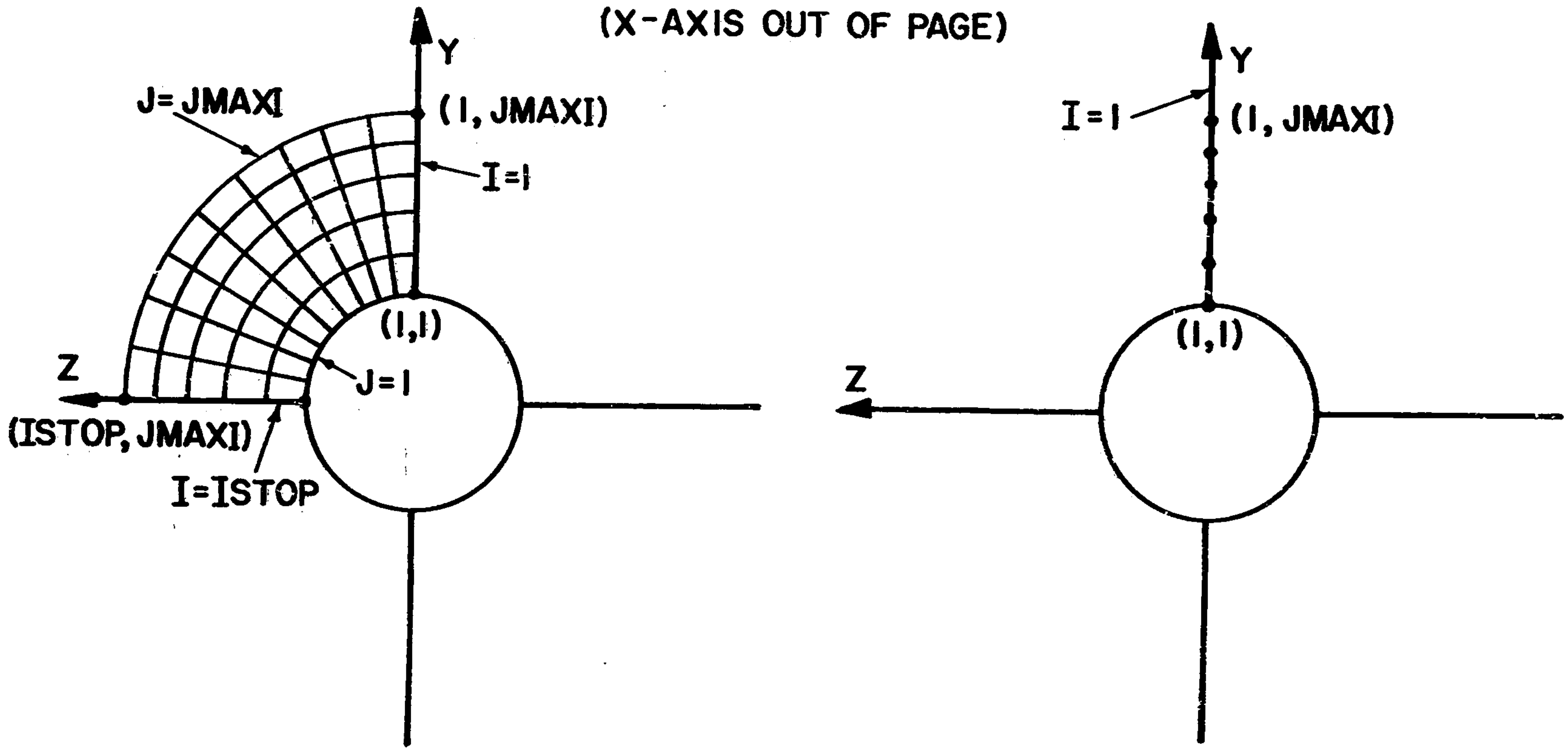
KSGLØB An integer variable denoting whether or not global correction is to be performed in obtaining the solution for the bow shock wave points. If KSGLØB = 1, global correction is performed. If KSGLØB = 0, global correction is not performed. Global correction can only be performed for the bow shock wave points and not for the internal flow field shock wave points. Hence, KSGLØB must be specified only if KCALL(1) = 1. A default value of 1 is specified for KSGLØB.



(a) NO PLANES OF SYMMETRY (KSYM=0)

(b) ONE PLANE OF SYMMETRY (KSYM=1)

FIGURE 3. COMPUTATIONAL POINT NETWORKS



(c) TWO PLANES OF SYMMETRY
(KSYM=2)

(d) AXISYMMETRIC FLOW
(KSYM=3)

FIGURE 3. (CONTINUED)

KPRINT An integer variable denoting which of three print options is to be employed in the program execution for the supersonic flow solution. KPRINT can have the following values.

KPRINT	Print Option
0	print body solution points and shock wave solution points only
1	print all solution points
2	print all solution points and shock wave parameters (incident normal Mach number and shock wave surface normal unit vector components)

A default value of 1 is specified for KPRINT.

IPRSTP A positive integer variable denoting the plane number at which the program execution is to be terminated. This input parameter is typically employed when the execution is intended to be restarted at plane number (IPRSTP + 1). Specifying IPRSTP $\leq$ 0 has no effect on the execution of the program. A default value of 0 is specified for IPRSTP.

KSTART An integer variable used in controlling the file operations involved in the restarting of the program (if desired). KSTART controls the storage and retrieval of the restart file as follows.

KSTART	Control of Restart File
0	no file operations
1	write restart file on TAPE 9
2	read information for program restart from TAPE 9, and write ensuing solution planes on this tape

A default value of 0 is specified for KSTART. TAPE 9 is linked to the dummy file RESTRT in the PRØGRAM card.

4. NAMELIST LIST2

The parameters entered in namelist LIST2 specify the free-stream conditions, the inlet orientation, and the parameters which control the internal generation of the supersonic flow property field on the initial-value plane.

MFS A positive real variable denoting the free-stream Mach number. The specified value of MFS must be greater than 1.0. A default value of 3.0 is specified for MFS.

PFS A positive real variable denoting the free-stream absolute pressure, in either (lbf/ft^2) or (N/m^2). A default value of 242.2 (lbf/ft^2) is specified for PFS (this value is the pressure of the standard atmosphere at an altitude of 50,000 ft).

RØFS — A positive real variable denoting the free-stream density, in either ($slug/ft^3$) or (kg/m^3). A default value of 0.0003622 ($slug/ft^3$) is specified for RØFS (this value is the density of the standard atmosphere at an altitude of 50,000 ft).

PITCH — A real variable denoting the angle, in degrees, subtended by the free-stream velocity vector and the projection of the free-stream velocity vector on the (x,z)-plane, as illustrated in Figure 4. A default value of 1.0 degree is specified for PITCH. If KBLAY=1 is specified in namelist LIST1, then PITCH≠0.0.

YAW — A real variable denoting the angle, in degrees, subtended by the x-axis and the projection of the free-stream velocity vector on the (x,z)-plane, as illustrated in Figure 4. A default value of 0.0 degrees is specified for YAW.

XI — A positive real variable denoting the axial (x) position, in either feet or meters, of the supersonic flow initial-value plane. If the forebody flow field integration option is specified [KCALL(1) =1], XI must be specified at the beginning of the forebody flow field computational regime (see Figure 1). If only the internal flow field integration option is specified [KCALL(1) = 0, KCALL(2) = 1 or KCALL(3) = 1], XI must be specified at the axial station of the cowl lip (see Figure 1). XI must not fall outside of the range of axial stations for which the centerbody geometry is specified. Also, XI must not be greater than the axial station up to which the cowl geometry is specified. A default vaule of 1.0 ft is specified for XI.

KIVS — An integer variable denoting whether the supersonic flow field on the initial-value plane is to be generated internally or read in. If KIVS = 1, the initial-value plane data are computed internally. If KIVS = 0, the initial-value plane data must be supplied by the user through a formatted read of file ITAP1. The formatted read input is described at the end of this section. The internally generated initial-value plane option is applicable only to cases where the forebody is conical up to the axial station where the initial-value plane is located. Specifying KIVS = 1 requires that YAW = 0.0. A default value of 1 is specified for KIVS.

KCØN — An integer variable denoting whether or not the bow shock wave is conical. KCØN must be specified only if the forebody flow field integration option is employed [KCALL(1) = 1]. If KCØN = 1, the bow shock wave is conical. In this case, the angle at each initial-value plane bow shock wave point that is subtended by the shock wave and the x-axis in the meridional plane defined by the shock wave point is computed internally. If KCØN = 0, the bow shock wave is not conical, and the shock wave angles must be supplied by the user through a

$$u_\infty = |\vec{V}_\infty| \cos(\text{PITCH}) \cos(\text{YAW})$$

$$v_\infty = |\vec{V}_\infty| \sin(\text{PITCH})$$

$$w_\infty = |\vec{V}_\infty| \cos(\text{PITCH}) \sin(\text{YAW})$$

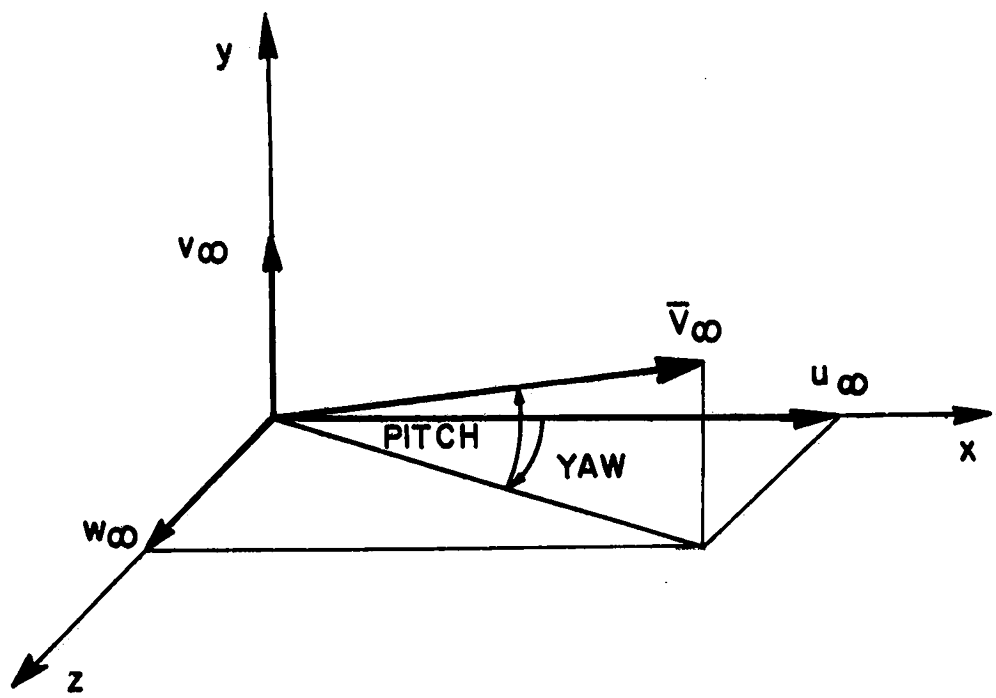


Figure 4. Pitch and yaw angles.

formatted read of file ITAP1. The formatted read input is described at the end of this section. If the initial-value plane is generated internally (KIVS = 1), a conical bow shock wave is assumed (KCØN = 1). A default value of 1 is specified for KCØN.

KSUPER — An integer variable denoting the method to be used in internally generating the supersonic flow initial data. KSUPER must be specified only if the initial data are to be generated internally (KIVS = 1). If KSUPER = 1, the supersonic flow initial data are computed using the approximate Taylor-Maccoll algorithm described in Section II. If KSUPER = 2, the supersonic flow initial data are computed using the Jones algorithm described in Section II. If KSUPER = 1, KSYM can have the values 1, 2, or 3, where if KSYM = 3 the angle of attack must be 0.0 (PITCH = 0.0). If KSUPER = 2, KSYM must be equal to 1 and PITCH ≠ 0.0. A default value of 2 is specified for KSUPER.

ITAP1 — A positive integer variable denoting the tape number from which the user supplied supersonic flow initial data are to be entered by a formatted read. ITAP1 must be specified only if the initial-value plane flow property field is to be supplied by the user (KIVS = 0). The default value assigned to ITAP1 is 5 (the input file). The user may specify ITAPE = 10, in which case the supersonic initial data are read from TAPE 10. TAPE 10 is linked to the dummy file IVS1 in the PRØGRAM card.

5. NAMELIST LIST3

The parameters entered in namelist LIST3 specify the number of circumferential and radial stations used in the supersonic flow computational point network.

ISTØP — A positive integer variable denoting the number of circumferential stations used in the supersonic solution computed flow field sector. The value specified for ISTØP must correspond to the flow symmetry option specified by KSYM (see namelist LIST1) as follows (see Figure 3).

KSYM	Allowable Value(s) of ISTØP
0	$5 \leq$ ISTØP ≤ 30
1	$4 \leq$ ISTØP ≤ 16
2	$3 \leq$ ISTØP ≤ 8
3	ISTØP = 1

A default value of 15 is specified for ISTØP (this recommended value corresponds to KSYM = 1). If the supersonic initial data are to be generated internally using the Jones algorithm (KIVS = 1, KSUPER =2), then ISTØP must be greater than 1.

JMAXI — A positive integer variable denoting the number of radial stations on the supersonic flow initial-value plane. Note that the initial-value plane input format is the same whether the computation is being started at an axial station upstream of the forebody computational flow regime or at the axial station of the cowl lip. The specified value for JMAXI must be at least 3 and no greater than 15. The default and recommended value for JMAXI is 11.

Whatever the value of JMAXI, the outermost radial station corresponds to the downstream bow shock wave points, and the remaining (JMAXI - 1) radial stations correspond to the streamline points.

JINLET — A positive integer variable denoting the number of radial stations on each solution plane in the supersonic internal flow field integration. JINLET must be specified only if the internal flow field is to be computed. The specified value of JINLET must be at least 4 and no greater than 15. The recommended value and the default value of JINLET is 11. It should be noted that JINLET is independent of JMAXI.

For the internal flow field integration option in which shock waves are not discretely fitted [KCALL(2) = 0, KCALL (3) = 1], JINLET specifies the number of streamline points at each circumferential station. For the internal flow field integration option in which shock waves are discretely fitted [KCALL(2) = 1, KCALL(3) =0], the number of streamline points at each circumferential station is equal to (JINLET - 2). The remianing two storage locations are assigned to the upstream and downstream shock wave solution points.

JLIMIT — A one-dimensional integer variable array consisting of two elements. JLIMIT must be specified only if the forebody flow field integration option is employed [KCALL(1) = 1]. The elements of JLIMIT are used in controlling the number of interior field points which are added in the computation of the forebody flow field. The first element of JLIMIT [JLIMIT(1)] denotes the allowable maximum number of radial stations on a solution plane in the forebody flow field computation when the mass flow rate across that plane is less than a specified fraction [denoted by CRIT(7) in namelist LIST10]of the estimated mass flow rate at XEND(1), the axial location at which the forebody flow field integration is to be terminated. The second element of JLIMIT [JLIMIT(2)] denotes the allowable maximum number of radial stations when the mass flow rate exceeds the specified fraction of the estimated mass flow rate at XEND(1). Each element of JLIMIT must be positive, odd, and no less than 5 but no greater than 15. JLIMIT(1) should be less than or equal to JLIMIT(2). A default value of 11 is specified for JLIMIT(1), and a default value of 15 is specified for JLIMIT(2).

6. NAMELIST LIST4

The parameters entered in namelist LIST4 specify the thermodynamic model and the molecular transport properties.

R A positive real variable denoting the gas constant, in either (ft-lbf)/(slug-R) or (J/kg-K). A default value of 1716.16116 (ft-lbf)/(slug-R) is specified for R.

GAMMA A positive real variable denoting the specific heat ratio. A default value of 1.4 is specified for GAMMA.

If the boundary layer computation is not employed (KBLAY = 0) and if the influence of molecular transport is not to be included in the supersonic flow computation (KVISCY = 0), then no other parameters need be specified in namelist LIST4. If these options are employed in the computation, then the parameters presented in the following discussion must be specified.

The molecular dynamic viscosity is represented in the computer program by the Sutherland formula (6).

$$\mu = \mu_o \left(\frac{T}{T_o}\right)^{1.5} \left(\frac{T_o + B}{T + B}\right) \tag{1}$$

In equation (1), μ is the dynamic viscosity at the absolute temperature T, and B is a constant. For air, B has the value of 198.6 R (110 K). The parameter μ_o is the viscosity at the reference temperature T_o. The constants μ_o, T_o, and B must be specified in the program input by entering the following three parameters.

VISØ A positive real variable denoting the reference viscosity μ_o in equation (1). The units of VISØ are either (lbf-sec/ft^2) or (N-s/m^2). A default value of 3.5×10^{-7} (lbf-sec/ft^2) is specified for VISØ (this value is the dynamic viscosity of air at 492.0 R).

TØ A positive real variable denoting the reference absolute temperature T_o in equation (1). The units of TØ are either R or K. The specified value of TØ must correspond to the specified value of VISØ. A default value of 492.0 R is specified for TØ.

B A positive real variable denoting the constant B in equation (1). The units for B are either R or K. A default value of 198.6 R is specified for B.

The molecular thermal conductivity is represented in the computer program by

$$\kappa = c_p\mu/Pr \tag{2}$$

where κ denotes the thermal conductivity, c_p is the constant pressure specific heat, and Pr is the laminar Prandtl number which is assumed constant in the analysis. The specific heat c_p is calculated internally in the program, whereas the Prandtl number Pr is user specified by entering the following parameter.

PR A positive real variable denoting the laminar Prandtl number. A default value of 0.71 is specified for PR.

7. NAMELIST LIST5

The input parameters entered in namelist LIST5 specify the contours of the centerbody and the cowl. It is assumed that both the centerbody and the cowl are axisymmetric. The x-coordinate axis is the longitudinal axis of both the centerbody and the cowl (see Figure 1). The forebody tip must be located at $x = 0.0$. The axial station of the cowl lip must be specified at $x > 0.0$.

For the purpose of geometry description, the axial (x) domain is divided into a number of intervals, as illustrated in Figure 5. The number of axial stations at which the centerbody geometry is specified is denoted by NCENT. The number of intervals on the centerbody is equal to (NCENT - 1). The number of axial stations at which the cowl geometry is specified is denoted by NCØWL. The number of intervals on the cowl is equal to (NCØWL - 1).

In any interval, the centerbody or cowl radius may be specified either by tabular input, or by supplying the coefficeints in a cubic polynomial written as a function of x. For the tabular input option, the body radius $r(x)$ at axial position x in the i th interval ($x_i \leq x < x_{i+1}$) is found by linear interpolation between point (x_i, r_i) and point (x_{i+1}, r_{i+1}). The local slope of the body for this interval in a given meridional plane is then given by the slope of the line segment joining these two points. Alternatively, employing the cubic polynomial

$$r(x) = a_i + b_i(x - x_i) + c_i(x - x_i)^2 + d_i(x - x_i)^3 \quad (x_i \leq x < x_{i+1}) \tag{3}$$

requires that the curve fit coefficients a_i, b_i, c_i, and d_i be supplied by the user. Since equation (3) is a cubic, slope and curvature can be matched at the junction point between two adjacent intervals employing this formulation. An option exists to employ the following cubic polynomial instead of equation (3).

$$r(x) = a_i + b_ix + c_ix^2 + d_ix^3 \quad (x_i \leq x < x_{i+1}) \tag{4}$$

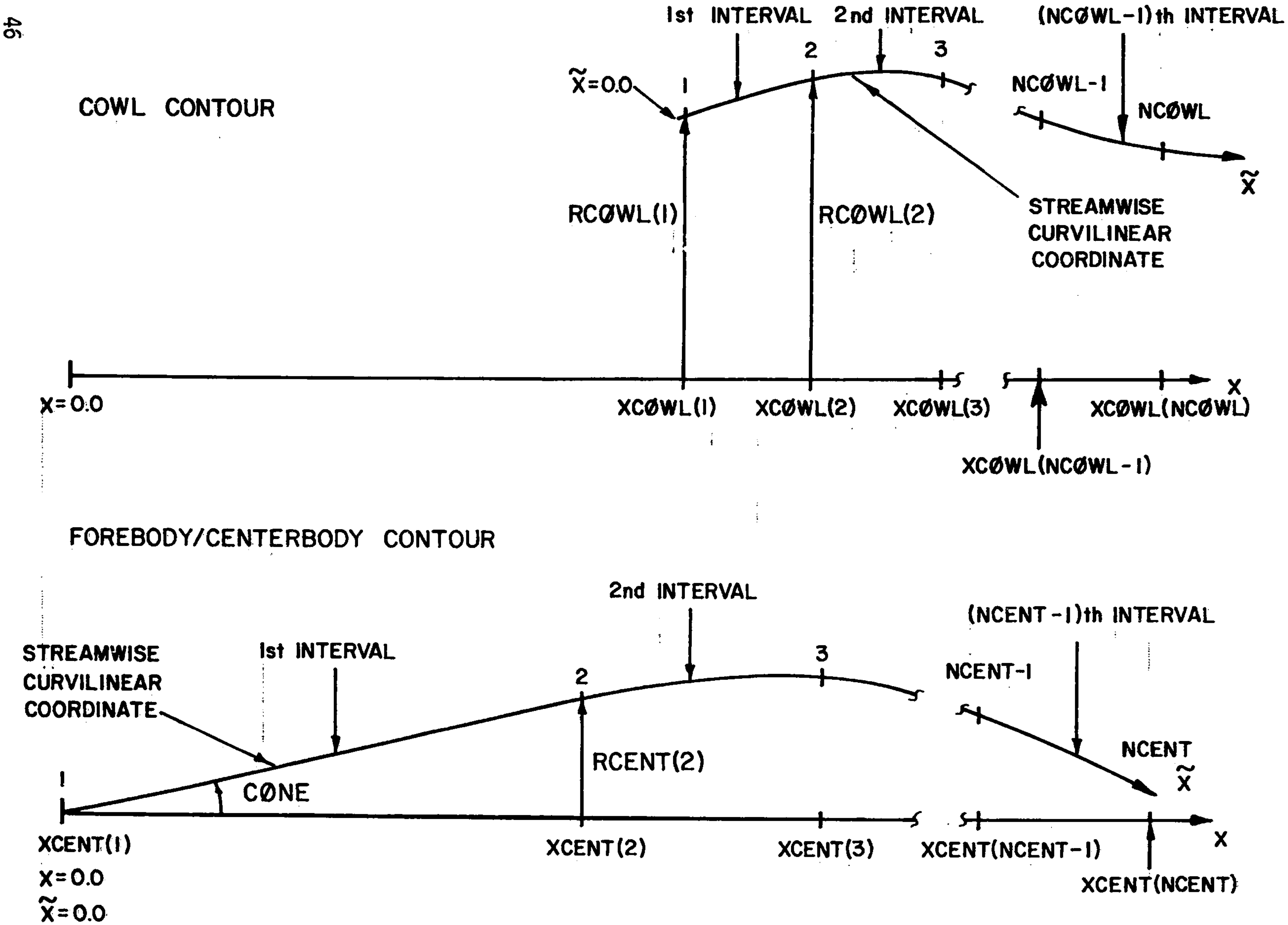


FIGURE 5. BOUNDARY CONTOUR DESCRIPTION

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When employing equation (3) or equation (4), the coefficients a_i, b_i, c_i and d_i must be specified for up to at most (NCENT - 1) and/or (NCØWL - 1) intervals. The axial location x_i must always be specified for NCENT and (if the internal flow field is to be computed) NCØWL axial stations, no matter which formulation is used.

If the forebody is conical ahead of a certain axial station, the forebody/centerbody geometry in this interval (1st interval) may be specified by entering the cone half-angle directly rather than by supplying the curve fit coefficients or entering the body radius by tabular input.

The geometry description option for a given interval is specified by the user and does not have to be the same for all intervals. For instance, the forebody/centerbody contour may have a conical tip, then a quadratic or cubic variation with x, then a linear variation with x, then again a quadratic or cubic variation with x. A way to describe this contour would be to input the cone half-angle for the first interval, the cubic curve fit coefficients for the second interval, the body radii at the ends of the third interval, and the cubic curve fit coefficients for the fourth interval. Alternatively, the appropriate cubic curve fit coefficients could be supplied for each of the four intervals. It should be noted that in the input of the geometry data, radius, slope, and curvature should be made compatible between adjacent intervals. The boundary contours are specified by entering the following parameters.

KBASE — An integer variable denoting whether equation (3) or equation (4) is to be employed when at least one interval of the centerbody or cowl geometry is specified by either of these two cubic equations. If neither equation (3) nor equation (4) is used in the geometry description, then KBASE does not have to be specified. If a cubic equation is to be used, then entering KBASE = 0 specifies that equation (3) will be employed. If KBASE = 1, then equation (4) will be used. A default value of 0 is specified for KBASE. The specified value of KBASE applies to both the forebody/centerbody contour and the cowl contour.

NCENT — A positive integer variable denoting the number of axial stations used in specifying the forebody/centerbody geometry. The number of intervals for the forebody/centerbody is equal to (NCENT - 1). The specified value for NCENT must be at least 2 and no greater than 25. A default value of 2 is specified for NCENT.

KDCENT — A one-dimensional integer variable array (dimensioned at 25) consisting of (NCENT -1) elements. Each element of KDCENT specifies the forebody/centerbody geometry description option to be used in the corresponding interval. Specifying KDCENT(I) = 1 for the i th interval selects the option in which the forebody/centerbody radius is described by equation (3) or equation (4) (depending on the value of KBASE). Specifying KDCENT(I) = 2 for the i th interval selects the option in which the forebody/centerbody radius is specified by tabular input. If the forebody tip is conical, the geometry in the first forebody/centerbody interval may be described by entering the cone half-angle directly and specifying KDCENT(1) = 3. The specified value for KDCENT(I) must be 1 or 2, except for the first interval (I = 1) in which case values of 1, 2, or 3 may be specified. Specifying other values than those allowed causes the program execution to be aborted. The default value for KDCENT(1) is 3, while all other elements of KDCENT have no default values specified.

XCENT — A one-dimensional real variable array (dimensioned at 25) consisting of NCENT elements. Each element of XCENT denotes the axial (x) position, in either feet or meters, of the beginning of a forebody/centerbody interval [XCENT(NCENT) denotes the axial position of the end of the last interval]. The elements of XCENT must be nonnegative and monotonically incresing. The default values for XCENT(1) and XCENT(2) are 1.0 ft and 3.5 ft, respectively. The remaining elements of XCENT do not have default values specified.

RCENT — A one-dimensional real variable array (dimensioned at 25) consisting of up to NCENT elements. Each element of RCENT specifies the forebody/centerbody radius, in either feet or meters, at the axial location specified by the corresponding element of XCENT. If KDCENT(I) = 2, then RCENT(I) and RCENT(I + 1) must be specified. If KDCENT(I) = 1 or 3, then RCENT(I) and RCENT(I + 1) do not have to be specified. Each element of RCENT must be nonnegative. No default values are specified for the elements of RCENT.

ACENT
BCENT
CCENT
DCENT — One-dimensional real variable arrays (each array is dimensioned at 25), where each array consists of up to (NCENT - 1) elements. These arrays are used in conjunction with equation (3) or equation (4) for specification of the forebody/centerbody geometry. The elements of ACENT, BCENT, CCENT, and DCENT specify the coefficients a_i, b_i, c_i, and d_i, respectively, in equation (3) or equation (4). If KDCENT(I) = 1, then ACENT(I), BCENT(I), CCENT(I), and DCENT(I) must be specified for the i th interval. If KDCENT(I) = 2 or 3, then ACENT(I), BCENT(I), CCENT(I), and DCENT(I) do not have to be specified for that interval. The units for the elements of ACENT are either feet or meters. The elements of BCENT are dimensionless. The units for the elements of CCENT are either $(\text{feet})^{-1}$ or $(\text{meters})^{-1}$. The units for the elements of DCENT are $(\text{feet})^{-2}$ or $(\text{meters})^{-2}$. No default values are specified for the elements of ACENT, BCENT, CCENT, and DCENT.

CØNE — A real variable denoting the cone half-angle, in degrees, of the forebody tip if it is conical. If KDCENT(1) = 3, then CØNE must be specified. If KDCENT(1) = 1 or 2, then CØNE does not have to be specified. A default value of 10.0 degrees is specified for CØNE.

If only the external flow field about the forebody is to be computed [KCALL(1) = 1, KCALL(2) = 0, and KCALL(3) = 0], no further parameters must be specified in namelist LIST5. If the flow field in the annulus is to be determined, the following parameters must be entered.

NCØWL — A positive integer variable denoting the number of axial stations used in specifying the cowl geometry. The number of intervals for the cowl is equal to (NCØWL - 1). The specified value for NCØWL must be at least 2 and no greater than 25. No default value is specified for NCØWL.

KDCØWL — A one-dimensional integer variable array (dimensioned at 25) consisting of (NCØWL - 1) elements. Each element of KDCØWL specifies the cowl geometry description option to be used for the corresponding interval. Specifying KDCØWL(I) = 1 for the i th interval selects the option in which the cowl radius is described by equation (3) or equation (4) (depending on the value of KBASE). Specifying KDCØWL(I) = 2 for the i th interval selects the option in which the cowl radius is specified by tabular input. The specified value for KDCØWL(I) must be either 1 or 2. Specifying other values than those allowed causes the program execution to be aborted. The elements of KDCØWL do not have default values specified.

XCØWL — A one-dimensional real variable array (dimensioned at 25) consisting of NCØWL elements. Each element of XCØWL specifies the axial (x) position, in either feet or meters, of the beginning of a cowl interval [XCØWL(NCØWL) denotes the axial position of the end of the last interval]. Each element of XCØWL must be nonnegative and monotonically increasing. The elements of XCØWL do not have default values specified.

RCØWL — A one-dimensional real variable array (dimensioned at 25) consisting of up to NCØWL elements. Each element of RCØWL specifies the cowl radius, in either feet or meters, at the axial location specified by the corresponding element of XCØWL. If KDCOWL(I) = 2, then RCØWL(I) and RCØWL(I + 1) must be specified. If KDCØWL(I) = 1, then RCØWL(I) and RCØWL(I + 1) do not have to be specified. Each element of RCØWL must be nonnegative. The elements of RCØWL do not have default values specified.

ACØWL
BCØWL
CCØWL
DCØWL — One-dimensional real variable arrays (each array is dimensioned at 25), where each array consists of up to (NCØWL - 1) elements. These arrays are used in conjunction with equation (3) or equation (4) for specification of the cowl geometry. The elements of ACØWL, BCØWL, CCØWL, and DCØWL specify the coefficients a_i, b_i, c_i, and d_i, respectively, in equation (3) or equation (4). If KDCØWL(I) = 1, then ACØWL(I), BCØWL(I), CCØWL(I), and DCØWL(I) must be specified for the i th interval. If KDCØWL(I) = 2, then ACØWL(I), BCØWL(I), CCØWL(I), and DCØWL(I) do not have to be specified for that interval. The units of the elements of ACØWL are either feet or meters. The elements of BCØWL are dimensionless. The units for the elements of CCØWL are either $(\text{feet})^{-1}$ or $(\text{meters})^{-1}$. The units for the elements of DCØWL are either $(\text{feet})^{-2}$ or $(\text{meters})^{-2}$. No default values are specified for the elements of ACØWL, BCØWL, CCØWL, and DCØWL.

DXTRAN — A real variable denoting the centerbody translation from the design point position, or, equivalently, the amount the cowl has been translated with respect to the centerbody. The units of DXTRAN are either feet or meters. Translation occurs solely in the x-direction. Moreover, the origin of the coordinate system is maintained at the forebody tip when translation occurs. A positive value for DXTRAN corresponds to a forward centerbody translation or a rearward cowl translation. A default value of 0.0 is specified for DXTRAN.

8. NAMELIST LIST6

The parameters entered in namelist LIST6 control the internal generation of the boundary layer initial data and specify the boundary layer computational mesh. The parameters entered in this namelist need only be specified if the boundary layer computation is to be performed [KBLAY = 1 specified in namelist LIST1].

The following six parameters are used for specification of the forebody/centerbody boundary layer initial data.

KBLIDA — An integer variable denoting whether or not the forebody/centerbody boundary layer initial data are to be internally generated by the Adams finite difference algorithm described in Section II. The Adams algorithm is applicable only to cases in which the forebody is conical ahead of the station where the boundary layer data are to be generated. If KBLIDA = 1, the initial data are internally generated. If KBLIDA = 0, the initial data are entered by a formatted read of file ITAP2. The formatted read is described at the end of this section. A default value of 1 is specified for KBLIDA.

If KBLIDA = 1, the following four parameters must be entered.

KTURB — An integer variable denoting if the Adams algorithm is to generate laminar flow or turbulent flow initial data for the forebody/centerbody boundary layer. If KTURB = 0, laminar flow initial data are generated. If KTURB = 1, turbulent flow initial data are generated. A default value of 0 is specified for KTURB.

CLENGH — A positive real variable denoting the length of the conical section of the forebody in either feet or meters. A default value of 4.0 ft is specified for CLENGH.

The following two parameters define the computational mesh used in the Adams algorithm solution [see Reference (5) for further discussion]. In general, the program is executed by retaining these input parameters at their default values.

ADY — A positive real variable denoting the first transformed mesh length in the surface normal direction that is used in the Adams algorithm solution. The default and recommended value of ADY is 0.010.

ARATIØ — A positive real variable denoting the ratio of successive normal mesh steps used in the Adams algorithm solution. The default and recommended value of ARATIØ is 1.0630.

If KBLIDA = 0 is specified in this namelist, then the following parameter must be entered.

ITAP2 A positive integer variable denoting the tape number from which the forebody/centerbody boundary layer initial data are to be entered by a formatted read. The default value assigned to ITAP2 is 5 (the input file). The user may specify ITAP2 = 11, in which case the forebody/centerbody boundary layer initial data are read from TAPE11. TAPE11 is linked to the dummy file IVS2 in the PRØGRAM card.

The following five parameters are used for specification of the cowl boundary layer initial data and must be entered only if the cowl boundary layer is to be calculated [KCALL(2) = 1 or KCALL(3) = 1 and KBLAY = 1 specified in namelist LIST1].

KBLIDB An integer variable denoting whether or not the cowl boundary layer initial data are to be internally generated by an approximate technique described in this section. If KBLIDB = 1, the initial data are internally generated. If KBLIDB = 0, the initial data are entered by a formatted read of file ITAP3. The formatted read is described at the end of this section. A default value of 1 is specified for KBLIDB.

The internally generated cowl boundary layer initial data are obtained using an approximate analysis briefly described below and presented in greater detail in Reference (1). The initial step in the analysis is to define the boundary layer thickness at each circumferential station in the computed sector. For laminar flow, the local boundary layer thickness δ is approximated by

$$\delta = 5.0 \left(\frac{\mu_e \tilde{x}}{\rho_e \tilde{u}_e} \right)^{1/2} \tag{5}$$

whereas for turbulent flow, δ is approximated by

$$\delta = 0.37\tilde{x} \left(\frac{\rho_e \tilde{u}_e \tilde{x}}{\mu_e} \right)^{-1/5} \tag{6}$$

where ρ_e, $\tilde{u}_e$, and μ_e denote the local boundary layer edge density, streamwise velocity, and laminar dynamic viscosity, respectively, and $\tilde{x}$ is the streamwise curvilinear coordinate on the cowl (see Figure 5). With the boundary layer thickness determined, the streamwise and cross-flow velocity profiles for laminar

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OF POOR QUALITY

flow are defined by

$$\frac{\tilde{u}}{\tilde{u}_e} = 2.0 \left(\frac{\tilde{y}}{\delta}\right) - \left(\frac{\tilde{y}}{\delta}\right)^2 \tag{7}$$

$$\frac{\tilde{w}}{\tilde{w}_e} = 2.0 \left(\frac{\tilde{y}}{\delta}\right) - \left(\frac{\tilde{y}}{\delta}\right)^2 \tag{8}$$

whereas for turbulent flow, the following power laws are employed

$$\frac{\tilde{u}}{\tilde{u}_e} = \left(\frac{\tilde{y}}{\delta}\right)^{\alpha} \tag{9}$$

$$\frac{\tilde{w}}{\tilde{w}_e} = \left(\frac{\tilde{y}}{\delta}\right)^{\beta} \tag{10}$$

In the above equations, $\tilde{u}$ and $\tilde{w}$ denote the velocity components in the streamwise ($\tilde{x}$) and cross-flow ($\tilde{z}$) directions, respectively, $\tilde{y}$ is the distance measured normal to the wall, α and β are constants, and the subscript e denotes boundary layer edge conditions. The total enthalpy H distribution is given by assuming a quadratic variation with distance across the boundary layer and then imposing the appropriate boundary conditions. This yields

$$H = H_w + 2(H_e - H_w)\left(\frac{\tilde{y}}{\delta}\right) + (H_w - H_e)\left(\frac{\tilde{y}}{\delta}\right)^2 \tag{11}$$

for cases in which the wall temperature is specified, and

$$H = (H_e - \frac{1}{2}\,\delta H_w') + \delta H_w'\left(\frac{\tilde{y}}{\delta}\right) - \frac{1}{2}\,\delta H_w'\left(\frac{\tilde{y}}{\delta}\right)^2 \tag{12}$$

for cases in which the temperature derivative at the wall is specified. In equations (11) and (12), H_w and H_w' denote the total enthalpy and total enthalpy normal derivative at the wall, respectively, and H_e denotes the total enthalpy at the boundary layer edge. Specification of the total enthalpy and velocity profiles allow the density distribution to be determined if the pressure is assumed to be constant along a given boundary layer normal.

The following three parameters must be entered if KBLIDB = 1 and are used for specification of the cowl boundary layer initial data.

KTURBB — An integer variable denoting whether laminar flow or turbulent flow cowl boundary layer initial data are to be generated internally by the approximate analysis presented above. If KTURBB = 0, laminar flow initial data are generated. If KTURBB = 1, turbulent flow initial data are generated. A default value of 0 is specified for KTURBB.

ALPCWL — A positive real variable denoting the exponent α in the turbulent power law streamwise velocity profile given by equation (9). ALPCWL must be entered only if KTURBB = 1 is specified in this namelist. A default value of 1.0/7.0 = 0.142857 is specified for ALPCWL. This value of ALPCWL ocrresponds to the assumptions made in deriving equation (6).

BETCWL — A positive real variable denoting the exponent β in the turbulent power law cross-flow velocity profile given by equation (10). BETCWL must be entered only if KTURBB = 1 is specified in this namelist. A default value of 1.0/7.0 = 0.142857 is specified for BETCWL. This value of BETCWL ocrresponds to the assumptions made in deriving equation (6).

If KBLIDB = 0 is specified in this namelist, then the following parameter must be entered.

ITAP3 — A positive integer variable denoting the tape number from which the cowl boundary layer initial data are to be entered by a formatted read. The default value assigned to ITAP3 is 5 (the input file). The user may specify ITAP3 = 12, in which case the cowl boundary layer initial data are read from TAPE12. TAPE12 is linked to the dummy file IVS3 in the PRØGRAM card.

The following two parameters designate the values of the streamwise curvilinear coordinate $\tilde{x}$ at which the boundary layer initial data are specified. See Figure 5 for definition of the $\tilde{x}$ coordinates for both the forebody/centerbody and cowl. Note that for the forebody/centerbody, $\tilde{x}$ = 0.0 is located at the forebody tip, while for the cowl, $\tilde{x}$ = 0.0, is located at the cowl lip.

XASTRT — A positive real variable denoting the value of the streamwise curvilinear coordinate $\tilde{x}$ (see Figure 5) at which the forebody/centerbody boundary layer initial data are specified. XASTRT must be entered only if KBLIDA = 0 is specified in this namelist. XASTRT must correspond to the value of XI specified in namelist LIST2. No default value is specified for XASTRT.

XBSTRT A positive real variable denoting the value of the streamwise curvilinear coordinate x (see Figure 5) at which the cowl boundary layer initial data are specified. XBSTRT must be entered only if KBLIDB = 0 is specified in this namelist. XBSTRT must correspond to the axial location of the first solution plane inside the annulus. No default value is specified for XBSTRT.

The following six parameters are used to specify the boundary layer computational mesh. The boundary layer computational point networks are illustrated in Figure 6.

MBLAY A positive integer variable denoting the number of circumferential stations to be used in the computation of both the forebody/centerbody and cowl boundary layers (see Figure 6). MBLAY must be at least 5 but no greater than 16. The default value and recommended value of MBLAY for KSYM = 1 is 15.

If the boundary layer initial data are specified by the user, then the following two parameters are entered to designate the number of radial points in the supplied data.

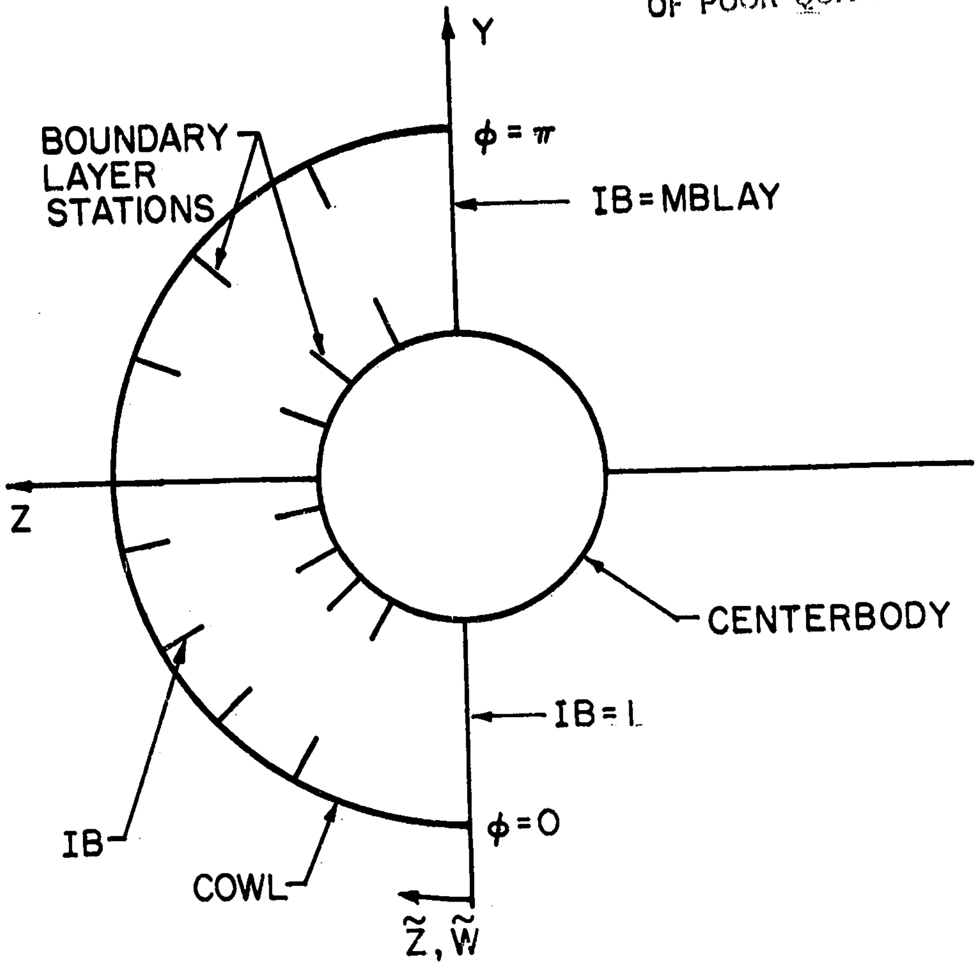
NINA A positive integer variable denoting the number of radial points in the user-supplied forebody/centerbody boundary layer initial data. NINA must be entered only if KBLIDA = 0 is specified in this namelist. NINA must be at least 5 but no greater than 20. A default value of 20 is specified for NINA.

NINB A positive integer variable denoting the number of radial points in the user-supplied cowl boundary layer initial data. NINB must be entered only if the cowl boundary layer is to be computed and if KBLIDB = 0 is specified in this namelist. NINB must be at least 5 but no greater than 20. A default of 20 is specified for NINB.

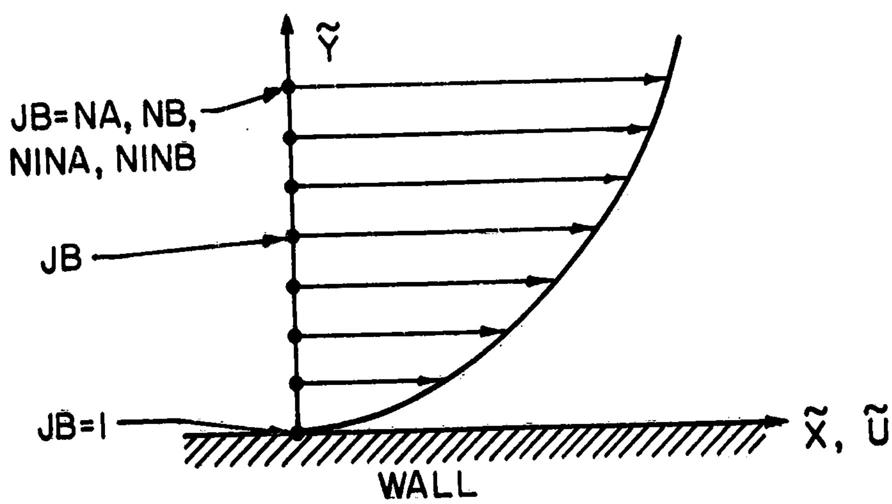
The following two parameters designate the number of radial points used in the boundary layer computation. The following parameters may be different from NINA and NINB since the user-supplied data will be interpolated.

NA A positive integer variable denoting the number of radial stations employed in the forebody/centerbody boundary layer computation. NA must be at least 5 but no greater than 20. A default value of 20 is specified for NA.

NB A positive integer variable denoting the number of radial stations employed in the cowl boundary layer computation. NB must be specified only if the cowl boundary layer is to be computed. NB must be at least 5 but no greater than 20. A default value of 20 is specified for NB.



(a) CIRCUMFERENTIAL NETWORK



(b) RADIAL NETWORK

FIGURE 6. BOUNDARY LAYER COMPUTATIONAL POINT NETWORKS

The following parameter specifies the mesh distortion in the boundary layer normal direction.

FACTØR A one-dimensional real variable array consisting of two elements. The elements of FACTØR denote the ratio of two successive step sizes in the boundary layer normal direction, the normal step size being expressed in terms of transformed variables [see Reference (1)]. FACTØR (1) and FACTØR (2) denote the successive normal step size ratios for the forebody/centerbody and cowl boundary layers, respectively. FACTØR (2) must be entered only if the cowl boundary layer is to be calculated. Specifying FACTØR(I) = 1.0 produces a mesh that is uniform in the boundary layer normal direction, whereas specifying FACTØR(I) > 1.0 produces a mesh which is more closely spaced near the wall. Default values of 1.0 are specified for both elements of FACTØR.

9. NAMELIST LIST7

The parameters entered in namelist LIST7 specify the wall temperature boundary condition to be used in the boundary layer computation. The parameters entered in this namelist need only be specified if the boundary layer computation is to be performed (KBLAY = 1 specified in namelist LIST1).

KTYPE An integer parameter denoting whether the wall temperature or wall temperature normal derivative is to be used as a boundary condition in both the forebody/centerbody and cowl boundary layer solutions. If KTYPE = 1, the wall temperature is used as a boundary condition. If KTYPE = 2, the normal derivative of the temperature at the wall is used as a boundary condition. If the forebody/centerbody boundary layer initial data are generated internally (KBLIDA = 1 specified in namelist LIST6), then the wall temperature boundary condition option must be specified (KTYPE = 1). A default value of 1 is specified for KTYPE.

The wall temperature or its normal derivative may be specified as being either a constant or as having functional dependence upon axial position. For the case of axial position dependency, the wall temperature or its derivative is specified by tabular input. The temperature boundary condition on the forebody/centerbody is specified by entering the following parameters.

KWLTA An integer variable denoting whether a constant or variable temperature or temperature derivative boundary condition is to be used for the forebody/centerbody boundary layer computation. If KWLTA = 1, a constant boundary condition is specified. If KWLTA = 2, a variable boundary condition is specified. A default value of 1 is specified for KWLTA.

If a constant temperature or temperature derivative boundary condition is to be specified, then one of the two following parameters is entered.

TCØNSTA — A positive real variable denoting the constant wall temperature, in either R or K, for the forebody/centerbody. TCØNSTA must be entered only if KTYPE = 1 and KWLTA = 1 are specified in this namelist. The free-stream stagnation temperature is recommended for TCØNSTA. A default value of 500.0 R is specified for TCØNSTA.

DTDYCA — A real variable denoting the constant wall temperature normal derivative, in either (R/ft) or (K/m), for the forebody/centerbody. DTDYCA must be entered only if KTYPE = 2 and KWLTA = 1 are specified in this namelist. A default value of 0.0 is specified for DTDYCA.

If a varibale temeprature or temperature derivative boundary condition is to be specified, then the following parameters are entered.

NTABA — A positive integer variable denoting the number of tabular data points used in the temperature boundary condition specification on the forebody/centerbody. NTABA must be entered only if KWLTA = 2 is specified in this namelist. NTABA must be at least 3 but no greater than 25. No default value is specified for NTABA.

XWLA — A one-dimensional real variable array (dimensioned at 25) consisting of NTABA elements. The XWLA array must be entered only if KWLTA = 2 is specified in this namelist. Each element of XWLA specifies the axial (x) position, in either feet or meters, at which the wall temperature or its normal derivative is to be specified for the forebody/centerbody. Each element of XWLA must be nonnegative, monotonically increasing, and within bounds of the specified geometry. No default values are specified for the elements of XWLA.

TWLA — A one-dimensional real variable array (dimensioned at 25) consisting of NTABA elements. The TWLA array must be entered only if KTYPE = 1 and KWLTA = 2 are specified in this namelist. Each element of TWLA specifies the forebody/centerbody wall temperature, in either R or K, at the axial position specified by the corresponding element XWLA. Each element of TWLA must be positive. No default values are specified for the elements of TWLA.

DTDYWA — A one-dimensional real variable array (dimensioned at 25) consisting of NTABA elements. The DTDYWA array must be entered only if KTYPE = 2 and KWLTA = 2 are specified in this namelist. Each element of DTDYWA specifies the forebody/centerbody wall temperature normal derivative, in either (R/ft) or (K/m), at the axial position specified by the corresponding element of XWLA. No default values are specified for the elements of DTDYWA.

If only the forebody flow field and boundary layer are to be calculated [KCALL(1) = 1, KCALL(2) = KCALL(3) = 0, and KBLAY = 1 specified in namelist LIST1], then no other input parameters have to be specified in this namelist. If the internal flow field and boundary layers are to be computed [KCALL(2) = 1 or KCALL(3) = 1, and KBLAY = 1 specified in namelist LIST1], then the following parameters must be entered to specify the wall temperature boundary condition for the cowl boundary layer solution.

KWLTB An integer variable denoting whether a constant or variable temperature or temperature derivative boundary condition is to be used for the cowl boundary layer computation. If KWLTB = 1, a constant boundary condition is specified. If KWLTB = 2, a variable boundary condition is specified. A default value of 1 is specified for KWLTB.

If a constant temperature or temperature derivative boundary condition is to be specified, then one of the two following parameters is entered.

TCØNSTB A positive real variable denoting the constant wall temperature, in either R or K, for the cowl. TCØNSTB must be entered only if KTYPE = 1 and KWLTB = 1 are specified in this namelist. The free-stream stagnation temperature is recommended for TCØNSTB. A default value of 500.0R is specified for TCØNSTB.

DTDYCB A real variable denoting the constant wall temperature normal derivative, in either (R/ft) or (K/m), for the cowl. DTDYCB must be entered only if KTYPE = 2 and KWLTB = 1 are specified in this namelist. A default value of 0.0 is specified for DTDYCB.

If a variable temperature or temperature derivative boundary condition is specified, then the following parameters are entered.

NTABB A positive integer variable denoting the number of tabular data points used in the temperature boundary condition specification on the cowl. NTABB must be entered only if KWLTB = 2 is specified in this namelist. NTABB must be at least 3 but no greater than 25. No default value is specified for NTABB.

XWLB A one-dimensional real variable array (dimensioned at 25) consisting of NTABB elements. The XWLB array must be entered only if KWLTB = 2 is specified in this namelist. Each element of XWLB specifies the axial (x) position, in either feet or meters, at which the wall temperature or its normal derivative is to be specified for the cowl. Each element of XWLB must be nonnegative, monotonically increasing, and within bounds of the specified geometry. No default values are specified for the elements of XWLB.

TWLB A one-dimensional real variable array (dimensioned at 25) consisting of NTABB elements. The TWLB array must be entered only if KTYPE = 1 and KWLTB = 2 are specified in this namelist. Each element of TWLB specifies the wall temperature, in either R or K, at the axial position specified by the corresponding element of XWLB. Each element of TWLB must be positive. No default values are specified for the elements of TWLB.

DTDYWB A one-dimensional real variable array (dimensioned at 25) consisting of NTABB elements. The DTDYWB array must be entered only if KTYPE =

2 and KWLTB = 2 are specified in this namelist. Each element of DTDYWB specifies the cowl wall temperature normal derivative, in either (R/ft) or (K/m), at the axial position specified by the corresponding element of XWLB. No default values are specified for the elements of DTDYWB.

10. NAMELIST LIST8

The parameters entered in namelist LIST8 specify the wall mass bleed distribution. If the case being considered requires no mass bleed, then the parameters entered in this namelist do not have to be specified. For those cases which require mass removal at the wall, the bleed distribution is specified by tabular input. The tabular input requires the specification of the axial location and extent of the bleed zones and specification of the bleed mass flux [(mass flow rate)/area] within each zone (see Figure 7). Options exist to specify a zero bleed rate for either the forebody/centerbody or cowl.

The bleed distribution for the forebody/centerbody is specified by entering the following parameters.

KDFA — An integer variable denoting whether or not mass transfer occurs at the forebody/centerbody wall. If KDFA = 0, a case with no mass transfer (bleed) is specified. If KDFA = 1, a case with mass transfer is specified. A default value of 0 is specified for KDFA.

If KDFA = 1 is specified, the following four parameters must be entered.

NRA — A positive integer variable denoting the number of bleed zones on the forebody/centerbody (see Figure 7). NRA must be at least 1 but no greater than 25. No default value is specified for NRA.

XSA — A one-dimensional real variable array (dimensioned at 25) consisting of NRA elements. Each element of XSA denotes the axial (x) position, in either feet or meters, of the beginning of a mass bleed zone on the forebody/centerbody (see Figure 7). The elements of XSA must be positive, monotonically increasing, and within bounds of the specified geometry. No default values are specified for the elements of XSA.

XEA — A one-dimensional real variable array (dimensioned at 25) consisting of NRA elements. Each element of XEA denotes the axial (x) position, in either feet or meters, of the end of a mass bleed zone on the forebody/centerbody (see Figure 7). The elements of XEA must be positive, monotonically increasing, and within bounds of the specified geometry. Moreover, for the I th element, XEA(I) $\geq$ XSA(I). No default values are specified for the elements of XEA.

RØVA — A one-dimensional real variable array (dimensioned at 25) consisting of NRA elements. Each element of RØVA denotes the mass flux (density x velocity), in units of (slug/($ft^2 \cdot sec$)) or (kg/($m^2 \cdot sec$)), for the bleed zone defined by the corresponding elements of XSA and XEA. For mass bleed, the elements of RØVA must be specified as positive.

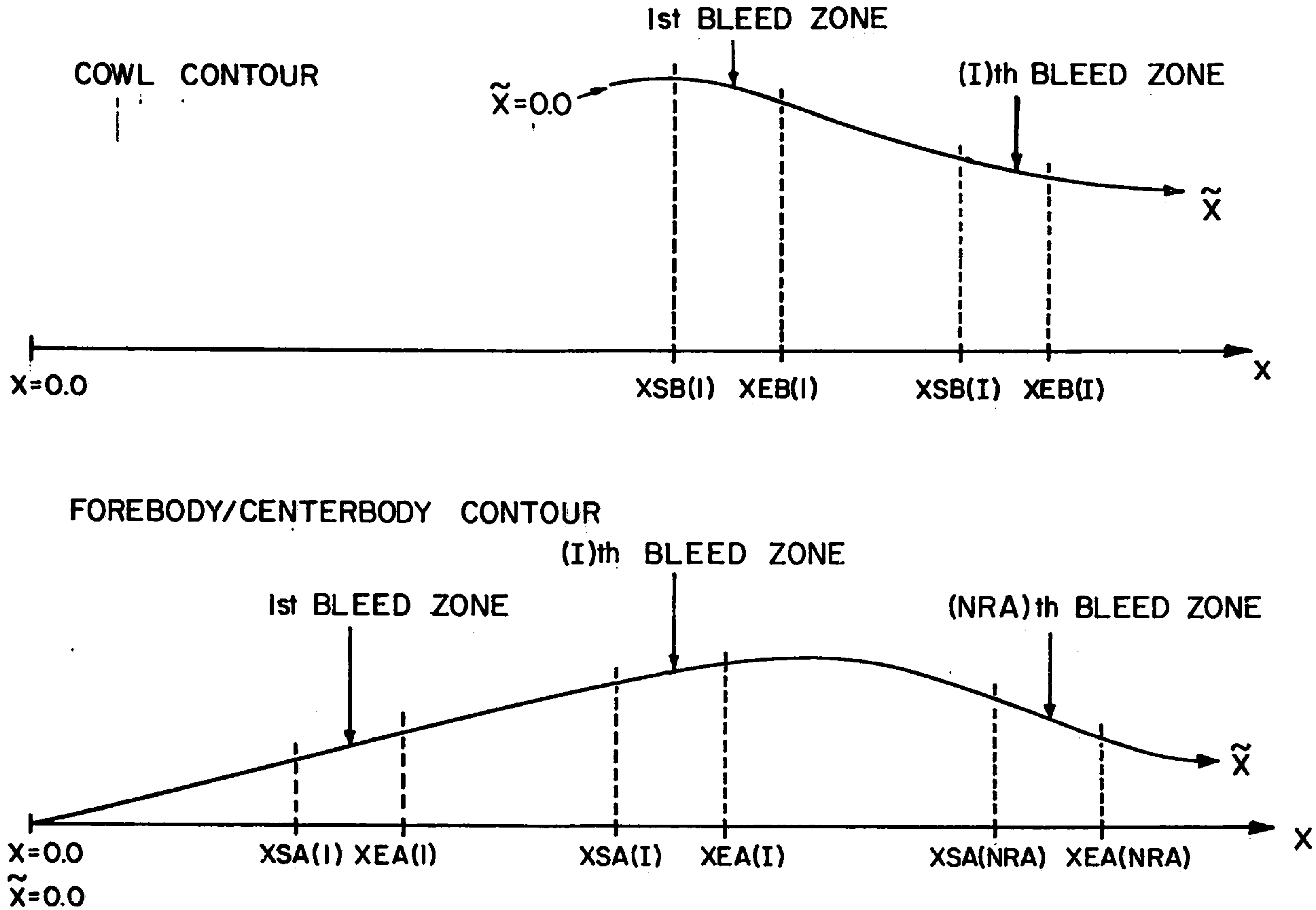


FIGURE 7. BLEED DISTRIBUTION SPECIFICATION

No default values are specified for the elements of RØVA.

If only the forebody flow field is to be calculated [KCALL(1) = 1, KCALL(2) = KCALL(3) = 0 specified in namelist LIST1], then no other parameters need be specified in this namelist. If the internal flow is to be calculated [KCALL(2) = 1 or KCALL(3) = 1 specified in namelist LIST1] and mass transfer occurs at the inlet walls, then the following parameters must be entered to specify the cowl bleed distribution.

KDFB — An integer variable denoting whether or not mass transfer occurs at the cowl wall. If KDFB = 0, a case with no mass transfer is specified. If KDFB = 1, a case with mass transfer (bleed) is specified. A default value of 0 is specified for KDFB.

If KDFB = 1 is specified, the following four parameters must be entered.

NRB — A positive integer variable denoting the number of bleed zones on the cowl (see Figure 7). NRB must be at least 1 but no greater than 25. No default value is specified for NRB.

XSB — A one-dimensional real variable array (dimensioned at 25) consisting of NRB elements. Each element of XSB denotes the axial (x) position, in either feet or meters, of the beginning of a mass bleed zone on the cowl (see Figure 7). The elements of XSB must be positive, monotonically increasing, and within bounds of the specified geometry. No default values are specified for the elements of XSB.

XEB — A one-dimensional real variable array (dimensioned at 25) consisting of NRB elements. Each element of XEB denotes the axial (x) position, in either feet or meters, of the end of a mass bleed zone on the cowl (see Figure 7). The elements of XEB must be positive, monotonically increasing, and within bounds of the specified geometry. Moreover, for the I th element, XEB(I) ≥ XSB(I). No default values are specified for the elements of XEB.

RØVB — A one-dimensional real variable array (dimensioned at 25) consisting of NRB elements. Each element of RØVB denotes the mass flux (density x velocity), in units of (slug/(ft^2 · sec)) or (kg/(m^2 · sec)), for the bleed zone defined by the corresponding elements of XSB and XEB. For mass bleed, the elements of RØVB must be specified as positive. No default values are specified for the elements of RØVB.

11. NAMELIST LIST9

The parameters entered in namelist LIST9 specify the turbulence model and the transition model used in the boundary layer computation. The parameters entered in this namelist need only be specified if the boundary layer computation is to be performed (KBLAY = 1 specified in namelist LIST1).

The three-dimensional turbulence model incorporated into the program is based on a two-layer formulation with [see Reference (1)]

$$\varepsilon_x = \varepsilon_{xi} \qquad (0 \le \tilde{y} \le \tilde{y}_T) \tag{13}$$

$$\varepsilon_x = \varepsilon_{xo} \qquad (\tilde{y}_T \le \tilde{y} \le \delta) \tag{14}$$

where ε_x denotes the eddy viscosity in the streamwise momentum equation, ε_{xi} is the inner region eddy viscosity, ε_{xo} is the outer region eddy viscosity, $\tilde{y}$ is the distance measured normal to the wall, $\tilde{y}_T$ is defined by the point where $\varepsilon_{xi} = \varepsilon_{xo}$, and δ is the local boundary layer thickness.

The inner layer eddy viscosity is given by

$$\varepsilon_{xi} = \delta_{TR} L^2 \left[\left(\frac{\partial \tilde{u}}{\partial \tilde{y}} \right)^2 + \left(\frac{\partial \tilde{w}}{\partial \tilde{y}} \right)^2 \right]^{1/2} \tag{15}$$

where $\tilde{u}$ and $\tilde{w}$ denote the velocity components in the boundary layer streamwise ($\tilde{x}$) and cross-flow ($\tilde{z}$) directions, respectively, L is the mixing length, and δ_{TR} is an appropriate factor accounting for the transition from laminar to turbulent flow. The mixing length L is given by

$$L = \kappa \tilde{y} \, [1 - \exp(-\tilde{y}/A)] \tag{16}$$

where κ is the von Karman parameter taken to be a constant with a recommended value of

$$\kappa = 0.40 \tag{17}$$

and A is defined by

$$A = A^{+} \cdot f \tag{18}$$

In equation (18), f is a function of the flow gradients and local properties and is presented in Reference (1). The parameter A^+ is the van Driest damping factor which is taken to be a constant with a recommended value of

$$A^+ = 26.0 \tag{19}$$

The outer region eddy viscosity is given by the velocity defect relation

$$\varepsilon_{xo} = \delta_{TR}\alpha \left| \int_0^\infty [(\tilde{u}_e^2 + \tilde{w}_e^2)^{1/2} - (\tilde{u}^2 + \tilde{w}^2)^{1/2}] d\tilde{y} \right| \tag{20}$$

where the subscript e denotes the boundary layer edge conditions, and α is taken to be a constant with a recommended value of

$$\alpha = 0.0168 \tag{21}$$

With the streamwise momentum equation eddy viscosity ε_x defined by the above relations, the cross-flow momentum equation eddy viscosity ε_z is defined by

$$\varepsilon_z = \lambda \varepsilon_x \tag{22}$$

where λ is a constant. For isotropic turbulence, λ takes the value

$$\lambda = 1.0 \tag{23}$$

The turbulent eddy thermal conductivity ε_Θ is given by

$$\varepsilon_\Theta = \frac{\varepsilon}{Pr_t} \tag{24}$$

where P_{r_t} is the turbulent Prandtl number which is assumed to be a constant in the analysis, and ε is defined by

$$\varepsilon = [\varepsilon_x^2 + \varepsilon_z^2]^{1/2} \tag{25}$$

The three-dimensional turbulence model is defined by entering the following parameters.

APLUS A positive real variable denoting the van Driest damping factor in equation (18). The default and recommended value of APLUS is 26.0.

XKAPPA A positive real variable denoting the von Karman parameter in equation (16). The default and recommended value of XKAPPA is 0.40.

XALPHA A positive real variable denoting the constant α in equation (20). The default and recommended value of XALPHA is 0.0168.

PRT A positive real variable denoting the turbulent Prandtl number in equation (24). The default and recommended value of PRT is 0.90.

TFACTR A positive real variable denoting the constant λ in equation (22). The default and recommended value of TFACTR is 1.0.

In addition to the above parameters, two other input parameters are employed in the turbulence model of the Adams algorithm which is used to internally generate the forebody/centerbody boundary layer initial data (KBLIDA = 1 specified in namelist LIST6). The user should consult Reference (5) for further discussion of these parameters. In general, the program is executed by retaining the following two parameters at their default values.

AKLM A positive real variable used in the Adams algorithm turbulence model [see Reference (5) for discussion]. The default and recommended value for AKLM is 0.435.

ALAM A positive real variable used in the Adams algorithm turbulence model [see Reference (5) for discussion]. The default and recommended value for ALAM is 0.09.

A number of models have been incorporated into the computer program for determining the transition parameter δ_{TR} in equations (15) and (20). The transition models include:

Model No. 1: An instantaneous transition model with fully turbulent flow being specified as occuring at a particular value $\tilde{x}_T$ of the boundary layer streamwise curvilinear coordinate $\tilde{x}$ (see Figure 5). The transition parameter δ_{TR} is calculated from

$$\delta_{TR} = 0.0 \qquad (\tilde{x} < \tilde{x}_T) \tag{26}$$

$$\delta_{TR} = 1.0 \qquad (\tilde{x} \geq \tilde{x}_T) \tag{27}$$

Model No. 2: An instantaneous transition model with fully turbulent flow being specified as occuring at a critical Reynolds number R_{e_T} where the Reynolds number R_e is given by

$$R_e = \frac{\rho_e \tilde{u}_e \tilde{x}}{\mu_e} \tag{28}$$

with ρ_e, $\tilde{u}_e$, and μ_e being the boundary layer edge density, streamwise velocity, and dynamic laminar viscosity, respectively. The transition parameter δ_{TR} is calculated from

$$\delta_{TR} = 0.0 \qquad (R_e < R_{e_T}) \tag{29}$$

$$\delta_{TR} = 1.0 \qquad (R_e \geq R_{e_T}) \tag{30}$$

Model No. 3: A progressive transition model with the onset of transitional flow occuring at $\tilde{x}_{T1}$ and with the onset of fully turbulent flow occuring at $\tilde{x}_{T2}$. The transition parameter δ_{TR} is calculated from

$$\delta_{TR} = 0.0 \qquad (\tilde{x} < \tilde{x}_{T1}) \tag{31}$$

$$\delta_{TR} = 1.0 \qquad (\tilde{x} > \tilde{x}_{T2}) \tag{32}$$

$$\delta_{TR} = \frac{\tilde{x} - \tilde{x}_{T1}}{\tilde{x}_{T2} - \tilde{x}_{T1}} \qquad (\tilde{x}_{T1} \leq \tilde{x} \leq \tilde{x}_{T2}) \tag{33}$$

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where $\tilde{x}$ is the local value of the boundary layer streamwise curvilinear coordinate.

Model No. 4: A progressive transition model with the onset of transitional flow occuring at the Reynolds number $R_{e_{T1}}$ and with the onset of fully turbulent flow occuring at $R_{e_{T2}}$. The transitional parameter δ_{TR} is calculated from

$$\delta_{TR} = 0.0 \qquad (R_e \leq R_{e_{T1}}) \tag{34}$$

$$\delta_{TR} = 1.0 \qquad (R_e > R_{e_{T2}}) \tag{35}$$

$$\delta_{TR} = \frac{R_e - R_{e_{T1}}}{R_{e_{T2}} - R_{e_{T1}}} \qquad (R_{e_{T1}} \leq R_e \leq R_{e_{T2}}) \tag{36}$$

where R_e is defined by equation (28).

Model No. 5: A progressive transition model using the Dhawan and Narasimha formulation (8). In this model the onset of transitional flow is specified as occuring at $\tilde{x}_{T1}$ and it is assumed that fully turbulent flow occurs at $\tilde{x} \cong 2\tilde{x}_{T1}$. The transition parameter δ_{TR} is calculated from

$$\delta_{TR} = 0.0 \qquad (\tilde{x} < \tilde{x}_{T1}) \tag{37}$$

$$\delta_{TR} = 1.0 - \exp\left[-3.6097\left(\frac{\tilde{x}}{\tilde{x}_{T1}} - 1.0\right)^2\right] \qquad (\tilde{x} \geq \tilde{x}_{T1}) \tag{38}$$

The transition models are specified by entering the following one-dimensional and two-dimensional arrays. For each array, K = 1 and K = 2 denote the forebody/centerbody and cowl boundary layers, respectively. For the two-dimensional arrays, the index IB denotes the IB*th* circumferential station (see Figure 6).

ITRANM — A one-dimensional integer variable array consisting of two elements. ITRANM(1) and ITRANM(2) denote the transition models to be used in the forebody/centerbody and cowl boundary layer computations, respectively. ITRANM(K) can have values of 1, 2, 3, 4, and 5 corresponding to the aforementioned transition models. Default values of 5 are specified for both elements of ITRANM.

XT — A two-dimensional real variable array dimensioned at (16, 2). XT (IB, K) (IB = 1, ..., MBLAY) denotes the transition distance ($\tilde{x}_T$) for the IB*th* circumferential station as described in Model No. 1 and must be entered only if ITRANM(K) = 1. No default values are specified for the elements of XT.

RET — A one-dimensional real variable array consisting of two elements. The RET array must be entered only if ITRANM(K) = 2 is specified in this namelist. The elements of RET specify the Reynolds number [defined by equation (28)] at which the flow transitions instantaneously from laminar to turbulent. RET(1) and RET(2) designate the transition Reynolds numbers for the forebody/centerbody and cowl, respectively. RET(2) must be entered only if the cowl boundary layer is to be calculated. No default values are specified for the elements of RET.

XT1 — A two-dimensional real variable array dimensioned at (16, 2). XT1 (IB, K) (IB = 1, ..., MBLAY) denotes the transition distance ($\tilde{x}_{T1}$) for the IB*th* circumferential station as described in Model Nos. 3 and 5, and must be entered only if ITRANM(K) = 3 or 5. No default values are specified for the elements of XT1.

XT2 — A two-dimensional real variable array dimensioned at (16, 2). XT2 (IB, K) (IB = 1, ..., MBLAY) denotes the transition distance ($\tilde{x}_{T2}$) for the IB*th* circumferential station as described in Model No. 3, and must be entered only if ITRANM(K) = 3. No default values are specified for the elements of XT2.

RET1 — A one-dimensional real variable array consisting of two elements. The RET1 array must be entered only if ITRANM(K) = 4 is specified in this namelist. The elements of RET1 specify the Reynolds number [defined by equation (28)] at which the onset of transitional flow occurs. RET1(1) and RET1(2) specify the transitional flow onset Reynolds number for the forebody/centerbody and cowl, respectively. RET1(2) must be specified only if the cowl boundary layer is to be calculated. No default values are specified for the elements of RET1.

RET2 — A one-dimensional real variable array consisting of two elements. The RET2 array must be entered only if ITRANM(K) = 4 is specified in this namelist. The elements of RET2 specify the Reynolds number [defined by equation (28)] at which the onset of fully turbulent flow occurs. RET2(1) and RET2(2) specify the fully turbulent flow onset Reynolds number for the forebody/centerbody and cowl, respectively. RET2(2) must be specified only if the cowl boundary layer is to be calculated. No default values are specified for the elements of RET2.

12. NAMELIST LIST10

The parameters entered in namelist LIST10 specify the various convergence tolerances and iteration limits used in the numerical integration. All parameters in this namelist have specified default values. In general, the program is executed without changing the values of any of the parameters in this namelist.

SAFEIN — A positive real variable denoting the ratio of the axial marching step taken to the axial marching step allowed by the Courant-Friedrichs-Lewy (CFL) stability criterion. This variable is used to determine the axial position of both the first solution plane in the forebody flow field integration [KCALL(1) = 1] and the first solution plane in the internal flow field integration in which shock waves are not discretely fitted [KCALL(3) = 1]. Ensuing solution planes for these integration options have their axial locations adjusted in accord with an internally computed value of SAFEIN. For the internal flow field integration option in which shock waves are discretely fitted [KCALL(2) = 1], the axial position of each solution plane (except in the vicinity of a shock wave reflection) is controlled by the input value of SAFEIN. The specified value of SAFEIN must be positive, and must be less than 1.0 to satisfy the CFL stability criterion. The default and recommended value of SAFEIN is 0.975.

CRIT — A one-dimensional real variable array consisting of 18 elements. Each element of CRIT specifies a convergence tolerance or other parameter. The elements of CRIT have the following definitions and default values.

CRIT(1) — A positive real variable denoting the tolerance, in either feet or meters, used to determine if a user supplied initial-value plane data point is sufficiently close to a plane of symmetry when the data point is supposed to lie on the plane of symmetry. CRIT(1) is also used to determine if a user supplied initial-value plane data point is sufficiently close to the solid boundary when that point is supposed to lie on the solid boundary. A default value of 0.1 ft (or 0.1m) is specified for CRIT(1).

CRIT(2) — A positive real variable denoting the relative tolerance used in testing for a loss of significance in IBM library subroutine GELG (GELG is used to solve a system of simultaneous linear equations). A default value of 10^{-7} is specified for CRIT(2).

CRIT(3) A positive real variable denoting the relative tolerance used in testing for convergence in the internal generation of the initial-value plane flow property field. A default value of 10^{-4} is specified for CRIT(3).

CRIT(4) A positive real variable denoting the relative tolerance used in testing for convergence of all three coordinates in the iterative scheme employed in computing a streamline-surface intersection or a bicharacteristic-surface intersection. A default value of 10^{-5} is specified for CRIT(4).

CRIT(5) A positive real variable denoting the relative tolerance used in testing for the convergence of the five flow properties u, v, w, P, and ρ in subroutine SØLVE. A default value of 10^{-4} is specified for CRIT(5).

CRIT(6) A positive real variable denoting the relative tolerance used in testing for the convergence of the static pressure in subroutine SHØCK. Convergence is attained in the local iteration loop if

$$|P(2)-P^*(2)|/P(2) \leq CRIT(6)$$

where P(2) is the solution point pressure obtained from the local Hugoniot relations, and P*(2) is the pressure obtained from the wave surface compatibility relation. A default value of 10^{-4} is specified for CRIT(6).

CRIT(7) A positive real variable denoting the mass flow rate ratio at which the maximum number of radial stations allowed in the fore-body flow field computation is changed from JLIMIT(1) to JLIMIT(2). The mass flow rate ratio is the mass flow rate at a given fore-body flow field solution plane divided by the estimated mass flow rate at the axial station corresponding to XEND(1). A default value of 0.5 is specified for CRIT(7).

CRIT(8) A positive real variable used as a multiplier of the mass flow ratio which is employed in determining whether or not point addition is to be performed on a solution plane in the forebody flow field integration. The mass flow rate ratio is the mass flow rate at the solution plane just computed divided by that at the last solution plane where point addition or deletion was performed. A default value of 1.0 is specified for CRIT(8).

CRIT(9) A positive real variable denoting the relative tolerance used in routine LINK31 for determining when the angle α calculated in the global correction for the bow shock wave points has converged. A default value of 10^{-4} is specified for CRIT(9).

CRIT(10) A positive real variable used in routine LINK31 for determining if a sufficient number of shock wave solution points have converged in global correction. Convergence is attained when

$$M/IST\not{O}P \geq CRIT(10)$$

where M is the number of shock wave solution points which have converged in global correction, and ISTØP is the number of circumferential stations in the computed sector. A default value of 0.8 is specified for CRIT(10).

CRIT(11) A positive real variable denoting the relative tolerance used in subroutine BSHØCK for determining if the velocity component downstream of the shock wave and normal to the surface of the solid boundary has converged to a specified value. A default value of 10^{-2} is specified for CRIT(11).

CRIT(12) A positive real variable used in routine LINK32 for determining if another solution plane is to be inserted between the last solution plane and the intersection of the incident internal shock wave with the solid boundary. Another solution plane is inserted if

$$\Delta x/\Delta x_{CFL} \geq CRIT(12)$$

where Δx is the axial (x) distance between the last computed plane and the nearest point on the space curve defined by the intersection of the incident interanl shock wave with solid boundary, and Δx_{CFL} is the axial step allowed by the Courant-Friedrichs-Lewy (CFL) stability criterion. A default value of 0.2 is specified for CRIT(12).

CRIT(13) Not presently employed.

CRIT(14) A positive real variable used in subroutine PENTRE for determining if a streamline-shock wave intersection point is sufficiently close to the current solution plane, so that an interior point unit process on the downstream side of the shock wave is not performed. Instead, a streamline projection onto the solution plane and subsequent flow property interpolation in this plane is performed. The application of the interior point unit process is not performed if

$$(x_s - x_{int})/\Delta x_{CFL} < CRIT(14)$$

where x_s is the axial position of the solution plane, x_{int} is the axial location of the streamline-shock wave intersection point, and Δx_{CFL} is the axial marching step allowed by the Courant-Friedrichs-Lewy stability criterion. A default value of 0.4 is specified for CRIT(14).

CRIT(15) A positive real variable used in subroutine STRSHK for determining if convergence has been obtained in calculating the intersection point of a body streamline with the space curve defined by the intersection of the incident internal shock wave with a solid boundary. Convergence is attained when

$$|\theta_{i+1} - \theta_i| \leq \text{CRIT(15)}$$

where θ_i is the polar angle of the intersection point on the i th iteration, and θ_{i+1} is the polar angle on the (i+1) th iteration. A default value of 10^{-4} radians is specified for CRIT(15).

CRIT(16) A positive real variable used in subroutine INTSCT for determining if convergence has been obtained in calculating the intersection point of a bicharacteristic with either a solid boundary or a shock wave, or the intersection point of a streamline with a shock wave. Convergence is attained when

$$|R_1 - R_s| \leq \text{CRIT(16)}$$

where R_1 is the radius of the intersection point obtained by integrating the equation for a streamline or bicharacteristic, and R_s is the intersection point radius obtained from the shock wave or boundary surface formulations. A default value of 10^{-4} ft (or 10^{-4}m) is specified for CRIT(16).

CRIT(17) A positive real variable denoting the relative tolerance used in subroutines ABLSLN and GBLSLN to test for convergence of the wall boundary streamwise velocity normal derivative in the boundary layer implicit finite difference algorithm. A default value of 10^{-2} is specified for CRIT(17).

CRIT(18) A positive real variable denoting the tolerance used in subroutine SBLINT to test for convergence of the continuity, streamwise momentum, and cross-flow momentum equations in the shock wave-boundary layer integral interaction analysis. A default value of 10^{-5} is specified for CRIT(18).

ITEND — A one-dimensional integer variable array consisting of 8 elements. Each element of ITEND specifies a limit to the number of iterations permissible in a given iteration loop. The elements of ITEND have the following definitions and default values.

ITEND(1) — A positive integer variable denoting the maximum number of inner interations permissible in determining the intersection coordinates of either a streamline with a surface, or a bicharacteristic with a surface. ITEND(1) is used in conjunction with CRIT(4). A default value of 10 is specified for ITEND(1).

ITEND(2) — A positive integer variable denoting the maximum number of outer iterations permissible in obtaining the five flow properties u, v, w, P, and ρ in all unit processes except the shock wave-solid boundary point unit process. A default value of 10 is specified for ITEND(2).

ITEND(3) — Not presently employed.

ITEND(4) — A positive integer variable denoting the maximum number of iterations permissible in the relaxation of the velocity component normal to the solid boundary and downstream of the reflected (cowl lip) shock wave in the shock wave-solid boundary point unit process (subroutine BSHØCK). A default value of 20 is specified for ITEND(4).

ITEND(5) — Not presently employed.

ITEND(6) — A positive integer variable denoting the maximum number of permissible subiterations in determining the intersection point of a line segment with a given three-dimensional surface (subroutine INTSCT). A default value of 10 is specified for ITEND(6).

ITEND(7) — A positive integer variable denoting the maximum number of iterations permissible in obtaining convergence for the wall boundary normal derivative of the streamwise velocity in the boundary layer implicit finite difference algorithm. ITEND(7) is used in conjunction with CRIT(17). A default value of 10 is specified for ITEND(7).

ITEND(8) — A positive integer variable denoting the maximum number of iterations permissible in obtaining convergence for the continuity, streamwise momentum, and cross-flow momentum equations in the integral shock wave-boundary layer interaction analysis. ITEND(8) is used in conjunction with CRIT(18). A default value of 15 is specified for ITEND(8).

13. NAMELIST LIST11

The parameters entered in namelist LIST11 specify if debug output is to be printed.

KDUMP — A one-dimensional integer variable array consisting of 9 elements.

Each element of KDUMP specifies whether or not a particular computational process is to have debug output printed. Specifying KDUMP(I) = 1 (I=1 to 9) activates the debug output option for the corresponding process. Specifying KDUMP(I) = 0 causes no debug output to be printed for the corresponding process. The elements of KDUMP activate the debug output option for the following processes and have the following default values.

KDUMP(I)	Activates Debug Output for	Default Value
KDUMP(1)	supersonic flow interior point scheme	0
KDUMP(2)	supersonic flow solid body point scheme	0
KDUMP(3)	supersonic flow field-shock wave point scheme	0
KDUMP(4)	supersonic flow solid body-shock wave point scheme	0
KDUMP(5)	boundary layer initial data generation schemes	0
KDUMP(6)	interpolation scheme for boundary layer edge conditions	0
KDUMP(7)	plane of symmetry finite difference boundary layer scheme	0
KDUMP(8)	three-dimensional finite difference boundary layer scheme	0
KDUMP(9)	shock wave-boundary layer interaction region scheme	0

ISTART A positive integer variable denoting the solution plane number at which debug output is to be initiated. A default value of 1 is specified for ISTART.

14. FORMATTED READ OF THE INITIAL-VALUE FLOW PROPERTY FIELDS

The user supplied supersonic flow initial data are entered by a formatted read of file ITAP1 after all eleven namelists have been input. To enter the supersonic flow initial data by tabular input, KIVS = 0 must be specified in namelist LIST2. The default value for ITAP1 is 5 (the input file). The supersonic flow initial-value plane may be read from TAPE10 by specifying ITAP1 = 10 in namelist LIST2. TAPE10 is linked to the dummy file IVS1 in the PRØGRAM card.

The index limits for the supersonic flow initial-value plane, ISTØP and JMAXI, are entered in namelist LIST3. The initial-value plane point networks for the four flow symmetry options are illustrated in Figure 3.

The supersonic flow initial data are entered by the formatted read statement

```
READ (ITAP1,II1) ((Y(I,J),Z(I,J),U(I,J),V(I,J),W(I,J),P(I,J),RØ(I,J),
                 J=1,JMAXI),I=1,ISTØP)
```

with the format (4E20.13/3E20.13). The parameters in the formatted read statement have the following definitions (see Figure 3).

I — An integer denoting the circumferential index of the data point.

J — An integer denoting the radial index of the data point.

Y — A two-dimensional real variable array, each element of which denotes the y-position, in either feet or meters, of point (I,J). The Y array is dimensioned at (30,15). No default values are specified for the elements of Y.

Z — A two-dimensional real variable array, each element of which denotes the z-position, in either feet or meters, of point (I,J). The Z array is dimensioned at (30,15). No default values are specified for the elements of Z.

U — A two-dimensional real variable array, each element of which denotes the x-component of velocity, in either (ft/sec) or (m/s), at point (I,J). The U array is dimensioned at (30,15). No default values are specified for the elements of U.

V — A two-dimensional real variable array, each element of which denotes the y-component of velocity, in either (ft/sec) or (m/s), at point (I,J). The V array is dimensioned at (30,15). No default values are specified for the elements of V.

W — A two-dimensional real variable array, each element of which denotes the z-component of the velocity, in either (ft/sec) or (m/s), at point (I,J). The W array is dimensioned at (30,15). No default values are specified for the elements of W.

P — A two-dimensional real variable array, each element of which denotes the pressure, in either (lbf/ft^2) or (N/m^2), at point (I,J). The P array is dimensioned at (30,15). No default values are specified for the elements of P.

RØ — A two-dimensional real variable array, each element of which denotes the density, in either ($slug/ft^3$) or (kg/m^3), at point (I,J). The RØ array is dimensioned at (30,15). No default values are specified for the elements of RØ.

In all cases, the supersonic flow initial-value plane data points with J = 1 must lie (to a close approximation) on the surface of the forebody/centerbody. The supersonic flow initial-value plane data points with J = JMAXI correspond to the downstream bow shock wave points. If only the internal flow is to be computed, the initial-value plane is located at the cowl lip axial station. It is sufficient to specify the flow property field, in this case, to a point just outside of the cowl lip. If the bow shock wave radius is less than that of the cowl lip, the execution is aborted.

For the case of no planes of flow symmetry (KSYM = 0), the computed sector is the entire solution plane corresponding to ISTØP circumferential stations and JMAXI radial stations [see Figure 3(a)]. For the case of one plane of flow symmetry (KSYM = 1), the computed sector is the half-plane bounded by the y-axis and containing the +z-axis [see Figure 3(b)]. In this case, the data points with I = 1 must lie on the +y-axis, and the data points with I = ISTØP must lie on the -y-axis. For the case of two planes of flow symmetry (KSYM = 2), the computed sector is the quadrant bounded by the +y-axis and the +z-axis [see Figure 3(c)]. In this case, the data points with I = 1 must lie on the +y-axis, and the data points with I = ISTØP must lie on the +z-axis. For the axisymmetric flow case (KSYM = 3), the computed sector is limited to the single circumferential station lying on the +y-axis [see Figure 3(d)]. In this case, the data points with I = 1 must lie on the +y-axis.

If the forebody supersonic flow field is not being calculated [KCALL(1) = 0], or if it is being computed and the bow shock wave is conical (KCØN = 1), then the following shock wave angle input parameters do not have to be entered. If, however, the forebody flow field is to be calculated [KCALL(1) = 1] and the bow shock wave is not conical (KCØN = 0), then the angle subtended by the bow shock wave and the x-axis in the meridional plane defined by the shock wave point for each shock wave point in the computed sector must be entered by the foramtted read statement.

```
READ (ITAP1,II2) (BETA(I),I=1,ISTØP)
```

with the format (E20.13). The parameters in the formatted read statement have the following definitions (see Figure 3).

I	An integer denoting the circumferential index of the initial-value plane shock wave point.
BETA	A one-dimensional real variable array (dimensioned at 30), each element of which denotes the angle, in radians, subtended by the bow shock wave and the x-axis in the meridional plane defined by the corresponding initial-value plane downstream shock wave point. Each element of BETA must be positive. No default values are specified for the elements of BETA.

The following parameters must be entered only if the boundary layer computation is to be performed (KBLAY = 1 specified in namelist LIST1).

The user-supplied forebody/centerbody boundary layer initial data are entered by a formatted read of file ITAP2 after all eleven namelists have been input and after the supersonic flow initial data have been input if that data was externally generated. To enter the forebody/centerbody boundary layer initial data by tabular input, KBLIDA = 0 must be specified in namelist LIST6. The default value for ITAP2 is 5 (the input file). The forebody/centerbody boundary layer initial data may be read from TAPE11 by specifying ITAP2 = 11 in namelist LIST6. TAPE11 is linked to the dummy file IVS2 in the PRØGRAM card.

The index limits for the forebody/centerbody boundary layer initial data, MBLAY and NINA, are entered in namelist LIST6. The boundary layer point networks are illustrated in Figure 6.

The forebody/centerbody boundary layer initial data are entered by the formatted read statements

```
READ (ITAP2,II3) ((ZZ(IB),FA(IB,JB),UA(IB,JB),WA(IB,JB),XLAMDA(IB,JB),
        JB=1,NINA),IB=1,MBLAY)

READ (ITAP2,II4) (UEA(IB),WEA(IB),PEA(IB),RØEA(IB),DUDXA(IB),DWDXA(IB),
        DPDXA(IB),DRDXA(IB),IB=1,MBLAY)
```

with the formats (4E20.13/E20.13) and (4E20.13/4E20.13), respectively. The parameters in the formatted read statements have the following definitions (see Figure 6).

IB	An integer denoting the circumferential index of the data point.
JB	An integer denoting the radial (or boundary layer normal) index of the solution point.
ZZ	A one-dimensional real variable array, each element of which denotes the circumferential angle, in radians, of the IB th circumferential station. The ZZ array is dimensioned at (16). No default values are specified for the elements of ZZ.
FA	A two-dimensional real variable array, each element of which denotes the distance, in either feet or meters, between point (IB,JB) and the surface as measured along the surface normal passing through point (IB,JB). The FA array is dimensioned at (16,20). No default values are specified for the elements of FA.
UA	A two-dimensional real variable array, each element of which denotes the boundary layer streamwise ($\tilde{x}$) component of velocity, in either (ft/sec) or (m/s), at point (IB,JB). The UA array is dimensioned at (16,20). No default values are specified for the elements of UA.
WA	A two-dimensional real variable array, each element of which denotes the boundary layer cross flow ($\tilde{z}$) component of velocity, in either (ft/sec) or (m/s), at point (IB,JB). The WA is dimensioned at (16,20). No default values are specified for the elements of WA.
XLAMDA	A two-dimensional real variable array, each element of which denotes the density, in either (slug/ft^3) or (kg/m^3), at point (IB,JB). The XLAMDA array is dimensioned at (16,20). No default values are specified for the elements of XLAMDA.
UEA	A one-dimensional real variable array, each element of which denotes

the boundary layer edge streamwise ($\tilde{x}$) component of velocity, in either (ft/sec) or (m/sec), at the IB $\underline{th}$ circumferential station. The UEA array is dimensioned at (16). No default values are specified for the elements of UEA.

WEA — A one-dimensional real variable array, each element of which denotes the boundary layer edge cross flow ($\tilde{z}$) component of velocity, in either (ft/sec) or (m/sec), at the IB $\underline{th}$ circumferential station. The WEA array is dimensioned at (16). No default values are specified for the elements of WEA.

PEA — A one-dimensional real variable array, each element of which denotes the boundary layer edge pressure, in either (lbf/ft^2) or (N/m^2), at the IB $\underline{th}$ circumferential station. The PEA array is dimensioned at (16). No default values are specified for the elements of PEA.

RØEA — A one-dimensional real variable array, each element of which denotes the boundary layer edge density, in either (slug/ft^3) or (kg/m^3), at the IB $\underline{th}$ circumferential station. The RØEA array is dimensioned at (16). No default values are specified for the elements of RØEA.

DUDXA — A one-dimensional real variable array, each element of which denotes the boundary layer edge derivative of the streamwise velocity component ($\tilde{u}_e$) with respect to the streamwise curvilinear coordinate ($\tilde{x}$) at the IB $\underline{th}$ circumferential station. The units for DUDXA are (sec^{-1}). The DUDXA array is dimensioned at (16). No default values are specified for the elements of DUDXA.

DWDXA — A one-dimensional real variable array, each element of which denotes the boundary layer edge derivative of the cross flow velocity component ($\tilde{w}_e$) with respect to the streamwise curvilinear coordinate ($\tilde{x}$) at the IB $\underline{th}$ circumferential station. The units for DWDXA are (sec^{-1}). The DWDXA array is dimensioned at (16). No default values are specified for the elements of DWDXA.

DPDXA — A one-dimensional real variable array, each element of which denotes the boundary layer edge derivative of the static pressure (P_e) with respect to the streamwise curvilinear coordinate ($\tilde{x}$) at the IB $\underline{th}$ circumferential station.The units for DPDXA are either (lbf/ft^3) or (N/m^3). The DPDXA array is dimensioned at (16). No default values are specified for the elements of DPDXA.

DRDXA — A one-dimensional real variable array, each element of which denotes the boundary layer edge derivative of the density (ρ_e) with respect to the streamwise curvilinear coordiante ($\tilde{x}$) at the IB $\underline{th}$ circumferential station. The units for DRDXA are either (slug/ft^4) or (kg/m^4). The DRDXA array is dimensioned at (16). No default values are specified for the elements of DRDXA.

The user-supplied cowl boundary layer initial data are entered by a formatted read of file ITAP3 after all eleven namelists have been input and after the supersonic flow and forebody/centerbody boundary layer flow initial data have been input if they are externally generated. To enter the cowl boundary layer initial data by tabular input, KBLIDB = 0 must be specified in namelist LIST6. The default value for ITAP3 is 5 (the input file). The cowl boundary layer initial data may be read from TAPE12 by specifying ITAP3 = 12 in namelist LIST6. TAPE12 is linked to the dummy file IVS3 in the PRØGRAM card.

The index limits for the cowl boundary layer initial data, MBLAY and NINB, are entered in namelist LIST6. The boundary layer point networks are illustrated in Figure 6.

The cowl boundary layer initial data are entered by the formatted read statements

```
READ (ITAP3,II3) ((ZZ(IB),FA(IB,JB),UA(IB,JB),WA(IB,JB),XLAMDA(IB,JB),
      JB=1,NINB),IB=1,MBLAY)

READ (ITAP3,II4)  (UEA (IB),WEA(IB),PEA(IB),RØEA(IB),DUDXA(IB),DWDXA(IB),
      DPDXA(IB),DRDXA(IB),IB=1,MBLAY)
```

with the same formats and parameter definitions as presented before for the forebody/centerbody boundary layer initial data formatted read.

In all cases, the boundary layer initial data points with JB = 1 must lie (to a close approximation) on the appropriate body surface. For the case of one plane of flow symmetry (KSYM = 1), the initial data points with IB = 1 must lie on the -y-axis, and the points with IB = MBLAY must lie on the +y-axis.

SECTION V

OUTPUT INTERPRETATION

1. INTRODUCTION

The initial portion of the computer output comprises preliminary information. This preliminary output consists of information identifying the problem being considered, the specified computation options, the flow symmetry option, the thermodynamic model and the molecular transport properties, the vehicle orientation and the free-stream conditions, certain index parameters, the contours of the centerbody and the cowl, and the convergence tolerances and the iteration limits. The initial-value plane is then printed. Alternatively, if a program restart is specified, the last solution plane written on the restart file is printed. Each solution plane is then printed in a format similar to the initial-value plane printout. The supersonic core flow solution is printed first, followed by the forebody/centerbody and cowl boundary layer solutions. Additionally, the redistributed data plane at the cowl lip axial station is printed if the internal flow integration option is specified. Moreover, for the internal flow field computation, the solution points are printed which lie along the space curves defined by the intersection of the internal shock wave with the solid boundaries.

2. SUPERSONIC CORE FLOW SOLUTION OUTPUT

The supersonic core flow solution output parameters listed on the computer printout are defined below.

I circumferential index of the solution point

J radial index of the solution point

X axial position of the solution plane or the solution point, (ft) or (m)

Y y-position, (ft) or (m)

Z z-position, (ft) or (m)

M Mach number

Q velocity magnitude, (ft/sec) or (m/sec)

P pressure, (lbf/ft^2) or (N/m^2)

RØ density, (slug/ft^3) or (kg/m^3)

T absolute temperature, (R) or (K)

U x-component of velocity, (ft/sec) or (m/sec)

V y-component of velocity, (ft/sec) or (m/sec)

W z-component of velocity, (ft/sec) or (m/sec)

PT stagnation pressure, (lbf/ft^2) or (N/m^2)

TT stagnation temperature, (R) or (K)

ITG number of global corrector applications

ITL number of local iterations

Streamline solution points have both I and J indices which are numbers. An upstream shock wave solution point is denoted by a numerical I index and the J index is U. A downstream shock wave solution point is denoted by a numerical I index and the J index is D.

For the external flow field about the forebody, the body streamline solution points are denoted by J = 1. The outer bound to the computational flow regime is defined by the locus of downstream shock wave solution points, points with J = D. Since periodic point addition and deletion are performed in the external flow field integration, continuous streamlines throughout the computational flow regime are not available. Inserted solution points are noted by ITG = ITL = 0.

For the continuous internal flow field integration option, the body streamline points on the surface of the centerbody are denoted by J =-1, and the body streamline points on the surface of the cowl are denoted J = JINLET. The solution is found on the continuous streamlines which pass through the redistributed points on the solution plane at the cowl lip axial station.

For the internal flow field integration option in which shock waves are discretely fitted, the body streamline points on the surface of the centerbody are denoted by J = 1. The body streamline points on the surface of the cowl are denoted by J = (JINLET - 2). The shock wave solution points float in the storage arrays as the internal shock wave travels between the centerbody and the cowl on successive solution planes. The streamline points between the upstream side solid boundary (either centerbody or cowl) and the upstream shock wave points on a given solution plane lie in the upstream flow field sector on that solution plane. In a like manner, streamline points which lie between the other solid boundary and the downstream shock wave points on a given solution plane lie in the downstream flow field sector on that solution plane. A reversal of the upstream and downstream sectors occurs at an internal shock wave-solid boundary intersection. It should be noted that continuous streamlines are followed in the internal flow field integration.

The intersection of the incident internal shock wave with a solid boundary at a shock wave-solid boundary intersection defines a space curve. The solution is found on both the upstream and downstream sides of both the incident and reflected shock waves at points on this space curve.

At the end of a solution plane printout, the Courant number and the x-step regulation parameters are printed. The Courant number is the ratio of the axial step taken to the axial step allowed by the Courant-Friedrichs-Lewy stability criterion (based on immediate neighbors in the interpolation fit point stencils). The Courant number listed is that used in obtaining the solution plane that was just printed. Likewise, the x-step regulation parameters refer to the solution plane that was just printed.

3. BOUNDARY LAYER FLOW SOLUTION OUTPUT

The boundary layer flow solution output parameters listed on the computer printout are defined below.

I circrumferential index of the solution point

J radial index of the solution point

X axial position of the corresponding supersonic core flow solution plane for the current boundary layer solution surface, (ft) or (m)

XC streamwise curvilinear coordinate ($\tilde{x}$) of the boundary layer solution surface (for the forebody/centerbody, XC=0.0 corresponds to the forebody tip; for the cowl, XC=0.0 corresponds to the cowl lip), (ft) or (m)

Y distance measured normal to the wall, (ft) or (m)

Z polar angle (see Figure 6), (Z=0.0° corresponds to the windward meridian; Z=180.0° corresponds to the leeward meridian), (degrees)

M Mach number

Q velocity magnitude, (ft/sec) or (m/sec)

P pressure, (lbf/ft^2) or (N/m^2)

RØ density, ($slug/ft^3$) or (kg/m^3)

T absolute temperature, (R) or (K)

U	streamwise ($\tilde{x}$) component of velocity, (ft/sec) or (m/sec)
V	normal ($\tilde{y}$) component of velocity, (ft/sec) or (m/sec)
W	cross-flow ($\tilde{z}$) component of velocity, (ft/sec) or (m/sec)
PT	stagnation pressure, (lbf/ft^2) or (N/m^2)
TT	stagnation temperature, (R) or (K)
UE	streamwise ($\tilde{x}$) component of velocity at the boundary layer edge, (ft/sec) or (m/sec)
WE	cross-flow ($\tilde{z}$) component of velocity at the boundary layer edge, (ft/sec) or (m/sec)
PE	pressure at the boundary layer edge, (lbf/ft^2) or (N/m^2)
RØE	density at the boundary layer edge, ($slug/ft^3$) or (kg/m^3)
TE	absolute temperature at the boundary layer edge, (R) or (K)
HTE	total enthalpy at the boundary layer edge, (ft^2/sec^2) or (m^2/sec^2)
DUEDX	first partial derivative of the boundary layer edge streamwise velocity component (UE) with respect to the streamwise curvilinear coordinate ($\tilde{x}$), (sec^{-1})
DWEDX	first partial derivative of the boundary layer edge cross-flow velocity component (WE) with respect to the streamwise curvilinear coordinate ($\tilde{x}$), (sec^{-1})
DPEDX	first partial derivative of the boundary layer edge pressure (PE) with respect to the streamwise curvilinear coordinate ($\tilde{x}$), (lbf/ft^3) or (N/m^3)
DRØEDX	first partial derivative of the boundary layer edge density (RØE) with respect to the streamwise curvilinear coordinate ($\tilde{x}$), ($slug/ft^4$) or (kg/m^4)
DUEDZ	first partial derivative of the boundary layer edge streamwise velocity component (UE) with respect to polar angle, (ft/sec/radian) or (m/sec/radian)

DWEDZ first partial derivative of the boundary layer edge cross-flow velocity component (WE) with respect to polar angle, (ft/sec/radian) or (m/sec/radian)

DPEDZ first partial derivative of the boundary layer edge pressure (PE) with respect to polar angle, (lbf/ft^2/radian) or (N/m^2/radian)

DRØEDZ first partial derivative of the boundary layer edge density (RØE) with respect to polar angle, ($slug/ft^3$/radian) or (kg/m^3/radian)

DTX streamwise boundary layer displacement thickness (δ_{tx}), (ft) or (m)

DTZ cross-flow boundary layer displacement thickness (δ_{tz}), (ft) or (m)

MTX streamwise boundary layer momentum thickness (δ_{mx}), (ft) or (m)

MTZ cross-flow boundary layer momentum thickness (δ_{mz}), (ft) or (m)

TWX streamwise wall shear stress component (τ_{wx}), (lbf/ft^2) or (N/m^2)

TWZ cross-flow wall shear stress component (τ_{wz}), (lbf/ft^2) or (N/m^2)

TWT total wall shear stress (τ_{wt}), (lbf/ft^2) or (N/m^2)

RØVB mass bleed flux (RØVB<0 denotes mass bleed), ($slug/(ft^2 \cdot sec)$) or ($kg/(m^2 \cdot sec)$)

The respective displacement and momentum thicknesses are defined by:

$$\delta_{tx} = \left| \int_0^\infty \left(1 - \frac{\rho\tilde{u}}{\rho_e\tilde{u}_e}\right) d\tilde{y} \right| \tag{39}$$

$$\delta_{tz} = \left| \int_0^\infty \left(1 - \frac{\rho\tilde{w}}{\rho_e\tilde{w}_e}\right) d\tilde{y} \right| \tag{40}$$

$$\delta_{mx} = \left| \int_0^\infty \frac{\rho\tilde{u}}{\rho_e\tilde{u}_e} \left(1 - \frac{\tilde{u}}{\tilde{u}_e}\right) d\tilde{y} \right| \tag{41}$$

$$\delta_{mz} = \left| \int_0^{\infty} \frac{\rho \tilde{w}}{\rho_e \tilde{w}_e} \left(1 - \frac{\tilde{w}}{\tilde{w}_e}\right) d\tilde{y} \right| \tag{42}$$

where $\tilde{u}$ and $\tilde{w}$ denote the velocity components in the boundary layer streamwise ($\tilde{x}$) and cross-flow ($\tilde{z}$) directions, respectively, ρ denotes density, $\tilde{y}$ denotes the normal coordinate, and the subscript e denotes boundary layer edge conditions.

In all cases, solution points with J = 1 correspond to the wall surface, and solution points with J = NA or J = NB correspond to the boundary layer edge. For the points on planes of flow symmetry, the cross-flow displacement and momentum thicknesses are output as 0.0 as is the cross-flow wall shear stress. For the initial-data surfaces and solution surfaces immediately downstream of a shock wave-wall reflection, the normal component of velocity is not computed and is output as 0.0

SECTION VI

SAMPLE CASES

1. INTRODUCTION

Four sample cases are presented in this section to illustrate the application of the computer program for calculating the flow field in supersonic mixed-compression aircraft inlets. For each of the four sample cases, a discussion of the problem is given, the required input data are presented, and selected portions of the computer output are listed. The input parameter discussions follow the order in which the input parameters are presented in Section IV.

Sample Case No. 1 considers the computation of the supersonic external flow about the forebody of a typical mixed-compression inlet at angle of attack. Sample Case No. 2 is concerned with the computation of both the supersonic external flow and the boundary layer flow for the forebody geometry considered in Sample Case No. 1. Sample Case No. 3 is concerned with the computation of the internal supersonic core flow for the Mach 3.5 inlet documented in Reference (9) at angle of attack. Sample Case No. 4 considers the computation of both the internal supersonic core flow and the boundary layer flow for the mixed-compression inlet considered in Sample Case No. 3.

It should be noted that additional sample cases may be found in Reference (3). Although Reference (3) does not discuss the boundary layer computational procedures, the discussion concerning the computation of the supersonic core flow is similar to that presented herein.

2. SAMPLE CASE NO. 1

This sample case is concerned with the computation of the supersonic external flow field about the axisymmetric forebody of a typical mixed-compression inlet at incidence. The supersonic initial-value plane is generated internally in the program using the Jones algorithm described in Section II.

The data deck for Sample Case No. 1 is presented in Figure 8. The first card of the data deck is the title card. English units are used, so KUNIT retains its default value of 1 in namelist LIST1. Since only the forebody flow field is to be computed, KCALL(2)=0 is specified in namelist LIST1, while KCALL(1) and KCALL(3) retain their default values of 1 and 0, respectively. The forebody flow integration termination point, denoted by XEND(1), is 2.0 ft, the default value. Since one plane of flow symmetry exists, KSYM is retained at its default value of 1. The molecular transport terms are not to be included in the computation, and global correction is to be performed on the bow shock wave solution points; hence, KVISCY and KSGLØB are retained at their default values of 0 and 1, respectively. Mass transfer effects are not to be included in the computation, hence KTRANS=0 is specified in namelist LIST1. For this sample case, the boundary layer computation will not be performed, thus KBLAY=0 is specified. The default value of RCAVG=0.8 ft is used for estimating the mass flow rate downstream of the bow shock wave at the cowl lip axial station. KPRINT retains its default value of 1, consequently all solution points are printed. IPRSTP and KSTART are both kept at their default values of 0, thus the execution is not terminated at a specified solution plane, nor are any restart file operations performed.

All input parameters in namelist LIST2 except for the free stream Mach number, MFS, retain their default values. Consequently, the free-stream pressure PFS and the free-stream density RØFS have values of 242.2 (lbf/ft^2) and 0.0003622 (slug/ft^3), respectively. The free-stream Mach number for this case is 2.5; hence MFS=2.5. PITCH and YAW retain their default values of 1.0 and 0.0 degrees, respectively. Thus, the specified angle of attack is 1.0 degree. The axial position of the initial-value plane, specified by the default value of XI, is 1.0 ft. Since KIVS and KCØN are both 1, the initial-value plane is internally generated and the bow shock wave is assumed to be conical (the forebody is conical). Since KSUPER retains its default value of 2, the supersonic flow initial data are generated using the Jones algorithm described in Section II. The parameter ITAP1 is not employed since the initial-value plane is generated internally (KIVS=1).

All input parameters in namelist LIST3 retain their default values. Consequently, ISTØP and JMAXI have values of 15 and 11, resepctively, so that 15 circumferential stations are employed, and 11 radial stations on the initial-value plane are specified. JLIMIT(1) and JLIMIT(2) retain their default values of 11 and 15 radial stations, respectively.

All input parameters in namelist LIST4 retain their default values. Thus, the specific heat ratio and gas constant, specified by GAMMA and R, respectively, have values of 1.4 and 1716.16116 (ft-lbf)/(slug-R), respectively. Since the molecular transport terms are not included in the computation (KVISCY=0), the input parameters VISØ, TØ, B and PR are not employed.

All input parameters in namelist LIST5 retain their default values. The default inlet geometry has a conical forebody/centerbody with a cone half-angle of 10.0 degrees. The forebody tip is located at x=0.0 ft, and the centerbody geometry is specified to x=3.5 ft. Thus, NCENT=2, KDCENT(1)=3, XCENT(1)=1.0, XCENT(2)=3.5, and CØNE=10.0. The remaining input parameters in namelist LIST5 are not employed.

Since the boundary layer computation is not invoked and mass transfer effects are not to be considered (KBLAY=0 and KTRANS=0 specified in namelist LIST1), the input parameters in namelists LIST6, LIST7, LIST8, and LIST9 do not have to be entered.

All convergence tolerances and iteration limits retain their default values in namelist LIST10.

No debug output is to be printed, hence all input parameters in namelist LIST11 retain their default values.

Selected portions of the computer output for this sample case are presented in Figure 9. The first portion of the program output presents the job title, the specified computation options, the flow symmetry option, the thermodynamic model, the vehicle orientation and free-stream data, the type of initial-value plane, certain index parameters, the centerbody and the cowl contours, and the various convergence tolerances and iteration limits. The next portion presents the internally generated initial-value plane flow property field. The final portion of the program output presents selected supersonic flow solution planes.

```
 CASE  NO.  1
&LIST1 KCALL(2)=0, KTRANS=0, KBLAY=0 &END
&LIST2 MFS=2.5 &END
&LIST3 &END
&LIST4 &END
&LIST5 &END
&LIST6 &END
&LIST7 &END
&LIST8 &END
&LIST9 &END
&LIST10 &END
&LIST11 &END
```

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Figure 8. Data deck for Sample Case No. 1.

```
THE ANALYSIS OF STEADY THREE-DIMENSIONAL FLOW IN SUPERSONIC MIXED-COMPRESSION AIRCRAFT INLETS

ABSTRACT
    THE FLOW FIELD IN A SUPERSONIC MIXED-COMPRESSION AIRCRAFT INLET IS COMPUTED USING A ZONAL ALGORITHM.
    THE SUPERSONIC CORE FLOW IS COMPUTED BY A BICHARACTERISTIC ALGORITHM WITH DISCRETE SHOCK WAVE
    FITTING.   THE BOUNDARY LAYER FLOW IS COMPUTED USING AN IMPLICIT FINITE DIFFERENCE METHOD.   THE
    FLOW IN A SHOCK WAVE-BOUNDARY LAYER INTERACTION REGION IS COMPUTED USING AN INTEGRAL ANALYSIS.

    THIS PROGRAM WAS DEVELOPED AT THE PURDUE UNIVERSITY THERMAL SCIENCES AND PROPULSION CENTER BY J. VADYAK UNDER
    SPONSORSHIP FROM THE NASA LEWIS RESEARCH CENTER.    J.D. HOFFMAN AND A.R. BISHOP SERVED AS THE
    PRINCIPAL INVESTIGATOR AND TECHNICAL MONITOR, RESPECTIVELY.

JOB TITLE
       CASE  NO.    1

SPECIFIED COMPUTATION OPTIONS
     1.) FOREBODY FLOW FIELD
     BOUNDARY LAYER COMPUTATION IS NOT INVOKED

FLOW SYMMETRY
     ONE PLANE OF SYMMETRY - COMPUTED SECTOR IS THE HALF-PLANE BOUNDED BY THE Y-AXIS AND CONTAINING THE +Z-AXIS

GLOBAL CORRECTION
     GLOBAL CORRECTION IS PERFORMED ON THE BOW SHOCK WAVE POINTS

THERMODYNAMIC MODEL
     A THERMALLY AND CALORICALLY PERFECT GAS IS SPECIFIED WITH
     SPECIFIC HEAT RATIO=1.40000          GAS CONSTANT= 0.171616E+04(FT-LBF/SLUG-DEG R)

MOLECULAR TRANSPORT TERMS FOR SUPERSONIC CORE FLOW SOLUTION
     VISCOUS AND THERMAL DIFFUSION TERMS ARE NOT INCLUDED IN THE COMPUTATION - INVISCID AND ADIABATIC FLOW IS ASSUMED

ORIENTATION AND FREE STREAM DATA
     ORIENTATION -      PITCH= 1.00000(DEGREES)          YAW= 0.00000(DEGREES)
     FREE STREAM DATA -     MACH NO.= 2.50000          PRESSURE= 0.242200E+03(LBF/FT**2)          DENSITY= 0.362200E-03(SLUG/FT**3)
```

Figure 9. Selected output for Sample Case No. 1.

```
TEMPERATURE= 0.[illegible]9644E+03(DEG R)          SONIC SPEED= 0.967598E+03(FT/SEC)

X-VELOCITY= 0.241853E+04(FT/SEC)          Y-VELOCITY= 0.422159E+02(FT/SEC)          Z-VELOCITY= 0.000000E+00(FT/SEC)


SUPERSONIC CORE FLOW INITIAL-VALUE SURFACE

     AN INTERNALLY GENERATED INITIAL VALUE SURFACE IS SPECIFIED AS BEING LOCATED AT X= 0.100000E+01(FT)

     A CONICAL BOW SHOCK WAVE IS SPECIFIED - THE INTERNALLY GENERATED SHOCK WAVE ANGLES ARE

          BETA( 1)= 0.454148E+00(RADIANS)
          BETA( 2)= 0.453814E+00(RADIANS)
          BETA( 3)= 0.452833E+00(RADIANS)
          BETA( 4)= 0.451262E+00(RADIANS)
          BETA( 5)= 0.449194E+00(RADIANS)
          BETA( 6)= 0.446747E+00(RADIANS)
          BETA( 7)= 0.444057E+00(RADIANS)
          BETA( 8)= 0.441267E+00(RADIANS)
          BETA( 9)= 0.438518E+00(RADIANS)
          BETA(10)= 0.435946E+00(RADIANS)
          BETA(11)= 0.433669E+00(RADIANS)
          BETA(12)= 0.431790E+00(RADIANS)
          BETA(13)= 0.430389E+00(RADIANS)
          BETA(14)= 0.429526E+00(RADIANS)
          BETA(15)= 0.429234E+00(RADIANS)


INDEX PARAMETERS

     ISTOP=15          IMAX=28          JMAXI=11

     JLIMIT(1)=11          JLIMIT(2)=15


INTEGRATION TERMINATION POINTS

     FOREBODY FLOW FIELD INTEGRATION TERMINATES AT X= 0.200000E+01(FT)

     FOR FOREBODY FLOW - RCAVG= 0.800000E+00(FT)


FOREBODY/CENTERBODY GEOMETRY

     CONE HALF ANGLE=10.00000(DEGREES)

     I   KDCENT      XCENT          RCENT          ACENT          BCENT          CCENT          DCENT
                     (FT)           (FT)           (FT)                          (FT**-1)       (FT**-2)

     1     3     0.100000E+01   0.600000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
     2     0     0.350000E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00


MASS TRANSFER BOUNDARY CONDITIONS
```

Figure 9. Continued.

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```
AN IMPERMEABLE FOREBODY/CENTERBODY WALL IS SPECIFIED


CONVERGENCE TOLERANCES, ITERATION LIMITS, AND OTHER PARAMETERS

    CONVERGENCE TOLERANCES AND OTHER PARAMETERS

        CRIT( 1)= 0.100000E+00
        CRIT( 2)= 0.100000E-06
        CRIT( 3)= 0.100000E-03
        CRIT( 4)= 0.100000E-04
        CRIT( 5)= 0.100000E-03
        CRIT( 6)= 0.100000E-03
        CRIT( 7)= 0.500000E+00
        CRIT( 8)= 0.100000E+01
        CRIT( 9)= 0.100000E-03
        CRIT(10)= 0.800000E+00
        CRIT(11)= 0.100000E-01
        CRIT(12)= 0.200000E+00
        CRIT(13)= 0.100000E-04
        CRIT(14)= 0.400000E+00
        CRIT(15)= 0.100000E-03
        CRIT(16)= 0.100000E-03
        CRIT(17)= 0.100000E-01
        CRIT(18)= 0.100000E-04

    ITERATION LIMITS

        ITEND(1)=10
        ITEND(2)=10
        ITEND(3)=10
        ITEND(4)=20
        ITEND(5)=10
        ITEND(6)=10
        ITEND(7)=10
        ITEND(8)=15

    INPUT SAFETY FACTOR= 0.975000E+00
```


Figure 9. Continued.

CORE FLOW INITIAL DATA PLANE X= 1.00000(FT) FOREBODY FLOW FIELD

I	J	Y (FT)	Z (FT)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
1	1	0.1763	0.0000	2.300	2327.1	330.54	0.4522E-03	425.9	2291.7	404.1	0.0	4135.8	876.7
2	1	0.1719	0.0392	2.300	2326.8	330.79	0.4525E-03	426.0	2291.4	397.1	75.9	4135.8	876.7
3	1	0.1589	0.0765	2.298	2326.1	331.53	0.4532E-03	426.3	2290.6	376.1	150.0	4135.8	876.7
4	1	0.1379	0.1099	2.296	2325.0	332.75	0.4544E-03	426.7	2289.3	340.6	220.3	4135.8	876.7
5	1	0.1099	0.1379	2.293	2323.4	334.42	0.4560E-03	427.3	2287.6	290.8	284.1	4135.8	876.7
6	1	0.0765	0.1589	2.289	2321.5	336.48	0.4580E-03	428.1	2285.5	226.6	338.1	4135.8	876.7
7	1	0.0392	0.1719	2.285	2319.2	338.86	0.4603E-03	429.0	2283.2	150.2	378.7	4135.8	876.7
8	1	0.0000	0.1763	2.280	2316.8	341.45	0.4628E-03	429.9	2280.7	63.5	402.2	4135.8	876.7
9	1	-0.0392	0.1719	2.275	2314.3	344.14	0.4654E-03	430.9	2278.3	-29.3	405.4	4135.8	876.7
10	1	-0.0765	0.1589	2.270	2311.9	346.78	0.4680E-03	431.8	2276.0	-123.0	386.2	4135.8	876.7
11	1	-0.1099	0.1379	2.265	2309.6	349.22	0.4703E-03	432.7	2274.0	-211.7	344.1	4135.8	876.7
12	1	-0.1379	0.1099	2.261	2307.7	351.30	0.4723E-03	433.4	2272.3	-289.0	280.3	4135.8	876.7
13	1	-0.1589	0.0765	2.259	2306.2	352.90	0.4739E-03	434.0	2271.0	-349.0	198.1	4135.8	876.7
14	1	-0.1719	0.0392	2.257	2305.3	353.91	0.4748E-03	434.3	2270.2	-387.2	102.6	4135.8	876.7
15	1	-0.1763	0.0000	2.256	2305.0	354.25	0.4752E-03	434.4	2270.0	-400.3	0.0	4135.8	876.7
1	2	0.2073	0.0000	2.303	2328.5	329.18	0.4509E-03	425.4	2301.4	353.9	0.0	4137.2	876.7
2	2	0.2023	0.0462	2.303	2328.2	329.43	0.4512E-03	425.5	2301.2	347.6	66.5	4137.2	876.7
3	2	0.1868	0.0900	2.301	2327.5	330.19	0.4519E-03	425.8	2300.4	328.7	131.3	4137.2	876.7
4	2	0.1620	0.1292	2.299	2326.3	331.44	0.4531E-03	426.2	2299.2	297.1	192.3	4137.1	876.7
5	2	0.1290	0.1618	2.296	2324.7	333.12	0.4548E-03	426.8	2297.7	252.9	247.1	4137.0	876.7
6	2	0.0896	0.1861	2.292	2322.8	335.18	0.4568E-03	427.6	2295.8	196.9	293.0	4136.9	876.7
7	2	0.0459	0.2011	2.287	2320.5	337.54	0.4591E-03	428.4	2293.7	130.2	327.0	4136.7	876.7
8	2	0.0000	0.2059	2.282	2318.1	340.10	0.4615E-03	429.4	2291.5	55.4	346.2	4136.6	876.7
9	2	-0.0457	0.2004	2.277	2315.7	342.72	0.4641E-03	430.3	2289.3	-24.1	347.9	4136.4	876.7
10	2	-0.0891	0.1849	2.273	2313.3	345.28	0.4665E-03	431.2	2287.2	-104.1	330.6	4136.2	876.7
11	2	-0.1278	0.1603	2.268	2311.1	347.63	0.4688E-03	432.1	2285.3	-179.4	293.9	4136.1	876.7
12	2	-0.1601	0.1277	2.265	2309.2	349.63	0.4707E-03	432.8	2283.7	-244.9	339.1	4136.0	876.7
13	2	-0.1843	0.0888	2.262	2307.8	351.16	0.4722E-03	433.3	2282.6	-295.8	148.8	4135.9	876.7
14	2	-0.1994	0.0455	2.260	2306.9	352.12	0.4731E-03	433.7	2281.8	-328.0	87.3	4135.8	876.7
15	2	-0.2045	0.0000	2.259	2306.6	352.45	0.4734E-03	433.9	2281.6	-339.1	0.0	4135.8	876.7
1	3	0.2387	0.0000	2.309	2331.4	326.08	0.4479E-03	424.2	2310.0	315.2	0.0	4137.2	876.7
2	3	0.2326	0.0531	2.309	2331.2	326.33	0.4481E-03	424.3	2309.8	309.5	59.1	4137.2	876.7
3	3	0.2148	0.1034	2.307	2330.5	327.07	0.4489E-03	424.6	2309.1	292.4	116.5	4137.2	876.7
4	3	0.1861	0.1484	2.305	2329.3	328.29	0.4500E-03	425.0	2308.0	264.0	170.3	4137.1	876.7
5	3	0.1481	0.1857	2.302	2327.8	329.93	0.4516E-03	425.7	2306.6	224.5	218.3	4137.0	876.7
6	3	0.1028	0.2134	2.298	2325.8	331.93	0.4536E-03	426.4	2304.9	174.6	258.2	4136.9	876.7
7	3	0.0526	0.2303	2.293	2323.7	334.21	0.4558E-03	427.2	2302.9	115.8	287.3	4136.8	876.7
8	3	0.0000	0.2355	2.289	2321.3	336.67	0.4582E-03	428.1	2300.9	50.1	303.3	4136.6	876.7
9	3	-0.6523	0.2290	2.284	2319.0	339.19	0.4607E-03	429.1	2298.9	-19.4	304.1	4136.4	876.7
10	3	-0.1016	0.2110	2.279	2316.7	341.63	0.4630E-03	429.9	2296.9	-89.6	288.4	4136.3	876.7
11	3	-0.1457	0.1827	2.275	2314.6	343.87	0.4652E-03	430.7	2295.2	-154.4	256.0	4136.1	876.7
12	3	-0.1823	0.1454	2.272	2312.8	345.77	0.4670E-03	431.4	2293.7	-211.1	208.0	4136.0	876.7
13	3	-0.2098	0.1010	2.269	2311.5	347.22	0.4684E-03	431.9	2292.7	-255.0	146.7	4135.9	876.7
14	3	-0.2268	0.0518	2.267	2310.6	348.12	0.4693E-03	432.3	2292.0	-282.8	75.9	4135.8	876.7
15	3	-0.2326	0.0000	2.267	2310.3	348.43	0.4696E-03	432.4	2291.8	-292.4	0.0	4135.8	876.7
1	4	0.2699	0.0000	2.317	2335.3	322.05	0.4439E-03	422.7	2318.0	283.9	0.0	4137.2	876.7
2	4	0.2630	0.0600	2.317	2335.1	322.30	0.4442E-03	422.8	2317.8	278.7	52.9	4137.2	876.7
3	4	0.2427	0.1169	2.315	2334.4	323.01	0.4449E-03	423.1	2317.2	263.2	104.2	4137.2	876.7
4	4	0.2102	0.1676	2.313	2333.3	324.18	0.4460E-03	423.5	2316.1	237.5	152.1	4137.1	876.7
5	4	0.1671	0.2096	2.310	2331.7	325.76	0.4476E-03	424.1	2314.8	201.9	194.7	4137.0	876.7
6	4	0.1159	0.2407	2.306	2329.9	327.68	0.4494E-03	424.8	2313.2	157.3	229.8	4136.9	876.7
7	4	0.0592	0.2595	2.302	2327.8	329.86	0.4516E-03	425.6	2311.4	104.8	255.2	4136.8	876.7
8	4	0.0000	0.2651	2.297	2325.6	332.20	0.4539E-03	426.5	2309.5	46.4	268.9	4136.6	876.7
9	4	-0.0588	0.2575	2.293	2323.3	334.59	0.4562E-03	427.4	2307.6	-15.1	269.1	4136.4	876.7
10	4	-0.1142	0.2371	2.288	2321.1	336.90	0.4584E-03	428.2	2305.8	-76.4	254.8	4136.3	876.7

Figure 9. Continued.

CORE FLOW INITIAL DATA PLANE X= 1.00000(FT) FOREBODY FLOW FIELD

I	J	Y (FT)	Z (FT)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
11	4	-0.1636	0.2051	2.284	2315.1	339.02	0.4605E-03	429.0	2304.2	-133.9	225.8	4136.1	876.7
12	4	-0.2046	0.1631	2.281	2317.4	340.81	0.4622E-03	429.7	2302.8	-183.7	183.2	4136.0	876.7
13	4	-0.2353	0.1133	2.278	2316.1	342.18	0.4635E-03	430.1	2301.8	-222.2	129.2	4135.9	876.7
14	4	-0.2543	0.0580	2.277	2315.3	343.03	0.4644E-03	430.5	2301.2	-246.5	66.8	4135.8	876.7
15	4	-0.2607	0.0000	2.276	2315.1	343.32	0.4646E-03	430.6	2301.0	-254.9	0.0	4135.8	876.7
1	5	0.3011	0.0000	2.326	2339.7	317.47	0.4394E-03	421.0	2325.5	257.4	0.0	4137.2	876.7
2	5	0.2934	0.0670	2.326	2339.5	317.70	0.4396E-03	421.1	2325.3	252.7	47.6	4137.2	876.7
3	5	0.2707	0.1303	2.325	2338.9	318.39	0.4403E-03	421.3	2324.8	238.6	93.6	4137.2	876.7
4	5	0.2343	0.1868	2.322	2337.8	319.50	0.4414E-03	421.8	2323.8	215.3	136.5	4137.1	876.7
5	5	0.1862	0.2335	2.319	2336.3	321.00	0.4429E-03	422.3	2322.6	183.3	174.5	4137.0	876.7
6	5	0.1290	0.2680	2.316	2334.5	322.83	0.4447E-03	423.0	2321.1	143.1	205.6	4136.9	876.7
7	5	0.0659	0.2887	2.312	2332.5	324.90	0.4467E-03	423.8	2319.4	96.0	228.0	4136.8	876.7
8	5	0.0000	0.2947	2.307	2330.4	327.11	0.4489E-03	424.6	2317.6	43.9	239.9	4136.6	876.7
9	5	-0.0653	0.2860	2.303	2328.2	329.37	0.4511E-03	425.5	2315.8	-10.9	239.7	4136.5	876.7
10	5	-0.1266	0.2632	2.299	2326.1	331.56	0.4532E-03	426.3	2314.2	-65.4	226.7	4136.3	876.7
11	5	-0.1815	0.2275	2.295	2324.2	333.55	0.4552E-03	427.0	2312.6	-116.4	200.7	4136.1	876.7
12	5	-0.2268	0.1809	2.291	2322.6	335.24	0.4568E-03	427.6	2311.4	-160.5	162.7	4136.0	876.7
13	5	-0.2608	0.1256	2.289	2321.4	336.53	0.4580E-03	428.1	2310.4	-194.5	114.7	4135.9	876.7
14	5	-0.2818	0.0643	2.287	2320.7	337.33	0.4588E-03	428.4	2309.8	-216.0	59.3	4135.8	876.7
15	5	-0.2889	0.0000	2.287	2320.4	337.60	0.4591E-03	428.5	2309.6	-223.4	0.0	4135.8	876.7
1	6	0.3323	0.0000	2.337	2344.6	312.50	0.4345E-03	419.1	2332.9	234.2	0.0	4137.2	876.7
2	6	0.3237	0.0739	2.336	2344.4	312.72	0.4347E-03	419.2	2332.7	229.9	42.8	4137.2	876.7
3	6	0.2986	0.1438	2.335	2343.9	313.37	0.4353E-03	419.4	2332.1	217.2	84.2	4137.2	876.7
4	6	0.2584	0.2060	2.333	2342.7	314.42	0.4364E-03	419.8	2331.3	196.1	122.7	4137.1	876.7
5	6	0.2052	0.2574	2.330	2341.3	315.84	0.4378E-03	420.4	2330.1	167.2	156.6	4137.0	876.7
6	6	0.1422	0.2952	2.326	2339.6	317.57	0.4395E-03	421.0	2328.7	131.0	184.4	4136.9	876.7
7	6	0.0726	0.3179	2.322	2337.7	319.52	0.4414E-03	421.8	2327.1	88.8	204.2	4136.8	876.7
8	6	0.0000	0.3243	2.318	2335.7	321.62	0.4435E-03	422.6	2325.4	42.1	214.6	4136.6	876.7
9	6	-0.0718	0.3146	2.314	2333.6	322.75	0.4456E-03	423.4	2323.8	-6.9	214.2	4136.5	876.7
10	6	-0.1393	0.2893	2.310	2331.6	325.81	0.4476E-03	424.2	2322.2	-55.5	202.4	4136.3	876.7
11	6	-0.1993	0.2500	2.306	2329.8	327.68	0.4494E-03	424.9	2320.7	-100.9	179.1	4136.1	876.7
12	6	-0.2491	0.1986	2.303	2328.3	329.27	0.4510E-03	425.4	2319.6	-140.1	145.1	4136.0	876.7
13	6	-0.2862	0.1378	2.301	2327.1	330.47	0.4521E-03	425.9	2318.7	-170.4	102.2	4135.9	876.7
14	6	-0.3092	0.0706	2.299	2326.4	331.23	0.4529E-03	426.2	2318.1	-189.5	52.8	4135.8	876.7
15	6	-0.3170	0.0000	2.299	2326.2	331.48	0.4531E-03	426.3	2317.9	-196.0	0.0	4135.8	876.7
1	7	0.3634	0.0000	2.348	2349.9	307.15	0.4292E-03	417.0	2340.2	213.1	0.0	4137.3	876.7
2	7	0.3541	0.0808	2.347	2349.7	307.35	0.4294E-03	417.1	2340.0	209.3	38.4	4137.3	876.7
3	7	0.3266	0.1573	2.346	2349.1	307.97	0.4300E-03	417.4	2339.5	197.8	75.5	4137.3	876.7
4	7	0.2845	0.2253	2.344	2348.1	308.97	0.4310E-03	417.7	2338.7	178.9	109.9	4137.2	876.7
5	7	0.2243	0.2813	2.341	2346.8	310.30	0.4323E-03	418.3	2337.6	152.8	140.2	4137.1	876.7
6	7	0.1553	0.3225	2.338	2345.1	311.93	0.4339E-03	418.9	2336.2	120.4	165.0	4137.0	876.7
7	7	0.0792	0.3471	2.334	2343.3	313.77	0.4357E-03	419.6	2334.8	82.6	182.6	4136.9	876.7
8	7	0.0000	0.3539	2.330	2341.4	315.74	0.4377E-03	420.4	2333.2	40.8	191.7	4136.7	876.7
9	7	-0.0783	0.3431	2.326	2339.4	317.74	0.4397E-03	421.1	2331.6	-2.9	191.2	4136.5	876.7
10	7	-0.1519	0.3154	2.322	2337.5	319.67	0.4416E-03	421.9	2330.1	-46.3	180.6	4136.4	876.7
11	7	-0.2172	0.2724	2.318	2335.8	321.43	0.4433E-03	422.5	2328.8	-86.7	159.7	4136.2	876.7
12	7	-0.2713	0.2164	2.315	2334.4	322.92	0.4447E-03	423.1	2327.6	-121.6	129.3	4136.1	876.7
13	7	-0.3117	0.1501	2.313	2333.3	324.05	0.4458E-03	423.5	2326.8	-148.5	91.0	4136.0	876.7
14	7	-0.3367	0.0768	2.312	2332.6	324.75	0.4465E-03	423.8	2326.3	-165.5	47.0	4135.9	876.7
15	7	-0.3451	0.0000	2.311	2332.4	324.99	0.4468E-03	423.9	2326.1	-171.3	0.0	4135.9	876.7
1	8	0.3946	0.0000	2.360	2355.6	301.43	0.4234E-03	414.8	2347.6	193.4	0.0	4137.3	876.7
2	8	0.3844	0.0877	2.359	2355.4	301.62	0.4236E-03	414.9	2347.5	190.0	34.2	4137.3	876.7
3	8	0.3545	0.1707	2.358	2354.8	302.20	0.4242E-03	415.1	2347.0	179.8	67.2	4137.3	876.7
4	8	0.3066	0.2445	2.356	2353.9	303.13	0.4251E-03	415.5	2346.2	162.8	97.9	4137.2	876.7
5	8	0.2434	0.3052	2.353	2352.6	304.38	0.4264E-03	416.0	2345.2	139.6	124.8	4137.1	876.7

Figure 9. Continued.

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CORE FLOW INITIAL DATA PLANE X= 1.00000(FT) FOREBODY FLOW FIELD

I	J	Y (FT)	Z (FT)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
6	8	0.1684	0.3498	2.350	2351.1	305.91	0.4279E-03	416.6	2343.9	110.7	146.8	4137.0	876.7
7	8	0.0859	0.3762	2.347	2349.4	307.63	0.4296E-03	417.2	2342.5	77.0	162.4	4136.9	876.7
8	8	0.0000	0.3835	2.343	2347.6	309.47	0.4315E-03	418.0	2341.0	30.9	170.4	4136.7	876.7
9	8	-0.0848	0.3716	2.339	2345.7	311.34	0.4333E-03	418.7	2339.5	1.0	169.9	4136.5	876.7
10	8	-0.1644	0.3415	2.335	2343.9	313.14	0.4351E-03	419.4	2338.1	-37.5	160.3	4136.4	876.7
11	8	-0.2351	0.2948	2.332	2342.3	314.78	0.4367E-03	420.0	2336.9	-73.3	141.7	4136.2	876.7
12	8	-0.2935	0.2361	2.329	2340.9	316.17	0.4381E-03	420.5	2335.8	-104.3	114.8	4136.1	876.7
13	8	-0.3372	0.1624	2.327	2339.9	317.22	0.4391E-03	420.9	2335.0	-128.1	80.8	4136.0	876.7
14	8	-0.3642	0.0831	2.325	2339.3	317.88	0.4398E-03	421.2	2334.5	-143.2	41.7	4135.9	876.7
15	8	-0.3733	0.0000	2.325	2339.0	318.10	0.4400E-03	421.3	2334.3	-148.3	0.0	4135.9	876.7
1	9	0.4258	0.0000	2.374	2362.1	294.93	0.4169E-03	412.2	2355.8	173.7	0.0	4137.3	876.7
2	9	0.4148	0.0947	2.373	2362.0	295.12	0.4171E-03	412.3	2355.6	170.7	29.9	4137.3	876.7
3	9	0.3825	0.1842	2.372	2361.4	295.65	0.4176E-03	412.5	2355.1	161.7	58.8	4137.3	876.7
4	9	0.3307	0.2637	2.370	2360.5	296.52	0.4185E-03	412.9	2354.4	146.9	85.6	4137.2	876.7
5	9	0.2624	0.3291	2.368	2359.3	297.69	0.4197E-03	413.3	2353.4	126.6	109.2	4137.1	876.7
6	9	0.1816	0.3771	2.364	2357.9	299.11	0.4211E-03	413.9	2352.2	101.3	128.4	4137.0	876.7
7	9	0.0925	0.4054	2.361	2356.3	300.72	0.4227E-03	414.5	2350.9	71.8	142.1	4136.9	876.7
8	9	0.0000	0.4131	2.357	2354.5	302.43	0.4244E-03	415.2	2349.5	39.3	149.1	4136.7	876.7
9	9	-0.0913	0.4002	2.354	2352.8	304.17	0.4262E-03	415.9	2348.1	5.3	148.7	4136.5	876.7
10	9	-0.1770	0.3675	2.350	2351.1	305.85	0.4278E-03	416.6	2346.7	-28.4	140.4	4136.4	876.7
11	9	-0.2530	0.3172	2.347	2349.6	307.38	0.4294E-03	417.2	2345.5	-59.9	124.1	4136.2	876.7
12	9	-0.3158	0.2518	2.344	2348.3	308.67	0.4306E-03	417.7	2344.5	-87.0	100.5	4136.1	876.7
13	9	-0.3627	0.1747	2.342	2347.3	309.65	0.4316E-03	418.0	2343.8	-107.9	70.7	4136.0	876.7
14	9	-0.3916	0.0894	2.341	2346.7	310.26	0.4322E-03	418.3	2343.3	-121.1	36.5	4135.9	876.7
15	9	-0.4014	0.0000	2.340	2346.5	310.47	0.4324E-03	418.4	2343.1	-125.6	0.0	4135.9	876.7
1	10	0.4570	0.0000	2.391	2370.1	287.17	0.4090E-03	409.1	2365.2	152.3	0.0	4137.3	876.7
2	10	0.4452	0.1016	2.390	2369.9	287.34	0.4092E-03	409.2	2365.0	149.8	25.2	4137.3	876.7
3	10	0.4104	0.1976	2.389	2369.4	287.83	0.4097E-03	409.4	2364.6	142.3	49.6	4137.3	876.7
4	10	0.3548	0.2829	2.387	2368.6	288.64	0.4105E-03	409.7	2363.9	129.8	72.2	4137.2	876.7
5	10	0.2815	0.3530	2.385	2367.4	289.73	0.4116E-03	410.1	2363.0	112.8	92.2	4137.1	876.7
6	10	0.1947	0.4043	2.382	2366.1	291.04	0.4129E-03	410.7	2361.8	91.4	108.6	4137.0	876.7
7	10	0.0992	0.4346	2.379	2364.6	292.53	0.4145E-03	411.3	2360.6	66.5	120.3	4136.9	876.7
8	10	0.0000	0.4427	2.375	2362.9	294.12	0.4161E-03	411.9	2359.2	39.0	126.4	4136.7	876.7
9	10	-0.0978	0.4287	2.372	2361.3	295.73	0.4177E-03	412.6	2357.9	10.1	126.2	4136.5	876.7
10	10	-0.1896	0.3936	2.368	2359.7	297.28	0.4192E-03	413.2	2356.6	-18.8	11[illegible]	4136.4	876.7
11	10	-0.2708	0.3396	2.365	2358.3	298.70	0.4207E-03	413.8	2355.5	-45.3	105.[illegible]	4136.2	876.7
12	10	-0.3380	0.2696	2.363	2357.0	299.89	0.4219E-03	414.2	2354.5	-68.4	85.[illegible]	4136.1	876.7
13	10	-0.3882	0.1869	2.361	2356.1	300.80	0.4228E-03	414.6	2353.8	-86.3	60.2	4136.0	876.7
14	10	-0.4191	0.0957	2.360	2355.6	301.36	0.4233E-03	414.8	2353.3	-97.6	31.1	4135.9	876.7
15	10	-0.4296	0.0000	2.359	2355.4	301.55	0.4235E-03	414.9	2353.2	-101.4	0.0	4135.9	876.7
1	D	0.4882	0.0000	2.417	2382.2	275.55	0.3971E-03	404.3	2379.0	123.1	0.0	4137.3	876.7
2	D	0.4750	0.1085	2.417	2382.1	275.71	0.3973E-03	404.4	2378.9	121.3	18.7	4137.3	876.7
3	D	0.4384	0.2111	2.416	2381.6	276.18	0.3978E-03	404.6	2378.4	115.9	36.8	4137.3	876.7
4	D	0.3789	0.3022	2.414	2380.7	276.95	0.3986E-03	404.9	2377.7	106.9	53.9	4137.2	876.7
5	D	0.3006	0.3769	2.411	2379.6	277.99	0.3996E-03	405.3	2376.8	94.5	69.1	4137.1	876.7
6	D	0.2079	0.4316	2.409	2378.3	279.24	0.4009E-03	405.8	2375.6	78.7	81.9	4137.0	876.7
7	D	0.1059	0.4638	2.405	2376.8	280.65	0.4024E-03	406.4	2374.3	60.0	91.2	4136.9	876.7
8	D	0.0000	0.4723	2.402	2375.2	282.16	0.4039E-03	407.1	2373.0	39.1	96.5	4136.7	876.7
9	D	-0.1044	0.4572	2.398	2373.6	283.69	0.4055E-03	407.7	2371.6	16.9	96.8	4136.5	876.7
10	D	-0.2021	0.4197	2.395	2372.1	285.16	0.4070E-03	408.3	2370.3	-5.3	92.0	4136.4	876.7
11	D	-0.2887	0.3620	2.392	2370.7	286.49	0.4083E-03	408.9	2369.2	-26.3	81.7	4136.2	876.7
12	D	-0.3603	0.2873	2.389	2369.5	287.62	0.4095E-03	409.3	2368.2	-44.5	66.5	4136.1	876.7
13	D	-0.4136	0.1992	2.387	2368.7	288.47	0.4103E-03	409.7	2367.5	-58.6	46.9	4136.0	876.7
14	D	-0.4466	0.1019	2.386	2368.1	289.01	0.4109E-03	409.9	2367.0	-67.6	24.3	4135.9	876.7
15	D	-0.4577	0.0000	2.386	2367.9	289.19	0.4110E-03	410.0	2366.9	-70.7	0.0	4135.9	876.7

MASS FLOW RATE FOR ENTIRE PLANE= 0.60975E+00(SLUG/SEC)

Figure 9. Continued.

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X-STEP REGULATION PARAMETERS
LIMITING POINT - I=15, J= 1        SAFETY FACTOR= 0.975000E+00        DELTA-X= 0.491170E-01(FT)
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Figure 9. Continued.

C-2

CORE FLOW SOLUTION PLANE NO. 4 X= 1.28954(FT) FOREBODY FLOW FIELD

I	J	Y (FT)	Z (FT)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)	ITG	ITL
1	1	0.2274	0.0000	2.306	2329.8	327.24	0.4490E-03	424.7	2294.4	404.6	0.0	4133.2	876.5	1	2
2	1	0.2221	0.0487	2.306	2329.6	327.46	0.4492E-03	424.8	2294.2	397.8	74.5	4133.1	876.5	1	2
3	1	0.2065	0.0953	2.305	2328.9	328.12	0.4498E-03	425.0	2293.4	377.4	147.2	4133.0	876.5	1	2
4	1	0.1811	0.1375	2.303	2327.9	329.22	0.4509E-03	425.4	2292.2	343.2	216.4	4132.9	876.5	1	2
5	1	0.1470	0.1735	2.300	2326.4	330.74	0.4524E-03	426.0	2290.6	294.9	279.5	4132.7	876.5	1	2
6	1	0.1056	0.2014	2.296	2324.6	332.64	0.4543E-03	426.7	2288.7	232.9	333.6	4132.4	876.5	1	2
7	1	0.0588	0.2197	2.292	2322.4	334.87	0.4564E-03	427.5	2286.5	158.1	375.0	4132.2	876.5	1	2
8	1	0.0086	0.2272	2.287	2320.0	337.36	0.4589E-03	428.4	2284.1	72.8	400.3	4131.9	876.5	1	2
9	1	-0.0424	0.2234	2.282	2317.5	339.99	0.4614E-03	429.4	2281.6	-19.6	405.8	4131.6	876.4	1	2
10	1	-0.0916	0.2081	2.277	2315.0	342.62	0.4640E-03	430.3	2279.3	-114.0	388.9	4131.4	876.4	1	2
11	1	-0.1364	0.1819	2.272	2312.7	345.09	0.4663E-03	431.2	2277.1	-204.5	348.5	4131.2	876.4	1	2
12	1	-0.1744	0.1459	2.268	2310.7	347.24	0.4684E-03	432.0	2275.3	-284.3	285.4	4131.1	876.4	1	2
13	1	-0.2032	0.1020	2.265	2309.1	348.92	0.4700E-03	432.6	2273.9	-346.9	202.6	4130.9	876.4	1	2
14	1	-0.2212	0.0525	2.263	2308.1	349.98	0.4710E-03	432.9	2273.0	-387.0	105.2	4130.9	876.4	1	2
15	1	-0.2274	0.0000	2.262	2307.8	350.34	0.4714E-03	433.1	2272.7	-400.7	0.0	4130.8	876.4	1	2
1	2	0.2795	0.0000	2.312	2332.8	324.67	0.4465E-03	423.7	2308.7	334.8	0.0	4137.4	876.7	1	2
2	2	0.2727	0.0606	2.312	2332.6	324.89	0.4467E-03	423.8	2308.4	329.2	61.2	4137.4	876.7	1	2
3	2	0.2527	0.1183	2.310	2332.0	325.57	0.4474E-03	424.0	2307.8	312.3	120.9	4137.4	876.7	1	2
4	2	0.2204	0.1702	2.308	2330.9	326.68	0.4485E-03	424.4	2306.7	283.9	177.4	4137.4	876.7	1	2
5	2	0.1775	0.2137	2.305	2329.4	328.19	0.4500E-03	425.0	2305.3	244.1	228.8	4137.2	876.7	1	2
6	2	0.1259	0.2468	2.302	2327.6	330.06	0.4518E-03	425.7	2303.5	193.1	272.6	4137.1	876.7	1	2
7	2	0.0681	0.2676	2.297	2325.6	332.23	0.4539E-03	426.5	2301.6	131.9	306.0	4137.0	876.7	1	2
8	2	0.0071	0.2751	2.293	2323.3	334.62	0.4562E-03	427.4	2299.5	62.4	326.0	4136.9	876.7	1	3
9	2	-0.0543	0.2689	2.288	2321.0	337.10	0.4586E-03	428.3	2297.4	-12.7	330.0	4136.7	876.7	1	3
10	2	-0.1129	0.2491	2.283	2318.6	339.56	0.4610E-03	429.2	2295.3	-89.2	315.9	4136.5	876.7	1	3
11	2	-0.1657	0.2167	2.279	2316.5	341.84	0.4632E-03	430.0	2293.4	-162.4	282.8	4136.4	876.7	1	3
12	2	-0.2100	0.1731	2.275	2314.7	343.82	0.4651E-03	430.7	2291.9	-226.9	231.4	4136.4	876.7	1	3
13	2	-0.2434	0.1207	2.272	2313.3	345.34	0.4666E-03	431.3	2290.7	-277.5	164.2	4136.3	876.7	1	3
14	2	-0.2642	0.0619	2.271	2312.4	346.30	0.4675E-03	431.6	2289.9	-309.8	85.2	4136.2	876.7	1	3
15	2	-0.2713	0.0000	2.270	2312.1	346.63	0.4678E-03	431.7	2289.7	-320.9	0.0	4136.2	876.7	1	3
1	3	0.3352	0.0000	2.322	2337.5	319.83	0.4417E-03	421.9	2319.8	286.9	0.0	4137.3	876.7	1	2
2	3	0.3269	0.0732	2.321	2337.3	320.05	0.4420E-03	422.0	2319.6	281.9	52.5	4137.2	876.7	1	2
3	3	0.3024	0.1427	2.320	2336.5	320.70	0.4426E-03	422.2	2319.0	267.0	103.5	4137.2	876.7	1	2
4	3	0.2630	0.2049	2.318	2335.6	321.75	0.4436E-03	422.6	2318.1	242.0	151.4	4137.2	876.7	1	2
5	3	0.2107	0.2567	2.315	2334.2	323.18	0.4450E-03	423.1	2316.9	207.4	194.4	4137.1	876.7	1	2
6	3	0.1483	0.2954	2.312	2332.5	324.93	0.4467E-03	423.8	2315.4	163.4	230.5	4137.0	876.7	1	2
7	3	0.0789	0.3192	2.308	2330.6	326.93	0.4487E-03	424.6	2313.7	111.3	257.3	4136.9	876.7	1	2
8	3	0.0060	0.3270	2.303	2328.5	329.11	0.4508E-03	425.4	2311.9	52.8	272.7	4136.8	876.7	1	2
9	3	-0.0666	0.3185	2.299	2326.4	331.35	0.4530E-03	426.2	2310.1	-9.7	274.5	4136.7	876.7	1	3
10	3	-0.1355	0.2940	2.295	2324.3	333.55	0.4552E-03	427.0	2308.4	-72.9	261.5	4136.5	876.7	1	2
11	3	-0.1972	0.2549	2.291	2322.4	335.58	0.4571E-03	427.8	2306.8	-132.7	233.1	4136.4	876.7	1	2
12	3	-0.2487	0.2032	2.288	2320.7	337.32	0.4588E-03	428.4	2305.5	-185.1	190.1	4136.3	876.7	1	2
13	3	-0.2874	0.1413	2.285	2319.5	338.65	0.4601E-03	428.9	2304.5	-226.0	134.5	4136.2	876.7	1	2
14	3	-0.3114	0.0725	2.283	2318.7	339.49	0.4609E-03	429.2	2303.9	-252.0	69.7	4136.0	876.7	1	2
15	3	-0.3195	0.0000	2.283	2318.4	339.78	0.4612E-03	429.3	2303.7	-260.9	0.0	4136.1	876.7	1	2
1	4	0.3924	0.0000	2.332	2342.4	314.80	0.4368E-03	420.0	2329.0	250.0	0.0	4137.5	876.7	1	2
2	4	0.3826	0.0861	2.331	2342.2	315.02	0.4370E-03	420.1	2328.8	245.6	45.3	4137.4	876.7	1	2
3	4	0.3535	0.1676	2.330	2341.5	315.67	0.4376E-03	420.3	2328.3	232.4	89.3	4137.4	876.7	1	2
4	4	0.3069	0.2404	2.328	2340.5	316.72	0.4387E-03	420.7	2327.3	210.7	130.5	4137.2	876.7	1	2
5	4	0.2452	0.3006	2.325	2339.1	318.14	0.4401E-03	421.3	2326.1	180.4	167.3	4137.1	876.7	1	2
6	4	0.1718	0.3453	2.322	2337.4	319.86	0.4418E-03	421.9	2324.7	142.4	197.8	4137.0	876.7	1	2
7	4	0.0905	0.3724	2.318	2335.5	321.83	0.4437E-03	422.7	2323.1	97.5	220.3	4137.0	876.7	1	3
8	4	0.0055	0.3807	2.313	2333.5	323.94	0.4458E-03	423.4	2321.4	47.3	232.8	4137.0	876.7	1	3
9	4	-0.0789	0.3699	2.309	2331.4	326.10	0.4479E-03	424.3	2319.7	-6.0	233.7	4136.9	876.7	1	3
10	4	-0.1586	0.3407	2.305	2329.4	328.20	0.4499E-03	425.0	2318.0	-59.5	222.0	4136.7	876.7	1	3

Figure 9. Continued.

CORE FLOW SOLUTION PLANE NO. 4   X= 1.28954(FT)   FOREBODY FLOW FIELD

I	J	Y (FT)	Z (FT)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)	ITG	ITL
11	4	-0.2297	0.2949	2.301	2327.6	330.12	0.4518E-03	425.7	2316.6	-109.9	197.4	4136.5	876.7	1	3
12	4	-0.2888	0.2347	2.298	2326.0	331.75	0.4534E-03	426.4	2315.3	-153.9	160.6	4136.4	876.7	1	3
13	4	-0.3331	0.1630	2.296	2324.8	332.99	0.4546E-03	426.8	2314.4	-188.1	113.5	4136.3	876.7	1	3
14	4	-0.3605	0.0835	2.294	2324.1	333.77	0.4554E-03	427.1	2313.8	-209.8	58.8	4136.1	876.7	1	3
15	4	-0.3698	0.0000	2.294	2323.8	334.03	0.4556E-03	427.2	2313.6	-217.2	0.0	4136.1	876.7	1	3
1	5	0.4505	0.0000	2.341	2346.9	310.14	0.4321E-03	418.2	2336.6	219.8	0.0	4137.5	876.7	1	3
2	5	0.4391	0.0951	2.341	2346.7	310.35	0.4324E-03	418.3	2336.4	215.9	39.4	4137.5	876.7	1	3
3	5	0.4054	0.1928	2.340	2346.1	310.98	0.4330E-03	418.5	2335.9	204.4	77.5	4137.4	876.7	1	3
4	5	0.3515	0.2763	2.338	2345.1	312.00	0.4340E-03	419.9	2335.0	185.2	113.1	4137.3	876.7	1	3
5	5	0.2803	0.3451	2.335	2343.7	313.37	0.4354E-03	419.4	2333.9	158.8	144.6	4137.1	876.7	1	3
6	5	0.1958	0.3960	2.331	2342.1	315.04	0.4370E-03	420.1	2332.5	125.7	170.7	4137.0	876.7	1	3
7	5	0.1024	0.4264	2.327	2340.2	316.94	0.4389E-03	420.8	2330.9	86.8	189.6	4137.0	876.7	1	3
8	5	0.0051	0.4352	2.323	2338.2	318.98	0.4409E-03	421.6	2329.3	43.5	199.9	4136.9	876.7	1	3
9	5	-0.0913	0.4222	2.319	2336.2	321.07	0.4430E-03	422.4	2327.6	-2.1	200.2	4136.8	876.7	1	3
10	5	-0.1819	0.3884	2.315	2334.3	323.09	0.4449E-03	423.1	2326.0	-47.8	189.7	4136.6	876.7	1	3
11	5	-0.2626	0.3357	2.311	2332.5	324.93	0.4467E-03	423.8	2324.6	-90.6	168.4	4136.4	876.7	1	3
12	5	-0.3295	0.2668	2.308	2331.0	326.49	0.4483E-03	424.4	2323.4	-127.9	136.8	4136.3	876.7	1	3
13	5	-0.3796	0.1852	2.306	2329.8	327.68	0.4494E-03	424.8	2322.5	-156.8	96.5	4136.2	876.7	1	3
14	5	-0.4105	0.0949	2.305	2329.1	328.43	0.4502E-03	425.1	2322.0	-175.1	49.9	4136.1	876.7	1	3
15	5	-0.4210	0.0000	2.304	2328.8	328.68	0.4504E-03	425.2	2321.8	-181.4	0.0	4136.1	876.7	1	3
1	6	0.5217	0.0000	2.362	2356.6	300.47	0.4224E-03	414.5	2349.3	185.0	0.0	4136.6	876.8	1	3
2	6	0.5084	0.1148	2.361	2356.4	300.66	0.4226E-03	414.5	2349.1	181.8	32.2	4136.6	876.8	1	3
3	6	0.4694	0.2234	2.360	2355.8	301.22	0.4232E-03	414.8	2348.7	172.2	63.4	4136.5	876.7	1	3
4	6	0.4069	0.3201	2.358	2354.9	302.12	0.4241E-03	415.1	2347.9	156.3	92.3	4136.4	876.7	1	3
5	6	0.3244	0.3998	2.355	2353.7	303.33	0.4253E-03	415.6	2346.9	134.5	117.9	4136.4	876.7	1	3
6	6	0.2265	0.4587	2.352	2352.2	304.80	0.4268E-03	416.2	2345.7	107.3	138.7	4136.3	876.7	1	3
7	6	0.1183	0.4939	2.349	2350.5	306.48	0.4284E-03	416.8	2344.3	75.6	153.7	4136.2	876.8	1	3
8	6	0.0056	0.5040	2.345	2348.8	308.27	0.4302E-03	417.5	2342.9	40.5	161.5	4136.2	876.8	1	3
9	6	-0.1060	0.4890	2.341	2347.0	310.09	0.4320E-03	418.2	2341.4	3.6	161.3	4136.2	876.8	1	4
10	6	-0.2110	0.4498	2.338	2345.2	311.85	0.4338E-03	418.9	2340.0	-33.0	152.5	4136.1	876.8	1	3
11	6	-0.3064	0.3887	2.334	2343.6	313.46	0.4354E-03	419.5	2338.8	-67.3	135.1	4136.0	876.8	1	3
12	6	-0.3818	0.3069	2.332	2342.3	314.82	0.4367E-03	420.1	2337.7	-96.9	109.5	4135.9	876.7	1	3
13	6	-0.4397	0.2144	2.329	2341.3	315.86	0.4377E-03	420.4	2336.9	-119.9	77.2	4135.9	876.7	1	3
14	6	-0.4755	0.1098	2.328	2340.7	316.51	0.4384E-03	420.7	2336.5	-134.4	39.9	4135.9	876.8	1	3
15	6	-0.4876	0.0000	2.328	2340.4	316.73	0.4386E-03	420.8	2336.3	-139.3	0.0	4135.8	876.8	1	3
1	D	0.6294	0.0000	2.418	2382.8	274.98	0.3965E-03	404.1	2379.7	121.8	0.0	4137.4	876.7	1	3
2	D	0.6134	0.1385	2.418	2382.7	275.14	0.3967E-03	404.1	2379.6	120.1	18.2	4137.3	876.7	1	3
3	D	0.5665	0.2696	2.417	2382.2	275.61	0.3972E-03	404.3	2379.1	114.9	35.9	4137.3	876.7	1	3
4	D	0.4912	0.3863	2.415	2381.3	276.39	0.3980E-03	404.7	2378.4	106.3	52.6	4137.2	876.7	1	3
5	D	0.3917	0.4827	2.413	2380.2	277.44	0.3991E-03	405.1	2377.4	94.3	67.7	4137.2	876.7	1	3
6	D	0.2735	0.5540	2.410	2378.9	278.71	0.4004E-03	405.6	2376.2	79.0	80.4	4137.1	876.7	1	3
7	D	0.1429	0.5967	2.406	2377.4	280.16	0.4019E-03	406.2	2374.9	60.8	89.9	4136.9	876.7	1	3
8	D	0.0067	0.6092	2.403	2375.7	281.70	0.4034E-03	406.9	2373.5	40.2	95.5	4136.8	876.7	1	3
9	D	-0.1282	0.5911	2.399	2374.1	283.26	0.4050E-03	407.5	2372.1	18.2	96.2	4136.6	876.7	1	3
10	D	-0.2552	0.5439	2.396	2372.5	284.77	0.4066E-03	408.1	2370.7	-4.0	91.7	4136.4	876.7	1	3
11	D	-0.3682	0.4702	2.393	2371.1	286.15	0.4080E-03	408.7	2369.5	-25.1	81.7	4136.3	876.7	1	3
12	D	-0.4619	0.3738	2.390	2369.9	287.32	0.4091E-03	409.2	2368.5	-43.5	66.7	4136.1	876.7	1	3
13	D	-0.5321	0.2595	2.388	2368.9	288.21	0.4100E-03	409.6	2367.8	-57.9	47.2	4136.0	876.7	1	3
14	D	-0.5755	0.1329	2.387	2368.4	288.76	0.4106E-03	409.8	2367.3	-67.0	24.4	4135.9	876.7	1	3
15	D	-0.5901	0.0000	2.386	2368.2	288.95	0.4108E-03	409.9	2367.1	-70.2	0.0	4135.9	876.7	1	3

MASS FLOW RATE FOR ENTIRE PLANE= 0.10101E+01(SLUG/SEC)

COURANT NUMBER= 1.00008

X-STEP REGULATION PARAMETERS

Figure 9. Continued.

LIMITING POINT - I=15, J= 1   SAFETY FACTOR= 0.999414E+00   DELTA-X= 0.789007E-01(FT)

Figure 9. Concluded.

3. SAMPLE CASE NO. 2

This sample case is concerned with the computation of both the supersonic external flow and the boundary layer flow for the forebody geometry considered in Sample Case No. 1. Both the supersonic flow initial data and the boundary layer flow initial data are generated internally in the program.

The data deck for Sample Case No. 2 is presented in Figure 10. Again, the first card of the data deck is the title card.

Namelist LIST1 for Sample Case No. 2 is identical to that for Sample Case No. 1 except for the value of KBLAY. Since in the present case, the boundary layer is to be computed, KBLAY is retained at its default value of 1.

Namelists LIST2, LIST3, LIST4, and LIST5 for Sample Case No. 2 are identical to those specified in Sample Case No. 1.

All input parameters in namelist LIST6 retain their default values except for FACTØR and CLENGH. As a consequence, KBLIDA and KTURB retain their default values of 1 and 0, respectively. Thereby, the forebody boundary layer initial data are generated internally and laminar flow is specified. CLENGH is specified as 3.5 ft, the value to which the forebody geometry is specified. The Adams program input parameters ADY and ARATIØ are retained at their default values of 0.010 and 1.0630, respectively. Since the boundary layer initial data are being internally generated, the input parameter XASTRT, which denotes the position of the initial data surface, does not have to be entered but rather is computed internally. Likewise, the input parameter ITAP2 is not specified. MBLAY and NA are retained at their default values of 15 and 20, respectively. Hence, 15 circumferential and 20 radial stations are used in the forebody boundary layer calculation. The boundary layer normal coordinate stretching factor is selected as 1.10; hence, FACTOR(1)=1.10 is specified in namelist LIST6. Note that since the cowl boundary layer computation is not invoked, the cowl boundary layer input parameters do not have to be specified.

All input parameters in namelist LIST7 retain their default values except for TCØNSTA. Consequently, KTYPE retains its default value of 1, which specifies that a wall temperature rather than temperature derivative boundary condition will be used in the boundary layer computation. The input parameter KWLTA retains its default of 1, hence a constant wall temperature boundary condition will be employed. Since KWLTA is specified, the wall temperature is specified by entering TCØNSTA, which has been selected as 876.7 R, the free-stream stagnation temperature. The other input parameters for the forebody boundary layer computation (DTDYCA, NTABA, XWLA, TWLA, and DTDYWA) are not used and hence are not specified. The input parameters in namelist LIST7 used for the cowl boundary layer computation are not entered.

All input parameters in namelist LIST8 retain their default values, thereby specifying a case with no wall mass bleed. The input parameter KDFA is left at its default value of 0, which specifies an impermeable forebody/centerbody wall. The other input parameters in namelist LIST8 used for specification of the forebody/centerbody mass bleed distribution (NRA, XSA, XEA, and RØVA) do not have to be entered. Since the cowl boundary layer computation is not invoked, the mass bleed input parameters used for the cowl boundary layer need not be entered.

All input parameters in namelist LIST9 retain their default values except for XT1. Consequently, the turbulence model parameters APLUS, XKAPPA, XALPHA, PRT, TFACTR, AKLM, and ALAM are left at their default values. The default transition model, denoted by ITRANM(1)=5, is retrained. This transition model requires that the input parameter array XT1 be entered. For this sample case, laminar flow has been specified as existing over the entire length of the forebody. This is accomplished by specifying the onset transition location for each circumferential station as being equal to 20.0 ft, hence XT1(1,1)=16*20.0. The other input parameters in namelist LIST9 do not have to be entered.

All convergence tolerances and iteration limits retain their default values in namelist LIST10.

No debug output is to be printed, hence all input parameters in namelist LIST11 retain their default values.

Selected portions of the computed output for Sample Case No. 2 are presented in Figure 11.

```
 CASE  NO.  2
&LIST1 KCALL(2)=0, KTRANS=0 &END
&LIST2 MFS=2.5 &END
&LIST3 &END
&LIST4 &END
&LIST5 &END
&LIST6 FACTOR(1)=1.10, CLENGH=3.5 &END
&LIST7 TCONSTA=876.7 &END
&LIST8 &END
&LIST9 XT1(1,1)=16*20.0 &END
&LIST10 &END
&LIST11 &END
```


Figure 10. Data deck for Sample Case No. 2.

```
THE ANALYSIS OF STEADY THREE-DIMENSIONAL FLOW IN SUPERSONIC MIXED-COMPRESSION AIRCRAFT INLETS

ABSTRACT
     THE FLOW FIELD IN A SUPERSONIC MIXED-COMPRESSION AIRCRAFT INLET IS COMPUTED USING A ZONAL ALGORITHM.
     THE SUPERSONIC CORE FLOW IS COMPUTED BY A BICHARACTERISTIC ALGORITHM WITH DISCRETE SHOCK WAVE
     FITTING.   THE BOUNDARY LAYER FLOW IS COMPUTED USING AN IMPLICIT FINITE DIFFERENCE METHOD.   THE
     FLOW IN A SHOCK WAVE-BOUNDARY LAYER INTERACTION REGION IS COMPUTED USING AN INTEGRAL ANALYSIS.

     THIS PROGRAM WAS DEVELOPED AT THE PURDUE UNIVERSITY THERMAL SCIENCES AND PROPULSION CENTER BY J. VADYAK UNDER
     SPONSORSHIP FROM THE NASA LEWIS RESEARCH CENTER.   J.D. HOFFMAN AND A.R. BISHOP SERVED AS THE
     PRINCIPAL INVESTIGATOR AND TECHNICAL MONITOR, RESPECTIVELY.

JOB TITLE
       CASE  NO.    2

SPECIFIED COMPUTATION OPTIONS
     1.) FOREBODY FLOW FIELD
     BOUNDARY LAYER COMPUTATION IS INVOKED

FLOW SYMMETRY
     ONE PLANE OF SYMMETRY - COMPUTED SECTOR IS THE HALF-PLANE BOUNDED BY THE Y-AXIS AND CONTAINING THE +Z-AXIS

GLOBAL CORRECTION
     GLOBAL CORRECTION IS PERFORMED ON THE BOW SHOCK WAVE POINTS

THERMODYNAMIC MODEL
     A THERMALLY AND CALORICALLY PERFECT GAS IS SPECIFIED WITH
     SPECIFIC HEAT RATIO=1.40000          GAS CONSTANT= 0.171616E+04(FT-LBF/SLUG-DEG R)

MOLECULAR TRANSPORT TERMS FOR SUPERSONIC CORE FLOW SOLUTION
     VISCOUS AND THERMAL DIFFUSION TERMS ARE NOT INCLUDED IN THE COMPUTATION - INVISCID AND ADIABATIC FLOW IS ASSUMED

MOLECULAR TRANSPORT PARAMETERS
     VISCOSITY IS REPRESENTED BY SUTHERLAND'S LAW WITH
```

Figure 11. Selected output for Sample Case No. 2.

```
    REFERENCE VISCOSITY= 0.350000E-06(LBF-SEC/FT**2)        REFERENCE TEMPERATURE= 0.492000E+03(DEG R)

    BASE TEMPERATURE= 0.198600E+03(DEG R)

  LAMINAR PRANDTL NUMBER=   0.710

ORIENTATION AND FREE STREAM DATA

  ORIENTATION -     PITCH= 1.00000(DEGREES)         YAW= 0.00000(DEGREES)

  FREE STREAM DATA -     MACH NO.= 2.50000          PRESSURE= 0.242200E+03(LBF/FT**2)         DENSITY= 0.362200E-03(SLUG/FT**3)

  TEMPERATURE= 0.389644E+03(DEG R)          SONIC SPEED= 0.967558E+03(FT/SEC)

  X-VELOCITY= 0.241853E+04(FT/SEC)          Y-VELOCITY= 0.422159E+02(FT/SEC)          Z-VELOCITY= 0.000000E+00(FT/SEC)

SUPERSONIC CORE FLOW INITIAL-VALUE SURFACE

  AN INTERNALLY GENERATED INITIAL VALUE SURFACE IS SPECIFIED AS BEING LOCATED AT X= 0.100000E+01(FT)

  A CONICAL BOW SHOCK WAVE IS SPECIFIED - THE INTERNALLY GENERATED SHOCK WAVE ANGLES ARE

    BETA( 1)= 0.454148E+00(RADIANS)
    BETA( 2)= 0.453814E+00(RADIANS)
    BETA( 3)= 0.452833E+00(RADIANS)
    BETA( 4)= 0.451262E+00(RADIANS)
    BETA( 5)= 0.449194E+00(RADIANS)
    BETA( 6)= 0.446747E+00(RADIANS)
    BETA( 7)= 0.444057E+00(RADIANS)
    BETA( 8)= 0.441267E+00(RADIANS)
    BETA( 9)= 0.438518E+00(RADIANS)
    BETA(10)= 0.435946E+00(RADIANS)
    BETA(11)= 0.433669E+00(RADIANS)
    BETA(12)= 0.431790E+00(RADIANS)
    BETA(13)= 0.430389E+00(RADIANS)
    BETA(14)= 0.429526E+00(RADIANS)
    BETA(15)= 0.429234E+00(RADIANS)

FOREBODY/CENTERBODY BOUNDARY LAYER INITIAL DATA

  THE INITIAL DATA ARE INTERNALLY GENERATED WITH

  KTURB= 0          CLENGH= 3.50000          ADY= 0.01000          ARATIO= 1.06300          FACTOR(1)= 1.10000

INDEX PARAMETERS

  ISTOP=15          IMAX=28          JMAXI=11

  JLIMIT(1)=11          JLIMIT(2)=15

  KBLAY=15          NA=20          NINA=20
```

Figure 11. Continued.

ORIGINAL PAGE IS
OF POOR QUALITY

```
INTEGRATION TERMINATION POINTS

     FOREBODY FLOW FIELD INTEGRATION TERMINATES AT X= 0.200000E+01(FT)

     FOR FOREBODY FLOW - RCAVG= 0.800000E+00(FT)


FOREBODY/CENTERBODY GEOMETRY

     CONE HALF ANGLE=10.00000(DEGREES)

       I   KDCENT       XCENT          RCENT          ACENT          BCENT          CCENT          DCENT
                         (FT)           (FT)           (FT)                        (FT**-1)       (FT**-2)

       1     3      0.100000E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
       2     0      0.350000E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00


FOREBODY/CENTERBODY TEMPERATURE BOUNDARY CONDITIONS

     A CONSTANT WALL TEMPERATURE IS SPECIFIED AT 0.876700E+03(R) OR (K)


MASS TRANSFER BOUNDARY CONDITIONS

     AN IMPERMEABLE FOREBODY/CENTERBODY WALL IS SPECIFIED


TURBULENCE MODEL PARAMETERS

     APLUS= 26.0000    XKAPPA=  0.4000    XALPHA= 0.01680    PRT=  0.9000    TFACTR=  1.0000    AKLM= 0.43500    ALAM= 0.09000

     TRANSITION MODEL NO. 5 IS USED FOR FOREBODY/CENTERBODY BOUNDARY LAYER COMPUTATION


CONVERGENCE TOLERANCES, ITERATION LIMITS, AND OTHER PARAMETERS

     CONVERGENCE TOLERANCES AND OTHER PARAMETERS

          CRIT( 1)= 0.100000E+09
          CRIT( 2)= 0.100000E-06
          CRIT( 3)= 0.100000E-03
          CRIT( 4)= 0.100000E-04
          CRIT( 5)= 0.100000E-03
          CRIT( 6)= 0.100000E-03
          CRIT( 7)= 0.500000E+00
          CRIT( 8)= 0.100000E+01
          CRIT( 9)= 0.100000E-03
          CRIT(10)= 0.800000E+00
          CRIT(11)= 0.100000E-01
          CRIT(12)= 0.200000E+00
          CRIT(13)= 0.100000E-04
          CRIT(14)= 0.400000E+00
          CRIT(15)= 0.100000E-03
          CRIT(16)= 0.100000E-03
          CRIT(17)= 0.100000E-01
```

Figure 11. Continued.

```
    CRIT(18)= 0.100000E-04

ITERATION LIMITS

    ITEND(1)=10
    ITEND(2)=10
    ITEND(3)=10
    ITEND(4)=20
    ITEND(5)=10
    ITEND(6)=10
    ITEND(7)=10
    ITEND(8)=15

INPUT SAFETY FACTOR= 0.975000E+00
```

Figure 11. Continued.

CENTERBODY BOUNDARY LAYER SOLUTION FOR PLANE NO. 0 XC= 1.01543(FT) X= 1.00000(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
1	1	0.000000	0.00	0.000	0.0	354.25	0.2355E-03	876.7	0.0	0.00E+00	0.0	354.3	876.7
1	2	0.000192	0.00	0.184	265.4	354.25	0.2386E-03	865.2	265.4	0.00E+00	0.0	362.7	871.0
1	3	0.000400	0.00	0.389	554.2	354.25	0.2448E-03	843.1	554.2	0.00E+00	0.0	393.3	868.7
1	4	0.000620	0.00	0.619	862.2	354.25	0.2554E-03	808.3	862.2	0.00E+00	0.0	458.6	870.2
1	5	0.000850	0.00	0.873	1179.3	354.25	0.2716E-03	760.0	1179.3	0.00E+00	0.0	581.8	875.8
1	6	0.001086	0.00	1.147	1487.9	354.25	0.2948E-03	700.2	1487.9	0.00E+00	0.0	802.5	884.5
1	7	0.001322	0.00	1.429	1763.9	354.25	0.3254E-03	634.3	1763.9	0.00E+00	0.0	1174.3	893.3
1	8	0.001557	0.00	1.702	1990.8	354.25	0.3624E-03	569.6	1990.8	0.00E+00	0.0	1753.4	899.5
1	9	0.001788	0.00	1.954	2163.8	354.25	0.4044E-03	510.5	2163.8	0.00E+00	0.0	2580.2	900.2
1	10	0.002021	0.00	2.093	2237.8	354.25	0.4338E-03	475.9	2237.8	0.00E+00	0.0	3203.2	892.8
1	11	0.002262	0.00	2.193	2284.8	354.25	0.4570E-03	451.7	2284.8	0.00E+00	0.0	3748.6	886.2
1	12	0.002517	0.00	2.240	2300.9	354.25	0.4699E-03	439.3	2300.9	0.00E+00	0.0	4030.2	880.0
1	13	0.002793	0.00	3.251	2304.1	354.25	0.4733E-03	436.1	2304.1	0.00E+00	0.0	4102.5	878.0
1	14	0.003095	0.00	2.256	2305.0	354.25	0.4751E-03	434.5	2305.0	0.00E+00	0.0	4134.4	876.8
1	15	0.003426	0.00	2.256	2305.0	354.25	0.4751E-03	434.5	2305.0	0.00E+00	0.0	4135.1	876.7
1	16	0.003790	0.00	2.256	2305.0	354.25	0.4752E-03	434.4	2305.0	0.00E+00	0.0	4135.8	876.7
1	17	0.004190	0.00	2.256	2305.0	354.25	0.4752E-03	434.4	2305.0	0.00E+00	0.0	4135.8	876.7
1	18	0.004631	0.00	2.256	2305.0	354.25	0.4752E-03	434.4	2305.0	0.00E+00	0.0	4135.8	876.7
1	19	0.005115	0.00	2.256	2305.0	354.25	0.4752E-03	434.4	2305.0	0.00E+00	0.0	4135.8	876.7
1	20	0.005648	0.00	2.256	2305.0	354.25	0.4752E-03	434.4	2305.0	0.00E+00	0.0	4135.8	876.7
2	1	0.000000	12.86	0.000	0.0	353.91	0.2352E-03	876.7	0.0	0.00E+00	0.0	353.9	876.7
2	2	0.000192	12.86	0.184	265.5	353.91	0.2384E-03	865.1	265.4	0.00E+00	5.1	362.4	871.0
2	3	0.000400	12.86	0.390	554.4	353.91	0.2466E-03	843.1	554.3	0.00E+00	9.5	392.9	868.7
2	4	0.000620	12.86	0.619	862.3	353.91	0.2551E-03	808.3	862.2	0.00E+00	12.8	458.2	870.2
2	5	0.000850	12.86	0.873	1179.5	353.91	0.2714E-03	760.0	1179.4	0.00E+00	15.1	581.4	875.8
2	6	0.001086	12.86	1.147	1488.1	353.91	0.2945E-03	700.2	1488.0	0.00E+00	16.2	801.9	884.5
2	7	0.001323	12.86	1.429	1764.2	353.91	0.3251E-03	634.2	1764.1	0.00E+00	16.3	1173.6	893.3
2	8	0.001557	12.86	1.702	1991.1	353.91	0.3621E-03	569.5	1991.0	0.00E+00	15.9	1752.6	899.5
2	9	0.001789	12.86	1.954	2164.1	353.91	0.4041E-03	510.4	2164.1	0.00E+00	15.1	2579.4	900.2
2	10	0.002022	12.86	2.093	2238.1	353.91	0.4334E-03	475.8	2238.1	0.00E+00	14.5	3202.6	892.9
2	11	0.002263	12.86	2.194	2285.1	353.91	0.4567E-03	451.5	2285.1	0.00E+00	14.1	3748.3	886.2
2	12	0.002518	12.86	2.240	2301.2	353.91	0.4695E-03	439.2	2301.2	0.00E+00	13.9	4030.1	880.0
2	13	0.002794	12.86	2.252	2304.4	353.91	0.4730E-03	436.0	2304.4	0.00E+00	13.9	4102.4	878.0
2	14	0.003095	12.86	2.257	2305.3	353.91	0.4747E-03	434.4	2305.3	0.00E+00	13.9	4134.4	876.8
2	15	0.003427	12.86	2.257	2305.3	353.91	0.4748E-03	434.3	2305.3	0.00E+00	13.9	4135.1	876.7
2	16	0.003791	12.86	2.257	2305.3	353.91	0.4748E-03	434.3	2305.3	0.00E+00	13.9	4135.8	876.7
2	17	0.004191	12.86	2.257	2305.3	353.91	0.4748E-03	434.3	2305.3	0.00E+00	13.9	4135.8	876.7
2	18	0.004632	12.86	2.257	2305.3	353.91	0.4748E-03	434.3	2305.3	0.00E+00	13.9	4135.8	876.7
2	19	0.005117	12.86	2.257	2305.3	353.91	0.4748E-03	434.3	2305.3	0.00E+00	13.9	4135.8	876.7
2	20	0.005650	12.86	2.257	2305.3	353.91	0.4748E-03	434.3	2305.3	0.00E+00	13.9	4135.8	876.7
3	1	0.000000	25.71	0.000	0.0	352.90	0.2346E-03	876.7	0.0	0.00E+00	0.0	352.9	876.7
3	2	0.000193	25.71	0.184	265.7	352.90	0.2377E-03	865.1	265.5	0.00E+00	9.9	361.4	871.0
3	3	0.000400	25.71	0.390	554.8	352.90	0.2439E-03	843.1	554.5	0.00E+00	18.5	391.9	868.7
3	4	0.000621	25.71	0.619	862.9	352.90	0.2544E-03	808.2	862.5	0.00E+00	25.1	457.1	870.2
3	5	0.000851	25.71	0.873	1180.1	352.90	0.2706E-03	759.8	1179.7	0.00E+00	29.5	580.1	875.8
3	6	0.001087	25.71	1.148	1488.8	352.90	0.2938E-03	700.0	1488.5	0.00E+00	31.7	800.3	884.5
3	7	0.001324	25.71	1.430	1765.0	352.90	0.3243E-03	634.0	1764.7	0.00E+00	31.9	1171.7	893.3
3	8	0.001559	25.71	1.703	1991.9	352.90	0.3612E-03	569.3	1991.7	0.00E+00	31.0	1750.5	899.5
3	9	0.001791	25.71	1.956	2164.9	352.90	0.4031E-03	510.1	2164.7	0.00E+00	29.5	2577.1	900.2
3	10	0.002024	25.71	2.095	2239.0	352.90	0.4325E-03	475.9	2238.8	0.00E+00	28.3	3200.9	892.8
3	11	0.002266	25.71	2.196	2286.0	352.90	0.4558E-03	451.2	2285.8	0.00E+00	27.6	3747.5	886.2
3	12	0.002521	25.71	2.242	2302.1	352.90	0.4686E-03	438.9	2302.0	0.00E+00	27.2	4029.6	880.0
3	13	0.002797	25.71	2.253	2305.3	352.90	0.4720E-03	435.6	2305.2	0.00E+00	27.1	4102.3	876.0
3	14	0.003098	25.71	2.258	2306.2	352.90	0.4738E-03	434.0	2306.1	0.00E+00	27.1	4134.4	876.8
3	15	0.003429	25.71	2.258	2306.2	352.90	0.4738E-03	434.0	2306.1	0.00E+00	27.1	4135.1	876.7

Figure 11. Continued.

CENTERBODY BOUNDARY LAYER SOLUTION FOR PLANE NO. 0 XC= 1.01543(FT) X= 1.00000(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
3	16	0.003794	25.71	2.259	2306.2	352.90	0.4739E-03	434.0	2306.1	0.00E+00	27.1	4135.8	876.7
3	17	0.004195	25.71	2.259	2306.2	352.90	0.4739E-03	434.0	2306.1	0.00E+00	27.1	4135.8	876.7
3	18	0.004635	25.71	2.259	2306.2	352.90	0.4739E-03	434.0	2306.1	0.00E+00	27.1	4135.8	876.7
3	19	0.005120	25.71	2.259	2306.2	352.90	0.4739E-03	434.0	2306.1	0.00E+00	27.1	4135.8	876.7
3	20	0.005654	25.71	2.259	2306.2	352.90	0.4739E-03	434.0	2306.1	0.00E+00	27.1	4135.8	876.7
4	1	0.000000	38.57	0.000	0.0	351.30	0.2335E-03	876.7	0.0	0.00E+00	0.0	351.3	876.7
4	2	0.000193	38.57	0.185	266.1	351.30	0.2366E-03	865.1	265.7	0.00E+00	14.3	359.8	871.0
4	3	0.000401	38.57	0.390	555.4	351.30	0.2428E-03	843.0	554.8	0.00E+00	26.7	390.2	868.7
4	4	0.000622	38.57	0.620	863.8	351.30	0.2533E-03	808.0	863.0	0.00E+00	36.2	455.2	870.1
4	5	0.000853	38.57	0.874	1181.1	351.30	0.2695E-03	759.6	1180.4	0.00E+00	42.5	578.0	875.8
4	6	0.001089	38.57	1.149	1489.9	351.30	0.2926E-03	699.7	1489.2	0.00E+00	45.6	797.8	884.5
4	7	0.001327	38.57	1.431	1766.2	351.30	0.3230E-03	633.7	1765.6	0.00E+00	46.0	1168.7	893.4
4	8	0.001562	38.57	1.705	1993.2	351.30	0.3599E-03	568.9	1992.7	0.00E+00	44.7	1747.1	899.6
4	9	0.001794	38.57	1.958	2166.2	351.30	0.4017E-03	509.7	2165.8	0.00E+00	42.5	2573.5	900.3
4	10	0.002028	38.57	2.097	2240.4	351.30	0.4310E-03	475.0	2240.0	0.00E+00	40.6	3198.3	892.8
4	11	0.002269	38.57	2.198	2287.5	351.30	0.4542E-03	450.7	2287.1	0.00E+00	39.7	3746.3	886.2
4	12	0.002525	38.57	2.245	2303.6	351.30	0.4670E-03	438.3	2303.3	0.00E+00	39.2	4029.0	880.0
4	13	0.002801	38.57	2.256	2306.8	351.30	0.4705E-03	435.1	2306.5	0.00E+00	39.0	4102.2	878.0
4	14	0.003103	38.57	2.261	2307.7	351.30	0.4722E-03	433.5	2307.4	0.00E+00	39.0	4134.4	876.8
4	15	0.003434	38.57	2.261	2307.7	351.30	0.4723E-03	433.4	2307.4	0.00E+00	39.0	4135.1	876.7
4	16	0.003799	38.57	2.261	2307.7	351.30	0.4723E-03	433.4	2307.4	0.00E+00	39.0	4135.8	876.7
4	17	0.004200	38.57	2.261	2307.7	351.30	0.4723E-03	433.4	2307.4	0.00E+00	39.0	4135.8	876.7
4	18	0.004641	38.57	2.261	2307.7	351.30	0.4723E-03	433.4	2307.4	0.00E+00	39.0	4135.8	876.7
4	19	0.005126	38.57	2.261	2307.7	351.30	0.4723E-03	433.4	2307.4	0.00E+00	39.0	4135.8	876.7
4	20	0.005660	38.57	2.261	2307.7	351.30	0.4723E-03	433.4	2307.4	0.00E+00	39.0	4135.8	876.7
5	1	0.000000	51.43	0.000	0.0	349.22	0.2321E-03	876.7	0.0	0.00E+00	0.0	349.2	876.7
5	2	0.000193	51.43	0.185	266.5	349.22	0.2352E-03	865.1	265.9	0.00E+00	18.0	357.6	871.0
5	3	0.000402	51.43	0.391	556.[illegible]	349.22	0.2414E-03	842.9	555.2	0.00E+00	33.6	388.0	868.7
5	4	0.000624	51.43	0.621	864.9	349.22	0.2519E-03	807.9	863.7	0.00E+00	45.6	452.8	870.1
5	5	0.000855	51.43	0.875	1182.5	349.22	0.2680E-03	759.4	1181.2	0.00E+00	53.5	575.2	875.8
5	6	0.001092	51.43	1.151	1491.4	349.22	0.2910E-03	699.4	1490.3	0.00E+00	57.4	794.5	884.5
5	7	0.001330	51.43	1.433	1767.8	349.22	0.3213E-03	633.3	1766.8	0.00E+00	57.9	1164.7	893.4
5	8	0.001566	51.43	1.707	1994.9	349.22	0.3581E-03	568.3	1994.2	0.00E+00	56.2	1742.7	899.6
5	9	0.001798	51.43	1.960	2167.9	349.22	0.3997E-03	509.1	2167.3	0.00E+00	53.4	2568.8	900.3
5	10	0.002032	51.43	2.100	2242.2	349.22	0.4290E-03	474.3	2241.6	0.00E+00	51.4	3195.0	892.8
5	11	0.002274	51.43	2.202	2289.4	349.22	0.4522E-03	450.0	2288.8	0.00E+00	49.9	3744.8	886.2
5	12	0.002530	51.43	2.248	2305.5	349.22	0.4650E-03	437.6	2305.0	0.00E+00	49.3	4028.2	880.0
5	13	0.002806	51.43	2.260	2308.7	349.22	0.4685E-03	434.3	2308.2	0.00E+00	49.1	4102.0	878.0
5	14	0.003108	51.43	2.265	2309.6	349.22	0.4702E-03	432.7	2309.1	0.00E+00	49.0	4134.4	876.8
5	15	0.003440	51.43	2.265	2309.6	349.22	0.4703E-03	432.7	2309.1	0.00E+00	49.0	4135.1	876.7
5	16	0.003805	51.43	2.265	2309.6	349.22	0.4703E-03	432.7	2309.1	0.00E+00	49.0	4135.8	876.7
5	17	0.004207	51.43	2.265	2309.6	349.22	0.4703E-03	432.7	2309.1	0.00E+00	49.0	4135.8	876.7
5	18	0.004648	51.43	2.265	2309.6	349.22	0.4703E-03	632.7	2309.1	0.00E+00	49.0	4135.8	876.7
5	19	0.005134	51.43	2.265	2309.6	349.22	0.4703E-03	432.7	2309.1	0.00E+00	49.0	4135.8	876.7
5	20	0.005669	51.43	2.265	2309.6	349.22	0.4703E-03	432.7	2309.1	0.00E+00	49.0	4135.8	876.7
6	1	0.000000	64.29	0.000	0.0	346.78	0.2305E-03	876.7	0.0	0.00E+00	0.0	346.8	876.7
6	2	0.000194	64.29	0.185	267.0	346.78	0.2336E-03	865.0	266.2	0.00E+00	20.9	355.2	871.0
6	3	0.000403	64.29	0.392	557.1	346.78	0.2398E-03	842.8	555.8	0.00E+00	38.9	385.4	868.6
6	4	0.000626	64.29	0.622	866.1	346.78	0.2502E-03	807.7	864.5	0.00E+00	52.8	450.0	870.1
6	5	0.000858	64.29	0.877	1184.0	346.78	0.2662E-03	759.1	1182.3	0.00E+00	62.0	572.0	875.8
6	6	0.001096	64.29	1.152	1493.1	346.78	0.2891E-03	699.0	1491.6	0.00E+00	66.5	790.6	884.5
6	7	0.001334	64.29	1.435	1769.6	346.78	0.3194E-03	632.7	1768.4	0.00E+00	67.0	1160.0	893.4
6	8	0.001570	64.29	1.710	1997.0	346.78	0.3559E-03	567.7	1995.9	0.00E+00	65.1	1737.6	899.7
6	9	0.001803	64.29	1.963	2169.9	346.78	0.3975E-03	508.4	2169.1	0.00E+00	61.8	2563.5	900.3
6	10	0.002037	64.29	2.104	2244.3	346.78	0.4267E-03	473.6	2243.5	0.00E+00	59.4	3191.2	892.9

Figure 11. Continued.

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CENTERBODY BOUNDARY LAYER SOLUTION FOR PLANE NO. 0 XC= 1.01543(FT) X= 1.00000(FT)

I	J	Y (FT)	Z (DEG)	M	Q' (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
6	11	0.002280	64.29	2.206	2291.6	346.78	0.4499E-03	449.1	2290.9	0.00E+00	57.8	3743.2	886.3
6	12	0.002536	64.29	2.253	2307.7	346.78	0.4627E-03	436.8	2307.0	0.00E+00	57.0	4027.3	880.1
6	13	0.002812	64.29	2.264	2311.0	346.78	0.4662E-03	433.5	2310.3	0.00E+00	56.8	4101.9	878.0
6	14	0.003115	64.29	2.270	2311.8	346.78	0.4679E-03	431.9	2311.2	0.00E+00	56.7	4134.4	876.8
6	15	0.003447	64.29	2.270	2311.9	346.78	0.4679E-03	431.8	2311.2	0.00E+00	56.7	4135.1	876.7
6	16	0.003813	64.29	2.270	2311.9	346.78	0.4680E-03	431.8	2311.2	0.00E+00	56.7	4135.8	876.7
6	17	0.004215	64.29	2.270	2311.9	346.78	0.4680E-03	431.8	2311.2	0.00E+00	56.7	4135.8	876.7
6	18	0.004657	64.29	2.270	2311.9	346.78	0.4680E-03	431.8	2311.2	0.00E+00	56.7	4135.8	876.7
6	19	0.005144	64.29	2.270	2311.9	346.78	0.4680E-03	431.8	2311.2	0.00E+00	56.7	4135.8	876.7
6	20	0.005679	64.29	2.270	2311.9	346.78	0.4680E-03	431.8	2311.2	0.00E+00	56.7	4135.8	876.7
7	1	0.000000	77.14	0.000	0.0	344.14	0.2287E-03	876.7	0.0	0.00E+00	0.0	344.1	876.7
7	2	0.000195	77.14	0.186	267.4	344.14	0.2318E-03	865.0	266.5	0.00E+00	22.8	352.5	871.0
7	3	0.000405	77.14	0.392	558.0	344.14	0.2380E-03	842.7	556.4	0.00E+00	42.3	382.6	868.6
7	4	0.000628	77.14	0.623	867.3	344.14	0.2483E-03	807.5	865.4	0.00E+00	57.4	447.0	870.1
7	5	0.000861	77.14	0.878	1185.5	344.14	0.2643E-03	758.8	1183.6	0.00E+00	67.4	568.5	875.8
7	6	0.001099	77.14	1.154	1495.0	344.14	0.2871E-03	698.5	1493.2	0.00E+00	72.3	786.4	884.6
7	7	0.001338	77.14	1.438	1771.7	344.14	0.3172E-03	632.2	1770.2	0.00E+00	72.9	1155.0	893.5
7	8	0.001575	77.14	1.713	1999.2	344.14	0.3537E-03	567.0	1998.0	0.00E+00	70.8	1732.1	899.7
7	9	0.001809	77.14	1.967	2172.2	344.14	0.3951E-03	507.6	2171.1	0.00E+00	67.2	2557.8	900.4
7	10	0.002043	77.14	2.108	2246.7	344.14	0.4242E-03	472.7	2245.8	0.00E+00	64.6	3187.2	892.9
7	11	0.002286	77.14	2.211	2294.0	344.14	0.4474E-03	448.2	2293.2	0.00E+00	62.8	3741.6	886.3
7	12	0.002542	77.14	2.257	2310.1	344.14	0.4601E-03	435.8	2309.3	0.00E+00	61.9	4026.3	880.1
7	13	0.002819	77.14	2.269	2313.4	344.14	0.4636E-03	432.5	2312.6	0.00E+00	61.7	4101.7	878.0
7	14	0.003122	77.14	2.274	2314.3	344.14	0.4653E-03	430.9	2313.5	0.00E+00	61.6	4134.4	876.8
7	15	0.003455	77.14	2.275	2314.3	344.14	0.4654E-03	430.9	2313.5	0.00E+00	61.6	4135.1	876.7
7	16	0.003821	77.14	2.275	2314.3	344.14	0.4654E-03	430.9	2313.5	0.00E+00	61.6	4135.8	876.7
7	17	0.004224	77.14	2.275	2314.3	344.14	0.4654E-03	430.9	2313.5	0.00E+00	61.6	4135.8	876.7
7	18	0.004667	77.14	2.275	2314.3	344.14	0.4654E-03	430.9	2313.5	0.00E+00	61.6	4135.8	876.7
7	19	0.005154	77.14	2.275	2314.3	344.14	0.4654E-03	430.9	2313.5	0.00E+00	61.6	4135.8	876.7
7	20	0.005689	77.14	2.275	2314.3	344.14	0.4654E-03	430.9	2313.5	0.00E+00	61.6	4135.8	876.7
8	1	0.000000	90.00	0.000	0.0	341.45	0.2269E-03	876.7	0.0	0.00E+00	0.0	341.5	876.7
8	2	0.000195	90.00	0.186	267.8	341.45	0.2300E-03	865.0	266.8	0.00E+00	23.5	349.8	870.9
8	3	0.000406	90.00	0.393	558.8	341.45	0.2361E-03	842.6	557.1	0.00E+00	43.7	379.8	868.6
8	4	0.000630	90.00	0.624	868.5	341.45	0.2464E-03	807.3	866.5	0.00E+00	59.2	443.8	870.1
8	5	0.000864	90.00	0.879	1187.1	341.45	0.2623E-03	758.5	1185.0	0.00E+00	69.6	564.8	875.8
8	6	0.001103	90.00	1.156	1496.8	341.45	0.2850E-03	698.1	1495.0	0.00E+00	74.6	782.1	884.6
8	7	0.001343	90.00	1.440	1773.8	341.45	0.3150E-03	631.6	1772.2	0.00E+00	75.2	1149.8	893.5
8	8	0.001580	90.00	1.726	2001.6	341.45	0.3514E-03	566.3	2000.3	0.00E+00	72.9	1726.6	899.8
8	9	0.001814	90.00	1.971	2174.5	341.45	0.3926E-03	506.8	2173.4	0.00E+00	69.3	2552.2	900.4
8	10	0.002049	90.00	2.112	2249.1	341.45	0.4217E-03	471.8	2248.1	0.00E+00	66.5	3183.4	892.9
8	11	0.002292	90.00	2.215	2296.6	341.45	0.4448E-03	447.3	2295.6	0.00E+00	64.7	3740.1	886.3
8	12	0.002549	90.00	2.262	2312.6	341.45	0.4575E-03	434.9	2311.7	0.00E+00	63.8	4025.4	880.1
8	13	0.002826	90.00	2.274	2315.9	341.45	0.4610E-03	431.6	2315.1	0.00E+00	63.6	4101.6	878.0
8	14	0.003130	90.00	2.279	2316.8	341.45	0.4627E-03	430.0	2315.9	0.00E+00	63.5	4134.4	876.8
8	15	0.003463	90.00	2.280	2316.8	341.45	0.4628E-03	429.9	2315.9	0.00E+00	63.5	4135.1	876.7
8	16	0.003830	90.00	2.280	2316.8	341.45	0.4628E-03	429.9	2315.9	0.00E+00	63.5	4135.8	876.7
8	17	0.004233	90.00	2.280	2316.8	341.45	0.4628E-03	429.9	2315.9	0.00E+00	63.5	4135.8	876.7
8	18	0.004670	90.00	2.280	2316.8	341.45	0.4628E-03	429.9	2315.9	0.00E+00	63.5	4135.8	876.7
8	19	0.005164	90.00	2.280	2316.8	341.45	0.4628E-03	429.9	2315.9	0.00E+00	63.5	4135.8	876.7
8	20	0.005700	90.00	2.280	2316.8	341.45	0.4628E-03	429.9	2315.9	0.00E+00	63.5	4135.8	876.7
9	1	0.000000	102.86	0.000	0.0	338.86	0.2252E-03	876.7	0.0	0.00E+00	0.0	338.9	876.7
9	2	0.000196	102.86	0.186	268.1	338.86	0.2283E-03	865.0	267.2	0.00E+00	23.0	347.1	870.9
9	3	0.000408	102.86	0.393	559.5	338.86	0.2343E-03	842.5	557.8	0.00E+00	42.8	377.0	868.6
9	4	0.000632	102.86	0.624	869.6	338.86	0.2446E-03	807.2	867.7	0.00E+00	58.1	440.7	870.1
9	5	0.000867	102.86	0.881	1188.5	338.86	0.2604E-03	758.2	1186.6	0.00E+00	68.2	561.3	875.8

Figure 11. Continued.

CENTERBODY BOUNDARY LAYER SOLUTION FOR PLANE NO. 0 XC= 1.01543(FT) X= 1.00000(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
9	6	0.001106	102.86	1.157	1498.6	338.86	0.2830E-03	697.7	1496.8	0.00E+00	73.1	777.8	884.6
9	7	0.001347	102.86	1.442	1775.9	338.86	0.3129E-03	631.0	1774.3	0.00E+00	73.6	1144.9	893.6
9	8	0.001585	102.86	1.719	2003.9	338.86	0.3491E-03	565.6	2002.6	0.00E+00	71.4	1721.4	899.8
9	9	0.001819	102.86	1.974	2176.7	338.86	0.3902E-03	506.0	2175.7	0.00E+00	67.8	2546.9	900.4
9	10	0.002055	102.86	2.117	2251.5	338.86	0.4192E-03	471.0	2250.6	0.00E+00	65.2	3179.9	893.0
9	11	0.002298	102.86	2.220	2299.0	338.86	0.4424E-03	446.3	2298.1	0.00E+00	63.3	3738.8	886.3
9	12	0.002556	102.86	2.267	2315.0	338.86	0.4550E-03	434.0	2314.2	0.00E+00	62.4	4024.5	880.1
9	13	0.002833	102.86	2.279	2318.4	338.86	0.4585E-03	430.6	2317.5	0.00E+00	62.2	4101.5	878.0
9	14	0.003137	102.86	2.284	2319.2	338.86	0.4602E-03	429.0	2318.4	0.00E+00	62.2	4134.4	876.8
9	15	0.003471	102.86	2.284	2319.2	338.86	0.4603E-03	429.0	2318.4	0.00E+00	62.2	4135.1	876.7
9	16	0.003838	102.86	2.285	2319.2	338.86	0.4603E-03	429.0	2318.4	0.00E+00	62.2	4135.8	876.7
9	17	0.004241	102.86	2.285	2319.2	338.86	0.4603E-03	429.0	2318.4	0.00E+00	62.2	4135.8	876.7
9	18	0.004685	102.86	2.285	2319.2	338.86	0.4603E-03	429.0	2318.4	0.00E+00	62.2	4135.8	876.7
9	19	0.005174	102.86	2.285	2319.2	338.86	0.4603E-03	429.0	2318.4	0.00E+00	62.2	4135.8	876.7
9	20	0.005711	102.86	2.285	2319.2	338.86	0.4603E-03	429.0	2318.4	0.00E+00	62.2	4135.8	876.7
10	1	0.000000	115.71	0.000	0.0	336.48	0.2236E-03	876.7	0.0	0.00E+00	0.0	336.5	876.7
10	2	0.000197	115.71	0.186	268.4	336.48	0.2267E-03	864.9	267.5	0.00E+00	21.4	344.7	870.9
10	3	0.000409	115.71	0.394	560.0	336.48	0.2327E-03	842.5	558.6	0.00E+00	39.8	374.4	868.6
10	4	0.000634	115.71	0.625	870.5	336.48	0.2429E-03	807.0	868.8	0.00E+00	54.0	437.9	870.1
10	5	0.000869	115.71	0.882	1189.8	336.48	0.2587E-03	758.0	1188.1	0.00E+00	63.3	558.0	875.8
10	6	0.001110	115.71	1.159	1500.2	336.48	0.2812E-03	697.3	1498.7	0.00E+00	67.9	773.9	884.6
10	7	0.001351	115.71	1.444	1777.8	336.48	0.3110E-03	630.5	1776.5	0.00E+00	68.4	1140.4	893.6
10	8	0.001589	115.71	1.722	2006.0	336.48	0.3471E-03	564.9	2005.0	0.00E+00	66.3	1716.8	899.9
10	9	0.001824	115.71	1.978	2178.8	336.48	0.3880E-03	505.3	2177.9	0.00E+00	62.9	2542.3	900.5
10	10	0.002060	115.71	2.120	2253.7	336.48	0.4170E-03	470.2	2252.9	0.00E+00	60.5	3176.9	893.0
10	11	0.002304	115.71	2.224	2301.3	336.48	0.4401E-03	445.5	2300.5	0.00E+00	58.7	3737.8	886.3
10	12	0.002561	115.71	2.271	2317.2	336.48	0.4527E-03	433.1	2316.5	0.00E+00	57.9	4023.8	880.1
10	13	0.002840	115.71	2.284	2320.6	336.48	0.4562E-03	429.8	2319.9	0.00E+00	57.7	4101.4	878.0
10	14	0.003144	115.71	2.289	2321.5	336.48	0.4579E-03	428.2	2320.7	0.00E+00	57.7	4134.4	876.8
10	15	0.003478	115.71	2.289	2321.5	336.48	0.4580E-03	428.1	2320.7	0.00E+00	57.7	4135.1	876.7
10	16	0.003845	115.71	2.289	2321.5	336.48	0.4580E-03	428.1	2320.7	0.00E+00	57.7	4135.8	876.7
10	17	0.004249	115.71	2.289	2321.5	336.48	0.4580E-03	428.1	2320.7	0.00E+00	57.7	4135.8	876.7
10	18	0.004694	115.71	2.289	2321.5	336.48	0.4580E-03	428.1	2320.7	0.00E+00	57.7	4135.8	876.7
10	19	0.005183	115.71	2.289	2321.5	336.48	0.4580E-03	428.1	2320.7	0.00E+00	57.7	4135.8	876.7
10	20	0.005721	115.71	2.289	2321.5	336.48	0.4580E-03	428.1	2320.7	0.00E+00	57.7	4135.8	876.7
11	1	0.000000	128.57	0.000	0.0	334.42	0.2223E-03	876.7	0.0	0.00E+00	0.0	334.4	876.7
11	2	0.000197	128.57	0.186	268.5	334.42	0.2253E-03	864.9	267.8	0.00E+00	18.7	342.6	870.9
11	3	0.000410	128.57	0.394	560.3	334.42	0.2313E-03	842.4	559.3	0.00E+00	34.7	372.2	868.6
11	4	0.000636	128.57	0.626	871.2	334.42	0.2415E-03	806.9	869.9	0.00E+00	47.0	435.4	870.1
11	5	0.000872	128.57	0.883	1190.8	334.42	0.2572E-03	757.8	1189.5	0.00E+00	55.2	555.1	875.8
11	6	0.001113	128.57	1.160	1501.6	334.42	0.2796E-03	697.0	1500.4	0.00E+00	59.2	770.5	884.7
11	7	0.001354	128.57	1.446	1779.5	334.42	0.3093E-03	630.0	1778.5	0.00E+00	59.6	1136.5	893.6
11	8	0.001593	128.57	1.724	2008.0	334.42	0.3453E-03	564.3	2007.1	0.00E+00	57.8	1712.9	899.9
11	9	0.001829	128.57	1.980	2180.7	334.42	0.3862E-03	504.6	2180.0	0.00E+00	54.8	2538.5	900.5
11	10	0.002065	128.57	2.124	2255.7	334.42	0.4151E-03	469.5	2255.1	0.00E+00	52.7	3174.5	893.0
11	11	0.002309	128.57	2.228	2303.3	334.42	0.4382E-03	444.7	2302.7	0.00E+00	51.2	3737.2	886.3
11	12	0.002567	128.57	2.275	2319.1	334.42	0.4507E-03	432.4	2318.6	0.00E+00	50.5	4023.2	880.1
11	13	0.002845	128.57	2.288	2322.5	334.42	0.4542E-03	429.0	2322.0	0.00E+00	50.3	4101.4	878.0
11	14	0.003150	128.57	2.293	2323.4	334.42	0.4559E-03	427.4	2322.9	0.00E+00	50.2	4134.4	876.8
11	15	0.003484	128.57	2.293	2323.4	334.42	0.4560E-03	427.4	2322.9	0.00E+00	50.2	4135.1	876.7
11	16	0.003852	128.57	2.293	2323.4	334.42	0.4560E-03	427.3	2322.9	0.00E+00	50.2	4135.8	876.7
11	17	0.004256	128.57	2.293	2323.4	334.42	0.4560E-03	427.3	2322.9	0.00E+00	50.2	4135.8	876.7
11	18	0.004701	128.57	2.293	2323.4	334.42	0.4560E-03	427.3	2322.9	0.00E+00	50.2	4135.8	876.7
11	19	0.005191	128.57	2.293	2323.4	334.42	0.4560E-03	427.3	2322.9	0.00E+00	50.2	4135.8	876.7
11	20	0.005729	128.57	2.293	2323.4	334.42	0.4560E-03	427.3	2322.9	0.00E+00	50.2	4135.8	876.7

Figure 11. Continued.

CENTERBODY BOUNDARY LAYER SOLUTION FOR PLANE NO. 0 XC= 1.01543(FT) X= 1.00000(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
12	1	0.000000	141.43	0.000	0.0	332.75	0.2212E-03	876.7	0.0	0.00E+00	0.0	332.8	876.7
12	2	0.000198	141.43	0.186	268.6	332.75	0.2242E-03	864.9	268.1	0.00E+00	14.9	340.9	870.9
12	3	0.000411	141.43	0.394	560.6	332.75	0.2302E-03	842.4	559.9	0.00E+00	27.8	370.3	868.5
12	4	0.000637	141.43	0.626	871.6	332.75	0.2403E-03	806.8	870.8	0.00E+00	37.7	433.3	870.1
12	5	0.000874	141.43	0.883	1191.6	332.75	0.2559E-03	757.6	1190.8	0.00E+00	44.2	552.7	875.8
12	6	0.001115	141.43	1.161	1502.7	332.75	0.2783E-03	696.7	1502.0	0.00E+00	47.4	767.7	884.7
12	7	0.001357	141.43	1.448	1780.9	332.75	0.3079E-03	629.7	1780.2	0.00E+00	47.7	1133.3	893.7
12	8	0.001596	141.43	1.727	2009.6	332.75	0.3429E-03	563.8	2009.0	0.00E+00	46.2	1709.8	900.0
12	9	0.001832	141.43	1.983	2182.3	332.75	0.3847E-03	504.1	2181.8	0.00E+00	43.9	2535.6	900.5
12	10	0.002069	141.43	2.127	2257.3	332.75	0.4135E-03	468.9	2256.9	0.00E+00	42.1	3172.7	893.0
12	11	0.002313	141.43	2.231	2304.9	332.75	0.4366E-03	444.1	2304.5	0.00E+00	40.9	3736.8	886.3
12	12	0.002571	141.43	2.278	2320.7	332.75	0.4490E-03	431.8	2320.4	0.00E+00	40.4	4022.7	880.1
12	13	0.002849	141.43	2.291	2324.1	332.75	0.4526E-03	428.4	2323.8	0.00E+00	40.2	4101.4	878.0
12	14	0.003154	141.43	2.296	2325.0	332.75	0.4543E-03	426.8	2324.6	0.00E+00	40.2	4134.4	876.8
12	15	0.003489	141.43	2.296	2325.0	332.75	0.4543E-03	426.8	2324.6	0.00E+00	40.2	4135.1	876.7
12	16	0.003857	141.43	2.296	2325.0	332.75	0.4544E-03	426.7	2324.6	0.00E+00	40.2	4135.8	876.7
12	17	0.004262	141.43	2.296	2325.0	332.75	0.4544E-03	426.7	2324.6	0.00E+00	40.2	4135.8	876.7
12	18	0.004707	141.43	2.296	2325.0	332.75	0.4544E-03	426.7	2324.6	0.00E+00	40.2	4135.8	876.7
12	19	0.005197	141.43	2.296	2325.0	332.75	0.4544E-03	426.7	2324.6	0.00E+00	40.2	4135.8	876.7
12	20	0.005736	141.43	2.296	2325.0	332.75	0.4544E-03	426.7	2324.6	0.00E+00	40.2	4135.8	876.7
13	1	0.000000	154.29	0.000	0.0	331.53	0.2204E-03	876.7	0.0	0.00E+00	0.0	331.5	876.7
13	2	0.000198	154.29	0.186	268.6	331.53	0.2234E-03	864.9	268.4	0.00E+00	10.4	339.7	870.9
13	3	0.000412	154.29	0.394	560.7	331.53	0.2293E-03	842.4	560.4	0.00E+00	19.4	369.0	868.5
13	4	0.000639	154.29	0.626	872.0	331.53	0.2394E-03	806.8	871.6	0.00E+00	26.3	431.8	870.1
13	5	0.000875	154.29	0.884	1192.2	331.53	0.2550E-03	757.5	1191.8	0.00E+00	30.8	551.0	875.8
13	6	0.001117	154.29	1.162	1503.6	331.53	0.2774E-03	696.5	1503.2	0.00E+00	33.0	765.7	884.7
13	7	0.001359	154.29	1.449	1781.9	331.53	0.3069E-03	629.4	1781.6	0.00E+00	33.3	1131.1	893.7
13	8	0.001599	154.29	1.728	2010.8	331.53	0.3429E-03	563.5	2010.5	0.00E+00	32.2	1707.7	900.0
13	9	0.001835	154.29	1.985	2183.4	331.53	0.3636E-03	503.7	2183.2	0.00E+00	30.6	2533.6	900.5
13	10	0.002071	154.29	2.129	2258.5	331.53	0.4124E-03	468.4	2258.3	0.00E+00	29.4	3171.5	893.0
13	11	0.002316	154.29	2.234	2306.1	331.53	0.4354E-03	443.6	2305.9	0.00E+00	28.5	3736.6	886.3
13	12	0.002574	154.29	2.281	2321.9	331.53	0.4478E-03	431.4	2321.7	0.00E+00	28.1	4022.5	880.1
13	13	0.002853	154.29	2.293	2325.3	331.53	0.4514E-03	428.0	2325.1	0.00E+00	28.0	4101.4	878.0
13	14	0.003158	154.29	2.298	2326.1	331.53	0.4531E-03	426.4	2326.0	0.00E+00	28.0	4134.4	876.8
13	15	0.003492	154.29	2.298	2326.1	331.53	0.4531E-03	426.3	2326.0	0.00E+00	28.0	4135.1	876.7
13	16	0.003861	154.29	2.298	2326.1	331.53	0.4532E-03	426.3	2326.0	0.00E+00	28.0	4135.8	876.7
13	17	0.004266	154.29	2.298	2326.1	331.53	0.4532E-03	426.3	2326.0	0.00E+00	28.0	4135.8	876.7
13	18	0.004711	154.29	2.298	2326.1	331.53	0.4532E-03	426.3	2326.0	0.00E+00	28.0	4135.8	876.7
13	19	0.005202	154.29	2.298	2326.1	331.53	0.4532E-03	426.3	2326.0	0.00E+00	28.0	4135.8	876.7
13	20	0.005741	154.29	2.298	2326.1	331.53	0.4532E-03	426.3	2326.0	0.00E+00	28.0	4135.8	876.7
14	1	0.000000	167.14	0.000	0.0	330.79	0.2199E-03	876.7	0.0	0.00E+00	0.0	330.8	876.7
14	2	0.000198	167.14	0.186	268.6	330.79	0.2229E-03	864.9	268.5	0.00E+00	5.4	338.9	870.9
14	3	0.000412	167.14	0.394	560.8	330.79	0.2288E-03	842.3	560.7	0.00E+00	10.0	368.2	868.5
14	4	0.000639	167.14	0.626	872.2	330.79	0.2389E-03	806.7	872.1	0.00E+00	13.5	430.9	870.1
14	5	0.000876	167.14	0.884	1192.6	330.79	0.2545E-03	757.4	1192.5	0.00E+00	15.8	549.9	875.8
14	6	0.001118	167.14	1.163	1504.1	330.79	0.2768E-03	696.4	1504.0	0.00E+00	17.0	764.5	884.7
14	7	0.001360	167.14	1.450	1782.6	330.79	0.3063E-03	629.2	1782.5	0.00E+00	17.1	1129.7	893.7
14	8	0.001600	167.14	1.729	2011.5	330.79	0.3422E-03	563.2	2011.4	0.00E+00	16.6	1706.4	900.0
14	9	0.001836	167.14	1.986	2184.1	330.79	0.3829E-03	503.4	2184.1	0.00E+00	15.7	2532.4	900.5
14	10	0.002073	167.14	2.130	2259.2	330.79	0.4117E-03	468.2	2259.1	0.00E+00	15.1	3170.9	893.0
14	11	0.002317	167.14	2.235	2306.8	330.79	0.4347E-03	443.4	2306.9	0.00E+00	14.7	3736.6	886.3
14	12	0.002576	167.14	2.282	2322.6	330.79	0.4471E-03	431.1	2322.5	0.00E+00	14.5	4022.3	880.1
14	13	0.002855	167.14	2.295	2326.0	330.79	0.4507E-03	427.7	2325.9	0.00E+00	14.4	4101.4	878.0
14	14	0.003140	167.14	2.300	2326.8	330.79	0.4524E-03	426.1	2326.8	0.00E+00	14.4	4134.4	876.8
14	15	0.003495	167.14	2.300	2326.8	330.79	0.4524E-03	426.0	2326.8	0.00E+00	14.4	4135.1	876.7

Figure 11. Continued.

CENTERBODY BOUNDARY LAYER SOLUTION FOR PLANE NO. 0 XC= 1.01543(FT) X= 1.00000(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
14	16	0.003863	167.14	2.300	2326.8	330.79	0.4525E-03	426.0	2326.8	0.00E+00	14.4	4135.8	876.7
14	17	0.004268	167.14	2.300	2326.8	330.79	0.4525E-03	426.0	2326.8	0.00E+00	14.4	4135.8	876.7
14	18	0.004714	167.14	2.300	2326.8	330.79	0.4525E-03	426.0	2326.8	0.00E+00	14.4	4135.8	876.7
14	19	0.005204	167.14	2.300	2326.8	330.79	0.4525E-03	426.0	2326.8	0.00E+00	14.4	4135.8	876.7
14	20	0.005744	167.14	2.300	2326.8	330.79	0.4525E-03	426.0	2326.8	0.00E+00	14.4	4135.8	876.7
15	1	0.000000	180.00	0.000	0.0	330.54	0.2197E-03	876.7	0.0	0.00E+00	0.0	330.5	876.7
15	2	0.000198	180.00	0.186	268.6	330.54	0.2227E-03	864.9	268.6	0.00E+00	0.0	338.6	870.9
15	3	0.000412	180.00	0.394	560.8	330.54	0.2287E-03	842.3	560.8	0.00E+00	0.0	367.9	868.5
15	4	0.000639	180.00	0.627	872.2	330.54	0.2387E-03	806.7	872.2	0.00E+00	0.0	430.6	870.0
15	5	0.000876	180.00	0.884	1192.7	330.54	0.2543E-03	757.4	1192.7	0.00E+00	0.0	549.6	875.8
15	6	0.001118	180.00	1.163	1504.2	330.54	0.2766E-03	696.3	1504.2	0.00E+00	0.0	764.1	884.7
15	7	0.001361	180.00	1.450	1782.8	330.54	0.3061E-03	629.1	1782.8	0.00E+00	0.0	1129.3	893.7
15	8	0.001601	180.00	1.730	2011.8	330.54	0.3420E-03	563.1	2011.8	0.00E+00	0.0	1708.0	900.0
15	9	0.001837	180.00	1.986	2184.4	330.54	0.3827E-03	503.3	2184.4	0.00E+00	0.0	2532.0	900.5
15	10	0.002073	180.00	2.131	2259.4	330.54	0.4115E-03	468.1	2259.4	0.00E+00	0.0	3170.7	893.0
15	11	0.002318	180.00	2.236	2307.1	330.54	0.4345E-03	443.3	2307.1	0.00E+00	0.0	3736.5	886.3
15	12	0.002576	180.00	2.283	2322.8	330.54	0.4469E-03	431.0	2322.8	0.00E+00	0.0	4022.2	880.1
15	13	0.002855	180.00	2.293	2326.2	330.54	0.4504E-03	427.6	2326.2	0.00E+00	0.0	4101.4	878.0
15	14	0.003160	180.00	2.300	2327.1	330.54	0.4521E-03	426.0	2327.1	0.00E+00	0.0	4134.4	876.8
15	15	0.003495	180.00	2.300	2327.1	330.54	0.4522E-03	426.0	2327.1	0.00E+00	0.0	4135.1	876.7
15	16	0.003864	180.00	2.300	2327.1	330.54	0.4522E-03	425.9	2327.1	0.00E+00	0.0	4135.8	876.7
15	17	0.004269	180.00	2.300	2327.1	330.54	0.4522E-03	425.9	2327.1	0.00E+00	0.0	4135.8	876.7
15	18	0.004715	180.00	2.300	2327.1	320.54	0.4522E-03	425.9	2327.1	0.00E+00	0.0	4135.8	876.7
15	19	0.005205	180.00	2.300	2327.1	330.54	0.4522E-03	425.9	2327.1	0.00E+00	0.0	4135.8	876.7
15	20	0.005745	180.00	2.300	2327.1	330.54	0.4522E-03	425.9	2327.1	0.00E+00	0.0	4135.8	876.7

Figure 11. Continued.

CENTERBODY BOUNDARY LAYER EDGE CONDITIONS AND OTHER PARAMETERS FOR PLANE NO. 0

I	UE (FT/SEC)	WE (FT/SEC)	PE (LBF/FT2)	ROE (SLUG/FT3)	TE (DEG R)	HTE (FT2/SEC2)
1	2304.99	0.00	354.25	0.4752E-03	434.4	0.5266E+07
2	2305.26	13.86	353.91	0.4748E-03	434.3	0.5266E+07
3	2306.07	27.06	352.90	0.4739E-03	434.0	0.5266E+07
4	2307.36	38.98	351.30	0.4723E-03	433.4	0.5266E+07
5	2309.09	49.04	349.22	0.4703E-03	432.7	0.5266E+07
6	2311.16	56.72	346.78	0.4680E-03	431.8	0.5266E+07
7	2313.48	61.63	344.14	0.4654E-03	430.9	0.5266E+07
8	2315.93	63.48	341.45	0.4628E-03	429.9	0.5266E+07
9	2318.40	62.15	338.86	0.4603E-03	429.0	0.5266E+07
10	2320.74	57.67	336.48	0.4580E-03	428.1	0.5266E+07
11	2322.86	50.22	334.42	0.4560E-03	427.3	0.5266E+07
12	2324.63	40.16	332.75	0.4544E-03	426.7	0.5266E+07
13	2325.97	28.01	331.53	0.4532E-03	426.3	0.5266E+07
14	2326.80	14.38	330.79	0.4525E-03	426.0	0.5266E+07
15	2327.08	0.00	330.54	0.4522E-03	425.9	0.5266E+07

I	DUEDX (SEC-1)	DWEDX (SEC-1)	DPEDX (LBF/FT3)	DROEDX (SLUG/FT4)	DUEDZ (FT/SEC/R)	DWEDZ (FT/SEC/R)	DPEDZ (LBF/FT2/R)	DROEDZ (SLUG/FT3/R)
1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.618E+02	0.000E+00	0.000E+00
2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.239E+01	0.603E+02	-0.301E+01	-0.288E-05
3	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.467E+01	0.560E+02	-0.580E+01	-0.557E-05
4	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.673E+01	0.490E+02	-0.821E+01	-0.789E-05
5	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.846E+01	0.395E+02	-0.101E+02	-0.970E-05
6	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.979E+01	0.281E+02	-0.113E+02	-0.109E-04
7	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.106E+02	0.151E+02	-0.119E+02	-0.115E-04
8	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.110E+02	0.117E+01	-0.118E+02	-0.114E-04
9	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.107E+02	-0.130E+02	-0.111E+02	-0.106E-04
10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.994E+01	-0.266E+02	-0.989E+01	-0.961E-05
11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.866E+01	-0.390E+02	-0.830E+01	-0.809E-05
12	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.692E+01	-0.495E+02	-0.644E+01	-0.628E-05
13	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.483E+01	-0.574E+02	-0.438E+01	-0.428E-05
14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.248E+01	-0.624E+02	-0.222E+01	-0.216E-05
15	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-0.641E+02	0.000E+00	0.000E+00

I	DTX (FT)	DTZ (FT)	MTX (FT)	MTZ (FT)	TWX (LBF/FT2)	TWZ (LBF/FT2)	TWT (LBF/FT2)	RCVB (SLUG/F28)
1	0.124E-02	0.000E+00	0.196E-03	0.000E+00	0.733E+00	0.000E+00	0.733E+00	0.000E+00
2	0.124E-02	0.774E-03	0.196E-03	0.863E-04	0.733E+00	0.141E-01	0.733E+00	0.000E+00
3	0.124E-02	0.775E-03	0.196E-03	0.868E-04	0.733E+00	0.274E-01	0.733E+00	0.000E+00
4	0.124E-02	0.777E-03	0.196E-03	0.875E-04	0.731E+00	0.395E-01	0.732E+00	0.000E+00
5	0.125E-02	0.779E-03	0.196E-03	0.885E-04	0.730E+00	0.495E-01	0.732E+00	0.000E+00
6	0.125E-02	0.782E-03	0.196E-03	0.897E-04	0.728E+00	0.572E-01	0.731E+00	0.000E+00
7	0.126E-02	0.785E-03	0.197E-03	0.910E-04	0.727E+00	0.620E-01	0.729E+00	0.000E+00
8	0.126E-02	0.788E-03	0.197E-03	0.923E-04	0.725E+00	0.638E-01	0.728E+00	0.000E+00
9	0.127E-02	0.791E-03	0.197E-03	0.935E-04	0.723E+00	0.624E-01	0.726E+00	0.000E+00
10	0.127E-02	0.794E-03	0.197E-03	0.947E-04	0.722E+00	0.578E-01	0.724E+00	0.000E+00
11	0.128E-02	0.797E-03	0.197E-03	0.956E-04	0.721E+00	0.502E-01	0.723E+00	0.000E+00
12	0.128E-02	0.799E-03	0.198E-03	0.964E-04	0.720E+00	0.401E-01	0.721E+00	0.000E+00
13	0.128E-02	0.800E-03	0.198E-03	0.970E-04	0.720E+00	0.280E-01	0.720E+00	0.000E+00
14	0.128E-02	0.801E-03	0.198E-03	0.973E-04	0.719E+00	0.144E-01	0.719E+00	0.000E+00
15	0.128E-02	0.000E+00	0.198E-03	0.000E+00	0.719E+00	0.000E+00	0.719E+00	0.000E+00

Figure 11. Concluded.

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4. SAMPLE CASE NO. 3

Sample Case No. 3 is concerned with the computation of the internal supersonic core flow for the Boeing Mach 3.5 mixed-compression inlet described in Reference (9). The internal supersonic flow field is computed for the off-design conditions of a free-stream Mach number of 2.5, a centerbody forward translation of 0.855 ft, and an angle of incidence of 1.0 degree.

The data deck for Sample Case No. 3 is presented in Figure 12. Again, the first card of the data deck is the title card. All input parameters in namelist LIST1 retain their default values except for KCALL, XEND, KBLAY, and KTRANS. Since only the internal flow field is to be computed, KCALL(1) = 0 is specified to bypass the forebody flow field computation. The integration termination point for the internal flow computation is x=5.05 ft, hence XEND(2)=5.05 is entered. For this sample case, neither the boundary layer computation is to be performed nor are bleed effects to be accounted for in the computation of the supersonic flow; hence, KBLAY=0 and KTRANS=0 are specified in namelist LIST1.

All input parameters in namelist LIST2 retain their default values except for MFS, XI, and KSUPER. Since the free-stream Mach number for this sample case is 2.5; MFS=2.5 is specified in namelist LIST2. With the prescribed centerbody translation of 0.855 ft, the axial location of the cowl lip, and thereby of the initial-value plane, is x=3.715 ft. Note that the origin of the coordinate system remains at the forebody tip, hence a forward centerbody translation corresponds to a rearward cowl translation. Consequently, XI=3.715 is specified in namelist LIST2. For this execution, the results of the approximate analysis described in Section II are used for the initial data since the forebody is conical. Hence, the initial-value plane flow property field is internally specified by entering KSUPER=1.

All input parameters in namelist LIST3, which specifies the supersonic flow computational mesh, are retained at their default values.

All parameters in namelist LIST4, which specifies the thermodynamic and molecular transport property models, retain their default values.

The contours of the centerbody and the cowl are specified in namelist LIST5. For this inlet, the centerbody contour and the cowl contour are described by equation (3) applied to a number of intervals on each contour. Consequently, KBASE retains its default value of 0. The number of axial stations used for the geometry description of the centerbody and the cowl are 11 and 14, respectively; hence NCENT=11 and NCØWL=14. Thus, the number of intervals on the centerbody and the cowl are 10 and 13, respectively. Since equation (3) is used to specify the body radius for all intervals, KDCENT(I)=1 (I=1 to 11) and KDCØWL(I)=1 (I=1 to 14). Note that except for XCENT(11) and XCØWL(14), the specifications for the other input parameters for the last station on either the centerbody or the cowl are immaterial. That is, only the XCENT and XCØWL arrays must be specified for NCENT and NCØWL elements, respectively. The other arrays require that only (NCENT-1) or (NCØWL-1) elements be entered. The 11 elements of the XCENT array are thus entered. Although not used in the computation, the 11 elements of the RCENT array are entered, each element being 0.0. The arrays ACENT, BCENT, CCENT, and DCENT are then entered. For each of these arrays, the last (11th) element is arbitrarily specified as 0.0. In a like manner, the arrays XCØWL, RCØWL, ACØWL, BCØWL, CCØWL, and DCØWL are entered. For this case, the centerbody has been translated forward by 0.855 ft, or, alternatively, the cowl has been translated backward by 0.855 ft. Hence, DXTRAN=0.855 is specified in namelist LIST5.

Since in this sample case the boundary layer computation is not invoked, the input parameters for namelists LIST6 and LIST7 need not be entered.

Mass transfer effects are not considered for this execution, thereby all input parameters in namelist LIST8 are retained at their default values. Thereby, impermeable forebody/centerbody and cowl contours are specified.

The input parameters for namelist LIST9, which is used for specification of the turbulence model, need not be entered for this sample case.

All convergence tolerances and iteration limits specified in namelist LIST10 retain their default values.

No debug output is to be printed, thereby all input parameters in namelist LIST11 retain their default values.

Selected portions of the computer printout for Sample Case No. 3 are presented in Figure 13.

```
CASE  NO.  3
&LIST1 KCALL(1)=0, XEND(2)=5.05, KBLAY=0, KTRANS=0 &END
&LIST2 MFS=2.5, XI=3.715, KSUPER=1 &END
&LIST3 &END
&LIST4 &END
&LIST5 NCENT=11, NCOWL=14, KDCENT(1)=11*1, KDCOWL(1)=14*1,
XCENT(1)= 0.0, 2.798794, 4.0, 4.2, 4.4, 4.55, 4.7, 4.9, 5.5, 6.28, 6.9,
RCENT(1)=11*0.0,
ACENT(1)= 0.0, .493511, .70532, .7367, .759, .763, .7585, .7391,
.6525, .4, 0.0,
BCENT(1)= .17633, .17633, .17633, .144, .052, 0.0, -.0646, -.1295, -.153,
0.0, 0.0,
CCENT(1)= 0.0, 0.0, .02020035, -.1774997, -.1600005, -.1693327,
-.1615001, -.03499995, .1651873, 0.0, 0.0,
DCENT(1)= 0.0, 0.0, -.3367512, -.1750011, -.05925696, -.2044475,
-2.499656E-03, .01712957, -.4923802, 0.0, 0.0,
XCOWL(1)= 2.86, 3.1, 3.4, 4.0, 4.2, 4.3, 4.5, 4.6, 4.7, 5.1, 5.6, 6.1, 6.5,
6.9,
RCOWL(1)=14*0.0,
ACOWL(1)=1.0, 1.004188, 1.0051, .9681, .9364, .9154, .8768, .864, .8572, .85,
.85, .8839, .9227, 0.0,
BCOWL(1)= .01745001, .01745, -.011, -.124, -.1942, -.213, -.163, -.093, -.0485,
0.0, 0.0, .107, .0729, 0.0,
CCOWL(1)= 0.0, -.04926635, -.06500001, -.1664999, -.2859976, .05000008,
.3500018, .3049997, .1075002, 0.0, .1928, .01025012, -.01512487, 0.0,
DCOWL(1)= 0.0, 4.110418E-03, -.03240740, -.0300005, 1.279984,
.2499996, -1.251464E-05, -.5499974, -.07812535, 0.0, -.1144, -.08812521,
8.74978E-03, 0.0,
DXTRAN=0.855 &END
&LIST6 &END
&LIST7 &END
&LIST8 &END
&LIST9 &END
&LIST10 &END
&LIST11 &END
```

Figure 12. Data deck for Sample Case No. 3.

```
THE ANALYSIS OF STEADY THREE-DIMENSIONAL FLOW IN SUPERSONIC MIXED-COMPRESSION AIRCRAFT INLETS

ABSTRACT

     THE FLOW FIELD IN A SUPERSONIC MIXED-COMPRESSION AIRCRAFT INLET IS COMPUTED USING A ZONAL ALGORITHM.
     THE SUPERSONIC CORE FLOW IS COMPUTED BY A BICHARACTERISTIC ALGORITHM WITH DISCRETE SHOCK WAVE
     FITTING.   THE BOUNDARY LAYER FLOW IS COMPUTED USING AN IMPLICIT FINITE DIFFERENCE METHOD.   THE
     FLOW IN A SHOCK WAVE-BOUNDARY LAYER INTERACTION REGION IS COMPUTED USING AN INTEGRAL ANALYSIS.

     THIS PROGRAM WAS DEVELOPED AT THE PURDUE UNIVERSITY THERMAL SCIENCES AND PROPULSION CENTER BY J. VADYAK UNDER
     SPONSORSHIP FROM THE NASA LEWIS RESEARCH CENTER.   J.D. HOFFMAN AND A.R. BISHOP SERVED AS THE
     PRINCIPAL INVESTIGATOR AND TECHNICAL MONITOR, RESPECTIVELY.


JOB TITLE

       CASE  NO.    3


SPECIFIED COMPUTATION OPTIONS

     1.) INTERNAL FLOW FIELD WITH SHOCK WAVE SYSTEM

     BOUNDARY LAYER COMPUTATION IS NOT INVOKED


FLOW SYMMETRY

     ONE PLANE OF SYMMETRY - COMPUTED SECTOR IS THE HALF-PLANE BOUNDED BY THE Y-AXIS AND CONTAINING THE +Z-AXIS


THERMODYNAMIC MODEL

     A THERMALLY AND CALORICALLY PERFECT GAS IS SPECIFIED WITH

     SPECIFIC HEAT RATIO=1.40000          GAS CONSTANT= 0.171616E+04(FT-LBF/SLUG-DEG R)


MOLECULAR TRANSPORT TERMS FOR SUPERSONIC CORE FLOW SOLUTION

     VISCOUS AND THERMAL DIFFUSION TERMS ARE NOT INCLUDED IN THE COMPUTATION - INVISCID AND ADIABATIC FLOW IS ASSUMED


ORIENTATION AND FREE STREAM DATA

     ORIENTATION -      PITCH= 1.00000(DEGREES)          YAW= 0.00000(DEGREES)

     FREE STREAM DATA -      MACH NO.= 2.50000          PRESSURE= 0.242200E+03(LBF/FT**2)          DENSITY= 0.362200E-03(SLUG/FT**3)

     TEMPERATURE= 0.389644E+03(DEG R)          SONIC SPEED= 0.967598E+03(FT/SEC)

     X-VELOCITY= 0.241853E+04(FT/SEC)          Y-VELOCITY= 0.422159E+02(FT/SEC)          Z-VELOCITY= 0.000000E+00(FT/SEC)
```

Figure 13. Selected output for Sample Case No. 3.

SUPERSONIC CORE FLOW INITIAL-VALUE SURFACE

AN INTERNALLY GENERATED INITIAL VALUE SURFACE IS SPECIFIED AS BEING LOCATED AT X= 0.371500E+01(FT)

INDEX PARAMETERS

ISTOP=18 IMAX=28 JMAXI=11

JINLET=11

INTEGRATION TERMINATION POINTS

INTERNAL FLOW FIELD INTEGRATION TERMINATES AT X= 0.505000E+01(FT)

FOREBODY/CENTERBODY GEOMETRY

I	KDCENT	XCENT (FT)	RCENT (FT)	ACENT (FT)	BCENT	CCENT (FT**-1)	DCENT (FT**-2)
1	1	0.000000E+00	0.000000E+00	0.000000E+00	0.176330E+00	0.000000E+00	0.000000E+00
2	1	0.279849E+01	0.000000E+00	0.493511E+00	0.176330E+00	0.000000E+00	0.000000E+00
3	1	0.400000E+01	0.000000E+00	0.705320E+00	0.176330E+00	0.202003E-01	-0.336751E+00
4	1	0.420000E+01	0.000000E+00	0.738700E+00	0.144000E+00	-0.177500E+00	-0.175001E+00
5	1	0.440000E+01	0.000000E+00	0.759000E+00	0.520000E-01	-0.160000E+00	-0.592570E-01
6	1	0.455000E+01	0.000000E+00	0.763000E+00	0.000000E+00	-0.169333E+00	-0.204447E+00
7	1	0.470000E+01	0.000000E+00	0.758500E+00	-0.646000E-01	-0.161500E+00	-0.249966E-02
8	1	0.490000E+01	0.000000E+00	0.739100E+00	-0.129500E+00	-0.349999E-01	0.171296E-01
9	1	0.550000E+01	0.000000E+00	0.652500E+00	-0.153000E+00	0.165187E+00	-0.492380E+00
10	1	0.628000E+01	0.000000E+00	0.400000E+00	0.000000E+00	0.000000E+00	0.000000E+00
11	1	0.690000E+01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00

COWL GEOMETRY

TRANSLATION FROM DESIGN POSITION= 0.855000E+00(FT)

I	KDCOWL	XCOWL (FT)	RCOWL (FT)	ACOWL (FT)	BCOWL	CCOWL (FT**-1)	DCOWL (FT**-2)
1	1	0.286000E+01	0.000000E+00	0.100000E+01	0.174500E-01	0.000000E+00	0.000000E+00
2	1	0.310000E+01	0.000000E+00	0.100419E+01	0.174500E-01	-0.492663E-01	0.411042E-02
3	1	0.340000E+01	0.000000E+00	0.100510E+01	-0.110000E-01	-0.650000E-01	-0.324074E-01
4	1	0.400000E+01	0.000000E+00	0.968100E+00	-0.124000E+00	-0.166500E+00	-0.300005E-01
5	1	0.420000E+01	0.000000E+00	0.936400E+00	-0.194200E+00	-0.285998E+00	0.127998E+01
6	1	0.430000E+01	0.000000E+00	0.915400E+00	-0.213000E+00	0.500001E-01	0.250000E+00
7	1	0.450000E+01	0.000000E+00	0.876800E+00	-0.163050E+00	0.350002E+00	-0.125146E-04
8	1	0.460000E+01	0.000000E+00	0.864000E+00	-0.930000E-01	0.305000E+00	-0.549997E+00
9	1	0.470000E+01	0.000000E+00	0.857200E+00	-0.485000E-01	0.107500E+00	-0.781253E-01
10	1	0.510000E+01	0.000000E+00	0.850000E+00	0.000000E+00	0.000000E+00	0.000000E+00
11	1	0.560000E+01	0.000000E+00	0.850000E+00	0.000000E+00	0.192800E+00	-0.114400E+00
12	1	0.610000E+01	0.000000E+00	0.883900E+00	0.107000E+00	0.102501E-01	-0.881252E-01
13	1	0.650000E+01	0.000000E+00	0.922700E+00	0.729000E-01	-0.151249E-01	0.874978E-02

Figure 13. Continued.

```
  14    1      0.690000E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00

MASS TRANSFER BOUNDARY CONDITIONS

    AN IMPERMEABLE FOREBODY/CENTERBODY WALL IS SPECIFIED

    AN IMPERMEABLE COLL WALL IS SPECIFIED


CONVERGENCE TOLERANCES, ITERATION LIMITS, AND OTHER PARAMETERS

    CONVERGENCE TOLERANCES AND OTHER PARAMETERS

        CRIT( 1)= 0.100000E+00
        CRIT( 2)= 0.100000E-06
        CRIT( 3)= 0.100000E-03
        CRIT( 4)= 0.100000E-04
        CRIT( 5)= 0.100000E-03
        CRIT( 6)= 0.100000E-03
        CRIT( 7)= 0.500000E+00
        CRIT( 8)= 0.100000E+01
        CRIT( 9)= 0.100000E-03
        CRIT(10)= 0.800000E+00
        CRIT(11)= 0.100000E-01
        CRIT(12)= 0.200000E+00
        CRIT(13)= 0.100000E-04
        CRIT(14)= 0.400000E+00
        CRIT(15)= 0.100000E-03
        CRIT(16)= 0.100000E-03
        CRIT(17)= 0.100000E-01
        CRIT(18)= 0.100000E-04

    ITERATION LIMITS

        ITEND(1)=10
        ITEND(2)=10
        ITEND(3)=10
        ITEND(4)=20
        ITEND(5)=10
        ITEND(6)=10
        ITEND(7)=10
        ITEND(8)=15

    INPUT SAFETY FACTOR= 0.975000E+00
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Figure 13. Continued.

ORIGINAL PAGE IS
OF POOR QUALITY

CORE FLOW INITIAL DATA PLANE   X= 3.71500(FT)   FOREBODY FLOW FIELD

I	J	Y (FT)	Z (FT)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
1	1	0.6551	0.0000	2.309	2331.4	326.19	0.4480E-03	424.3	2296.0	404.7	0.0	4137.6	876.7
2	1	0.6417	0.1317	2.309	2331.0	326.52	0.4483E-03	424.4	2295.6	398.0	73.4	4137.6	876.7
3	1	0.6019	0.2586	2.307	2330.1	327.49	0.4493E-03	424.7	2294.7	377.8	145.1	4137.6	876.7
4	1	0.5364	0.3760	2.303	2328.5	329.15	0.4509E-03	425.4	2293.0	344.6	213.5	4137.5	876.7
5	1	0.4468	0.4790	2.299	2326.4	331.36	0.4531E-03	426.2	2290.8	297.4	275.9	4137.4	876.7
6	1	0.3357	0.5625	2.294	2323.8	334.08	0.4557E-03	427.2	2288.1	236.7	329.6	4137.3	876.7
7	1	0.2067	0.6216	2.288	2320.9	337.22	0.4588E-03	428.3	2285.1	163.4	371.3	4137.1	876.7
8	1	0.0648	0.6518	2.281	2317.7	340.63	0.4621E-03	429.6	2282.0	79.3	397.1	4136.8	876.7
9	1	-0.0835	0.6497	2.275	2314.3	344.18	0.4655E-03	430.6	2278.8	-12.1	404.0	4136.6	876.7
10	1	-0.2305	0.6132	2.269	2311.1	347.67	0.4688E-03	432.1	2275.7	-106.3	388.6	4136.3	876.7
11	1	-0.3676	0.5422	2.262	2308.1	350.89	0.4719E-03	433.2	2272.9	-197.3	349.5	4136.0	876.7
12	1	-0.4860	0.4393	2.257	2305.5	353.65	0.4746E-03	434.2	2270.6	-278.1	287.1	4135.7	876.7
13	1	-0.5774	0.3093	2.253	2303.6	355.77	0.4766E-03	435.0	2268.9	-341.9	204.3	4135.4	876.7
14	1	-0.6353	0.1598	2.251	2302.3	357.11	0.4779E-03	435.4	2267.8	-382.9	106.3	4135.3	876.7
15	1	-0.6551	0.0000	2.250	2301.9	357.57	0.4783E-03	435.6	2267.4	-397.0	0.0	4135.2	876.7
1	2	0.7688	0.0000	2.312	2332.9	324.58	0.4464E-03	423.7	2306.9	347.5	0.0	4137.6	876.7
2	2	0.7525	0.1569	2.312	2332.6	324.91	0.4467E-03	423.8	2306.6	341.8	62.9	4137.6	876.7
3	2	0.7040	0.3078	2.310	2331.7	325.87	0.4477E-03	424.1	2305.6	324.6	124.3	4137.6	876.7
4	2	0.6248	0.4466	2.306	2330.1	327.54	0.4493E-03	424.8	2303.9	296.3	183.0	4137.5	876.7
5	2	0.5171	0.5671	2.302	2327.9	329.75	0.4515E-03	425.6	2301.7	256.0	236.7	4137.4	876.7
6	2	0.3844	0.6635	2.297	2325.3	332.48	0.4542E-03	426.6	2299.0	204.1	283.0	4137.3	876.7
7	2	0.2318	0.7304	2.291	2322.4	335.62	0.4572E-03	427.7	2296.0	141.2	319.1	4137.1	876.7
8	2	0.0649	0.7628	2.284	2319.1	339.03	0.4605E-03	429.0	2292.8	69.1	341.6	4136.8	876.7
9	2	-0.1080	0.7574	2.278	2315.8	342.60	0.4640E-03	430.3	2289.5	-9.6	347.8	4136.6	876.7
10	2	-0.2781	0.7122	2.271	2312.5	346.08	0.4673E-03	431.5	2286.4	-90.8	334.7	4136.3	876.7
11	2	-0.4358	0.6278	2.265	2309.5	349.31	0.4704E-03	432.7	2283.5	-169.3	301.2	4136.0	876.7
12	2	-0.5712	0.5072	2.260	2307.0	352.08	0.4731E-03	433.7	2281.2	-239.1	247.6	4135.7	876.7
13	2	-0.6754	0.3565	2.256	2305.0	354.20	0.4751E-03	434.4	2279.4	-294.2	176.3	4135.4	876.7
14	2	-0.7411	0.1840	2.254	2303.8	355.54	0.4764E-03	434.9	2278.2	-329.6	91.7	4135.3	876.7
15	2	-0.7636	0.0000	2.253	2303.4	356.00	0.4768E-03	435.1	2277.9	-341.8	0.0	4135.2	876.7
1	3	0.8926	0.0000	2.319	2336.3	321.09	0.4430E-03	422.4	2316.2	305.3	0.0	4137.6	876.7
2	3	0.8634	0.1823	2.319	2336.0	321.42	0.4433E-03	422.5	2315.9	300.3	54.9	4137.6	876.7
3	3	0.8063	0.3571	2.317	2335.0	322.38	0.4443E-03	422.8	2315.0	285.4	108.5	4137.6	876.7
4	3	0.7133	0.5171	2.313	2333.4	324.04	0.4459E-03	423.5	2313.3	260.8	159.8	4137.5	876.7
5	3	0.5876	0.6553	2.309	2331.3	326.24	0.4480E-03	424.3	2311.1	225.7	206.8	4137.4	876.7
6	3	0.4331	0.7647	2.304	2328.7	328.95	0.4507E-03	425.3	2308.5	180.5	247.4	4137.3	876.7
7	3	0.2564	0.8393	2.298	2325.7	332.07	0.4537E-03	426.4	2305.5	125.6	279.2	4137.1	876.7
8	3	0.0648	0.8739	2.291	2322.5	335.47	0.4570E-03	427.7	2302.3	62.4	299.2	4136.8	876.7
9	3	-0.1326	0.8651	2.284	2319.1	339.02	0.4605E-03	429.0	2299.0	-6.6	304.8	4136.6	876.7
10	3	-0.3258	0.8113	2.278	2315.9	342.49	0.4638E-03	430.2	2295.9	-77.9	293.6	4136.3	876.7
11	3	-0.5041	0.7134	2.272	2312.9	345.70	0.4669E-03	431.4	2293.0	-146.8	264.4	4136.0	876.7
12	3	-0.6565	0.5753	2.267	2310.3	348.46	0.4696E-03	432.4	2290.6	-208.1	217.4	4135.7	876.7
13	3	-0.7735	0.4037	2.263	2308.3	350.58	0.4716E-03	433.2	2288.8	-256.7	154.8	4135.4	876.7
14	3	-0.8471	0.2081	2.260	2307.1	351.91	0.4729E-03	433.6	2287.6	-287.8	80.5	4135.3	876.7
15	3	-0.8722	0.0000	2.259	2306.7	352.37	0.4733E-03	433.8	2287.3	-298.6	0.0	4135.2	876.7
1	4	0.9965	0.0000	2.328	2340.5	316.76	0.4387E-03	420.7	2324.6	272.1	0.0	4137.6	876.7
2	4	0.9744	0.2076	2.327	2340.2	317.07	0.4390E-03	420.8	2324.3	267.8	48.4	4137.6	876.7
3	4	0.9087	0.4064	2.325	2339.2	318.02	0.4400E-03	421.2	2323.4	254.6	95.7	4137.6	876.7
4	4	0.8019	0.5878	2.322	2337.7	319.65	0.4416E-03	421.8	2321.7	233.1	141.1	4137.5	876.7
5	4	0.6578	0.7435	2.318	2335.6	321.81	0.4437E-03	422.6	2319.6	202.2	182.7	4137.4	876.7
6	4	0.4819	0.8659	2.312	2333.0	324.49	0.4463E-03	423.6	2317.0	162.2	218.8	4137.3	876.7
7	4	0.2813	0.9483	2.306	2330.0	327.56	0.4493E-03	424.8	2314.1	113.7	247.1	4137.1	876.7
8	4	0.0646	0.9851	2.300	2326.8	330.91	0.4526E-03	426.0	2310.9	57.8	265.0	4136.8	876.7
9	4	-0.1572	0.9730	2.293	2323.5	334.42	0.4560E-03	427.3	2307.7	-3.4	270.2	4136.6	876.7
10	4	-0.3736	0.9105	2.287	2320.2	337.85	0.4593E-03	428.6	2304.6	-66.7	260.4	4136.3	876.7

Figure 13. Continued.

CORE FLOW INITIAL DATA PLANE X= 3.71500(FT) FOREBODY FLOW FIELD

I	J	Y (FT)	Z (FT)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
11	4	-0.5724	0.7991	2.280	2317.2	341.03	0.4624E-03	429.7	2301.8	-127.9	234.7	4136.0	876.7
12	4	-0.7419	0.6434	2.275	2314.7	343.75	0.4650E-03	430.7	2299.4	-182.5	193.1	4135.7	876.7
13	4	-0.8716	0.4519	2.271	2312.7	345.85	0.4671E-03	431.5	2297.5	-225.7	137.5	4135.4	876.7
14	4	-0.9531	0.2323	2.269	2311.5	347.17	0.4683E-03	431.9	2296.4	-253.5	71.6	4135.3	876.7
15	4	-0.9809	0.0000	2.268	2311.0	347.62	0.4688E-03	432.1	2296.0	-263.1	0.0	4135.2	876.7
1	5	1.1106	0.0000	2.336	2345.1	311.98	0.4340E-03	418.9	2332.3	244.8	0.0	4137.6	876.7
2	5	1.0855	0.2330	2.337	2344.8	312.28	0.4343E-03	419.0	2332.0	240.9	43.0	4137.6	876.7
3	5	1.0112	0.4558	2.335	2343.9	313.20	0.4352E-03	419.4	2331.1	229.4	85.0	4137.6	876.7
4	5	0.8906	0.6586	2.332	2342.4	314.80	0.4368E-03	420.0	2329.5	210.3	125.4	4137.5	876.7
5	5	0.7283	0.8319	2.328	2340.3	316.91	0.4389E-03	420.8	2327.5	182.9	162.5	4137.4	876.7
6	5	0.5307	0.9673	2.322	2337.8	319.51	0.4414E-03	421.8	2325.0	147.4	194.7	4137.3	876.7
7	5	0.3062	1.0574	2.316	2334.6	322.52	0.4444E-03	422.9	2322.1	104.3	220.1	4137.1	876.7
8	5	0.0648	1.0964	2.310	2331.7	325.80	0.4476E-03	424.1	2319.0	54.5	236.2	4136.8	876.7
9	5	-0.1819	1.0810	2.303	2328.4	329.22	0.4509E-03	425.4	2315.9	-0.1	241.1	4136.6	876.7
10	5	-0.4214	1.0098	2.297	2325.2	332.59	0.4542E-03	426.7	2312.8	-56.7	232.6	4136.3	876.7
11	5	-0.6408	0.8849	2.291	2322.2	335.70	0.4573E-03	427.8	2310.0	-111.6	209.7	4136.0	876.7
12	5	-0.8274	0.7116	2.285	2319.7	338.38	0.4598E-03	428.8	2307.7	-160.5	172.7	4135.7	876.7
13	5	-0.9699	0.4983	2.281	2317.7	340.44	0.4618E-03	429.5	2305.9	-199.3	123.0	4135.4	876.7
14	5	-1.0593	0.2566	2.279	2316.5	341.74	0.4631E-03	430.0	2304.7	-224.2	64.0	4135.3	876.7
15	5	-1.0897	0.0000	2.278	2316.1	342.18	0.4635E-03	430.2	2304.4	-232.8	0.0	4135.2	876.7
1	6	1.2248	0.0000	2.348	2350.2	306.91	0.4289E-03	416.9	2339.7	221.3	0.0	4137.6	876.7
2	6	1.1968	0.2584	2.347	2349.9	307.20	0.4292E-03	417.0	2339.4	217.9	38.2	4137.6	876.7
3	6	1.1139	0.5052	2.346	2349.0	308.09	0.4301E-03	417.4	2338.6	207.7	75.7	4137.6	876.7
4	6	0.9794	0.7294	2.342	2347.5	309.63	0.4316E-03	418.0	2337.0	190.7	111.6	4137.5	876.7
5	6	0.7988	0.9203	2.338	2345.4	311.67	0.4337E-03	418.8	2335.0	166.4	144.8	4137.4	876.7
6	6	0.5795	1.0687	2.333	2342.9	314.19	0.4362E-03	419.7	2332.6	134.9	173.7	4137.3	876.7
7	6	0.3311	1.1666	2.327	2340.1	317.11	0.4390E-03	420.9	2329.8	96.5	196.5	4137.1	876.7
8	6	0.0648	1.2079	2.321	2337.0	320.29	0.4422E-03	422.1	2326.8	52.0	211.1	4136.8	876.7
9	6	-0.2065	1.1890	2.314	2333.8	323.62	0.4454E-03	423.3	2323.8	3.1	215.7	4136.6	876.7
10	6	-0.4693	1.1092	2.308	2330.6	326.89	0.4486E-03	424.6	2320.8	-47.7	208.3	4136.3	876.7
11	6	-0.7093	0.9708	2.302	2327.7	329.92	0.4516E-03	425.7	2318.0	-96.9	188.0	4136.0	876.7
12	6	-0.9130	0.7798	2.297	2325.2	332.53	0.4542E-03	426.7	2315.7	-141.0	154.9	4135.7	876.7
13	6	-1.0663	0.5457	2.293	2323.3	334.54	0.4561E-03	427.4	2314.0	-175.9	110.4	4135.4	876.7
14	6	-1.1655	0.2808	2.290	2322.1	335.80	0.4573E-03	427.9	2312.9	-198.3	57.5	4135.3	876.7
15	6	-1.1986	0.0000	2.289	2321.6	336.24	0.4577E-03	428.0	2312.5	-206.1	0.0	4135.2	876.7
1	7	1.3391	0.0000	2.359	2355.5	301.57	0.4236E-03	414.8	2346.9	200.3	0.0	4137.6	876.7
2	7	1.3083	0.2838	2.359	2355.2	301.85	0.4239E-03	415.0	2346.7	197.3	33.9	4137.6	876.7
3	7	1.2166	0.5546	2.357	2354.3	302.70	0.4247E-03	415.3	2345.8	188.3	67.2	4137.6	876.7
4	7	1.0683	0.8003	2.354	2352.9	304.17	0.4262E-03	415.9	2344.4	173.4	99.2	4137.5	876.7
5	7	0.8694	1.0089	2.350	2350.9	306.13	0.4281E-03	416.6	2342.5	151.9	128.7	4137.4	876.7
6	7	0.6284	1.1703	2.345	2348.5	308.55	0.4306E-03	417.6	2340.1	123.9	154.6	4137.3	876.7
7	7	0.3561	1.2760	2.339	2345.7	311.38	0.4333E-03	418.7	2337.5	89.7	175.2	4137.1	876.7
8	7	0.0648	1.3194	2.333	2342.7	314.41	0.4364E-03	419.8	2334.6	50.0	188.5	4136.8	876.7
9	7	-0.2312	1.2972	2.326	2339.5	317.62	0.4395E-03	421.1	2331.6	6.3	192.8	4136.6	876.7
10	7	-0.5172	1.2087	2.220	2336.5	320.78	0.4426E-03	422.3	2328.7	-39.1	186.4	4136.3	876.7
11	7	-0.7778	1.0567	2.314	2333.6	323.72	0.4455E-03	423.4	2326.0	-83.4	168.4	4136.0	876.7
12	7	-0.9987	0.8481	2.309	2331.2	326.24	0.4480E-03	424.3	2323.8	-123.0	138.9	4135.7	876.7
13	7	-1.1667	0.5931	2.305	2329.3	328.19	0.4499E-03	425.1	2322.0	-154.4	99.1	4135.4	876.7
14	7	-1.2719	0.3051	2.302	2328.1	329.42	0.4511E-03	425.5	2321.0	-174.7	51.6	4135.3	876.7
15	7	-1.3077	0.0000	2.302	2327.7	329.84	0.4515E-03	425.7	2320.6	-181.7	0.0	4135.2	876.7
1	8	1.4536	0.0000	2.372	2361.2	295.87	0.4178E-03	412.6	2354.3	180.8	0.0	4137.6	876.7
2	8	1.4197	0.3092	2.371	2360.9	296.14	0.4181E-03	412.7	2354.0	178.2	29.9	4137.6	876.7
3	8	1.3194	0.6042	2.369	2360.1	296.95	0.4189E-03	413.0	2353.2	170.3	59.1	4137.6	876.7
4	8	1.1573	0.8712	2.366	2358.7	298.34	0.4203E-03	413.6	2351.8	157.2	87.4	4137.5	876.7
5	8	0.9401	1.0975	2.362	2356.8	300.20	0.4222E-03	414.3	2350.0	138.4	113.6	4137.4	876.7

Figure 13. Continued.

ORIGINAL PAGE IS
OF POOR QUALITY

CORE FLOW INITIAL DATA PLANE X= 3.71500(FT) FOREBODY FLOW FIELD

I	J	Y (FT)	Z (FT)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
6	8	0.6774	1.2720	2.357	2354.5	302.50	0.4245E-03	415.2	2347.8	113.8	136.7	4137.3	876.7
7	8	0.3811	1.3854	2.352	2351.8	305.17	0.4272E-03	416.3	2345.2	83.6	155.1	4137.1	876.7
8	8	0.0648	1.4311	2.346	2348.9	308.10	0.4301E-03	417.4	2342.5	48.5	167.1	4136.8	876.7
9	8	-0.2560	1.4055	2.339	2345.9	311.17	0.4331E-03	418.6	2339.6	9.6	171.3	4136.6	876.7
10	8	-0.5652	1.3083	2.333	2342.9	314.20	0.4361E-03	419.8	2336.8	-30.9	165.9	4136.3	876.7
11	8	-0.8465	1.1428	2.327	2340.1	317.01	0.4389E-03	420.9	2334.2	-70.4	150.1	4136.0	876.7
12	8	-1.0844	0.9165	2.322	2337.7	319.44	0.4413E-03	421.8	2332.0	-105.9	123.9	4135.7	876.7
13	8	-1.2653	0.6406	2.318	2335.9	321.31	0.4431E-03	422.5	2330.4	-134.1	88.5	4135.4	876.7
14	8	-1.3784	0.3294	2.316	2334.7	322.50	0.4443E-03	422.9	2329.3	-152.3	46.1	4135.3	876.7
15	8	-1.4168	0.0000	2.315	2334.3	322.90	0.4447E-03	423.1	2328.9	-158.6	0.0	4135.2	876.7
1	9	1.5681	0.0000	2.385	2367.6	289.58	0.4115E-03	410.1	2362.1	161.5	0.0	4137.6	876.7
2	9	1.5313	0.3367	2.385	2367.4	289.84	0.4117E-03	410.2	2361.9	159.3	25.8	4137.6	876.7
3	9	1.4224	0.6537	2.383	2366.6	290.60	0.4125E-03	410.5	2361.1	152.6	51.2	4137.6	876.7
4	9	1.2464	0.9423	2.380	2365.3	291.90	0.4138E-03	411.0	2359.8	141.4	75.7	4137.5	876.7
5	9	1.0109	1.1863	2.376	2363.5	293.64	0.4156E-03	411.7	2358.1	125.2	98.6	4137.4	876.7
6	9	0.7264	1.3738	2.372	2361.3	295.81	0.4178E-03	412.6	2356.0	104.0	118.9	4137.3	876.7
7	9	0.4061	1.4950	2.366	2358.7	298.33	0.4203E-03	413.6	2353.5	77.8	135.2	4137.1	876.7
8	9	0.0648	1.5429	2.360	2355.9	301.20	0.4231E-03	414.7	2350.9	47.2	146.1	4136.8	876.7
9	9	-0.2807	1.5140	2.354	2353.0	304.01	0.4260E-03	415.8	2348.1	13.2	150.0	4136.6	876.7
10	9	-0.6132	1.4080	2.348	2350.1	306.89	0.4289E-03	417.0	2345.4	-22.5	145.6	4136.3	876.7
11	9	-0.9152	1.2289	2.342	2347.4	309.57	0.4315E-03	418.0	2343.0	-57.4	132.0	4136.0	876.7
12	9	-1.1703	0.9850	2.338	2345.1	311.89	0.4238E-03	418.9	2340.9	-88.9	109.2	4135.7	876.7
13	9	-1.3639	0.6881	2.334	2343.3	313.68	0.4356E-03	419.6	2339.2	-113.9	78.1	4135.4	876.7
14	9	-1.4850	0.3537	2.331	2342.2	314.81	0.4367E-03	420.0	2338.2	-130.1	40.7	4135.3	876.7
15	9	-1.5261	0.0000	2.331	2341.8	315.19	0.4371E-03	420.2	2337.9	-135.7	0.0	4135.2	876.7
1	10	1.6828	0.0000	2.402	2375.3	282.13	0.4039E-03	407.0	2371.2	140.9	0.0	4137.6	876.7
2	10	1.6430	0.3602	2.401	2375.1	282.37	0.4041E-03	407.1	2370.9	139.1	21.4	4137.6	876.7
3	10	1.5254	0.7034	2.400	2374.4	283.08	0.4049E-03	407.4	2370.2	133.6	42.5	4137.6	876.7
4	10	1.3356	1.0134	2.397	2373.1	284.27	0.4061E-03	407.9	2369.0	124.5	63.1	4137.5	876.7
5	10	1.0817	1.2751	2.393	2371.4	285.89	0.4077E-03	408.6	2367.4	111.2	82.4	4137.4	876.7
6	10	0.7765	1.4757	2.389	2369.3	287.90	0.4098E-03	409.4	2365.4	93.7	99.7	4137.3	876.7
7	10	0.4311	1.6047	2.384	2366.9	290.25	0.4121E-03	410.4	2363.1	71.8	113.8	4137.1	876.7
8	10	0.0648	1.6540	2.378	2364.2	292.84	0.4148E-03	411.4	2360.6	46.0	123.5	4136.8	876.7
9	10	-0.3055	1.6225	2.372	2361.5	295.57	0.4175E-03	412.5	2358.0	17.2	127.4	4136.6	876.7
10	10	-0.6613	1.5078	2.366	2358.7	298.27	0.4202E-03	413.6	2355.4	-13.3	124.1	4136.3	876.7
11	10	-0.9840	1.3152	2.361	2356.1	300.81	0.4228E-03	414.6	2353.0	-43.4	112.9	4136.0	876.7
12	10	-1.2562	1.0535	2.356	2353.9	303.00	0.4250E-03	415.5	2351.0	-70.6	93.6	4135.7	876.7
13	10	-1.4627	0.7358	2.352	2352.2	304.69	0.4266E-03	416.1	2349.4	-92.3	67.0	4135.4	876.7
14	10	-1.5917	0.3781	2.350	2351.1	305.76	0.4277E-03	416.6	2348.4	-106.4	35.0	4135.3	876.7
15	10	-1.6355	0.0000	2.349	2350.7	306.13	0.4281E-03	416.7	2348.1	-112.3	0.0	4135.2	876.7
1	D	1.7976	0.0000	2.428	2387.2	270.87	0.3923E-03	402.3	2384.6	112.3	0.0	4137.6	876.7
2	D	1.7549	0.3857	2.428	2387.0	271.09	0.3925E-03	402.4	2384.3	111.2	15.3	4137.6	876.7
3	D	1.6286	0.7531	2.426	2386.3	271.75	0.3932E-03	402.7	2383.7	107.6	30.5	4137.6	876.7
4	D	1.4249	1.0846	2.423	2385.1	272.85	0.3944E-03	403.2	2382.5	101.5	45.6	4137.5	876.7
5	D	1.1526	1.3640	2.420	2383.5	274.36	0.3959E-03	403.8	2380.9	92.4	60.2	4137.4	876.7
6	D	0.8246	1.5777	2.415	2381.5	276.24	0.3978E-03	404.6	2379.0	80.0	73.7	4137.3	876.7
7	D	0.4562	1.7145	2.410	2379.2	278.45	0.4001E-03	405.5	2376.8	64.2	85.2	4137.1	876.7
8	D	0.0648	1.7668	2.405	2376.6	280.90	0.4026E-03	406.5	2374.3	44.9	93.6	4136.8	876.7
9	D	-0.3303	1.7311	2.399	2373.9	283.48	0.4052E-03	407.6	2371.7	22.8	97.7	4136.6	876.7
10	D	-0.7094	1.6077	2.393	2371.2	286.06	0.4079E-03	408.7	2369.2	-1.1	96.2	4136.3	876.7
11	D	-1.0528	1.4015	2.387	2368.7	288.47	0.4103E-03	409.7	2366.9	-25.0	88.3	4136.0	876.7
12	D	-1.3422	1.1221	2.383	2366.5	290.57	0.4124E-03	410.5	2364.9	-47.0	73.8	4135.7	876.7
13	D	-1.5616	0.7832	2.379	2364.8	292.20	0.4141E-03	411.2	2363.3	-64.7	53.1	4135.4	876.7
14	D	-1.6985	0.4025	2.377	2363.7	293.23	0.4151E-03	411.6	2362.3	-76.3	27.0	4135.3	876.7
15	D	-1.7450	0.0000	2.376	2363.4	293.58	0.4155E-03	411.7	2362.0	-80.3	0.0	4135.2	876.7

MASS FLOW RATE FOR ENTIRE PLANE= 0.85538E+01(SLUG/SEC)

Figure 13. Continued.

CORE FLOW REDISTRIBUTED PLANE AT COWL ENTRANCE X= 3.71500(FT) INTERNAL FLOW FIELD WITH SHOCK WAVE SYSTEM

I	J	Y (FT)	Z (FT)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
1	1	0.6551	0.0000	2.309	2331.3	326.22	0.4480E-03	424.3	2296.0	404.1	0.0	4137.2	876.7
2	1	0.6386	0.1458	2.308	2330.9	326.62	0.4484E-03	424.4	2295.6	395.9	80.6	4137.2	876.7
3	1	0.5902	0.2842	2.306	2329.7	327.81	0.4496E-03	424.9	2294.4	371.8	158.5	4137.1	876.7
4	1	0.5122	0.4084	2.302	2327.9	329.74	0.4515E-03	425.6	2292.4	332.3	230.9	4137.0	876.7
5	1	0.4084	0.5122	2.297	2325.4	332.29	0.4540E-03	426.5	2289.9	277.7	294.6	4136.7	876.7
6	1	0.2842	0.5902	2.291	2322.6	335.30	0.4569E-03	427.6	2287.0	209.6	346.3	4136.5	876.7
7	1	0.1458	0.6386	2.285	2319.4	338.64	0.4601E-03	428.8	2283.9	130.2	382.8	4136.2	876.7
8	1	0.0000	0.6551	2.278	2316.1	342.13	0.4635E-03	430.1	2280.7	42.9	401.3	4135.9	876.6
9	1	-0.1458	0.6386	2.272	2312.8	345.61	0.4669E-03	431.4	2277.5	-48.2	399.7	4135.6	876.6
10	1	-0.2842	0.5902	2.266	2309.8	348.89	0.4700E-03	432.5	2274.7	-138.2	376.7	4135.3	876.6
11	1	-0.4084	0.5122	2.260	2307.1	351.81	0.4728E-03	433.6	2272.2	-221.9	332.5	4135.0	876.6
12	1	-0.5122	0.4084	2.256	2304.9	354.24	0.4751E-03	434.4	2270.2	-293.9	269.5	4134.8	876.6
13	1	-0.5902	0.2842	2.253	2303.2	356.06	0.4769E-03	435.1	2268.7	-349.3	189.1	4134.6	876.6
14	1	-0.6386	0.1458	2.251	2302.2	357.19	0.4779E-03	435.5	2267.8	-384.2	97.6	4134.5	876.7
15	1	-0.6551	0.0000	2.250	2301.8	357.57	0.4783E-03	435.6	2267.5	-396.1	0.0	4134.4	876.7
1	2	0.6982	0.0000	2.310	2331.9	325.67	0.4475E-03	424.1	2300.1	383.8	0.0	4138.1	876.7
2	2	0.6807	0.1554	2.309	2331.6	326.06	0.4479E-03	424.2	2299.8	376.0	76.2	4138.1	876.7
3	2	0.6290	0.3029	2.307	2330.4	327.24	0.4490E-03	424.6	2298.6	353.4	149.9	4138.0	876.7
4	2	0.5459	0.4353	2.303	2328.6	329.17	0.4509E-03	425.4	2296.6	316.1	218.5	4137.9	876.7
5	2	0.4353	0.5459	2.298	2326.1	331.71	0.4534E-03	426.3	2294.1	264.6	279.0	4137.7	876.7
6	2	0.3029	0.6290	2.293	2323.3	334.72	0.4563E-03	427.4	2291.2	200.2	328.3	4137.6	876.7
7	2	0.1554	0.6807	2.286	2320.1	338.06	0.4596E-03	428.6	2288.1	125.0	363.3	4137.4	876.7
8	2	0.0000	0.6982	2.280	2316.8	341.56	0.4630E-03	429.9	2284.9	42.1	381.3	4137.2	876.7
9	2	-0.1554	0.6807	2.273	2313.6	345.04	0.4663E-03	431.2	2281.7	-44.6	380.2	4137.0	876.7
10	2	-0.3029	0.6290	2.267	2310.5	348.34	0.4695E-03	432.3	2278.8	-130.5	358.7	4136.8	876.7
11	2	-0.4353	0.5459	2.262	2307.8	351.28	0.4723E-03	433.4	2276.3	-210.4	317.0	4136.6	876.7
12	2	-0.5459	0.4353	2.257	2305.6	353.72	0.4746E-03	434.3	2274.2	-279.3	256.6	4136.5	876.8
13	2	-0.6290	0.3029	2.254	2303.9	355.55	0.4764E-03	434.9	2272.7	-332.4	180.5	4136.4	876.8
14	2	-0.6807	0.1554	2.252	2302.9	356.69	0.4775E-03	435.3	2271.7	-365.9	93.2	4136.3	876.8
15	2	-0.6982	0.0000	2.251	2302.6	357.07	0.4778E-03	435.4	2271.4	-377.3	0.0	4136.3	876.8
1	3	0.7413	0.0000	2.311	2332.2	325.21	0.4470E-03	423.9	2304.5	358.7	0.0	4137.1	876.7
2	3	0.7227	0.1650	2.310	2331.9	325.60	0.4474E-03	424.0	2304.1	351.6	71.2	4137.1	876.7
3	3	0.6679	0.3216	2.308	2330.8	326.75	0.4486E-03	424.5	2303.0	330.4	139.9	4137.1	876.7
4	3	0.5796	0.4622	2.304	2328.9	328.67	0.4504E-03	425.2	2301.0	295.9	204.2	4137.0	876.7
5	3	0.4622	0.5796	2.299	2326.5	331.16	0.4529E-03	426.1	2298.6	247.8	260.8	4136.9	876.7
6	3	0.3216	0.6679	2.294	2323.7	334.14	0.4558E-03	427.2	2295.7	187.7	307.0	4136.8	876.7
7	3	0.1650	0.7227	2.287	2320.6	337.46	0.4590E-03	428.4	2292.6	117.4	339.8	4136.7	876.7
8	3	0.0000	0.7413	2.281	2317.3	340.94	0.4624E-03	429.7	2289.4	39.9	356.8	4136.5	876.7
9	3	-0.1650	0.7227	2.274	2314.0	344.43	0.4657E-03	430.9	2286.2	-41.2	355.5	4136.2	876.7
10	3	-0.3216	0.6679	2.268	2311.0	347.72	0.4689E-03	432.1	2283.3	-121.5	335.3	4135.9	876.7
11	3	-0.4622	0.5796	2.263	2308.2	350.67	0.4717E-03	433.2	2280.7	-196.1	296.1	4135.6	876.7
12	3	-0.5796	0.4622	2.258	2305.9	353.13	0.4741E-03	434.0	2278.7	-260.2	239.5	4135.3	876.7
13	3	-0.6679	0.3216	2.255	2304.2	354.98	0.4758E-03	434.7	2277.1	-309.6	168.5	4135.1	876.7
14	3	-0.7227	0.1650	2.253	2303.2	356.13	0.4769E-03	435.1	2276.2	-340.8	87.0	4135.0	876.7
15	3	-0.7413	0.0000	2.252	2302.8	356.51	0.4773E-03	435.2	2275.9	-351.4	0.0	4135.0	876.7
1	4	0.7844	0.0000	2.313	2333.3	324.21	0.4461E-03	423.5	2308.3	340.9	0.0	4137.9	876.7
2	4	0.7647	0.1745	2.312	2332.9	324.59	0.4464E-03	423.7	2307.9	334.2	67.1	4137.9	876.7
3	4	0.7067	0.3403	2.310	2331.9	325.72	0.4475E-03	424.1	2306.8	314.3	132.0	4137.9	876.7
4	4	0.6133	0.4891	2.306	2330.0	327.63	0.4494E-03	424.8	2304.9	282.0	192.8	4137.8	876.7
5	4	0.4891	0.6133	2.302	2327.7	330.09	0.4518E-03	425.7	2302.5	236.7	246.4	4137.7	876.7
6	4	0.3403	0.7067	2.296	2324.9	333.05	0.4547E-03	426.8	2299.6	180.1	290.4	4137.6	876.7
7	4	0.1745	0.7647	2.290	2321.7	336.35	0.4579E-03	428.0	2296.5	113.7	321.9	4137.4	876.7
8	4	0.0000	0.7844	2.283	2318.5	339.82	0.4613E-03	429.3	2293.3	40.3	338.2	4137.2	876.7
9	4	-0.1745	0.7647	2.276	2315.2	343.31	0.4646E-03	430.5	2290.1	-36.7	337.8	4137.0	876.7
10	4	-0.3403	0.7067	2.270	2312.1	346.61	0.4678E-03	431.7	2287.2	-113.2	319.1	4136.7	876.7

Figure 13. Continued.

CORE FLOW REDISTRIBUTED PLANE AT COWL ENTRANCE X= 3.71500(FT) INTERNAL FLOW FIELD WITH SHOCK WAVE SYSTEM

I	J	Y (FT)	Z (FT)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
11	4	-0.4691	0.6133	2.265	2309.4	349.56	0.4707E-03	432.8	2284.6	-184.5	282.2	4136.5	876.7
12	4	-0.6133	0.4891	2.260	2307.1	352.03	0.4730E-03	433.7	2282.5	-246.1	228.7	4136.2	876.7
13	4	-0.7067	0.3403	2.257	2305.4	353.89	0.4748E-03	434.3	2281.0	-293.6	161.0	4136.1	876.7
14	4	-0.7647	0.1745	2.255	2304.3	355.04	0.4759E-03	434.7	2280.0	-323.6	83.2	4136.0	876.7
15	4	-0.7844	0.0000	2.254	2304.0	355.43	0.4763E-03	434.9	2279.7	-333.8	0.0	4136.0	876.7
1	5	0.8275	0.0000	2.315	2334.4	322.94	0.4448E-03	423.0	2311.9	323.1	0.0	4137.1	876.7
2	5	0.8068	0.1841	2.315	2334.0	323.31	0.4452E-03	423.2	2311.6	316.9	63.1	4137.1	876.7
3	5	0.7456	0.3591	2.313	2333.0	324.43	0.4463E-03	423.6	2310.5	298.2	124.2	4137.0	876.7
4	5	0.6470	0.5160	2.309	2331.2	326.30	0.4481E-03	424.3	2308.6	267.9	181.4	4136.9	876.7
5	5	0.5160	0.6470	2.304	2328.8	328.73	0.4505E-03	425.2	2306.2	225.4	232.1	4136.8	876.7
6	5	0.3591	0.7456	2.298	2326.0	331.66	0.4534E-03	426.3	2303.4	172.1	273.8	4136.7	876.7
7	5	0.1841	0.8068	2.292	2322.9	334.93	0.4565E-03	427.5	2300.4	109.6	303.7	4136.5	876.7
8	5	0.0000	0.8275	2.285	2319.7	338.38	0.4599E-03	428.8	2297.2	40.3	319.4	4136.3	876.7
9	5	-0.1841	0.8068	2.279	2316.4	341.86	0.4632E-03	430.0	2294.1	-32.6	319.2	4136.0	876.7
10	5	-0.3591	0.7456	2.273	2313.3	345.15	0.4664E-03	431.2	2291.1	-105.0	301.7	4135.6	876.7
11	5	-0.5160	0.6470	2.267	2310.5	348.11	0.4693E-03	432.3	2288.6	-172.6	267.0	4135.3	876.7
12	5	-0.6470	0.5160	2.263	2308.2	350.59	0.4716E-03	433.1	2286.4	-230.9	216.3	4135.0	876.7
13	5	-0.7456	0.3591	2.259	2306.5	352.45	0.4734E-03	433.8	2284.9	-275.9	152.3	4134.8	876.7
14	5	-0.8068	0.1841	2.257	2305.4	353.61	0.4745E-03	434.2	2283.9	-304.4	78.7	4134.7	876.7
15	5	-0.8275	0.0000	2.256	2305.1	354.00	0.4749E-03	434.4	2283.6	-314.1	0.0	4134.7	876.7
1	6	0.8706	0.0000	2.318	2335.9	321.51	0.4434E-03	422.5	2315.3	308.9	0.0	4137.6	876.7
2	6	0.8488	0.1937	2.318	2335.5	321.88	0.4438E-03	422.6	2315.0	303.0	59.9	4137.6	876.7
3	6	0.7844	0.3778	2.315	2334.4	322.98	0.4448E-03	423.1	2313.9	285.4	118.0	4137.5	876.7
4	6	0.6807	0.5428	2.312	2332.6	324.83	0.4467E-03	423.8	2312.1	256.7	172.4	4137.4	876.7
5	6	0.5428	0.6807	2.307	2330.3	327.24	0.4490E-03	424.7	2309.7	216.5	220.7	4137.3	876.7
6	6	0.3778	0.7844	2.301	2327.6	330.14	0.4519E-03	425.7	2307.0	165.9	260.5	4137.2	876.7
7	6	0.1937	0.8488	2.295	2324.5	333.38	0.4550E-03	426.9	2303.9	106.5	289.3	4137.1	876.7
8	6	0.0000	0.8706	2.289	2321.2	336.81	0.4584E-03	428.2	2300.8	40.5	304.7	4136.9	876.7
9	6	-0.1937	0.8488	2.282	2318.0	340.27	0.4617E-03	429.4	2297.7	-29.1	304.9	4136.6	876.7
10	6	-0.3778	0.7844	2.276	2314.9	343.56	0.4649E-03	430.6	2294.7	-98.4	288.5	4136.3	876.7
11	6	-0.5428	0.6807	2.270	2312.1	346.52	0.4677E-03	431.7	2292.1	-163.2	255.6	4136.0	876.7
12	6	-0.6807	0.5428	2.266	2309.8	349.00	0.4701E-03	432.6	2290.0	-219.4	207.3	4135.7	876.7
13	6	-0.7844	0.3778	2.262	2308.1	350.87	0.4719E-03	433.3	2288.4	-262.8	146.1	4135.6	876.7
14	6	-0.8488	0.1937	2.260	2307.0	352.03	0.4730E-03	433.7	2287.4	-290.2	75.5	4135.5	876.7
15	6	-0.8706	0.0000	2.259	2306.7	352.43	0.4734E-03	433.8	2287.1	-299.6	0.0	4135.5	876.7
1	7	0.9138	0.0000	2.322	2337.4	319.97	0.4419E-03	421.9	2318.6	295.9	0.0	4138.0	876.7
2	7	0.8909	0.2033	2.321	2337.1	320.33	0.4422E-03	422.1	2318.3	290.3	56.9	4137.9	876.7
3	7	0.8233	0.3965	2.319	2336.0	321.41	0.4433E-03	422.5	2317.2	273.6	112.1	4137.9	876.7
4	7	0.7144	0.5697	2.315	2334.2	323.24	0.4451E-03	423.2	2315.4	246.5	163.9	4137.8	876.7
5	7	0.5697	0.7144	2.310	2332.0	325.61	0.4474E-03	424.0	2313.1	208.3	210.0	4137.7	876.7
6	7	0.3965	0.8233	2.305	2329.2	328.48	0.4502E-03	425.1	2310.4	160.4	248.1	4137.6	876.7
7	7	0.2033	0.8909	2.298	2326.1	331.69	0.4534E-03	426.3	2307.4	103.9	275.8	4137.4	876.7
8	7	0.0000	0.9138	2.292	2322.9	335.09	0.4567E-03	427.6	2304.3	40.9	290.8	4137.2	876.7
9	7	-0.2033	0.8909	2.285	2319.7	338.54	0.4600E-03	428.8	2301.1	-25.5	291.4	4137.0	876.7
10	7	-0.3965	0.8233	2.279	2316.6	341.82	0.4632E-03	430.0	2298.2	-91.9	276.1	4136.7	876.7
11	7	-0.5697	0.7144	2.274	2313.8	344.77	0.4660E-03	431.1	2295.6	-154.3	245.0	4136.4	876.7
12	7	-0.7144	0.5697	2.269	2311.5	347.25	0.4684E-03	432.0	2293.5	-208.3	199.0	4136.2	876.7
13	7	-0.8233	0.3965	2.265	2309.8	349.12	0.4702E-03	432.6	2291.9	-250.2	140.3	4136.0	876.7
14	7	-0.8909	0.2033	2.263	2308.7	350.28	0.4713E-03	433.1	2290.9	-276.7	72.6	4135.9	876.7
15	7	-0.9138	0.0000	2.263	2308.3	350.68	0.4717E-03	433.2	2290.6	-285.8	0.0	4135.9	876.7
1	8	0.9569	0.0000	2.325	2338.9	318.33	0.4403E-03	421.3	2321.8	282.3	0.0	4137.5	876.7
2	8	0.9329	0.2129	2.324	2338.6	318.68	0.4406E-03	421.4	2321.5	277.0	53.9	4137.4	876.7
3	8	0.8621	0.4152	2.322	2337.5	319.74	0.4417E-03	421.8	2320.5	261.3	106.3	4137.4	876.7
4	8	0.7481	0.5966	2.318	2335.8	321.54	0.4434E-03	422.5	2318.7	235.6	155.4	4137.3	876.7
5	8	0.5966	0.7481	2.314	2333.5	323.87	0.4457E-03	423.4	2316.4	199.5	199.2	4137.2	876.7

Figure 13. Continued.

CORE FLOW REDISTRIBUTED PLANE AT COWL ENTRANCE X= 3.71800(FT) INTERNAL FLOW FIELD WITH SHOCK WAVE SYSTEM

I	J	Y (FT)	Z (FT)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
6	8	0.4152	0.8621	2.308	2330.8	326.69	0.4485E-03	424.5	2313.8	154.0	235.5	4137.1	876.7
7	8	0.2129	0.9329	2.302	2327.8	329.86	0.4516E-03	425.6	2310.8	100.4	261.9	4136.9	876.7
8	8	0.0000	0.9569	2.295	2324.6	333.23	0.4549E-03	426.9	2307.7	40.6	276.3	4136.6	876.7
9	8	-0.2129	0.9329	2.289	2321.3	336.64	0.4582E-03	428.1	2304.6	-22.6	277.0	4136.3	876.7
10	8	-0.4152	0.8621	2.283	2318.3	339.90	0.4613E-03	429.3	2301.8	-85.8	262.5	4136.1	876.7
11	8	-0.5966	0.7481	2.277	2315.5	342.84	0.4642E-03	430.4	2299.2	-145.1	233.0	4135.8	876.7
12	8	-0.7481	0.5966	2.272	2313.2	345.30	0.4665E-03	431.3	2297.0	-196.6	189.2	4135.5	876.7
13	8	-0.8621	0.4152	2.269	2311.5	347.17	0.4683E-03	431.9	2295.5	-236.4	133.4	4135.3	876.7
14	8	-0.9329	0.2129	2.267	2310.4	348.33	0.4694E-03	432.4	2294.5	-261.7	69.0	4135.2	876.7
15	8	-0.9569	0.0000	2.266	2310.0	348.72	0.4698E-03	432.5	2294.1	-270.3	0.0	4135.2	876.7
1	U	1.0000	0.0000	2.328	2340.6	316.61	0.4386E-03	420.7	2324.9	271.4	0.0	4137.8	876.7
2	U	0.9749	0.2225	2.328	2340.3	316.96	0.4389E-03	420.8	2324.5	266.3	51.5	4137.7	876.7
3	U	0.9010	0.4339	2.325	2339.3	318.00	0.4399E-03	421.2	2323.5	251.4	101.4	4137.7	876.7
4	U	0.7818	0.6235	2.322	2337.6	319.77	0.4417E-03	421.9	2321.8	226.9	148.4	4137.5	876.7
5	U	0.6235	0.7818	2.317	2335.3	322.06	0.4439E-03	422.7	2319.6	192.6	190.2	4137.5	876.7
6	U	0.4339	0.9010	2.312	2332.6	324.85	0.4467E-03	423.8	2317.0	149.2	225.0	4137.4	876.7
7	U	0.2225	0.9749	2.306	2329.6	327.98	0.4497E-03	424.9	2314.0	98.1	250.6	4137.2	876.7
8	U	0.0000	1.0000	2.299	2326.3	331.31	0.4530E-03	426.2	2311.0	40.9	264.6	4136.9	876.7
9	U	-0.2225	0.9749	2.293	2323.2	334.70	0.4563E-03	427.4	2307.9	-19.7	265.5	4136.7	876.7
10	U	-0.4339	0.9010	2.286	2320.2	337.93	0.4594E-03	428.6	2305.0	-80.4	252.0	4136.4	876.7
11	U	-0.6235	0.7818	2.281	2317.4	340.85	0.4622E-03	429.7	2302.5	-137.5	223.8	4136.1	876.7
12	U	-0.7818	0.6235	2.276	2315.1	343.31	0.4646E-03	430.6	2300.3	-187.1	181.9	4135.9	876.7
13	U	-0.9010	0.4339	2.273	2313.4	345.18	0.4664E-03	431.2	2298.8	-225.6	128.4	4135.7	876.7
14	U	-0.9749	0.2225	2.271	2312.3	346.33	0.4675E-03	431.7	2297.8	-250.0	66.4	4135.6	876.7
15	U	-1.0000	0.0000	2.270	2311.9	346.72	0.4679E-03	431.8	2297.4	-258.4	0.0	4135.6	876.7
1	D	1.0000	0.0000	2.106	2225.1	446.37	0.5599E-03	464.6	2224.7	38.8	0.0	4120.8	876.7
2	D	0.9749	0.2225	2.106	2224.8	446.70	0.5602E-03	464.7	2224.5	39.9	-0.2	4120.7	876.7
3	D	0.9010	0.4339	2.104	2224.0	447.69	0.5610E-03	465.0	2223.6	42.7	0.9	4120.9	876.7
4	D	0.7818	0.6235	2.101	2222.3	449.80	0.5629E-03	465.6	2221.8	46.2	4.2	4120.8	876.7
5	D	0.6235	0.7818	2.098	2220.4	452.25	0.5651E-03	466.3	2219.8	49.1	10.4	4121.0	876.7
6	D	0.4339	0.9010	2.094	2218.0	455.24	0.5678E-03	467.2	2217.4	50.0	18.9	4121.2	876.7
7	D	0.2225	0.9749	2.089	2215.4	458.62	0.5708E-03	468.2	2214.7	47.5	28.8	4121.3	876.7
8	D	0.0000	1.0000	2.084	2212.6	462.17	0.5740E-03	469.2	2211.9	40.9	38.6	4121.4	876.7
9	D	-0.2225	0.9749	2.079	2209.6	465.93	0.5773E-03	470.3	2208.9	30.3	46.5	4121.5	876.7
10	D	-0.4339	0.9010	2.074	2206.9	469.44	0.5804E-03	471.3	2206.2	16.5	50.7	4121.5	876.7
11	D	-0.6235	0.7818	2.070	2204.4	472.63	0.5832E-03	472.2	2203.8	1.1	50.0	4121.5	876.7
12	D	-0.7818	0.6235	2.066	2202.3	475.32	0.5856E-03	473.0	2201.8	-14.1	43.9	4121.4	876.7
13	D	-0.9010	0.4339	2.063	2200.7	477.35	0.5874E-03	473.6	2200.3	-26.9	32.7	4121.4	876.7
14	D	-0.9749	0.2225	2.061	2199.8	478.62	0.5885E-03	473.9	2199.4	-35.4	17.4	4121.4	876.7
15	D	-1.0000	0.0000	2.061	2199.4	479.03	0.5888E-03	474.0	2199.1	-38.4	0.0	4121.4	876.7
1	9	1.0000	0.0000	2.106	2225.1	446.37	0.5599E-03	464.6	2224.7	38.8	0.0	4120.8	876.7
2	9	0.9749	0.2225	2.106	2224.8	446.70	0.5602E-03	464.7	2224.5	39.9	-0.2	4120.7	876.7
3	9	0.9010	0.4339	2.104	2224.0	447.69	0.5610E-03	465.0	2223.6	42.7	0.9	4120.9	876.7
4	9	0.7818	0.6235	2.101	2222.3	449.80	0.5629E-03	465.6	2221.8	46.2	4.2	4120.8	876.7
5	9	0.6235	0.7818	2.098	2220.4	452.25	0.5651E-03	466.3	2219.8	49.1	10.4	4121.0	876.7
6	9	0.4339	0.9010	2.094	2218.0	455.24	0.5678E-03	467.2	2217.4	50.0	18.9	4121.2	876.7
7	9	0.2225	0.9749	2.089	2215.4	458.62	0.5708E-03	468.2	2214.7	47.5	28.8	4121.3	876.7
8	9	0.0000	1.0000	2.084	2212.6	462.17	0.5740E-03	469.2	2211.9	40.9	38.6	4121.4	876.7
9	9	-0.2225	0.9749	2.079	2209.6	465.93	0.5773E-03	470.3	2208.9	30.3	46.5	4121.5	876.7
10	9	-0.4339	0.9010	2.074	2206.9	469.44	0.5804E-03	471.3	2206.2	16.5	50.7	4121.5	876.7
11	9	-0.6235	0.7818	2.070	2204.4	472.63	0.5832E-03	472.2	2203.8	1.1	50.0	4121.5	876.7
12	9	-0.7818	0.6235	2.066	2202.3	475.32	0.5856E-03	473.0	2201.8	-14.1	43.9	4121.4	876.7
13	9	-0.9010	0.4339	2.063	2200.7	477.35	0.5874E-03	473.6	2200.3	-26.9	32.7	4121.4	876.7
14	9	-0.9749	0.2225	2.061	2199.8	478.62	0.5885E-03	473.9	2199.4	-35.4	17.4	4121.4	876.7
15	9	-1.0000	0.0000	2.061	2199.4	479.03	0.5888E-03	474.0	2199.1	-38.4	0.0	4121.4	876.7

MASS FLOW RATE FOR ENTIRE PLANE= 0.18754E+01(SLUG/SEC)

Figure 13. Continued.

```
X-STEP REGULATION PARAMETERS
LIMITING POINT - I=15, J=11        SAFETY FACTOR= 0.975000E+00        DELTA-X= 0.750005E-01(FT)
```

Figure 13. Concluded.

5. SAMPLE CASE NO. 4

This sample case is concerned with the computation of both the supersonic core flow and forebody/centerbody and cowl boundary layer flows for the Mach 3.5 mixed-compression inlet considered in Sample Case No. 3. The internal flow field is again computed for the off-design conditions of a free-stream Mach number of 2.5, a centerbody forward translation of 0.855 ft, and an angle of attack of 1.0 degree. The computation for this sample case includes the effects of distributed mass bleed. Independent turbulent transition models are specified for the forebody/centerbody and cowl boundary layer calculations.

The data deck for Sample Case No. 4 is presented in Figure 14. The first card of the data deck is again the title card. Namelist LIST1 for this sample case is identical to that in Sample Case No. 3 except for the input parameter KBLAY. Since the boundary layer computation is to be invoked for this sample case, KBLAY retains its default value of 1. Mass transfer effects will not be considered in the computation of the supersonic core flow, hence KTRANS is retained at the value of 0.

Namelists LIST2, LIST3, LIST4, and LIST5 for this sample are identical to those in Sample Case No. 3.

All input parameters in namelist LIST6 retain their default values except for the coordinate stretching parameter FACTØR. Hence, the laminar forebody/centerbody boundary layer initial data will be generated internally using the Adams algorithm (KBLIDA=1 and KTURB=0). Since CLENGH=4.0, the length of the conical forebody section is specified as 4.0 ft. The Adams algorithm mesh parameters ADY and ARATIØ retain their default values of 0.010 and 1.0630. The laminar cowl boundary layer initial data are internally generated (KBLIDB=1 and KTURBB=0). Since MBLAY, NA, and NB retain their default values of 15, 20, and 20 respectively, both the forebody/centerbody and cowl boundary layer computations employ 15 circumferential stations and 20 radial stations. For this sample case, the boundary layer normal coordinate stretching factor is specified as 1.175 for both boundary layers; hence, both elements of FACTØR are specified as 1.175.

All input parameters in namelist LIST7 are retained at their default values except for TCØNSTA and TCØNSTB. Consequently, constant wall temperature boundary conditions are specified for both the forebody/centerbody and cowl boundary layer computations (KTYPE=1, KWLTA=1, and KWLTB=1). TCØNSTA and TCØNSTB are both specified as 876.698, which is the free-stream stagnation temperature of 876.698 R.

Distributed mass bleed is specified on both the forebody/centerbody contour and the cowl contour for this computation, hence KDFA=1 and KDFB=1 are entered in namelist LIST8. Two bleed zones on the forebody/centerbody contour and one bleed zone on the cowl contour are employed, thus NRA=2 and NRB=1. The bleed zones for the forebody/centerbody contour extend from x=4.2 ft to x=4.4 ft for the first zone, and from x=4.9 ft to x=5.1 ft for the second zone. Hence, XSA(1)=4.2, XEA(1)=4.4, XSA(2)=4.9, and XEA(2)=5.1 are entered in namelist LIST8. For the cowl, the bleed zone extends from x=3.75 ft to x=3.[illegible] ft; hence, XSB(1)=3.75 and XEB(1)=3.85 are specified. The bleed mass flux for each zone is 0.000001 (slug/ft^2·sec). Consequently, RØVA(1), RØVA(2), and RØVB(1) are each entered as 0.000001.

The turbulence model parameters are specified in namelist LIST9. For this computation, transition models No. 5 and No. 3 will be used for the forebody/centerbody and cowl boundary layer computations, respectively. Hence, ITRANM(1)=5 and ITRANM(2)=3 are entered. Both models require specification the transition onset location array XT1. Although a different transition onset distance for each circumferential station can be specified, a constant distance is used in the present computation. For the forebody/centerbody, a transition onset location of $\tilde{x}$=4.0 ft is arbitrarily selected; whereas for the cowl, a transition onset location of $\tilde{x}$=0.3 ft is selected. Consequently, XT1(1,1)=16*4.0 and XT1(1,2)=16*0.3 are entered. The transition model used for the cowl boundary layer computation requires that the XT2 array be entered to denote the onset location of fully turbulent flow. For the present case, all circumferential stations on the cowl have $\tilde{x}$=1.8 ft selected as this fully turbulent onset location; hence, XT2(1,2)=16*1.8 is entered in namelist LIST9.

All convergence tolerances and iteration limits retain their default values in namelist LIST10.

No debug output is to be printed for this sample case, so all input parameters in namelist LIST11 retain their default values.

Selected portions of the computer output for Sample Case No. 4 are presented in Figure 15.

```
CASE  NO.  4
&LIST1 KCALL(1)=0, XEND(2)=5.05, KTRANS=0 &END
&LIST2 MFS=2.5, XI=3.715, KSUPER=1 &END
&LIST3 &END
&LIST4 &END
&LIST5 NCENT=11, NCOWL=14, KDCENT(1)=11*1, KDCOWL(1)=14*1,
XCENT(1)= 0.0, 2.798794, 4.0, 4.2, 4.4, 4.55, 4.7, 4.9, 5.5, 6.28, 6.9,
RCENT(1)=11*0.0,
ACENT(1)= 0.0, .493511, .70532, .7367, .759, .763, .7585, .7391,
.6525, .4, 0.0,
BCENT(1)= .17633, .17633, .17633, .144, .052, 0.0, -.0646, -.1295, -.153,
0.0, 0.0,
CCENT(1)= 0.0, 0.0, .02020035, -.1774997, -.1600005, -.1693327,
-.1615001, -.03499995, .1651873, 0.0, 0.0,
DCENT(1)= 0.0, 0.0, -.3367512, -.1750011, -.05925696, -.2044475,
-2.499656E-03, .01712957, -.4923802, 0.0, 0.0,
XCOWL(1)= 2.86, 3.1, 3.4, 4.0, 4.2, 4.3, 4.5, 4.6, 4.7, 5.1, 5.6, 6.1, 6.5,
6.9,
RCOWL(1)=14*0.0,
ACOWL(1)=1.0, 1.004188, 1.0051, .9681, .9364, .9154, .8768, .864, .8572, .85,
.85, .8839, .9227, 0.0,
BCOWL(1)= .01745001, .01745, -.011, -.124, -.1942, -.213, -.163, -.093, -.0485,
0.0, 0.0, .107, .0729, 0.0,
CCOWL(1)= 0.0, -.04926635, -.06500001, -.1664999, -.2859976, .05000008,
.3500018, .3049997, .1075002, 0.0, .1928, .01025012, -.01512487, 0.0,
DCOWL(1)= 0.0, 4.110418E-03, -.03240740, -.0300005, 1.279984,
.2499998, -1.251464E-05, -.5499974, -.07812535, 0.0, -.1144, -.08812521,
8.74978E-03, 0.0,
DXTRAN=0.855 &END
&LIST6 FACTOR(1)=2*1.175 &END
&LIST7 TCONSTA=876.698, TCONSTB=876.698 &END
&LIST8 KDFA=1, KDFB=1, NRA=2, NRB=1, XSA(1)=4.2, 4.9,
XEA(1)=4.4, 5.1, XSB(1)=3.75, XEB(1)=3.85,
ROVA(1)=2*1.0E-06, ROVB(1)=1.0E-06 &END
&LIST9 ITRANM(1)=5,3, XT1(1,1)=16*4.0, XT1(1,2)=16*0.3,
XT2(1,2)=16*1.8 &END
&LIST10 &END
&LIST11 &END
```

Figure 14. Data deck for Sample Case No. 4.

ORIGINAL PAGE IS
OF POOR QUALITY

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THE ANALYSIS OF STEADY THREE-DIMENSIONAL FLOW IN SUPERSONIC MIXED-COMPRESSION AIRCRAFT INLETS

ABSTRACT

     THE FLOW FIELD IN A SUPERSONIC MIXED-COMPRESSION AIRCRAFT INLET IS COMPUTED USING A ZONAL ALGORITHM.
     THE SUPERSONIC CORE FLOW IS COMPUTED BY A BICHARACTERISTIC ALGORITHM WITH DISCRETE SHOCK WAVE
     FITTING.   THE BOUNDARY LAYER FLOW IS COMPUTED USING AN IMPLICIT FINITE DIFFERENCE METHOD.   THE
     FLOW IN A SHOCK WAVE-BOUNDARY LAYER INTERACTION REGION IS COMPUTED USING AN INTEGRAL ANALYSIS.

     THIS PROGRAM WAS DEVELOPED AT THE PURDUE UNIVERSITY THERMAL SCIENCES AND PROPULSION CENTER BY J. VADYAK UNDER
     SPONSORSHIP FROM THE NASA LEWIS RESEARCH CENTER.   J.D. HOFFMAN AND A.R. BISHOP SERVED AS THE
     PRINCIPAL INVESTIGATOR AND TECHNICAL MONITOR, RESPECTIVELY.

JOB TITLE

       CASE  NO.    4

SPECIFIED COMPUTATION OPTIONS

     1.) INTERNAL FLOW FIELD WITH SHOCK WAVE SYSTEM

     BOUNDARY LAYER COMPUTATION IS INVOKED

FLOW SYMMETRY

     ONE PLANE OF SYMMETRY - COMPUTED SECTOR IS THE HALF-PLANE BOUNDED BY THE Y-AXIS AND CONTAINING THE +Z-AXIS

THERMODYNAMIC MODEL

     A THERMALLY AND CALORICALLY PERFECT GAS IS SPECIFIED WITH

     SPECIFIC HEAT RATIO=1.40000          GAS CONSTANT= 0.171616E+04(FT-LBF/SLUG-DEG R)

MOLECULAR TRANSPORT TERMS FOR SUPERSONIC CORE FLOW SOLUTION

     VISCOUS AND THERMAL DIFFUSION TERMS ARE NOT INCLUDED IN THE COMPUTATION - INVISCID AND ADIABATIC FLOW IS ASSUMED

MOLECULAR TRANSPORT PARAMETERS

     VISCOSITY IS REPRESENTED BY SUTHERLAND'S LAW WITH

          REFERENCE VISCOSITY= 0.350000E-06(LBF-SEC/FT**2)          REFERENCE TEMPERATURE= 0.492000E+03(DEG R)

          BASE TEMPERATURE= 0.198600E+03(DEG R)

     LAMINAR PRANDTL NUMBER=   0.710
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Figure 15. Selected output for Sample Case No. 4.

```
ORIENTATION AND FREE STREAM DATA

     ORIENTATION -     PITCH= 1.00000(DEGREES)          YAW= 0.00000(DEGREES)

     FREE STREAM DATA -     MACH NO.= 2.50000          PRESSURE= 0.242200E+03(LBF/FT**2)          DENSITY= 0.362200E-03(SLUG/FT**3)

     TEMPERATURE= 0.389644E+03(DEG R)          SONIC SPEED= 0.967558E+03(FT/SEC)

     X-VELOCITY= 0.241853E+04(FT/SEC)          Y-VELOCITY= 0.422155E+02(FT/SEC)          Z-VELOCITY= 0.000000E+00(FT/SEC)


SUPERSONIC CORE FLOW INITIAL-VALUE SURFACE

     AN INTERNALLY GENERATED INITIAL VALUE SURFACE IS SPECIFIED AS BEING LOCATED AT X= 0.371500E+01(FT)


FOREBODY/CENTERBODY BOUNDARY LAYER INITIAL DATA

     THE INITIAL DATA ARE INTERNALLY GENERATED WITH

     NTURB= 0          CLENGH= 4.00000          ADY= 0.01000          ARATIO= 1.06300          FACTOR(1)= 1.17500


COWL BOUNDARY LAYER INITIAL DATA

     THE INITIAL DATA ARE INTERNALLY GENERATED WITH

     NTURBB= 0          ALPCWL= 0.14286          BETCWL= 0.14286          FACTOR(2)= 1.17500


INDEX PARAMETERS

     ISTOP=15          IMAX=28          JMAXI=11

     JINLET=11

     NBLAY=15          NA=20          NINA=20

     NB=20          NINB=20


INTEGRATION TERMINATION POINTS

     INTERNAL FLOW FIELD INTEGRATION TERMINATES AT X= 0.505000E+01(FT)


FOREBODY/CENTERBODY GEOMETRY

     I   KOCENT      XCENT          RCENT          ACENT          BCENT          CCENT          DCENT
                      (FT)           (FT)           (FT)                         (FT**-1)       (FT**-2)

     1     1     0.000000E+00   0.000000E+00   0.000000E+00   0.176330E+00   0.000000E+00   0.000000E+00
     2     1     0.279879E+01   0.000000E+00   0.493511E+00   0.176330E+00   0.000000E+00   0.000000E+00
```

Figure 15. Continued.

3	1	0.400000E+01	0.000000E+00	0.705320E+00	0.176330E+00	0.202003E-01	-0.336751E+00
4	1	0.420000E+01	0.000000E+00	0.738700E+00	0.144000E+00	-0.177500E+00	-0.175001E+00
5	1	0.440000E+01	0.000000E+00	0.759000E+00	0.520000E-01	-0.160000E+00	-0.592570E-01
6	1	0.455000E+01	0.000000E+00	0.763000E+00	0.000000E+00	-0.169333E+00	-0.204447E+00
7	1	0.470000E+01	0.000000E+00	0.758500E+00	-0.646000E-01	-0.161500E+00	-0.249966E-02
8	1	0.490000E+01	0.000000E+00	0.739100E+00	-0.129500E+00	-0.349999E-01	0.171296E-01
9	1	0.550000E+01	0.000000E+00	0.652500E+00	-0.153000E+00	0.165187E+00	-0.492380E+00
10	1	0.628000E+01	0.000000E+00	0.400000E+00	0.000000E+00	0.000000E+00	0.000000E+00
11	1	0.690000E+01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00

COWL GEOMETRY

TRANSLATION FROM DESIGN POSITION= 0.855000E+00(FT)

I	KDCOWL	XCOWL (FT)	RCOWL (FT)	ACOWL (FT)	BCOWL	CCOWL (FT**-1)	DCOWL (FT**-2)
1	1	0.286000E+01	0.000000E+00	0.100000E+01	0.174500E-01	0.000000E+00	0.000000E+00
2	1	0.310000E+01	0.000000E+00	0.100419E+01	0.174500E-01	-0.492663E-01	0.411042E-02
3	1	0.340000E+01	0.000000E+00	0.100510E+01	-0.110000E-01	-0.650000E-01	-0.324074E-01
4	1	0.400000E+01	0.000000E+00	0.969100E+00	-0.124000E+00	-0.166500E+00	-0.300005E-01
5	1	0.420000E+01	0.000000E+00	0.936400E+00	-0.194200E+00	-0.285998E+00	0.127998E+01
6	1	0.430000E+01	0.000000E+00	0.915400E+00	-0.213000E+00	0.500001E-01	0.250000E+00
7	1	0.450000E+01	0.000000E+00	0.876800E+00	-0.163000E+00	0.350002E+00	-0.125146E-04
8	1	0.460000E+01	0.000000E+00	0.864000E+00	-0.930000E-01	0.305000E+00	-0.549997E+00
9	1	0.470000E+01	0.000000E+00	0.857200E+00	-0.485000E-01	0.107500E+00	-0.781253E-01
10	1	0.510000E+01	0.000000E+00	0.850000E+00	0.000000E+00	0.000000E+00	0.000000E+00
11	1	0.560000E+01	0.000000E+00	0.850000E+00	0.000000E+00	0.192800E+00	-0.114400E+00
12	1	0.610000E+01	0.000000E+00	0.883900E+00	0.107000E+00	0.102501E-01	-0.881252E-01
13	1	0.650000E+01	0.000000E+00	0.922700E+00	0.729000E-01	-0.151249E-01	0.874978E-02
14	1	0.690000E+01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00

FOREBODY/CENTERBODY TEMPERATURE BOUNDARY CONDITIONS

A CONSTANT WALL TEMPERATURE IS SPECIFIED AT 0.876698E+03(R) OR (K)

COWL TEMPERATURE BOUNDARY CONDITIONS

A CONSTANT WALL TEMPERATURE IS SPECIFIED AT 0.876698E+03(R) OR (K)

MASS TRANSFER BOUNDARY CONDITIONS

A PERMEABLE FOREBODY/CENTERBODY WALL IS SPECIFIED WITH

I	XSA (FT OR M)	XEA (FT OR M)	ROVA (MASS FLUX)
1	4.2000	4.4000	0.100000E-05
2	4.9000	5.1000	0.100000E-05

A PERMEABLE COWL WALL IS SPECIFIED WITH

I	XSB	XEB	ROVB

Figure 15. Continued.

```
        (FT OR M)  (FT OR M)   (MASS FLUX)
     1    3.7500     3.8500    0.100000E-05

TURBULENCE MODEL PARAMETERS
     APLUS= 26.0000    XKAPPA=  0.4000    XALPHA= 0.01680    PRT=  0.9000    TFACTR=  1.0000    AKLM= 0.43500    ALAM= 0.09000
     TRANSITION MODEL NO. 5 IS USED FOR FOREBODY/CENTERBODY BOUNDARY LAYER COMPUTATION
     TRANSITION MODEL NO. 3 IS USED FOR COWL BOUNDARY LAYER COMPUTATION

CONVERGENCE TOLERANCES, ITERATION LIMITS, AND OTHER PARAMETERS
     CONVERGENCE TOLERANCES AND OTHER PARAMETERS
          CRIT( 1)= 0.100000E+00
          CRIT( 2)= 0.100000E-06
          CRIT( 3)= 0.100000E-03
          CRIT( 4)= 0.100000E-04
          CRIT( 5)= 0.100000E-03
          CRIT( 6)= 0.100000E-03
          CRIT( 7)= 0.500000E+00
          CRIT( 8)= 0.100000E+01
          CRIT( 9)= 0.100000E-03
          CRIT(10)= 0.800000E+00
          CRIT(11)= 0.100000E-01
          CRIT(12)= 0.200000E+00
          CRIT(13)= 0.100000E-04
          CRIT(14)= 0.400000E+00
          CRIT(15)= 0.100000E-03
          CRIT(16)= 0.100000E-03
          CRIT(17)= 0.100000E-01
          CRIT(18)= 0.100000E-04
     ITERATION LIMITS
          ITEND(1)=10
          ITEND(2)=10
          ITEND(3)=10
          ITEND(4)=20
          ITEND(5)=10
          ITEND(6)=10
          ITEND(7)=10
          ITEND(8)=15
     INPUT SAFETY FACTOR= 0.975000E+00
```

Figure 15. Continued.

CENTERBODY BOUNDARY LAYER SOLUTION FOR PLANE NO. 0 XC= 3.77231(FT) X= 3.71500(FT)

I	J	Y (FT)	Z (DEG)	[illegible]	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
1	1	0.000000	0.00	0.000	0.0	357.57	0.2377E-03	876.7	0.0	0.00E+00	0.0	357.6	876.7
1	2	0.000162	0.00	0.080	116.3	357.57	0.2388E-03	872.7	116.3	0.00E+00	0.0	359.2	873.8
1	3	0.000352	0.00	0.175	252.7	357.57	0.2406E-03	865.9	252.7	0.00E+00	0.0	365.3	871.2
1	4	0.000573	0.00	0.287	412.1	357.57	0.2436E-03	855.3	412.1	0.00E+00	0.0	378.7	869.4
1	5	0.000828	0.00	0.421	597.5	357.57	0.2483E-03	839.2	597.5	0.00E+00	0.0	403.9	869.0
1	6	0.001121	0.00	0.579	810.3	357.57	0.2555E-03	815.4	810.3	0.00E+00	0.0	448.7	870.0
1	7	0.001453	0.00	0.767	1050.6	357.57	0.2665E-03	781.9	1050.6	0.00E+00	0.0	527.5	873.8
1	8	0.001823	0.00	0.988	1314.5	357.57	0.2827E-03	737.0	1314.5	0.00E+00	0.0	667.3	880.9
1	9	0.002229	0.00	1.238	1582.8	357.57	0.3063E-03	680.1	1582.8	0.00E+00	0.0	911.8	888.7
1	10	0.002666	0.00	1.506	1832.2	357.57	0.3381E-03	616.2	1832.2	0.00E+00	0.0	1323.8	895.6
1	11	0.003128	0.00	1.769	2038.8	357.57	0.3767E-03	553.1	2038.8	0.00E+00	0.0	1958.4	899.1
1	12	0.003616	0.00	2.001	2189.5	357.57	0.4182E-03	498.2	2189.5	0.00E+00	0.0	2803.4	897.2
1	13	0.004138	0.00	2.169	2274.9	357.57	0.4549E-03	458.0	2274.9	0.00E+00	0.0	3639.9	888.8
1	14	0.004718	0.00	2.222	2293.8	357.57	0.4697E-03	443.6	2293.8	0.00E+00	0.0	3957.1	881.6
1	15	0.005383	0.00	2.245	2301.1	357.57	0.4765E-03	437.2	2301.1	0.00E+00	0.0	4102.7	878.0
1	16	0.006158	0.00	2.250	2301.9	357.57	0.4782E-03	435.7	2301.9	0.00E+00	0.0	4134.1	876.8
1	17	0.007067	0.00	2.250	2301.9	357.57	0.4783E-03	435.6	2301.9	0.00E+00	0.0	4135.1	876.7
1	18	0.008134	0.00	2.250	2301.9	357.57	0.4783E-03	435.6	2301.9	0.00E+00	0.0	4135.2	876.7
1	19	0.009389	0.00	2.250	2301.9	357.57	0.4783E-03	435.6	2301.9	0.00E+00	0.0	4135.2	876.7
1	20	0.010863	0.00	2.250	2301.9	357.57	0.4783E-03	435.6	2301.9	0.00E+00	0.0	4135.2	876.7
2	1	0.000000	12.86	0.000	0.0	357.11	0.2374E-03	876.7	0.0	0.00E+00	0.0	357.1	876.7
2	2	0.000162	12.86	0.080	116.4	357.11	0.2384E-03	872.7	116.3	0.00E+00	1.6	358.7	873.8
2	3	0.000352	12.86	0.175	252.7	357.11	0.2403E-03	865.9	252.7	0.00E+00	3.4	364.8	871.2
2	4	0.000573	12.86	0.288	412.2	357.11	0.2433E-03	855.3	412.1	0.00E+00	5.2	378.2	869.4
2	5	0.000828	12.86	0.421	597.6	357.11	0.2480E-03	839.2	597.6	0.00E+00	7.0	403.4	868.9
2	6	0.001121	12.86	0.579	810.5	357.11	0.2552E-03	815.3	810.4	0.00E+00	8.6	448.2	870.0
2	7	0.001453	12.86	0.767	1050.8	357.11	0.2661E-03	781.9	1050.7	0.00E+00	10.0	526.9	873.8
2	8	0.001824	12.86	0.988	1314.7	357.11	0.2824E-03	737.0	1314.7	0.00E+00	11.0	666.6	880.9
2	9	0.002231	12.86	1.238	1583.0	357.11	0.3060E-03	680.0	1583.0	0.00E+00	11.4	910.9	888.7
2	10	0.002667	12.86	1.506	1832.4	357.11	0.3378E-03	616.1	1832.4	0.00E+00	11.3	1322.7	895.6
2	11	0.003129	12.86	1.769	2039.2	357.11	0.3763E-03	553.0	2039.1	0.00E+00	10.9	1957.2	899.1
2	12	0.003618	12.86	2.002	2189.9	357.11	0.4178E-03	498.0	2189.8	0.00E+00	10.3	2802.4	897.2
2	13	0.004140	12.86	2.169	2275.3	357.11	0.4545E-03	457.9	2275.3	0.00E+00	9.9	3639.4	888.8
2	14	0.004720	12.86	2.223	2294.2	357.11	0.4693E-03	443.4	2294.2	0.00E+00	9.7	3956.9	881.6
2	15	0.005385	12.86	2.246	2301.5	357.11	0.4761E-03	437.1	2301.5	0.00E+00	9.7	4102.7	878.0
2	16	0.006160	12.86	2.251	2302.3	357.11	0.4778E-03	435.5	2302.3	0.00E+00	9.6	4134.1	876.8
2	17	0.007069	12.86	2.251	2302.3	357.11	0.4779E-03	435.5	2302.3	0.00E+00	9.6	4135.1	876.7
2	18	0.008137	12.86	2.251	2302.3	357.11	0.4779E-03	435.4	2302.3	0.00E+00	9.6	4135.3	876.7
2	19	0.009392	12.86	2.251	2302.3	357.11	0.4779E-03	435.4	2302.3	0.00E+00	9.6	4135.3	876.7
2	20	0.010866	12.86	2.251	2302.3	357.11	0.4779E-03	435.4	2302.3	0.00E+00	9.6	4135.3	876.7
3	1	0.000000	25.71	0.000	0.0	355.77	0.2365E-03	876.7	0.0	0.00E+00	0.0	355.8	876.7
3	2	0.000163	25.71	0.080	116.4	355.77	0.2376E-03	872.7	116.4	0.00E+00	3.2	357.4	873.8
3	3	0.000353	25.71	0.175	252.9	355.77	0.2394E-03	865.9	252.8	0.00E+00	6.6	363.5	871.2
3	4	0.000574	25.71	0.288	412.4	355.77	0.2424E-03	855.2	412.3	0.00E+00	10.1	376.8	869.4
3	5	0.000830	25.71	0.421	598.0	355.77	0.2470E-03	839.1	597.8	0.00E+00	13.5	401.9	868.9
3	6	0.001123	25.71	0.579	810.9	355.77	0.2543E-03	815.2	810.8	0.00E+00	16.7	446.6	870.0
3	7	0.001456	25.71	0.767	1051.3	355.77	0.2652E-03	781.7	1051.2	0.00E+00	19.4	525.2	873.7
3	8	0.001827	25.71	0.989	1315.4	355.77	0.2814E-03	736.8	1315.2	0.00E+00	21.3	664.6	880.8
3	9	0.002234	25.71	1.239	1583.8	355.77	0.3050E-03	679.8	1583.6	0.00E+00	22.1	908.5	888.6
3	10	0.002671	25.71	1.507	1833.3	355.77	0.3367E-03	615.8	1833.1	0.00E+00	21.9	1319.7	895.6
3	11	0.003134	25.71	1.770	2040.1	355.77	0.3751E-03	552.7	2040.0	0.00E+00	21.1	1953.9	899.1
3	12	0.003623	25.71	2.004	2190.9	355.77	0.4166E-03	497.7	2190.9	0.00E+00	20.0	2799.6	897.2
3	13	0.004146	25.71	2.171	2276.5	355.77	0.4532E-03	457.4	2276.4	0.00E+00	19.1	3638.2	888.8
3	14	0.004726	25.71	2.225	2295.4	355.77	0.4660E-03	443.0	2295.4	0.00E+00	18.8	3956.2	881.6
3	15	0.005394	25.71	2.248	2302.7	355.77	0.4748E-03	436.6	2302.6	0.00E+00	18.7	4102.7	878.0

Figure 15. Continued.

CENTERBODY BOUNDARY LAYER SOLUTION FOR PLANE NO. 0 XC= 3.77231(FT) X= 3.71500(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
3	16	0.006167	25.71	2.253	2303.6	355.77	0.4765E-03	435.0	2303.5	0.00E+00	18.7	4134.3	876.8
3	17	0.007077	25.71	2.253	2303.6	355.77	0.4766E-03	435.0	2303.5	0.00E+00	18.7	4135.3	876.7
3	18	0.008145	25.71	2.253	2303.6	355.77	0.4766E-03	435.0	2303.5	0.00E+00	18.7	4135.4	876.7
3	19	0.009401	25.71	2.253	2303.6	355.77	0.4766E-03	435.0	2303.5	0.00E+00	18.7	4135.4	876.7
3	20	0.010876	25.71	2.253	2303.6	355.77	0.4756E-03	435.0	2303.5	0.00E+00	18.7	4135.4	876.7
4	1	0.000000	38.57	0.000	0.0	353.65	0.2351E-03	876.7	0.0	0.00E+00	0.0	353.7	876.7
4	2	0.000163	38.57	0.081	116.6	353.65	0.2361E-03	872.6	116.5	0.00E+00	4.5	355.3	873.8
4	3	0.000354	38.57	0.176	253.2	353.65	0.2380E-03	865.8	253.0	0.00E+00	9.3	361.3	871.2
4	4	0.000576	38.57	0.288	412.8	353.65	0.2410E-03	855.1	412.6	0.00E+00	14.3	374.6	869.3
4	5	0.000832	38.57	0.422	598.5	353.65	0.2456E-03	839.0	598.2	0.00E+00	19.3	399.6	868.8
4	6	0.001126	38.57	0.580	811.7	353.65	0.2528E-03	815.0	811.3	0.00E+00	23.8	444.2	869.9
4	7	0.001460	38.57	0.768	1052.2	353.65	0.2637E-03	781.5	1051.9	0.00E+00	27.6	522.4	873.6
4	8	0.001832	38.57	0.990	1316.5	353.65	0.2798E-03	736.5	1316.1	0.00E+00	30.3	661.4	880.7
4	9	0.002240	38.57	1.241	1585.0	353.65	0.3033E-03	679.4	1584.6	0.00E+00	31.4	904.6	888.5
4	10	0.002678	38.57	1.509	1834.6	353.65	0.3349E-03	615.3	1834.3	0.00E+00	31.1	1315.0	895.5
4	11	0.003141	38.57	1.773	2041.7	353.65	0.3732E-03	552.1	2041.4	0.00E+00	30.0	1948.8	899.1
4	12	0.003631	38.57	2.007	2192.7	353.65	0.4146E-03	497.0	2192.5	0.00E+00	28.5	2795.3	897.3
4	13	0.004155	38.57	2.175	2278.4	353.65	0.4512E-03	456.7	2278.2	0.00E+00	27.2	3636.2	888.8
4	14	0.004735	38.57	2.229	2297.3	353.65	0.4660E-03	442.2	2297.2	0.00E+00	26.8	3955.2	881.6
4	15	0.005402	38.57	2.252	2304.7	353.65	0.4728E-03	435.9	2304.5	0.00E+00	26.6	4102.7	878.0
4	16	0.006178	38.57	2.257	2305.5	353.65	0.4745E-03	434.3	2305.4	0.00E+00	26.5	4134.5	876.8
4	17	0.007089	38.57	2.257	2305.5	353.65	0.4746E-03	434.2	2305.4	0.00E+00	26.5	4135.5	876.7
4	18	0.008159	38.57	2.257	2305.5	353.65	0.4746E-03	434.2	2305.4	0.00E+00	26.5	4135.7	876.7
4	19	0.009415	38.57	2.257	2305.5	353.65	0.4746E-03	434.2	2305.4	0.00E+00	26.5	4135.7	876.7
4	20	0.010892	38.57	2.257	2305.5	353.65	0.4746E-03	434.2	2305.4	0.00E+00	26.5	4135.7	876.7
5	1	0.000000	51.43	0.000	0.0	350.89	0.2332E-03	876.7	0.0	0.00E+00	0.0	350.9	876.7
5	2	0.000164	51.43	0.081	116.7	350.89	0.2343E-03	872.6	116.6	0.00E+00	5.6	352.5	873.7
5	3	0.000355	51.43	0.176	253.5	350.89	0.2362E-03	865.8	253.2	0.00E+00	11.6	358.5	871.1
5	4	0.000578	51.43	0.288	413.4	350.89	0.2391E-03	855.0	413.0	0.00E+00	17.7	371.7	869.3
5	5	0.000835	51.43	0.422	599.3	350.89	0.2437E-03	838.9	598.8	0.00E+00	23.8	396.6	868.8
5	6	0.001130	51.43	0.581	812.6	350.89	0.2509E-03	814.8	812.1	0.00E+00	29.4	441.0	869.8
5	7	0.001465	51.43	0.769	1053.4	350.89	0.2617E-03	781.2	1052.9	0.00E+00	34.1	518.9	873.6
5	8	0.001838	51.43	0.991	1317.9	350.89	0.2778E-03	736.1	1317.4	0.00E+00	37.6	657.3	880.7
5	9	0.002247	51.43	1.242	1586.5	350.89	0.3012E-03	678.9	1586.1	0.00E+00	38.9	899.5	888.5
5	10	0.002686	51.43	1.511	1836.4	350.89	0.3326E-03	614.7	1836.0	0.00E+00	38.5	1308.9	895.5
5	11	0.003151	51.43	1.776	2043.7	350.89	0.3708E-03	551.4	2043.4	0.00E+00	37.1	1942.2	899.1
5	12	0.003642	51.43	2.010	2195.0	350.89	0.4120E-03	496.2	2194.7	0.00E+00	35.2	2789.9	897.3
5	13	0.004166	51.43	2.180	2280.9	350.89	0.4486E-03	455.8	2280.6	0.00E+00	33.6	3633.8	888.9
5	14	0.004748	51.43	2.233	2299.9	350.89	0.4633E-03	441.3	2299.6	0.00E+00	33.1	3953.9	881.6
5	15	0.005416	51.43	2.257	2307.2	350.89	0.4701E-03	434.9	2307.0	0.00E+00	32.9	4102.8	878.0
5	16	0.006193	51.43	2.262	2308.1	350.89	0.4719E-03	433.3	2307.8	0.00E+00	32.8	4134.8	876.8
5	17	0.007105	51.43	2.262	2308.1	350.89	0.4719E-03	433.3	2307.9	0.00E+00	32.8	4135.8	876.7
5	18	0.008176	51.43	2.262	2308.1	350.89	0.4719E-03	433.2	2307.9	0.00E+00	32.8	4136.0	876.7
5	19	0.009434	51.43	2.262	2308.1	350.89	0.4719E-03	433.2	2307.9	0.00E+00	32.8	4136.0	876.7
5	20	0.010913	51.43	2.262	2308.1	350.89	0.4719E-03	433.2	2307.9	0.00E+00	32.8	4136.0	876.7
6	1	0.000000	64.29	0.000	0.0	347.67	0.2311E-03	876.6	0.0	0.00E+00	0.0	347.7	876.6
6	2	0.000164	64.29	0.081	116.9	347.67	0.2322E-03	872.6	116.7	0.00E+00	6.4	349.3	873.7
6	3	0.000357	64.29	0.176	253.9	347.67	0.2340E-03	865.7	253.6	0.00E+00	13.1	355.3	871.1
6	4	0.000580	64.29	0.289	414.0	347.67	0.2370E-03	854.9	413.5	0.00E+00	20.1	368.4	869.2
6	5	0.000838	64.29	0.423	600.2	347.67	0.2415E-03	838.7	599.6	0.00E+00	27.1	393.1	868.7
6	6	0.001135	64.29	0.582	813.8	347.67	0.2487E-03	814.6	813.1	0.00E+00	33.4	437.2	869.7
6	7	0.001470	64.29	0.770	1054.9	347.67	0.2594E-03	780.8	1054.2	0.00E+00	38.7	514.7	873.5
6	8	0.001845	64.29	0.993	1319.6	347.67	0.2754E-03	735.6	1318.9	0.00E+00	42.6	652.5	880.6
6	9	0.002256	64.29	1.244	1588.5	347.67	0.2986E-03	678.3	1587.6	0.00E+00	44.1	893.7	888.4
6	10	0.002696	64.29	1.514	1838.6	347.67	0.3299E-03	614.0	1838.1	0.00E+00	43.7	1301.9	895.4

Figure 15. Continued.

CENTERBODY BOUNDARY LAYER SOLUTION FOR PLANE NO. 0 XC= 3.77231(FT) X= 3.71500(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
6	11	0.003163	64.29	1.779	2046.2	347.67	0.3679E-03	550.5	2045.8	0.00E+00	42.0	1934.6	809.1
6	12	0.003695	64.29	2.015	2197.8	347.67	0.4091E-03	495.2	2197.4	0.00E+00	39.9	2783.8	897.3
6	13	0.004180	64.29	2.185	2283.8	347.67	0.4455E-03	454.7	2283.5	0.00E+00	38.1	3631.1	888.9
6	14	0.004783	64.29	2.239	2302.8	347.67	0.4602E-03	440.2	2302.5	0.00E+00	37.5	3952.5	881.6
6	15	0.005432	64.29	2.263	2310.2	347.67	0.4670E-03	433.8	2309.9	0.00E+00	37.2	4102.8	878.0
6	16	0.006210	64.29	2.268	2311.1	347.67	0.4688E-03	432.2	2310.8	0.00E+00	37.2	4135.1	876.8
6	17	0.007123	64.29	2.268	2311.1	347.67	0.4688E-03	432.1	2310.8	0.00E+00	37.2	4136.1	876.7
6	18	0.008196	64.29	2.268	2311.1	347.67	0.4688E-03	432.1	2310.8	0.00E+00	37.2	4136.3	876.7
6	19	0.009457	64.29	2.268	2311.1	347.67	0.4688E-03	432.1	2310.8	0.00E+00	37.2	4136.3	876.7
6	20	0.010938	64.29	2.268	2311.1	347.67	0.4688E-03	432.1	2310.8	0.00E+00	37.2	4136.3	876.7
7	1	0.000000	77.14	0.000	0.0	344.18	0.2288E-03	876.6	0.0	0.00E+00	0.0	344.2	876.6
7	2	0.000165	77.14	0.081	117.1	344.18	0.2299E-03	872.5	116.9	0.00E+00	6.8	345.8	873.7
7	3	0.000358	77.14	0.176	254.3	344.18	0.2317E-03	865.7	253.9	0.00E+00	13.9	351.7	871.0
7	4	0.000583	77.14	0.289	414.7	344.18	0.2346E-03	854.8	414.1	0.00E+00	21.4	364.8	869.2
7	5	0.000842	77.14	0.423	601.1	344.18	0.2392E-03	838.6	600.4	0.00E+00	28.8	389.4	868.6
7	6	0.001143	77.14	0.583	815.0	344.18	0.2463E-03	814.4	814.3	0.00E+00	35.5	433.2	869.7
7	7	0.001477	77.14	0.771	1056.5	344.18	0.2570E-03	780.5	1055.7	0.00E+00	41.2	510.2	873.4
7	8	0.001853	77.14	0.994	1321.5	344.18	0.2728E-03	735.2	1320.7	0.00E+00	45.3	647.2	880.5
7	9	0.002266	77.14	1.247	1590.6	344.18	0.2959E-03	677.7	1589.9	0.00E+00	46.9	887.4	888.3
7	10	0.002708	77.14	1.517	1841.1	344.18	0.3270E-03	613.3	1840.5	0.00E+00	46.4	1294.5	895.4
7	11	0.003175	77.14	1.783	2049.0	344.18	0.3649E-03	549.7	2048.5	0.00E+00	44.6	1926.7	899.2
7	12	0.003668	77.14	2.020	2200.9	344.18	0.4059E-03	494.2	2200.5	0.00E+00	42.4	2777.5	897.4
7	13	0.004195	77.14	2.191	2287.0	344.18	0.4422E-03	453.5	2286.7	0.00E+00	40.4	3628.5	888.9
7	14	0.004779	77.14	2.245	2306.0	344.18	0.4568E-03	439.0	2305.7	0.00E+00	39.8	3951.0	881.7
7	15	0.005449	77.14	2.269	2313.4	344.18	0.4637E-03	432.5	2313.1	0.00E+00	39.5	4102.8	878.0
7	16	0.006229	77.14	2.275	2314.3	344.18	0.4654E-03	430.9	2314.0	0.00E+00	39.4	4135.4	876.3
7	17	0.007144	77.14	2.275	2314.3	344.18	0.4655E-03	430.9	2314.0	0.00E+00	39.4	4136.4	876.7
7	18	0.008218	77.14	2.275	2314.3	344.18	0.4655E-03	430.8	2314.0	0.00E+00	39.4	4136.6	876.7
7	19	0.009481	77.14	2.275	2314.3	344.18	0.4655E-03	430.8	2314.0	0.00E+00	39.4	4136.6	876.7
7	20	0.010965	77.14	2.275	2314.3	344.18	0.4655E-03	430.8	2314.0	0.00E+00	39.4	4136.6	876.7
8	1	0.000000	90.00	0.000	0.0	340.63	0.2264E-03	876.6	0.0	0.00E+00	0.0	340.6	876.6
8	2	0.000166	90.00	0.081	117.3	340.63	0.2275E-03	872.5	117.1	0.00E+00	6.8	342.2	873.7
8	3	0.000360	90.00	0.177	254.7	340.63	0.2293E-03	865.6	254.3	0.00E+00	14.1	348.1	871.0
8	4	0.000585	90.00	0.290	415.3	340.63	0.2322E-03	854.7	414.8	0.00E+00	21.5	361.1	869.1
8	5	0.000846	90.00	0.424	602.1	340.63	0.2367E-03	838.4	601.4	0.00E+00	29.0	385.5	868.6
8	6	0.001145	90.00	0.584	816.4	340.63	0.2438E-03	814.1	815.6	0.00E+00	35.8	429.0	869.6
8	7	0.001484	90.00	0.773	1058.2	340.63	0.2544E-03	780.2	1057.3	0.00E+00	41.5	505.6	873.4
8	8	0.001862	90.00	0.996	1323.5	340.63	0.2702E-03	734.7	1322.7	0.00E+00	45.6	641.9	880.5
8	9	0.002276	90.00	1.249	1593.0	340.63	0.2931E-03	677.1	1592.3	0.00E+00	47.2	881.1	888.3
8	10	0.002719	90.00	1.520	1843.7	340.63	0.3241E-03	612.5	1843.1	0.00E+00	46.7	1287.1	895.4
8	11	0.003188	90.00	1.787	2051.9	340.63	0.3617E-03	548.7	2051.4	0.00E+00	44.9	1919.0	899.2
8	12	0.003683	90.00	2.025	2204.1	340.63	0.4026E-03	493.0	2203.7	0.00E+00	42.6	2771.6	897.4
8	13	0.004211	90.00	2.197	2290.4	340.63	0.4389E-03	452.3	2290.0	0.00E+00	40.6	3626.3	886.9
8	14	0.004796	90.00	2.252	2309.3	340.63	0.4534E-03	437.8	2309.0	0.00E+00	40.0	3949.7	881.7
8	15	0.005467	90.00	2.276	2316.8	340.63	0.4603E-03	431.2	2316.4	0.00E+00	39.7	4102.9	878.0
8	16	0.006248	90.00	2.281	2317.6	340.63	0.4620E-03	429.6	2317.3	0.00E+00	39.6	4135.7	876.8
8	17	0.007164	90.00	2.281	2317.7	340.63	0.4621E-03	429.6	2317.3	0.00E+00	39.6	4136.7	876.7
8	18	0.008241	90.00	2.281	2317.7	340.63	0.4621E-03	429.6	2317.3	0.00E+00	39.6	4136.8	876.7
8	19	0.009506	90.00	2.281	2317.7	340.63	0.4621E-03	429.6	2317.3	0.00E+00	39.6	4136.8	876.7
8	20	0.010992	90.00	2.281	2317.7	340.63	0.4621E-03	429.6	2317.3	0.00E+00	39.6	4136.8	876.7
9	1	0.000000	102.86	0.000	0.0	337.22	0.2242E-03	876.6	0.0	0.00E+00	0.0	337.2	876.6
9	2	0.000167	102.86	0.081	117.5	337.22	0.2252E-03	872.5	117.3	0.00E+00	6.5	338.8	873.6
9	3	0.000362	102.86	0.177	255.1	337.22	0.2270E-03	865.6	254.8	0.00E+00	13.5	344.7	871.0
9	4	0.000588	102.86	0.290	416.0	337.22	0.2299E-03	854.7	415.5	0.00E+00	20.6	357.5	869.1
9	5	0.000850	102.86	0.425	603.1	337.22	0.2344E-03	838.3	602.4	0.00E+00	27.7	381.8	868.6

Figure 15. Continued.

CENTERBODY BOUNDARY LAYER SOLUTION FOR PLANE NO. 6 XC= 3.77231(FT) X= 3.71500(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
9	6	0.001150	102.86	0.585	817.7	337.22	0.2414E-03	813.9	817.0	0.00E+00	34.2	425.1	869.6
9	.	0.001490	102.86	0.774	1059.9	337.22	0.2520E-03	779.9	1059.1	0.00E+00	39.7	501.2	873.4
9	8	0.001870	102.86	0.998	1325.6	337.22	0.2676E-03	734.2	1324.9	0.00E+00	43.6	636.9	880.5
9	9	0.002285	102.86	1.251	1595.4	337.22	0.2905E-03	676.5	1594.8	0.00E+00	45.1	875.2	888.3
9	10	0.002730	102.84	1.523	1846.5	337.22	0.3212E-03	611.7	1645.9	0.00E+00	44.6	1280.3	895.5
9	11	0.003201	102.86	1.791	2055.0	337.22	0.3587E-03	547.7	2054.5	0.00E+00	42.9	1912.0	899.3
9	12	0.003697	102.86	2.030	2207.3	337.22	0.3995E-03	491.9	2206.9	0.00E+00	40.7	2766.4	897.5
9	13	0.004226	102.86	2.203	2293.7	337.22	0.4356E-03	451.0	2293.3	0.00E+00	38.8	3624.5	889.0
9	14	0.004812	102.86	2.258	2312.5	337.22	0.4501E-03	436.5	2312.2	0.00E+00	38.2	3948.5	881.7
9	15	0.005484	102.86	2.283	2320.0	337.22	0.4570E-03	430.0	2319.7	0.00E+00	37.9	4103.0	878.0
9	16	0.006267	102.86	2.286	2320.9	337.22	0.4587E-03	428.4	2320.6	0.00E+00	37.9	4135.9	876.8
9	17	0.007185	102.86	2.288	2320.9	337.22	0.4587E-03	428.3	2320.6	0.00E+00	37.9	4136.9	876.7
9	18	0.008263	102.86	2.288	2320.9	337.22	0.4588E-03	428.3	2320.6	0.00E+00	37.9	4137.1	876.7
9	19	0.009530	102.86	2.288	2320.9	337.22	0.4588E-03	426.3	2320.6	0.00E+00	37.9	4137.1	876.7
9	20	0.011019	102.86	2.288	2320.9	337.22	0.4588E-03	428.3	2320.6	0.00E+00	37.9	4137.1	676.7
10	1	0.000000	115.71	0.000	0.0	334.08	0.2221E-03	876.6	0.0	0.00E+00	0.0	334.1	876.6
10	2	0.000168	115.71	0.081	117.7	334.08	0.2231E-03	872.5	117.5	0.00E+00	5.9	335.6	873.6
10	3	0.000363	115.71	0.177	255.5	334.08	0.2249E-03	865.5	255.2	0.00E+00	12.2	341.5	871.0
10	4	0.000590	115.71	0.291	416.6	334.08	0.2278E-03	854.6	416.2	0.00E+00	18.7	354.3	869.1
10	5	0.000853	115.71	0.426	604.0	334.08	0.2322E-03	838.2	603.5	0.00E+00	25.2	378.4	868.6
10	6	0.001155	115.71	0.586	819.0	334.08	0.2392E-03	813.8	818.4	0.00E+00	31.1	421.4	869.6
10	7	0.001497	115.71	0.776	1061.6	334.06	0.2497E-03	779.6	1060.9	0.00E+00	36.0	497.2	873.4
10	8	0.001878	115.71	1.000	1327.7	334.08	0.2653E-03	733.8	1327.1	0.00E+00	39.6	632.3	880.5
10	9	0.002294	115.71	1.254	1597.8	334.08	0.2880E-03	675.9	1597.3	0.00E+00	40.9	869.9	888.4
10	10	0.002741	115.71	1.526	1849.2	334.08	0.3187E-03	610.9	1848.7	0.00E+00	40.5	1274.2	895.6
10	11	0.003213	115.71	1.795	2057.9	334.08	0.3560E-03	546.8	2057.5	0.00E+00	38.9	1906.0	899.3
10	12	0.003710	115.71	2.035	2210.4	334.08	0.3966E-03	490.8	2210.1	0.00E+00	36.9	2762.3	897.5
10	13	0.004240	115.71	2.209	2296.7	334.08	0.4327E-03	449.9	2296.4	0.00E+00	35.2	3623.4	889.0
10	14	0.004827	115.71	2.264	2315.5	334.08	0.4471E-03	435.4	2315.2	0.00E+00	34.6	3947.7	881.7
10	15	0.005500	115.72	2.289	2323.0	334.08	0.4539E-03	428.8	2322.7	0.00E+00	34.4	4103.1	878.0
10	16	0.006284	115.71	2.294	2323.8	334.08	0.4556E-03	427.2	2323.6	0.00E+00	34.3	4136.1	876.8
10	17	0.007204	115.71	2.294	2323.8	334.08	0.4557E-03	427.2	2323.6	0.00E+00	34.3	4137.1	876.7
10	18	0.008284	115.71	2.294	2323.8	334.08	0.4557E-03	427.2	2323.6	0.00E+00	34.3	4137.3	876.7
10	19	0.009553	115.71	2.293	2323.8	334.08	0.4557E-03	427.2	2323.6	0.00E+00	34.3	4137.3	876.7
10	20	0.011044	115.71	2.294	2323.8	33-.08	0.4557E-03	427.2	2323.6	0.00E+00	34.3	4137.3	876.7
11	1	0.000000	128.57	0.000	0.0	331.36	0.2203E-03	876.6	0.0	0.00E+00	0.0	331.4	876.6
11	2	0.000168	128.57	0.081	117.8	331.36	0.2213E-03	872.4	117.7	0.00E+00	5.1	332.9	873.6
11	3	0.000364	128.57	0.177	255.9	331.36	0.2231E-03	865.5	255.7	0.00E+00	10.4	338.7	871.0
11	4	0.000593	128.57	0.291	417.2	331.36	0.2259E-03	854.6	416.9	0.00E+00	16.0	351.4	869.1
11	5	0.000857	128.57	0.426	604.9	331.36	0.2304E-03	838.1	604.5	0.00E+00	21.5	375.4	868.6
11	6	0.001159	128.57	0.587	820.2	331.36	0.2373E-03	813.6	819.7	0.00E+00	26.5	418.3	869.6
11	7	0.001502	128.57	0.777	1063.1	331.36	0.2477E-03	779.4	1062.7	0.00E+00	30.8	493.8	873.5
11	8	0.001884	128.57	1.002	1329.6	331.36	0.2632E-03	733.5	1329.2	0.00E+00	33.8	628.4	880.6
11	9	0.002302	128.57	1.256	1600.1	331.36	0.2859E-03	675.4	1599.8	0.00E+00	34.9	865.4	888.5
11	10	0.002750	128.57	1.529	1851.7	331.30	0.3164E-03	610.2	1851.4	0.00E+00	34.5	1269.3	895.7
11	11	0.003223	128.57	1.799	2060.6	331.36	0.3536E-03	546.0	2060.3	0.00E+00	33.2	1901.3	899.4
11	12	0.003721	128.57	2.040	2213.2	331.36	0.3941E-03	489.9	2212.9	0.00E+00	31.5	2759.3	897.6
11	13	0.004252	128.57	2.214	2299.4	331.36	0.4302E-03	448.9	2299.2	0.00E+00	30.0	3622.8	889.0
11	14	0.004840	128.57	2.269	2318.1	331.36	0.4445E-03	434.4	2317.9	0.00E+00	29.5	3947.1	881.7
11	15	0.005514	128.57	2.294	2325.6	331.36	0.4513E-03	427.8	2325.4	0.00E+00	29.3	4103.2	878.0
11	16	0.006299	128.57	2.299	2326.4	331.36	0.4530E-03	426.2	2326.2	0.00E+00	29.3	4136.2	876.8
11	17	0.007220	128.57	2.299	2326.4	331.36	0.4531E-03	426.2	2326.2	0.00E+00	29.3	4137.2	876.7
11	18	0.008302	128.57	2.299	2326.4	331.36	0.4531E-03	426.2	2326.2	0.00E+00	29.3	4137.4	876.7
11	19	0.009572	128.57	2.299	2326.4	331.36	0.4531E-03	426.2	2326.2	0.00E+00	29.3	4137.4	876.7
11	20	0.011066	128.57	2.299	2326.4	331.36	0.4531E-03	426.2	2326.2	0.00E+00	29.3	4137.4	876.7

Figure 15. Continued.

CENTERBODY BOUNDARY LAYER SOLUTION FOR PLANE NO. 0 XC= 3.77231(FT) X= 3.71500(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
12	1	0.000000	141.43	0.000	0.0	329.15	0.2188E-03	876.6	0.0	0.00E+00	0.0	329.2	876.6
12	2	0.000169	141.43	0.081	116.0	329.15	0.2198E-03	872.4	117.9	0.00E+00	4.0	330.7	873.6
12	3	0.000366	141.43	0.178	256.2	329.15	0.2216E-03	865.5	256.0	0.00E+00	8.2	336.5	870.9
12	4	0.000594	141.43	0.292	417.7	329.15	0.2244E-03	854.5	417.5	0.00E+00	12.6	349.2	869.1
12	5	0.000859	141.43	0.427	605.6	329.15	0.2289E-03	838.1	605.4	0.00E+00	16.9	373.1	868.6
12	6	0.001163	141.43	0.587	821.2	329.15	0.2358E-03	813.5	821.0	0.00E+00	20.9	415.7	869.7
12	7	0.001506	141.43	0.778	1064.5	329.15	0.2461E-03	779.2	1064.3	0.00E+00	24.2	491.0	873.5
12	8	0.001890	141.43	1.003	1331.3	329.15	0.2618E-03	733.2	1331.1	0.00E+00	26.6	625.3	880.7
12	9	0.002309	141.43	1.258	1602.1	329.15	0.2842E-03	675.0	1601.9	0.00E+00	27.5	861.9	888.6
12	10	0.002758	141.43	1.532	1853.9	329.15	0.3146E-03	609.7	1853.7	0.00E+00	27.2	1265.5	895.8
12	11	0.003232	141.43	1.802	2062.9	329.15	0.3517E-03	545.3	2062.8	0.00E+00	26.1	1897.9	899.5
12	12	0.003731	141.43	2.044	2215.5	329.15	0.3922E-03	489.1	2215.4	0.00E+00	24.7	2757.4	897.7
12	13	0.004242	141.43	2.218	2301.7	329.15	0.4281E-03	448.0	2301.5	0.00E+00	23.6	3622.8	889.0
12	14	0.004851	141.43	2.273	2320.2	329.15	0.4423E-03	433.6	2320.1	0.00E+00	23.2	3946.9	881.7
12	15	0.005526	141.43	2.298	2327.7	329.15	0.4492E-03	427.0	2327.6	0.00E+00	23.0	4103.4	878.0
12	16	0.006312	141.43	2.303	2328.5	329.15	0.4508E-03	425.4	2328.4	0.00E+00	23.0	4136.4	876.8
12	17	0.007233	141.43	2.303	2328.5	329.15	0.4509E-03	425.4	2328.4	0.00E+00	23.0	4137.4	876.7
12	18	0.008316	141.43	2.303	2328.5	329.15	0.4509E-03	425.4	2328.4	0.00E+00	23.0	4137.5	876.7
12	19	0.009588	141.43	2.303	2328.5	329.15	0.4509E-03	425.4	2328.4	0.00E+00	23.0	4137.5	876.7
12	20	0.011083	141.43	2.303	2328.5	329.15	0.4509E-03	425.4	2328.4	0.00E+00	23.0	4137.5	876.7
13	1	0.000000	154.29	0.000	0.0	327.49	0.2177E-03	876.6	0.0	0.00E+00	0.0	327.5	876.6
13	2	0.000169	154.29	0.082	118.1	327.49	0.2187E-03	872.4	118.0	0.00E+00	2.7	329.0	873.6
13	3	0.000366	154.29	0.178	256.4	327.49	0.2205E-03	865.5	256.4	0.00E+00	5.7	334.8	870.9
13	4	0.000596	154.29	0.292	418.2	327.49	0.2233E-03	854.5	418.1	0.00E+00	8.7	347.4	869.1
13	5	0.000861	154.29	0.427	606.2	327.49	0.2277E-03	838.0	606.1	0.00E+00	11.7	371.3	868.6
13	6	0.001165	154.29	0.588	822.1	327.49	0.2346E-03	813.5	822.0	0.00E+00	14.4	413.9	869.7
13	7	0.001510	154.29	0.779	1065.7	327.49	0.2449E-03	779.1	1065.6	0.00E+00	16.7	489.0	873.6
13	8	0.001894	154.29	1.004	1332.7	327.49	0.2604E-03	733.0	1332.6	0.00E+00	18.3	623.0	880.8
13	9	0.002314	154.29	1.260	1603.8	327.49	0.2829E-03	674.6	1603.7	0.00E+00	18.9	859.4	888.7
13	10	0.002764	154.29	1.534	1855.7	327.49	0.3132E-03	609.2	1855.6	0.00E+00	18.7	1262.9	895.9
13	11	0.003238	154.29	1.805	2064.8	327.49	0.3503E-03	544.7	2064.7	0.00E+00	18.0	1895.7	899.6
13	12	0.003738	154.29	2.047	2217.4	327.49	0.3907E-03	488.4	2217.3	0.00E+00	17.0	2756.5	897.7
13	13	0.004270	154.29	2.222	2303.4	327.49	0.4266E-03	447.3	2303.3	0.00E+00	16.2	3623.1	889.0
13	14	0.004859	154.29	2.276	2321.8	327.49	0.4407E-03	433.0	2321.8	0.00E+00	16.0	3946.8	881.7
13	15	0.005534	154.29	2.301	2329.3	327.49	0.4476E-03	426.4	2329.2	0.00E+00	15.9	4103.5	878.0
13	16	0.006321	154.29	2.306	2330.1	327.49	0.4492E-03	424.8	2330.1	0.00E+00	15.8	4136.5	876.8
13	17	0.007243	154.29	2.307	2330.1	327.49	0.4493E-03	424.7	2330.1	0.00E+00	15.8	4137.4	876.7
13	18	0.008327	154.29	2.307	2330.1	327.49	0.4493E-03	424.7	2330.1	0.00E+00	15.8	4137.6	876.7
13	19	0.009600	154.29	2.307	2330.1	327.49	0.4493E-03	424.7	2330.1	0.00E+00	15.8	4137.6	876.7
13	20	0.011097	154.29	2.307	2330.1	327.49	0.4493E-03	424.7	2330.1	0.00E+00	15.8	4137.6	876.7
14	1	0.000000	167.14	0.000	0.0	326.52	0.2171E-03	876.6	0.0	0.00E+00	0.0	326.5	876.6
14	2	0.000169	167.14	0.082	118.1	326.52	0.2181E-03	872.4	118.1	0.00E+00	1.4	328.0	873.6
14	3	0.000367	167.14	0.178	256.6	326.52	0.2198E-03	865.5	256.6	0.00E+00	2.9	333.8	870.9
14	4	0.000597	167.14	0.292	418.4	326.52	0.2227E-03	854.5	418.4	0.00E+00	4.4	346.4	869.1
14	5	0.000862	167.14	0.428	606.7	326.52	0.2270E-03	838.0	606.6	0.00E+00	6.0	370.2	868.6
14	6	0.001167	167.14	0.588	822.7	326.52	0.2339E-03	813.4	822.6	0.00E+00	7.3	412.8	869.8
14	7	0.001512	167.14	0.780	1066.5	326.52	0.2442E-03	779.0	1066.4	0.00E+00	8.5	487.8	873.7
14	8	0.001897	167.14	1.005	1333.7	326.52	0.2596E-03	732.8	1333.7	0.00E+00	9.3	621.8	880.9
14	9	0.002317	167.14	1.261	1604.9	326.52	0.2821E-03	674.4	1604.9	0.00E+00	9.6	858.1	888.8
14	10	0.002767	167.14	1.535	1856.9	326.52	0.3124E-03	608.9	1856.9	0.00E+00	9.5	1261.6	896.0
14	11	0.003242	167.14	1.806	2066.0	326.52	0.3495E-03	544.4	2066.0	0.00E+00	9.2	1894.7	899.7
14	12	0.003742	167.14	2.049	2218.5	326.52	0.3898E-03	488.0	2218.5	0.00E+00	8.7	2756.3	897.7
14	13	0.004274	167.14	2.224	2304.4	326.52	0.4257E-03	446.9	2304.4	0.00E+00	8.3	3623.6	889.0
14	14	0.004863	167.14	2.278	2322.8	326.52	0.4398E-03	432.6	2322.7	0.00E+00	8.1	3946.9	881.7
14	15	0.005539	167.14	2.303	2330.2	326.52	0.4466E-03	426.0	2330.2	0.00E+00	8.1	4103.7	878.0

Figure 15. Continued.

CENTERBODY BOUNDARY LAYER SOLUTION FOR PLANE NO. 0 XC= 3.77231(FT) X= 3.71500(FT)

I	J	Y (FT)	Z (DEG)	M	G (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
14	16	0.006326	167.14	2.308	2331.0	326.52	0.4483E-03	424.4	2331.0	0.00E+00	8.1	4136.5	876.8
14	17	0.007249	167.14	2.308	2331.0	326.52	0.4483E-03	424.4	2331.0	0.00E+00	8.1	4137.5	876.7
14	18	0.008333	167.14	2.309	2331.0	326.52	0.4483E-03	424.4	2331.0	0.00E+00	8.1	4137.6	876.7
14	19	0.009607	167.14	2.309	2331.0	326.52	0.4483E-03	424.4	2331.0	0.00E+00	8.1	4137.6	876.7
14	20	0.011104	167.14	2.309	2331.0	326.52	0.4483E-03	424.4	2331.0	0.00E+00	8.1	4137.6	876.7
15	1	0.000000	180.00	0.000	0.0	326.19	0.2168E-03	876.5	0.0	0.00E+00	0.0	326.2	876.5
15	2	0.000169	180.00	0.082	118.2	326.19	0.2179E-03	872.4	118.2	0.00E+00	0.0	327.7	873.6
15	3	0.000367	180.00	0.178	256.6	326.19	0.2196E-03	865.4	256.6	0.00E+00	0.0	333.5	870.9
15	4	0.000597	180.00	0.252	418.5	326.19	0.2224E-03	854.5	418.5	0.00E+00	0.0	346.1	869.0
15	5	0.000863	180.00	0.426	606.8	326.19	0.2268E-03	838.0	606.8	0.00E+00	0.0	369.9	868.6
15	6	0.001107	180.00	0.589	822.9	326.19	0.2337E-03	813.4	822.9	0.00E+00	0.0	412.4	869.7
15	7	0.001512	180.00	0.780	1066.7	326.19	0.2440E-03	779.0	1066.7	0.00E+00	0.0	487.4	873.7
15	8	0.001897	180.00	1.005	1334.0	326.19	0.2594E-03	732.8	1334.0	0.00E+00	0.0	621.4	880.9
15	9	0.002318	180.00	1.261	1605.3	326.19	0.2819E-03	674.3	1605.3	0.00E+00	0.0	857.6	888.8
15	10	0.002768	180.00	1.536	1857.3	326.19	0.3122E-03	608.8	1857.3	0.00E+00	0.0	1261.2	896.0
15	11	0.003243	180.00	1.807	2066.4	326.19	0.3492E-03	544.3	2066.4	0.00E+00	0.0	1894.4	899.7
15	12	0.003743	180.00	2.049	2218.9	326.19	0.3896E-03	487.9	2218.9	0.00E+00	0.0	2756.3	897.7
15	13	0.004275	180.00	2.224	2304.7	326.19	0.4254E-03	446.8	2304.7	0.00E+00	0.0	3623.8	889.0
15	14	0.004865	180.00	2.279	3323.1	326.19	0.4395E-03	432.5	2323.1	0.00E+00	0.0	3947.0	881.7
15	15	0.005541	180.00	2.304	2330.5	326.19	0.4463E-03	425.9	2330.5	0.00E+00	0.0	4103.7	878.0
15	16	0.006328	180.00	2.309	2331.4	326.19	0.4479E-03	424.3	2331.4	0.00E+00	0.0	4136.5	876.8
15	17	0.007251	180.00	2.309	2331.4	326.19	0.4480E-03	424.3	2331.4	0.00E+00	0.0	4137.5	876.7
15	18	0.008335	180.00	2.309	2331.4	326.19	0.4480E-03	424.3	2331.4	0.00E+00	0.0	4137.6	876.7
15	19	0.009610	180.00	2.309	2331.4	326.19	0.4480E-03	424.3	2331.4	0.00E+00	0.0	4137.6	876.7
15	20	0.011107	180.00	2.309	2331.4	326.19	0.4480E-03	424.3	2331.4	0.00E+00	0.0	4137.6	876.7

Figure 15. Continued.

CENTERBODY BOUNDARY LAYER EDGE CONDITIONS AND OTHER PARAMETERS FOR PLANE NO. 0

I	UE (FT/SEC)	WE (FT/SEC)	PE (LBF/FT2)	ROE (SLUG/FT3)	TE (DEG R)	HTE (FT2/SEC2)
1	2301.93	0.00	357.57	0.4783E-03	435.6	0.5266E+07
2	2302.32	9.64	357.11	0.4779E-03	435.4	0.5266E+07
3	2303.50	18.67	355.77	0.4766E-03	435.0	0.5266E+07
4	2305.38	26.54	353.65	0.4746E-03	434.2	0.5266E+07
5	2307.85	32.81	350.89	0.4719E-03	433.2	0.5266E+07
6	2310.78	37.16	347.67	0.4688E-03	432.1	0.5266E+07
7	2313.99	39.44	344.18	0.4655E-03	430.8	0.5266E+07
8	2317.31	39.64	340.63	0.4621E-03	429.6	0.5266E+07
9	2320.56	37.87	337.22	0.4588E-03	428.3	0.5266E+07
10	2323.58	34.32	334.08	0.4557E-03	427.2	0.5266E+07
11	2326.24	29.27	331.36	0.4531E-03	426.2	0.5266E+07
12	2328.41	23.00	329.15	0.4509E-03	425.4	0.5266E+07
13	2330.06	15.83	327.49	0.4493E-03	424.7	0.5266E+07
14	2331.03	8.06	326.52	0.4483E-03	424.4	0.5266E+07
15	2331.36	0.00	326.19	0.4480E-03	424.3	0.5266E+07

I	DUEDX (SEC-1)	DWEDX (SEC-1)	DPEDX (LBF/FT3)	DROEDX (SLUG/FT4)	DUEDZ (FT/SEC/R)	DWEDZ (FT/SEC/R)	DPEDZ (LBF/FT2/R)	DROEDZ (SLUG/FT3/R)
1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.430E+02	0.000E+00	0.000E+00
2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.350E+01	0.416E+02	-0.399E+01	-0.380E-05
3	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.680E+01	0.377E+02	-0.771E+01	-0.735E-05
4	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.970E+01	0.315E+02	-0.109E+02	-0.104E-04
5	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.120E+02	0.237E+02	-0.133E+02	-0.128E-04
6	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.137E+02	0.148E+02	-0.149E+02	-0.143E-04
7	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.146E+02	0.553E+01	-0.157E+02	-0.151E-04
8	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.146E+02	-0.351E+01	-0.155E+02	-0.150E-04
9	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.140E+02	-0.119E+02	-0.146E+02	-0.141E-04
10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.127E+02	-0.192E+02	-0.131E+02	-0.127E-04
11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.108E+02	-0.252E+02	-0.110E+02	-0.107E-04
12	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.853E+01	-0.299E+02	-0.862E+01	-0.842E-05
13	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.584E+01	-0.333E+02	-0.586E+01	-0.574E-05
14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.289E+01	-0.353E+02	-0.289E+01	-0.283E-05
15	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-0.359E+02	0.000E+00	0.000E+00

I	DTX (FT)	DTZ (FT)	MTX (FT)	MTZ (FT)	TWX (LBF/FT2)	TWZ (LBF/FT2)	TWT (LBF/FT2)	ROVB (SLUG/F2S)
1	0.238E-02	0.000E+00	0.379E-03	0.000E+00	0.382E+00	0.000E+00	0.382E+00	0.000E+00
2	0.238E-02	0.148E-02	0.379E-03	0.164E-03	0.382E+00	0.539E-02	0.382E+00	0.000E+00
3	0.239E-02	0.148E-02	0.379E-03	0.166E-03	0.381E+00	0.104E-01	0.382E+00	0.000E+00
4	0.240E-02	0.149E-02	0.380E-03	0.167E-03	0.381E+00	0.148E-01	0.381E+00	0.000E+00
5	0.241E-02	0.149E-02	0.380E-03	0.170E-03	0.380E+00	0.182E-01	0.380E+00	0.000E+00
6	0.242E-02	0.150E-02	0.381E-03	0.173E-03	0.379E+00	0.206E-01	0.379E+00	0.000E+00
7	0.243E-02	0.151E-02	0.382E-03	0.176E-03	0.377E+00	0.218E-01	0.378E+00	0.000E+00
8	0.244E-02	0.152E-02	0.382E-03	0.179E-03	0.376E+00	0.219E-01	0.377E+00	0.000E+00
9	0.245E-02	0.152E-02	0.383E-03	0.183E-03	0.375E+00	0.209E-01	0.376E+00	0.000E+00
10	0.247E-02	0.153E-02	0.383E-03	0.186E-03	0.374E+00	0.189E-01	0.375E+00	0.000E+00
11	0.247E-02	0.154E-02	0.384E-03	0.188E-03	0.373E+00	0.161E-01	0.374E+00	0.000E+00
12	0.248E-02	0.154E-02	0.384E-03	0.190E-03	0.373E+00	0.126E-01	0.373E+00	0.000E+00
13	0.249E-02	0.155E-02	0.384E-03	0.192E-03	0.372E+00	0.867E-02	0.373E+00	0.000E+00
14	0.249E-02	0.155E-02	0.384E-03	0.192E-03	0.372E+00	0.441E-02	0.372E+00	0.000E+00
15	0.249E-02	0.000E+00	0.384E-03	0.000E+00	0.372E+00	0.000E+00	0.372E+00	0.000E+00

Figure 15. Continued.

COWL BOUNDARY LAYER SOLUTION FOR PLANE NO. 1 XC= 0.07501(FT) X= 3.79000(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
1	1	0.000000	0.00	0.000	0.0	485.23	0.3225E-03	876.7	0.0	0.00E+00	0.0	485.2	876.7
1	2	0.000010	0.00	0.042	60.7	485.23	0.3229E-03	875.6	60.7	0.00E+00	0.0	485.8	875.9
1	3	0.000022	0.00	0.091	132.0	485.23	0.3234E-03	874.2	132.0	0.00E+00	0.0	488.0	875.7
1	4	0.000035	0.00	0.149	215.8	485.23	0.3240E-03	872.7	215.8	0.00E+00	0.0	492.8	876.5
1	5	0.000051	0.00	0.214	308.7	485.23	0.3258E-03	867.9	308.7	0.00E+00	0.0	500.9	875.8
1	6	0.000070	0.00	0.290	417.1	485.23	0.3280E-03	861.9	417.1	0.00E+00	0.0	514.4	876.4
1	7	0.000092	0.00	0.375	536.7	485.23	0.3319E-03	851.9	536.7	0.00E+00	0.0	534.7	875.9
1	8	0.000117	0.00	0.474	672.3	485.23	0.3371E-03	838.6	672.3	0.00E+00	0.0	565.8	876.3
1	9	0.000146	0.00	0.583	821.8	485.23	0.3446E-03	820.4	821.8	0.00E+00	0.0	611.9	876.6
1	10	0.000180	0.00	0.710	981.6	485.23	0.3551E-03	796.2	981.6	0.00E+00	0.0	678.9	876.4
1	11	0.000218	0.00	0.849	1151.9	485.23	0.3691E-03	766.1	1151.9	0.00E+00	0.0	777.5	876.5
1	12	0.000260	0.00	1.003	1328.2	485.23	0.3874E-03	729.8	1328.2	0.00E+00	0.0	921.8	876.6
1	13	0.000308	0.00	1.169	1503.5	485.23	0.4108E-03	688.2	1503.5	0.00E+00	0.0	1130.7	876.4
1	14	0.000360	0.00	1.348	1675.6	485.23	0.4399E-03	642.8	1675.6	0.00E+00	0.0	1436.7	876.5
1	15	0.000417	0.00	1.533	1834.9	485.23	0.4742E-03	596.3	1834.9	0.00E+00	0.0	1868.8	876.6
1	16	0.000480	0.00	1.718	1976.9	485.23	0.5128E-03	551.4	1976.9	0.00E+00	0.0	2459.4	876.7
1	17	0.000548	0.00	1.882	2089.5	485.23	0.5509E-03	513.3	2089.5	0.00E+00	0.0	3160.3	876.7
1	18	0.000622	0.00	2.006	2166.9	485.23	0.5819E-03	485.9	2166.9	0.00E+00	0.0	3829.4	876.7
1	19	0.000707	0.00	2.053	2194.7	485.23	0.5943E-03	475.8	2194.7	0.00E+00	0.0	4121.5	876.7
1	20	0.000806	0.00	2.053	2194.7	485.23	0.5943E-03	475.8	2194.7	0.00E+00	0.0	4121.5	876.7
2	1	0.000000	12.86	0.000	0.0	484.82	0.3222E-03	876.7	0.0	0.00E+00	0.0	484.8	876.7
2	2	0.000010	12.86	0.042	60.7	484.82	0.3226E-03	875.6	60.7	0.00E+00	0.3	485.4	875.9
2	3	0.000022	12.86	0.091	132.1	484.82	0.3231E-03	874.2	132.1	0.00E+00	0.6	487.6	875.7
2	4	0.000035	12.86	0.149	215.9	484.82	0.3237E-03	872.7	215.9	0.00E+00	0.9	492.4	876.5
2	5	0.000051	12.86	0.214	308.8	484.82	0.3255E-03	867.9	308.8	0.00E+00	1.3	500.5	875.8
2	6	0.000070	12.86	0.290	417.3	484.82	0.3278E-03	861.9	417.3	0.00E+00	1.8	514.0	876.4
2	7	0.000092	12.86	0.375	536.9	484.82	0.3316E-03	851.9	536.9	0.00E+00	2.3	534.3	875.9
2	8	0.000117	12.86	0.474	672.6	484.82	0.3369E-03	838.6	672.6	0.00E+00	2.9	565.4	876.3
2	9	0.000146	12.86	0.586	822.1	484.82	0.3444E-03	820.4	822.1	0.00E+00	3.5	611.5	876.6
2	10	0.000180	12.86	0.710	981.9	484.82	0.3548E-03	796.2	981.9	0.00E+00	4.2	678.5	876.4
2	11	0.000218	12.86	0.849	1152.3	484.82	0.3688E-03	766.0	1152.3	0.00E+00	4.9	777.1	876.5
2	12	0.000260	12.86	1.003	1328.6	484.82	0.3871E-03	729.7	1328.6	0.00E+00	5.6	921.4	876.6
2	13	0.000308	12.86	1.170	1503.9	484.82	0.4105E-03	688.1	1503.9	0.00E+00	6.4	1130.3	876.4
2	14	0.000360	12.86	1.349	1676.1	484.82	0.4396E-03	642.7	1676.1	0.00E+00	7.1	1436.4	876.5
2	15	0.000417	12.86	1.534	1835.3	484.82	0.4738E-03	596.2	1835.3	0.00E+00	7.8	1868.6	876.6
2	16	0.000480	12.86	1.718	1977.3	484.82	0.5124E-03	551.3	1977.3	0.00E+00	8.4	2459.3	876.7
2	17	0.000548	12.86	1.882	2089.9	484.82	0.5505E-03	513.1	2089.9	0.00E+00	8.9	3160.5	876.7
2	18	0.000623	12.86	2.006	2167.2	484.82	0.5816E-03	485.7	2167.2	0.00E+00	9.2	3829.8	876.7
2	19	0.000707	12.86	2.053	2195.0	484.82	0.5939E-03	475.7	2195.0	0.00E+00	9.3	4121.5	876.7
2	20	0.000806	12.86	2.053	2195.0	484.82	0.5939E-03	475.7	2195.0	0.00E+00	9.3	4121.5	876.7
3	1	0.000000	25.71	0.000	0.0	483.62	0.3214E-03	876.7	0.0	0.00E+00	0.0	483.6	876.7
3	2	0.000010	25.71	0.042	60.8	483.62	0.3219E-03	875.6	60.8	0.00E+00	0.5	484.2	875.9
3	3	0.000022	25.71	0.091	132.2	483.62	0.3224E-03	874.2	132.2	0.00E+00	1.1	486.4	875.7
3	4	0.000035	25.71	0.149	216.1	483.62	0.3229E-03	872.7	216.1	0.00E+00	1.8	491.2	876.5
3	5	0.000051	25.71	0.214	309.1	483.62	0.3247E-03	867.8	309.1	0.00E+00	2.6	499.3	875.8
3	6	0.000070	25.71	0.290	417.7	483.62	0.3270E-03	861.9	417.7	0.00E+00	3.4	512.8	876.4
3	7	0.000092	25.71	0.376	537.5	483.62	0.3308E-03	851.8	537.4	0.00E+00	4.4	533.1	875.9
3	8	0.000117	25.71	0.474	673.3	483.62	0.3361E-03	838.5	673.2	0.00E+00	5.6	564.2	876.3
3	9	0.000147	25.71	0.586	822.9	483.62	0.3436E-03	820.3	822.9	0.00E+00	6.8	610.3	876.6
3	10	0.000180	25.71	0.711	982.9	483.62	0.3540E-03	796.0	982.8	0.00E+00	8.1	677.3	876.4
3	11	0.000218	25.71	0.850	1153.4	483.62	0.3680E-03	765.8	1153.3	0.00E+00	9.5	775.9	876.5
3	12	0.000261	25.71	1.004	1329.7	483.62	0.3863E-03	729.4	1329.6	0.00E+00	11.0	920.2	876.6
3	13	0.000308	25.71	1.171	1505.1	483.62	0.4097E-03	687.8	1505.1	0.00E+00	12.4	1129.3	876.4
3	14	0.000361	25.71	1.350	1677.3	483.62	0.4387E-03	642.3	1677.3	0.00E+00	13.8	1435.6	876.5
3	15	0.000418	25.71	1.535	1836.6	483.62	0.4730E-03	595.8	1836.5	0.00E+00	15.2	1868.1	876.6

Figure 15. Continued.

COWL BOUNDARY LAYER SOLUTION FOR PLANE NO. 1 XC= 0.07501(FT) X= 3.79000(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
3	16	0.000480	25.71	1.720	1978.5	483.62	0.5115E-03	550.9	1978.4	0.00E+00	16.3	2459.2	876.7
3	17	0.000548	25.71	1.884	2091.0	483.62	0.5496E-03	512.7	2091.0	0.00E+00	17.3	3161.4	876.7
3	18	0.000623	25.71	2.008	2168.3	483.62	0.5806E-03	485.4	2168.2	0.00E+00	17.9	3830.9	876.7
3	19	0.000708	25.71	2.055	2195.9	483.62	0.5929E-03	475.3	2195.9	0.00E+00	18.1	4121.6	876.7
3	20	0.000806	25.71	2.055	2195.9	483.62	0.5929E-03	475.3	2195.9	0.00E+00	18.1	4121.6	876.7
4	1	0.000000	38.57	0.000	0.0	481.69	0.3202E-03	876.7	0.0	0.00E+00	0.0	481.7	876.7
4	2	0.000010	38.57	0.042	60.9	481.69	0.3206E-03	875.6	60.9	0.00E+00	0.7	482.3	875.9
4	3	0.000022	38.57	0.091	132.5	481.69	0.3211E-03	874.2	132.4	0.00E+00	1.6	484.5	875.7
4	4	0.000035	38.57	0.150	216.5	481.69	0.3216E-03	872.6	216.5	0.00E+00	2.6	489.3	876.5
4	5	0.000052	38.57	0.214	309.7	481.69	0.3234E-03	867.8	309.7	0.00E+00	3.7	497.4	875.8
4	6	0.000070	38.57	0.291	418.5	481.69	0.3257E-03	861.8	418.4	0.00E+00	5.0	510.8	876.4
4	7	0.000092	38.57	0.376	538.4	481.69	0.3295E-03	851.7	538.3	0.00E+00	6.4	531.2	875.9
4	8	0.000118	38.57	0.475	674.4	481.69	0.3348E-03	838.4	674.3	0.00E+00	8.0	562.2	876.3
4	9	0.000147	38.57	0.587	824.3	481.69	0.3423E-03	820.1	824.2	0.00E+00	9.8	608.3	876.7
4	10	0.000180	38.57	0.712	984.4	481.69	0.3527E-03	795.8	984.4	0.00E+00	11.7	675.4	876.5
4	11	0.000218	38.57	0.852	1155.1	481.69	0.3667E-03	765.5	1155.1	0.00E+00	13.7	774.0	876.5
4	12	0.000261	38.57	1.006	1331.5	481.69	0.3850E-03	729.0	1331.4	0.00E+00	15.8	918.3	876.6
4	13	0.000309	38.57	1.173	1507.1	481.69	0.4084E-03	687.3	1507.0	0.00E+00	17.9	1127.5	876.4
4	14	0.000361	38.57	1.352	1679.4	481.69	0.4374E-03	641.8	1679.3	0.00E+00	19.9	1434.3	876.5
4	15	0.000418	38.57	1.537	1838.5	481.69	0.4716E-03	595.2	1838.4	0.00E+00	21.8	1867.3	876.6
4	16	0.000481	38.57	1.722	1980.3	481.69	0.5101E-03	550.3	1980.2	0.00E+00	23.5	2459.0	876.7
4	17	0.000549	38.57	1.887	2092.9	481.69	0.5481E-03	512.1	2092.7	0.00E+00	24.8	3162.7	876.7
4	18	0.000624	38.57	2.011	2170.0	481.69	0.5790E-03	484.7	2169.8	0.00E+00	25.7	3832.5	876.7
4	19	0.000709	38.57	2.057	2197.4	481.69	0.5912E-03	474.8	2197.3	0.00E+00	26.0	4121.6	876.7
4	20	0.000807	38.57	2.057	2197.4	481.69	0.5912E-03	474.8	2197.3	0.00E+00	26.0	4121.6	876.7
5	1	0.000000	51.43	0.000	0.0	479.13	0.3185E-03	876.7	0.0	0.00E+00	0.0	479.1	876.7
5	2	0.000010	51.43	0.042	61.0	479.13	0.3189E-03	875.6	61.0	0.00E+00	0.9	479.7	875.9
5	3	0.000022	51.43	0.092	132.8	479.13	0.3194E-03	874.2	132.8	0.00E+00	2.0	481.9	875.7
5	4	0.000036	51.43	0.150	217.1	479.13	0.3199E-03	872.6	217.0	0.00E+00	3.2	486.7	876.5
5	5	0.000052	51.43	0.215	310.4	479.13	0.3217E-03	867.8	310.4	0.00E+00	4.6	494.8	875.8
5	6	0.000071	51.43	0.292	419.5	479.13	0.3240E-03	861.7	419.4	0.00E+00	6.2	508.2	876.4
5	7	0.000092	51.43	0.377	539.6	479.13	0.3278E-03	851.6	539.5	0.00E+00	8.0	528.6	875.9
5	8	0.000118	51.43	0.476	675.8	479.13	0.3331E-03	838.2	675.8	0.00E+00	10.0	559.6	876.2
5	9	0.000147	51.43	0.589	826.1	479.13	0.3405E-03	819.9	826.0	0.00E+00	12.3	605.7	876.7
5	10	0.000181	51.43	0.714	986.5	479.13	0.3510E-03	795.4	986.4	0.00E+00	14.6	672.8	876.5
5	11	0.000219	51.43	0.854	1157.5	479.13	0.3649E-03	765.0	1157.3	0.00E+00	17.2	771.4	876.6
5	12	0.000262	51.43	1.008	1333.9	479.13	0.3832E-03	728.5	1333.7	0.00E+00	19.8	915.7	876.6
5	13	0.000309	51.43	1.175	1509.6	479.13	0.4066E-03	686.7	1509.5	0.00E+00	22.4	1125.3	876.4
5	14	0.000362	51.43	1.355	1682.1	479.13	0.4355E-03	641.0	1681.9	0.00E+00	25.0	1432.6	876.5
5	15	0.000419	51.43	1.541	1841.1	479.13	0.4697E-03	594.4	1840.9	0.00E+00	27.3	1866.1	876.6
5	16	0.000482	51.43	1.726	1982.8	479.13	0.5081E-03	549.4	1982.6	0.00E+00	29.4	2458.8	876.7
5	17	0.000550	51.43	1.891	2095.4	479.13	0.5461E-03	511.2	2095.1	0.00E+00	31.1	3164.5	876.7
5	18	0.000625	51.43	2.015	2172.3	479.13	0.5769E-03	483.9	2172.0	0.00E+00	32.2	3834.8	876.7
5	19	0.000710	51.43	2.061	2199.4	479.13	0.5889E-03	474.1	2199.1	0.00E+00	32.6	4121.6	876.7
5	20	0.000808	51.43	2.061	2199.4	479.13	0.5889E-03	474.1	2199.1	0.00E+00	32.6	4121.6	876.7
6	1	0.000000	64.29	0.000	0.0	476.07	0.3164E-03	876.7	0.0	0.00E+00	0.0	476.1	876.7
6	2	0.000010	64.29	0.042	61.2	476.07	0.3168E-03	875.5	61.2	0.00E+00	1.0	476.7	875.9
6	3	0.000022	64.29	0.092	133.2	476.07	0.3173E-03	874.2	133.1	0.00E+00	2.3	478.9	875.7
6	4	0.000036	64.29	0.150	217.7	476.07	0.3179E-03	872.6	217.7	0.00E+00	3.7	483.6	876.6
6	5	0.000052	64.29	0.216	311.3	476.07	0.3197E-03	867.7	311.2	0.00E+00	5.3	491.7	875.8
6	6	0.000071	64.29	0.292	420.7	476.07	0.3219E-03	861.7	420.6	0.00E+00	7.2	505.2	876.4
6	7	0.000093	64.29	0.378	541.1	476.07	0.3258E-03	851.5	541.0	0.00E+00	9.2	525.5	875.9
6	8	0.000118	64.29	0.478	677.6	476.07	0.3310E-03	838.0	677.5	0.00E+00	11.6	556.5	876.2
6	9	0.000148	64.29	0.590	828.3	476.07	0.3385E-03	819.6	828.2	0.00E+00	14.1	602.6	876.7
6	10	0.000181	64.29	0.716	989.0	476.07	0.3489E-03	795.1	988.9	0.00E+00	16.9	659.7	876.5

Figure 15. Continued.

COWL BOUNDARY LAYER SOLUTION FOR PLANE NO. 1 XC= 0.07501(FT) X= 3.79000(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
6	11	0.000219	64.29	0.856	1160.3	476.07	0.3629E-03	764.5	1160.1	0.00E+00	19.8	768.4	876.6
6	12	0.000262	64.29	1.011	1336.8	476.07	0.3811E-03	727.8	1336.6	0.00E+00	22.8	912.7	876.[illegible]
6	13	0.000310	64.29	1.178	1512.7	476.07	0.4044E-03	685.9	1512.5	0.00E+00	25.8	1122.5	876.4
6	14	0.000363	64.29	1.359	1685.3	476.07	0.4334E-03	640.1	1685.1	0.00E+00	28.8	1430.6	876.5
6	15	0.000420	64.29	1.545	1844.3	476.07	0.4675E-03	593.4	1844.0	0.00E+00	31.5	1864.8	876.6
6	16	0.000483	64.29	1.730	1985.8	476.07	0.5058E-03	548.4	1985.5	0.00E+00	33.9	2458.5	876.7
6	17	0.000551	64.29	1.895	2098.3	476.07	0.5437E-03	510.2	2098.0	0.00E+00	35.8	3166.6	876.7
6	18	0.000626	64.29	2.019	2175.0	476.07	0.5744E-03	482.9	2174.6	0.00E+00	37.1	3837.6	876.7
6	19	0.000711	64.29	2.065	2201.7	476.07	0.5862E-03	473.2	2201.4	0.00E+00	37.6	4121.6	876.7
6	20	0.000810	64.29	2.065	2201.7	476.07	0.5862E-03	473.2	2201.4	0.00E+00	37.6	4121.6	876.7
7	1	0.000000	77.14	0.000	0.0	472.62	0.3141E-03	876.7	0.0	0.00E+00	0.0	472.6	876.7
7	2	0.000010	77.14	0.042	61.4	472.62	0.3145E-03	875.5	61.4	0.00E+00	1.1	473.2	875.9
7	3	0.000022	77.14	0.092	133.6	472.62	0.3150E-03	874.2	133.6	0.00E+00	2.5	475.4	875.7
7	4	0.000036	77.14	0.151	218.4	472.62	0.3156E-03	872.6	218.4	0.00E+00	4.0	480.2	876.6
7	5	0.000052	77.14	0.216	312.3	472.62	0.3174E-03	867.7	312.2	0.00E+00	5.8	488.3	875.8
7	6	0.000071	77.14	0.293	422.0	472.62	0.3196E-03	861.6	421.9	0.00E+00	7.8	501.7	876.4
7	7	0.000093	77.14	0.380	542.8	472.62	0.3235E-03	851.3	542.7	0.00E+00	10.0	522.0	875.9
7	8	0.000119	77.14	0.479	679.6	472.62	0.3287E-03	837.8	679.5	0.00E+00	12.5	553.0	876.2
7	9	0.000148	77.14	0.592	830.8	472.62	0.3362E-03	819.2	830.6	0.00E+00	15.3	599.1	876.7
7	10	0.000182	77.14	0.718	991.9	472.62	0.3466E-03	794.6	991.7	0.00E+00	18.3	666.2	876.5
7	11	0.000220	77.14	0.859	1163.5	472.62	0.3605E-03	763.9	1163.3	0.00E+00	21.5	765.0	876.6
7	12	0.000263	77.14	1.014	1340.0	472.62	0.3788E-03	727.1	1339.8	0.00E+00	24.7	909.3	876.5
7	13	0.000311	77.14	1.182	1516.2	472.62	0.4020E-03	685.0	1516.0	0.00E+00	28.0	1119.5	876.4
7	14	0.000364	77.14	1.363	1689.0	472.62	0.4309E-03	639.1	1688.8	0.00E+00	31.2	1428.3	876.5
7	15	0.000421	77.14	1.549	1847.8	472.62	0.4649E-03	592.3	1847.5	0.00E+00	34.1	1863.3	876.5
7	16	0.000484	77.14	1.735	1989.2	472.62	0.5032E-03	547.3	1988.8	0.00E+00	36.7	2458.3	876.7
7	17	0.000552	77.14	1.900	2101.7	472.62	0.5410E-03	509.0	2101.3	0.00E+00	38.8	3169.2	876.7
7	18	0.000627	77.14	2.024	2178.0	472.62	0.5716E-03	481.8	2177.7	0.00E+00	40.2	3840.8	876.7
7	19	0.000712	77.14	2.070	2204.4	472.62	0.5832E-03	472.2	2204.0	0.00E+00	40.7	4121.6	876.7
7	20	0.000811	77.14	2.070	2204.4	472.62	0.5832E-03	472.2	2204.0	0.00E+00	40.7	4121.6	876.7
8	1	0.000000	90.00	0.000	0.0	469.00	0.3117E-03	876.7	0.0	0.00E+00	0.0	469.0	876.7
8	2	0.000010	90.00	0.042	61.6	469.00	0.3121E-03	875.5	61.6	0.00E+00	1.2	469.6	875.9
8	3	0.000022	90.00	0.093	134.1	469.00	0.3126E-03	874.2	134.0	0.00E+00	2.5	471.8	875.7
8	4	0.000036	90.00	0.151	219.2	469.00	0.3132E-03	872.6	219.1	0.00E+00	4.1	476.6	874.6
8	5	0.000052	90.00	0.217	313.3	469.00	0.3150E-03	867.6	313.3	0.00E+00	5.9	484.6	875.8
8	6	0.000071	90.00	0.294	423.4	469.00	0.3172E-03	861.5	423.4	0.00E+00	8.0	498.1	876.4
8	7	0.000093	90.00	0.381	544.5	469.00	0.3211E-03	851.2	544.4	0.00E+00	10.3	518.4	875.9
8	8	0.000119	90.00	0.481	681.8	469.00	0.3263E-03	837.5	681.6	0.00E+00	12.9	549.3	876.2
8	9	0.000149	90.00	0.594	833.2	469.00	0.3337E-03	818.9	833.1	0.00E+00	15.7	595.4	876.7
8	10	0.000182	90.00	0.720	994.9	469.00	0.3441E-03	794.1	994.7	0.00E+00	18.8	662.6	876.5
8	11	0.000221	90.00	0.862	1166.8	469.00	0.3580E-03	763.3	1166.6	0.00E+00	22.0	761.4	876.6
8	12	0.000264	90.00	1.017	1343.5	469.00	0.3763E-03	726.3	1343.3	0.00E+00	25.4	905.7	876.5
8	13	0.000312	90.00	1.186	1520.0	469.00	0.3995E-03	684.1	1519.7	0.00E+00	28.7	1116.2	876.4
8	14	0.000365	90.00	1.367	1693.0	469.00	0.4284E-03	638.0	1692.7	0.00E+00	32.0	1425.9	876.6
8	15	0.000422	90.00	1.554	1851.6	469.00	0.4623E-03	591.1	1851.3	0.00E+00	35.0	1861.8	876.5
8	16	0.000485	90.00	1.740	1992.7	469.00	0.5004E-03	546.1	1992.4	0.00E+00	37.6	2458.0	876.7
8	17	0.000553	90.00	1.906	2105.2	469.00	0.5382E-03	507.8	2104.8	0.00E+00	39.8	3171.8	876.7
8	18	0.000628	90.00	2.030	2181.3	469.00	0.5686E-03	480.6	2180.9	0.00E+00	41.2	3844.2	876.7
8	19	0.000713	90.00	2.075	2207.2	469.00	0.5800E-03	471.2	2206.8	0.00E+00	41.7	4121.6	876.7
8	20	0.000813	90.00	2.075	2207.2	469.00	0.5800E-03	471.2	2206.8	0.00E+00	41.7	4121.6	876.7
9	1	0.000000	102.86	0.000	0.0	465.43	0.3093E-03	876.7	0.0	0.00E+00	0.0	465.4	876.7
9	2	0.000010	102.86	0.043	61.9	465.43	0.3098E-03	875.5	61.8	0.00E+00	1.1	466.0	875.9
9	3	0.000022	102.86	0.093	134.5	465.43	0.3102E-03	874.2	134.5	0.00E+00	2.5	468.2	875.7
9	4	0.000036	102.86	0.152	219.9	465.43	0.3108E-03	872.6	219.9	0.00E+00	4.0	473.0	876.6
9	5	0.000052	102.86	0.218	314.4	465.43	0.3126E-03	867.5	314.3	0.00E+00	5.8	481.1	875.8

Figure 15. Continued.

COWL BOUNDARY LAYER SOLUTION FOR PLANE NO. 1 XC= 0.07501(FT) X= 3.79000(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
9	6	0.000071	102.86	0.295	424.9	465.43	0.3148E-03	861.4	424.8	0.00E+00	7.8	494.5	876.4
9	7	0.000094	102.86	0.382	546.3	465.43	0.3187E-03	851.0	546.2	0.00E+00	10.0	514.7	875.9
9	8	0.000119	102.86	0.482	683.9	465.43	0.3239E-03	837.3	683.7	0.00E+00	12.6	545.7	876.2
9	9	0.000149	102.86	0.596	835.7	465.43	0.3313E-03	818.5	835.6	0.00E+00	15.4	591.8	876.7
9	10	0.000183	102.86	0.723	997.9	465.43	0.3417E-03	793.6	997.7	0.00E+00	18.3	659.0	876.5
9	11	0.000221	102.86	0.864	1170.2	465.43	0.3556E-03	762.6	1170.0	0.00E+00	21.5	757.9	876.6
9	12	0.000265	102.86	1.020	1346.9	465.43	0.3738E-03	725.5	1346.7	0.00E+00	24.8	902.2	876.5
9	13	0.000313	102.86	1.189	1523.6	465.43	0.3970E-03	683.1	1523.4	0.00E+00	28.0	1113.0	876.4
9	14	0.000368	102.86	1.372	1696.8	465.43	0.4258E-03	636.9	1696.5	0.00E+00	31.2	1423.5	876.6
9	15	0.000423	102.86	1.558	1855.3	465.43	0.4597E-03	590.0	1855.0	0.00E+00	34.1	1860.3	876.5
9	16	0.000486	102.86	1.745	1996.3	465.43	0.4977E-03	544.9	1995.9	0.00E+00	36.7	2457.8	876.7
9	17	0.000554	102.86	1.911	2108.7	465.43	0.5354E-03	506.5	2108.4	0.00E+00	38.8	3174.5	876.7
9	18	0.000630	102.86	2.035	2184.5	465.43	0.5656E-03	479.5	2184.1	0.00E+00	40.2	3847.4	876.7
9	19	0.000715	102.86	2.079	2210.0	465.43	0.5769E-03	470.1	2209.6	0.00E+00	40.6	4121.5	876.7
9	20	0.000814	102.86	2.079	2210.0	465.43	0.5769E-03	470.1	2209.6	0.00E+00	40.6	4121.5	876.7
10	1	0.000000	115.71	0.000	0.0	462.09	0.3071E-03	876.7	0.0	0.00E+00	0.0	462.1	876.7
10	2	0.000010	115.71	0.043	62.1	462.09	0.3075E-03	875.5	62.0	0.00E+00	1.1	462.7	875.8
10	3	0.000022	115.71	0.093	135.0	462.09	0.3080E-03	874.2	134.9	0.00E+00	2.3	464.9	875.7
10	4	0.000036	115.71	0.152	220.6	462.09	0.3086E-03	872.5	220.6	0.00E+00	3.7	469.6	876.6
10	5	0.000053	115.71	0.218	315.3	462.09	0.3104E-03	867.5	315.3	0.00E+00	5.4	477.7	875.8
10	6	0.000072	115.71	0.296	426.2	462.09	0.3126E-03	861.3	426.1	0.00E+00	7.2	491.1	876.4
10	7	0.000094	115.71	0.383	548.0	462.09	0.3165E-03	850.9	547.9	0.00E+00	9.3	511.4	875.8
10	8	0.000120	115.71	0.484	685.9	462.09	0.3217E-03	837.0	685.8	0.00E+00	11.6	542.3	876.2
10	9	0.000149	115.71	0.596	838.0	462.09	0.3291E-03	818.2	837.9	0.00E+00	14.2	588.3	876.6
10	10	0.000183	115.71	0.725	1000.7	462.09	0.3395E-03	793.2	1000.5	0.00E+00	17.0	655.6	876.6
10	11	0.000222	115.71	0.867	1173.3	462.09	0.3533E-03	762.1	1173.2	0.00E+00	19.9	754.5	876.7
10	12	0.000265	115.71	1.023	1350.2	462.09	0.3715E-03	724.8	1350.0	0.00E+00	22.9	898.8	876.5
10	13	0.000313	115.71	1.193	1527.1	462.09	0.3947E-03	682.2	1526.9	0.00E+00	25.9	1110.0	876.4
10	14	0.000366	115.71	1.376	1700.5	462.09	0.4234E-03	635.9	1700.2	0.00E+00	28.9	1421.3	876.6
10	15	0.000424	115.71	1.563	1858.8	462.09	0.4572E-03	568.9	1858.6	0.00E+00	31.5	1858.8	876.5
10	16	0.000487	115.71	1.749	1999.6	462.09	0.4951E-03	543.8	1999.3	0.00E+00	33.9	2457.5	876.7
10	17	0.000555	115.71	1.917	2112.0	462.09	0.5328E-03	505.4	2111.7	0.00E+00	35.8	3176.9	876.7
10	18	0.000631	115.71	2.040	2187.5	462.09	0.5629E-03	476.4	2187.2	0.00E+00	37.1	3850.5	876.7
10	19	0.000716	115.71	2.084	2212.6	462.09	0.5739E-03	469.2	2212.3	0.00E+00	37.5	4121.2	876.7
10	20	0.000816	115.71	2.084	2212.6	462.09	0.5739E-03	469.2	2212.3	0.00E+00	37.5	4121.2	876.7
11	1	0.000000	128.57	0.000	0.0	459.11	0.3051E-03	876.7	0.0	0.00E+00	0.0	459.1	876.7
11	2	0.000010	128.57	0.043	62.2	459.11	0.3056E-03	875.5	62.2	0.00E+00	0.9	459.7	875.8
11	3	0.000022	128.57	0.093	135.3	459.11	0.3060E-03	874.1	135.3	0.00E+00	2.0	461.9	875.7
11	4	0.000036	128.57	0.153	221.3	459.11	0.3066E-03	872.5	221.2	0.00E+00	3.3	466.7	876.6
11	5	0.000053	128.57	0.219	316.2	459.11	0.3084E-03	867.4	316.2	0.00E+00	4.7	474.7	875.8
11	6	0.000072	128.57	0.297	427.4	459.11	0.3106E-03	861.3	427.3	0.00E+00	6.3	488.1	876.5
11	7	0.000094	128.57	0.384	549.4	459.11	0.3145E-03	850.7	549.4	0.00E+00	8.1	508.4	875.8
11	8	0.000120	128.57	0.485	687.6	459.11	0.3197E-03	836.8	687.6	0.00E+00	10.1	539.2	876.2
11	9	0.000150	128.57	0.599	840.1	459.11	0.3271E-03	817.9	840.0	0.00E+00	12.4	585.3	876.6
11	10	0.000184	128.57	0.727	1003.2	459.11	0.3374E-03	792.8	1003.1	0.00E+00	14.8	652.5	876.6
11	11	0.000223	128.57	0.870	1176.2	459.11	0.3513E-03	761.5	1176.0	0.00E+00	17.3	751.6	876.7
11	12	0.000266	128.57	1.026	1353.0	459.11	0.3695E-03	724.1	1352.9	0.00E+00	19.9	895.9	876.5
11	13	0.000314	128.57	1.196	1530.2	459.11	0.3926E-03	681.4	1530.0	0.00E+00	22.5	1107.4	876.4
11	14	0.000367	128.57	1.379	1703.7	459.11	0.4213E-03	635.0	1703.5	0.00E+00	25.1	1419.3	876.6
11	15	0.000425	128.57	1.567	1862.0	459.11	0.4550E-03	587.9	1861.8	0.00E+00	27.4	1857.6	876.5
11	16	0.000488	128.57	1.753	2002.5	459.11	0.4928E-03	543.8	2002.3	0.00E+00	29.5	2457.3	876.7
11	17	0.000557	128.57	1.921	2114.9	459.11	0.5304E-03	504.4	2114.7	0.00E+00	31.1	3179.2	876.7
11	18	0.000632	128.57	2.045	2190.2	459.11	0.5604E-03	477.4	2189.9	0.00E+00	32.2	3853.2	876.7
11	19	0.000717	128.57	2.088	2214.9	459.11	0.5712E-03	468.3	2214.7	0.00E+00	32.6	4121.1	876.7
11	20	0.000817	128.57	2.088	2214.9	459.11	0.5712E-03	468.3	2214.7	0.00E+00	32.6	4121.1	876.7

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Figure 15. Continued.

COWL BOUNDARY LAYER SOLUTION FOR PLANE NO. 1   XC= 0.07501(FT)   X= 3.79000(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
12	1	0.000000	141.43	0.000	0.0	456.53	0.3034E-03	876.7	0.0	0.00E+00	0.0	456.5	876.7
12	2	0.000010	141.43	0.043	62.4	456.53	0.3038E-03	875.5	62.4	0.00E+00	0.7	457.1	875.8
12	3	0.000022	141.43	0.094	135.7	456.53	0.3043E-03	874.1	135.7	0.00E+00	1.6	459.3	875.7
12	4	0.000036	141.43	0.153	221.8	456.53	0.3049E-03	872.5	221.8	0.00E+00	2.6	464.1	876.6
12	5	0.000053	141.43	0.220	317.0	456.53	0.3067E-03	867.4	317.0	0.00E+00	3.7	472.1	875.8
12	6	0.000072	141.43	0.298	428.4	456.53	0.3089E-03	861.2	428.4	0.00E+00	5.0	485.5	876.5
12	7	0.000094	141.43	0.385	550.7	456.53	0.3127E-03	850.6	550.7	0.00E+00	6.5	505.7	875.8
12	8	0.000120	141.43	0.486	689.2	456.53	0.3180E-03	836.6	689.2	0.00E+00	8.1	536.8	876.2
12	9	0.000150	141.43	0.601	841.9	456.53	0.3254E-03	817.6	841.9	0.00E+00	9.9	582.6	876.6
12	10	0.000184	141.43	0.729	1005.4	456.53	0.3357E-03	792.4	1005.3	0.00E+00	11.8	649.9	876.6
12	11	0.000223	141.43	0.872	1178.6	456.53	0.3495E-03	761.1	1178.6	0.00E+00	13.8	749.0	876.7
12	12	0.000267	141.43	1.028	1355.6	456.53	0.3677E-03	723.5	1355.5	0.00E+00	15.9	893.3	876.5
12	13	0.000315	141.43	1.199	1532.9	456.53	0.3908E-03	680.8	1532.8	0.00E+00	18.0	1105.1	876.4
12	14	0.000368	141.43	1.383	1706.6	456.53	0.4195E-03	634.2	1706.5	0.00E+00	20.0	1417.7	876.6
12	15	0.000428	141.43	1.570	1864.7	456.53	0.4531E-03	587.1	1864.6	0.00E+00	21.9	1856.5	876.5
12	16	0.000489	141.43	1.757	2005.1	456.53	0.4908E-03	542.0	2005.6	0.00E+00	23.5	2457.1	876.7
12	17	0.000557	141.43	1.925	2117.5	456.53	0.5284E-03	503.4	2117.4	0.00E+00	24.9	3181.2	876.7
12	18	0.000633	141.43	2.049	2192.5	456.53	0.5582E-03	476.6	2192.3	0.00E+00	25.7	3855.2	876.7
12	19	0.000718	141.43	2.092	2217.0	456.53	0.5689E-03	467.6	2216.8	0.00E+00	26.0	4120.9	876.7
12	20	0.000818	141.43	2.092	2217.0	456.53	0.5689E-03	467.6	2216.8	0.00E+00	26.0	4120.9	876.7
13	1	0.000000	154.29	0.000	0.0	454.54	0.3021E-03	876.7	0.0	0.00E+00	0.0	454.5	876.7
13	2	0.000010	154.29	0.043	62.5	454.54	0.3025E-03	875.5	62.5	0.00E+00	0.5	455.1	875.8
13	3	0.000022	154.29	0.094	136.0	454.54	0.3030E-03	874.1	136.0	0.00E+00	1.1	457.3	875.7
13	4	0.000036	154.29	0.154	222.3	454.54	0.3036E-03	872.5	222.3	0.00E+00	1.8	462.1	876.6
13	5	0.000053	154.29	0.220	317.6	454.54	0.3054E-03	867.4	317.6	0.00E+00	2.6	470.1	875.8
13	6	0.000072	154.29	0.298	429.3	454.54	0.3076E-03	861.1	429.2	0.00E+00	3.5	483.5	876.5
13	7	0.000095	154.29	0.386	551.8	454.54	0.3114E-03	850.5	551.7	0.00E+00	4.5	503.7	875.8
13	8	0.000121	154.29	0.487	690.4	454.54	0.3166E-03	836.5	690.4	0.00E+00	5.6	534.6	876.2
13	9	0.000151	154.29	0.602	843.4	454.54	0.3240E-03	817.4	843.3	0.00E+00	6.9	580.6	876.6
13	10	0.000185	154.29	0.730	1007.1	454.54	0.3343E-03	792.2	1007.1	0.00E+00	8.2	647.9	876.6
13	11	0.000224	154.29	0.873	1180.5	454.54	0.3482E-03	760.7	1180.4	0.00E+00	9.6	747.0	876.7
13	12	0.000267	154.29	1.030	1357.5	454.54	0.3663E-03	723.1	1357.5	0.00E+00	11.1	891.3	876.5
13	13	0.000315	154.29	1.201	1535.0	454.54	0.3894E-03	680.2	1535.0	0.00E+00	12.5	1103.3	876.4
13	14	0.000369	154.29	1.385	1708.8	454.54	0.4181E-03	633.5	1708.7	0.00E+00	13.9	1416.4	876.6
13	15	0.000427	154.29	1.573	1866.8	454.54	0.4517E-03	586.4	1866.8	0.00E+00	15.2	1855.7	876.5
13	16	0.000490	154.29	1.760	2007.1	454.54	0.4893E-03	541.3	2007.1	0.00E+00	16.4	2457.1	876.7
13	17	0.000558	154.29	1.928	2119.5	454.54	0.5268E-03	502.8	2119.4	0.00E+00	17.3	3182.9	876.7
13	18	0.000634	154.29	2.052	2194.2	454.54	0.5565E-03	475.9	2194.1	0.00E+00	17.9	3856.1	876.7
13	19	0.000719	154.29	2.094	2218.6	454.54	0.5672E-03	467.0	2218.5	0.00E+00	18.1	4121.0	876.7
13	20	0.000819	154.29	2.094	2218.6	454.54	0.5672E-03	467.0	2218.5	0.00E+00	18.1	4121.0	876.7
14	1	0.000000	167.14	0.000	0.0	453.39	0.3013E-03	876.7	0.0	0.00E+00	0.0	453.4	876.7
14	2	0.000010	167.14	0.043	62.6	453.39	0.3018E-03	875.5	62.6	0.00E+00	0.3	454.0	875.8
14	3	0.000022	167.14	0.094	136.1	453.39	0.3022E-03	874.1	136.1	0.00E+00	0.6	456.2	875.7
14	4	0.000036	167.14	0.154	222.5	453.39	0.3028E-03	872.5	222.5	0.00E+00	0.9	460.9	876.6
14	5	0.000053	167.14	0.220	318.0	453.39	0.3046E-03	867.3	317.9	0.00E+00	1.3	469.0	875.8
14	6	0.000072	167.14	0.299	429.7	453.39	0.3068E-03	861.1	429.7	0.00E+00	1.8	482.4	876.5
14	7	0.000095	167.14	0.386	552.2	453.39	0.3106E-03	850.5	552.3	0.00E+00	2.3	502.6	875.8
14	8	0.000121	167.14	0.488	691.1	453.39	0.3159E-03	836.4	691.1	0.00E+00	2.9	533.4	876.1
14	9	0.000151	167.14	0.602	844.2	453.39	0.3233E-03	817.3	844.2	0.00E+00	3.5	579.4	876.6
14	10	0.000185	167.14	0.731	1008.1	453.39	0.3336E-03	792.0	1008.1	0.00E+00	4.2	646.8	876.6
14	11	0.000224	167.14	0.874	1181.5	453.39	0.3474E-03	760.5	1181.5	0.00E+00	4.9	745.8	876.7
14	12	0.000267	167.14	1.031	1358.7	453.39	0.3655E-03	722.8	1358.7	0.00E+00	5.7	890.2	876.5
14	13	0.000316	167.14	1.202	1536.2	453.39	0.3886E-03	679.9	1536.2	0.00E+00	6.4	1102.3	876.4
14	14	0.000369	167.14	1.386	1710.1	453.39	0.4172E-03	633.2	1710.0	0.00E+00	7.1	1415.6	876.6
14	15	0.000427	167.14	1.574	1868.0	453.39	0.4508E-03	586.0	1868.0	0.00E+00	7.8	1855.2	876.5

Figure 15. Continued.

COWL BOUNDARY LAYER SOLUTION FOR PLANE NO. 1 XC= 0.07501(FT) X= 3.79000(FT)

I	J	Y (FT)	Z (DEG)	M	Q (FT/SEC)	P (LBF/FT2)	RO (SLUG/FT3)	T (DEG R)	U (FT/SEC)	V (FT/SEC)	W (FT/SEC)	PT (LBF/FT2)	TT (DEG R)
14	16	0.000490	167.14	1.762	2008.3	453.39	0.4884E-03	540.9	2008.3	0.00E+00	8.4	2457.1	876.7
14	17	0.000559	167.14	1.930	2120.6	453.39	0.5259E-03	502.3	2120.6	0.00E+00	8.9	3183.8	876.7
14	18	0.000634	167.14	2.054	2195.2	453.39	0.5555E-03	475.6	2195.2	0.00E+00	9.2	3856.6	876.7
14	19	0.000720	167.14	2.096	2219.5	453.39	0.5661E-03	466.6	2219.4	0.00E+00	9.3	4120.9	876.7
14	20	0.000819	167.14	2.096	2219.5	453.39	0.5661E-03	466.6	2219.4	0.00E+00	9.3	4120.9	876.7
15	1	0.000000	180.00	0.000	0.0	453.12	0.3012E-03	876.7	0.0	0.00E+00	0.0	453.1	876.7
15	2	0.000010	180.00	0.043	62.6	453.12	0.3016E-03	875.5	62.6	0.00E+00	0.0	453.7	875.8
15	3	0.000022	180.00	0.094	136.1	453.12	0.3021E-03	874.1	136.1	0.00E+00	0.0	455.9	875.7
15	4	0.000036	180.00	0.154	222.6	453.12	0.3026E-03	872.5	222.6	0.00E+00	0.0	460.7	876.6
15	5	0.000053	180.00	0.220	318.0	453.12	0.3044E-03	867.3	318.0	0.00E+00	0.0	468.7	875.8
15	6	0.000072	180.00	0.299	429.8	453.12	0.3066E-03	861.1	429.8	0.00E+00	0.0	482.1	876.5
15	7	0.000095	180.00	0.386	552.5	453.12	0.3105E-03	850.4	552.5	0.00E+00	0.0	502.3	875.8
15	8	0.000121	180.00	0.488	691.3	453.12	0.3157E-03	836.4	691.3	0.00E+00	0.0	533.1	876.1
15	9	0.000151	180.00	0.603	844.4	453.12	0.3231E-03	817.2	844.4	0.00E+00	0.0	579.1	876.6
15	10	0.000185	180.00	0.731	1008.3	453.12	0.3334E-03	792.0	1008.3	0.00E+00	0.0	646.5	876.6
15	11	0.000224	180.00	0.874	1181.8	453.12	0.3472E-03	760.4	1181.8	0.00E+00	0.0	745.5	876.7
15	12	0.000267	180.00	1.031	1358.9	453.12	0.3653E-03	722.7	1358.9	0.00E+00	0.0	889.9	876.5
15	13	0.000316	180.00	1.202	1536.5	453.12	0.3884E-03	679.8	1536.5	0.00E+00	0.0	1102.0	876.4
15	14	0.000369	180.00	1.387	1710.4	453.12	0.4171E-03	633.1	1710.4	0.00E+00	0.0	1415.4	876.6
15	15	0.000427	180.00	1.575	1868.3	453.12	0.4506E-03	586.0	1868.3	0.00E+00	0.0	1855.1	876.5
15	16	0.000490	180.00	1.762	2008.6	453.12	0.4882E-03	540.8	2008.6	0.00E+00	0.0	2457.0	876.6
15	17	0.000559	180.00	1.931	2120.9	453.12	0.5257E-03	502.3	2120.9	0.00E+00	0.0	3183.9	876.7
15	18	0.000634	180.00	2.054	2195.4	453.12	0.5553E-03	475.5	2195.4	0.00E+00	0.0	3856.6	876.7
15	19	0.000720	180.00	2.096	2219.7	453.12	0.5659E-03	466.6	2219.7	0.00E+00	0.0	4120.7	876.7
15	20	0.000820	180.00	2.096	2219.7	453.12	0.5659E-03	466.6	2219.7	0.00E+00	0.0	4120.7	876.7

Figure 15. Continued.

COWL BOUNDARY LAYER EDGE CONDITIONS AND OTHER PARAMETERS FOR PLANE NO. 1

I	UE (FT/SEC)	WE (FT/SEC)	PE (LBF/FT2)	RGE (SLUG/FT3)	TE (DEG R)	HTE (FT2/SEC2)
1	2194.70	0.00	485.23	0.5943E-03	475.8	0.5266E+07
2	2195.00	9.30	484.82	0.5939E-03	475.7	0.5266E+07
3	2195.86	18.13	483.62	0.5929E-03	475.3	0.5266E+07
4	2197.26	26.04	481.69	0.5912E-03	474.8	0.5266E+07
5	2199.13	32.63	479.13	0.5889E-03	474.1	0.5266E+07
6	2201.41	37.59	476.07	0.5862E-03	473.2	0.5266E+07
7	2204.03	40.66	472.62	0.5832E-03	472.2	0.5266E+07
8	2206.83	41.68	469.00	0.5800E-03	471.2	0.5266E+07
9	2209.63	40.63	465.43	0.5769E-03	470.1	0.5266E+07
10	2212.29	37.54	462.09	0.5739E-03	469.2	0.5266E+07
11	2214.70	32.61	459.11	0.5712E-03	468.3	0.5266E+07
12	2216.92	26.03	456.53	0.5689E-03	467.6	0.5266E+07
13	2218.49	18.11	454.54	0.5672E-03	467.0	0.5266E+07
14	2219.44	9.27	453.39	0.5661E-03	465.4	0.5266E+07
15	2219.67	0.00	453.12	0.5659E-03	466.6	0.5266E+07

I	DUEDX (SEC-1)	DWEDX (SEC-1)	DPEDX (LBF/FT3)	DROEDX (SLUG/FT4)	DUEDZ (FT/SEC/R)	DWEDZ (FT/SEC/R)	DPEDZ (LBF/FT2/R)	DROEDZ (SLUG/FT3/R)
1	-0.632E+02	0.000E+00	0.826E+02	0.723E-04	0.000E+00	0.414E+02	0.000E+00	0.000E+00
2	-0.632E+02	0.220E+01	0.827E+02	0.724E-04	0.260E+01	0.404E+02	-0.357E+01	-0.312E-05
3	-0.640E+02	0.434E+01	0.836E+02	0.733E-04	0.503E+01	0.373E+02	-0.696E+01	-0.608E-05
4	-0.654E+02	0.631E+01	0.850E+02	0.746E-04	0.729E+01	0.323E+02	-0.100E+02	-0.876E-05
5	-0.670E+02	0.790E+01	0.866E+02	0.762E-04	0.926E+01	0.257E+02	-0.125E+02	-0.110E-04
6	-0.688E+02	0.938E+01	0.884E+02	0.780E-04	0.109E+02	0.179E+02	-0.145E+02	-0.127E-04
7	-0.698E+02	0.103E+02	0.893E+02	0.789E-04	0.121E+02	0.912E+01	-0.158E+02	-0.139E-04
8	-0.715E+02	0.107E+02	0.910E+02	0.807E-04	0.125E+02	-0.585E-01	-0.160E+02	-0.142E-04
9	-0.718E+02	0.103E+02	0.908E+02	0.807E-04	0.122E+02	-0.923E+01	-0.154E+02	-0.137E-04
10	-0.724E+02	0.951E+01	0.912E+02	0.812E-04	0.113E+02	-0.179E+02	-0.141E+02	-0.125E-04
11	-0.729E+02	0.868E+01	0.916E+02	0.816E-04	0.101E+02	-0.256E+02	-0.124E+02	-0.110E-04
12	-0.714E+02	0.707E+01	0.896E+02	0.801E-04	0.844E+01	-0.323E+02	-0.102E+02	-0.908E-05
13	-0.728E+02	0.492E+01	0.913E+02	0.816E-04	0.583E+01	-0.373E+02	-0.698E+01	-0.623E-05
14	-0.713E+02	0.224E+01	0.893E+02	0.799E-04	0.263E+01	-0.403E+02	-0.318E+01	-0.284E-05
15	-0.721E+02	0.000E+00	0.899E+02	0.804E-04	0.000E+00	-0.413E+02	0.000E+00	0.000E+00

I	DTX (FT)	DTZ (FT)	MTX (FT)	MTZ (FT)	TWX (LBF/FT2)	TWZ (LBF/FT2)	TWT (LBF/FT2)	ROVB (SLUG/F2S)
1	0.320E-03	0.000E+00	0.629E-04	0.000E+00	0.326E+01	0.000E+00	0.326E+01	0.000E+00
2	0.320E-03	0.320E-03	0.629E-04	0.629E-04	0.326E+01	0.138E-01	0.326E+01	0.000E+00
3	0.320E-03	0.320E-03	0.629E-04	0.629E-04	0.326E+01	0.269E-01	0.326E+01	0.000E+00
4	0.320E-03	0.320E-03	0.629E-04	0.629E-04	0.326E+01	0.386E-01	0.326E+01	0.000E+00
5	0.321E-03	0.321E-03	0.629E-04	0.629E-04	0.326E+01	0.483E-01	0.326E+01	0.000E+00
6	0.321E-03	0.321E-03	0.629E-04	0.629E-04	0.326E+01	0.556E-01	0.326E+01	0.000E+00
7	0.322E-03	0.322E-03	0.629E-04	0.629E-04	0.326E+01	0.601E-01	0.326E+01	0.000E+00
8	0.323E-03	0.323E-03	0.629E-04	0.629E-04	0.326E+01	0.615E-01	0.326E+01	0.000E+00
9	0.323E-03	0.323E-03	0.628E-04	0.628E-04	0.326E+01	0.599E-01	0.326E+01	0.000E+00
10	0.324E-03	0.324E-03	0.628E-04	0.628E-04	0.326E+01	0.553E-01	0.326E+01	0.000E+00
11	0.324E-03	0.324E-03	0.628E-04	0.628E-04	0.326E+01	0.480E-01	0.326E+01	0.000E+00
12	0.325E-03	0.325E-03	0.628E-04	0.628E-04	0.326E+01	0.382E-01	0.326E+01	0.000E+00
13	0.325E-03	0.325E-03	0.628E-04	0.629E-04	0.326E+01	0.266E-01	0.326E+01	0.000E+00
14	0.326E-03	0.326E-03	0.628E-04	0.628E-04	0.326E+01	0.136E-01	0.326E+01	0.000E+00
15	0.326E-03	0.000E+00	0.628E-04	0.000E+00	0.326E+01	0.000E+00	0.326E+01	0.000E+00

X-STEP REGULATION PARAMETERS

Figure 15. Continued.

LIMITING POINT - I=13, J=11 SAFETY FACTOR= 0.975000E+00 DELTA-X= 0.614365E-01(FT)

Figure 15. Concluded.

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