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NAVSWC TR 91-86

ZEUS USER MANUAL "REAL GAS" EFFECTS

BY F. J. PRIOLO AND A. B. WARDLAW, JR
RESEARCH AND TECHNOLOGY DEPARTMENT

6 MAY 1991

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91-14550



NAVAL SURFACE WARFARE CENTER

Dahlgren, Virginia 22448-5000 • Silver Spring, Maryland 20903-5000

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FOREWORD

The extension and application of the ZEUS code to high, hypersonic Mach numbers by incorporating high-temperature equilibrium air effects is described. The ZEUS code is a space-marching Euler solver. It uses an automatic multiple zone grid generation technique and a finite volume, second-order Godunov scheme for steady supersonic flow. High-temperature effects are achieved by using curve fits of the thermodynamic properties of equilibrium air. Sample calculations for a sharp cone and a blunt nosed cylinder are provided.

This work was supported by the Naval Weapons Center at China Lake.



CARL W. LARSON, Head
Physics & Technology Division

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CHAPTER 1

INTRODUCTION

This report describes the extension and application of the ZEUS code to high, hypersonic Mach numbers by incorporating high-temperature equilibrium air or "real gas" effects. This approach is important for accurate aerodynamic predictions in support of atmospheric reentry vehicles with high maneuverability and future hypersonic weapons. The program employs an automatic multiple zone grid generation technique which is particularly suited to describing missile-type geometries in supersonic flight. The ZEUS code,¹⁻⁹ whose numerical algorithm is well described in References 1-2 and applications in References 2-9, is a supersonic/hypersonic space-marching Euler solver which is capable of computing internal as well as external flows. The present report provides recent modifications to the program (described in Reference 2) for real gas effects and user instructions for its application.

The ZEUS code uses a zonal, finite volume, second order Godunov scheme to integrate the Euler equations. The computation proceeds for an initial data plane on which the flow field is specified, as shown in Figure 1, and marches in a streamwise direction until the end of the region of interest is encountered. In the case of a missile, the initial data plane is taken near the nose of the missile, and the flow field on this plane can be defined using conical flow, a blunt body solution, or uniform flow. The calculation is marched down the axis of the missile until the base of the missile is encountered. Throughout the computation, the flow field must remain supersonic everywhere.

At high flight Mach numbers and altitudes, computation of the flow field in local chemical and thermodynamic equilibrium is necessary to account for the high-temperature or real gas effects. These high temperature effects are taken into account by using the curve fits of Scrivansan et. al.¹⁰ to compute the thermodynamic properties of equilibrium air as well as modifying parts of the ZEUS code.

CHAPTER 2

HIGH-TEMPERATURE EQUILIBRIUM AIR

The computation of missiles or atmospheric reentry bodies at high hypersonic Mach numbers and high altitudes requires the flow field to be calculated in local thermodynamic and chemical equilibrium. To solve an equilibrium flow field, two thermodynamic state variables (such as T and p) need to be expressed in terms of two other state variables (such as ρ and h).¹¹ The high-temperature thermodynamic properties of equilibrium chemically reacting air are obtained from statistical thermodynamics as discussed in Reference 11. To simplify matters, tables of thermodynamic properties of high-temperature air have been constructed (see Hilsenrath and Klein¹²) which can be used in numerical flow field calculations via a "table look-up" procedure which interpolates between discrete entries from the tables. Furthermore, polynomial curve fits of the tabulated thermodynamic data for equilibrium air as discussed in Reference 10 have been correlated for computational convenience and efficiency. This latter method is the approach implemented in the ZEUS code.

2.1 COMPUTED THERMODYNAMIC PROPERTIES

The tabulated thermodynamic properties of equilibrium air are curve fit as discussed in Reference 10 and are implemented in ZEUS through the equilibrium air subroutines used in NASA Langley's CFL3DE program,¹³ a time-dependent Navier-Stokes program. Each subroutine correlates different properties. For instance, subroutine:

- TGAS1 — computes p, a, T as a function of e and ρ .
- TGAS2 — computes s as a function of e and ρ .
- TGAS4 — computes h as a function of p and ρ .
- TGAS5 — computes ρ as a function of p and s .
- TGAS7 — computes a as a function of p and s .

where, p = pressure, ρ = density, T = temperature, e = internal energy, h = enthalpy, s = entropy, and a = sound speed.

2.2 EFFECTIVE GAMMA

It is convenient to define an "effective gamma" as follows:

$$\Gamma = 1 / \left(1 - \frac{p}{\rho h} \right) \quad (1)$$

This is used in decoding the flow variables as discussed in Section 3.2.

CHAPTER 3

NUMERICAL PROCEDURE

3.1 GOVERNING EQUATIONS

Using the notation and coordinates of Figure 2, control volume mass and momentum conservation equations are given by:

$$\bar{U}_{i,j}^{n+1} = \bar{U}_{i,j}^n - \bar{F}_{i+\frac{1}{2},j} + \bar{F}_{i-\frac{1}{2},j} - \bar{F}_{i,j+\frac{1}{2}} + \bar{F}_{i,j-\frac{1}{2}} \quad (2)$$

where:

$$\bar{U}_{i,j}^n = A_{i,j}^n \begin{bmatrix} \rho w \\ \rho w^2 + p \\ \rho w u \\ \rho w v \end{bmatrix}_{i,j} = \begin{bmatrix} U_1 \\ U_2 \\ U_3 \\ U_4 \end{bmatrix}_{i,j} \quad (3)$$

$$\bar{F}_{i+\frac{1}{2},j} = \begin{bmatrix} \rho V \\ \rho w V + n_z p \\ \rho u V + n_x p \\ \rho v V + n_y p \end{bmatrix}_{i+\frac{1}{2},j} \quad (4)$$

$$V = \bar{n}_{i+\frac{1}{2},j} \bullet (u, v, w)_{i+\frac{1}{2},j} \quad (5)$$

Here, $\bar{U}$ is the flux in the z -direction which passes through the shaded cell ends while the $\bar{F}$'s are the fluxes associated with the remaining cell edges. The A 's are the cell edge areas, $\bar{n}$ is the vector normal to the cell, and u, v, w are the cartesian velocity components. Equations (2) - (5) are closed using the constant total enthalpy condition

$$H_0 = h + \frac{1}{2}(u^2 + v^2 + w^2) \quad (6)$$

where $h = h(p, \rho)$.

3.2 DECODING

After the corrector step, the flow variables ρ, p, u, v, w must be determined or decoded from the computed conservative variables U_1, U_2, U_3, U_4 , as displayed in Equation (3). This is done using an iterative procedure similar to that used by Solomon et. al.¹⁴

By definition, we have

$$u = U_3/U_1 \quad (7)$$

$$v = U_4/U_1 \quad (8)$$

$$p = (U_2 - U_1 w)/A \quad (9)$$

$$\rho = U_1/w/A \quad (10)$$

Substitute Equations (7) – (10) into Equation (6) which yields:

$$h = \frac{1}{2}[H' - w^2] \quad (11)$$

where:

$$H' = 2H_0 - \frac{U_3^2 + U_4^2}{U_1^2} \quad (12)$$

Substitute Equations (9–11) into Equation (1) to get a quadratic for w . The root of this equation corresponding to $w^2 > \Gamma p/\rho$ is

$$w = \frac{U_2[\Gamma + \sqrt{1 - \Phi}]}{U_1[\Gamma + 1]} \quad (13)$$

where:

$$\Phi = (\Gamma^2 - 1) \left[H' \left(\frac{U_1}{U_2} \right)^2 - 1 \right] \quad (14)$$

In the case of a perfect gas, $\Gamma = \gamma$, which is known, and Equations (7) – (10), and (13) provide the desired decoding formulas. For a more general gas (such as equilibrium air) where $h=h(p,\rho)$ is curve fit to thermodynamic data, Γ is not known a-priori, and the decoding can not be done in closed form. In this case, the decoding is done by solving the nonlinear equation

$$h(p, \rho) - \frac{1}{2}[H' - w^2] = 0 \quad (15)$$

for w . In the code, Equation (15) is solved iteratively using the Secant Method. This is done in the following manner:

- (a.) Guess a value of Γ_1 from p, ρ, h computed in the predictor step and substitute Γ_1 into Equation (13) to get w .

- (b.) Decode values of u, v and compute new values of p, ρ with the value of w computed in Step (a.)
- (c.) Solve Equation (15) by using the equilibrium air subroutine, TGAS4, for $h(p, \rho)$. This gives the first error estimate, $f(\Gamma_1)$.
- (d.) Use the values of p, ρ, h from Step (b.) to compute second guess value of Γ_2 using Equation (1).
- (e.) Use Γ_2 to compute new values of w from Equation (13) and p, ρ from Equations (9) and (10) which gives a new value of $h(p, \rho)$ using subroutine TGAS4.
- (f.) Solve Equation (15) using the new values of w, p, ρ, h to get second error estimate, $f(\Gamma_2)$.
- (g.) Compute new value of Γ_3 by

$$\Gamma_3 = \frac{\Gamma_1 f(\Gamma_2) - \Gamma_2 f(\Gamma_1)}{f(\Gamma_2) - f(\Gamma_1)} \quad (16)$$

- (h.) Use Γ_3 to compute new values of w, p, ρ, h as in Step (e.) and solve Equation (15) to get $f(\Gamma_3)$.
- (i.) If $\left| \frac{f(\Gamma_3)}{h(p, \rho)} \right| < 10^{-3}$ is true, then the solution for w is converged. If it is false, then go to Step (e.) and continue until converged.

3.3 NEW DENSITY

The predictor step uses Euler's equations in non-conservation form to predict the properties of u, v, w , and p . For a perfect gas computation, the known total enthalpy constraint is used to determine ρ . For equilibrium air, the density must be obtained by numerically solving the differential equation for ρ .

To construct the differential equation, $d\rho$, the equation for total enthalpy is written as

$$H_0 = h(p, \rho) + \frac{q^2}{2} \quad (17)$$

where q is the velocity. Rearranging Equation (17) for $h(p, \rho)$ gives

$$h(p, \rho) = H_0 - \frac{q^2}{2} \quad (18)$$

Casting Equation (18) in terms of differentials which gives

$$\left(\frac{\partial h}{\partial p} \right)_\rho dp + \left(\frac{\partial h}{\partial \rho} \right)_p d\rho = -q dq \quad (19)$$

and rearranging Equation (19) for $d\rho$ yields

$$d\rho = \frac{\left[-q dq - \left(\frac{\partial h}{\partial p} \right)_\rho dp \right]}{\left(\frac{\partial h}{\partial \rho} \right)_p} \quad (20)$$

Using the following finite difference expressions for the differentials, Equation (20) can be computed in closed form:

$$\left(\frac{\partial h}{\partial \rho} \right)_p = \frac{h(p, \rho) - h(p, \rho + \Delta\rho)}{\Delta\rho} \quad (21)$$

$$\left(\frac{\partial h}{\partial p} \right)_\rho = \frac{h(p, \rho) - h(p + \Delta p, \rho)}{\Delta p} \quad (22)$$

$$dp = p_2 - p_1 \quad (23)$$

$$d\rho = \rho_2 - \rho_1 \quad (24)$$

$$dq = q_2 - q_1 \quad (25)$$

$$\Delta p = .001 p_1 \quad (26)$$

$$\Delta \rho = .001 \rho_1 \quad (27)$$

Equations (21) – (27) are substituted into Equation (20) and solved for the new density, ρ_2 with p_1 , ρ_1 , q_1 , p_2 , q_2 , h given. Here the values of h are determined using the equilibrium air subroutine, TGAS4. This yields the following expression for ρ_2

$$\rho_2 = \rho_1 - \left\{ \frac{q_1(q_2 - q_1) + \left[\frac{h(p_1, \rho_1) - h(1.001 p_1, \rho_1)}{.001 p_1} \right] (p_2 - p_1)}{\left[\frac{h(p_1, \rho_1) - h(p_1, 1.001 \rho_1)}{.001 \rho_1} \right]} \right\} \quad (28)$$

where

$$q_1 = \sqrt{u_1^2 + v_1^2 + w_1^2} \quad (29)$$

$$q_2 = \sqrt{u_2^2 + v_2^2 + w_2^2}$$

3.4 OBLIQUE SHOCKS

The inviscid boundary conditions at a surface require that the flow be tangent to the surface. ZEUS requires that the velocity vector be turned through either a shock or an expansion wave to align the velocity with the surface as illustrated in Figure 3. To solve for flow properties across an oblique shock wave in equilibrium air, a closed form solution does not exist. Referring to Figure 3(a), the following energy equation is solved iteratively:

$$u_-^2 + 2h_-(p_-, \rho_-) = u_+^2 + 2h_+(p_+, \rho_+) \quad (30)$$

where for an oblique shock,

$$u_- = V_- \sin \beta$$

$$u_+ = V_- \cos \beta \frac{(1 - \tan \theta \cot \beta)}{(\tan \theta + \cot \beta)}$$

$$\rho_+ = \rho_- u_- / u_+ \quad (31)$$

$$p_+ = \rho_- u_- (u_- - u_+) + p_-$$

$$\theta = \cos^{-1} [(\vec{n}_+ \cdot \vec{n}_-) / |\vec{n}_+| |\vec{n}_-|]$$

and β is the shock wave angle to be determined. Here the $-$ and $+$ subscripts denote the upstream and downstream conditions, respectively. V_- is the upstream velocity component tangent to the surface, u_- and u_+ are the velocity components normal to the shock, $\vec{n}_-$, $\vec{n}_+$ are the surface normal vectors, p_- , p_+ are the pressures, and ρ_- , ρ_+ are the densities, and θ is the deflection angle.

To solve Equations (30) – (31), the Secant Method iterative procedure is implemented in a similar fashion as in Section 3.2 for decoding. Computations proceed by initializing

$$\sin \beta > \max [\sin \theta, \sin (1/M_-)] \quad (32)$$

where M_- is the upstream Mach number. The error is estimated using Equation (30) as follows:

$$f(\sin \beta) = u_-^2 + 2h_-(p_-, \rho_-) - u_+^2 - 2h_+(p_+, \rho_+) \quad (33)$$

The value of $\sin \beta$ is increased until the relative error is less than 10^{-3} or

$$\left| \frac{f(\sin \beta)}{h_+(p_+, \rho_+)} \right| < 10^{-3} \quad (34)$$

This results in the final properties behind the shock, p_+ , ρ_+ , V_+ for which the velocity is tangent to the surface.

3.5 EXPANSION WAVES

To satisfy the inviscid boundary condition at a surface, often the velocity vector must be turned through a Prandtl-Meyer expansion to align the flow tangent to the surface. As in the case for oblique shock turns, a closed form solution does not exist for equilibrium air conditions; therefore, the expansion must be computed iteratively.

Referring to Figure 3(b), the equation for a centered expansion can be written in differential form:

$$\frac{dp}{d\phi} = \frac{-\rho q^2}{\sqrt{q^2/a^2 - 1}} \quad \text{for } 0 \leq \phi \leq \theta \quad (35)$$

where

$$\begin{aligned} q^2 &= 2H_0 - 2h(p, \rho) \\ s_- &= s(p_-, \rho_-) \\ \rho &= \rho(s_-, p) \\ a^2 &= a^2(p, \rho) \\ \theta &= \cos^{-1} [(\vec{n}_+ \cdot \vec{n}_-) / |\vec{n}_+| |\vec{n}_-|] = \text{turn angle} \end{aligned} \quad (36)$$

The $-$ and $+$ subscripts represent upstream and downstream conditions, respectively. The unsubscripted variables are integrated values. Computations proceed by integrating Equations (35) – (36) on the interval $0 \leq \phi \leq \theta$ subject to the initial conditions $p = p_-$ and $q = V_-$ at $\phi=0$ using the second-order Improved Euler method. Subdivisions are every $.377^\circ$. The final results at $\phi=\theta$ give $p_+ = p_{\phi=\theta}$, $\rho_+ = \rho_{\phi=\theta}$, $V_+ = q_{\phi=\theta}$.

3.6 SHOCK ANGLE

The computation of the bow shock angle is determined using information along the positive characteristic at the cell adjacent to the bow shock. The shock angle is

$$\beta_+ = \tan^{-1} \left[\theta + \frac{1}{\sqrt{M^2 - 1}} \right] \quad (37)$$

or in terms of velocities

$$\beta_+ = \tan^{-1} \left[\frac{V_n}{w} + \frac{1}{\sqrt{\frac{V_n^2 + w^2}{a^2} - 1}} \right]_{av} \quad (38)$$

Here, the variables are Roe averaged in the following manner:

$$\begin{aligned} V_{nav} &= \frac{(\rho_+^{\frac{1}{2}} V_{n+} + \rho_-^{\frac{1}{2}} V_{n-})}{\rho_+^{\frac{1}{2}} + \rho_-^{\frac{1}{2}}} \\ w_{av} &= \frac{(\rho_+^{\frac{1}{2}} w_+ + \rho_-^{\frac{1}{2}} w_-)}{\rho_+^{\frac{1}{2}} + \rho_-^{\frac{1}{2}}} \\ a_{av}^2 &= (\Gamma_{av} - 1) \left[H_{0av} - \frac{1}{2} (V_{nav}^2 + w_{av}^2) \right] \\ H_{0av} &= \frac{(\rho_+^{\frac{1}{2}} H_{0+} + \rho_-^{\frac{1}{2}} H_{0-})}{\rho_+^{\frac{1}{2}} + \rho_-^{\frac{1}{2}}} \\ \Gamma_{av} &= \frac{(\rho_+^{\frac{1}{2}} \Gamma_+ + \rho_-^{\frac{1}{2}} \Gamma_-)}{\rho_+^{\frac{1}{2}} + \rho_-^{\frac{1}{2}}} \end{aligned} \quad (39)$$

The + and - subscripts represent properties in the free stream and at the cell adjacent to the shock, respectively. V_n is the velocity component normal to the cell edge; w is the velocity component in the streamwise direction; a is the speed of sound; H_0 is the total enthalpy; and Γ is the effective gamma.

CHAPTER 4

ZEUS INPUT FILE (TAPE 5)

The ZEUS input file, as described in Reference 2, allows the user to:

1. Control the manner in which ZEUS integrates the Euler equations;
2. Select boundary condition options;
3. Specify the amount of output generated;
4. Choose the separation model;
5. Select the type of initial data to be used;
6. Specify mesh size and clustering.

The set up commands and options for the current version of ZEUS include the items outlined above from Reference 2. However, two more options are included which are inserted between items 4 and 5 above in the input file. They are:

- Selection of the gas type;
- Specification of the dimensional units.

Moreover, two input parameters are added to item 1 and one parameter to item 3 above. The complete input file is listed in Appendix A. The following sections give a description of the input variables, in order of their occurrence in file **zeuse.da**.

4.1 INTEGRATION CONTROL

ZETAEND — Terminate the calculation when $ZETA \geq ZETAEND$. The last step size is adjusted to place the final integration plane at ZETAEND.

KEND — Terminate the calculation after executing KEND steps. If the initial step number is STEPI, the termination step number is STEPI+KEND.

FCFL — Step size safety factor. The step size is determined by multiplying the allowed step size, based on the CFL condition, by FCFL. For values of FCFL > 1, the calculation should be unstable. A value of .9 is typically used. Program abort can sometimes be rectified by using a smaller value. Also, oscillations in surface properties may be reduced by decreasing FCFL.

XKI — Limiting constant for cells not adjacent to a surface. The recommend value for this quantity is 1, however, XKI may be assigned any value between 2 and 0. Increasing XKI promotes increased accuracy and sharper shock capturing but may lead to oscillations in the solution. If $XKI = 0$, the scheme reduces to the first order Godunov method.

IAPR — The Davis approximate Riemann problem is applied if $IAPR = 0$, while the complete Riemann problem is solved if $IAPR = 1$. On most computing systems $IAPR = 0$ is faster, more robust and gives nearly the same results as $IAPR = 1$. However, $IAPR = 0$ is more dissipative, and differences between these solvers can be noted in solutions featuring strong crossflow shocks. For equilibrium air ($IGAS = 1$), $IAPR$ must be set to 0.

ISHFLUX — The flux at the cell edge next to the bow shock is determined using the full Riemann problem if $ISHFLUX = 0$ or the free stream conditions if $ISHFLUX = 1$. For most cases, a value of 0 can be used; however, use 1 if wiggles occur at the shock.

ISHANG — The bow shock angle is determined using information from the full Riemann problem if $ISHANG = 0$ or determined from Roe averaged variables as described in Section 3.6 if $ISHANG = 1$. In general, a value of 0 can be used; however, for equilibrium air a value of 1 is recommended.

4.2 BOUNDARY CONDITIONS

NXKE — Number of edges at which the default limiter setting will not be applied. Cells adjacent to a surface use different limiter values than the interior point setting of XKI. Increasing the limiter values improve the solution accuracy in smooth flow regions, but can lead to surface pressure oscillations near shocks and fin edges. Different limiter values can be selected for each edge of each zone. If $NXKE = 0$, default limiter values will be applied at all edges. These are 2 on edges 1 and 3 and 0 on edges 2 and 4. The presumption here is that a smooth flow, such as that generated by a tangent ogive body, will occur near edges 1 or 3. However, shocks or expansions may occur near edges 2 and 4 as a consequence of surface slope discontinuities and fin edges. If these default values do not fit the case under consideration, set $NXKE$ to the number of edges at which default values are to be changed. List the zone number, edge number, and limiter value for each edge which is to be changed at the indicated position in the input file.

NSUR — Number of edges which do not feature the default surface type. The user has the latitude of specifying the type of surface which occurs on each zone edge. The possibilities are:

- 0 — interior; do not apply boundary conditions;
- 1 — solid surface; apply tangent flow boundary conditions;
- 2 — free stream boundary; cell value fixed at free stream conditions;
- 3 — fitted shock or expansion.

If $NSUR = 0$, edge 1 will be type 1 and edge 3 will be type 1 unless a shock is being fitted (i.e., $ISHOCK = 1$). In this case edge 3 will automatically be set to 3. If edge 3 is defined outside the bow shock in the free stream, set to 2. Edges 2 and 4 will be set to 0, however, a surface will be assumed to occur for $\omega < s < \Omega$. To change these options, set $NSUR$ to the number of

edges to be altered and for each edge list zone number, edge number and option number. Insert this list at the indicated position in the input file.

DFAC — At locations where local Mach number is too small to allow the flow to be turned parallel to the wall, the turn angle is diminished. This is accomplished by computing the maximum turn angle associated with this Mach number. The turn angle to be used in the calculation is calculated by multiplying this maximum angle by DFAC. DFAC should be set between 0 and 1 and is typically taken to be .9.

4.3 OUTPUT CONTROL

Tape 6 (output file) The first and last crossflow planes are always written to tape 6.

IPRINT — Print the crossflow plane if the step number is evenly divisible by IPRINT. If IPRINT = 100, the crossflow plane will be printed at step 100, 200, etc. The crossflow plane at the first and last step of the calculation will also be printed.

NSKIP — The crossflow plane output only contains those N planes which are evenly divisible by NSKIP. Set NSKIP to 1 if all n planes are to be printed.

MSKIP — The crossflow plane output only contains those M planes which are evenly divisible by MSKIP. Set MSKIP to 1 if all m planes are to be printed.

ISKIP — Print the step size if the step number is evenly divisible by ISKIP. Set ISKIP to 1 if the step size is to be printed after every step.

PLOTZA (Force and Surface Pressure Summary)

JSPPR — Following the completion of the final computational step, PLOTZA, which contains a list of forces and pressures at zone edges for each step, is read, and surface pressures along each edge may be printed. The default option is to list pressures only along edge 1 of each zone. JSPPR is the number of edges at which this output convention is to be changed. For each altered edge, list the zone number, edge number and the print option; 1 print, 0 don't print this edge. Insert this list at the indicated position in the input file.

JSPDIS — Print the location of each grid point on the edges specified by JSPPR in addition to the surface pressures if JSPDIS is 1 (does not appear on PLOTZA). Do not print if JSPDIS is 0.

KSKIP — Write the surface pressures, forces and moments to PLOTZA at steps with numbers which are evenly divisible by KSKIP.

NPRT — On edges 2 and 4, only list the surface pressures for n planes less than NPRT.

DELZA — Write surface pressures, forces and moments to PLOTZA at step zeta intervals of DELZA.

PLOTZC (Plot tape) Crossflow plane at first and last step is always written to PLOTZC

IPLOT — Write the crossflow plane to PLOTZC at step numbers which are evenly divisible by IPLOT.

DELZC — Write the crossflow plane to DELZC at zeta intervals of DELZC.

IPLOTN — Number of target zeta stations at which crossflow plane will be written to PLOTZC. If IPLOTN > 0, a list of these stations, in ascending order should be included as indicated in the input file.

4.4 AERODYNAMIC DATA

AREF — Reference area to be used in the force and moment calculations.

XLREF — Reference length to be used in the force and moment calculations.

IEFORCE — Controls the output of forces on individual edges. Application of this option allows forces on individual fins to be determined. Set IEFORCE = 1 to invoke this option. Otherwise let IEFORCE = 0.

4.5 SEPARATION MODELING

IVIS — Type of separation model:

- 0 — no separation modeling;
- 1 — clipping;
- 2 — forced separation.

If options 0 or 1 are selected, the remainder of the information in this section is unnecessary. Note that option 2 can only be used with cylindrical coordinates. If option 2 is used, the information listed below is needed:

- 1 **NSEP** — The number of separation lines. Use of more than one separation line is necessary if separation on a body without pitch plane symmetry is to be modeled. Additional separation lines can also be used to model secondary separation.
2. For each separation line specify:
 - **ISSIDE** — the side of the body on which separation occurs; $0 - 0^\circ \leq \phi_s \leq 180^\circ$, $1 - 180^\circ \leq \phi_s \leq 360^\circ$, where ϕ_s is the location of the separation line;
 - **ISEP** — number of points used to define the separation line;
 - **ZSSEP** — Zeta value at which separation is started;
 - **ZESEP** — Zeta value at which separation is terminated;
 - **PHICD, PHIAD, BETACD, BETAAD** — Flow direction in degrees. Typical values are 20° , 20° , 20° , 5° , respectively.
 - A list of ISEP pairs of separation line coordinates (**ZEPZ, ZEPP**), where ZEPZ and ZEPP are the z and ϕ coordinates for each point.

4.6 GAS TYPE

IGAS — Type of gas

- 0 — Air is treated as a perfect gas;
- 1 — Air is treated in chemical equilibrium. Thermodynamic properties are determined using the subroutines for equilibrium air. IAPR must equal 0. Use of CONES is not recommended, and the flowfield must be initialized from uniform conditions (IMOD = 0) or using the blunt body program, BLUNT2.

4.7 UNITS

IUNITS — Dimensional units of problem. All input units must be consistent. Output units are the same.

- 0 — English units are used for input and output.
($p = \text{lb} / \text{ft}^2$; $\rho = \text{slug} / \text{ft}^3$; $T = ^\circ\text{R}$; $x, y, z = \text{ft}$);
- 1 — Metric units are used for input and output.
($p = \text{N} / \text{m}^2$; $\rho = \text{kg} / \text{m}^3$; $T = ^\circ\text{K}$; $x, y, z = \text{m}$).

4.8 INITIAL PLANE DATA

IMOD

- 0 — Use a uniform initial flow field to start the calculation.
- 1 — Read the initial flow field from file START. This flow field can be generated by:
 - The RESTART file from another ZEUS run;
 - Program CONVERT which rezones RESTART files;
 - Program CONES which generates an approximate conical flow field;
 - Program NOSETIP or BLUNT2 which generates the starting data plane from a blunt body solution for flow over a sphere.

If IMOD = 1, the remainder of the data in this section is unnecessary. Instructions for applying CONVERT, CONES and NOSETIP are given in Reference 2. For IMOD = 0, the initial flow field and mesh size are defined using the following information:

- IZN — Number of zones;
- NA — Number of cells in the ξ direction;

MA — Number of cells in the η direction summed over all zones. This information is followed by a list of the number of cells in the η direction in each zone;

ZETA — z coordinate of initial data plane;

ALPHA — Angle of attack in degrees (see Figure 1);

BETA — Yaw angle in degrees (see Figure 1);

XMINF — Free stream Mach number;

PINF — Free stream pressure. The magnitude of the free stream pressure scales out of solution. For example, if the free stream pressure is doubled, all solution pressures are doubled. Setting $PINF = 1$ insures that solution pressures are scaled by $PINF$. However, for $IGAS = 1$, $PINF$ must be dimensional;

DINF — Free stream density. The magnitude of the free stream density also scales out of the solution. However, for $IGAS = 1$, $DINF$ must be dimensional;

ICORD — 0,1,2 for cartesian, cylindrical or elliptical coordinates.

IASYM — 0 – flow is not symmetric about pitch plane; 1 – flow is symmetric about pitch plane symmetry;

ISHOCK — Set to 1 if edge 3 is to be fitted as a shock or expansion; otherwise set to zero.

4.9 MESH CLUSTERING

IMESHF — 0 if the mesh is to be uniform in the ξ direction, 1 for a clustered mesh. If clustering in this direction is used, a list of the f clustering function values at cell centers must be inserted into the input file as indicated. Start the list at the cell center adjacent to edge 1.

IMESHG — 0 if the mesh is to be uniform in the η direction, 1 for a clustered mesh. If clustering in this direction is used, a different clustering function may be used in each zone. Hence it is necessary to specify g values at cell centers in each zone. Insert cell center g values into the input file as indicated, starting at zone 1 and ending at the final zone. Start the list at the cell center adjacent to edge 4.

CHAPTER 5

PRE-PROCESSING PROGRAMS

This section describes the programs used to generate the START file for a ZEUS. Programs CONES, NOSETIP, GEOTEST, and CONVERT are described in Reference 2 and will not be further discussed here.

5.1 BLUNT2

The BLUNT2 program generates the START tape for flow over a sphere for air as both a perfect gas and in chemical equilibrium. The program in turn creates the ZEUS START file. BLUNT2 can be applied for Mach numbers greater than 1.5; however, the freestream Mach number must be large enough to insure that the axial component of the flow is supersonic at the sphere-afterbody junction so that the ZEUS code is marchable.

The BLUNT2 INPUT file is prepared by editing the following file:

The following file describes the required input for BLUNT2. To execute BLUNT2, replace the () symbols in the value column with the desired variable value. Add information supporting specific options between the lines containing the >>>> and <<<< symbols. Do not eliminate any lines from this file.

VALUE	VARIABLE	DESCRIPTION

*****TITLE*****		
Read in the title of computation using A-format with a maximum of 72 characters.		
	>>>>	start title
	<<<<	end title

*****FREESTREAM CONDITIONS*****		
()	AMINF	Mach number
()	PINF	Pressure used if IATMP=0; otherwise, set PINF=1. For English units (IUNITS=0) use lbf/ft**2, and for metric units (IUNITS=1) use N/m**2.
()	TINF	Temperature used if IATMP=0; otherwise set TINF=1. For English units (IUNITS=0) use Rankine, and for metric units (IUNITS=1) use Kelvin.
()	IATMP	0-use input values of PINF and TINF; 59-use 1959 ARDC Tables; or 62-use 1962 U.S. Standard Tables to compute PINF and TINF.

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- () ALT Altitude used if IATMP=59 or 62 to compute PINF and TINF; otherwise, if IATMP=0, set ALT=0. For English units (IUNITS=0) use feet, and for metric units (IUNITS=1) use meters.

*****GAS AND UNITS OPTIONS*****

- () IRG 0, 1 - air is a perfect gas or in chemical equilibrium.
- () IUNITS 0, 1 - dimensions are in English or metric units.

*****SPHERE DATA*****

- () RN Nose radius of the sphere in ft for IUNITS=0 or m for IUNITS=1.
- () YMAX Maximum angle (in degrees) over the sphere for which the flow field will be computed. The 0 deg line corresponds to the stagnation streamline. (Typically 120.)
- () NMAX Number of mesh points between the body and the shock. (Typically 18).
- () MMAX Number of mesh points in the streamwise direction. (Typically 18)
- () IMAX Number of time steps. Generally at least 500 steps is needed to converge the solution.

*****ZEUS DATA*****

- () ZSTART Axial distance from the nosetip to the starting plane in ft for IUNITS=0 or m for IUNITS=1.
- () Z0 Axial distance from the nosetip to the center of the sphere in ft for IUNITS=0 or m for IUNITS=1
- () IASYM 0, 1 - non symmetric or symmetric flowfield computation. If BETA not equal to 0, then set IASYM=0.
- () NA Number of mesh points between the body and shock for the ZEUS starting crossflow plane.
- () MA Number of mesh points in the circumferential direction for the ZEUS starting crossflow plane.
- () ALPHA Angle of attack (in degrees).
- () BETA Angle of yaw (in degrees).

CHAPTER 6

SAMPLE CASES

This section discusses the computation of sample cases using ZEUS for equilibrium chemically reacting air.

6.1 HYPERSONIC SHARP CONE

This case compares perfect gas and equilibrium air computations for a sharp cone at 0° incidence and an altitude of 100,000 ft. Solutions were computed for three different hypersonic similarity parameters, $K_c = M_\infty \sin \theta_c = 5.18, 8.45, 14.79$. Calculations were performed using the geometry described in cylindrical coordinates on a one zone 18×18 mesh. The solution was initiated using uniform flow conditions at $ZETA = .1$ and terminated at $ZETA = 50$. In addition, results are provided, as well as output found in Appendix B, for the sharp cone at the same altitude for $M_\infty = 20$ and 20° incidence on a 18×36 single zone mesh.

6.1.1 Geometry

A description of the edges of the zone are as follows:

EDGE 1: $b = \zeta \tan \theta_c$, $b_z = \tan \theta_c$, $b_\phi = 0$.

EDGE 2: $\psi = \pi$, $\psi_z = \psi_r = 0$.

EDGE 3: not needed (shock fitted)

EDGE 4: $\sigma = 0$, $\sigma_z = \sigma_r = 0$.

The required geometry routines are as follows:

```

SUBROUTINE BCONST(ZETA,BOFZ,BZOFZ)
C.....THIS SUBROUTINE CALCULATES THE MAJOR AXIS OF AN ELLIPSE
C      (BOFZ) AND ITS Z DERIVATIVE (BZOFZ)
      RETURN

```

```

END
SUBROUTINE EDGE1 (IN,ZETA,YY,BT,BZT,BYT)
C.....THIS SUBROUTINE DEFINES EDGE1
C.....USER DEFINES BT,BZT AND BYT AS A FUNCTION OF ZETA (ZETA)
C      Y OR PHI (YY) AND ZONE NUMBER (IN).
C      INPUT: IN    - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: BT   - X OR R LOCATION OF EDGE 1
C              BZT  - Z DERIVATIVE OF BT.
C              BYT  - DERIVATIVE OF BT.
C.....CHOOSE CONE ANGLE, THETAC=15,20,25,ETC.
      THETAC=25.
      PI=4.*ATAN(1.)
      RAD=PI/180.
      THETAR=THETAC*RAD
      BT=ZETA*TAN(THETAR)
      BZT=TAN(THETAR)
      BYT=0.
      RETURN
END
SUBROUTINE EDGE2 (IN,ZETA,XX,THT,THZT,THXT)
C.....THIS SUBROUTINE DEFINES EDGE2
C.....USER DEFINES THT,THZT AND THXT AS A FUNCTION OF ZETA (ZETA)
C      X OR R (XX) AND ZONE NUMBER (IN).
C      INPUT: IN    - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: THT  - Y OR PHI LOCATION OF FACE 2
C              THZT - Z DERIVATIVE OF THT
C              THXT - X DERIVATIVE OF THT.
C
      THT=4.*ATAN(1.)
      THZT=0.
      THXT=0.
      RETURN
END
SUBROUTINE EDGE3 (IN,ZETA,PHI,CT,CZT,CYT)
C.....USER DEFINES CT,CZT,CYT IF BOW SHOCK IS NOT BEING TRACKED.
C      Y OR PHI (YY) AND ZONE NUMBER (IN).
C      INPUT: IN    - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: CT   - X OR R LOCATION OF EDGE 3
C              CZT  - Z DERIVATIVE OF CT.
C              CYT  - Y DERIVATIVE OF CT.
C
      RETURN
END
SUBROUTINE EDGE4 (IN,ZETA,XX,SGT,SGZT,SGXT)
C.....THIS SUBROUTINE DEFINES EDGE4
C.....THE USER MUST PROVIDE A DEFINITION OF SGT,SGZT,SGXT, AS A FUNCTION
C      OF ZETA (ZETA), X OR R (YY) AND ZONE NUMBER (IN).
C      INPUT: IN    - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: SGT  - Y OR PHI LOCATION OF EDGE 4

```

```

C          SGZT - Z DERIVATIVE OF SGT.
C          SGXT - X DERIVATIVE OF SGT.
C
      SGT=0.
      SGZT=0.
      SGXT=0.
      RETURN
      END
      SUBROUTINE PEDGE(IN,II,ZETA,POUTL,PINL)
C      THIS SUBROUTINE CALCULATES THE FIN EDGE LOCATION
C      REQUIRED INPUT
C          IN - ZONE NUMBER
C          II - 1 FOR EDGE 4, 2 FOR EDGE 2
C          ZETA - ZETA
C
      POUTL=0.
      PINL=0.
C.....USER PROVIDES DEFINITION OF POUTL AND PINL
      RETURN
      END

```

6.1.2 ZEUS Input File — I

The following ZEUS input file is used for the sharp cone with a 25° half-angle at Mach 35 and 0° incidence (note that the flowfield is initiated with uniform conditions and the START file is not needed):

The following file describes the required input for ZEUS. To execute ZEUS, replace the () symbols in the value column with the desired variable value. Add information supporting specific options between the lines containing the >>>> and <<<< symbols. Variables enclosed by {} should be placed by themselves on a line. Do not eliminate any lines from this file.

VALUE	VARIABLE	DESCRIPTION

*****INTEGRATION CONTROL*****		
50.	ZETAEND	Terminate calculation if ZETA > ZETAEND.
5000.	KEND	Terminate calculation if STEP NUMBER > KEND.
.9	FCFL	Step size safety factor (1. > FCFL > 0.) Typically use .9 .
1.	XKI	Interior point limiting constant (2. > XKI > 0.) Typically use 1.
0	IAPR	0,1 for approximate or complete Riemann Problem. Typically use 0. Must use 0 for equilibrium air.
0	ISHFLUX	0,1 for using complete Riemann Problem or freestream properties to compute the flux at the cell edge next to the bow shock. Typically use 0.
1	ISHANG	0,1 for using complete Riemann Problem or Roe averaged variables to compute shock angle. Typically use 0. For equilibrium air, a value of 1 is preferred.

*****BOUNDARY CONDITIONS*****		

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0 NXKE Number of edges at which default limiter setting won't be used. Default settings are 2 on edges 1 or 3 and 0 on edges 2 or 4. For each edge at which the default limiter is non-standard, add a line containing the following information:
zone number (KEZ), edge number (KEE) and limiter value (XKE)
>>>>start list of [KEZ,KEE,XKE]
<<<<end list

0 NSUR Number of edges not featuring default surface types. Default values are 1 on edges 1 and 3 and 0 on edge 2 and 4. Program will automatically account a fitted shock on edge 3 or fin surfaces on edges 2 or 4. For each edge at which the surface type is not of default, add a line that specifies the zone number(KSURZ), edge number(KSURE) and surface type (KSUR).
>>>>start list of [KSURZ,KSURE,KSUR]
<<<<end list

.9 DFAC In case of a local wall Mach number which is too small to allow the flow to be turned parallel to the wall, the turn angle is multiplied by the constant DFAC (1. > DFAC > 0.).

*****OUTPUT CONTROL*****

---Printer---

250 IPRINT Print crossflow plane if step number is evenly divided by IPRINT
3 NSKIP Print n planes which are evenly divisible by NSKIP
6 MSKIP Print m planes which are evenly divisible by MSKIP
10 ISKIP Print step size if step number is evenly divided by ISKIP

---PLOTZA/Force-Pressure Summary---

0 JSPPR In default mode, only edge 1 of each zone will be written to PLOTZA. JSPPR is the number of additional edges which are not to be written in the default manner. For each edge added or deleted from this print list, include a line which specifies zone number (JSPZ), edge number (JSPE) and print code (JSP). JSP = 1 will write this zone edge to PLOTZA, 0 will not.
>>>>start list of [JSPZ,JSPE,JSP]
<<<<end list

0 JSPDIS 1 - print grid point locations for the edges specified by JSPPR.
0 - do not print.

50 KSKIP Write surface properties on selected edges to PLOTZA if if STEP NUMBER is evenly divisible by KSKIP

100 NPRT On summary sheet, print surface pressures of edges 2 or 4 if n < NPRT.

10000. DELZA Write to PLOTZA if (ZETA - ZETA at last write) > DELZA

---PLOTZC (Plot file)

10000 IPLOT Write to PLOTZC if STEP NUMBER is evenly divisible by IPLOT.
10000. DELZC Write to PLOTZC if (ZETA - ZETA at last write) > DELZC

0 IPLOTN Number of target Z stations (ZTARGET) at which PLOTZC will be written. If IPLOTN > 0, Include a list of these stations on the next line (maximum of 20). Stations must be listed in ascending order.
>>>>start ZTARGET list
<<<<end list

*****AERODYNAMIC DATA*****

1. AREF Reference area used in calculating force and moment coefficients.
1. XLREF Reference length used in calculating moment coefficients and center-of-pressure.

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```

0      IEFORCE 0, 1 don't, do print force and moments for individual edges.
-----
      *****SEPARATION MODELING*****
0      IVIS      0,1,2 for no modeling, clipping, and forced separation. Clipping
      and forced separation can only be used in conjunction with
      cylindrical coordinates. If IVIS = 2, specify the number of
      separation lines (NSEP).
      >>>> NSEP
      <<<<<
      For each separation line specify:
      ISSIDE - 0 separation line located between 0 and 180 degrees,
      1 separation line located between 180 and 360 degrees.
      ISEP - number of points used to define the separation line.
      ZSSEP - Zeta value at which separation is started
      ZESEP - Zeta value at which separation is terminated
      PHICD - separation angle phiC (degrees)
      PHIAD - separation angle phiA (degrees)
      BETACD - separation angle BetaC (degrees)
      BETAAD - separation angle BetaA (degrees)
      >>>> [ISSIDE, ISEP, ZSSEP, ZESEP, PHICD, PHIAD, BETACD, BETAAD]
      <<<<<
      A list of ISEP pairs of points (ZEPZ, ZEPP) describing the zeta
      and phi coordinates of the separation line. This list should
      start at the most forward section and move aft. Start the list
      for each separation line on a separate line and list in same
      order as used in the above data.
      >>>> start list of ZEPZ, ZEPP
      <<<<<
-----
      *****GAS TYPE*****
1      IGAS      0-perfect gas; 1-equilibrium air
-----
      *****UNITS *****
1      IUNITS    0-english (p=lbf/ft**2, rho=slug/ft**3, t=rankine, xyz=ft);
      1-metric (p=n/m**2, rho=kg/m**3, t=kelvin, xyz=m).
      All input units must be consistent. Output units are the same.
-----
      *****INITIAL DATA*****
0      IMOD      0,1 for new start or restart respectively. For a restart, the
      initial flow field is read from TAPE3. Additional information
      is not needed and the remaining entries in this section should
      be disregarded. A new start assumes a uniform flow field which
      is described in the following section.

      ---Mesh Size---
1      IZN      Number of zones.
18     NA      Number of cells in xi direction (i.e., between edges 1 and 3)
18     MA      Number of cells in eta direction (i.e., between edge 4 of zone 1
      and edge 2 of zone IZN)

      List the number of M planes in each zone, starting from zone 1
      and ending at zone MA.
      >>>>Start list of MA for each zone
18
      <<<<<end list

      ---Flow Properties---
.01    ZETA      Zeta coordinate of initial data plane

```

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0. ALPHA Angle of attack (degrees)
 0. BETA Angle of yaw (degrees)
 35. XMINF Mach number
 1185.5 PINF Pressure
 .017861 DINF Density

---Problem Definition---

PROBLEM DEFINITION

1 ICORD 0,1,2 for cartesian, cylindrical or elliptic coordinates
 1 IASYM 0 - no pitch plane symmetry; 1 - pitch plane symmetry.
 1 ISHOCK Set to 1 if edge 3 is to be fitted by the calculation
 (either as a shock or sonic line); otherwise set to 0.
 ISHOCK = 1 is only valid for ICORD =1 or 2. If edge 3
 is to be fitted, the r and phi (cylindrical coordinates)
 or s, tau (elliptic coordinates) of the shock location on each
 M plane, (SS, SSZ) must be defined, starting from M = 1.
 etc.,

>>>>Start list of {SS,SSZ}

.20 5.
 .20 15.
 .20 25.
 .20 35.
 .20 45.
 .20 55.
 .20 65.
 .20 75.
 .20 85.
 .20 95.
 .20 105.
 .20 115.
 .20 125.
 .20 135.
 .20 145.
 .20 155.
 .20 165.
 .20 175.

>>>>End list

*****MESH DEFINITION*****

0 IMESHF 0 for uniform mesh in xi direction. 1 for clustered mesh. If
 a clustered mesh is to be used, the clustering function (FN) in
 the xi direction at the NA cell centers must be defined
 starting at cell 1, located adjacent to edge 1 and moving to
 edge 3 (usually body to shock).

>>>>start list of FN

>>>>end list

0 IMESHG 0 for uniform mesh in eta direction. 1 for clustered mesh. If
 a clustered mesh is to be used, the clustering function (GN) in
 the eta direction at the MA(i) cell centers in each zone must
 be defined, starting with zone 1 and ending with zone IZN. Start
 with cell 1, located adjacent to edge 4, and end at the cell
 adjacent to edge 2. The list for each zone should be started
 on a new card

>>>>>>start list GN

end list<<<<<<

6.1.3 ZEUS Input File — II

The following ZEUS input file is used for the sharp cone with a 25° half-angle at Mach 20 and 20° incidence (note that the flowfield is initiated with uniform conditions and the START file is not needed):

The following file describes the required input for ZEUS. To execute ZEUS, replace the () symbols in the value column with the desired variable value. Add information supporting specific options between the lines containing the >>>> and <<<< symbols. Variables enclosed by [] should be placed by themselves on a line. Do not eliminate any lines from this file.

VALUE	VARIABLE	DESCRIPTION

*****INTEGRATION CONTROL*****		
50.	ZETAEND	Terminate calculation if ZETA > ZETAEND.
5000.	KEND	Terminate calculation if STEP NUMBER > KEND.
.9	FCFL	Step size safety factor (1. > FCFL > 0.) Typically use .9 .
1.	XKI	Interior point limiting constant (2. > XKI > 0.) Typically use 1.
0	IAPR	0,1 for approximate or complete Riemann Problem. Typically use 0. Must use 0 for equilibrium air.
0	ISHFLUX	0,1 for using complete Riemann Problem or freestream properties to compute the flux at the cell edge next to the bow shock. Typically use 0.
1	ISHANG	0,1 for using complete Riemann Problem or Roe averaged variables to compute shock angle. Typically use 0. For equilibrium air, a value of 1 is preferred.

*****BOUNDARY CONDITIONS*****		
1	NXKE	Number of edges at which default limiter setting won't be used. Default settings are 2 on edges 1 or 3 and 0 on edges 2 or 4. For each edge at which the default limiter is non-standard, add a line containing the following information: zone number (KEZ), edge number (KEE) and limiter value (XKE) >>>>start list of [KEZ,KEE,XKE]
1	3	0
		<<<<end list
0	NSUR	Number of edges not featuring default surface types. Default values are 1 on edges 1 and 3 and 0 on edge 2 and 4. Program will automatically account a fitted shock on edge 3 or fin surfaces on edges 2 or 4. For each edge at which the surface type is not of default, add a line that specifies the zone number(KSURZ), edge number(KSURE) and surface type (KSUR). >>>>start list of [KSURZ,KSURE,KSUR] <<<<end list
.9	DFAC	In case of a local wall Mach number which is too small to allow the flow to be turned parallel to the wall, the turn angle is multiplied by the constant DFAC (1. > DFAC > 0.).

*****OUTPUT CONTROL*****		
---Printer---		
250	IPRINT	Print crossflow plane if step number is evenly divided by IPRINT
3	NSKIP	Print n planes which are evenly divisible by NSKIP

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```

6      MSKIP  Print m planes which are evenly divisible by MSKIP
10     ISKIP  Print step size if step number is evenly divided by ISKIP
.
      ---PLOTZA/Force-Pressure Summary---
0      JSPPR  In default mode, only edge 1 of each zone will be written to
      PLOTZA. JSPPR is the number of additional edges which are not
      to be written in the default manner. For each edge added or
      deleted from this print list, include a line which specifies
      zone number (JSPZ), edge number (JSPE) and print code (JSP).
      JSP = 1 will write this zone edge to PLOTZA, 0 will not.
      >>>>start list of [JSPZ,JSPE,JSP]
      <<<<end list
0      JSPDIS 1 - print grid point locations for the edges specified by JSPPR.
      0 - do not print.
50     KSKIP  Write surface properties on selected edges to PLOTZA if
      if STEP NUMBER is evenly divisible by KSKIP
100    NPRT   On summary sheet, print surface pressures of edges 2 or 4 if
      n < NPRT.
10000. DELZA  Write to PLOTZA if (ZETA - ZETA at last write) > DELZA
.
      ---PLOTZC (Plot file)
10000  IPLOT  Write to PLOTZC if STEP NUMBER is evenly divisible by IPLOT.
10000. DELZC  Write to PLOTZC if (ZETA - ZETA at last write) > DELZC
0      IPLOTN Number of target Z stations (ZTARGET) at which PLOTZC will
      be written. If IPLOTN > 0, Include a list of these
      stations on the next line (maximum of 20). Stations must be
      listed in ascending order.
      >>>>start ZTARGET list
      <<<<end list
-----
      *****AERODYNAMIC DATA*****
1.     AREF   Reference area used in calculating force and moment coefficients.
1.     XLREF   Reference length used in calculating moment coefficients and
      center-of-pressure.
0      IEFORCE 0, 1 don't, do print force and moments for individual edges.
-----
      *****SEPARATION MODELING*****
0      IVIS   0,1,2 for no modeling, clipping, and forced separation. Clipping
      and forced separation can only be used in conjunction with
      cylindrical coordinates. If IVIS = 2, specify the number of
      separation lines (NSEP).
      >>>> NSEP
      <<<<
      For each separation line specify:
      ISSIDE - 0 separation line located between 0 and 180 degrees,
      1 separation line located between 180 and 360 degrees.
      ISEP - number of points used to define the separation line.
      ZSSEP - Zeta value at which separation is started
      ZESEP - Zeta value at which separation is terminated
      PHICD - separation angle phiC (degrees)
      PHIAD - separation angle phiA (degrees)
      BETACD - separation angle BetaC (degrees)
      BETAAD - separation angle BetaA (degrees)
      >>>> [ISSIDE, ISEP, ZSSEP, ZESEP, PHICD, PHIAD, BETACD, BETAAD]
      <<<<
      A list of ISEP pairs of points (ZEPZ,ZEPP) describing the zeta
      and phi coordinates of the separation line. This list should
      start at the most forward section and move aft. Start the list

```

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for each separation line on a separate line and list in same order as used in the above data.

>>>> start list of ZEPZ, ZEPP

<<<<

*****GAS TYPE*****

1 IGAS 0-perfect gas; 1-equilibrium air

*****UNITS *****

1 IUNITS 0-english (p=lbf/ft**2, rho=slug/ft**3, t=rankine, xyz=ft);
1-metric (p=n/m**2, rho=kg/m**3, t=kelvin, xyz=m).
All input units must be consistant. Output units are the same.

*****INITIAL DATA*****

0 IMOD 0,1 for new start or restart respectively. For a restart, the initial flow field is read from TAPE3. Additional information is not needed and the remaining entries in this section should be disregarded. A new start assumes a uniform flow field which is described in the following section.

---Mesh Size---

1 IZN Number of zones.
18 NA Number of cells in xi direction (i.e., between edges 1 and 3)
36 MA Number of cells in eta direction (i.e., between edge 4 of zone 1 and edge 2 of zone IZN)

List the number of M planes in each zone, starting from zone 1 and ending at zone MA.

>>>>Start list of MA for each zone

36

<<<<end list

---Flow Properties---

.1 ZETA Zeta coordinate of initial data plane
20. ALPHA Angle of attack (degrees)
0. BETA Angle of yaw (degrees)
20. XMINF Mach number
1185.5 PINF Pressure
.017861 DINF Density

---Problem Definition---

PROBLEM DEFINITION

1 ICORD 0,1,2 for cartesian, cylindrical or elliptic coordinates
1 IASYM 0 - no pitch plane symmetry; 1 - pitch plane symmetry.
1 ISHOCK Set to 1 if edge 3 is to be fitted by the calculation (either as a shock or sonic line); otherwise set to 0. ISHOCK = 1 is only valid for ICORD =1 or 2. If edge 3 is to be fitted, the r and phi (cylindrical coordinates) or s, tau (elliptic coordinates) of the shock location on each M plane, (SS, SSZ) must be defined, starting from M = 1, etc.,

>>>>Start list of (SS,SSZ)

.30 2.5
.30 7.5
.30 12.5
.30 17.5
.30 22.5
.30 27.5

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```
.30 32.5
.30 37.5
.30 42.5
.30 47.5
.30 52.5
.30 57.5
.30 62.5
.30 67.5
.30 72.5
.30 77.5
.30 82.5
.30 87.5
.30 92.5
.30 97.5
.30 102.5
.30 107.5
.30 112.5
.30 117.5
.30 122.5
.30 127.5
.30 132.5
.30 137.5
.30 142.5
.30 147.5
.30 152.5
.30 157.5
.30 162.5
.30 167.5
.30 172.5
.30 177.5
```

>>>>>End list

*****MESH DEFINITION*****

```
0      IMESHF  0 for uniform mesh in xi direction.  1 for clustered mesh.  If
              a clustered mesh is to be used, the clustering function (FN) in
              the xi direction at the NA cell centers must be defined
              starting at cell 1, located adjacent to edge 1 and moving to
              edge 3 (usually body to shock).
              >>>>>start list of FN
              >>>>>end list

0      IMESHG  0 for uniform mesh in eta direction.  1 for clustered mesh.  If
              a clustered mesh is to be used, the clustering function (GN) in
              the eta direction at the MA(1) cell centers in each zone must
              be defined, starting with zone 1 and ending with zone IZN. Start
              with cell 1, located adjacent to edge 4, and end at the cell
              adjacent to edge 2.  The list for each zone should be started
              on a new card
              >>>>>>>start list GN
              end list<<<<<<<
```

6.1.4 Results

Conical flow solutions have been computed for a right circular sharp cone with $\theta_c = 25^\circ$ and for Mach 20 at 0° incidence. Results are compared with tabulated cone properties by Hudgins¹⁵ at an altitude of 100,000 ft. Figure 4 displays surface property comparisons between equilibrium air and calorically perfect results as a function of the hypersonic similarity parameter, K_c . Computed results are in good agreement with tabulated results for values of $K_c = 5.18, 8.45$, and 14.79 . The characteristics of equilibrium chemically reacting air are well predicted which show that for chemically reacting air (1) the pressure is strongly dependent on the mechanical aspects of the flow and not the chemical reactions, (2) the density ratio is higher implying a smaller shock layer thickness, and (3) the equilibrium temperatures are lower than calorically perfect results, a result of the dissociated air. Figure 5 illustrates pressure contours for Mach 20 at 20° incidence. Equilibrium air results demonstrate a smaller shock layer thickness as compared to calorically perfect results.

6.2 HYPERSONIC BLUNT NOSE CYLINDER

This case consists of a spherically blunt nosed cylinder at Mach 20, incidences of 0° and 20° , and an altitude of 20,000 meters for equilibrium air. The output for 20° is provided in Appendix B. The calculation, which uses a cylindrical coordinate description of the geometry, is divided into two sections. The first is the spherically blunt nose calculation using the program BLUNT2 on a 18×25 mesh which generates a ZEUS starting solution at $ZETA = .5$. The second computes the cylinder body using a 36×36 single zone mesh and is terminated at $ZETA = 20$.

6.2.1 Geometry

A description of the edges of the zone are as follows:

EDGE 1: $b = .5, b_z = b_\phi = 0.$

EDGE 2: $\psi = \pi, \psi_z = \psi_r = 0.$

EDGE 3: not needed (shock fitted)

EDGE 4: $\sigma = 0., \sigma_z = \sigma_r = 0.$

The required geometry routines are as follows:

```

SUBROUTINE BCONST(ZETA,BOFZ,BZOFZ)
C.....THIS SUBROUTINE CALCULATES THE MAJOR AXIS OF AN ELLIPSE
C      (BOFZ) AND ITS Z DERIVATIVE (BZOFZ)
      RETURN

```

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```

END
SUBROUTINE EDGE1 (IN, ZETA, YY, BT, BZT, BYT)
C.....THIS SUBROUTINE DEFINES EDGE1
C.....USER DEFINES BT, BZT AND BYT AS A FUNCTION OF ZETA (ZETA)
C      Y OR PHI (YY) AND ZONE NUMBER (IN).
C      INPUT: IN      - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: BT      - X OR R LOCATION OF EDGE 1
C              BZT     - Z DERIVATIVE OF BT.
C              BYT     - Y DERIVATIVE OF BT.

BT=.5
BZT=0.
BYT=0.
RETURN
END
SUBROUTINE EDGE2 (IN, ZETA, XX, THT, THZT, THXT)
C.....THIS SUBROUTINE DEFINES EDGE2
C.....USER DEFINES THT, THZT AND THXT AS A FUNCTION OF ZETA (ZETA)
C      X OR R (XX) AND ZONE NUMBER (IN).
C      INPUT: IN      - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: THT     - Y OR PHI LOCATION OF EDGE 2
C              THZT    - Z DERIVATIVE OF THT.
C              THXT    - X DERIVATIVE OF THT.

THT=4.*ATAN(1.)
THZT=0.
THXT=0.
RETURN
END
SUBROUTINE EDGE3 (IN, ZETA, PHI, CT, CZT, CXT)
C.....USER DEFINES CT, CZT, CYT IF BOW SHOCK IS NOT BEING TRACKED.
C      Y OR PHI (YY) AND ZONE NUMBER (IN).
C      INPUT: IN      - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: CT      - X OR R LOCATION OF EDGE 3
C              CZT     - Z DERIVATIVE OF CT.
C              CYT     - Y DERIVATIVE OF CT.

RETURN
END
SUBROUTINE EDGE4 (IN, ZETA, XX, SGT, SGZT, SGXT)
C.....THIS SUBROUTINE DEFINES EDGE4
C.....THE USER MUST PROVIDE A DEFINITION OF SGT, SGZT, SGXT, AS A FUNCTION
C      OF ZETA (ZETA), X OR R (YY) AND ZONE NUMBER (IN).
C      INPUT: IN      - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: SGT     - Y OR PHI LOCATION OF EDGE 4
C              SGZT    - Z DERIVATIVE OF SGT.
C              SGXT    - X DERIVATIVE OF SGT.

SGT=0.
SGZT=0.

```

```

SGXT=0.
RETURN
END
SUBROUTINE PEDGE(IN,II,ZETA,POUTL,PINL)
C THIS SUBROUTINE CALCULATES THE FIN EDGE LOCATION
C REQUIRED INPUT
C     IN - ZONE NUMBER
C     II - 1 FOR EDGE 4, 2 FOR EDGE 2
C     ZETA - ZETA
C
POUTL=0.
PINL=0.
C.....USER PROVIDES DEFINITION OF POUTL AND PINL
RETURN
END

```

6.2.2 START File

The start file for 20° incidence is generated using the BLUNT2 program using the following input:

The following file describes the required input for BLUNT2. To execute BLUNT2, replace the () symbols in the value column with the desired variable value. Add information supporting specific options between the lines containing the >>>> and <<<< symbols. Do not eliminate any lines from this file.

VALUE	VARIABLE	DESCRIPTION

*****TITLE*****		
Read in the title of computation using A-format with a maximum of 72 characters.		
	>>>>start title	
	Hypersonic Blunt Nose Cylinder, M=20, Alpha=0, Alt=20,000 m	
	<<<<end title	

*****FREESTREAM CONDITIONS*****		
20.	AMINF	Mach number
1.	PINF	Pressure used if IATMP=0; otherwise, set PINF=1. For English units (IUNITS=0) use lbf/ft**2, and for metric units (IUNITS=1) use N/m**2.
1.	TINF	Temperature used if IATMP=0; otherwise set TINF=1. For English units (IUNITS=0) use Rankine, and for metric units (IUNITS=1) use Kelvin.
59	IATMP	0-use input values of PINF and TINF; 59-use 1959 ARDC Tables; or 62-use 1962 U.S. Standard Tables to compute PINF and TINF.
20000.	ALT	Altitude used if IATMP=59 or 62 to compute PINF and TINF; otherwise, if IATMP=0, set ALT=0. For English units (IUNITS=0) use feet, and for metric units (IUNITS=1) use meters.

*****GAS AND UNITS OPTIONS*****		
1	IRG	0, 1 - air is a perfect gas or in chemical equilibrium.
1	IUNITS	0, 1 - dimensions are in English or metric units.

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```

*****SPHERE DATA*****
.5      RN      Nose radius of the sphere in ft for IUNITS=0 or m for IUNITS=1.
120.    YMAX     Maximum angle (in degrees) over the sphere for which the flow
           field will be computed. The 0 deg line corresponds to the
           stagnation streamline. (Typically 120.)
18.     NMAX     Number of mesh points between the body and the shock.
           (Typically 18).
25.     MMAX     Number of mesh points in the streamwise direction. (Typically 18)
2000    IMAX     Number of time steps. Generally at least 500 steps is needed
           to converge the solution.

```

```

*****ZEUS DATA*****
.5      ZSTART   Axial distance from the nosetip to the starting plane in
           ft for IUNITS=0 or m for IUNITS=1.
.5      Z0       Axial distance from the nosetip to the center of the sphere in
           ft for IUNITS=0 or m for IUNITS=1.
1       IASYM    0, 1 - non symmetric or symmetric flowfield computation. If
           BETA not equal to 0, then set IASYM=0.
36      NA       Number of mesh points between the body and shock for the
           ZEUS starting crossflow plane.
36      MA       Number of mesh points in the circumferential direction for the
           ZEUS starting crossflow plane.
20.     ALPHA    Angle of attack (in degrees).
0.      BETA     Angle of yaw (in degrees).

```

6.2.3 ZEUS Input File

The following ZEUS input file is used for the afterbody:

The following file describes the required input for ZEUS. To execute ZEUS, replace the () symbols in the value column with the desired variable value. Add information supporting specific options between the lines containing the >>>> and <<<< symbols. Variables enclosed by {} should be placed by themselves on a line. Do not eliminate any lines from this file.

```

-----
VALUE  VARIABLE      DESCRIPTION
-----
*****INTEGRATION CONTROL*****
10.    ZETAEND Terminate calculation if ZETA > ZETAEND.
5000.  KEND      Terminate calculation if STEP NUMBER > KEND.
.9     FCFL      Step size safety factor (1. > FCFL > 0.) Typically use .9 .
1.     XKI       Interior point limiting constant (2. > XKI > 0.) Typically use 1.
0      IAPR      0,1 for approximate or complete Riemann Problem. Typically use 0.
           Must use 0 for equilibrium air.
1      ISHFLUX   0,1 for using complete Riemann Problem or freestream properties
           to compute the flux at the cell edge next to the bow shock.

```

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Typically use 0.

- 1 ISHANG 0,1 for using complete Riemann Problem or Roe averaged variables to compute shock angle. Typically use 0. For equilibrium air, a value of 1 is preferred.

*****BOUNDARY CONDITIONS*****

- 1 NXKE Number of edges at which default limiter setting won't be used. Default settings are 2 on edges 1 or 3 and 0 on edges 2 or 4. For each edge at which the default limiter is non-standard, add a line containing the following information:
zone number (KEZ), edge number (KEE) and limiter value (XKE)
>>>>start list of (KEZ,KEE,XKE)

1 1 1.

<<<<end list

- 0 NSUR Number of edges not featuring default surface types. Default values are 1 on edges 1 and 3 and 0 on edge 2 and 4. Program will automatically account a fitted shock on edge 3 or fin surfaces on edges 2 or 4. For each edge at which the surface type is not of default, add a line that specifies the zone number(KSURZ), edge number(KSURE) and surface type (KSUR).
>>>>start list of (KSURZ,KSURE,KSUR)

<<<<end list

- .9 DFAC In case of a local wall Mach number which is too small to allow the flow to be turned parallel to the wall, the turn angle is multiplied by the constant DFAC (1. > DFAC > 0.).

*****OUTPUT CONTROL*****

---Printer---

- 250 IPRINT Print crossflow plane if step number is evenly divided by IPRINT
6 NSKIP Print n planes which are evenly divisible by NSKIP
6 MSKIP Print m planes which are evenly divisible by MSKIP
10 ISKIP Print step size if step number is evenly divided by ISKIP

---PLOTZA/Force-Pressure Summary---

- 0 JSPPR In default mode, only edge 1 of each zone will be written to PLOTZA. JSPPR is the number of additional edges which are not to be written in the default manner. For each edge added or deleted from this print list, include a line which specifies zone number (JSPZ), edge number (JSPE) and print code (JSP).
JSP = 1 will write this zone edge to PLOTZA, 0 will not.

>>>>start list of (JSPZ,JSPE,JSP)

<<<<end list

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```

0      JSPDIS 1 - print grid point locations for the edges specified by JSPPR.
          0 - do not print.
40     KSKIP  Write surface properties on selected edges to PLOTZA if
          if STEP NUMBER is evenly divisible by KSKIP
100    NPRT   On summary sheet, print surface pressures of edges 2 or 4 if
          n < NPRT.
10000. DELZA Write to PLOTZA if (ZETA - ZETA at last write) > DELZA
.
          ---PLOTZC (Plot file)
10000 IPLOT  Write to PLOTZC if STEP NUMBER is evenly divisible by IPLOT.
10000. DELZC Write to PLOTZC if (ZETA - ZETA at last write) > DELZC
2      IPLOTN Number of target Z stations (ZTARGET) at which PLOTZC will
          be written. If IPLOTN > 0, Include a list of these
          stations on the next line (maximum of 20). Stations must be
          listed in ascending order.
          >>>>start ZTARGET list

```

.5 10.

<<<<end list

*****AERODYNAMIC DATA*****

```

1.     AREF   Reference area used in calculating force and moment coefficients.
1.     XLREF   Reference length used in calculating moment coefficients and
          center-of-pressure.
0      IEFORCE 0, 1 don't, do print force and moments for individual edges.

```

*****SEPARATION MODELING*****

```

0      IVIS   0,1,2 for no modeling, clipping, and forced separation. Clipping
          and forced separation can only be used in conjunction with
          cylindrical coordinates. If IVIS = 2, specify the number of
          separation lines (NSEP).
          >>>> NSEP
          <<<<
          For each separation line specify:
          ISSIDE - 0 separation line located between 0 and 180 degrees,
                  1 separation line located between 180 and 360 degrees.
          ISEP - number of points used to define the separation line.
          ZSSEP - Zeta value at which separation is started
          ZESEP - Zeta value at which separation is terminated
          PHICD - separation angle phiC (degrees)
          PHIAD - separation angle phiA (degrees)
          BETACD - separation angle BetaC (degrees)
          BETAAD - separation angle BetaA (degrees)
          >>>> [ISSIDE, ISEP, ZSSEP, ZESEP, PHICD, PHIAD, BETACD, BETAAD]

```

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<<<<<

A list of ISEP pairs of points (ZEP2,ZEPP) describing the zeta and phi coordinates of the separation line. This list should start at the most forward section and move aft. Start the list for each separation line on a separate line and list in same order as used in the above data.

>>>> start list of ZEP2,ZEPP

<<<<<

*****GAS TYPE*****

1 IGAS 0-perfect gas; 1-equilibrium air

*****UNITS *****

1 IUNITS 0-english (p=lbf/ft**2, rho=slug/ft**3, t=rankine, xyz=ft);
1-metric (p=n/m**2, rho=kg/m**3, t=kelvin, xyz=m).
All input units must be consistant. Output units are the same.

*****INITIAL DATA*****

1 IMOD 0,1 for new start or restart respectively. For a restart, the initial flow field is read from TAPE3. Additional information is not needed and the remaining entries in this section should be disregarded. A new start assumes a uniform flow field which is described in the following section.

---Mesh Size---

() IZN Number of zones.
() NA Number of cells in xi direction (i.e., between edges 1 and 3)
() MA Number of cells in eta direction (i.e., between edge 4 of zone 1 and edge 2 of zone IZN)

List the number of M planes in each zone, starting from zone 1 and ending at zone MA.

>>>>Start list of MA for each zone

<<<<<end list

---Flow Properties---

() ZETA Zeta coordinate of initial data plane
() ALPHA Angle of attack (degrees)
() BETA Angle of yaw (degrees)
() XMINF Mach number
() PINF Pressure
() DINF Density

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---Problem Definition---

PROBLEM DEFINITION

```
( )   ICORD   0,1,2 for cartesian, cylindrical or elliptic coordinates
( )   IASYM   0 - no pitch plane symmetry; 1 - pitch plane symmetry.
( )   ISHOCK  Set to 1 if edge 3 is to be fitted by the calculation
              (either as a shock or sonic line); otherwise set to 0.
              ISHOCK = 1 is only valid for ICORD =1 or 2. If edge 3
              is to be fitted, the r and phi (cylindrical coordinates)
              or s, tau (elliptic coordinates) of the shock location on each
              M plane, (SS, SSZ) must be defined, starting from M = 1,
              etc.,

              >>>>Start list of [SS,SSZ]
              >>>>End list
```

*****MESH DEFINITION*****

```
0     IMESHF  0 for uniform mesh in xi direction. 1 for clustered mesh. If
              a clustered mesh is to be used, the clustering function (FN) in
              the xi direction at the NA cell centers must be defined
              starting at cell 1, located adjacent to edge 1 and moving to
              edge 3 (usually body to shock).

              >>>>start list of FN
              >>>>end list

0     IMESHG  0 for uniform mesh in eta direction. 1 for clustered mesh. If
              a clustered mesh is to be used, the clustering function (GN) in
              the eta direction at the MA(i) cell centers in each zone must
              be defined, starting with zone 1 and ending with zone IZN. Start
              with cell 1, located adjacent to edge 4, and end at the cell
              adjacent to edge 2. The list for each zone should be started
              on a new card

              >>>>>>start list GN
              end list<<<<<<
```

6.2.4 Results

Computations were performed for a spherically blunt nosed cylinder at an altitude of 20 km for Mach 20 at 0° and 20° incidences. ZEUS computations are compared with computed results of Palmer¹⁶ for 0° incidence. Density and temperature contour plots in Figures 6 and 7 compare well for both calorically perfect and equilibrium air. ZEUS predicts the exhibited higher densities and thinner shock layer and lower temperatures associated with the chemically reacting air. Figure 8 illustrates density contours for the 20° incidence case at an axial station 9.5 diameters downstream.

6.3 HYPERSONIC AIRCRAFT

The hypersonic aircraft configuration¹⁷ of Figure 9 was computed at Mach 24.5 at 1° angle of incidence. A uniform 36 x 18 single zone mesh was implemented over the nose cone. For the wing section, the flow field was rezoned into two zones with each zone containing a 72 x 36 uniform mesh. Here, the outer boundary, edge 3, was defined outside the bow shock in the free stream.

6.3.1 Geometry — Nose Section

A description of the edges of the zone are as follows:

EDGE 1: $b = \zeta \tan \theta_c$, $b_z = \tan \theta_c$, $b_\phi = 0$.

EDGE 2: $\psi = \pi$, $\psi_z = \psi_r = 0$.

EDGE 3: not needed (shock fitted)

EDGE 4: $\sigma = 0$, $\sigma_z = \sigma_r = 0$.

The required geometry routines are as follows:

```

SUBROUTINE BCONST(ZETA,BOFZ,BZOFZ)
C.....THIS SUBROUTINE CALCULATES THE MAJOR AXIS OF AN ELLIPSE
C      (BOFZ) AND ITS Z DERIVATIVE (BZOFZ)
      RETURN
      END
      SUBROUTINE EDGE1(IN,ZETA,YY,BT,BZT,BYT)
C.....THIS SUBROUTINE DEFINES EDGE1
C.....USER DEFINES BT,BZT AND BYT AS A FUNCTION OF ZETA (ZETA)
C      Y OR PHI (YY) AND ZONE NUMBER (IN).
C      INPUT: IN      - ZONE NUMBER
C              ZETA    - ZETA
C      OUTPUT: BT     - X OR R LOCATION OF EDGE 1
C              BZT     - Z DERIVATIVE OF BT.
C              BYT     - Y DERIVATIVE OF BT.
C
      BYT=0.
      BZT=0.
      BT=5.08333
      IF(ZETA.LE.63.0) THEN
        THETAC=4.6
        PI=4.*ATAN(1.)
        RAD=PI/180.
        THETAR=THETAC*RAD
        BT=ZETA*TAN(THETAR)
        BZT=TAN(THETAR)
        BYT=0.
      ENDIF

```

```

RETURN
END
SUBROUTINE EDGE2(IN,ZETA,XX,THT,THZT,THXT)
C.....THIS SUBROUTINE DEFINES EDGE2
C.....USER DEFINES THT,THZT AND THXT AS A FUNCTION OF ZETA (ZETA)
C      X OR R (XX) AND ZONE NUMBER (IN).
C      INPUT: IN   - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: THT  - Y OR PHI LOCATION OF EDGE 2
C              THZT - Z DERIVATIVE OF THT.
C              THXT - X DERIVATIVE OF THT.
C
      THT=4.*ATAN(1.)
      THXT=0.
      THZT=0.
      RETURN
      END
SUBROUTINE EDGE3(IN,ZETA,PHI,CT,CZT,CYT)
C.....USER DEFINES CT,CZT,CYT IF BOW SHOCK IS NOT BEING TRACKED.
C      Y OR PHI (YY) AND ZONE NUMBER (IN).
C      INPUT: IN   - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: CT   - X OR R LOCATION OF EDGE 3
C              CZT  - Z DERIVATIVE OF CT.
C              CYT  - Y DERIVATIVE OF CT.
C
      RETURN
      END
SUBROUTINE EDGE4(IN,ZETA,XX,SGT,SGZT,SGXT)
C.....THIS SUBROUTINE DEFINES EDGE4
C.....THE USER MUST PROVIDE A DEFINITION OF SGT,SGZT,SGXT, AS A FUNCTION
C      OF ZETA (ZETA), X OR R (YY) AND ZONE NUMBER (IN).
C      INPUT: IN   - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: SGT  - Y OR PHI LOCATION OF EDGE 4
C              SGZT - Z DERIVATIVE OF SGT.
C              SGXT - X DERIVATIVE OF SGT.
C
      SGT=0.
      SGXT=0.
      SGZT=0.
      RETURN
      END
SUBROUTINE PEDGE(IN,II,ZETA,POUTL,PINL)
C      THIS SUBROUTINE CALCULATES THE FIN EDGE LOCATION
C      REQUIRED INPUT
C      IN - ZONE NUMBER
C      II - 1 FOR EDGE 4, 2 FOR EDGE 2
C      ZETA - ZETA
C
C.....USER PROVIDES DEFINITION OF POUTL AND PINL
      POUTL=0.
      PINL=0.

```

RETURN
END

6.3.2 Zeus Input File - - Nose Section

The following input file is used for the hypersonic aircraft nose section run at Mach 24.5 and 1° incidence. Computations were initiated from uniform free stream conditions.

The following file describes the required input for ZEUS. To execute ZEUS, replace the () symbols in the value column with the desired variable value. Add information supporting specific options between the lines containing the >>>> and <<<< symbols. Variable enclosed by [] should be placed by themselves on a line. Do not eliminate any lines from this file.

VALUE	VARIABLE	DESCRIPTION

*****INTEGRATION CONTROL*****		
48.	ZETAEND	Terminate calculation if ZETA > ZETAEND.
5000.	KEND	Terminate calculation if STEP NUMBER > KEND.
.9	FCFL	Step size safety factor (1. > FCFL > 0.) Typically use .9 .
1.	XKI	Interior point limiting constant (2. > XKI > 0.) Typically use 1.
0	IAPR	0,1 for approximate or complete Riemann Problem. Typically use 0. Must use 0 for equilibrium air.
0	ISHFLUX	0,1 for using complete Riemann Problem or freestream properties to compute the flux at the cell edge next to the bow shock. Typically use 0.
1	ISHANG	0,1 for using complete Riemann Problem or Roe averaged variables to compute shock angle. Typically use 0. For equilibrium air, a value of 1 is preferred.

*****BOUNDARY CONDITIONS*****		
0	NXKE	Number of edges at which default limiter setting won't be used. Default settings are 2 on edges 1 or 3 and 0 on edges 2 or 4. For each edge at which the default limiter is non-standard, add a line containing the following information: zone number (KEZ), edge number (KEE) and limiter value (XKE) >>>>start list of [KEZ,KEE,XKE] <<<<end list
0	NSUR	Number of edges not featuring default surface types. Default values are 1 on edges 1 and 3 and 0 on edge 2 and 4. Program will automatically account a fitted shock on edge 3 or fin surfaces on edges 2 or 4. For each edge at which the surface type is not of default, add a line that specifies the zone number(KSURZ), edge number(KSURE) and surface type (KSUR). >>>>start list of [KSURZ,KSURE,KSUR] <<<<end list
.9	DFAC	In case of a local wall Mach number which is too small to allow the flow to be turned parallel to the wall, the turn angle is

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multiplied by the constant DFAC (1. > DFAC > 0.).

*****OUTPUT CONTROL*****

```

.
      ---Printer---
250   IPRINT  Print crossflow plane if step number is evenly divided by IPRINT
1     NSKIP   Print n planes which are evenly divisible by NSKIP
3     MSKIP   Print m planes which are evenly divisible by MSKIP
1     ISKIP   Print step size if step number is evenly divided by ISKIP
.
      ---PLOTZA/Force-Pressure Summary---
0     JSPPR   In default mode, only edge 1 of each zone will be written to
            PLOTZA. JSPPR is the number of additional edges which are not
            to be written in the default manner. For each edge added or
            deleted from this print list, include a line which specifies
            zone number (JSPZ), edge number (JSPE) and print code (JSP).
            JSP = 1 will write this zone edge to PLOTZA, 0 will not.
            >>>>>start list of [JSPZ,JSPE,JSP]
            <<<<<end list
0     JSPDIS  1 - print grid point locations for the edges specified by JSPPR.
            0 - do not print.
5     KSKIP   Write surface properties on selected edges to PLOTZA if
            if STEP NUMBER is evenly divisible by KSKIP
100   NPRT    On summary sheet, print surface pressures of edges 2 or 4 if
            n < NPRT.
1000. DELZA   Write to PLOTZA if (ZETA - ZETA at last write) > DELZA
.
      ---PLOTZC (Plot file)
1000  IPLOT   Write to PLOTZC if STEP NUMBER is evenly divisible by IPLOT.
1000. DELZC   Write to PLOTZC if (ZETA - ZETA at last write) > DELZC
2     IPLOTN  Number of target Z stations (ZTARGET) at which PLOTZC will
            be written. If IPLOTN > 0, Include a list of these
            stations on the next line (maximum of 20). Stations must be
            listed in ascending order.
            >>>>>start ZTARGET list
21.33 48.
            <<<<<end list

```

*****AERODYNAMIC DATA*****

```

1.     AREF   Reference area used in calculating force and moment coefficients.
1.     XLREF   Reference length used in calculating moment coefficients and
            center-of-pressure.
0     IEFORCE 0, 1 don't, do print force and moments for individual edges.

```

*****SEPARATION MODELING*****

```

0     IVIS    0,1,2 for no modeling, clipping, and forced separation. Clipping
            and forced separation can only be used in conjunction with
            cylindrical coordinates. If IVIS = 2, specify the number of
            separation lines (NSEP).
            >>>>> NSEP
            <<<<<
            For each separation line specify:
            ISSIDE - 0 separation line located between 0 and 180 degrees,

```

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1 separation line located between 180 and 360 degrees.
 ISEP - number of points used to define the separation line.
 ZSSEP - Zeta value at which separation is started
 ZESEP - Zeta value at which separation is terminated
 PHICD - separation angle ϕ_iC (degrees)
 PHIAD - separation angle ϕ_iA (degrees)
 BETACD - separation angle β_iC (degrees)
 BETAAD - separation angle β_iA (degrees)
 >>>> [ISSIDE, ISEP, ZSSEP, ZESEP, PHICD, PHIAD, BETACD, BETAAD]
 <<<<

A list of ISEP pairs of points (ZEPZ, ZEPP) describing the zeta and phi coordinates of the separation line. This list should start at the most forward section and move aft. Start the list for each separation line on a separate line and list in same order as used in the above data.

>>>> start list of ZEPZ, ZEPP
 <<<<

*****GAS TYPE*****

1 IGAS 0-perfect gas; 1-equilibrium air

*****UNITS *****

0 IUNITS 0-english (p=lbf/ft**2, rho=slug/ft**3, t=rankine, xyz=ft);
 1-metric (p=n/m**2, rho=kg/m**3, t=kelvin, xyz=m).
 All input units must be consistent. Output units are the same.

*****INITIAL DATA*****

0 IMOD 0,1 for new start or restart respectively. For a restart, the initial flow field is read from TAPE3. Additional information is not needed and the remaining entries in this section should be disregarded. A new start assumes a uniform flow field which is described in the following section.

---Mesh Size---

1 IZN Number of zones.
 36 NA Number of cells in xi direction (i.e., between edges 1 and 3)
 18 MA Number of cells in eta direction (i.e., between edge 4 of zone 1 and edge 2 of zone IZN)

List the number of M planes in each zone, starting from zone 1 and ending at zone MA.

>>>>Start list of MA for each zone

18

<<<<end list

---Flow Properties---

.01 ZETA Zeta coordinate of initial data plane
 1. ALPHA Angle of attack (degrees)
 0. BETA Angle of yaw (degrees)
 24.5 XMINF Mach number
 1.543 PINF Pressure
 1.9135e-06 DINF Density

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---Problem Definition---

PROBLEM DEFINITION

1 ICORD 0,1,2 for cartesian, cylindrical or elliptic coordinates
 1 IASYM 0 - no pitch plane symmetry; 1 - pitch plane symmetry.
 1 ISHOCK Set to 1 if edge 3 is to be fitted by the calculation
 (either as a shock or sonic line); otherwise set to 0.
 ISHOCK = 1 is only valid for ICORD =1 or 2. If edge 3
 is to be fitted, the r and phi (cylindrical coordinates)
 or s, tau (elliptic coordinates) of the shock location on each
 M plane, (SS, SSZ) must be defined, starting from M = 1,
 etc.,

>>>>>Start list of [SS,SSZ]

.01 5.
 .01 15.
 .01 25.
 .01 35.
 .01 45.
 .01 55.
 .01 65.
 .01 75.
 .01 85.
 .01 95.
 .01 105.
 .01 115.
 .01 125.
 .01 135.
 .01 145.
 .01 155.
 .01 165.
 .01 175.

>>>>>End list

*****MESH DEFINITION*****

0 IMESHF 0 for uniform mesh in xi direction. 1 for clustered mesh. If
 a clustered mesh is to be used, the clustering function (FN) in
 the xi direction at the NA cell centers must be defined
 starting at cell 1, located adjacent to edge 1 and moving to
 edge 3 (usually body to shock).

>>>>>start list of FN

>>>>>end list

0 IMESHG 0 for uniform mesh in eta direction. 1 for clustered mesh. If
 a clustered mesh is to be used, the clustering function (GN) in
 the eta direction at the MA(i) cell centers in each zone must
 be defined, starting with zone 1 and ending with zone IZN. Start
 with cell 1, located adjacent to edge 4, and end at the cell
 adjacent to edge 2. The list for each zone should be started
 on a new card

>>>>>>>start list GN

end list<<<<<<<

6.3.3 Geometry — Wing Section

This section of the hypersonic aircraft is run using a two zone model with $NA=72$, $MAZ(1)=36$ and $MAZ(2)=36$ mesh. The geometry is as follows:

ZONE 1, EDGE 1: $b = \zeta \tan \theta_c$, $b_z = \tan \theta_c$, $b_\phi = 0$.

ZONE 1, EDGE 2: top of the wing surface, $OFFSET = \pi/2$.

ZONE 1, EDGE 3: outer boundary defined outside the bow shock in the free stream.

ZONE 1, EDGE 4: leeward pitch plane symmetry.

ZONE 2, EDGE 1: $b = \zeta \tan \theta_c$, $b_z = \tan \theta_c$, $b_\phi = 0$.

ZONE 2, EDGE 2: windward pitch plane symmetry.

ZONE 2, EDGE 3: outer boundary defined outside the bow shock in the free stream.

ZONE 2, EDGE 4: bottom of the wing surface, $OFFSET = \pi/2$.

The top of the wing surface is described in terms of b_I , b_{I_z} and x_m parameters for a flat fin surface (described in Reference 2) as follows:

$$x_0 = -2.048642$$

$$x_{LE} = x_0 - (\zeta - 33.75) \tan 1^\circ$$

$$y_{LE} = (\zeta - 33.75) \tan 12^\circ$$

$$x_{ru} = 2x_0 - x_{LE}$$

$$y_{ru} = 0$$

$$x_m = (x_{LE} - x_{ru}) / (y_{LE} - y_{ru})$$

$$b_I = x_{ru}$$

$$b_{I_z} = \tan 1^\circ$$

Similarly, for the bottom of the wing surface,

$$x_0 = -2.048642$$

$$x_{LE} = x_0 - (\zeta - 33.75) \tan 1^\circ$$

$$x_m = 0$$

$$b_I = x_{LE}$$

$$b_{I_z} = -\tan 1^\circ$$

Knowledge of b_I , b_{I_z} and x_m allows the appropriate σ and ψ functions to be calculated using coding described in Reference 2. The wing edges are computed as follows:

Inner Edge : $\omega = 0$

Outer Edge : $\Omega = 0$ *if* $z < 48.717$
 $\Omega = \sqrt{x_{LE}^2 + y_{LE}^2}$ *otherwise*

The required geometry routines for the wing section are as follows:

```

SUBROUTINE BCONST(ZETA,BOFZ,BZOFZ)
C.....THIS SUBROUTINE CALCULATES THE MAJOR AXIS OF AN ELLIPSE
C      (BOFZ) AND ITS Z DERIVATIVE (BZOFZ)
      RETURN
      END
      SUBROUTINE EDGE1(IN,ZETA,YY,BT,BZT,BYT)
C.....THIS SUBROUTINE DEFINES EDGE1
C.....USER DEFINES BT,BZT AND BYT AS A FUNCTION OF ZETA (ZETA)
C      Y OR PHI (YY) AND ZONE NUMBER (IN).
C      INPUT: IN    - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: BT   - X OR R LOCATION OF EDGE 1
C              BZT  - Z DERIVATIVE OF BT.
C              BYT  - Y DERIVATIVE OF BT.
      BYT=0.
      BZT=0.
      BT=5.08333
      IF(ZETA.LE.63.0) THEN
      THETAC=4.6
      PI=4.*ATAN(1.)
      RAD=PI/180.
      THETAR=THETAC*RAD
      BT=ZETA*TAN(THETAR)
      BZT=TAN(THETAR)
      BYT=0.
      ENDIF
      RETURN
      END
      SUBROUTINE EDGE2(IN,ZETA,XX,THT,THZT,THXT)
C.....THIS SUBROUTINE DEFINES EDGE2
C.....USER DEFINES THT,THZT AND THXT AS A FUNCTION OF ZETA (ZETA)
C      X OR R (XX) AND ZONE NUMBER (IN).
C      INPUT: IN    - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: THT  - Y OR PHI LOCATION OF EDGE 2
C              THZT - Z DERIVATIVE OF THT.
C              THXT - X DERIVATIVE OF THT.
      PI=4.*ATAN(1.)
      RAD=PI/180.
      IF(IN.EQ.1) THEN

```

```

OFFSET=PI/2.
TAN12=TAN(12.*RAD)
TAN1=TAN(1.*RAD)
Y0=0.
X0=-2.048642
YLE=(ZETA-33.75)*TAN12
XLE=X0-(ZETA-33.75)*TAN1
RLE=SQRT(XLE*XLE+YLE*YLE)
XBWI=XLE
XRU=2.*X0-XBWI
YRU=0.
IF (XX.LE.RLE.AND.ZETA.GE.48.717) THEN
  XM=(XLE-XRU)/(YLE-YRU)
  BI=XRU
  BIZ=TAN1
ELSE
  XM=(XLE-X0)/(YLE-Y0)
  BI=X0
  BIZ=0.
ENDIF
ELSE IF (IN.EQ.2) THEN
  OFFSET=PI
  XM=0.
  BI=0.
  BIZ=0.
ENDIF
XM2P1=XM*XM+1.
SINT=(BI/XX+XM*SQRT(XM2P1-(BI/XX)**2))/XM2P1
COST=SQRT(1.-SINT*SINT)
C1=COST+XM*SINT
THT=OFFSET-ASIN(SINT)
THXT=BI/(XX*XX*C1)
THZT=-BIZ/(XX*C1)
RETURN
END
SUBROUTINE EDGE3(IN,ZETA,PHI,CT,CZT,CYT)
C....USER DEFINES CT,CZT,CYT IF BOW SHOCK IS NOT BEING TRACKED.
C  Y OR PHI (YY) AND ZONE NUMBER (IN).
C      INPUT: IN    - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: CT   - X OR R LOCATION OF EDGE 3
C              CZT  - Z DERIVATIVE OF CT.
C              CYT  - Y DERIVATIVE OF CT.
C
  PI=4.*ATAN(1.)
  RAD=PI/180.
  BT=5.08333
  IF (ZETA.LE.63.0) THEN
    TAN4P6=TAN(4.6*RAD)
    BT=ZETA*TAN4P6
  ENDIF
  CFAC1=1.3
  CT1=BT*CFAC1

```

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```

CZT=TAN4P6*CFAC1
CXT=0.
CT2=0.
IF (ZETA.GT.48.717) THEN
  CFAC2=1.1
  TAN12=TAN(12.*RAD)
  TAN1=TAN(1.*RAD)
  X0=-2.048642
  YLE=(ZETA-33.75)*TAN12
  XLE=X0-(ZETA-33.75)*TAN1
  RLE=SQRT(XLE*XLE+YLE*YLE)
  CT2=RLE*CFAC2
  CZT2=CFAC2*(-TAN1*XLE+TAN12*YLE)/RLE
ENDIF
CT=AMAX1(CT1,CT2)
IF (CT2.GE.CT1) CZT=CZT2
RETURN
END
SUBROUTINE EDGE4(IN,ZETA,XX,SGT,SGZT,SGXT)

```

```

C.....THIS SUBROUTINE DEFINES EDGE4
C.....THE USER MUST PROVIDE A DEFINITION OF SGT,SGZT,SGXT, AS A FUNCTION
C      OF ZETA (ZETA), X OR R (YY) AND ZONE NUMBER (IN).
C      INPUT: IN   - ZONE NUMBER
C              ZETA - ZETA
C      OUTPUT: SGT  - Y OR PHI LOCATION OF EDGE 4
C              SGZT - Z DERIVATIVE OF SGT.
C              SGXT - X DERIVATIVE OF SGT.
C

```

```

PI=4.*ATAN(1.)
RAD=PI/180.
IF (IN.EQ.1) THEN
  OFFSET=0.
  XM=0.
  BI=0.
  BIZ=0.
ELSE IF (IN.EQ.2) THEN
  OFFSET=PI/2.
  TAN12=TAN(12.*RAD)
  TAN1=TAN(1.*RAD)
  Y0=0.
  X0=-2.048642
  YLE=(ZETA-33.75)*TAN12
  XLE=X0-(ZETA-33.75)*TAN1
  RLE=SQRT(XLE*XLE+YLE*YLE)
  IF (XX.LE.RLE.AND.ZETA.GE.48.717) THEN
    XM=0.
    BI=XLE
    BIZ=-TAN1
  ELSE
    XM=(XLE-X0)/(YLE-Y0)
    BI=X0
    BIZ=0.
  ENDIF

```

```

ENDIF
XM2P1=XM*XM+1.
SINT=(BI/XX+XM*SQRT(XM2P1-(BI/XX)**2))/XM2P1
COST=SQRT(1.-SINT*SINT)
C1=COST+XM*SINT
SGT=OFFSET-ASIN(SINT)
SGXT=BI/(XX*XX*C1)
SGZT=-BIZ/(XX*C1)
RETURN
END
SUBROUTINE PEDGE(IN,II,ZETA,POUTL,PINL)
C THIS SUBROUTINE CALCULATES THE FIN EDGE LOCATION
C REQUIRED INPUT
C IN - ZONE NUMBER
C II - 1 FOR EDGE 4, 2 FOR EDGE 2
C ZETA - ZETA
C
C.....USER PROVIDES DEFINITION OF POUTL AND PINL
POUTL=0.
PINL=0.
IF(ZETA.GE.48.717)THEN
  IF((IN.EQ.1.AND.II.EQ.2).OR.(IN.EQ.2.AND.II.EQ.1))THEN
    PI=4.*ATAN(1.)
    RAD=PI/180.
    TAN12=TAN(12.*RAD)
    TAN1=TAN(1.*RAD)
    X0=-2.048642
    YLE=(ZETA-33.75)*TAN12
    XLE=X0-(ZETA-33.75)*TAN1
    POUTL=SQRT(XLE*XLE+YLE*YLE)
  ENDIF
ENDIF
RETURN
END

```

6.3.4 CONVERT Input File

The flow field is rezoned from a one zone 36 x 18 mesh into two zones each with a 72 x 36 mesh using the program CONVERT. The input file for CONVERT is as follows:

INPUT file for CONVERT. To execute, append the geometry subroutines BCONST, EDGE1, EDGE2, EDGE3, EDGE4, and PEDGE to CONVERT and execute using this file as input, with () replaced by the desired values and required lists inserted between lines containing >>>> and <<<<. Do not delete or add any lines to this file.

```

-----
VALUE VARIABLE DESCRIPTION
1 IASYMN symmetry of the final flow field; 1 - symmetric

```

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```

0 - asymmetric
2      IZNN    number of new zones
72     NAN     Number of cells between edge 1 and 3 of new mesh.
72     MAN     Number of cells between edge 4, zone 1 and edge2,
              zone IZNN. The number of cells in each zone between
              edges 4 and 2 must also be specified, starting at
              zone 1 .
              >>>>>Start MAZ(1), MAZ(2), ... MAZ(IZNN)
36     36
              <<<<<End list
0      ISHOCKN 0 - Edge 3 will not be fitted with a shock
              1 - Shock fitted on edge 3
0      IMESHF  0 - uniform mesh in xi direction of new mesh.
              1 - clustered mesh. If a clustered mesh is used,
              the clustering (FNN) must be specified, starting
              at the cell center adjacent to edge 1 and ending
              at the cell center adjacent to edge 3.
              >>>>>Start list FNN
              <<<<<End list of FNN
0      IMESHG  0 - uniform mesh between edges 2 and 4 of new mesh.
              1 - clustered mesh. If a clustered mesh is used,
              the clustering (GNN) for each zone must be
              specified, starting with zone 1 and ending at zone
              IZN. The clustering for each zone should be started
              on a new card. Beginning this list at the cell
              center adjacent to edge 4 and terminate it at the
              cell center next to edge 2.
              >>>>>Start list GNN
              <<<<<End list of GNN

```

6.3.5 Zeus Input File — Wing Section

The following ZEUS input file is used for the wing section:

The following file describes the required input for ZEUS. To execute ZEUS, replace the () symbols in the value column with the desired variable value. Add information supporting specific options between the lines containing the >>>>> and <<<<< symbols. Variable enclosed by [] should be placed by themselves on a line. Do not eliminate any lines from this file.

VALUE	VARIABLE	DESCRIPTION
*****INTEGRATION CONTROL*****		
114.25	ZETAEND	Terminate calculation if ZETA > ZETAEND.
5000.	KEND	Terminate calculation if STEP NUMBER > KEND.
.9	FCFL	Step size safety factor (1. > FCFL > 0.) Typically use .9 .
1.	XKI	Interior point limiting constant (2. > XKI > 0.) Typically use 1.
0	IAPR	0,1 for approximate or complete Riemann Problem. Typically use 0.

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Must use 0 for equilibrium air.

- 0 ISHFLUX 0,1 for using complete Riemann Problem or freestream properties to compute the flux at the cell edge next to the bow shock. Typically use 0.
- 1 ISHANG 0,1 for using complete Riemann Problem or Roe averaged variables to compute shock angle. Typically use 0. For equilibrium air, a value of 1 is preferred.

*****BOUNDARY CONDITIONS*****

- 0 NXKE Number of edges at which default limiter setting won't be used. Default settings are 2 on edges 1 or 3 and 0 on edges 2 or 4. For each edge at which the default limiter is non-standard, add a line containing the following information:
zone number (KEZ), edge number (KEE) and limiter value (XKE)
>>>>start list of [KEZ,KEE,XKE]
<<<<end list
- 2 NSUR Number of edges not featuring default surface types. Default values are 1 on edges 1 and 3 and 0 on edge 2 and 4. Program will automatically account a fitted shock on edge 3 or fin surfaces on edges 2 or 4. For each edge at which the surface type is not of default, add a line that specifies the zone number(KSURZ), edge number(KSURE) and surface type (KSUR).
>>>>start list of [KSURZ,KSURE,KSUR]

1 3 2
2 3 2

<<<<end list

- .9 DFAC In case of a local wall Mach number which is too small to allow the flow to be turned parallel to the wall, the turn angle is multiplied by the constant DFAC (1. > DFAC > 0.).

*****OUTPUT CONTROL*****

---Printer---

- 200 IPRINT Print crossflow plane if step number is evenly divided by IPRINT
- 1 NSKIP Print n planes which are evenly divisible by NSKIP
- 6 MSKIP Print m planes which are evenly divisible by MSKIP
- 1 ISKIP Print step size if step number is evenly divided by ISKIP

---PLOTZA/Force-Pressure Summary---

- 2 JSPPR In default mode, only edge 1 of each zone will be written to PLOTZA. JSPPR is the number of additional edges which are not to be written in the default manner. For each edge added or deleted from this print list, include a line which specifies zone number (JSPZ), edge number (JSPE) and print code (JSP).
JSP = 1 will write this zone edge to PLOTZA, 0 will not.
>>>>start list of [JSPZ,JSPE,JSP]

1 2 1
2 4 1

<<<<end list

- 0 JSFDIS 1 - print grid point locations for the edges specified by JSPPR.
0 - do not print.
- 1 KSKIP Write surface properties on selected edges to PLOTZA if if STEP NUMBER is evenly divisible by KSKIP

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100 NPRT On summary sheet, print surface pressures of edges 2 or 4 if
n < NPRT.
1000. DELZA Write to PLOTZA if (ZETA - ZETA at last write) > DELZA

---PLOTZC (Plot file)

1000 IPLOT Write to PLOTZC if STEP NUMBER is evenly divisible by IPLOT.
1000. DELZC Write to PLOTZC if (ZETA - ZETA at last write) > DELZC
2 IPLOTN Number of target Z stations (ZTARGET) at which PLOTZC will
be written. If IPLOTN > 0, Include a list of these
stations on the next line (maximum of 20). Stations must be
listed in ascending order.
>>>>>start ZTARGET list

63.917 108.67

<<<<<end list

*****AERODYNAMIC DATA*****

1. AREF Reference area used in calculating force and moment coefficients.
1. XLREF Reference length used in calculating moment coefficients and
center-of-pressure.
0 IEFORCE 0, 1 don't, do print force and moments for individual edges.

*****SEPARATION MODELING*****

0 IVIS 0,1,2 for no modeling, clipping, and forced separation. Clipping
and forced separation can only be used in conjunction with
cylindrical coordinates. If IVIS = 2, specify the number of
separation lines (NSEP).

>>>>> NSEP

<<<<<

For each separation line specify:

ISSIDE - 0 separation line located between 0 and 180 degrees,
1 separation line located between 180 and 360 degrees.

ISEP - number of points used to define the separation line.

ZSSEP - Zeta value at which separation is started

ZESEP - Zeta value at which separation is terminated

PHICD - separation angle phiC (degrees)

PHIAD - separation angle phiA (degrees)

BETACD - separation angle BetaC (degrees)

BETAAD - separation angle BetaA (degrees)

>>>>> [ISSIDE, ISEP, ZSSEP, ZESEP, PHICD, PHIAD, BETACD, BETAAD]

<<<<<

A list of ISEP pairs of points (ZEPZ, ZEPP) describing the zeta
and phi coordinates of the separation line. This list should
start at the most forward section and move aft. Start the list
for each separation line on a separate line and list in same
order as used in the above data.

>>>>> start list of ZEPZ, ZEPP

<<<<<

*****GAS TYPE*****

1 IGAS 0-perfect gas; 1-equilibrium air

*****UNITS *****

0 IUNITS 0-english (p=lb/ft**2, rho=slug/ft**3, t=rankine, xyz=ft);

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1-metric (p=n/m**2, rho=kg/m**3, t=kelvin, xyz=m).
All input units must be consistant. Output units are the same.

*****INITIAL DATA*****

1 IMOD 0,1 for new start or restart respectively. For a restart, the initial flow field is read from TAPE3. Additional information is not needed and the remaining entries in this section should be disregarded. A new start assumes a uniform flow field which is described in the following section.

---Mesh Size---

() IZN Number of zones.
() NA Number of cells in xi direction (i.e., between edges 1 and 3)
() MA Number of cells in eta direction (i.e., between edge 4 of zone 1 and edge 2 of zone IZN)

List the number of M planes in each zone, starting from zone 1 and ending at zone MA.

>>>>Start list of MA for each zone
<<<<end list

---Flow Properties---

() ZETA Zeta coordinate of initial data plane
() ALPHA Angle of attack (degrees)
() BETA Angle of yaw (degrees)
() XMINF Mach number
() PINF Pressure
() DINF Density

---Problem Definition---

PROBLEM DEFINITION

() ICORD 0,1,2 for cartesian, cylindrical or elliptic coordinates
() IASYM 0 - no pitch plane symmetry; 1 - pitch plane symmetry.
() ISHOCK Set to 1 if edge 3 is to be fitted by the calculation (either as a shock or sonic line); otherwise set to 0. ISHOCK = 1 is only valid for ICORD =1 or 2. If edge 3 is to be fitted, the r and phi (cylindrical coordinates) or s, tau (elliptic coordinates) of the shock location on each M plane, (SS, SSZ) must be defined, starting from M = 1, etc.,

>>>>Start list of [SS,SSZ]
>>>>End list

*****MESH DEFINITION*****

0 IMESHF 0 for uniform mesh in xi direction. 1 for clustered mesh. If a clustered mesh is to be used, the clustering function (FN) in the xi direction at the NA cell centers must be defined starting at cell 1, located adjacent to edge 1 and moving to edge 3 (usually body to shock).

>>>>start list of FN
>>>>end list

0 IMESHG 0 for uniform mesh in eta direction. 1 for clustered mesh. If a clustered mesh is to be used, the clustering function (GN) in

the eta direction at the MA(i) cell centers in each zone must be defined, starting with zone 1 and ending with zone IZN. Start with cell 1, located adjacent to edge 4, and end at the cell adjacent to edge 2. The list for each zone should be started on a new card

```
>>>>>>>start list GN
end list<<<<<<<
```

6.3.6 Results

Computations were performed for the hypersonic airplane configuration of Figure 9 at Mach 24.5 and 1° incidence. A comparison of pressure profiles between ZEUS and the Parabolized Navier-Stokes computations of Korte¹⁷ on the windward symmetry plane at $z = 108.67$ feet shows good agreement except near the surface where viscous effects are not predicted by ZEUS. In Figure 10, pressure contours are also computed at an axial station near the end of the body ($z = 108.67$ feet) for equilibrium air. Computations illustrate good agreement except in the vicinity of the wing tip where ZEUS does not effectively predict the viscous layer.

6.4 CONCLUDING REMARKS

The ZEUS code has been extended to high Mach numbers by incorporating the high-temperature effects of air in chemical equilibrium. These high-temperature effects are accounted for by using the curve fits of Reference 10 to compute the thermodynamic properties of equilibrium air.

Various hypersonic missile-type bodies were computed including sharp cones, a spherically blunt nosed cylinder and a hypersonic aircraft. ZEUS predicted the smaller shock layer thickness and lower temperatures characteristic of equilibrium chemically reacting air. The computed ZEUS results compare well with measured high-temperature effects and other computational efforts except in regions where viscous effects are dominant. This enhanced version of ZEUS is an economic predictive tool for missiles and will help provide accurate predictions in support of future hypersonic weapons.

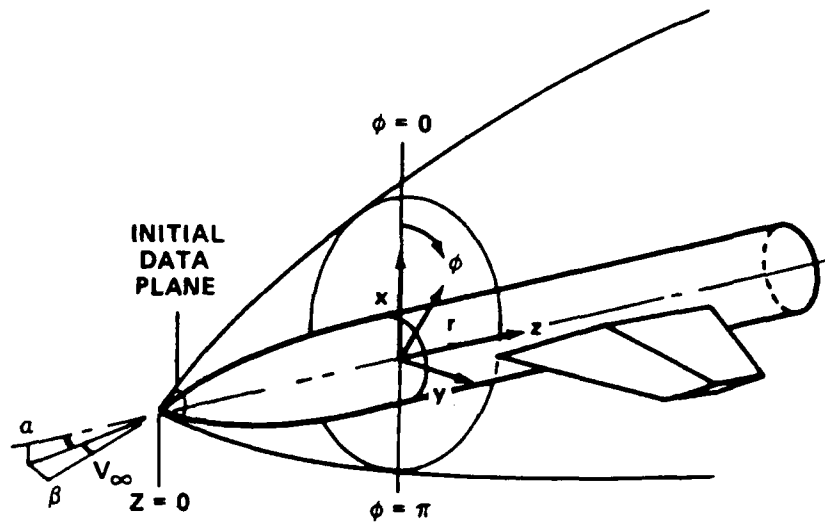


FIGURE 1. CARTESIAN AND CYLINDRICAL COORDINATE SYSTEM FOR ZEUS, A SPACE-MARCHING EULER SOLVER

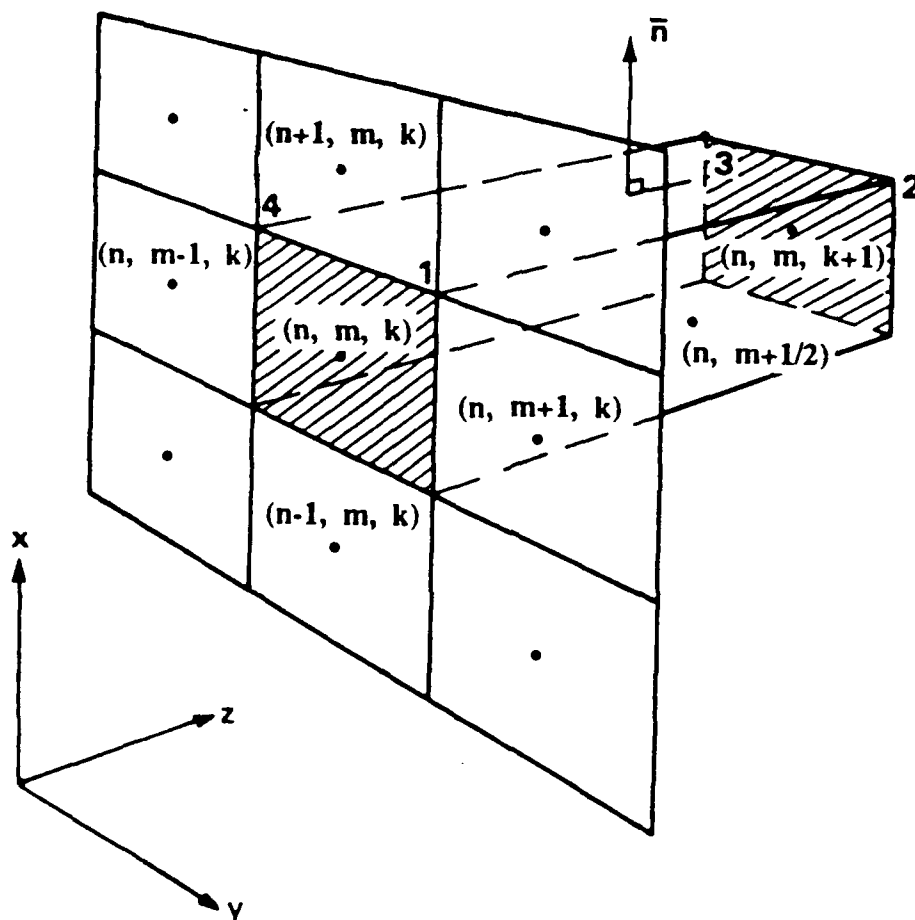


FIGURE 2. CONTROL VOLUME NOMENCLATURE

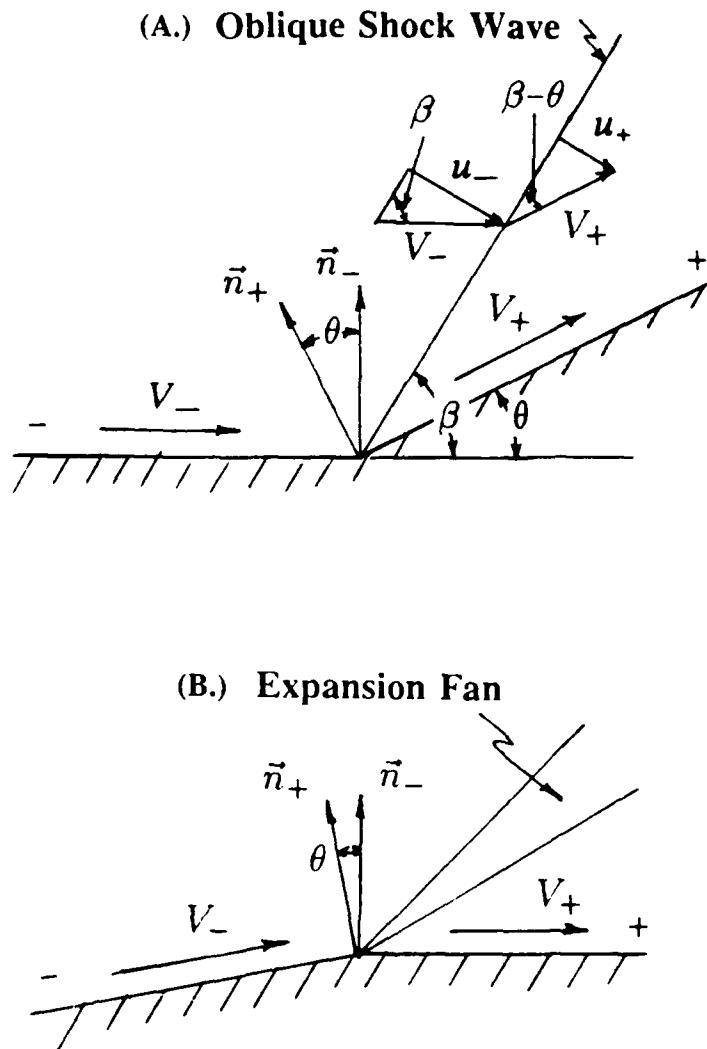


FIGURE 3. FLOW DISCONTINUITIES IN THE CASE $\frac{V_-}{a} > 1$ (A.) OBLIQUE SHOCK WAVE (B.) EXPANSION FAN

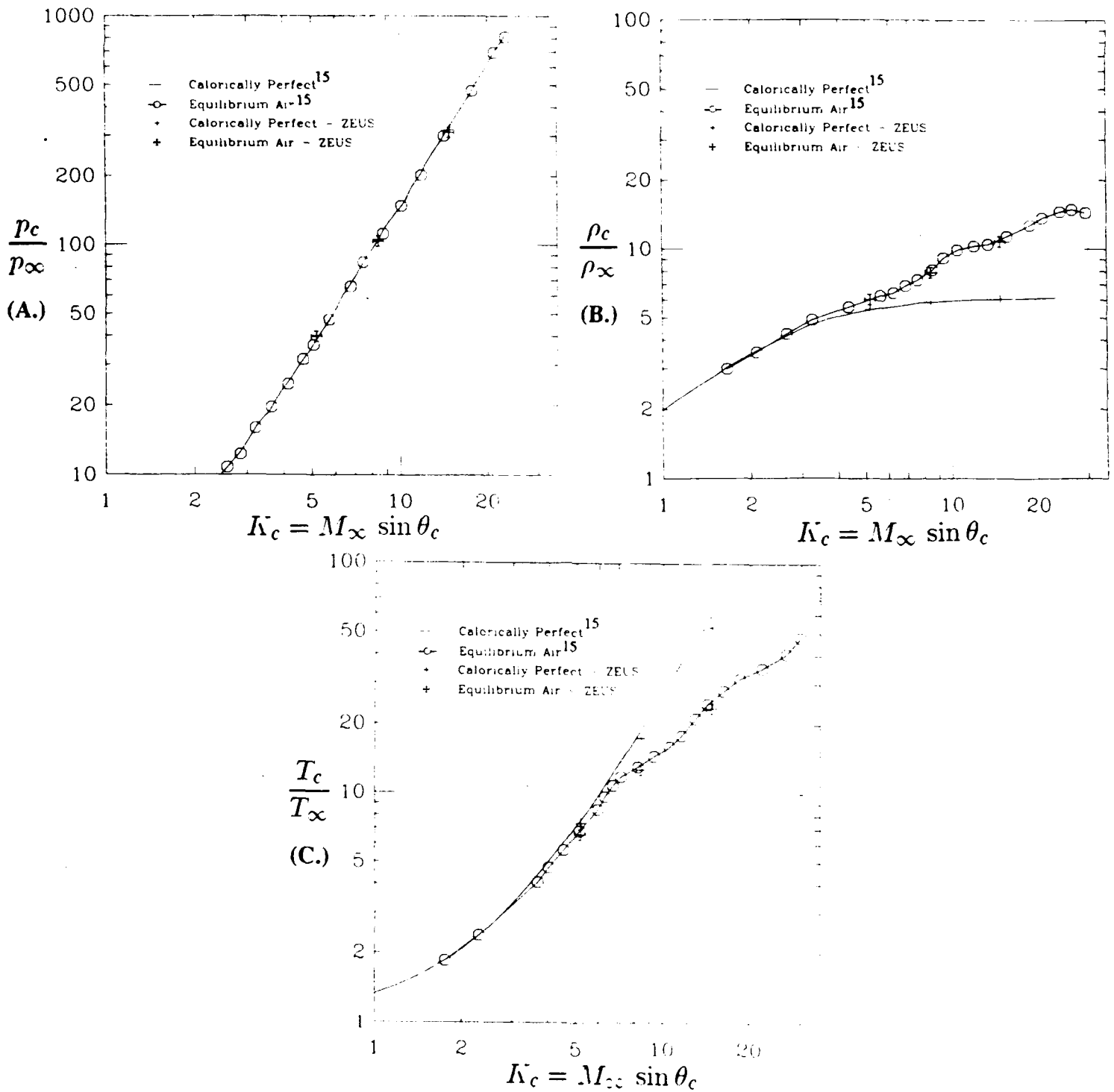
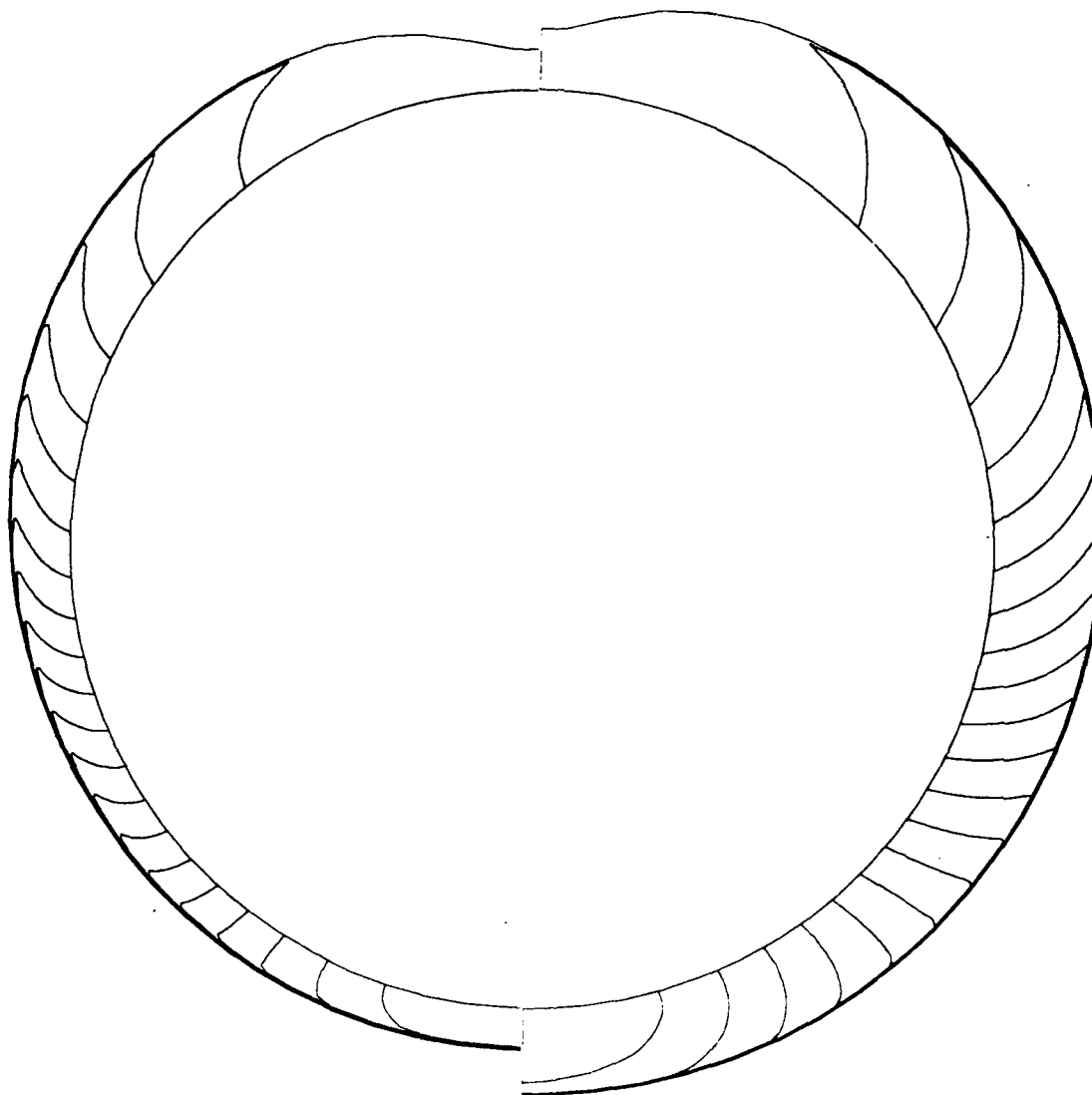


FIGURE 4. SURFACE (A.) PRESSURES (B.) DENSITIES (C.) TEMPERATURES ON CONES AT AN ALTITUDE OF 100,000 FT. A COMPARISON BETWEEN CALORICALLY PERFECT AND EQUILIBRIUM AIR RESULTS FOR ZEUS AND HUDGINS¹⁵ COMPUTATIONS



(A.) EQUILIBRIUM AIR

(B.) CALORICALLY PERFECT AIR

FIGURE 5. COMPUTED PRESSURE CONTOURS FOR A SHARP CONE WITH A 25° HALF-ANGLE AT MACH 20, AN INCIDENCE OF 20°, AND AN ALTITUDE OF 100,000 FT. RESULTS ARE COMPARED BETWEEN (A.) EQUILIBRIUM AIR AND (B.) CALORICALLY PERFECT

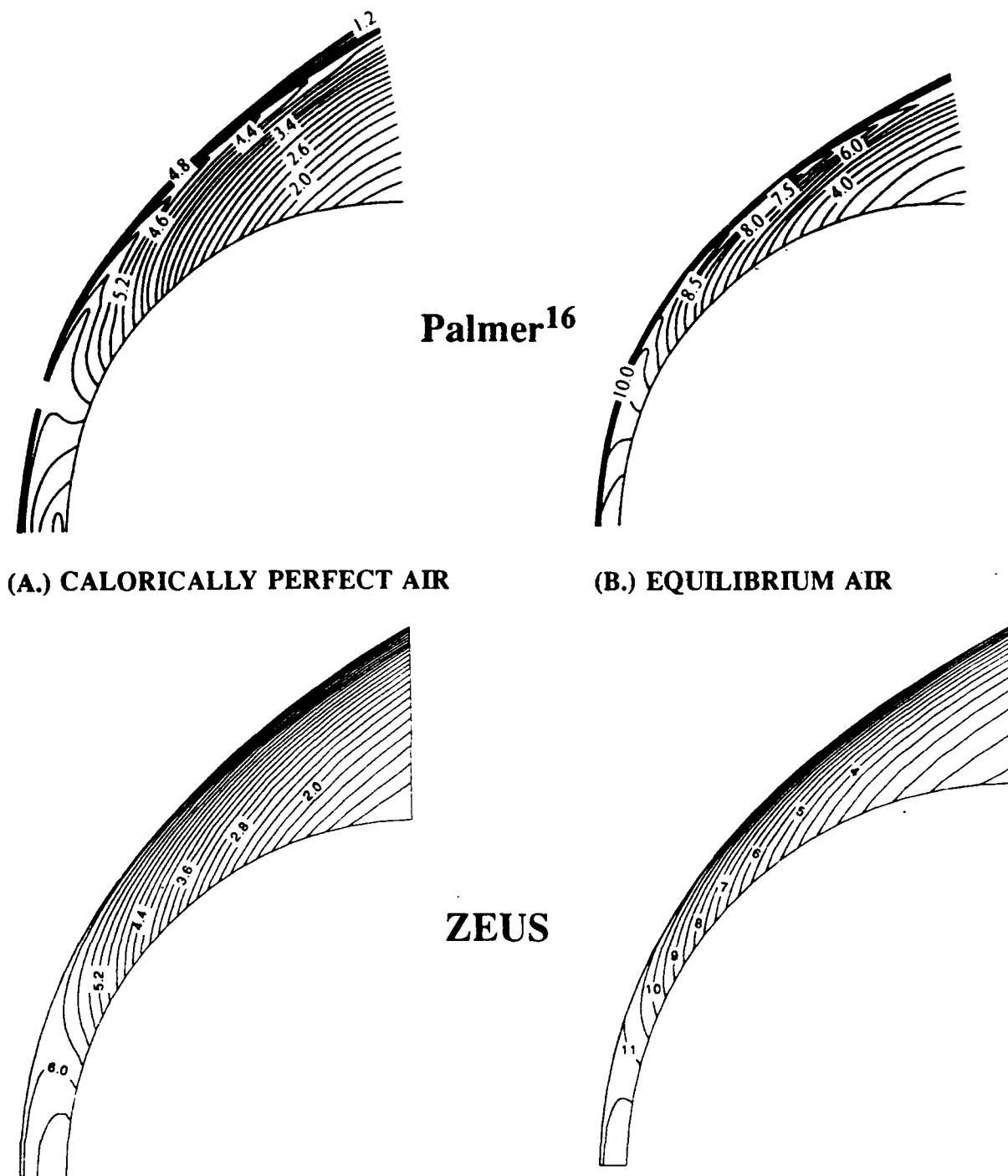


FIGURE 6. DENSITY CONTOURS FOR A HYPERSONIC SPHERICALLY BLUNT NOSED CYLINDER AT MACH 20 AND AN INCIDENCE OF 0° FOR (A.) CALORICALLY PERFECT AND (B.) EQUILIBRIUM CHEMICALLY REACTING AIR. RESULTS ARE COMPARED WITH COMPUTATIONS OF ZEUS AND PALMER¹⁶

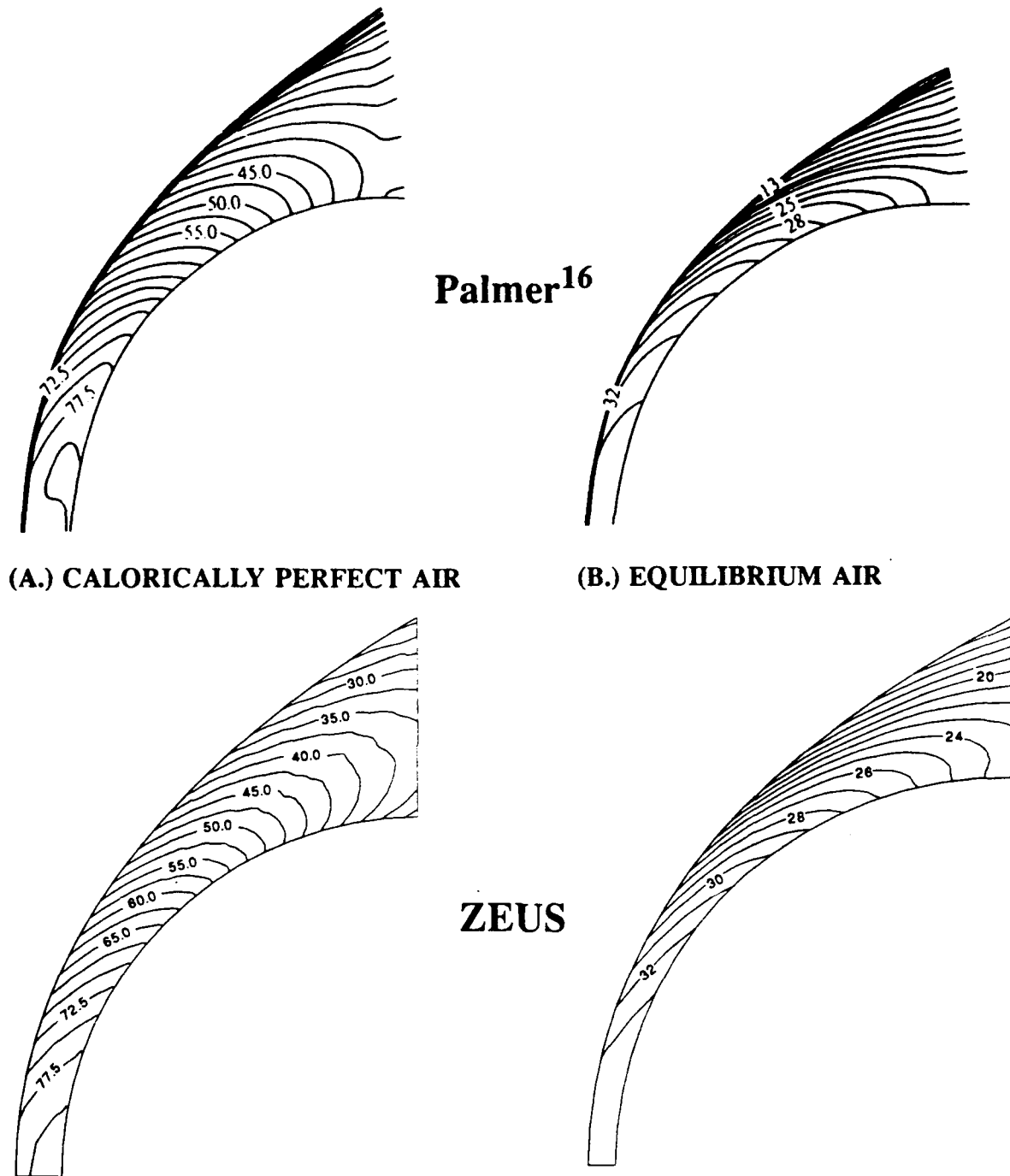


FIGURE 7. TEMPERATURE CONTOURS FOR A HYPERSONIC SPHERICALLY BLUNT NOSED CYLINDER AT MACH 20 AND AN INCIDENCE OF 0° FOR (A.) CALORICALLY PERFECT AND (B.) EQUILIBRIUM CHEMICALLY REACTING AIR. RESULTS ARE COMPARED WITH COMPUTATIONS OF ZEUS AND PALMER¹⁶

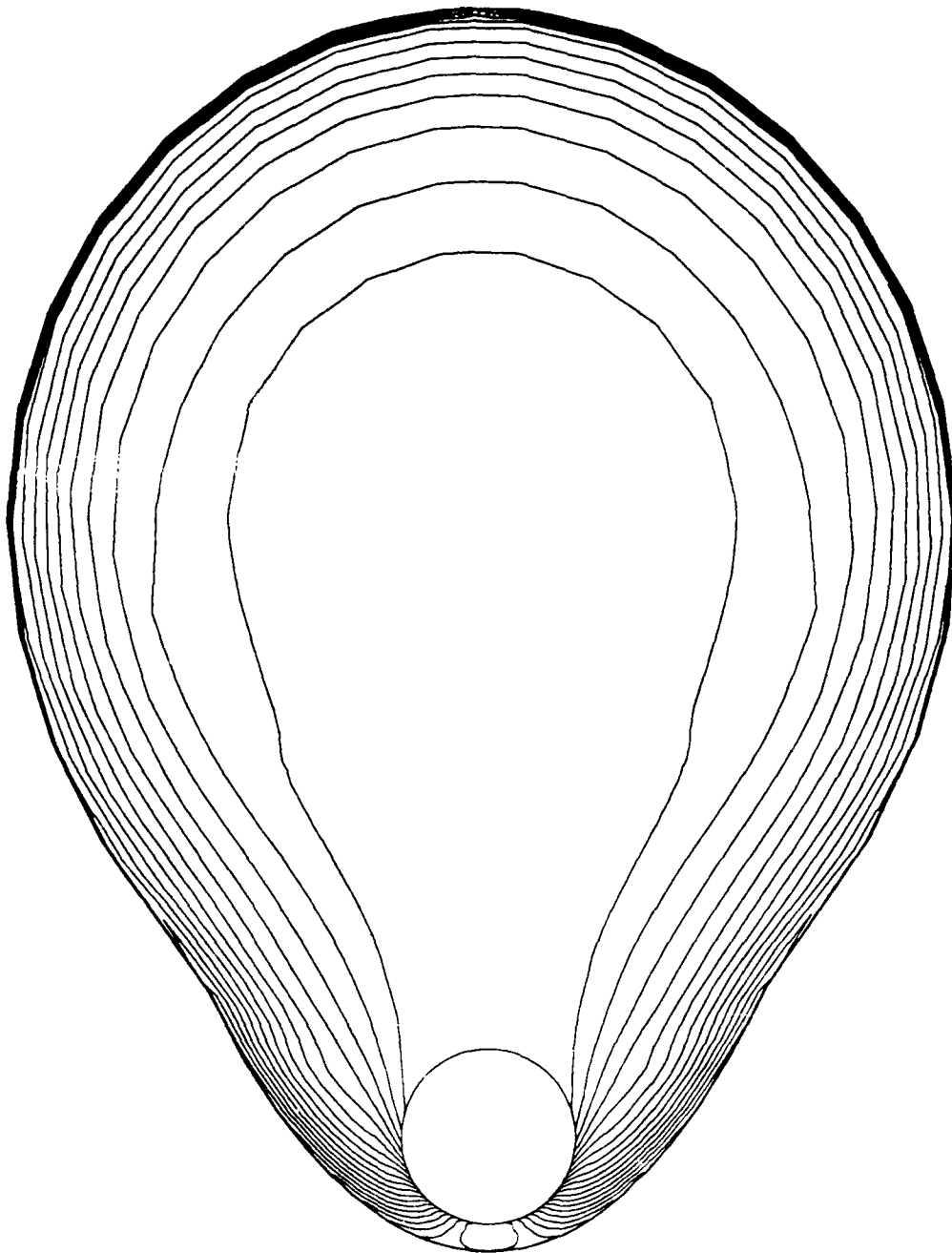
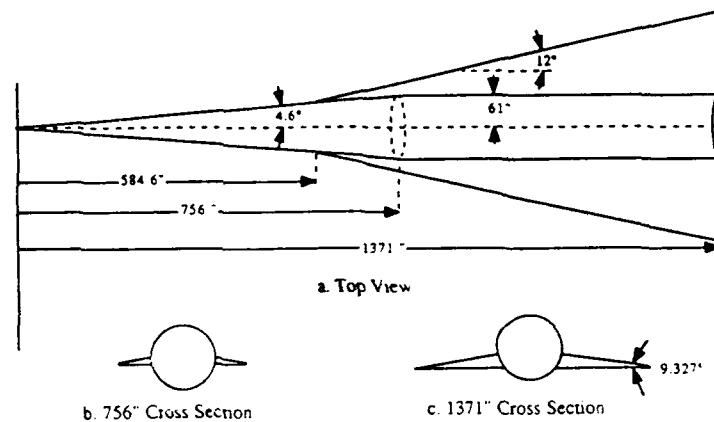


FIGURE 8. COMPUTED DENSITY CONTOURS FOR A HYPERSONIC SPHERICALLY BLUNT NOSED CYLINDER AT MACH 20 AND AN INCIDENCE OF 20° FOR EQUILIBRIUM AIR AT AN AXIAL STATION 9.5 DIAMETERS DOWNSTREAM



Generic hypersonic airplane configuration.¹⁷

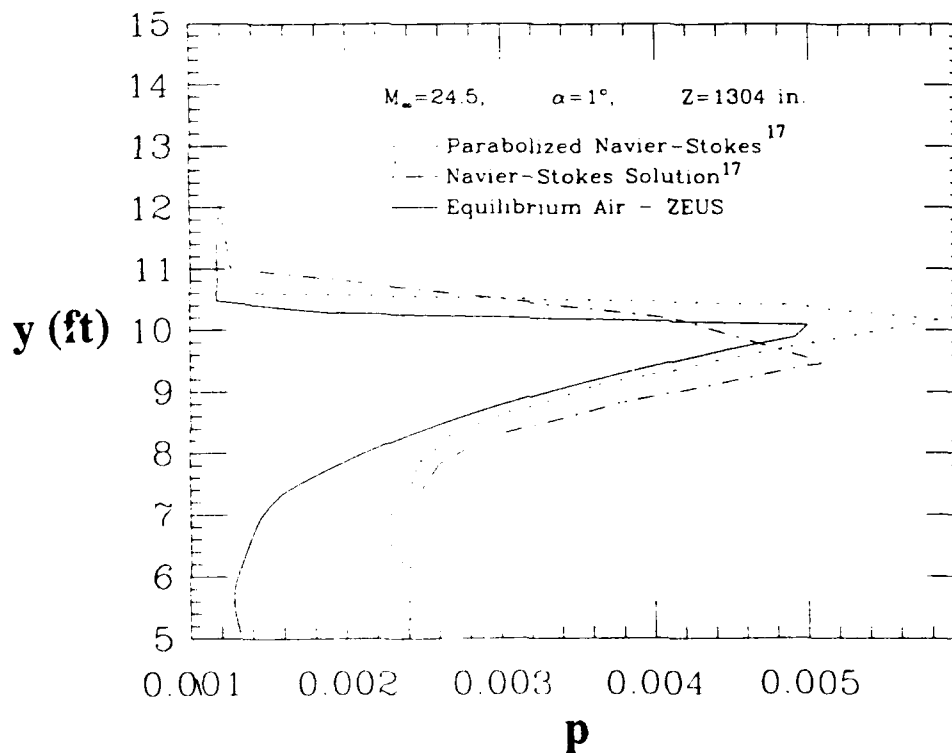
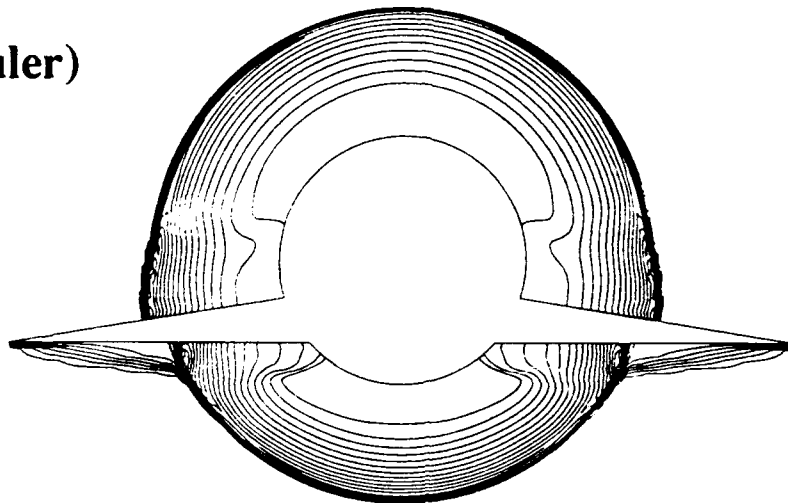


FIGURE 9. COMPARISON OF COMPUTED PRESSURE PROFILES FOR EQUILIBRIUM AIR ON THE WINDWARD SYMMETRY PLANE AT MACH 24.5, AN INCIDENCE OF 1° AND $Z = 108.67$ FT FOR ZEUS AND THE PNS SOLUTIONS OF KORTE¹⁷

ZEUS (Euler)



Korte¹⁷ (PNS)

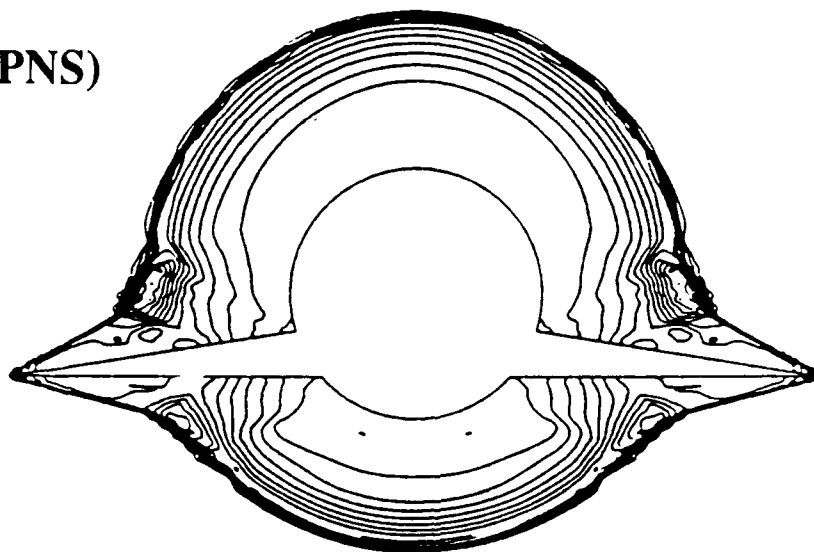


FIGURE 10. COMPARISON OF COMPUTED PRESSURE CONTOURS FOR EQUILIBRIUM AIR AT MACH 24.5, AN INCIDENCE OF 1° AND $Z = 108.67$ FT FOR ZEUS AND THE PNS SOLUTIONS OF KORTE¹⁷

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APPENDIX A

ZEUS INPUT FILE

The following file describes the required input for ZEUS. To execute ZEUS, replace the () symbols in the value column with the desired variable value. Add information supporting specific options between the lines containing the >>>> and <<<< symbols. Variables enclosed by [] should be placed by themselves on a line. Do not eliminate any lines from this file.

VALUE	VARIABLE	DESCRIPTION

	*****INTEGRATION CONTROL*****	
()	ZETAEND	Terminate calculation if ZETA > ZETAEND.
()	KEND	Terminate calculation if STEP NUMBER > KEND.
()	FCFL	Step size safety factor (1. > FCFL > 0.) Typically use .9 .
()	XKI	Interior point limiting constant (2. > XKI > 0.) Typically use 1.
()	IAPR	0,1 for approximate or complete Riemann Problem. Typically use 0. Must use 0 for equilibrium air.
()	ISHFLUX	0,1 for using complete Riemann Problem or freestream properties to compute the flux at the cell edge next to the bow shock. Typically use 0.
()	ISHANG	0,1 for using complete Riemann Problem or Roe averaged variables to compute shock angle. Typically use 0. For equilibrium air, a value of 1 is preferred.

	*****BOUNDARY CONDITIONS*****	
()	NXKE	Number of edges at which default limiter setting won't be used. Default settings are 2 on edges 1 or 3 and 0 on edges 2 or 4. For each edge at which the default limiter is non-standard, add a line containing the following information: zone number (KEZ), edge number (KEE) and limiter value (XKE) >>>>start list of [KEZ,KEE,XKE] <<<<end list
()	NSUR	Number of edges not featuring default surface types. Default values are 1 on edges 1 and 3 and 0 on edge 2 and 4. Program will automatically account a fitted shock on edge 3 or fin surfaces on edges 2 or 4. For each edge at which the surface type is not of default, add a line that specifies the zone number(KSURZ), edge number(KSURE) and surface type (KSUR). >>>>start list of [KSURZ,KSURE,KSUR] <<<<end list
()	DFAC	In case of a local wall Mach number which is too small to allow the flow to be turned parallel to the wall, the turn angle is multiplied by the constant DFAC (1. > DFAC > 0.).

	*****OUTPUT CONTROL*****	

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```

---Printer---
() IPRINT Print crossflow plane if step number is evenly divided by IPRINT
() NSKIP Print n planes which are evenly divisible by NSKIP
() MSKIP Print m planes which are evenly divisible by MSKIP
() ISKIP Print step size if step number is evenly divided by ISKIP

.

---PLOTZA/Force-Pressure Summary---
() JSPPR In default mode, only edge 1 of each zone will be written to
PLOTZA. JSPPR is the number of additional edges which are not
to be written in the default manner. For each edge added or
deleted from this print list, include a line which specifies
zone number (JSPZ), edge number (JSPE) and print code (JSP).
JSP = 1 will write this zone edge to PLOTZA, 0 will not.
    >>>>start list of [JSPZ,JSPE,JSP]
    <<<<end list
() JSPDIS 1 - print grid point locations for the edges specified by JSPPR.
0 - do not print.
() KSKIP Write surface properties on selected edges to PLOTZA if
if STEP NUMBER is evenly divisible by KSKIP
() NPRT On summary sheet, print surface pressures of edges 2 or 4 if
n < NPRT.
() DELZA Write to PLOTZA if (ZETA - ZETA at last write) > DELZA

.

---PLOTZC (Plot file)
() IPLOT Write to PLOTZC if STEP NUMBER is evenly divisible by IPLOT.
() DELZC Write to PLOTZC if (ZETA - ZETA at last write) > DELZC
() IPLOTN Number of target Z stations (ZTARGET) at which PLOTZC will
be written. If IPLOTN > 0, Include a list of these
stations on the next line (maximum of 20). Stations must be
listed in ascending order.
    >>>>start ZTARGET list
    <<<<end list

```

```

*****AERODYNAMIC DATA*****
() AREF Reference area used in calculating force and moment coefficients.
() XLREF Reference length used in calculating moment coefficients and
center-of-pressure.
() IEFORCE 0, 1 don't, do print force and moments for individual edges.

```

```

*****SEPARATION MODELING*****
() IVIS 0,1,2 for no modeling, clipping, and forced separation. Clipping
and forced separation can only be used in conjunction with
cylindrical coordinates. If IVIS = 2, specify the number of
separation lines (NSEP).
    >>>> NSEP
    <<<<
For each separation line specify:
ISSIDE - 0 separation line located between 0 and 180 degrees,
        1 separation line located between 180 and 360 degrees.
ISEP - number of points used to define the separation line.
ZSSEP - Zeta value at which separation is started
ZESSEP - Zeta value at which separation is terminated
PHICD - separation angle phiC (degrees)
PHIAD - separation angle phiA (degrees)
BETACD - separation angle BetaC (degrees)
BETAAD - separation angle BetaA (degrees)
    >>>> [ISSIDE,ISEP,ZSSEP,ZESSEP,PHICD,PHIAD,BETACD,BETAAD]
    <<<<

```

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A list of ISEP pairs of points (ZEPZ,ZEPP) describing the zeta and phi coordinates of the separation line. This list should start at the most forward section and move aft. Start the list for each separation line on a separate line and list in same order as used in the above data.

>>>> start list of ZEPZ,ZEPP
<<<<

*****GAS TYPE*****

() IGAS 0-perfect gas; 1-equilibrium air

*****UNITS *****

() IUNITS 0-english (p=lbf/ft**2, rho=slug/ft**3, t=rankine, xyz=ft);
1-metric (p=n/m**2, rho=kg/m**3, t=kelvin, xyz=m).
All input units must be consistant. Output units are the same.

*****INITIAL DATA*****

() IMOD 0,1 for new start or restart respectively. For a restart, the initial flow field is read from TAPE3. Additional information is not needed and the remaining entries in this section should be disregarded. A new start assumes a uniform flow field which is described in the following section.

---Mesh Size---

() IZN Number of zones.
() NA Number of cells in xi direction (i.e., between edges 1 and 3)
() MA Number of cells in eta direction (i.e., between edge 4 of zone 1 and edge2 of zone IZN)

List the number of M planes in each zone, starting from zone 1 and ending at zone MA.

>>>>Start list of MA for each zone
<<<<end list

---Flow Properties---

() ZETA Zeta coordinate of initial data plane
() ALPHA Angle of attack (degrees)
() BETA Angle of yaw (degrees)
() XMINF Mach number
() PINF Pressure
() DINF Density

---Problem Definition---

PROBLEM DEFINITION

() ICORD 0,1,2 for cartesian, cylindrical or elliptic coordinates
() IASYM 0 - no pitch plane symmetry; 1 - pitch plane symmetry.
() ISHOCK Set to 1 if edge 3 is to be fitted by the calculation (either as a shock or sonic line); otherwise set to 0.
ISHOCK = 1 is only valid for ICORD =1 or 2. If edge 3 is to be fitted, the r and phi (cylindrical coordinates) or s, tau (elliptic coordinates) of the shock location on each M plane, (SS, SS2) must be defined, starting from M = 1, etc.,

>>>>Start list of [SS,SS2]
>>>>End list

*****MESH DEFINITION*****

() IMESH 0 for uniform mesh in xi direction. 1 for clustered mesh. If

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a clustered mesh is to be used, the clustering function (FN) in the xi direction at the NA cell centers must be defined starting at cell 1, located adjacent to edge 1 and moving to edge 3 (usually body to shock).

>>>>>start list of FN

>>>>>end list

- () IMESHG 0 for uniform mesh in eta direction. 1 for clustered mesh. If a clustered mesh is to be used, the clustering function (GN) in the eta direction at the MA(i) cell centers in each zone must be defined, starting with zone 1 and ending with zone IZN. Start with cell 1, located adjacent to edge 4, and end at the cell adjacent to edge 2. The list for each zone should be started on a new card

>>>>>>start list GN

end list<<<<<<

APPENDIX B

SAMPLE CASE OUTPUT

B.1 HYPERSONIC SHARP CONE

B.1.1 ZEUS Output — II

```

1      P R O G R A M   Z E U S

**** INTEGRATION CONTROL ****
ICORD  =      1      (0-CARTESIAN, 1-CYLINDRICAL COORDINATES)
ZETA   =      0.10000 (INITIAL ZETA)
ZETAEND =     50.00000 (MAXIMUM ZETA)
KSTART =      0      (INITIAL STEP NUMBER)
KEND   =     5000     (MAXIMUM STEP NUMBER)
FCFL   =      0.90000 (CFL SAFETY FACTOR)
XKI    =     1.000000 (INTERIOR POINT LIMITER)
IAPR   =      0      (0-APPROXIMATE RIEMANN PROBLEM
                     1-COMplete RIEMANN PROBLEM)
ISHFLUX =      0      (FLUX AT SHOCK- 0-RIEMANN PROBLEM
                     1-FREESTREAM PROPERTIES)
ISHANG  =      1      (SHOCK ANGLE - 0-RIEMANN PROBLEM
                     1-ROE AVERAGED VARIABLES)

**** BOUNDARY CONDITIONS ****
NXKE   =      0      (NUMBER OF EDGES WITH NON-DEFAULT LIMITER SETTINGS)
NSUR   =      0      (NUMBER OF EDGES WITH NON-DEFAULT SURFACE TYPE)
DFAC   =      0.9000 (REDUCE TURNS WHICH ARE TOO LARGE BY DFAC)
ISHOCK =      1      (1-SHOCK, 0-NO SHOCK ON EDGE 3)
IASYM  =      1      (0-NO SYMMETRY, 1-PITCH PLANE SYMMETRY)

SURFACE POINT LIMITER
ZONE   EDGE 1   EDGE 2   EDGE 3   EDGE 4
1      2.000   0.000   0.000   0.000

SURFACE TYPE
ZONE   EDGE 1   EDGE 2   EDGE 3   EDGE 4
1      1       0       1       0

**** OUTPUT CONTROL ****
PRINTER (file 6)
IPRINT =     250     (PRINT FLOW FIELD IF STEP NUMBER IS EVENLY DIVISIBLE BY IPRINT)
ISKIP  =      10     (PRINT STEP SIZE IF STEP NUMBER IS EVENLY DIVISIBLE BY ISKIP)
NSKIP  =      3      (PRINT N PLANES WHICH ARE EVENLY DIVISIBLE BY NSKIP)
MSKIP  =      6      (PRINT M PLANES WHICH ARE EVENLY DIVISIBLE BY MSKIP)

```

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PRESSURE SUMMARY (PLOTZA)
 KSKIP = 50 (PRINT SURFACE PRESSURE IF STEP NUMBER IS EVENLY DIVISIBLE BY KSKIP)
 NPRT = 100 (DON'T PRINT POINTS IF N>NPRT)
 DELZA = 10000.000 (PRINT SURFACE PRESSURE EVERY ZETA = DELZA)
 JSPPR = 0 (NUMBER OF NON-DEFAULT EDGES)
 JSPDIS = 0 (PRINT SURFACE GRID POINT LOCATIONS)
 SURFACE PRESSURE OUTPUT CONTROL: 0-DON'T PRINT, 1-PRINT.
 ZONE EDGE 1 EDGE 2 EDGE 3 EDGE 4
 1 1 0 0 0

PLOT FILE (PLOT2C)
 IPLOT = 10000 WRITE TO PLOT2C IF STEP NUMBER IS EVENLY DIVISIBLE BY IPLOT
 DEL2C = 10000.000 (WRITE PLOT TAPE EVERY ZETA = DEL2C).
 IPLOTN = 0 NUMBER OF TARGET PLOT STATIONS

*****AERODYNAMICS DATA*****
 AREF = 1.0000 (REFERENCE AREA)
 ALREF = 1.0000 (REFERENCE LENGTH)
 IEFORCE = 0 (0 - DONT:1 - DO PRINT EDGE LOADS)

*****SEPARATION MODELING*****
 IVIS = 0 (0 - INVISCID, 1 - CLIPPING, 2 - FORCED SEPARATION)

*****GAS TYPE*****
 IGAS = 1 (0-PERFECT, 1-EQUILIBRIUM AIR)

*****UNITS*****
 IUNITS = 1 (0-ENGLISH, 1-METRIC)

0 ***** INITIAL DATA PLANE *****
 IMOD = 0 (0 SELF START:1 FROM TAPE START)
 MACH = 20.0000 (FREE-STREAM MACH NUMBER)
 ALPHA = 20.0000 (ANGLE OF ATTACK)
 BETA = 0.0000 (YAW ANGLE)
 PINF = 1185.5000 (FREE-STREAM PRESSURE)
 DINF = 1.7861E-02 (FREE-STREAM DENSITY)
 HO = 1.7269E+12 (STAGNATION ENTHALPY)
 SINP = 0.0000 (FREE-STREAM ENTROPY)
 IZN = 1 (NUMBER OF ZONES)
 NA = 18 (CELLS BETWEEN EDGES 1 AND 3)
 MA = 36 (TOTAL CELLS BETWEEN EDGES 2 AND 4)
 MA/ZONE: 36
 IMESH1 = 0 (0-UNIFORM MESH, 1-CLUSTERED MESH
 BETWEEN EDGES 1 AND 3)
 IMESH2 = 0 (0-UNIFORM, 1-CLUSTERED MESH
 BETWEEN EDGES 2 AND 4)

1 STEP = 0 ZETA = 1.0000000E+01 DZETA = 0.0000000E+00
 MACH NO. = 2.0000000E+01 ALPHA = 2.0000000E+01 BETA = 0.0000000E+00

0 ZONE NO. 1

CELL PLANE M = 1
 C = 3.0000001E-01 CZ = -3.1076.36E-01 CT = 0.0000000E+00 VX = 9.99048233E-01 4.36193906E-02 0.00000000E+00 ISUR 3
 B = 4.6630766E-02 BZ = 4.6630764E-01 BT = 0.0000000E+00 VY = 0.00000000E+00 0.00000000E+00 0.00000000E+00 ISUR 1

N	S	T	P	D	U	V	M	E	M
10.5	2.929620E-01	4.363323E-02	1.185500E+03	1.786100E-02	2.079097E+03	-9.077533E-01	5.717713E+03	7.007000E-03	2.027047E+01
16.5	2.648090E-01	4.363323E-02	1.185500E+03	1.786100E-02	2.079097E+03	-9.077533E-01	5.717713E+03	7.007000E-03	2.027047E+01
13.5	2.225816E-01	4.363323E-02	1.185500E+03	1.786100E-02	2.079097E+03	-9.077533E-01	5.717713E+03	7.007000E-03	2.027047E+01
10.5	1.803534E-01	4.363323E-02	1.185500E+03	1.786100E-02	2.079097E+03	-9.077533E-01	5.717713E+03	7.007000E-03	2.027047E+01
7.5	1.381252E-01	4.363323E-02	1.185500E+03	1.786100E-02	2.079097E+03	-9.077533E-01	5.717713E+03	7.007000E-03	2.027047E+01
4.5	9.589700E-02	4.363323E-02	1.185500E+03	1.786100E-02	2.079097E+03	-9.077533E-01	5.717713E+03	7.007000E-03	2.027047E+01
1.5	5.366880E-02	4.363323E-02	1.185500E+03	1.786100E-02	2.079097E+03	-9.077533E-01	5.717713E+03	7.007000E-03	2.027047E+01

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CELL PLANE M = 12

C = 3.0000001E-01 C2 = -3.1076136E-01 CT = 0.0000000E+00 VX = 5.37299573E-01 8.43391478E-01 0.0000000E+00 ISUR 3
B = 4.6630766E-02 B2 = 4.6630764E-01 BT = 0.0000000E+00 VX = 0.0000000E+00 0.0000000E+00 0.0000000E+00 ISUR 1

N	S	T	P	D	U	V	W	E	M
18.5	2.929620E-01	1.003564E+00	1.185500E+03	1.786100E-02	1.118162E+03	-1.755163E+03	5.717713E+03	7.887008E+03	2.027047E+01
16.5	2.648098E-01	1.003564E+00	1.185500E+03	1.786100E-02	1.118162E+03	-1.755163E+03	5.717713E+03	7.887008E+03	2.027047E+01
13.5	2.225816E-01	1.003564E+00	1.185500E+03	1.786100E-02	1.118162E+03	-1.755163E+03	5.717713E+03	7.887008E+03	2.027047E+01
10.5	1.803534E-01	1.003564E+00	1.185500E+03	1.786100E-02	1.118162E+03	-1.755163E+03	5.717713E+03	7.887008E+03	2.027047E+01
7.5	1.381252E-01	1.003564E+00	1.185500E+03	1.786100E-02	1.118162E+03	-1.755163E+03	5.717713E+03	7.887008E+03	2.027047E+01
4.5	9.589700E-02	1.003564E+00	1.185500E+03	1.786100E-02	1.118162E+03	-1.755163E+03	5.717713E+03	7.887008E+03	2.027047E+01
1.5	5.366880E-02	1.003564E+00	1.185500E+03	1.786100E-02	1.118162E+03	-1.755163E+03	5.717713E+03	7.887008E+03	2.027047E+01

CELL PLANE M = 24

C = 3.0000001E-01 C2 = -3.1076136E-01 CT = 0.0000000E+00 VX = -4.61748660E-01 8.87010813E-01 0.0000000E+00 ISUR 3
B = 4.6630766E-02 B2 = 4.6630764E-01 BT = 0.0000000E+00 VX = 0.0000000E+00 0.0000000E+00 0.0000000E+00 ISUR 1

N	S	T	P	D	U	V	W	E	M
18.5	2.929620E-01	2.050762E+00	1.185500E+03	1.786100E-02	-9.609347E-02	-1.845938E+03	5.717713E+03	7.887008E+03	2.027047E+01
16.5	2.648098E-01	2.050762E+00	1.185500E+03	1.786100E-02	-9.609347E-02	-1.845938E+03	5.717713E+03	7.887008E+03	2.027047E+01
13.5	2.225816E-01	2.050762E+00	1.185500E+03	1.786100E-02	-9.609347E-02	-1.845938E+03	5.717713E+03	7.887008E+03	2.027047E+01
10.5	1.803534E-01	2.050762E+00	1.185500E+03	1.786100E-02	-9.609347E-02	-1.845938E+03	5.717713E+03	7.887008E+03	2.027047E+01
7.5	1.381252E-01	2.050762E+00	1.185500E+03	1.786100E-02	-9.609347E-02	-1.845938E+03	5.717713E+03	7.887008E+03	2.027047E+01
4.5	9.589700E-02	2.050762E+00	1.185500E+03	1.786100E-02	-9.609347E-02	-1.845938E+03	5.717713E+03	7.887008E+03	2.027047E+01
1.5	5.366880E-02	2.050762E+00	1.185500E+03	1.786100E-02	-9.609347E-02	-1.845938E+03	5.717713E+03	7.887008E+03	2.027047E+01

CELL PLANE M = 36

C = 3.0000001E-01 C2 = -3.1076136E-01 CT = 0.0000000E+00 VX = -9.99048233E-01 4.36192900E-02 0.0000000E+00 ISUR 3
B = 4.6630766E-02 B2 = 4.6630764E-01 BT = 0.0000000E+00 VX = 0.0000000E+00 0.0000000E+00 0.0000000E+00 ISUR 1

N	S	T	P	D	U	V	W	E	M
18.5	2.929620E-01	3.097960E+00	1.185500E+03	1.786100E-02	-2.079097E+03	-9.077512E+01	5.717713E+03	7.887008E+03	2.027047E+01
16.5	2.648098E-01	3.097960E+00	1.185500E+03	1.786100E-02	-2.079097E+03	-9.077512E+01	5.717713E+03	7.887008E+03	2.027047E+01
13.5	2.225816E-01	3.097960E+00	1.185500E+03	1.786100E-02	-2.079097E+03	-9.077512E+01	5.717713E+03	7.887008E+03	2.027047E+01
10.5	1.803534E-01	3.097960E+00	1.185500E+03	1.786100E-02	-2.079097E+03	-9.077512E+01	5.717713E+03	7.887008E+03	2.027047E+01
7.5	1.381252E-01	3.097960E+00	1.185500E+03	1.786100E-02	-2.079097E+03	-9.077512E+01	5.717713E+03	7.887008E+03	2.027047E+01
4.5	9.589700E-02	3.097960E+00	1.185500E+03	1.786100E-02	-2.079097E+03	-9.077512E+01	5.717713E+03	7.887008E+03	2.027047E+01
1.5	5.366880E-02	3.097960E+00	1.185500E+03	1.786100E-02	-2.079097E+03	-9.077512E+01	5.717713E+03	7.887008E+03	2.027047E+01

OSTEP	ZETA	DZETA	NCFL	MCFL
10	1.66340232E-01	7.32434215E-03	1	27
20	2.46382982E-01	7.83461425E-03	2	32
30	3.14146966E-01	5.60534699E-03	3	34
40	3.61406982E-01	3.79312504E-03	5	34
50	3.89135122E-01	1.99062913E-03	9	36
60	4.02772427E-01	1.00138236E-03	16	36
70	4.14162219E-01	1.27577584E-03	14	30
80	4.27247405E-01	1.31077075E-03	15	28
90	4.42338258E-01	1.54344493E-03	15	26
100	4.59667981E-01	1.76806981E-03	5	35
500	2.12085581E+00	7.79856928E-03	1	35
510	2.20042610E+00	8.08693748E-03	1	35
520	2.28293014E+00	8.38514324E-03	1	35
530	2.36848688E+00	8.69592931E-03	1	35
540	2.45721507E+00	9.02224984E-03	1	35
550	2.54922724E+00	9.35304537E-03	1	35
1000	1.32442169E+01	4.83423956E-02	1	35
1010	1.37375603E+01	5.01389466E-02	1	35
1020	1.42492847E+01	5.20309620E-02	1	35
1030	1.47800245E+01	5.39502650E-02	1	35
1040	1.53305435E+01	5.59661500E-02	1	35
1050	1.59015741E+01	5.80477230E-02	1	35
1300	3.96720963E+01	1.44775480E-01	1	35
1310	4.11496048E+01	1.50181472E-01	1	35
1320	4.26822090E+01	1.55758888E-01	1	35
1330	4.42718430E+01	1.61552802E-01	1	35
1340	4.59206314E+01	1.67567953E-01	1	35
1350	4.76309128E+01	1.73890367E-01	1	35
1360	4.94047623E+01	1.80341914E-01	1	35

1
MACH NO. = 1364 ZETA = 5.0000000E+01 DZETA = 5.0300598E-02
ALPHA = 2.0000000E-01 BETA = 0.0000000E+00

0
0
0
ZONE NO. 1

LEFT EDGE PLANE GEOMETRY

N	X	Y	SG	SG2	SGS	VE1	VE2	VE3	ISUR
18.5	2.536409E-01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	5.885727E-03	0.000000E+00	0
16.5	2.512995E-01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	5.885727E-03	0.000000E+00	0
13.5	2.477875E-01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	5.885679E-03	0.000000E+00	0
10.5	2.442754E-01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	5.885727E-03	0.000000E+00	0
7.5	2.407633E-01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	5.885727E-03	0.000000E+00	0
4.5	2.372512E-01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	5.885727E-03	0.000000E+00	0
1.5	2.337392E-01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	5.885727E-03	0.000000E+00	0

0
0
LEFT EDGE PLANE CEF = 2.5422626E-01 BEF = 2.3315382E-01

N	S	T	P	D	U	V	W	E	M
18.5	2.536409E-01	0.000000E+00	7.529634E+03	5.602545E-02	2.518240E+03	0.000000E+00	5.495166E-03	8.065181E-03	1.402778E+01
16.5	2.512995E-01	0.000000E+00	7.736206E+03	5.708840E-02	2.522448E+03	0.000000E+00	5.492869E-03	8.065892E-03	1.397147E+01
13.5	2.477875E-01	0.000000E+00	7.635601E+03	5.796134E-02	2.517731E+03	0.000000E+00	5.497313E-03	8.040668E-03	1.417292E+01
10.5	2.442754E-01	0.000000E+00	7.555978E+03	5.702781E-02	2.502159E+03	0.000000E+00	5.501538E-03	8.049583E-03	1.412739E+01
7.5	2.407633E-01	0.000000E+00	7.490213E+03	5.923714E-02	2.506906E+03	0.000000E+00	5.510096E-03	8.040421E-03	1.408658E+01
4.5	2.372512E-01	0.000000E+00	7.489551E+03	5.776165E-02	2.522607E+03	0.000000E+00	5.517053E-03	8.029995E-03	1.433513E+01
1.5	2.337392E-01	0.000000E+00	7.561136E+03	5.035129E-02	2.551719E+03	0.000000E+00	5.518031E-03	8.095816E-03	1.389353E+01

NAVSVC TR 91-86

CELL PLANE M = 1

C = 2.542262E-01 CZ = 5.080894E-01 CT = 3.2884135E+00 VX = 1.12653807E-01 -9.50830709E-03 -5.72629124E-02 ISUR 3
B = 2.3315382E+01 BZ = 4.6630764E-01 BT = 0.0000000E+00 VX = 1.02162898E-01 4.46052663E-03 -4.76371348E-02 ISUR 1

N	S	T	P	D	U	V	W	E	M
19.0	2.542262E+01	4.363323E-02	1.185500E+03	1.786100E-02	2.079097E+03	-9.077533E+01	5.717713E+03	7.887008E+03	2.027047E+01
18.5	2.536409E+01	4.363323E-02	7.529713E+03	5.602494E-02	2.515650E+03	-1.439398E+02	5.495166E+03	8.065197E+03	1.402926E+01
16.5	2.512995E+01	4.363323E-02	7.736723E+03	5.708947E-02	2.520995E+03	-1.409128E+02	5.492065E+03	8.065921E+03	1.397012E+01
13.5	2.477875E+01	4.363323E-02	7.636763E+03	5.638063E-02	2.514873E+03	-1.327365E+02	5.495119E+03	8.069142E+03	1.397467E+01
10.5	2.442754E+01	4.363323E-02	7.556172E+03	5.534533E-02	2.509848E+03	-1.236716E+02	5.496924E+03	8.080334E+03	1.391816E+01
7.5	2.407633E+01	4.363323E-02	7.490260E+03	5.475292E-02	2.510205E+03	-1.111874E+02	5.496849E+03	8.084900E+03	1.390301E+01
4.5	2.372512E+01	4.363323E-02	7.480650E+03	5.335860E-02	2.521093E+03	-8.984129E+01	5.490033E+03	7.988110E+03	1.457410E+01
1.5	2.337392E+01	4.363323E-02	7.515809E+03	4.711765E-02	2.540626E+03	-7.808256E+01	5.468434E+03	8.192176E+03	1.316598E+01
1.0	2.331538E+01	4.363323E-02	7.524885E+03	4.558864E-02	2.544866E+03	-7.793466E+01	5.462936E+03	8.243973E+03	1.283707E+01

CELL PLANE M = 12

C = 2.7497099E+01 CZ = 5.4949588E-01 CT = -1.8066899E+00 VX = 5.81143498E-02 1.05959825E-01 -6.62183762E-02 ISUR 3
B = 2.3315382E+01 BZ = 4.6630764E-01 BT = 0.0000000E+00 VX = 5.49443252E-02 8.62453654E-02 -4.76394892E-02 ISUR 1

N	S	T	P	D	U	V	W	E	M
19.0	2.749710E+01	1.003564E+00	1.185500E+03	1.786100E-02	1.118162E+03	-1.755163E+03	5.717713E+03	7.887008E+03	2.027047E+01
18.5	2.738094E+01	1.003564E+00	5.095232E+04	9.814434E-02	2.461871E+03	-1.620774E+03	4.976275E+03	9.182064E+03	6.841063E+00
16.5	2.691631E+01	1.003564E+00	4.870170E+04	9.022895E-02	2.450539E+03	-1.571799E+03	4.979076E+03	9.239487E+03	6.734838E+00
13.5	2.621935E+01	1.003564E+00	4.401868E+04	7.431101E-02	2.405281E+03	-1.468554E+03	4.984081E+03	9.378059E+03	6.485871E+00
10.5	2.552240E+01	1.003564E+00	4.066099E+04	6.220262E-02	2.362587E+03	-1.360251E+03	4.974688E+03	9.525863E+03	6.219797E+00
7.5	2.482545E+01	1.003564E+00	3.830177E+04	5.270589E-02	2.318820E+03	-1.247093E+03	4.942063E+03	9.699641E+03	5.912765E+00
4.5	2.412849E+01	1.003564E+00	3.661623E+04	4.465511E-02	2.263812E+03	-1.126602E+03	4.859703E+03	9.943349E+03	5.510729E+00
1.5	2.343154E+01	1.003564E+00	3.557748E+04	3.702518E-02	2.177514E+03	-1.005357E+03	4.676496E+03	1.031587E+04	4.977870E+00
1.0	2.331538E+01	1.003564E+00	3.540671E+04	3.575058E-02	2.159746E+03	-9.831878E+02	4.635984E+03	1.039148E+04	4.882626E+00

CELL PLANE M = 24

C = 2.5741262E+01 CZ = 5.1437604E-01 CT = -8.7557318E-01 VX = -5.55456318E-02 9.83904079E-02 -5.80633879E-02 ISUR 3
B = 2.3315382E+01 BZ = 4.6630764E-01 BT = 0.0000000E+00 VX = -4.72184531E-02 9.07058865E-02 -4.76386547E-02 ISUR 1

N	S	T	P	D	U	V	W	E	M
19.0	2.574126E+01	2.050762E+00	1.185500E+03	1.786100E-02	-9.609347E-02	-1.845938E+03	5.717713E+03	7.887008E+03	2.027047E+01
18.5	2.567388E+01	2.050762E+00	1.781103E+05	1.476145E-01	1.738169E+03	-1.709724E+03	4.283757E+03	1.028196E+04	4.047510E+00
16.5	2.540434E+01	2.050762E+00	2.019468E+05	1.246489E-01	1.853366E+03	-1.633532E+03	4.191143E+03	1.031568E+04	3.925658E+00
13.5	2.500002E+01	2.050762E+00	1.974213E+05	1.557487E-01	1.855684E+03	-1.491412E+03	4.182808E+03	1.037886E+04	3.838576E+00
10.5	2.459571E+01	2.050762E+00	1.941177E+05	1.489927E-01	1.858733E+03	-1.333302E+03	4.157729E+03	1.045551E+04	3.729883E+00
7.5	2.419139E+01	2.050762E+00	1.916110E+05	1.408848E-01	1.863031E+03	-1.158393E+03	4.118698E+03	1.054066E+04	3.608327E+00
4.5	2.378708E+01	2.050762E+00	1.898341E+05	1.307118E-01	1.860083E+03	-9.694445E+02	4.059790E+03	1.063963E+04	3.467702E+00
1.5	2.338277E+01	2.050762E+00	1.886289E+05	1.214036E-01	1.846912E+03	-7.718042E+02	3.974862E+03	1.075421E+04	3.305039E+00
1.0	2.331538E+01	2.050762E+00	1.884866E+05	1.199857E-01	1.843947E+03	-7.381380E+02	3.958180E+03	1.077506E+04	3.276075E+00

CELL PLANE M = 36

C = 2.5460409E+01 CZ = 5.0951618E-01 CT = 1.6851434E-02 VX = -1.11555427E-01 4.94450005E-03 -5.6856215CE-02 ISUR 3
B = 2.3315382E+01 BZ = 4.6630764E-01 BT = 0.0000000E+00 VX = -1.02162883E-01 4.46052663E-03 -4.76371348E-02 ISUR 1

N	S	T	P	D	U	V	W	E	M
19.0	2.546041E+01	3.097960E+00	1.185500E+03	1.786100E-02	-2.079097E+03	-9.077512E+01	5.717713E+03	7.887008E+03	2.027047E+01
18.5	2.540083E+01	3.097960E+00	2.826340E+05	1.583696E-01	1.354601E+03	-8.783905E+01	3.891533E+03	1.090033E+04	2.891081E+00
16.5	2.516249E+01	3.097960E+00	3.143388E+05	1.809442E-01	1.525436E+03	-8.345345E+01	3.752207E+03	1.090203E+04	2.806446E+00
13.5	2.480499E+01	3.097960E+00	3.339543E+05	1.820482E-01	1.559446E+03	-7.420601E+01	3.731489E+03	1.090281E+04	2.801837E+00
10.5	2.444748E+01	3.097960E+00	3.358455E+05	1.828575E-01	1.596512E+03	-6.469098E+01	3.712040E+03	1.090362E+04	2.797826E+00
7.5	2.408998E+01	3.097960E+00	3.371473E+05	1.832652E-01	1.631025E+03	-5.556303E+01	3.691342E+03	1.090629E+04	2.791395E+00
4.5	2.373247E+01	3.097960E+00	3.379689E+05	1.833719E-01	1.663145E+03	-4.636639E+01	3.670344E+03	1.091007E+04	2.785327E+00
1.5	2.337497E+01	3.097960E+00	3.383808E+05	1.840850E-01	1.700140E+03	-3.665276E+01	3.663723E+03	1.090272E+04	2.795253E+00
1.0	2.331538E+01	3.097960E+00	3.384338E+05	1.842610E-01	1.706701E+03	-3.497089E+01	3.663687E+03	1.090061E+04	2.797570E+00

RIGHT EDGE PLANE CEF = 2.5460409E+01 BEF = 2.3315382E+01

N	S	T	P	D	U	V	W	E	M
19.0	2.540083E+01	3.141593E+00	2.831531E+05	1.584500E-01	1.359465E+03	-1.188552E-04	3.889310E+03	1.090287E+04	2.888619E+00
18.5	2.516249E+01	3.141593E+00	3.200278E+05	1.810446E-01	1.525419E+03	-1.133642E-04	3.749913E+03	1.090430E+04	2.804468E+00
16.5	2.480499E+01	3.141593E+00	3.345346E+05	1.821877E-01	1.564752E+03	-1.1368030E-04	3.729273E+03	1.090459E+04	2.799585E+00
13.5	2.444748E+01	3.141593E+00	3.363885E+05	1.830209E-01	1.601616E+03	-1.400259E-04	3.710251E+03	1.090482E+04	2.796546E+00
10.5	2.408998E+01	3.141593E+00	3.376875E+05	1.834504E-01	1.635668E+03	-1.430030E-04	3.689932E+03	1.090714E+04	2.791149E+00
7.5	2.373247E+01	3.141593E+00	3.384210E+05	1.835633E-01	1.667296E+03	-1.457682E-04	3.669750E+03	1.091027E+04	2.785576E+00
1.5	2.337497E+01	3.141593E+00	3.388041E+05	1.842960E-01	1.703438E+03	-1.489280E-04	3.663629E+03	1.090246E+04	2.795472E+00

RIGHT EDGE PLANE GEOMETRY

N	X	Y	TH	TH2	TH3	VE1	VE2	VE3	ISUR
18.5	2.540083E+01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	5.237989E-10	-5.991213E-03	-9.936496E-15	0
16.5	2.516249E+01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	5.237989E-10	-5.991166E-03	-1.720846E-15	0
13.5	2.480499E+01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	5.237989E-10	-5.991213E-03	1.115774E-14	0
10.5	2.444748E+01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	5.237989E-10	-5.991213E-03	-2.525757E-14	0
7.5	2.408998E+01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	5.237989E-10	-5.991166E-03	-4.662937E-15	0
4.5	2.373247E+01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	5.237989E-10	-5.991213E-03	-2.442491E-15	0
1.5	2.337497E+01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	5.237932E-10	-5.991166E-03	1.809664E-14	0

1 ZONE = 1 EDGE = 1 MACH NO. = 20.000 ANGLE OF ATTACK = 20.000 YAW ANGLE = 0.000

SURFACE PRESSURES

OSTEP	ZETA	1	2	3	4	5	6	7	8	9	10
1	0.104	8.366E+035	8.703E+035	9.399E+035	1.050E+045	1.206E+045	1.417E+045	1.692E+045	2.040E+045	2.473E+045	3.001E+045
100	0.459	7.342E+035	7.854E+035	9.040E+035	1.042E+045	1.343E+045	1.205E+045	1.386E+045	1.669E+045	1.971E+045	2.202E+045
200	0.683	1.075E+045	9.332E+035	7.550E+035	7.318E+035	9.424E+035	1.082E+045	1.277E+045	1.533E+045	1.822E+045	2.227E+045
300	1.005	7.656E+035	7.094E+035	7.061E+035	7.741E+035	8.610E+035	1.025E+045	1.247E+045	1.494E+045	1.843E+045	2.384E+045
400	1.463	8.009E+035	7.186E+035	6.967E+035	7.554E+035	8.802E+035	1.091E+045	1.382E+045	1.701E+045	1.994E+045	2.418E+045
500	2.117	7.964E+035	6.826E+035	7.017E+035	8.252E+035	9.732E+035	1.114E+045	1.330E+045	1.612E+045	1.963E+045	2.388E+045
600	3.057	8.278E+035	7.099E+035	7.498E+035	8.132E+035	9.089E+035	1.093E+045	1.321E+045	1.608E+045	1.949E+045	2.395E+045
700	4.411	8.031E+035	7.451E+035	7.294E+035	7.879E+035	9.084E+035	1.087E+045	1.328E+045	1.605E+045	1.955E+045	2.398E+045
800	6.361	7.666E+035	7.419E+035	7.213E+035	7.896E+035	9.167E+035	1.084E+045	1.328E+045	1.611E+045	1.955E+045	2.398E+045

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900	9.170	7.603E+03S	7.350E+03S	7.172E+03S	7.905E+03S	9.099E+03S	1.090E+04S	1.320E+04S	1.611E+04S	1.957E+04S	2.401E+04S
1000	13.220	7.604E+03S	7.242E+03S	7.167E+03S	7.961E+03S	9.073E+03S	1.092E+04S	1.327E+04S	1.614E+04S	1.955E+04S	2.402E+04S
1100	19.057	7.577E+03S	7.244E+03S	7.167E+03S	7.963E+03S	9.092E+03S	1.090E+04S	1.329E+04S	1.613E+04S	1.957E+04S	2.401E+04S
1200	27.471	7.531E+03S	7.250E+03S	7.157E+03S	7.969E+03S	9.100E+03S	1.089E+04S	1.330E+04S	1.612E+04S	1.958E+04S	2.401E+04S
1300	39.600	7.539E+03S	7.239E+03S	7.155E+03S	7.979E+03S	9.098E+03S	1.090E+04S	1.330E+04S	1.612E+04S	1.959E+04S	2.400E+04S
1364	49.975	7.525E+03S	7.240E+03S	7.148E+03S	7.968E+03S	9.089E+03S	1.091E+04S	1.330E+04S	1.612E+04S	1.958E+04S	2.401E+04S

1 ZONE = 1 EDGE = 1 MACH NO. = 20.000 ANGLE OF ATTACK = 20.000 YAW ANGLE = 0.000

S U R F A C E P R E S S U R E S

OSTEP	ZETA	11	12	13	14	15	16	17	18	19	20
1	0.104	3.635E+04S	4.382E+04S	5.250E+04S	6.245E+04S	7.362E+04S	8.598E+04S	9.933E+04S	1.137E+05S	1.292E+05S	1.455E+05S
100	0.459	2.470E+04S	3.255E+04S	3.952E+04S	4.697E+04S	5.498E+04S	6.231E+04S	7.014E+04S	8.043E+04S	9.274E+04S	1.074E+05S
200	0.683	2.730E+04S	3.317E+04S	4.000E+04S	4.735E+04S	5.626E+04S	6.942E+04S	8.630E+04S	9.739E+04S	1.089E+05S	1.229E+05S
300	1.005	3.071E+04S	3.694E+04S	4.320E+04S	5.100E+04S	5.971E+04S	6.968E+04S	8.109E+04S	9.362E+04S	1.072E+05S	1.219E+05S
400	1.463	2.919E+04S	3.529E+04S	4.239E+04S	5.053E+04S	5.976E+04S	6.994E+04S	8.118E+04S	9.353E+04S	1.070E+05S	1.222E+05S
500	2.117	2.911E+04S	3.525E+04S	4.248E+04S	5.070E+04S	5.986E+04S	6.995E+04S	8.111E+04S	9.354E+04S	1.073E+05S	1.224E+05S
600	3.057	2.912E+04S	3.533E+04S	4.255E+04S	5.075E+04S	5.984E+04S	6.992E+04S	8.116E+04S	9.363E+04S	1.073E+05S	1.223E+05S
700	4.411	2.917E+04S	3.536E+04S	4.257E+04S	5.073E+04S	5.985E+04S	6.995E+04S	8.123E+04S	9.364E+04S	1.073E+05S	1.222E+05S
800	6.361	2.917E+04S	3.537E+04S	4.258E+04S	5.074E+04S	5.988E+04S	6.997E+04S	8.122E+04S	9.365E+04S	1.073E+05S	1.222E+05S
900	9.170	2.921E+04S	3.537E+04S	4.259E+04S	5.075E+04S	5.988E+04S	6.996E+04S	8.123E+04S	9.366E+04S	1.073E+05S	1.221E+05S
1000	13.220	2.921E+04S	3.539E+04S	4.258E+04S	5.076E+04S	5.988E+04S	6.996E+04S	8.122E+04S	9.366E+04S	1.073E+05S	1.221E+05S
1100	19.057	2.920E+04S	3.540E+04S	4.259E+04S	5.077E+04S	5.987E+04S	6.997E+04S	8.120E+04S	9.368E+04S	1.073E+05S	1.222E+05S
1200	27.471	2.922E+04S	3.540E+04S	4.259E+04S	5.076E+04S	5.987E+04S	6.996E+04S	8.121E+04S	9.368E+04S	1.073E+05S	1.222E+05S
1300	39.600	2.922E+04S	3.540E+04S	4.258E+04S	5.076E+04S	5.987E+04S	6.996E+04S	8.120E+04S	9.367E+04S	1.073E+05S	1.222E+05S
1364	49.975	2.918E+04S	3.541E+04S	4.257E+04S	5.076E+04S	5.986E+04S	6.996E+04S	8.120E+04S	9.368E+04S	1.073E+05S	1.221E+05S

1 ZONE = 1 EDGE = 1 MACH NO. = 20.000 ANGLE OF ATTACK = 20.000 YAW ANGLE = 0.000

S U R F A C E P R E S S U R E S

OSTEP	ZETA	21	22	23	24	25	26	27	28	29	30
1	0.104	1.628E+05S	1.807E+05S	1.990E+05S	2.175E+05S	2.358E+05S	2.547E+05S	2.737E+05S	2.914E+05S	3.078E+05S	3.228E+05S
100	0.459	1.245E+05S	1.440E+05S	1.633E+05S	1.843E+05S	2.035E+05S	2.224E+05S	2.415E+05S	2.639E+05S	2.826E+05S	3.098E+05S
200	0.683	1.382E+05S	1.545E+05S	1.711E+05S	1.882E+05S	2.051E+05S	2.219E+05S	2.393E+05S	2.571E+05S	2.739E+05S	2.891E+05S
300	1.005	1.386E+05S	1.557E+05S	1.721E+05S	1.885E+05S	2.052E+05S	2.221E+05S	2.394E+05S	2.568E+05S	2.732E+05S	2.883E+05S
400	1.463	1.387E+05S	1.555E+05S	1.719E+05S	1.885E+05S	2.052E+05S	2.221E+05S	2.394E+05S	2.568E+05S	2.733E+05S	2.883E+05S
500	2.117	1.387E+05S	1.554E+05S	1.719E+05S	1.885E+05S	2.053E+05S	2.222E+05S	2.395E+05S	2.569E+05S	2.733E+05S	2.884E+05S
600	3.057	1.386E+05S	1.553E+05S	1.719E+05S	1.885E+05S	2.053E+05S	2.222E+05S	2.394E+05S	2.569E+05S	2.733E+05S	2.883E+05S
700	4.411	1.386E+05S	1.553E+05S	1.719E+05S	1.885E+05S	2.053E+05S	2.222E+05S	2.396E+05S	2.569E+05S	2.733E+05S	2.884E+05S
800	6.361	1.386E+05S	1.553E+05S	1.719E+05S	1.884E+05S	2.053E+05S	2.222E+05S	2.394E+05S	2.568E+05S	2.733E+05S	2.883E+05S
900	9.170	1.385E+05S	1.553E+05S	1.719E+05S	1.885E+05S	2.053E+05S	2.222E+05S	2.395E+05S	2.568E+05S	2.733E+05S	2.884E+05S
1000	13.220	1.385E+05S	1.553E+05S	1.719E+05S	1.884E+05S	2.052E+05S	2.222E+05S	2.395E+05S	2.568E+05S	2.733E+05S	2.884E+05S
1100	19.057	1.385E+05S	1.553E+05S	1.719E+05S	1.886E+05S	2.053E+05S	2.222E+05S	2.395E+05S	2.568E+05S	2.733E+05S	2.884E+05S
1200	27.471	1.385E+05S	1.553E+05S	1.719E+05S	1.884E+05S	2.051E+05S	2.222E+05S	2.395E+05S	2.569E+05S	2.733E+05S	2.885E+05S
1300	39.600	1.385E+05S	1.553E+05S	1.720E+05S	1.885E+05S	2.053E+05S	2.223E+05S	2.394E+05S	2.568E+05S	2.733E+05S	2.883E+05S
1364	49.975	1.385E+05S	1.553E+05S	1.719E+05S	1.885E+05S	2.053E+05S	2.222E+05S	2.395E+05S	2.568E+05S	2.732E+05S	2.884E+05S

1 ZONE = 1 EDGE = 1 MACH NO. = 20.000 ANGLE OF ATTACK = 20.000 YAW ANGLE = 0.000

S U R F A C E P R E S S U R E S

OSTEP	ZETA	31	32	33	34	35	36
1	0.104	3.360E+05S	3.474E+05S	3.567E+05S	3.638E+05S	3.687E+05S	3.711E+05S
100	0.459	3.365E+05S	3.363E+05S	3.357E+05S	3.381E+05S	3.434E+05S	3.467E+05S
200	0.683	3.023E+05S	3.134E+05S	3.229E+05S	3.306E+05S	3.363E+05S	3.388E+05S
300	1.005	3.016E+05S	3.131E+05S	3.229E+05S	3.304E+05S	3.359E+05S	3.383E+05S
400	1.463	3.018E+05S	3.133E+05S	3.229E+05S	3.305E+05S	3.359E+05S	3.384E+05S
500	2.117	3.018E+05S	3.133E+05S	3.228E+05S	3.305E+05S	3.361E+05S	3.384E+05S
600	3.057	3.017E+05S	3.133E+05S	3.229E+05S	3.305E+05S	3.360E+05S	3.384E+05S
700	4.411	3.017E+05S	3.133E+05S	3.229E+05S	3.306E+05S	3.361E+05S	3.384E+05S
800	6.361	3.018E+05S	3.133E+05S	3.229E+05S	3.305E+05S	3.361E+05S	3.384E+05S
900	9.170	3.017E+05S	3.133E+05S	3.229E+05S	3.305E+05S	3.360E+05S	3.385E+05S
1000	13.220	3.017E+05S	3.133E+05S	3.229E+05S	3.305E+05S	3.358E+05S	3.384E+05S
1100	19.057	3.017E+05S	3.133E+05S	3.229E+05S	3.306E+05S	3.360E+05S	3.385E+05S
1200	27.471	3.018E+05S	3.133E+05S	3.229E+05S	3.305E+05S	3.360E+05S	3.385E+05S
1300	39.600	3.017E+05S	3.132E+05S	3.229E+05S	3.305E+05S	3.360E+05S	3.384E+05S
1364	49.975	3.017E+05S	3.133E+05S	3.228E+05S	3.305E+05S	3.360E+05S	3.384E+05S

1 ZONE = 1 EDGE = 1 MACH NO. = 20.000 ANGLE OF ATTACK = 20.000 YAW ANGLE = 0.000

A E R O D Y N A M I C D A T A

0 F R E E S T R E A M C O N D I T I O N S

MACH NO. = 20.000 ANGLE OF ATTACK = 20.000 ANGLE OF SIDE SLIP = 0.0000

REF AREA = 1.000000E+00 REF LENGTH = 1.000000E+00

OSTEP	ZETA	CX	CY	CZ	CMX	CMY	CMZ	XCP	YCP
1	0.107	5.88457E-04	0.00000E+00	4.70158E-04	0.00000E+00	7.41649E-05	0.00000E+00	1.26033E-01	0.00000E+00
100	0.460	7.01070E-02	0.00000E+00	5.50821E-02	0.00000E+00	2.75195E-02	0.00000E+00	3.92535E-01	0.00000E+00
200	0.685	1.63137E-01	0.00000E+00	1.26780E-01	0.00000E+00	9.30832E-02	0.00000E+00	5.70584E-01	0.00000E+00
300	1.007	3.59929E-01	0.00000E+00	2.79272E-01	0.00000E+00	2.98114E-01	0.00000E+00	8.28259E-01	0.00000E+00
400	1.465	7.68080E-01	0.00000E+00	5.96013E-01	0.00000E+00	9.19218E-01	0.00000E+00	1.19677E+00	0.00000E+00
500	2.121	1.61481E+00	0.00000E+00	1.25340E+00	0.00000E+00	2.78758E+00	0.00000E+00	1.72626E+00	0.00000E+00
600	3.063	3.37413E+00	0.00000E+00	2.61921E+00	0.00000E+00	8.39841E+00	0.00000E+00	2.48906E+00	0.00000E+00
700	4.419	7.02909E+00	0.00000E+00	5.45666E+00	0.00000E+00	2.52216E+01	0.00000E+00	3.58817E+00	0.00000E+00
800	6.372	1.46236E+01	0.00000E+00	1.13508E+01	0.00000E+00	7.56375E+01	0.00000E+00	5.17228E+00	0.00000E+00
900	9.187	3.04037E+01	0.00000E+00	2.35981E+01	0.00000E+00	2.26676E+02	0.00000E+00	7.45556E+00	0.00000E+00
1000	13.244	6.31926E+01	0.00000E+00	4.90456E+01	0.00000E+00	6.79121E+02	0.00000E+00	1.07468E+01	0.00000E+00
1100	19.092	1.31327E+02	0.00000E+00	1.01922E+02	0.00000E+00	2.03441E+03	0.00000E+00	1.54912E+01	0.00000E+00
1200	27.521	2.72901E+02	0.00000E+00	2.11790E+02	0.00000E+00	6.09393E+03	0.00000E+00	2.23302E+01	0.00000E+00
1300	39.672	5.67081E+02	0.00000E+00	4.40088E+02	0.00000E+00	1.82535E+04	0.00000E+00	3.21885E+01	0.00000E+00
1364	50.000	9.00777E+02	0.00						

B.2 HYPERSONIC BLUNT NOSE CYLINDER

B.2.1 BLUNT2 Output

1Hypersonic Blunt Nose Cylinder, M=20, Alpha=0, Alt=20,000 m

EXTERNAL PARAMETERS-KENSE- 0 0 1 0 0 0 0 0 0 0

TEST(1) = 1.0000E-04
TEST(2) = 4.0000E-03
TEST(3) = 5.0000E-02
TEST(4) = 5.0000E-04
TEST(5) = 5.0000E-04
TEST(11) = 1.0000E-04
TEST(12) = 1.0000E-04

IRG = 1 AIR
RIDEAL ZIDEAL GIDEAL RREAL P0 H0 G0 PREF TREF SRREF
2.8705E+02 1.0000E+00 1.3990E+00 2.8705E+02 1.0133E+05 2.3255E+03 1.0000E+00 2.0265E+01 2.3222E+02 3.1450E+01

DEL = 1.0000000E+00
IMAX =2000 IMIN =2000 IMOD = 25 IPRINT=2000
IRSPCE= 0 ISTART= -1
JMAX = 50 JPRINT=2000
MMAX = 25 MMAXI = 25
NMAX = 18
RN = 5.0000000E-01
STAB = 1.0000000E+00
X0 = 5.0000000E-01 XSTAG = 0.0000000E+00
YMAX = 1.2000000E+02 YSTAR = 4.5000000E+01

ZEUS RELATED INPUT:

NA = 36 MA = 36 IASYM = 1
ZSTART = 5.0000000E-01 Z0 = 5.0000000E-01 ALPHA = 2.0000000E+01 BETA = 0.0000000E+00
IBL = 0 NSTREM = 9 FTCONV = 1.0000000E+00 IUNITS = 1

FREE STREAM CONDITIONS

ALTITUDE = 20000.

1959 ARDC TABLES

P S/R H Q M RHO T Z G QQ
5.52988E+03 2.53209E+01 2.16967E+05 5.87380E+03 2.00000E+01 8.89148E-02 2.16662E+02 1.00000E+00 1.38687E+00 1.53385E+06

91 ENTRIES IN SHOCK TABLE

UW1/Q1(MIN) = 1.000000E-01

UW1/Q1(MAX) = 1.100000E+00

PSTAG= 2.9485E+06 TSTAG= 7.3519E+03 RHSTG= 1.0549E+00 GSTAG= 1.1845E+00 HTOT= 1.7468E+07
PSH= 2.8032E+06 TSH= 7.3119E+03 RHOSH= 1.0101E+00 GSH= 1.1839E+00 HSH= 1.7334E+07
SRSH= 3.9222E+01 AMSH= 2.8524E-01
DSH = 7.0793211E-01

1Hypersonic Blunt Nose Cylinder, M=20, Alpha=0, Alt=20,000 m

DEFAULT SPHERICAL GEOMETRY USED

RN = 5.00000E-01

1Hypersonic Blunt Nose Cylinder, M=20, Alpha=0, Alt=20,000 m

M	Y	RB	RBTH
1	0.0000000E+00	5.0000000E-01	0.0000000E+00
2	8.7266468E-02	5.0000000E-01	0.0000000E+00
3	1.7453294E-01	5.0000000E-01	0.0000000E+00
4	2.6179940E-01	5.0000000E-01	0.0000000E+00
5	3.4906587E-01	5.0000000E-01	0.0000000E+00
6	4.3633235E-01	5.0000000E-01	-1.5355615E-08
7	5.2359879E-01	5.0000000E-01	0.0000000E+00
8	6.1086529E-01	5.0000000E-01	0.0000000E+00
9	6.9813174E-01	5.0000000E-01	0.0000000E+00
10	7.8539819E-01	5.0000000E-01	2.5692719E-08
11	8.7266469E-01	5.0000000E-01	0.0000000E+00
12	9.5993114E-01	5.0000000E-01	0.0000000E+00
13	1.0471976E+00	5.0000000E-01	0.0000000E+00
14	1.1344640E+00	5.0000000E-01	0.0000000E+00
15	1.2217306E+00	5.0000000E-01	0.0000000E+00
16	1.3089970E+00	4.9999997E-01	0.0000000E+00
17	1.3962635E+00	5.0000000E-01	0.0000000E+00

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18 1.4835299E+00 5.0000000E-01 0.0000000E+00
19 1.5707964E+00 5.0000000E-01 0.0000000E+00
20 1.6580629E+00 5.0000000E-01 0.0000000E+00
21 1.7453294E+00 5.0000000E-01 0.0000000E+00
22 1.8325958E+00 5.0000000E-01 0.0000000E+00
23 1.9198623E+00 5.0000000E-01 0.0000000E+00
24 2.0071287E+00 5.0000000E-01 0.0000000E+00
25 2.0943952E+00 5.0000000E-01 0.0000000E+00

```

1Hypersonic Blunt Nose Cylinder, M=20, Alpha=0, Alt=20,000 m

STEP	TIME	DELTA	PSTAG	WRMS
1	5.5728725E-07	6.5766737E-02	2.9429010E+06	5.0127559E+00
2	1.1144186E-06	6.5759756E-02	2.9360023E+06	9.4505558E+00
3	1.6714025E-06	6.5748170E-02	2.9278905E+06	1.4038545E+01
4	2.2283821E-06	6.5731928E-02	2.9186713E+06	1.8675589E+01
5	2.7853721E-06	6.5711141E-02	2.9084403E+06	2.3286003E+01

UW1/Q1 (MIN) = 4.752480E-01 UW1/Q1 (MAX) = 1.003999E+00

1Hypersonic Blunt Nose Cylinder, M=20, Alpha=0, Alt=20,000 m

STEP	TIME	DELTA	PSTAG	WRMS
201	1.0931705E-04	4.0710162E-02	2.9427413E+06	2.6345813E+02
202	1.0978320E-04	4.0722951E-02	2.9403565E+06	2.6139301E+02
203	1.1024878E-04	4.0736869E-02	2.9376098E+06	2.5923465E+02
204	1.1071380E-04	4.0751837E-02	2.9345803E+06	2.5699255E+02
205	1.1117827E-04	4.0767789E-02	2.9313635E+06	2.5467589E+02

MMAX = 25 NMAX = 18 UW1/Q1 (MAX) = 9.966639E-01

UW1/Q1 (MIN) = 3.239257E-01

STEP	TIME	DELTA	PSTAG	WRMS
401	1.9852728E-04	3.7458688E-02	2.9282870E+06	4.5209958E+02
402	1.9895344E-04	3.7450656E-02	2.9283540E+06	4.4930344E+02
403	1.9937946E-04	3.7442811E-02	2.9284715E+06	4.4651422E+02
404	1.9980536E-04	3.7435144E-02	2.9286308E+06	4.4373187E+02
405	2.0023114E-04	3.7427694E-02	2.9288178E+06	4.4095642E+02

MMAX = 25 NMAX = 18

UW1/Q1 (MIN) = 3.434784E-01 UW1/Q1 (MAX) = 9.983664E-01

STEP	TIME	DELTA	PSTAG	WRMS
601	2.8191469E-04	3.6079410E-02	2.9361170E+06	9.7029724E+01
602	2.8232345E-04	3.6075525E-02	2.9360975E+06	9.6875244E+01
603	2.8273216E-04	3.6071673E-02	2.9360833E+06	9.6731621E+01
604	2.8314081E-04	3.6067858E-02	2.9360750E+06	9.6598328E+01

MMAX = 25 NMAX = 18

UW1/Q1 (MIN) = 3.616154E-01 UW1/Q1 (MAX) = 9.991269E-01

STEP	TIME	DELTA	PSTAG	WRMS
801	3.6272925E-04	3.5485916E-02	2.9385738E+06	8.2728256E+01
802	3.6312939E-04	3.5483882E-02	2.9385738E+06	8.2704887E+01
803	3.6352949E-04	3.5481848E-02	2.9385738E+06	8.2679306E+01
804	3.6392955E-04	3.5479810E-02	2.9385738E+06	8.2651451E+01
805	3.6432958E-04	3.5477776E-02	2.9385738E+06	8.2621193E+01

MMAX = 25 NMAX = 18

UW1/Q1 (MIN) = 3.575845E-01 UW1/Q1 (MAX) = 9.995127E-01

STEP	TIME	DELTA	PSTAG	WRMS
1001	4.4225689E-04	3.5176776E-02	2.9396670E+06	4.5741180E+01
1002	4.4265250E-04	3.5175651E-02	2.9396725E+06	4.5658882E+01
1003	4.4304808E-04	3.5174560E-02	2.9396838E+06	4.5577564E+01
1004	4.4344366E-04	3.5173472E-02	2.9396923E+06	4.5497143E+01
1005	4.4383921E-04	3.5172381E-02	2.9396978E+06	4.5417595E+01

MMAX = 25 NMAX = 18

UW1/Q1 (MIN) = 3.552338E-01 UW1/Q1 (MAX) = 9.997421E-01

STEP	TIME	DELTA	PSTAG	WRMS
1201	5.2111130E-04	3.5010364E-02	2.9405473E+06	2.7454748E+01
1202	5.2150449E-04	3.5009783E-02	2.9405500E+06	2.7373650E+01
1203	5.2189769E-04	3.5009202E-02	2.9405500E+06	2.7293016E+01
1204	5.2229088E-04	3.5008620E-02	2.9405528E+06	2.7212839E+01
1205	5.2268407E-04	3.5008039E-02	2.9405585E+06	2.7133110E+01
1246	5.3879584E-04	3.4985255E-02	2.9406680E+06	2.4211784E+01
1247	5.3918862E-04	3.4984749E-02	2.9406680E+06	2.4147606E+01
1248	5.3958141E-04	3.4984238E-02	2.9406708E+06	2.4083683E+01
1249	5.3997413E-04	3.4983728E-02	2.9406735E+06	2.4020014E+01
1250	5.4036686E-04	3.4983221E-02	2.9406735E+06	2.3956598E+01

MMAX = 25 NMAX = 18

UW1/Q1 (MIN) = 3.547883E-01 UW1/Q1 (MAX) = 9.997761E-01

CONVERGENCE CRITERIA SATISFIED AT STEP 1258

1Hypersonic Blunt Nose Cylinder, M=20, Alpha=0, Alt=20,000 m

STEP	TIME	DELTA	PSTAG	WRMS
1251	5.4075959E-04	3.4982711E-02	2.9406763E+06	2.3893423E+01
1252	5.4115232E-04	3.4982204E-02	2.9406790E+06	2.3830505E+01
1253	5.4154504E-04	3.4981694E-02	2.9406790E+06	2.3767822E+01
1254	5.4193777E-04	3.4981187E-02	2.9406790E+06	2.370533E+01
1255	5.4233044E-04	3.4980677E-02	2.9406820E+06	2.3643064E+01
1256	5.4272311E-04	3.4980170E-02	2.9406848E+06	2.3581018E+01
1257	5.4311578E-04	3.4979660E-02	2.9406875E+06	2.3519159E+01
1258	5.4350845E-04	3.4979153E-02	2.9406933E+06	2.3457474E+01

MMAX = 25 NMAX = 18

UW1/Q1 (MIN) = 3.547164E-01 UW1/Q1 (MAX) = 9.997822E-01

1Hypersonic Blunt Nose Cylinder, M=20, Alpha=0, Alt=20,000 m

STEP *** DT = 3.9266E-07 AT N = 18 M = 7

TIME = 5.4351E-04

I = 1258

M Y RST RSTH PRESSURE CHECK XB YB XS YS SIGMA

NAVSWC TR 91-86

1	0.00	-1.2791E+00	0.0000E+00	2.6385E-03	0.0000E+00	0.0000E+00	-3.4979E-02	0.0000E+00	90.00
2	5.00	-1.3049E+00	-4.5730E-03	2.6157E-03	1.9026E-03	4.3178E-02	-3.3136E-02	4.6643E-02	81.49
3	10.00	-1.3203E+00	-9.5072E-03	2.5038E-03	7.5961E-03	8.6824E-02	-2.7650E-02	9.3039E-02	81.02
4	15.00	-1.3744E+00	-1.4586E-02	2.4143E-03	1.7037E-02	1.2941E-01	-1.8539E-02	1.3894E-01	76.56
5	20.00	-1.5935E+00	-2.0505E-02	2.4132E-03	3.0154E-02	1.7101E-01	-5.8889E-03	1.8413E-01	72.18
6	25.00	-1.3975E+00	-2.7470E-02	2.2751E-03	4.6846E-02	2.1131E-01	1.0201E-02	2.2840E-01	67.91
7	30.00	-1.9017E+00	-3.5874E-02	2.3108E-03	6.6987E-02	2.5000E-01	2.9581E-02	2.7160E-01	63.78
8	35.00	-2.3294E+00	-4.5470E-02	2.9303E-03	9.0424E-02	2.8679E-01	5.2150E-02	3.1359E-01	59.75
9	40.00	-1.7411E+00	-5.7176E-02	1.9174E-03	1.1698E-01	3.2139E-01	7.7770E-02	3.5429E-01	55.92
10	45.00	-2.7134E+00	-7.1186E-02	2.1361E-03	1.4645E-01	3.5355E-01	1.0631E-01	3.9369E-01	52.29
11	50.00	-4.5933E+00	-8.7775E-02	2.4802E-03	1.7861E-01	3.8302E-01	1.3768E-01	4.3180E-01	48.85
12	55.00	-3.3941E+00	-1.0751E-01	2.3172E-03	2.1321E-01	4.0958E-01	1.7181E-01	4.6871E-01	45.64
13	60.00	-3.5115E+00	-1.3068E-01	2.5401E-03	2.5000E-01	4.3301E-01	2.0875E-01	5.0445E-01	42.64
14	65.00	-6.1584E+00	-1.6037E-01	1.1400E-03	2.8869E-01	4.5315E-01	2.4846E-01	5.3944E-01	40.08
15	70.00	-5.6121E+00	-1.9358E-01	1.0881E-03	3.2899E-01	4.6985E-01	2.9118E-01	5.7373E-01	37.59
16	75.00	-9.6899E+00	-2.3484E-01	5.8347E-04	3.7059E-01	4.8296E-01	3.3714E-01	6.0778E-01	35.47
17	80.00	-9.7146E+00	-2.8222E-01	-1.4887E-04	4.1318E-01	4.9240E-01	3.6883E-01	6.4180E-01	33.41
18	85.00	-1.4621E+01	-3.3966E-01	-6.0058E-04	4.5642E-01	4.9810E-01	4.0842E-01	6.7615E-01	31.58
19	90.00	-1.5556E+01	-4.0856E-01	-2.8661E-04	5.0000E-01	5.0000E-01	5.0000E-01	7.1131E-01	29.87
20	95.00	-1.3845E+01	-4.9055E-01	-6.9174E-04	5.4358E-01	4.9810E-01	5.6540E-01	7.4749E-01	28.18
21	100.00	-2.0175E+01	-5.9399E-01	-1.0921E-03	5.8682E-01	4.9240E-01	6.3848E-01	7.8535E-01	26.68
22	105.00	-2.9370E+01	-7.2331E-01	-1.3102E-03	6.2941E-01	4.8296E-01	7.2121E-01	8.2556E-01	25.24
23	110.00	-4.1586E+01	-8.8911E-01	-1.0894E-03	6.7101E-01	4.6985E-01	8.1622E-01	8.6881E-01	23.88
24	115.00	-5.7368E+01	-1.1055E+00	-8.0395E-04	7.1131E-01	4.5315E-01	9.2737E-01	9.1650E-01	22.55
25	120.00	-8.0531E+01	-1.3984E+00	-4.0456E-04	7.5000E-01	4.3301E-01	1.0601E+00	9.7018E-01	21.30

I -1258

N - 1

M	P	RHO	T	U	V	S/R	MACH	R	DH
1	2.9407E+06	1.0525E+00	7.3498E-03	0.0000E+00	0.0000E+00	3.9222E+01	0.0000E+00	5.0000E-01	-4.0048E-04
3	2.8326E+06	1.0192E+00	7.3201E-03	0.0000E+00	-4.5719E+02	3.9222E+01	2.5203E-01	5.0000E-01	-9.4771E-05
5	2.5264E+06	9.2372E-01	7.2308E-03	0.0000E+00	-9.1623E+02	3.9222E+01	5.0941E-01	5.0000E-01	8.4126E-04
7	2.0794E+06	7.8100E-01	7.0835E-03	0.0000E+00	-1.3754E+03	3.9222E+01	7.7578E-01	5.0000E-01	2.5986E-03
9	1.5688E+06	6.1345E-01	6.8633E-03	0.0000E+00	-1.8346E+03	3.9222E+01	1.0570E+00	5.0000E-01	2.0270E-03
11	1.0832E+06	4.4664E-01	6.5813E-03	0.0000E+00	-2.2804E+03	3.9222E+01	1.3508E+00	5.0000E-01	8.9502E-04
13	6.8541E+05	3.0129E-01	6.2570E-03	0.0000E+00	-2.7094E+03	3.9222E+01	1.6594E+00	5.0000E-01	5.2810E-04
15	4.0303E+05	1.9171E-01	5.8679E-03	0.0000E+00	-3.1077E+03	3.9222E+01	1.9815E+00	5.0000E-01	7.1990E-04
17	2.2305E+05	1.1603E-01	5.4763E-03	0.0000E+00	-3.4701E+03	3.9222E+01	2.3149E+00	5.0000E-01	-3.9634E-03
19	1.1817E+05	6.7846E-02	5.0097E-03	0.0000E+00	-3.7843E+03	3.9222E+01	2.6512E+00	5.0000E-01	-2.8210E-03
21	5.9394E+04	3.8522E-02	4.4836E-03	0.0000E+00	-4.0726E+03	3.9222E+01	3.0285E+00	5.0000E-01	-2.6614E-03
23	2.8834E+04	2.1455E-02	3.9683E-03	0.0000E+00	-4.3188E+03	3.9222E+01	3.4323E+00	5.0000E-01	5.0437E-04
25	1.3531E+04	1.1435E-02	3.5627E-03	0.0000E+00	-4.5277E+03	3.9222E+01	3.8230E+00	5.0000E-01	-2.0030E-03

I -1258

N - 3

M	P	RHO	T	U	V	S/R	MACH	R	DH
1	2.9391E+06	1.0539E+00	7.3421E+03	-4.4882E+01	0.0000E+00	3.9200E+01	2.4696E-02	5.0412E-01	-3.0492E-03
3	2.8330E+06	1.0223E+00	7.3088E+03	-4.4156E+01	-5.1143E+02	3.9187E+01	2.8339E-01	5.0421E-01	-2.6464E-03
5	2.5329E+06	9.3160E-01	7.2077E+03	-4.1267E+01	-1.0179E+03	3.9144E+01	5.6814E-01	5.0451E-01	-2.2354E-03
7	2.0948E+06	7.9465E-01	7.0467E+03	-3.4719E+01	-1.5112E+03	3.9085E+01	8.5697E-01	5.0508E-01	-8.1640E-04
9	1.5948E+06	6.3329E-01	6.8020E+03	-2.1201E+01	-1.9874E+03	3.9018E+01	1.1540E+00	5.0602E-01	-1.2001E-03
11	1.1192E+06	4.7046E-01	6.5109E+03	5.0937E+00	-2.4271E+03	3.8946E+01	1.4517E+00	5.0749E-01	-4.3488E-03
13	7.2884E+05	3.2722E-01	6.1742E+03	5.1610E+01	-2.8294E+03	3.8910E+01	1.7510E+00	5.0970E-01	-3.7591E-03
15	4.4979E+05	2.1752E-01	5.8088E+03	1.2701E+02	-3.1785E+03	3.8880E+01	2.0444E+00	5.1301E-01	-5.7803E-03
17	2.6949E+05	1.4134E-01	5.4506E+03	2.3867E+02	-3.4732E+03	3.8864E+01	2.3306E+00	5.1785E-01	-1.2101E-02
19	1.6075E+05	9.1805E-02	5.0526E+03	3.9714E+02	-3.7015E+03	3.8854E+01	2.5997E+00	5.2486E-01	-1.6260E-02
21	9.6596E+04	6.0473E-02	4.6395E+03	6.1060E+02	-3.8742E+03	3.8825E+01	2.8647E+00	5.3500E-01	-2.3673E-02
23	6.0575E+04	4.1569E-02	4.2749E+03	8.8010E+02	-3.9783E+03	3.8802E+01	3.1123E+00	5.4995E-01	-2.8008E-02
25	4.0098E+04	2.9842E-02	3.9864E+03	1.2237E+03	-4.0071E+03	3.8771E+01	3.3276E+00	5.7297E-01	-3.5580E-02

I -1258

N - 6

M	P	RHO	T	U	V	S/R	MACH	R	DH
1	2.9378E+06	1.0508E+00	7.3451E+03	-1.2024E+02	0.0000E+00	3.9214E+01	6.6130E-02	5.1029E-01	-1.3214E-03
3	2.8307E+06	1.0225E+00	7.3045E+03	-1.1757E+02	-5.9218E+02	3.9176E+01	3.3348E-01	5.1053E-01	-1.1870E-03
5	2.5420E+06	9.4018E-01	7.1864E+03	-1.0815E+02	-1.1720E+03	3.9069E+01	6.5771E-01	5.1128E-01	-6.0230E-04
7	2.1205E+06	8.1596E-01	6.9876E+03	-8.8132E+01	-1.7191E+03	3.8902E+01	9.8299E-01	5.1270E-01	-2.7817E-04
9	1.6390E+06	6.6544E-01	6.7143E+03	-4.9154E+01	-2.2224E+03	3.8720E+01	1.3053E+00	5.1505E-01	-1.6170E-03
11	1.1794E+06	5.1021E-01	6.4027E+03	1.9901E+01	-2.6712E+03	3.8545E+01	1.6209E+00	5.1873E-01	-4.1646E-03
13	7.9853E+05	3.7144E-01	6.0353E+03	1.3360E+02	-3.0415E+03	3.8417E+01	1.9166E+00	5.2426E-01	-5.6229E-03
15	5.2025E+05	2.5947E-01	5.6957E+03	3.0799E+02	-3.3522E+03	3.8347E+01	2.1955E+00	5.3252E-01	-5.2820E-03
17	3.3557E+05	1.8019E-01	5.3587E+03	5.2957E+02	-3.5852E+03	3.8339E+01	2.4523E+00	5.4462E-01	-4.5436E-03
19	2.1828E+05	1.2672E-01	5.0034E+03	8.2006E+02	-3.7288E+03	3.8310E+01	2.6850E+00	5.6215E-01	-9.8028E-03
21	1.4518E+05	9.0471E-02	4.6880E+03	1.1743E+03	-3.8062E+03	3.8327E+01	2.9003E+00	5.8749E-01	-1.1181E-02
23	1.0063E+05	6.6889E-02	4.4217E+03	1.5813E+03	-3.7862E+03	3.8360E+01	3.0791E+00	6.2487E-01	-9.1432E-02
25	7.2984E+04	5.1977E-02	4.1586E+03	2.0407E+03	-3.6727E+03	3.8275E+01	3.2645E+00	6.8243E-01	-1.7842E-02

I -1258

N - 9

M	P	RHO	T	U	V	S/R	MACH	R	DH
1	2.9185E+06	1.0462E+00	7.3420E+03	-2.0472E+02	0.0000E+00	3.9217E+01	1.1263E-01	5.1646E-01	-9.9379E-04
3	2.8219E+06	1.0219E+00	7.2936E+03	-1.9923E+02	-6.7443E+02	3.9150E+01	3.8895E-01	5.1684E-01	-9.8628E-04
5	2.5484E+06	9.5020E-01	7.1550E+03	-1.8067E+02	-1.3269E+03	3.8965E+01	7.5215E-01	5.1805E-01	-6.1482E-04
7	2.1487E+06	8.4179E-01	6.9127E+03	-1.4293E+02	-1.9360E+03	3.8679E+01	1.1187E+00	5.2033E-01	-3.6591E-04
9	1.6904E+06	7.0490E-01	6.6104E+03	-7.3319E+01	-2.4778E+03	3.8374E+01	1.4753E+00	5.2409E-01	-8.0066E-04
11	1.7415E+06	5.5987E-01	6.2539E+03	4.3484E+01	-2.9358E+03	3.8113E+01	1.8124E+00	5.2996E-01	-1.7344E-03
13	8.742E+05	4.2687E-01	5.8596E+03	2.2114E+02	-3.2964E+03	3.7845E+01	2.1260E+00	5.3882E-01	-4.4641E-03
15	5.9751E+05	3.1633E-01	5.4558E+03	4.6562E+02	-3.5632E+03	3.7638E+01	2.4117E+00	5.5202E-01	-9.4227E-03
17	4.0624E+05	2.3301E-01	5.0903E+03	7.8308E+02	-3.7504E+03	3.7558E+01	2.6751E+00	5.7139E-01	-6.5944E-03
19	2.7940E+05	1.7698E-01	4.6726E+03	1.1433E+03	-3.8098E+03	3.7343E+01	2.9149E+00	5.9944E-01	-2.7275E-02
21	1.9422E+05	1.2637E-01	4.5456E+03	1.6106E+03	-3.8471E+03	3.7634E+01	3.0986E+00	6.3998E-01	-9.2082E-03

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23 1.3941E+05 1.0048E-01 4.1654E+03 2.0684E+03 -3.7363E+03 3.7316E+01 3.3324E+00 6.9979E-01 -1.4117E-02
 25 1.0335E+05 7.7825E-02 4.0067E+03 2.5941E+03 -3.5538E+03 3.7367E+01 3.5057E+00 7.9189E-01 -2.5703E-03

I = 1258

N = 12

M	P	RHO	T	U	V	S/R	MACH	R	DH
1	2.0938E+06	1.0385E+00	7.3357E+03	-2.9875E+02	0.0000E+00	3.9218E+01	1.6445E-01	5.2263E-01	-7.7492E-04
3	2.8043E+06	1.0188E+00	7.2788E+03	-2.8960E+02	-7.5843E+02	3.9120E+01	4.4980E-01	5.2316E-01	-7.6270E-04
5	2.5505E+06	9.6040E-01	7.1164E+03	-2.5948E+02	-1.4886E+03	3.8843E+01	8.5303E-01	5.2482E-01	-7.7415E-04
7	2.1790E+06	8.7156E-01	6.8265E+03	-1.9974E+02	-2.1602E+03	3.8427E+01	1.2633E+00	5.2795E-01	8.1182E-05
9	1.7506E+06	7.5803E-01	6.4521E+03	-9.4250E+01	-2.7449E+03	3.7929E+01	1.6656E+00	5.3312E-01	-3.7701E-03
11	1.3337E+06	6.3671E-01	5.9857E+03	7.4652E+01	-3.2300E+03	3.7415E+01	2.0575E+00	5.4120E-01	-9.2729E-03
13	9.7204E+05	5.1322E-01	5.5162E+03	3.1809E+02	-3.5871E+03	3.7012E+01	2.4111E+00	5.5338E-01	-1.3239E-02
15	6.9337E+05	4.0760E-01	5.0299E+03	6.3818E+02	-3.8333E+03	3.6665E+01	2.7421E+00	5.7153E-01	-1.6039E-02
17	4.9392E+05	3.1355E-01	4.7034E+03	1.0425E+03	-3.9969E+03	3.6569E+01	3.0261E+00	5.9816E-01	-2.5350E-04
19	3.5390E+05	2.4280E-01	4.4065E+03	1.4920E+03	-4.0296E+03	3.6446E+01	3.2688E+00	6.3673E-01	4.5977E-03
21	2.5599E+05	1.9352E-01	4.0808E+03	1.9865E+03	-3.9646E+03	3.6125E+01	3.5320E+00	6.9248E-01	-8.8475E-03
23	1.8764E+05	1.5147E-01	3.8735E+03	2.5371E+03	-3.8222E+03	3.5992E+01	3.7680E+00	7.7472E-01	-1.9185E-03
25	1.3991E+05	1.2227E-01	3.6449E+03	3.0949E+03	-3.5721E+03	3.5668E+01	4.0254E+00	9.0135E-01	-5.9186E-03

I = 1258

N = 15

M	P	RHO	T	U	V	S/R	MACH	R	DH
1	2.8565E+06	1.0269E+00	7.3256E+03	-4.0274E+02	0.0000E+00	3.9218E+01	2.2131E-01	5.2881E-01	-5.7846E-04
3	2.7757E+06	1.0127E+00	7.2596E+03	-3.8924E+02	-6.4172E+02	3.9086E+01	5.1494E-01	5.2947E-01	-5.9706E-04
5	2.5465E+06	9.7107E-01	7.0611E+03	-3.4549E+02	-1.6493E+03	3.8704E+01	9.5743E-01	5.3159E-01	-8.5163E-04
7	2.2104E+06	9.0622E-01	6.7247E+03	-2.6005E+02	-2.3855E+03	3.8134E+01	1.4150E+00	5.3557E-01	-6.4486E-04
9	1.8209E+06	8.2604E-01	6.2450E+03	-1.1452E+02	-3.0212E+03	3.7430E+01	1.8759E+00	5.4215E-01	-4.5486E-03
11	1.4361E+06	7.3726E-01	5.6735E+03	1.0967E+02	-3.5387E+03	3.6698E+01	2.3361E+00	5.5243E-01	-1.1452E-02
13	1.0943E+06	6.4275E-01	5.0715E+03	4.2374E+02	-3.9181E+03	3.6065E+01	2.7769E+00	5.6793E-01	-8.2090E-03
15	8.2020E+05	5.4821E-01	4.5670E+03	8.2885E+02	-4.1806E+03	3.5513E+01	3.1961E+00	5.9104E-01	-1.5545E-03
17	6.1567E+05	4.5984E-01	4.1911E+03	1.3090E+03	-4.3013E+03	3.5035E+01	3.5532E+00	6.2493E-01	-5.4294E-04
19	4.6403E+05	3.8540E-01	3.8677E+03	1.8491E+03	-4.3141E+03	3.4534E+01	3.8968E+00	6.7402E-01	-4.0585E-03
21	3.4983E+05	3.2132E-01	3.5817E+03	2.4218E+03	-4.2172E+03	3.4037E+01	4.2256E+00	7.4497E-01	-6.2888E-03
23	2.6439E+05	2.6775E-01	3.3154E+03	3.0232E+03	-4.0086E+03	3.3561E+01	4.5577E+00	8.4964E-01	-4.3620E-03
25	1.9847E+05	2.2716E-01	2.9998E+03	3.6303E+03	-3.6902E+03	3.2972E+01	4.9568E+00	1.0108E+00	-4.2408E-03

I = 1258

N = 18

M	P	RHO	T	U	V	S/R	MACH	R	DH
1	2.8019E+06	1.0100E+00	7.3106E+03	-5.1827E+02	0.0000E+00	3.9219E+01	2.8597E-01	5.3498E-01	-3.9011E-04
3	2.7316E+06	1.0020E+00	7.2347E+03	-4.9969E+02	-9.2620E+02	3.9047E+01	5.8602E-01	5.3579E-01	-3.8892E-04
5	2.5322E+06	9.8003E-01	6.9953E+03	-4.4002E+02	-1.8155E+03	3.8549E+01	1.0694E+00	5.3836E-01	-4.3017E-04
7	2.2407E+06	9.4535E-01	6.6073E+03	-3.2508E+02	-2.6224E+03	3.7804E+01	1.5811E+00	5.4319E-01	-7.8297E-04
9	1.9032E+06	9.0989E-01	6.0172E+03	-1.3488E+02	-3.3228E+03	3.6855E+01	2.1174E+00	5.5118E-01	-3.9637E-04
11	1.5671E+06	8.8496E-01	5.2654E+03	1.5160E+02	-3.8880E+03	3.5864E+01	2.6885E+00	5.6367E-01	-1.1504E-03
13	1.2667E+06	8.6562E-01	4.5359E+03	5.4399E+02	-4.3059E+03	3.4769E+01	3.2852E+00	5.8249E-01	-6.8939E-04
15	1.0201E+06	8.1823E-01	4.0263E+03	1.0310E+03	-4.5557E+03	3.3787E+01	3.8089E+00	6.1055E-01	-9.3299E-04
17	8.2228E+05	7.5790E-01	3.6203E+03	1.5928E+03	-4.6531E+03	3.2946E+01	4.2720E+00	6.5170E-01	-1.4128E-03
19	6.6379E+05	6.9963E-01	3.2391E+03	2.2042E+03	-4.6077E+03	3.2191E+01	4.7114E+00	7.1131E-01	-1.9228E-03
21	5.3255E+05	6.4705E-01	2.8490E+03	2.8333E+03	-4.4339E+03	3.1499E+01	5.1739E+00	7.9747E-01	-2.0699E-03
23	4.2331E+05	6.0219E-01	2.4439E+03	3.4514E+03	-4.1324E+03	3.0850E+01	5.6880E+00	9.2456E-01	-3.4659E-03
25	3.3099E+05	5.6701E-01	2.0336E+03	4.0352E+03	-3.7159E+03	3.0189E+01	6.3132E+00	1.1203E+00	-5.1491E-03

12EUS INITIAL DATA GENERATED BY 217

IZN = 1 NA = 36 MA = 36
 PINF = 5.52988E+03 DINF = 8.89148E-02 XMINF = 20.00 ALPHA = 20.00 BETA = 0.00
 RSTART = 0 ZSTART = 5.00000E-01 IASYM = 1 ICORD = 1 ISHOCK = 1

XFX, XFY, XFZ = 7.56896E+04 0.00000E+00 2.33032E+05 XMX, XMY, XMZ = 0.00000E+00 1.24163E+05 0.00000E+00

PLANE M = 1 PHI = 2.500

N	R	P	RHO	U	V	W
1	5.05893E-01	4.50897E-04	3.11471E-02	1.27880E-02	-6.06103E-01	4.19273E+03
3	5.29464E-01	6.19923E-04	4.17315E-02	5.95243E-02	-3.78768E-01	4.11372E+03
5	5.53036E-01	7.76170E-04	5.07866E-02	9.17566E-02	-2.24753E-01	4.00558E+03
7	5.76607E-01	9.20749E-04	5.89468E-02	1.18508E-01	-1.02045E-01	3.89545E+03
9	6.00179E-01	1.05993E-03	6.75026E-02	1.38283E-01	-6.58090E-01	3.82352E+03
11	6.23750E-01	1.19354E-03	7.60630E-02	1.57321E-01	7.79345E+00	3.75556E+03
13	6.47322E-01	1.32654E-03	8.66395E-02	1.75442E-01	1.61820E+01	3.73176E+03
15	6.70893E-01	1.46549E-03	9.94741E-02	1.89733E-01	2.27478E+01	3.75253E+03
17	6.94464E-01	1.61006E-03	1.11496E-01	2.03713E-01	2.86028E+01	3.73170E+03
19	7.18036E-01	1.76311E-03	1.24023E-01	2.17855E-01	3.43416E+01	3.69344E+03
21	7.41607E-01	1.92797E-03	1.39335E-01	2.32558E-01	4.01628E+01	3.67679E+03
23	7.65179E-01	2.10943E-03	1.59588E-01	2.47622E-01	4.60887E+01	3.70605E+03
25	7.88750E-01	2.31518E-03	1.85743E-01	2.62524E-01	5.17797E+01	3.76957E+03
27	8.12322E-01	2.55723E-03	2.19139E-01	2.77733E-01	5.73931E+01	3.83861E+03
29	8.35893E-01	2.84824E-03	2.61990E-01	2.93297E-01	6.30440E+01	3.89883E+03
31	8.59465E-01	3.20557E-03	3.19316E-01	3.08639E-01	6.86052E+01	3.95446E+03
33	8.83036E-01	3.65237E-03	3.98443E-01	3.23089E-01	7.39098E+01	4.00467E+03
35	9.06607E-01	4.22123E-03	5.11269E-01	3.36008E-01	7.87909E+01	4.05064E+03
36	9.18393E-01	4.56959E-03	5.83705E-01	3.41795E-01	8.11490E+01	4.06414E+03

PLANE M = 6 PHI = 27.500

N	R	P	RHO	U	V	W
1	5.05443E-01	4.50897E-04	3.11471E-02	4.20612E-02	-5.59446E-02	4.13632E+03
3	5.27213E-01	6.19923E-04	4.17315E-02	7.91129E-02	-3.39193E-02	4.06663E+03

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5	5.48983E-01	7.76170E+04	5.07866E-02	1.05281E+03	-1.87350E+02	3.96783E+03
7	5.70754E-01	9.20749E+04	5.89468E-02	1.27470E+03	-6.48887E+01	3.86652E+03
9	5.92524E-01	1.05993E+05	6.75026E-02	1.43884E+03	3.12820E+01	3.80267E+03
11	6.14295E-01	1.19353E+05	7.60629E-02	1.60396E+03	1.18882E+02	3.74064E+03
13	6.36065E-01	1.32654E+05	8.66395E-02	1.75075E+03	1.99872E+02	3.72911E+03
15	6.57835E-01	1.46549E+05	9.94741E-02	1.86776E+03	2.65649E+02	3.75802E+03
17	6.79606E-01	1.61006E+05	1.11496E-01	1.99553E+03	3.29237E+02	3.73975E+03
19	7.01376E-01	1.76311E+05	1.24023E-01	2.12338E+03	3.90662E+02	3.70505E+03
21	7.23147E-01	1.92797E+05	1.39335E-01	2.25462E+03	4.51951E+02	3.69339E+03
23	7.44917E-01	2.10942E+05	1.59588E-01	2.38586E+03	5.12611E+02	3.73007E+03
25	7.66687E-01	2.31518E+05	1.85743E-01	2.51762E+03	5.71610E+02	3.79988E+03
27	7.88458E-01	2.55723E+05	2.19139E-01	2.65474E+03	6.30916E+02	3.87376E+03
29	8.10228E-01	2.84824E+05	2.61990E-01	2.79529E+03	6.90618E+02	3.93911E+03
31	8.31999E-01	3.20557E+05	3.19316E-01	2.93426E+03	7.49587E+02	3.99957E+03
33	8.53769E-01	3.65237E+05	3.98443E-01	3.06557E+03	8.06136E+02	4.05387E+03
35	8.75539E-01	4.22123E+05	5.11269E-01	3.18249E+03	8.58063E+02	4.10360E+03
36	8.86424E-01	4.56959E+05	5.83704E-01	3.23641E+03	8.83128E+02	4.11893E+03

PLANE M = 12 PHI = 57.500

N	R	P	RHO	U	V	W
1	5.04225E-01	6.34664E+04	4.10708E-02	1.04589E+03	-5.64818E+02	3.90466E+03
3	5.21126E-01	8.16284E+04	5.21969E-02	1.19143E+03	-2.72905E+02	3.87758E+03
5	5.38026E-01	9.85473E+04	6.15427E-02	1.30958E+03	-5.89800E+01	3.80134E+03
7	5.54927E-01	1.14405E+05	7.02708E-02	1.41774E+03	1.22095E+02	3.72462E+03
9	5.71827E-01	1.29591E+05	7.96893E-02	1.49515E+03	2.67083E+02	3.69481E+03
11	5.88728E-01	1.44484E+05	8.99847E-02	1.58199E+03	4.04385E+02	3.68475E+03
13	6.05629E-01	1.59635E+05	1.01025E-01	1.64603E+03	5.17193E+02	3.70446E+03
15	6.22529E-01	1.75028E+05	1.13089E-01	1.72294E+03	6.30603E+02	3.68213E+03
17	6.39430E-01	1.90641E+05	1.23906E-01	1.81116E+03	7.47163E+02	3.63451E+03
19	6.56330E-01	2.07648E+05	1.39327E-01	1.88523E+03	8.47820E+02	3.65202E+03
21	6.73231E-01	2.26294E+05	1.59374E-01	1.96009E+03	9.45574E+02	3.71328E+03
23	6.90132E-01	2.47109E+05	1.83111E-01	2.03619E+03	1.04083E+03	3.78562E+03
25	7.07032E-01	2.70445E+05	2.10358E-01	2.12140E+03	1.14050E+03	3.84431E+03
27	7.23933E-01	2.97344E+05	2.44598E-01	2.21350E+03	1.24370E+03	3.91111E+03
29	7.40833E-01	3.29214E+05	2.89741E-01	2.30849E+03	1.34771E+03	3.99205E+03
31	7.57734E-01	3.68133E+05	3.49240E-01	2.40493E+03	1.45292E+03	4.06844E+03
33	7.74634E-01	4.16310E+05	4.28576E-01	2.49731E+03	1.55553E+03	4.13355E+03
35	7.91535E-01	4.76444E+05	5.38075E-01	2.58180E+03	1.65203E+03	4.19076E+03

PLANE M = 18 PHI = 87.500

N	R	P	RHO	U	V	W
1	5.03028E-01	1.23005E+05	7.08036E-02	1.28778E+03	-1.97149E+00	3.58388E+03
3	5.15138E-01	1.43567E+05	8.31044E-02	1.27554E+03	2.07542E+02	3.61011E+03
5	5.27248E-01	1.63061E+05	9.30635E-02	1.28304E+03	3.79843E+02	3.55344E+03
7	5.39358E-01	1.81443E+05	1.03159E-01	1.29183E+03	5.34189E+02	3.52405E+03
9	5.51468E-01	1.99460E+05	1.14567E-01	1.29398E+03	6.59440E+02	3.54041E+03
11	5.63578E-01	2.17451E+05	1.26178E-01	1.30940E+03	7.87416E+02	3.54576E+03
13	5.75688E-01	2.35613E+05	1.38530E-01	1.32026E+03	8.96784E+02	3.56114E+03
15	5.87798E-01	2.54830E+05	1.54077E-01	1.33812E+03	1.00956E+03	3.61124E+03
17	5.99908E-01	2.74814E+05	1.72582E-01	1.34998E+03	1.10528E+03	3.68427E+03
19	6.12019E-01	2.96206E+05	1.88850E-01	1.37526E+03	1.21367E+03	3.68076E+03
21	6.24129E-01	3.18532E+05	2.05784E-01	1.40528E+03	1.32622E+03	3.66616E+03
23	6.36239E-01	3.43313E+05	2.30763E-01	1.43249E+03	1.43248E+03	3.71679E+03
25	6.48349E-01	3.70979E+05	2.64277E-01	1.46235E+03	1.53979E+03	3.81119E+03
27	6.60459E-01	4.03127E+05	3.05099E-01	1.49569E+03	1.64975E+03	3.91289E+03
29	6.72569E-01	4.40569E+05	3.53783E-01	1.53265E+03	1.76422E+03	4.00332E+03
31	6.84679E-01	4.84861E+05	4.14701E-01	1.57193E+03	1.88136E+03	4.09026E+03
33	6.96789E-01	5.38671E+05	4.94172E-01	1.61135E+03	1.99660E+03	4.17619E+03
35	7.08899E-01	6.03931E+05	5.97105E-01	1.64937E+03	2.10946E+03	4.25181E+03
36	7.14954E-01	6.43207E+05	6.63077E-01	1.66419E+03	2.16115E+03	4.29193E+03

PLANE M = 24 PHI = 117.500

N	R	P	RHO	U	V	W
1	5.02176E-01	2.28381E+05	1.19312E-01	9.28784E+02	5.19228E+02	3.34506E+03
3	5.10878E-01	2.50513E+05	1.32477E-01	8.66217E+02	6.26276E+02	3.40472E+03
5	5.19580E-01	2.72160E+05	1.42805E-01	8.24651E+02	7.28943E+02	3.36917E+03
7	5.28282E-01	2.93069E+05	1.54380E-01	7.84388E+02	8.22790E+02	3.38072E+03
9	5.36984E-01	3.13836E+05	1.66631E-01	7.50668E+02	9.06307E+02	3.40409E+03
11	5.45686E-01	3.34619E+05	1.79596E-01	7.21911E+02	9.97112E+02	3.42983E+03
13	5.54388E-01	3.55826E+05	1.95192E-01	6.93737E+02	1.07126E+03	3.49630E+03
15	5.63090E-01	3.78247E+05	2.10722E-01	6.71876E+02	1.15772E+03	3.52805E+03
17	5.71792E-01	4.01063E+05	2.28749E-01	6.49778E+02	1.23895E+03	3.58100E+03
19	5.80485E-01	4.38881E+05	2.67750E-01	6.17791E+02	1.35704E+03	3.74900E+03
21	5.89196E-01	4.52474E+05	2.80733E-01	6.09400E+02	1.39597E+03	3.78001E+03
23	5.97898E-01	4.81672E+05	3.04456E-01	5.94946E+02	1.48750E+03	3.79640E+03
25	6.06600E-01	5.13473E+05	3.35090E-01	5.80409E+02	1.57746E+03	3.84300E+03
27	6.15302E-01	5.49507E+05	3.76422E-01	5.65184E+02	1.66594E+03	3.92522E+03
29	6.24004E-01	5.90424E+05	4.26995E-01	5.51831E+02	1.75970E+03	4.02243E+03
31	6.32706E-01	6.38042E+05	4.89390E-01	5.40513E+02	1.85747E+03	4.12672E+03
33	6.41408E-01	6.94979E+05	5.68801E-01	5.29407E+02	1.95656E+03	4.23842E+03
35	6.50110E-01	7.62267E+05	6.69329E-01	5.17479E+02	2.05189E+03	4.34954E+03
36	6.54461E-01	8.01766E+05	7.26968E-01	5.10658E+02	2.09835E+03	4.39239E+03

PLANE M = 30 PHI = 147.500

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N	R	P	RHO	U	V	W
1	5.01703E-01	4.08408E+05	1.95198E-01	3.04170E+02	5.13634E+02	3.07553E+03
3	5.08516E-01	4.30444E+05	2.08815E-01	2.40892E+02	5.57370E+02	3.16573E+03
5	5.15329E-01	4.52607E+05	2.19100E-01	1.85903E+02	6.06221E+02	3.15583E+03
7	5.22142E-01	4.74431E+05	2.31443E-01	1.32243E+02	6.50613E+02	3.19875E+03
9	5.28954E-01	4.96483E+05	2.44829E-01	8.42503E+01	6.93089E+02	3.25552E+03
11	5.35767E-01	5.19221E+05	2.58831E-01	3.64799E+01	7.38915E+02	3.30857E+03
13	5.42580E-01	5.42419E+05	2.73770E-01	-7.84019E+00	7.80442E+02	3.36065E+03
15	5.49393E-01	5.66474E+05	2.92048E-01	-5.54704E+01	8.27221E+02	3.44004E+03
17	5.56206E-01	5.91772E+05	3.11717E-01	-9.67004E+01	8.69075E+02	3.51383E+03
19	5.63018E-01	6.18997E+05	3.32967E-01	-1.41673E+02	9.19302E+02	3.57623E+03
21	5.69831E-01	6.48039E+05	3.63394E-01	-1.88979E+02	9.65733E+02	3.69532E+03
23	5.76644E-01	6.79971E+05	3.95218E-01	-2.33293E+02	1.01254E+03	3.78615E+03
25	5.83457E-01	7.14208E+05	4.22519E-01	-2.75813E+02	1.06301E+03	3.82090E+03
27	5.90270E-01	7.51810E+05	4.59481E-01	-3.21601E+02	1.11676E+03	3.89004E+03
29	5.97082E-01	7.94100E+05	5.13409E-01	-3.68408E+02	1.17146E+03	4.00891E+03
31	6.03895E-01	8.42786E+05	5.76693E-01	-4.15074E+02	1.22720E+03	4.12177E+03
33	6.10708E-01	8.99287E+05	6.50744E-01	-4.63621E+02	1.28481E+03	4.23323E+03
35	6.17521E-01	9.64052E+05	7.40231E-01	-5.11990E+02	1.34240E+03	4.34964E+03
36	6.20927E-01	1.00107E+06	7.91198E-01	-5.36850E+02	1.37190E+03	4.40335E+03

PLANE M - 36 PHI - 177.500

N	R	P	RHO	U	V	W
1	5.01536E-01	4.08408E+05	1.95198E-01	-1.31155E+01	4.99661E+01	3.13250E+03
3	5.07682E-01	4.30444E+05	2.08815E-01	-7.37718E+01	5.28534E+01	3.22216E+03
5	5.13828E-01	4.52607E+05	2.19100E-01	-1.32389E+02	5.63776E+01	3.21569E+03
7	5.19974E-01	4.74431E+05	2.31443E-01	-1.88779E+02	5.95523E+01	3.26092E+03
9	5.26120E-01	4.96483E+05	2.44829E-01	-2.41482E+02	6.26842E+01	3.32019E+03
11	5.32266E-01	5.19221E+05	2.58831E-01	-2.96377E+02	6.61558E+01	3.37665E+03
13	5.38412E-01	5.42419E+05	2.73770E-01	-3.47417E+02	6.93123E+01	3.43185E+03
15	5.44558E-01	5.66474E+05	2.92048E-01	-4.01517E+02	7.28219E+01	3.51493E+03
17	5.50704E-01	5.91772E+05	3.11717E-01	-4.52259E+02	7.61256E+01	3.59184E+03
19	5.56850E-01	6.18997E+05	3.32967E-01	-5.09706E+02	8.01403E+01	3.65901E+03
21	5.62996E-01	6.48039E+05	3.63394E-01	-5.59717E+02	8.34615E+01	3.78200E+03
23	5.69141E-01	6.79971E+05	3.95219E-01	-6.13079E+02	8.70884E+01	3.87700E+03
25	5.75287E-01	7.14208E+05	4.22519E-01	-6.71988E+02	9.12928E+01	3.91732E+03
27	5.81433E-01	7.51810E+05	4.59481E-01	-7.31551E+02	9.56097E+01	3.99232E+03
29	5.87579E-01	7.94100E+05	5.13409E-01	-7.91341E+02	9.99577E+01	4.11621E+03
31	5.93725E-01	8.42786E+05	5.76695E-01	-8.53208E+02	1.04475E+02	4.23420E+03
33	5.99871E-01	8.99286E+05	6.50744E-01	-9.16009E+02	1.09079E+02	4.35143E+03
35	6.06017E-01	9.64052E+05	7.40230E-01	-9.78731E+02	1.13688E+02	4.47356E+03
36	6.09090E-01	1.00107E+06	7.91198E-01	-1.01152E+03	1.16073E+02	4.53025E+03

1SHOCK DATA FOR ZEUS

M	C	CZ	CPHI	PHI
1	9.24286E-01	9.61111E-01	-1.41036E-02	2.50000E+00
3	9.17666E-01	9.48112E-01	-6.85406E-02	1.25000E+01
5	9.02486E-01	9.18274E-01	-1.15430E-01	2.25000E+01
7	8.79361E-01	8.72594E-01	-1.50059E-01	3.25000E+01
9	8.50172E-01	8.14522E-01	-1.70278E-01	4.25000E+01
11	8.20553E-01	7.56569E-01	-1.79262E-01	5.25000E+01
13	7.88859E-01	6.93760E-01	-1.76687E-01	6.25000E+01
15	7.58857E-01	6.33946E-01	-1.66993E-01	7.25000E+01
17	7.31205E-01	5.79489E-01	-1.52921E-01	8.25000E+01
19	7.05739E-01	5.28376E-01	-1.35594E-01	9.25000E+01
21	6.83649E-01	4.82485E-01	-1.17210E-01	1.02500E+02
23	6.65103E-01	4.42779E-01	-9.90278E-02	1.12500E+02
25	6.49050E-01	4.07447E-01	-8.11792E-02	1.22500E+02
27	6.36596E-01	3.79871E-01	-6.48930E-02	1.32500E+02
29	6.26445E-01	3.56429E-01	-4.94732E-02	1.42500E+02
31	6.19289E-01	3.39007E-01	-3.52838E-02	1.52500E+02
33	6.14146E-01	3.26190E-01	-2.19254E-02	1.62500E+02
35	6.11218E-01	3.18767E-01	-9.25615E-03	1.72500E+02
36	6.10626E-01	3.17255E-01	-3.07567E-03	1.77500E+02

USER TIME = 305.0160
SYSTEM TIME = 1.234340

FORTRAN STOP

B.2.2 ZEUS Output

1 PROGRAM ZEUS

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```

**** INTEGRATION CONTROL ****
ICORD = 1 (0-CARTESIAN, 1-CYLINDRICAL COORDINATES)
ZETA = 0.50000 (INITIAL ZETA)
ZETAEND = 10.00000 (MAXIMUM ZETA)
KSTART = 0 (INITIAL STEP NUMBER)
KEND = 5000 (MAXIMUM STEP NUMBER)
FCFL = 0.90000 (CFL SAFETY FACTOR)
XKI = 1.000000 (INTERIOR POINT LIMITER)
IAPR = 0 (0-APPROXIMATE RIEMANN PROBLEM
1-COMplete RIEMANN PROBLEM)
ISHFLUX = 0 (FLUX AT SHOCK- 0-RIEMANN PROBLEM
1-FREESTREAM PROPERTIES)
ISHANG = 1 (SHOCK ANGLE - 0-RIEMANN PROBLEM
1-ROE AVERAGED VARIABLES)

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```

**** BOUNDARY CONDITIONS ****
MXKE = 0 (NUMBER OF EDGES WITH NON-DEFAULT LIMITER SETTINGS)
NSUR = 0 (NUMBER OF EDGES WITH NON-DEFAULT SURFACE TYPE)
DFAC = 0.9000 (REDUCE TURNS WHICH ARE TOO LARGE BY DFAC)
ISHOCK = 1 (1-SHOCK, 0-NO SHOCK ON EDGE 3)
IASYM = 1 (0-NO SYMMETRY, 1-PITCH PLANE SYMMETRY)

```

```

SURFACE POINT LIMITER
ZONE EDGE 1 EDGE 2 EDGE 3 EDGE 4
1 1.000 0.000 2.000 0.000

```

```

SURFACE TYPE
ZONE EDGE 1 EDGE 2 EDGE 3 EDGE 4
1 1 0 1 0

```

**** OUTPUT CONTROL ****

```

PRINTER (file 6)
IPRINT = 250 (PRINT FLOW FIELD IF STEP NUMBER IS EVENLY DIVISIBLE BY IPRINT)
ISKIP = 10 (PRINT STEP SIZE IF STEP NUMBER IS EVENLY DIVISIBLE BY ISKIP)
NSKIP = 6 (PRINT N PLANES WHICH ARE EVENLY DIVISIBLE BY NSKIP)
MSKIP = 6 (PRINT M PLANES WHICH ARE EVENLY DIVISIBLE BY MSKIP)

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PRESSURE SUMMARY (PLOTZA)
KSKIP = 40 (PRINT SURFACE PRESSURE IF STEP NUMBER IS EVENLY DIVISIBLE BY KSKIP)
NPRT = 100 (DON'T PRINT POINTS IF N>NPRT)
DELZA = 10000.000 (PRINT SURFACE PRESSURE EVERY ZETA = DELZA)
JSPPR = 0 (NUMBER OF NON-DEFAULT EDGES)
JSPDIS = 0 (PRINT SURFACE GRID POINT LOCATIONS)
SURFACE PRESSURE OUTPUT CONTROL: 0-DON'T PRINT, 1-PRINT.
ZONE EDGE 1 EDGE 2 EDGE 3 EDGE 4
1 1 0 0 0

```

```

PLOT FILE (PLOTZC)
IPLOT = 10000 (WRITE TO PLOTZC IF STEP NUMBER IS EVENLY DIVISIBLE BY IPLOT)
DELZC = 10000.000 (WRITE PLOT TAPE EVERY ZETA = DELZC)
IPLOTN = 2 (NUMBER OF TARGET PLOT STATIONS)
ZPLOT = 0.50000 10.00000

```

```

*****AERODYNAMICS DATA*****
AREF = 1.0000 (REFERENCE AREA)
ALREF = 1.0000 (REFERENCE LENGTH)
IEFORCE = 0 (0 - DON'T; 1 - DO PRINT EDGE LOADS)

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```

*****SEPARATION MODELING*****
IVIS = 0 (0 - INVISCID, 1 - CLIPPING, 2 - FORCED SEPARATION)

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*****GAS TYPE*****

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IGAS = 1 (0-PERFECT EQUILIBRIUM AIR)

*****UNITS*****

IUNITS = 1 (0-ENGLISH, 1-METRIC)

**** INITIAL DATA PLANE ****

IMOD = 1 (0 SELF START:1 FROM TAPE START)
MACH = 20.0000(FREE-STREAM MACH NUMBER)
ALPHA = 20.0000(ANGLE OF ATTACK)
BETA = 0.0000(YAW ANGLE)
PINF = 5529.0779(FREE-STREAM PRESSURE)
DINF = 8.8915E-02(FREE-STREAM DENSITY)
HO = 1.5162E+12(STAGNATION ENTHALPY)
SINF = 0.0000(FREE-STREAM ENTROPY)
IZN = 1 (NUMBER OF ZONES)
NA = 36 (CELLS BETWEEN EDGES 1 AND 3)
MA = 36 (TOTAL CELLS BETWEEN EDGES 2 AND 4)
MA/ZONE: 36
IMESHF = 0 (0-UNIFORM MESH,1-CLUSTERED MESH
BETWEEN EDGES 1 AND 3)
IMESHG = 0 (0-UNIFORM,1-CLUSTERED MESH
BETWEEN EDGES 2 AND 4)

STEP = 0 ZETA = 5.0000000E-01 DZETA = 0.0000000E+00
MACH NO. = 2.0000000E+01 ALPHA = 2.0000000E+01 BETA = 0.0000000E+00

ZONE NO. 1

CELL PLANE M = 1

C = 9.2428601E-01 C2 = 9.6111101E-01 CT = -1.4103631E-02 VX = 9.9838262E-01 5.88638149E-02 0.0000000E+00 ISUR 3
B = 5.0000000E-01 B2 = 0.0000000E+00 BT = 0.0000000E+00 VX = 0.0000000E+00 0.0000000E+00 0.0000000E+00 ISUR 1

N	S	T	P	D	U	V	W	E	M
36.5	9.183931E-01	4.363323E-02	4.569594E-05	5.837047E-01	3.420235E+03	-6.810439E+01	4.064138E+03	8.944247E+03	5.566885E+00
31.5	8.594645E-01	4.363323E-02	3.205568E-05	3.193162E-02	3.086448E+03	-6.608672E+01	3.954461E+03	9.694987E+03	4.497383E+00
25.5	7.887502E-01	4.363323E-02	2.315177E-05	1.857429E-01	2.625004E+03	-6.278110E+01	3.769571E+03	1.027318E+04	3.700651E+00
19.5	7.180359E-01	4.363323E-02	1.763107E-05	1.240225E-01	2.177979E+03	-6.071832E+01	3.693437E+03	1.063360E+04	3.276337E+00
13.5	6.473215E-01	4.363323E-02	1.326544E-05	8.663950E-02	1.755453E+03	-6.044731E+01	3.731761E+03	1.085489E+04	3.085242E+00
7.5	5.766072E-01	4.363323E-02	9.207491E-04	5.894683E-02	1.183502E+03	-6.188703E+01	3.893451E+03	1.102903E+04	3.029335E+00
1.5	5.058929E-01	4.363323E-02	4.508974E-04	3.114715E-02	1.251147E+02	-6.613063E+01	4.192732E+03	1.114449E+04	3.218029E+00

CELL PLANE M = 12

C = 8.0421042E-01 C2 = 7.2419882E-01 CT = -1.7878149E-01 VX = 3.49807858E-01 9.62836862E-01 0.0000000E+00 ISUR 3
B = 5.0000000E-01 B2 = 0.0000000E+00 BT = 0.0000000E+00 VX = 0.0000000E+00 0.0000000E+00 0.0000000E+00 ISUR 1

N	S	T	P	D	U	V	W	E	M
36.5	7.999853E-01	1.003564E+00	5.131466E-05	6.080638E-01	2.840198E+03	-1.297386E+03	4.212109E+03	9.046637E+03	5.323775E+00
31.5	7.577338E-01	1.003564E+00	3.681330E-05	3.492402E-01	2.517548E+03	-1.247642E+03	4.068437E+03	9.747701E+03	4.321056E+00
25.5	7.070321E-01	1.003564E+00	2.704453E-05	2.103579E-01	2.101715E+03	-1.176383E+03	3.844306E+03	1.030159E+04	3.586752E+00
19.5	6.563303E-01	1.003564E+00	2.076475E-05	1.393267E-01	1.727978E+03	-1.134454E+03	3.652021E+03	1.064846E+04	3.157021E+00
13.5	6.056286E-01	1.003564E+00	1.596352E-05	1.019252E-01	1.320608E+03	-1.110360E+03	3.704460E+03	1.083014E+04	3.029101E+00
7.5	5.549269E-01	1.003564E+00	1.144051E-05	7.027075E-02	8.647255E+02	-1.130109E+03	3.724623E+03	1.103635E+04	2.916554E+00
1.5	5.042251E-01	1.003564E+00	6.346638E-04	4.107080E-02	8.559204E+01	-1.185570E+03	3.904660E+03	1.114655E+04	3.053542E+00

CELL PLANE M = 24

C = 6.5663689E-01 C2 = 4.2421091E-01 CT = -8.9929581E-02 VX = -5.83229065E-01 8.23772132E-01 0.0000000E+00 ISUR 3
B = 5.0000000E-01 B2 = 0.0000000E+00 BT = 0.0000000E+00 VX = 0.0000000E+00 0.0000000E+00 0.0000000E+00 ISUR 1

N	S	T	P	D	U	V	W	E	M
36.5	6.544614E-01	2.050762E+00	8.017663E-05	7.269682E-01	1.625465E+03	-1.421870E+03	4.392387E+03	9.486033E+03	4.264193E+00
31.5	6.327063E-01	2.050762E+00	6.380416E-05	4.893899E-01	1.398019E+03	-1.337128E+03	4.126717E+03	9.991312E+03	3.595501E+00
25.5	6.066001E-01	2.050762E+00	5.134731E-05	3.350902E-01	1.131219E+03	-1.243218E+03	3.843002E+03	1.037733E+04	3.103972E+00
19.5	5.804939E-01	2.050762E+00	4.257402E-05	2.540733E-01	8.791566E+02	-1.165272E+03	3.695823E+03	1.060195E+04	2.856104E+00
13.5	5.543878E-01	2.050762E+00	3.558261E-05	1.951924E-01	6.298855E+02	-1.110004E+03	3.496295E+03	1.086138E+04	2.584120E+00
7.5	5.282817E-01	2.050762E+00	2.930691E-05	1.543802E-01	3.676338E+02	-1.075683E+03	3.380723E+03	1.104831E+04	2.431878E+00
1.5	5.021755E-01	2.050762E+00	2.283814E-05	1.193118E-01	3.169659E+01	-1.063594E+03	3.345056E+03	1.117764E+04	2.384751E+00

CELL PLANE M = 36

C = 6.1062628E-01 C2 = 3.1725460E-01 CT = -3.0756728E-03 VX = -9.99267936E-01 3.85871679E-02 0.0000000E+00 ISUR 3
B = 5.0000000E-01 B2 = 0.0000000E+00 BT = 0.0000000E+00 VX = 0.0000000E+00 0.0000000E+00 0.0000000E+00 ISUR 1

N	S	T	P	D	U	V	W	E	M
36.5	6.090898E-01	3.097960E+00	1.001066E+06	7.911978E-01	1.015618E+03	-7.184073E+01	4.530247E+03	9.748788E+03	3.726900E+00
31.5	5.937250E-01	3.097960E+00	8.427879E+05	5.766953E-01	8.569534E+02	-6.715912E+01	4.234202E+03	1.012967E+04	3.234094E+00
25.5	5.752873E-01	3.097960E+00	7.142076E+05	4.225185E-01	6.753306E+02	-6.189426E+01	3.917321E+03	1.053936E+04	2.778456E+00
19.5	5.568496E-01	3.097960E+00	6.189971E+05	3.329672E-01	5.127166E+02	-5.783103E+01	3.659011E+03	1.068942E+04	2.538745E+00
13.5	5.384119E-01	3.097960E+00	5.424189E+05	2.737695E-01	3.501100E+02	-5.409221E+01	3.431850E+03	1.098889E+04	2.302670E+00
7.5	5.199742E-01	3.097960E+00	4.744309E+05	2.314432E-01	1.911973E+02	-5.126116E+01	3.260924E+03	1.106457E+04	2.144908E+00
1.5	5.015365E-01	3.097960E+00	4.084078E+05	1.951976E-01	1.528248E+01	-4.934645E+01	3.132501E+03	1.119398E+04	2.035921E+00

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SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      1  34
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      2  34
OSTEP = 20 ZETA = 6.10449910E-01 DZETA = 6.26837742E-03 NCFL,MCFL = 1  35
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      14  35
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      17  36
OSTEP = 30 ZETA = 6.77150786E-01 DZETA = 7.00617116E-03 NCFL,MCFL = 1  35
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      15  34
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      18  36
OSTEP = 40 ZETA = 7.51731277E-01 DZETA = 7.77146500E-03 NCFL,MCFL = 1  36
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      18  34
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      20  35
OSTEP = 50 ZETA = 8.33479047E-01 DZETA = 8.54412373E-03 NCFL,MCFL = 1  35
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      29  36
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      32  35
OSTEP = 60 ZETA = 9.22998130E-01 DZETA = 9.22467839E-03 NCFL,MCFL = 1  36
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      27  34
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      28  34
OSTEP = 70 ZETA = 1.01756394E+00 DZETA = 9.61779151E-03 NCFL,MCFL = 1  36
OSTEP = 80 ZETA = 1.11583364E+00 DZETA = 1.00026354E-02 NCFL,MCFL = 1  35
OSTEP = 90 ZETA = 1.21771550E+00 DZETA = 1.03135379E-02 NCFL,MCFL = 1  36
OSTEP = 100 ZETA = 1.32186139E+00 DZETA = 1.04742153E-02 NCFL,MCFL = 1  36
OSTEP = 110 ZETA = 1.42711949E+00 DZETA = 1.05639528E-02 NCFL,MCFL = 1  35
OSTEP = 120 ZETA = 1.53316963E+00 DZETA = 1.06327394E-02 NCFL,MCFL = 1  35
OSTEP = 130 ZETA = 1.63970387E+00 DZETA = 1.06570804E-02 NCFL,MCFL = 1  36
OSTEP = 140 ZETA = 1.74617064E+00 DZETA = 1.06357168E-02 NCFL,MCFL = 1  35
OSTEP = 150 ZETA = 1.85228038E+00 DZETA = 1.05827358E-02 NCFL,MCFL = 1  35
OSTEP = 160 ZETA = 1.95765221E+00 DZETA = 1.04967644E-02 NCFL,MCFL = 1  35
OSTEP = 170 ZETA = 2.06214452E+00 DZETA = 1.04126129E-02 NCFL,MCFL = 1  35
OSTEP = 180 ZETA = 2.16567969E+00 DZETA = 1.02975955E-02 NCFL,MCFL = 1  35
OSTEP = 190 ZETA = 2.26793245E+00 DZETA = 1.01717506E-02 NCFL,MCFL = 1  35
OSTEP = 200 ZETA = 2.36898994E+00 DZETA = 1.00452183E-02 NCFL,MCFL = 1  36
OSTEP = 210 ZETA = 2.46855021E+00 DZETA = 9.88018699E-03 NCFL,MCFL = 1  36
OSTEP = 220 ZETA = 2.56648564E+00 DZETA = 9.71829426E-03 NCFL,MCFL = 1  36
OSTEP = 230 ZETA = 2.66279626E+00 DZETA = 9.56043880E-03 NCFL,MCFL = 1  35
OSTEP = 240 ZETA = 2.75750709E+00 DZETA = 9.39748995E-03 NCFL,MCFL = 1  36
OSTEP = 250 ZETA = 2.85059977E+00 DZETA = 9.24461149E-03 NCFL,MCFL = 1  36
OSTEP = 260 ZETA = 2.94215298E+00 DZETA = 9.08483285E-03 NCFL,MCFL = 1  36
OSTEP = 270 ZETA = 3.03217936E+00 DZETA = 8.93738307E-03 NCFL,MCFL = 1  36
OSTEP = 280 ZETA = 3.12084389E+00 DZETA = 8.81141145E-03 NCFL,MCFL = 1  36
OSTEP = 290 ZETA = 3.20843863E+00 DZETA = 8.72045569E-03 NCFL,MCFL = 1  36
OSTEP = 300 ZETA = 3.29529333E+00 DZETA = 8.66061728E-03 NCFL,MCFL = 1  36
OSTEP = 310 ZETA = 3.38171387E+00 DZETA = 8.62895790E-03 NCFL,MCFL = 1  36
OSTEP = 320 ZETA = 3.46789980E+00 DZETA = 8.60986672E-03 NCFL,MCFL = 1  36
OSTEP = 330 ZETA = 3.55392647E+00 DZETA = 8.59935209E-03 NCFL,MCFL = 1  36
OSTEP = 340 ZETA = 3.63992476E+00 DZETA = 8.59925617E-03 NCFL,MCFL = 1  36
OSTEP = 350 ZETA = 3.72585368E+00 DZETA = 8.60059541E-03 NCFL,MCFL = 1  36
OSTEP = 360 ZETA = 3.81194711E+00 DZETA = 8.63548182E-03 NCFL,MCFL = 1  36
OSTEP = 370 ZETA = 3.89869714E+00 DZETA = 8.72740336E-03 NCFL,MCFL = 1  36
OSTEP = 380 ZETA = 3.98677015E+00 DZETA = 8.88944138E-03 NCFL,MCFL = 1  36
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      36  7
OSTEP = 390 ZETA = 4.07670307E+00 DZETA = 9.08970740E-03 NCFL,MCFL = 1  36
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      36  7
OSTEP = 400 ZETA = 4.16891718E+00 DZETA = 9.32839606E-03 NCFL,MCFL = 1  36
OSTEP = 410 ZETA = 4.26368237E+00 DZETA = 9.58875287E-03 NCFL,MCFL = 1  36
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      35  6
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      36  6
OSTEP = 420 ZETA = 4.36092186E+00 DZETA = 9.82640963E-03 NCFL,MCFL = 1  36
OSTEP = 430 ZETA = 4.46059608E+00 DZETA = 1.00939022E-02 NCFL,MCFL = 1  36
OSTEP = 440 ZETA = 4.56333208E+00 DZETA = 1.04226097E-02 NCFL,MCFL = 1  36
OSTEP = 450 ZETA = 4.66950130E+00 DZETA = 1.07863303E-02 NCFL,MCFL = 1  36
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      35  5
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      35  5
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      36  5
OSTEP = 460 ZETA = 4.77955532E+00 DZETA = 1.11917388E-02 NCFL,MCFL = 1  35
OSTEP = 470 ZETA = 4.89393473E+00 DZETA = 1.16407908E-02 NCFL,MCFL = 1  35
OSTEP = 480 ZETA = 5.01288700E+00 DZETA = 1.21093737E-02 NCFL,MCFL = 1  35
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      35  4
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      35  4
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      35  4
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      36  4
SECANT METHOD IN DECODE DID NOT CONVERGE FOR M.N      36  4
OSTEP = 490 ZETA = 5.13669157E+00 DZETA = 1.26054632E-02 NCFL,MCFL = 1  35
OSTEP = 500 ZETA = 5.26547289E+00 DZETA = 1.31032886E-02 NCFL,MCFL = 1  35
1 STEP = 500 ZETA = 5.2654729E+00 DZETA = 1.3103289E-02
MACH NO. = 2.0000000E+01 ALPHA = 2.0000000E+01 BETA = 0.0000000E+00

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0
0
0
LEFT EDGE PLANE GEOMETRY
M X Y SG SG2 SGS VE1 VE2 VE3 ISUR
36.5 3.948509E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 1.271564E-03 0.000000E+00 0
31.5 3.462803E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 1.271566E-03 0.000000E+00 0
25.5 2.879957E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 1.271563E-03 0.000000E+00 0
19.5 2.297110E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 1.271566E-03 0.000000E+00 0
13.5 1.714264E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 1.271566E-03 0.000000E+00 0
7.5 1.131417E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 1.271566E-03 0.000000E+00 0
1.5 5.485706E-01 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 1.271565E-03 0.000000E+00 0
0
0
LEFT EDGE PLANE CEF = 3.9970794E+00 BEF = 5.0000000E-01
M S T P D U V W E M
36.5 3.948509E+00 0.000000E+00 5.273677E+04 3.019022E+01 2.569173E+03 0.000000E+00 5.224500E+03 7.728162E-03 1.217545E+01

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NAVSWC TR 91-86

31.5	3.462803E+00	0.000000E+00	2.202334E+04	6.423993E-02	2.237354E+03	0.000000E+00	5.251650E+03	8.908890E+03	8.044763E+00
25.5	2.879957E+00	0.000000E+00	2.501182E+04	3.115077E-02	2.041357E+03	0.000000E+00	4.868468E+03	1.001343E+04	5.368529E+00
19.5	2.297110E+00	0.000000E+00	2.791483E+04	2.495513E-02	1.690490E+03	0.000000E+00	4.419418E+03	1.077295E+04	4.206345E+00
13.5	1.714264E+00	0.000000E+00	3.215629E+04	2.529749E-02	1.317421E+03	0.000000E+00	4.251283E+03	1.104708E+04	3.571992E+00
7.5	1.131417E+00	0.000000E+00	2.793257E+04	2.115690E-02	4.214730E+02	0.000000E+00	4.379603E+03	1.116279E+04	3.487218E+00
1.5	5.485706E-01	0.000000E+00	1.920391E+04	1.518229E-02	-7.475690E+01	0.000000E+00	4.446773E+03	1.122167E+04	3.609775E+00

CELL PLANE M = 1

C =	3.9970794E+00	CZ =	5.4630756E-01	CT =	-2.1438050E-01	VX =	4.53934819E-03	4.42986522E-04	-2.47700280E-03	ISUR	3
B =	5.0000000E-01	BZ =	0.0000000E+00	BT =	0.0000000E+00	VX =	5.71013428E-04	2.49308396E-05	0.0000000E+00	ISUR	1

N	S	T	P	D	U	V	W	E	M
37.0	3.997079E+00	4.363323E-02	5.529878E+03	8.891485E-02	2.012553E+03	-8.786999E+01	5.534712E+03	7.379570E+03	2.025339E+01
36.5	3.948509E+00	4.363323E-02	5.273540E+04	3.021779E-01	2.564426E+03	-5.788649E+01	5.226327E+03	7.726613E+03	1.218586E+01
31.5	3.462803E+00	4.363323E-02	2.202091E+04	6.451037E-02	2.236015E+03	-6.924432E+01	5.252910E+03	8.903811E+03	8.060996E+00
25.5	2.879957E+00	4.363323E-02	2.478445E+04	3.119242E-02	2.039936E+03	-5.978442E+01	4.874799E+03	9.999036E+03	5.393028E+00
19.5	2.297110E+00	4.363323E-02	2.791492E+04	2.495842E-02	1.695213E+03	-5.701541E+01	4.420810E+03	1.077262E+04	4.209551E+00
13.5	1.714264E+00	4.363323E-02	3.213380E+04	2.530545E-02	1.334913E+03	-7.568957E+01	4.256738E+03	1.104527E+04	3.582257E+00
7.5	1.131417E+00	4.363323E-02	2.766521E+04	2.084335E-02	4.296613E+02	-8.523690E+01	4.363805E+03	1.117456E+04	3.469384E+00
1.5	5.485706E-01	4.363323E-02	1.916898E+04	1.512489E-02	-7.183366E+01	4.609303E+01	4.446430E+03	1.122607E+04	3.606447E+00
1.0	5.000000E-01	4.363323E-02	2.044163E+04	1.594067E-02	1.239777E-05	4.786615E+01	4.428868E+03	1.122467E+04	3.565625E+00

CELL PLANE M = 12

C =	2.2698357E+00	CZ =	1.2464654E-01	CT =	-2.5217483E+00	VX =	-1.03046116E-03	3.73550295E-03	-3.23832966E-04	ISUR	3
B =	5.0000000E-01	BZ =	0.0000000E+00	BT =	0.0000000E+00	VX =	3.07097391E-04	4.82046336E-04	0.0000000E+00	ISUR	1

N	S	T	P	D	U	V	W	E	M
37.0	2.269836E+00	1.003564E+00	5.529878E+03	8.891485E-02	1.082374E+03	-1.698987E+03	5.534712E+03	7.379570E+03	2.025339E+01
36.5	2.245255E+00	1.003564E+00	6.943661E+04	3.561593E-01	1.576275E+03	-1.140037E+03	5.473394E+03	7.823369E+03	1.120743E+01
31.5	1.999444E+00	1.003564E+00	4.758683E+04	1.962632E-01	1.448847E+03	-1.177382E+03	5.467701E+03	8.257305E+03	9.649740E+00
25.5	1.704472E+00	1.003564E+00	3.610051E+04	1.003784E-01	1.336081E+03	-1.228663E+03	5.399285E+03	8.838265E+03	7.811549E+00
19.5	1.409499E+00	1.003564E+00	3.073950E+04	5.858904E-02	1.256304E+03	-1.313848E+03	5.266307E+03	9.321718E+03	6.619675E+00
13.5	1.114526E+00	1.003564E+00	2.595551E+04	3.752777E-02	1.218603E+03	-1.495716E+03	5.067339E+03	9.723487E+03	5.663133E+00
7.5	8.195537E-01	1.003564E+00	1.878327E+04	2.367537E-02	1.191168E+03	-1.917458E+03	4.777876E+03	1.007396E+04	5.410516E+00
1.5	5.245811E-01	1.003564E+00	4.965557E+03	6.155840E-03	4.426134E+02	-2.957131E+03	4.291173E+03	1.052813E+04	5.33321E+00
1.0	5.000000E-01	1.003564E+00	2.435716E+03	3.271021E-03	-2.441406E-04	-3.032494E+03	4.359388E+03	1.055487E+04	5.635487E+00

CELL PLANE M = 24

C =	7.7768797E-01	CZ =	-2.9416770E-02	CT =	-4.2291144E-01	VX =	-8.41408968E-04	5.68058749E-04	2.42916867E-05	ISUR	3
B =	5.0000000E-01	BZ =	0.0000000E+00	BT =	0.0000000E+00	VX =	-2.63915746E-04	5.06977551E-04	0.0000000E+00	ISUR	1

N	S	T	P	D	U	V	W	E	M
37.0	7.776880E-01	2.050762E+00	5.529878E+03	8.891485E-02	-9.301791E+02	-1.786857E+03	5.534712E+03	7.379570E+03	2.025339E+01
36.5	7.738312E-01	2.050762E+00	1.710458E+05	4.670250E-01	1.514464E+02	-1.106505E+03	5.565351E+03	8.221758E+03	8.294338E+00
31.5	7.352634E-01	2.050762E+00	1.698592E+05	4.514147E-01	1.346068E+02	-1.131142E+03	5.569876E+03	8.252963E+03	8.190520E+00
25.5	6.889821E-01	2.050762E+00	1.630559E+05	4.213221E-01	1.007591E+02	-1.070628E+03	5.574574E+03	8.294351E+03	8.086326E+00
19.5	6.427008E-01	2.050762E+00	1.545377E+05	3.888446E-01	8.120139E+01	-1.044015E+03	5.570907E+03	8.589527E+03	7.288208E+00
13.5	5.964195E-01	2.050762E+00	1.418794E+05	3.239850E-01	6.818683E+01	-1.079013E+03	5.533795E+03	8.727136E+03	6.979320E+00
7.5	5.501381E-01	2.050762E+00	1.254745E+05	2.085441E-01	6.318880E+01	-1.264988E+03	5.368826E+03	9.134972E+03	6.098162E+00
1.5	5.038568E-01	2.050762E+00	1.027455E+05	9.935740E-02	1.394836E+01	-1.780916E+03	4.613887E+03	1.012782E+04	4.445147E+00
1.0	5.000000E-01	2.050762E+00	1.002207E+05	9.341722E-02	-3.051758E-04	-1.833005E+03	4.525642E+03	1.021808E+04	4.291087E+00

CELL PLANE M = 36

C =	6.3154739E-01	CZ =	1.1087256E-02	CT =	-5.3487187E-03	VX =	-7.21694028E-04	2.53912494E-05	-8.01097121E-06	ISUR	3
B =	5.0000000E-01	BZ =	0.0000000E+00	BT =	0.0000000E+00	VX =	-5.71013312E-04	2.49308396E-05	0.0000000E+00	ISUR	1

N	S	T	P	D	U	V	W	E	M
37.0	6.315474E-01	3.097960E+00	5.529878E+03	8.891485E-02	-2.012553E+03	-8.786999E+01	5.534712E+03	7.379570E+03	2.025339E+01
36.5	6.297203E-01	3.097960E+00	3.182085E+05	5.426152E-01	-2.792198E+02	-7.145551E+01	5.513780E+03	8.616888E+03	6.546313E+00
31.5	6.114499E-01	3.097960E+00	3.419219E+05	5.813736E-01	-2.039548E+02	-6.440948E+01	5.515732E+03	8.601406E+03	6.530947E+00
25.5	5.895253E-01	3.097960E+00	3.500373E+05	6.174279E-01	-1.585223E+02	-5.546131E+01	5.534923E+03	8.547185E+03	6.652716E+00
19.5	5.676007E-01	3.097960E+00	3.554863E+05	6.759090E-01	-1.214980E+02	-4.856411E+01	5.569305E+03	8.448100E+03	6.906699E+00
13.5	5.456762E-01	3.097960E+00	3.590069E+05	6.875332E-01	-8.845501E+01	-4.616547E+01	5.573000E+03	8.436517E+03	6.931144E+00
7.5	5.237516E-01	3.097960E+00	3.616938E+05	5.646593E-01	-5.514233E+01	-4.876560E+01	5.474557E+03	8.701936E+03	6.247940E+00
1.5	5.018271E-01	3.097960E+00	3.622339E+05	3.185101E-01	-6.563220E+00	-6.632203E+01	4.838916E+03	9.903799E+03	4.080756E+00
1.0	5.000000E-01	3.097960E+00	3.630869E+05	3.051126E-01	1.025206E-05	-6.835564E+01	4.759313E+03	9.997381E+03	3.927740E+00

RIGHT EDGE PLANE CEF = 6.3154739E-01 BEF = 5.0000000E-01

N	S	T	P	D	U	V	W	E	M
36.5	6.297203E-01	3.141593E+00	3.201479E+05	5.444122E-01	-2.764165E+02	2.416652E-05	5.513451E+03	8.618904E+03	6.537652E+00
31.5	6.114499E-01	3.141593E+00	3.431077E+05	5.824809E-01	-2.003571E+02	1.751680E-05	5.515789E+03	8.602415E+03	6.527291E+00
25.5	5.895253E-01	3.141593E+00	3.511046E+05	6.190424E-01	-1.544773E+02	1.350563E-05	5.535276E+03	8.546843E+03	6.651822E+00
19.5	5.676007E-01	3.141593E+00	3.568815E+05	6.781964E-01	-1.277091E+02	1.029106E-05	5.569451E+03	8.447686E+03	6.904570E+00
13.5	5.456762E-01	3.141593E+00	3.602058E+05	6.891600E-01	-8.521702E+01	7.450345E-06	5.572905E+03	8.436807E+03	6.927418E+00
7.5	5.237516E-01	3.141593E+00	3.627357E+05	5.645319E-01	-5.252833E+01	4.592442E-06	5.473858E+03	8.705418E+03	6.238805E+00
1.5	5.018271E-01	3.141593E+00	3.637773E+05	3.186427E-01	-2.869228E+00	2.508506E-07	4.833836E+03	9.910045E+03	4.069021E+00

RIGHT EDGE PLANE GEOMETRY

N	X	Y	TH	TH2	TH3	VE1	VE2	VE3	ISUR
36.5	6.297203E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.183765E-12	-4.785408E-05	2.602085E-18	0
31.5	6.114499E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.183789E-12	-4.785408E-05	1.084202E-19	0
25.5	5.895253E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.183765E-12	-4.785408E-05	-6.396793E-18	0
19.5	5.676007E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.183742E-12	-4.785369E-05	3.848918E-18	0
13.5	5.456762E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.183765E-12	-4.785408E-05	9.215178E-19	0
7.5	5.237516E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.183812E-12	-4.785408E-05	1.246832E-18	0
1.5	5.018271E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.183812E-12	-4.785446E-05	4.77049CE-18	0
OSTEP = 510	ZETA =	5.39954615E+00	DZETA =	1.36473980E-02	NCFL,MCFL =	:	35		
OSTEP = 520	ZETA =	5.53909492E+00	DZETA =	1.42097995E-02	NCFL,MCFL =	:	35		
OSTEP = 530	ZETA =	5.68428564E+00	DZETA =	1.47799272E-02	NCFL,MCFL =	:	35		
OSTEP = 540	ZETA =	5.83527756E+00	DZETA =	1.53615372E-02	NCFL,MCFL =	:	35		
OSTEP = 550	ZETA =	5.99135590E+00	DZETA =	1.57251675E-02	NCFL,MCFL =	:	36 35		

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OSTEP - 560 ZETA - 6.14980888E+00 DZETA - 1.59400385E-02 MCFL,MCFL - 36 35
OSTEP - 570 ZETA - 6.31033754E+00 DZETA - 1.61408186E-02 MCFL,MCFL - 36 35
OSTEP - 580 ZETA - 6.47278452E+00 DZETA - 1.63221005E-02 MCFL,MCFL - 36 35
OSTEP - 590 ZETA - 6.63692427E+00 DZETA - 1.64844971E-02 MCFL,MCFL - 36 35
OSTEP - 600 ZETA - 6.80253077E+00 DZETA - 1.66177899E-02 MCFL,MCFL - 36 35
OSTEP - 610 ZETA - 6.96941757E+00 DZETA - 1.67439282E-02 MCFL,MCFL - 36 35
OSTEP - 620 ZETA - 7.13750696E+00 DZETA - 1.68575849E-02 MCFL,MCFL - 36 35
OSTEP - 630 ZETA - 7.30665827E+00 DZETA - 1.69603694E-02 MCFL,MCFL - 36 35
OSTEP - 640 ZETA - 7.47673845E+00 DZETA - 1.70457773E-02 MCFL,MCFL - 36 35
OSTEP - 650 ZETA - 7.64765215E+00 DZETA - 1.71293113E-02 MCFL,MCFL - 36 35
OSTEP - 660 ZETA - 7.81940603E+00 DZETA - 1.72100961E-02 MCFL,MCFL - 36 35
OSTEP - 670 ZETA - 7.99185705E+00 DZETA - 1.72719564E-02 MCFL,MCFL - 36 35
OSTEP - 680 ZETA - 8.16499519E+00 DZETA - 1.73444562E-02 MCFL,MCFL - 36 35
OSTEP - 690 ZETA - 8.33881378E+00 DZETA - 1.74126029E-02 MCFL,MCFL - 36 35
OSTEP - 700 ZETA - 8.51332664E+00 DZETA - 1.74790341E-02 MCFL,MCFL - 36 35
OSTEP - 710 ZETA - 8.68850803E+00 DZETA - 1.75497290E-02 MCFL,MCFL - 36 35
OSTEP - 720 ZETA - 8.86436749E+00 DZETA - 1.76208410E-02 MCFL,MCFL - 36 35
OSTEP - 730 ZETA - 9.04093361E+00 DZETA - 1.76907927E-02 MCFL,MCFL - 36 35
OSTEP - 740 ZETA - 9.21816254E+00 DZETA - 1.77549366E-02 MCFL,MCFL - 36 35
OSTEP - 750 ZETA - 9.39608288E+00 DZETA - 1.78225134E-02 MCFL,MCFL - 36 35
OSTEP - 760 ZETA - 9.57468128E+00 DZETA - 1.78908873E-02 MCFL,MCFL - 36 35
OSTEP - 770 ZETA - 9.75395012E+00 DZETA - 1.79551002E-02 MCFL,MCFL - 36 35
OSTEP - 780 ZETA - 9.93386841E+00 DZETA - 1.80215687E-02 MCFL,MCFL - 36 35

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1 STEP = 784 ZETA = 1.0000000E+01 DZETA = 1.2024879E-02
MACH NO. = 2.0000000E+01 ALPHA = 2.0000000E+01 BETA = 0.0000000E+00

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0
0 ZONE NO. 1
0

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LEFT EDGE PLANE GEOMETRY

N	X	Y	SG	SG2	SGS	VE1	VE2	VE3	ISUR
36.5	6.369873E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.987295E-03	0.000000E+00	0
31.5	5.543130E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.987295E-03	0.000000E+00	0
25.5	4.551040E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.987290E-03	0.000000E+00	0
19.5	3.558948E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.987295E-03	0.000000E+00	0
13.5	2.566857E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.987297E-03	0.000000E+00	0
7.5	1.574766E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.987296E-03	0.000000E+00	0
1.5	5.826743E-01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.987295E-03	0.000000E+00	0

```

0 LEFT EDGE PLANE CEF = 6.4525476E+00 BEF = 5.0000000E-01
0

```

N	S	T	P	D	U	V	W	E	M
36.5	6.369873E+00	0.000000E+00	2.835976E+04	2.326600E-01	2.399441E+03	0.000000E+00	5.340361E+03	7.583657E+03	1.429512E+01
31.5	5.543130E+00	0.000000E+00	1.712667E+04	6.258249E-02	2.263370E+03	0.000000E+00	5.291910E+03	8.699800E+03	9.044283E+00
25.5	4.551040E+00	0.000000E+00	1.625102E+04	1.801091E-02	1.910288E+03	0.000000E+00	4.723252E+03	1.042361E+04	4.945440E+00
19.5	3.558948E+00	0.000000E+00	1.535448E+04	1.386239E-02	1.593242E+03	0.000000E+00	4.459707E+03	1.097202E+04	4.303402E+00
13.5	2.566857E+00	0.000000E+00	1.477381E+04	1.272523E-02	9.965613E+02	0.000000E+00	4.525190E+03	1.110420E+04	4.104843E+00
7.5	1.574766E+00	0.000000E+00	1.236026E+04	1.036081E-02	-7.418800E+01	0.000000E+00	4.596021E+03	1.124411E+04	4.005785E+00
1.5	5.826743E-01	0.000000E+00	1.136822E+04	9.580553E-03	-1.492610E+00	0.000000E+00	4.565692E+03	1.126121E+04	4.016198E+00

CELL PLANE M = 1

```

C = 6.4525476E+00 C2 = 4.9833539E-01 CT = -4.4835544E-01 VX = 6.71839295E-03 7.63475779E-04 -3.34365666E-03 ISUR 3
B = 5.0000000E-01 B2 = 0.0000000E+00 BT = 0.0000000E+00 VX = 5.24018658E-04 2.28790159E-05 0.00000000E+00 ISUR 1

```

N	S	T	P	D	U	V	W	E	M
37.0	6.452548E+00	4.363323E-02	5.529878E+03	8.891485E-02	2.012553E+03	-8.786999E+01	5.534712E+03	7.379570E+03	2.025339E+01
36.5	6.369873E+00	4.363323E-02	2.843150E+04	2.328795E-01	2.395420E+03	-6.075201E+01	5.341506E+03	7.584509E+03	1.428369E+01
31.5	5.543130E+00	4.363323E-02	1.712721E+04	6.306680E-02	2.257681E+03	-6.177565E+01	5.296678E+03	8.690151E+03	9.083074E+00
25.5	4.551040E+00	4.363323E-02	1.633682E+04	1.809420E-02	1.916805E+03	-5.579166E+01	4.723445E+03	1.042350E+04	4.947368E+00
19.5	3.558948E+00	4.363323E-02	1.541495E+04	1.409267E-02	1.607132E+03	-5.958138E+01	4.463837E+03	1.093974E+04	4.331780E+00
13.5	2.566857E+00	4.363323E-02	1.506393E+04	1.350154E-02	1.110398E+03	-1.128655E+02	4.570978E+03	1.099703E+04	4.264982E+00
7.5	1.574766E+00	4.363323E-02	1.229905E+04	1.056915E-02	2.377518E+02	-9.104774E+00	4.602365E+03	1.117967E+04	4.104311E+00
1.5	5.826743E-01	4.363323E-02	1.133518E+04	9.577113E-03	3.455939E-01	6.543094E+00	4.566873E+03	1.125551E+04	4.026333E+00
1.0	5.000000E-01	4.363323E-02	1.151925E+04	9.710311E-03	2.801418E-06	1.073677E-01	4.562448E+03	1.125556E+04	4.011530E+00

CELL PLANE M = 12

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C = 2.1922967E+00 C2 = -1.3917419E-01 CT = -5.4829402E+00 VX = -3.58463288E-03 5.07450337E-03 2.28501856E-04 ISUR 3
B = 5.0000000E-01 B2 = 0.0000000E+00 BT = 0.0000000E+00 VX = 2.8182371E-04 4.42373625E-04 0.00000000E+00 ISUR 1

```

N	S	T	P	D	U	V	W	E	M
37.0	2.192297E+00	1.003564E+00	5.529878E+03	8.891485E-02	1.082374E+03	-1.698987E+03	5.534712E+03	7.379570E+03	2.025339E+01
36.5	2.168793E+00	1.003564E+00	5.379106E+04	3.079025E-01	1.327001E+03	-1.101241E+03	5.560495E+03	7.722196E+03	1.217836E+01
31.5	1.933751E+00	1.003564E+00	5.734669E+04	2.925380E-01	1.328432E+03	-1.074552E+03	5.551104E+03	7.888898E+03	1.114894E+01
25.5	1.651702E+00	1.003564E+00	4.884989E+04	2.216371E-01	1.254504E+03	-1.094788E+03	5.547774E+03	8.113352E+03	1.026252E+01
19.5	1.369653E+00	1.003564E+00	4.051941E+04	1.616060E-01	1.134498E+03	-1.114193E+03	5.548768E+03	8.348363E+03	9.459097E+00
13.5	1.087603E+00	1.003564E+00	3.157511E+04	1.177420E-01	9.766517E+02	-1.152951E+03	5.558644E+03	8.506893E+03	9.108573E+00
7.5	8.055536E-01	1.003564E+00	2.113138E+04	8.006677E-02	7.888049E+02	-1.278627E+03	5.564006E+03	8.596039E+03	9.214929E+00
1.5	5.235041E-01	1.003564E+00	4.487952E+03	1.573135E-02	2.863460E+02	-1.909607E+03	5.414955E+03	9.114477E+03	8.945442E+00
1.0	5.000000E-01	1.003564E+00	2.017152E+03	7.307110E-03	-6.103516E-05	-1.955887E+03	5.426243E+03	9.294407E+03	9.165657E+00

CELL PLANE M = 24

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C = 8.1506759E-01 C2 = 1.7268816E-03 CT = -3.7919417E-01 VX = -7.48510647E-04 5.77229075E-04 -4.47372440E-06 ISUR 3
B = 5.0000000E-01 B2 = 0.0000000E+00 BT = 0.0000000E+00 VX = -2.42195310E-04 4.65252990E-04 0.00000000E+00 ISUR 1

```

N	S	T	P	D	U	V	W	E	M
37.0	8.150676E-01	2.050762E+00	5.529878E+03	8.891485E-02	-9.301791E+02	-1.786857E+03	5.534712E+03	7.379570E+03	2.025339E+01
36.5	8.106917E-01	2.050762E+00	1.871800E+05	4.677424E-01	2.484109E+02	-1.224342E+03	5.528264E+03	8.295788E+03	7.945295E+00
31.5	7.669322E-01	2.050762E+00	1.818370E+05	4.318679E-01	2.333861E+02	-1.164260E+03	5.525999E+03	8.360540E+03	7.757390E+00
25.5	7.144210E-01	2.050762E+00	1.680170E+05	3.795747E-01	1.916971E+02	-1.092590E+03	5.524593E+03	8.697998E+03	6.925679E+00
19.5	6.619097E-01	2.050762E+00	1.526877E+05	3.372666E-01	1.533927E+02	-1.042682E+03	5.521814E+03	8.763992E+03	6.815301E+00
13.5	6.093985E-01	2.050762E+00	1.419970E+05	3.010550E-01	1.223891E+02	-1.029058E+03	5.516377E+03	8.814532E+03	6.754023E+00
7.5	5.568872E-01	2.050762E+00	1.253541E+05	2.745954E-01	8.102298E+01	-1.034079E+03	5.527946E+03	8.806996E+03	6.866488E+00
1.5	5.043759E-01	2.050762E+00	1.019108E+05	2.181150E-01	9.391754E+00	-1.133734E+03	5.500610E+03	8.885802E+03	6.821244E+00

NAVSVC TR 91-86

1.0 5.000000E-01 2.050762E+00 9.935689E+04 2.111421E-01 -1.031055E-04 -1.145961E+03 5.496159E+03 8.900356E+03 6.804149E+00

CELL PLANE M = 36

C = 6.5807253E-01 CZ = 2.7095687E-03 CT = -7.1115894E-03 VX = -6.90316549E-04 2.26822704E-05 -1.97892587E-06 ISUR 3
B = 5.0000000E-01 BZ = 0.0000000E+00 BT = 0.0000000E+00 VY = -5.24018542E-04 2.28790159E-05 0.0000000E+00 ISUR 1

N	S	T	P	D	U	V	W	E	M
37.0	6.580725E-01	3.097960E+00	5.529878E+03	8.891485E-02	-2.012553E+03	-8.786978E+01	5.534712E+03	7.379570E+03	2.025339E+01
36.5	6.558771E-01	3.097960E+00	3.045827E+05	5.367669E-01	-3.203971E+02	-6.794724E+01	5.527374E+03	8.585774E+03	6.658715E+00
31.5	6.339226E-01	3.097960E+00	3.250288E+05	5.640563E-01	-2.469801E+02	-6.106850E+01	5.523912E+03	8.588305E+03	6.603658E+00
25.5	6.075771E-01	3.097960E+00	3.315201E+05	5.722141E-01	-1.981648E+02	-5.440464E+01	5.523361E+03	8.590006E+03	6.584314E+00
19.5	5.812317E-01	3.097960E+00	3.363574E+05	5.780598E-01	-1.521657E+02	-4.991786E+01	5.522771E+03	8.591692E+03	6.569045E+00
13.5	5.548863E-01	3.097960E+00	3.401503E+05	5.789958E-01	-1.059386E+02	-4.737104E+01	5.519175E+03	8.601271E+03	6.535852E+00
7.5	5.285408E-01	3.097960E+00	3.427994E+05	5.818673E-01	-5.765707E+01	-4.623574E+01	5.518505E+03	8.602950E+03	6.526002E+00
1.5	5.021955E-01	3.097960E+00	3.441940E+05	5.712519E-01	-5.029838E+00	-4.718049E+01	5.507557E+03	8.631653E+03	6.451591E+00
1.0	5.000000E-01	3.097960E+00	3.442662E+05	5.690289E-01	7.152557E-06	-4.732533E+01	5.505655E+03	8.637185E+03	6.438723E+00

N	S	T	P	D	U	V	W	E	M
36.5	6.558771E-01	3.141593E+00	3.059876E+05	5.380911E-01	-3.180764E+02	2.780875E-05	5.527134E+03	8.587212E+03	6.652566E+00
31.5	6.339226E-01	3.141593E+00	3.262401E+05	5.651340E-01	-2.436019E+02	2.129760E-05	5.523849E+03	8.589589E+03	6.597500E+00
25.5	6.075771E-01	3.141593E+00	3.327498E+05	5.734701E-01	-1.940851E+02	1.696846E-05	5.523282E+03	8.590962E+03	6.579158E+00
19.5	5.812317E-01	3.141593E+00	3.374402E+05	5.793388E-01	-1.482357E+02	1.295994E-05	5.522747E+03	8.592255E+03	6.564567E+00
13.5	5.548863E-01	3.141593E+00	3.413332E+05	5.803013E-01	-1.021664E+02	8.932198E-06	5.519071E+03	8.601974E+03	6.532262E+00
7.5	5.285408E-01	3.141593E+00	3.439713E+05	5.834245E-01	-5.441161E+01	4.757093E-06	5.518532E+03	8.602936E+03	6.525324E+00
1.5	5.021955E-01	3.141593E+00	3.452419E+05	5.720574E-01	-2.981076E+00	2.606293E-07	5.507153E+03	8.633156E+03	6.446509E+00

N	X	Y	TH	TH2	THS	VE1	VE2	VE3	ISUR
36.5	6.558771E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.615678E-12	-5.279425E-05	4.770490E-18	0
31.5	6.339226E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.615721E-12	-5.279461E-05	-4.770490E-18	0
25.5	6.075771E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.615700E-12	-5.279425E-05	1.843144E-18	0
19.5	5.812317E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.615721E-12	-5.279461E-05	1.084202E-19	0
13.5	5.548863E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.615743E-12	-5.279461E-05	2.493665E-18	0
7.5	5.285408E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.615678E-12	-5.279425E-05	-6.559423E-18	0
1.5	5.021955E-01	3.141593E+00	3.141593E+00	0.000000E+00	0.000000E+00	4.615700E-12	-5.279425E-05	-4.174178E-18	0

1 ZONE = 1 EDGE = 1 MACH NO. = 20.000 ANGLE OF ATTACK = 20.000 YAW ANGLE = 0.000

OSTEP	ZETA	1	2	3	4	5	6	7	8	9	10
1	0.502	4.029E+04S	4.030E+04S	4.031E+04S	4.033E+04S	4.035E+04S	4.037E+04S	4.041E+04S	4.043E+04S	5.814E+04S	5.824E+04S
40	0.748	3.677E+04S	3.672E+04S	3.660E+04S	3.691E+04S	3.787E+04S	3.867E+04S	3.850E+04S	3.930E+04S	4.577E+04S	4.919E+04S
80	1.111	3.792E+04S	3.834E+04S	3.864E+04S	3.817E+04S	3.678E+04S	3.478E+04S	3.205E+04S	3.225E+04S	3.454E+04S	3.554E+04S
600	6.794	1.565E+04S	1.530E+04S	1.479E+04S	1.457E+04S	1.435E+04S	1.408E+04S	1.151E+04S	2.120E+03S	3.729E+02S	7.667E+02S
640	7.468	1.346E+04S	1.321E+04S	1.316E+04S	1.323E+04S	1.319E+04S	1.297E+04S	8.017E+03S	9.410E+02S	2.790E+02S	6.699E+02S
680	8.156	1.218E+04S	1.217E+04S	1.220E+04S	1.229E+04S	1.220E+04S	1.160E+04S	4.900E+03S	1.752E+02S	4.009E+02S	6.930E+02S
720	8.856	1.184E+04S	1.177E+04S	1.182E+04S	1.166E+04S	1.171E+04S	7.760E+03S	1.666E+03S	1.867E+02S	3.918E+02S	6.748E+02S
760	9.566	1.172E+04S	1.170E+04S	1.161E+04S	1.135E+04S	9.881E+03S	4.268E+03S	1.313E+02S	1.532E+02S	3.683E+02S	6.382E+02S
784	9.994	1.152E+04S	1.140E+04S	1.121E+04S	1.094E+04S	8.188E+03S	2.742E+03S	6.873E+01S	1.689E+02S	3.166E+02S	6.126E+02S

1 ZONE = 1 EDGE = 1 MACH NO. = 20.000 ANGLE OF ATTACK = 20.000 YAW ANGLE = 0.000

OSTEP	ZETA	11	12	13	14	15	16	17	18	19	20
1	0.502	5.831E+04S	5.836E+04S	8.314E+04S	8.329E+04S	8.334E+04S	1.165E+05S	1.167E+05S	1.169E+05S	1.609E+05S	1.612E+05S
40	0.748	5.102E+04S	5.406E+04S	6.417E+04S	6.785E+04S	7.214E+04S	8.603E+04S	9.284E+04S	9.901E+04S	1.173E+05S	1.275E+05S
80	1.111	3.616E+04S	3.901E+04S	4.299E+04S	4.498E+04S	4.962E+04S	5.638E+04S	6.076E+04S	6.735E+04S	7.630E+04S	8.268E+04S
600	6.794	1.118E+03S	1.866E+03S	2.911E+03S	4.473E+03S	6.592E+03S	9.720E+03S	1.392E+04S	1.975E+04S	2.740E+04S	3.732E+04S
640	7.468	1.139E+03S	1.847E+03S	3.036E+03S	4.620E+03S	6.697E+03S	9.891E+03S	1.408E+04S	1.996E+04S	2.770E+04S	3.759E+04S
680	8.156	1.159E+03S	1.898E+03S	3.047E+03S	4.665E+03S	6.934E+03S	1.008E+04S	1.443E+04S	2.060E+04S	2.848E+04S	3.805E+04S
720	8.856	1.194E+03S	1.923E+03S	3.176E+03S	4.781E+03S	7.100E+03S	1.041E+04S	1.501E+04S	2.127E+04S	2.894E+04S	3.830E+04S
760	9.566	1.169E+03S	1.950E+03S	3.213E+03S	5.002E+03S	7.468E+03S	1.080E+04S	1.543E+04S	2.155E+04S	2.900E+04S	3.850E+04S
784	9.994	1.157E+03S	2.017E+03S	3.266E+03S	5.164E+03S	7.656E+03S	1.090E+04S	1.555E+04S	2.152E+04S	2.896E+04S	3.867E+04S

1 ZONE = 1 EDGE = 1 MACH NO. = 20.000 ANGLE OF ATTACK = 20.000 YAW ANGLE = 0.000

OSTEP	ZETA	21	22	23	24	25	26	27	28	29	30
1	0.502	1.615E+05S	2.210E+05S	2.213E+05S	2.217E+05S	3.002E+05S	3.005E+05S	3.008E+05S	3.013E+05S	4.001E+05S	4.006E+05S
40	0.748	1.387E+05S	1.578E+05S	1.710E+05S	1.853E+05S	2.076E+05S	2.278E+05S	2.402E+05S	2.495E+05S	2.605E+05S	2.808E+05S
80	1.111	9.074E+04S	1.029E+05S	1.141E+05S	1.268E+05S	1.418E+05S	1.591E+05S	1.756E+05S	1.896E+05S	2.030E+05S	2.168E+05S
600	6.794	4.955E+04S	6.418E+04S	8.051E+04S	9.896E+04S	1.205E+05S	1.432E+05S	1.665E+05S	1.929E+05S	2.196E+05S	2.457E+05S
640	7.468	4.919E+04S	6.333E+04S	7.949E+04S	9.818E+04S	1.195E+05S	1.425E+05S	1.656E+05S	1.908E+05S	2.196E+05S	2.450E+05S
680	8.156	4.939E+04S	6.353E+04S	7.997E+04S	9.870E+04S	1.199E+05S	1.428E+05S	1.661E+05S	1.927E+05S	2.198E+05S	2.460E+05S
720	8.856	4.979E+04S	6.390E+04S	8.032E+04S	9.925E+04S	1.204E+05S	1.434E+05S	1.666E+05S	1.939E+05S	2.195E+05S	2.456E+05S
760	9.566	5.030E+04S	6.437E+04S	8.059E+04S	9.934E+04S	1.204E+05S	1.432E+05S	1.662E+05S	1.947E+05S	2.196E+05S	2.451E+05S
784	9.994	5.049E+04S	6.443E+04S	8.060E+04S	9.936E+04S	1.205E+05S	1.432E+05S	1.660E+05S	1.944E+05S	2.197E+05S	2.451E+05S

1 ZONE = 1 EDGE = 1 MACH NO. = 20.000 ANGLE OF ATTACK = 20.000 YAW ANGLE = 0.000

OSTEP	ZETA	31	32	33	34	35	36
1	0.502	4.009E+05S	4.012E+05S	4.015E+05S	4.017E+05S	4.017E+05S	4.018E+05S
40	0.748	2.977E+05S	3.086E+05S	3.164E+05S	3.222E+05S	3.265E+05S	3.290E+05S
80	1.111	2.320E+05S	2.467E+05S	2.593E+05S	2.683E+05S	2.741E+05S	2.768E+05S
600	6.794	2.699E+05S	2.927E+05S	3.123E+05S	3.280E+05S	3.392E+05S	3.443E+05S
640	7.468	2.702E+05S	2.929E+05S	3.129E+05S	3.285E+05S	3.398E+05S	3.450E+05S
680	8.156	2.710E+05S	2.936E+05S	3.133E+05S	3.291E+05S	3.405E+05S	3.457E+05S
720	8.856	2.707E+05S	2.937E+05S	3.132E+05S	3.288E+05S	3.401E+05S	3.452E+05S
760	9.566	2.701E+05S	2.930E+05S	3.128E+05S	3.284E+05S	3.393E+05S	3.445E+05S
784	9.994	2.699E+05S	2.927E+05S	3.123E+05S	3.280E+05S	3.392E+05S	3.443E+05S

A E R O D Y N A M I C D A T A

0 F R E E S T R E A M C O N D I T I O N S

MACH NO. = 20.000 ANGLE OF ATTACK = 20.000 ANGLE OF SIDE SLIP = 0.0000

REF AREA = 1.000000E+00 REF LENGTH = 1.000000E+00

OSTEP	ZETA	CX	CY	CZ	CMX	CMY	CMZ	XCP	YCP
1	0.505	4.98029E-02	0.00000E+00	1.50502E-01	0.00000E+00	8.06514E-02	0.00000E+00	1.61941E+00	0.00000E+00
40	0.752	9.10349E-02	0.00000E+00	1.50502E-01	0.00000E+00	1.06323E-01	0.00000E+00	1.16794E+00	0.00000E+00

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80	1.116	1.35740E-01	0.00000E+00	1.50502E-01	0.00000E+00	1.47675E-01	0.00000E+00	1.08793E+00	0.00000E+00
600	6.803	8.90488E-01	0.00000E+00	1.50502E-01	0.00000E+00	3.30087E+00	0.00000E+00	3.70681E+00	0.00000E+00
640	7.477	9.89464E-01	0.00000E+00	1.50502E-01	0.00000E+00	4.00754E+00	0.00000E+00	4.05021E+00	0.00000E+00
680	8.165	1.09110E+00	0.00000E+00	1.50502E-01	0.00000E+00	4.80249E+00	0.00000E+00	4.40149E+00	0.00000E+00
720	8.864	1.19486E+00	0.00000E+00	1.50502E-01	0.00000E+00	5.68595E+00	0.00000E+00	4.75869E+00	0.00000E+00
760	9.575	1.30044E+00	0.00000E+00	1.50502E-01	0.00000E+00	6.65938E+00	0.00000E+00	5.12087E+00	0.00000E+00
784	10.000	1.36373E+00	0.00000E+00	1.50502E-01	0.00000E+00	7.27879E+00	0.00000E+00	5.33743E+00	0.00000E+00

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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 6 May 1991		3. REPORT TYPE AND DATES COVERED Summary; 8/90 - 2/91	
4. TITLE AND SUBTITLE ZEUS User Manual - "Real Gas" Effects				5. FUNDING NUMBERS	
6. AUTHOR(S) Priolo, F. J. and Wardlaw, A. B., Jr.					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Surface Warfare Center (Code R44) 10901 New Hampshire Avenue Silver Spring, Maryland 20903-5000				8. PERFORMING ORGANIZATION REPORT NUMBER NAVSWC TR 91-86	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Naval Weapons Center China Lake, California 93555-6001				10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES					
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.				12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The extension and application of the ZEUS code to high, hypersonic Mach numbers by incorporating high-temperature equilibrium air or "real gas" effects is described. This approach is important for accurate aerodynamic predictions in sonic weapons. The ZEUS code is a space-marching Euler solver. It uses an automatic multiple zone grid generation technique and a finite volume, second-order Godunov scheme for steady supersonic flow. High-temperature effects are achieved by using curve fits of the thermodynamic properties of equilibrium air. Sample calculations for a sharp cone and a blunt-nosed cylinder are provided.					
14. SUBJECT TERMS ZEUS Code Hypersonic Flight tactical missile				15. NUMBER OF PAGES 97	
				16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT SAR		

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