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COMPUTER IMPLEMENTATION OF A MUZZLE
BLAST PREDICTION TECHNIQUE

Charles W. Heaps
Kevin S. Fansler
Edward M. Schmidt

May 1985

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I. INTRODUCTION

High levels of muzzle blast overpressure can have adverse effects on weapon crew members, nearby structures, and instrumentation. Control of these effects requires the ability to predict the details of the blast pulse as a function of weapon design and emplacement, propellant and projectile characteristics, and launch conditions. Additionally, techniques to reduce or control the blast through changes in these properties are of practical importance. Fansler and Schmidt¹ developed scaling relations that permit estimation of peak incident overpressure, blast wave time of arrival, and positive phase duration. Comparison of these estimates with experiment demonstrates that the scaling approach provides a reasonable initial estimate of muzzle blast characteristics. Since the relations are sensitive to weapon launch conditions and propellant charge design, they may be used to study the influence of these properties on muzzle blast.

The present work has two main objectives. The first is to extend the scaling approach to treat the problem of pressure loadings on surfaces adjacent to the weapon. The second is to use the scaling relations in the development of a computer code called BLAST that plots contour maps of the muzzle blast quantities. We believe that the results obtained from the scaling relations are most easily interpreted when presented in this form.

The remainder of this report may be outlined as follows. First we present the scaling relations used to calculate the incident overpressure, blast wave time of arrival, and positive phase duration at points on a surface that can have any desired orientation with respect to the cannon boreline. From the calculations of incident overpressure and time of arrival, the reflected blast overpressure on the surface of interest is determined. For all of the blast properties, an algorithm is established to generate contour plots. Representative plots obtained from BLAST are selected for comparison with experimental results.

II. FREE FIELD MUZZLE BLAST CALCULATIONS

The free field blast computations are performed using scaling relations developed by Fansler and Schmidt. Their scaling approach has been described in detail;¹ hence, only the final results of the work are presented here. The quantities of interest in the free field blast problem are the peak incident overpressure in atmospheres, $\bar{P}$, the blast wave time of arrival, t_a , and the positive phase duration, τ . The expressions derived for these quantities are summarized by

$$\bar{P} = 2.4 Z \quad (1a)$$

-
1. K. S. Fansler and E. M. Schmidt, "The Prediction of Gun Muzzle Blast Properties Utilizing Scaling," U. S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, BRL Technical Report ARBRL-TR-02504, July 1983 (AD B 075859L).

$$t_a = \frac{r}{a_\infty} f(Z) - \frac{a_\infty}{L^2} (0.94 \cos \theta + 9.24) \quad (1b)$$

$$\tau = (L'/a_\infty) [1 + 0.13 (r/L')] \quad (1c)$$

where

$$L' = L [\mu \cos \theta + (1 - \mu^2 \sin^2 \theta)^{1/2}] \quad (1d)$$

$$Z = (r/L')^{-1.1}, \text{ and} \quad (1e)$$

$$f(Z) = 1 + 10Z - (Z^2/1.2) + (Z^3/2.3) - (Z^4/3.4) + (Z^5/4.5) - (Z^6/5.6). \quad (1f)$$

For subsonic exit flow ($V_p \leq a_m$)

$$L = D \left\{ \frac{(8.62 \times 10^{-3}) p_m a_m}{(\gamma-1) p_\infty a_\infty} \left[1 + \frac{\gamma(\gamma-1)}{2} \right] \left[\frac{2}{\gamma+1} \left(1 + \frac{(\gamma-1)}{2} \frac{V_p^2}{a_m^2} \right) \right]^{\frac{3\gamma-1}{\gamma-1}} \right\}^{1/2} \quad (2)$$

For supersonic exit flow ($V_p > a_m$),

$$L = (9.28 \times 10^{-2}) D \left[\frac{p_m V_p}{(\gamma-1) p_\infty a_\infty} \left(1 + \frac{\gamma(\gamma-1)}{2} \frac{V_p^2}{a_m^2} \right) \right]^{1/2} \quad (3)$$

To use these relations, it is necessary to know the weapon characteristics and propellant gas properties at shot ejection. When the

latter are not known from experiment, they may be determined using interior ballistics theory. The user of BLAST has the option of employing the following simplistic interior ballistics model to obtain the gas properties at shot ejection.

Lagrangian interior ballistics as given by Corner² is utilized. The internal energy of the propellant gases immediately prior to projectile ejection is given by

$$E = \frac{BCRT_{\text{mean}}}{\gamma-1} = \frac{BCRT_a}{\gamma-1} - \frac{1}{2} (m_1 + C/3) (1 + \chi) v_p^2 \quad (4)$$

where B is the fraction of propellant burnt, C is the propellant mass, m_1 is the effective projectile mass accounting for bore friction, and χ is the ratio of heat losses to kinetic energy. The following semi-empirical formulation for χ is used

$$\chi = \frac{(10500) U D^{3/2} (T_a - 300) \Omega}{A_e v_p^2 (m_p + C/3) [1.7 + 6710^{1/2} (D^2/C)^{.86}]} \quad (5)$$

where Ω is the roughness factor. In this report the roughness factor is taken as 1.35, an average of large and small gun values. If we assume an ideal gas the muzzle pressure is given by

$$p_m = \frac{(\gamma-1) E}{U [1 + C/(3m_1)]} \quad (6)$$

where U is the combined volume of the bore and chamber. The following expression is obtained for the exit sound speed of the propellant gases

$$a_m = (\gamma R T_m)^{1/2} = \left\{ \gamma (\gamma-1) E / [C + C^2/(3m_1)] \right\}^{1/2} \quad (7)$$

Results obtained from this simple theory were compared with those of a more exact computer model³ and shown to produce similar results. Once the weapon

2. J. Corner, *Theory of the Interior Ballistics of Guns*, John Wiley, New York, 1950.

3. Private communication from Brian Bertrand.

characteristics and launch conditions are determined, the scaling relations given in Equation (1) are used to compute $\bar{P}$, t_a , and τ as functions of r and θ .

The contour plotting algorithm requires the evaluation of these functions at regularly spaced points (gridpoints) in the plotting domain. The values of r and θ must therefore be determined for each gridpoint. The geometry of the problem is shown in Figure 1. The origin of the polar coordinate system in which contours are plotted is the perpendicular projection of the muzzle of the gun into the plane of interest. The distance from the origin to the muzzle is h , and ϕ is the angle between the plane and the boreline of the gun. The contour algorithm requires a rectangular grid in the contour plane. For this reason, the gridpoints are located in a cartesian coordinate system originating at the muzzle of the gun. The x-y plane of this coordinate system is taken parallel to the contour plane; thus, any point in the contour plane is defined by $(x, y, -h)$. The distance from the muzzle to a point in the plane is given by the magnitude of $\vec{r}$:

$$r = (x^2 + y^2 + h^2)^{1/2} \quad (8)$$

Let $\vec{u}$ be a unit vector parallel to the boreline. The angle θ between $\vec{u}$ and $\vec{r}$ is given by

$$\theta = \cos^{-1} \frac{\vec{r} \cdot \vec{u}}{r} = \cos^{-1} \left[\frac{y \cos \phi - h \sin \phi}{(x^2 + y^2 + h^2)^{1/2}} \right] \quad (9)$$

The values of r and θ may be used to obtain $\bar{P}$, t_a , and τ from the scaling relations at each point in the contour plane.

III. REFLECTED SHOCK WAVE CALCULATIONS

The reflection of shock waves from surfaces can be quite complex. Edney⁴ has identified a number of possible flow structures depending upon the strength of the incident wave and the angle of reflection. In the present context, the process is considerably simplified. Only two types of reflection are considered: regular and single Mach stem.⁵

4. B. E. Edney, *Effects of Shock Impingement on the Heat Transfer Around Blunt Bodies*, "AIAA Journal", Vol. 16, No. 1, January 1968, pp. 15-21.
5. B. P. Bertrand, "Measurement of Pressure in Mach Reflection of Strong Shock Waves in a Shock Tube," U. S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, BRL-MR-2196, June 1972 (AD 748613).

For points very close to the reflecting surface (the contour plane), the blast may be considered planar. The shock wave angle of incidence, α_1 , is simply the angle between the direction of propagation of the blast and the surface normal, $\vec{n}$, to the contour plane (Figure 2). One method of obtaining the direction of propagation of the blast wave is to evaluate the gradient of t_a since the shape of the wave is equivalent to the surface defined by constant t_a . This gradient is normal to the blast wave surface; therefore, it points in the direction of propagation. The difficulty with this approach is that the computer time required to evaluate the gradient of t_a at each grid point is excessive. In Appendix A we describe an alternate method for calculating the shock wave angle of incidence. This alternate method may be shown to be mathematically equivalent to the gradient approach, but it is more efficient computationally. In BLAST we use the approach described in Appendix A.

Once the shock wave angle of incidence, α_1 , is obtained, we determine whether regular reflection or Mach reflection of the shock wave occurs. The first step in this procedure is to shift from a fixed reference frame to one moving along the reflecting surface at the same velocity as the shock waves. In this reference frame the shock wave is stationary and has a streamline flowing through it parallel to the reflecting surface (Figure 3). The relations for compressible flow through an oblique shock wave⁶ are applicable to this system.

The Mach number of the streamline in the region in front of the incident shock is given by

$$M_1 = \left\{ \left[\frac{\gamma+1}{2\gamma} \left(\frac{p_1 - p_\infty}{p_\infty} \right) + 1 \right] / \sin^2 \alpha_1 \right\}^{1/2} \quad (10)$$

where p_1 and p_∞ are the pressures behind and in front of the incident shock, respectively. Across the incident shock, the flow is deflected through an angle, δ_1 , given by

$$\delta_1 = \tan^{-1} \left[2(\cot \alpha_1) \frac{M_1^2 \sin^2 \alpha_1 - 1}{M_1^2 (\gamma + \cos 2\alpha_1) + 2} \right] \quad (11)$$

6. H. W. Liepmann and A. Roshko, Elements of Gasdynamics, J. Wiley, New York, 1957.

and the Mach number behind the incident shock is obtained from

$$M_2 = \left\{ \frac{(\gamma-1) \frac{p_I}{p_\infty} + (\gamma+1)}{2\gamma \frac{p_I}{p_\infty}} \right\}^{1/2} / \sin(\alpha_1 - \delta_1). \quad (12)$$

The question of whether regular reflection is possible may now be addressed. The maximum stream deflection for a specified upstream Mach number is given approximately by

$$\delta_{\max} = \frac{4}{3\sqrt{3}(\gamma+1)} \frac{(M_1^2 - 1)^{3/2}}{M_1^2}. \quad (13)$$

If $\delta_1 \geq \delta_{\max}$, regular reflection is not possible and Mach reflection occurs. If $\delta_1 < \delta_{\max}$, regular reflection occurs and the analytic solution for the reflected overpressure may proceed.

If regular reflection is possible, the flow is deflected through the reflected shock. This deflection angle, δ_2 , must be equal to δ_1 because the boundary condition requires the flow to be parallel to the reflecting surface. Equation (11) applied to the flow across the reflected shock, with $\delta_1 = \delta_2$, yields

$$2(\cot \alpha_2) \frac{M_2^2 \sin^2 \alpha_2 - 1}{M_2^2 (\gamma + \cos 2\alpha_2)} - \tan \delta_2 = 0 \quad (14)$$

where α_2 is the wave angle of the reflected shock. Equation (14) is solved for α_2 by iteration. Once α_2 is known, the following equation is used to determine the pressure behind the reflected shock, p_R

$$\frac{p_R}{p_I} = \frac{2\gamma}{\gamma+1} (M_2^2 \sin^2 \alpha_2 - 1) + 1. \quad (15)$$

Finally, the reflected overpressure in atmospheres is given by

$$\bar{P}_R = \frac{P_R - P_\infty}{P_\infty} = \frac{P_R}{P_I} \frac{P_I}{P_\infty} - 1 \quad (16)$$

A computational problem arises in the preceding development as α_1 approaches zero. The expression for M_1 given in Equation (10) becomes arbitrarily large due to the $\sin \alpha_1$ term in the denominator. To avoid this difficulty we do not use the relations presented above for angles of incidence less than one degree. For angles of incidence less than this value, the solution for plane shock wave reflection normal to the surface is adequate. In this special case the ratio of reflected overpressure to incident overpressure is given by

$$\frac{P_R}{P_I} = \frac{(3\gamma-1) P_I - (\gamma-1)}{(\gamma-1) P_I + (\gamma+1)} \quad (17)$$

If regular reflection does not occur ($\delta_1 \geq \delta_{\max}$) it is impossible to obtain an analytic solution for the reflected overpressure using the theory of simple oblique waves. In this case the reflected overpressure is extracted from empirical results. A typical data plot of reflected overpressure versus shock wave angle of incidence for various incident overpressures⁷ is presented in Figure 4. Similar data from a variety of sources were examined and two general features noted. First, beyond a certain angle of incidence whose value depends on the incident overpressure, the reflected overpressure curves may be approximated by straight lines. To determine the equations of these lines a point and slope are needed. At $\alpha_1 = 90^\circ$, the blast wave is at grazing incidence to the surface and the ratio of reflected to incident overpressure equals one, independent of the incident overpressure. Thus, the right end point of all the straight lines is defined. The slopes of the lines are taken to be a function of the incident overpressure and are obtained for 11 values of this parameter. Lagrangian interpolation is then used to obtain a slope for any intermediate value of incident overpressure. The interpolation procedure is also used to determine the angle of incidence beyond which the linear approximation is valid.

7. S. Glasstone, Editor, The Effects of Nuclear Weapons, Dept. of the Army Pamphlet No. 50-3, March 1977, p. 123.

The second feature apparent in the empirical plots pertains to the region near the maxima of the reflected overpressure curves. For values of α_1 between the regular reflection and the linear interpolation regimes, the curves have a shape that can be approximated by cubic polynomials in α_1 . The four boundary values needed to evaluate the polynomial are provided from the solutions at points A and B of Figure 5. The reflected overpressure at point A, $\pi(\alpha_A)$, is determined from the analytic solution for regular reflection. The slope at A, $\pi'(\alpha_A)$, can be approximated by taking a finite difference. At point B, $\pi(\alpha_B)$ and $\pi'(\alpha_B)$ are obtained from the Lagrangian interpolation procedure described above. The four-term polynomial at A is

$$\pi(\alpha_A) = \pi_0 + \pi_1\alpha_A + \pi_2\alpha_A^2 + \pi_3\alpha_A^3. \quad (18)$$

The derivative of this polynomial is

$$\pi'(\alpha_A) = \pi_1 + 2\pi_2\alpha_A + 3\pi_3\alpha_A^2 \quad (19)$$

with two corresponding equations at point B. These four equations are solved for the four unknown coefficients π_0 , π_1 , π_2 , and π_3 .

The joining of the regular reflection solution, the cubic fit, and the linear fit produces a continuous variation of reflected overpressure coefficient versus angle of incidence for any specified incident overpressure. Results of this procedure are plotted in Figure 6. While this method of determining the reflected overpressure is relatively simple, it substantially reproduces the empirical plots as is demonstrated by comparison with experimental data (Figure 7).

IV. THE CONTOUR PLOTTING METHOD

The results of the analysis have been formulated as a computer code, BLAST, which is programmed in FORTRAN 77 and is designed for interactive use on graphics terminals. A listing of BLAST may be found in Appendix B.

The method used to plot the contours is relatively standard and originated from an ALGOL computer code.⁸ A grid is constructed covering the

8. B. R. Heap, et al., "Three Contouring Algorithms," NPL-81, National Physical Laboratory, Teddington, England, December 1969.

region of space that is of interest. This grid is composed of many small rectangular cells. At each corner of every cell (a gridpoint), the value of the function to be plotted must be known. Each contour value is processed individually, i.e., all contours at a particular level are plotted before moving to the next level. The search for contours at a particular level begins by locating all the contours that intersect the outside boundary of the grid (open contours). The search along the boundary progresses counterclockwise from the bottom left corner of the grid until two adjacent gridpoints are found that bound the contour level. To avoid repeatedly finding and plotting the same contours, an additional requirement is imposed: the larger functional values must be to the right of the intersection point of the contour and the grid boundary for the point to be recognized as the beginning of a contour. Once the beginning of a contour is found, it is followed cell by cell through the grid by comparison of adjacent grid points. The precise path of the contour across any cell boundary is determined by linear interpolation. The coordinates of this interpolated point are passed to a plotting subroutine which uses a commercial graphics package, DISSPLA, to draw each line segment on the plotting device. Because the grid squares are very small, there is no perception of the contour lines being composed of straight segments.

After all the open contours at a particular level are located and plotted, the grid is searched for closed contours at that level. The closed contours, once found, are followed through the grid and plotted in the same manner as the open contours. When plotting of the closed contours is complete, the process is repeated for the next contour level.

V. RESULTS

In Figures 8 and 9 we present contour maps, generated by BLAST, of peak incident overpressure, peak reflected overpressure, blast wave time of arrival, and positive phase duration. Maps of incident overpressure, time of arrival, and positive phase duration are generated within thirty seconds on a VAX 11/780. Plots of reflected overpressure require additional computations and are produced in approximately five minutes. The predictions shown are for the 30 mm. XM230 Chain Gun. The weapon is positioned parallel to the contour plane with the muzzle 0.26 meter distant from the origin of the contour grid. The strong directional dependence of the muzzle blast field is readily apparent in the plots of incident and reflected overpressure. The contours of time of arrival represent the blast wave surface as it propagates outward from the muzzle. This surface rapidly becomes spherical with a center displaced in the forward direction. The positive phase duration map shows the rate of increase of the blast wavelength to be larger in the forward direction than to the rear of the muzzle.

To check the validity of our model, we compare BLAST predictions with experimental blast measurements obtained in a previous test program⁹ of the 30mm

9. E. M. Schmidt, "Muzzle Blast Pressure Loadings on Aircraft Surfaces," U. S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, ARBRL-MR-03338, February 1984 (AD A 139132).

Chain Gun. For these tests, pressure transducers were mounted in a linear array on an aluminum plate. The plate was then aligned at angles of zero and minus five degrees relative to the line of fire, with separations of 0.26 meter and 0.23 meter respectively. For the zero degree orientation, data were collected with the transducer array aligned both parallel and normal to the line of fire. For the minus five degree orientation, only the parallel array alignment was used. In Figures 10, 11, and 12 we compare the experimental measurements of reflected overpressure, time of arrival, and positive phase duration for each of the three transducer orientations. In these plots the abscissa, S , denotes distance on the plate surface measured from the point on the plate nearest the muzzle. Negative values of S indicate positions behind the muzzle.

Figure 10 shows that the peak reflected overpressure measurements agree very favorably with BLAST predictions, particularly along the line of fire. The small plateau which is apparent in each of the predicted curves denotes the transition from regular reflection to Mach reflection of the incident wave. For this blast field, the effect appears too small to be defined experimentally. From the plots of time of arrival in Figure 11, we see that the location of minimum t_a predicted by BLAST is shifted forward from the location measured experimentally; however, the shape of the experimental t_a distribution is predicted quite well. It is obvious from Figure 12 that there is a definite deficiency in the positive phase duration scaling relation. We note that the expression for τ was determined by fitting scaled experimental data and that the scatter in this data justified only a simple linear curve fit. Clearly, a more complete analysis is desirable.

VI. CONCLUSIONS

The muzzle blast pressure distribution on a surface located in the vicinity of a cannon has been calculated. The computational procedure accounts for shock reflection processes and is based upon previously developed scaling relations describing muzzle blast. The approach is formalized in a computer program, BLAST, that calculates and plots contour maps of peak incident overpressure, peak reflected overpressure, blast wave time of arrival, and positive phase duration. The contours are plotted in a plane having an arbitrary orientation with respect to the gun tube. The overpressure and time of arrival predictions compare favorably with experimental measurements. The positive phase duration is over-predicted by BLAST due to problems in the scaling expression used. BLAST is completely interactive and requires only minutes of computer (VAX 11/780) time to run.

ACKNOWLEDGMENT

The authors would like to thank David H. Lyon for developing a number of original programming improvements used in this effort.

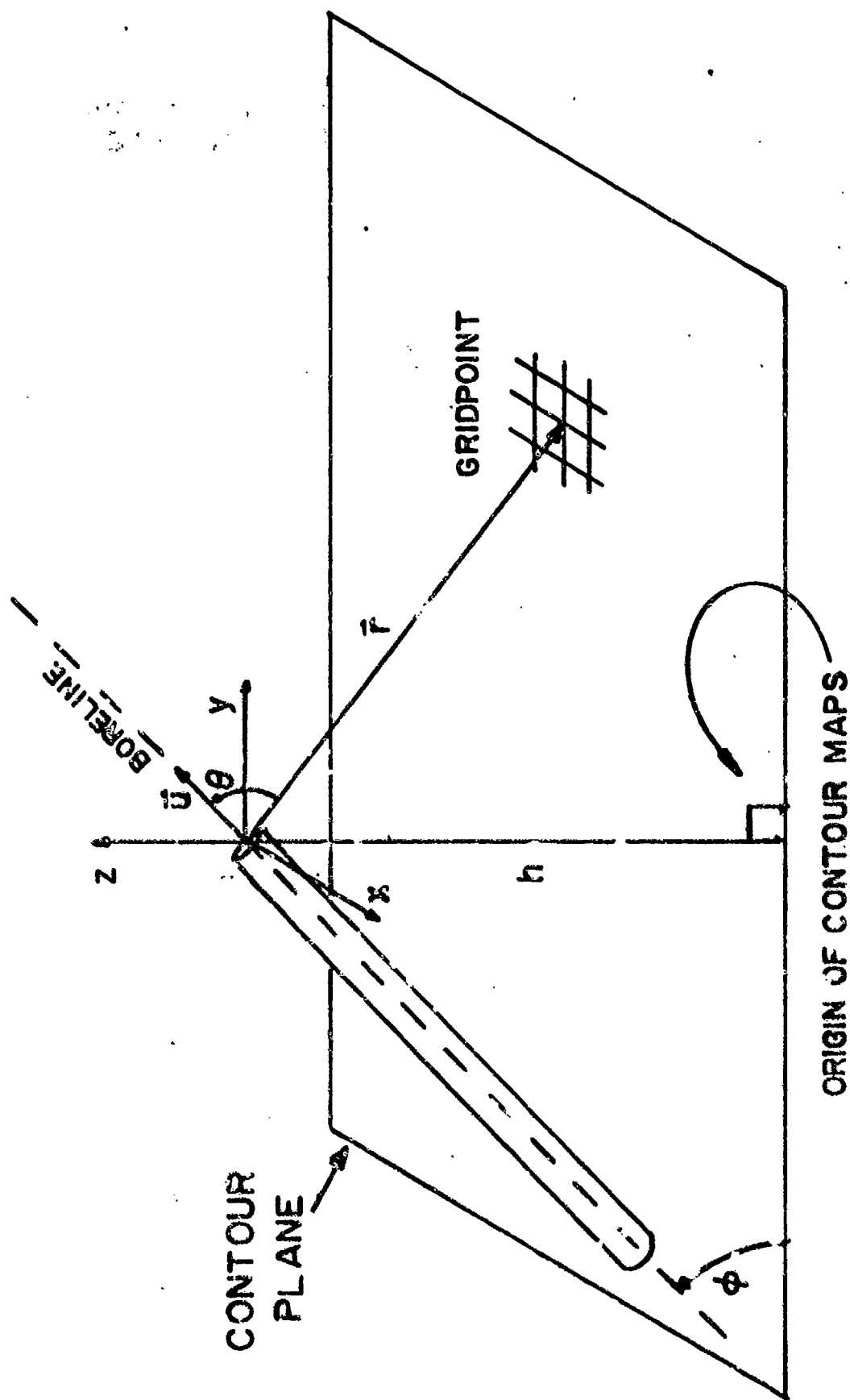


Figure 1. Geometry of the Problem of Determining r and θ at a Point in a Plane with Arbitrary Orientation with Respect to the Boreline

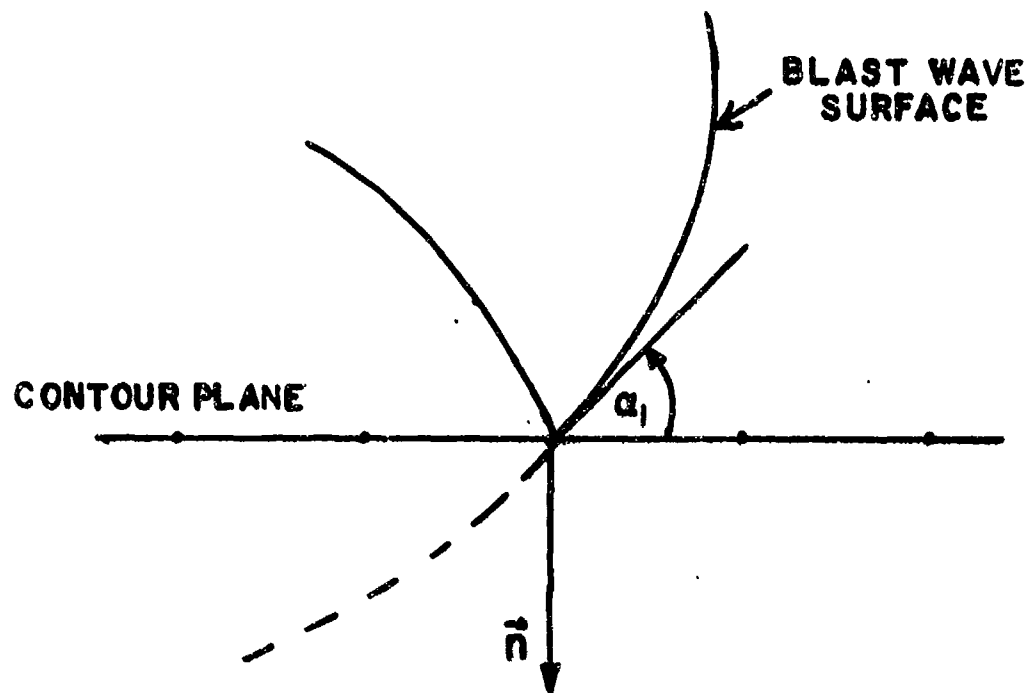


Figure 2. Geometry Illustrating the Shock Wave Angle of Incidence at a Gridpoint

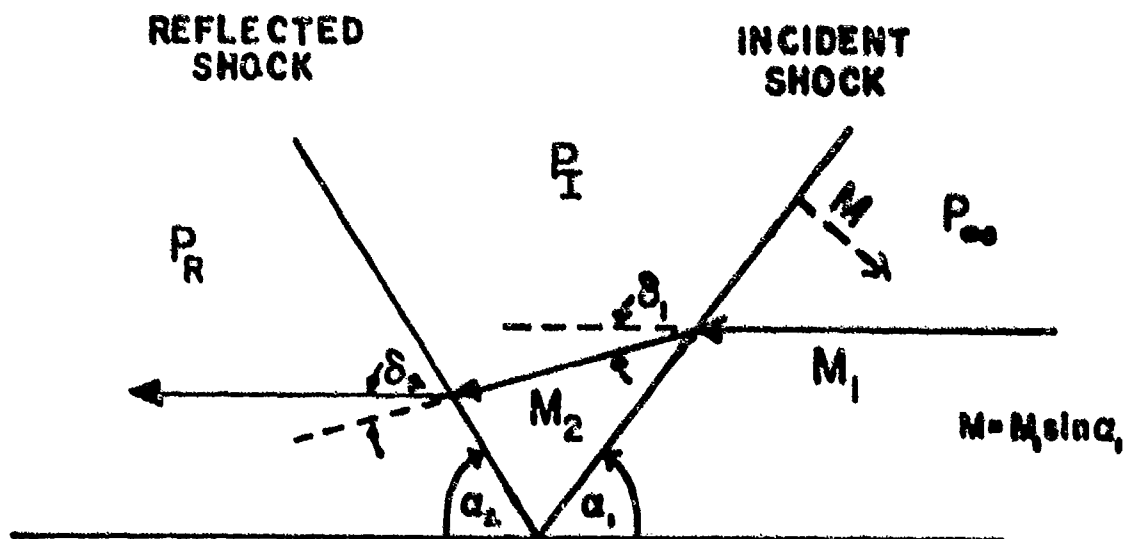


Figure 3. The Oblique Shock Wave Solution for Reflected Shock

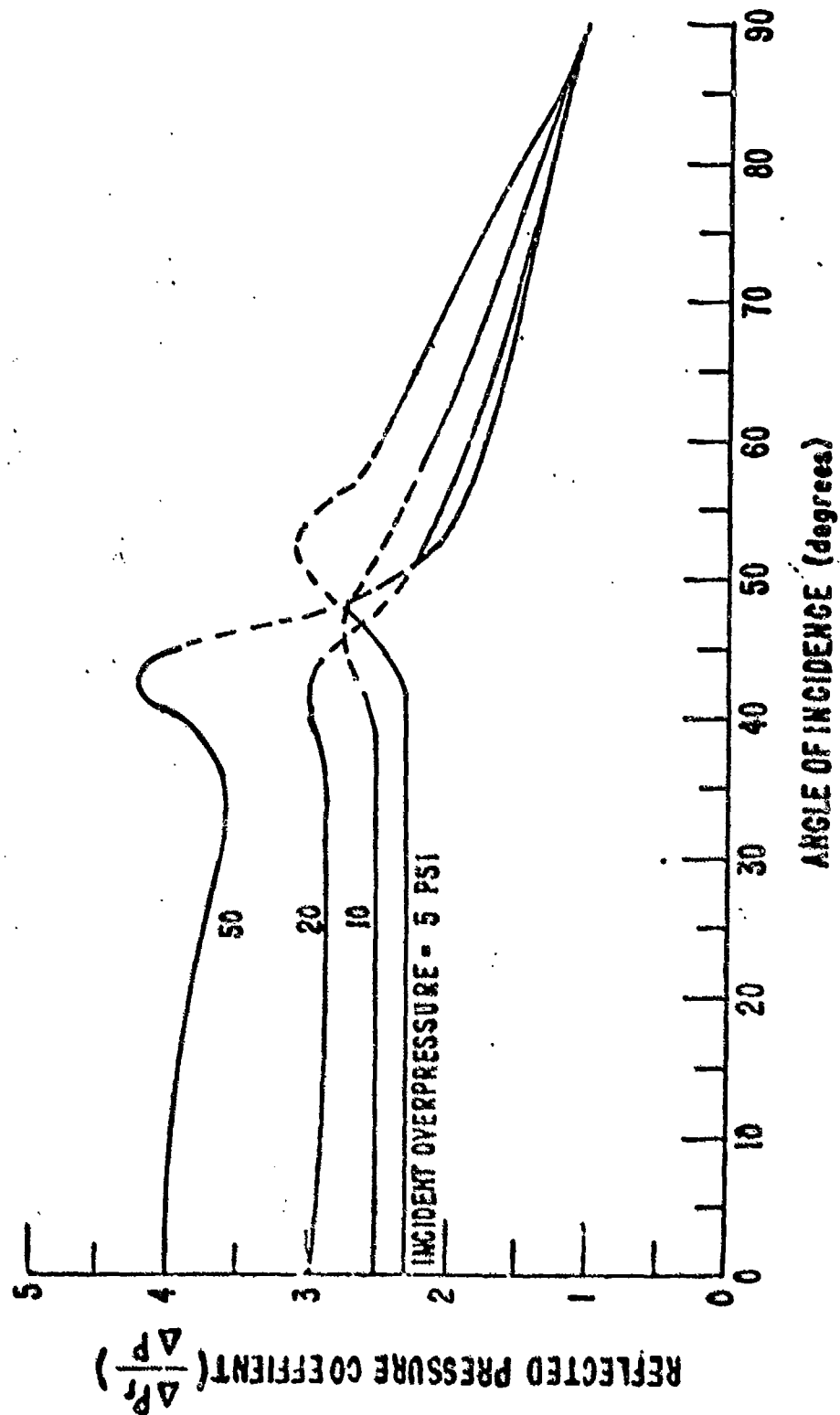


Figure 4. Reflected Pressure Coefficient vs. Angle of Incidence for Various Incident Overpressures.

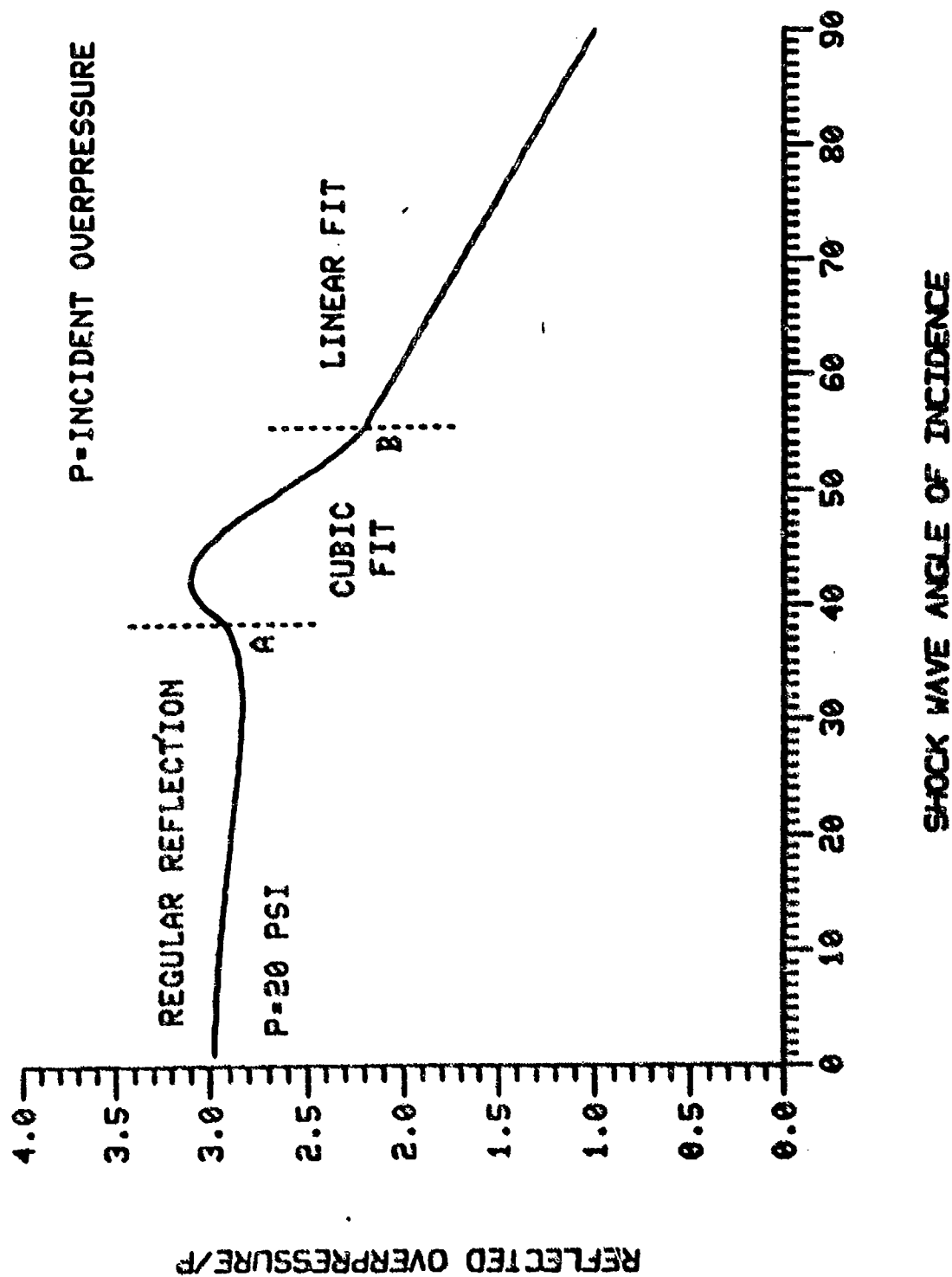
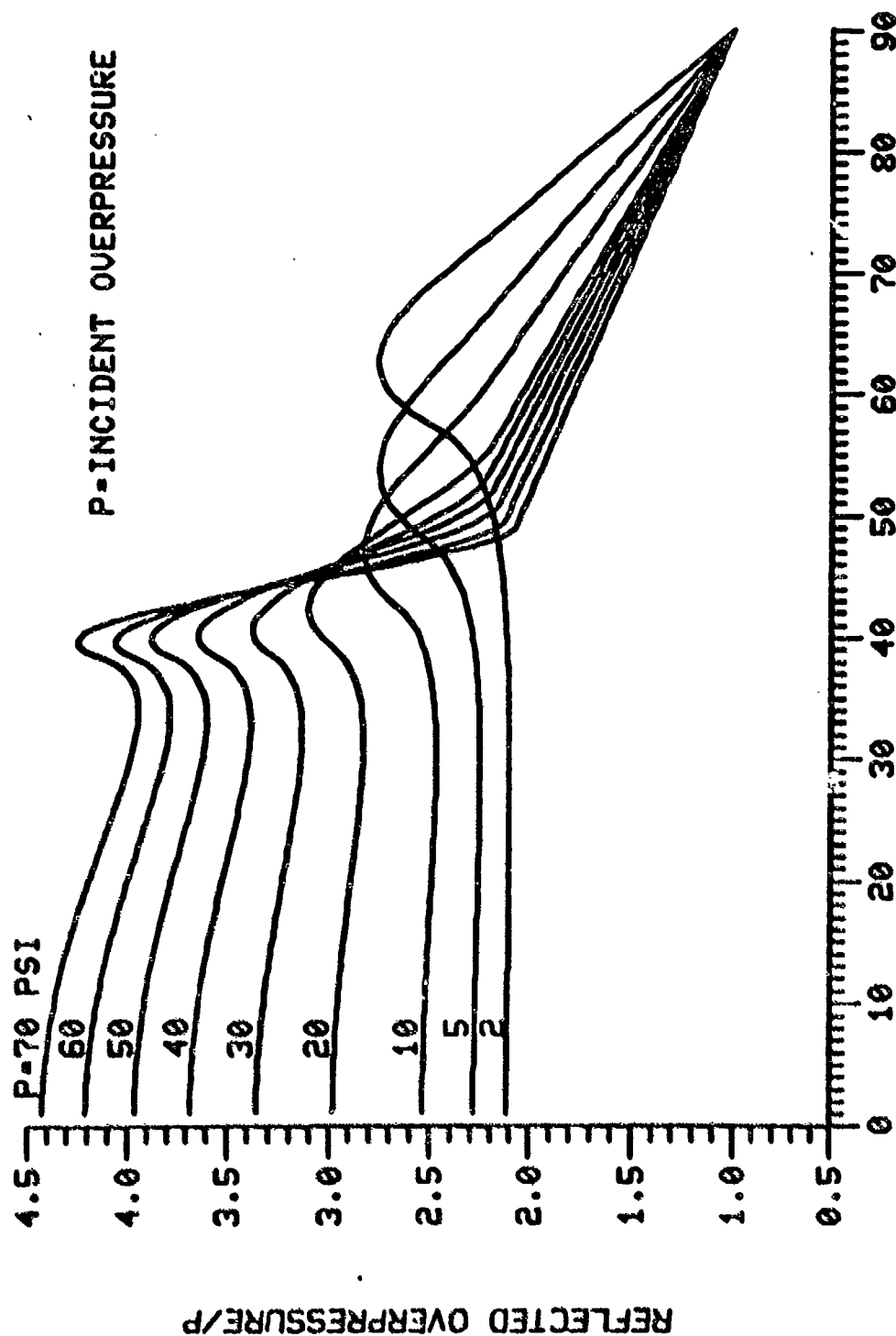


Figure 5. The Three Regions of a Typical Reflected Overpressure vs. Angle of Incidence Curve (BLAST Generated)

SHOCK REFLECTION COEFFICIENTS



SHOCK WAVE ANGLE OF INCIDENCE

Figure 6. Reflected Pressure Coefficient vs. Angle of Incidence for Various Incident Overpressures, Obtained by Method used in BLAST

CALCULATIONS COMPARED WITH OTHER SOURCES

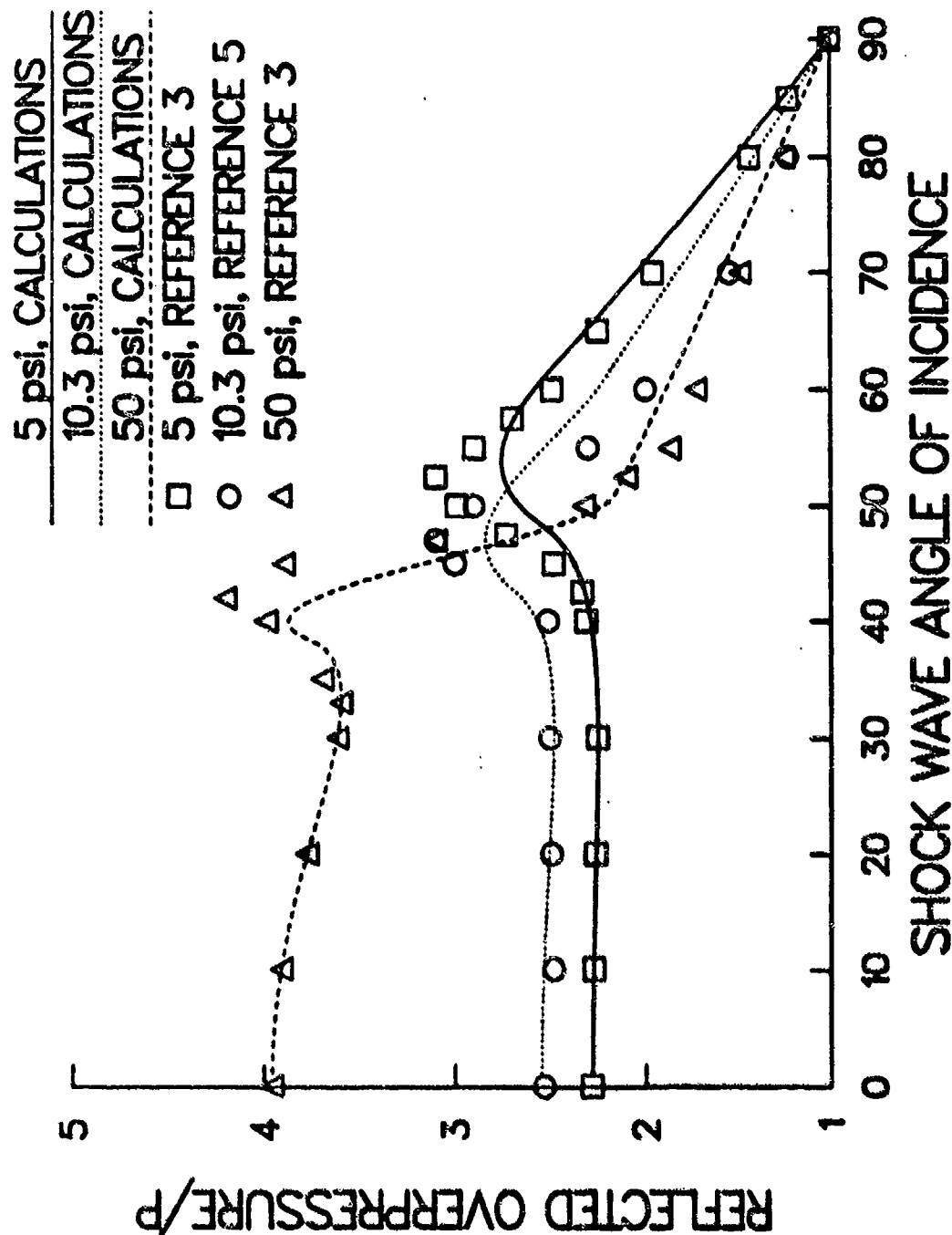
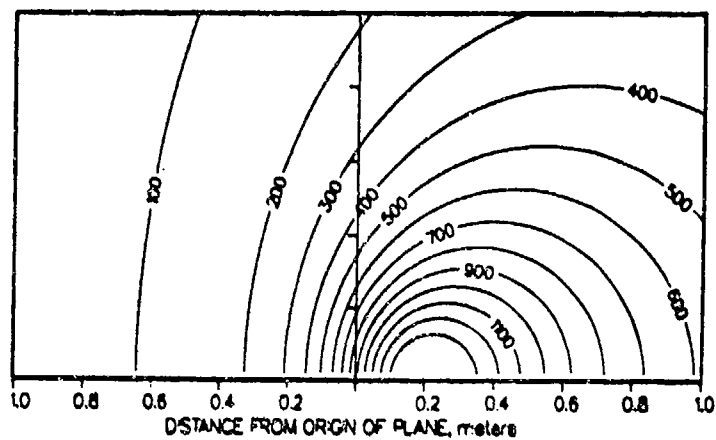


Figure 7. Comparisons Between Reflection Pressure Results Obtained with BLAST and from Other Sources

CONTOURS OF PEAK INCIDENT OVERPRESSURE, mbar

ASUBM(m/s)=	920.0	30 MM CHAIN GUN, BARE MUZZLE	
PRATIO=	330.0	ANGLE OF ELEVATION (deg)=	0.00
VSUBP(m/s)=	780.0	HEIGHT OF MUZZLE (meters)=	0.26
GAMMA=	1.24		
MU=	0.78		

a.



CONTOURS OF PEAK REFLECTED OVERPRESSURE, mbar

ASUBM(m/s)=	920.0	30 MM CHAIN GUN, BARE MUZZLE	
PRATIO=	330.0	ANGLE OF ELEVATION (deg)=	0.00
VSUBP(m/s)=	780.0	HEIGHT OF MUZZLE (meters)=	0.26
GAMMA=	1.24		
MU=	0.78		

b.

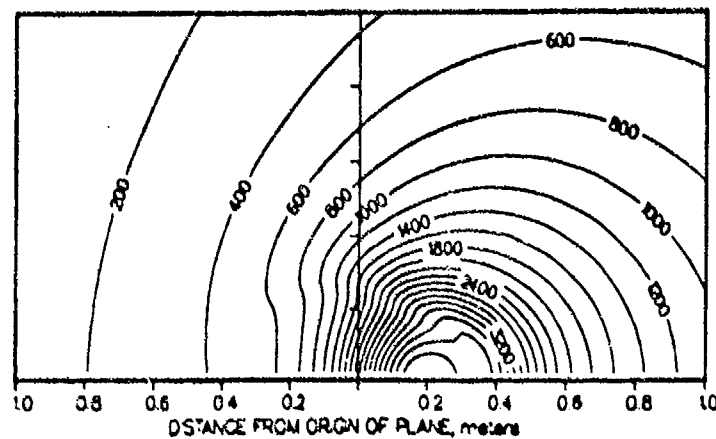
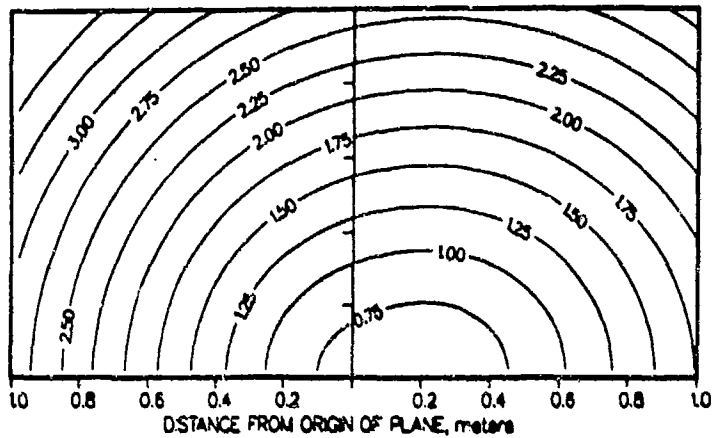


Figure 8. Contour Maps of Peak Incident Overpressure (a) and Peak Reflected Overpressure (b)

CONTOURS OF BLAST WAVE TIME OF ARRIVAL, msec

ASUBM(m/s)=	920.0	30 MM CHAIN GUN, BARE MUZZLE	
PRATIO=	330.0	ANGLE OF ELEVATION (deg)=	0.00
VSUBP(m/s)=	780.0	HEIGHT OF MUZZLE (meters)=	0.26
GAMMA=	1.24		
MU=	0.78		

a.



CONTOURS OF POSITIVE PHASE DURATION, msec

ASUBM(m/s)=	920.0	30 MM CHAIN GUN, BARE MUZZLE	
PRATIO=	330.0	ANGLE OF ELEVATION (deg)=	0.00
VSUBP(m/s)=	780.0	HEIGHT OF MUZZLE (meters)=	0.26
GAMMA=	1.24		
MU=	0.78		

b.

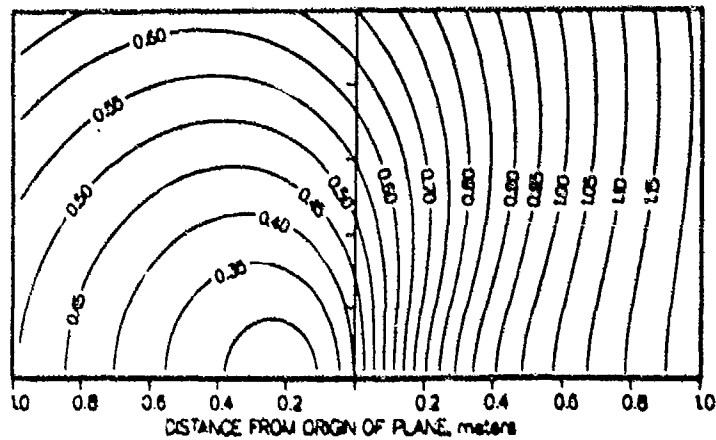
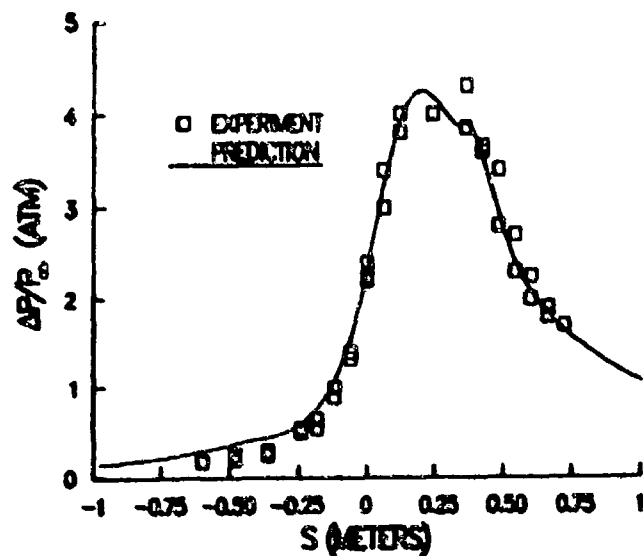
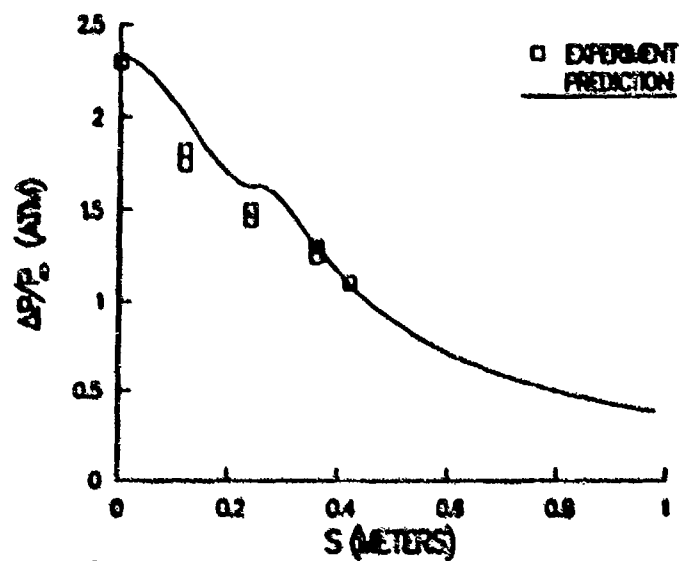


Figure 9. Contour Maps of Blast Wave Time of Arrival (a) and Positive Phase Duration (b)

a. 0° Plate Orientation,
Parallel to Line of
Fire



b. 0° Plate Orientation,
Perpendicular to Line
of Fire



c. -5° Plate Orientation,
Parallel to Line of
Fire

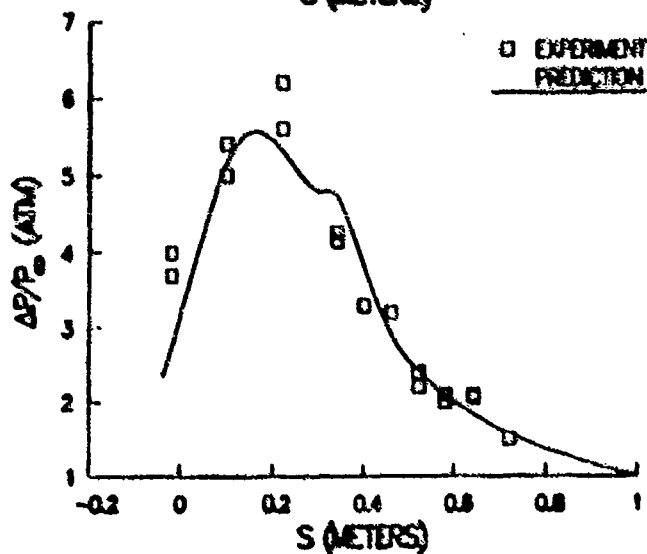
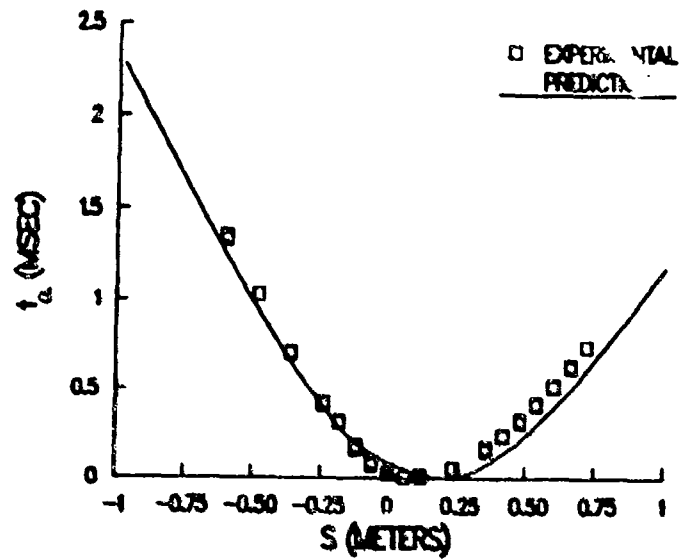
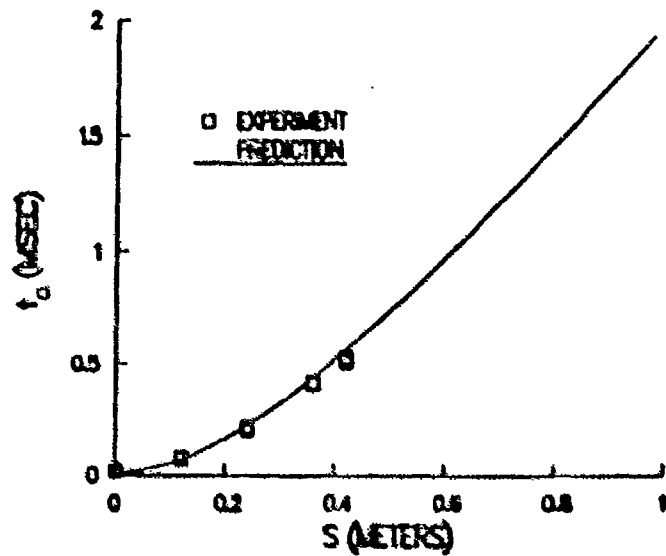


Figure 10. Comparison of Predicted Peak Reflected Overpressure with Experiment

a. 0° Plate Orientation,
Parallel to Line of
Fire



b. 0° Plate Orientation,
Perpendicular to Line of
Fire



c. -5° Plate Orientation,
Parallel to Line of
Fire

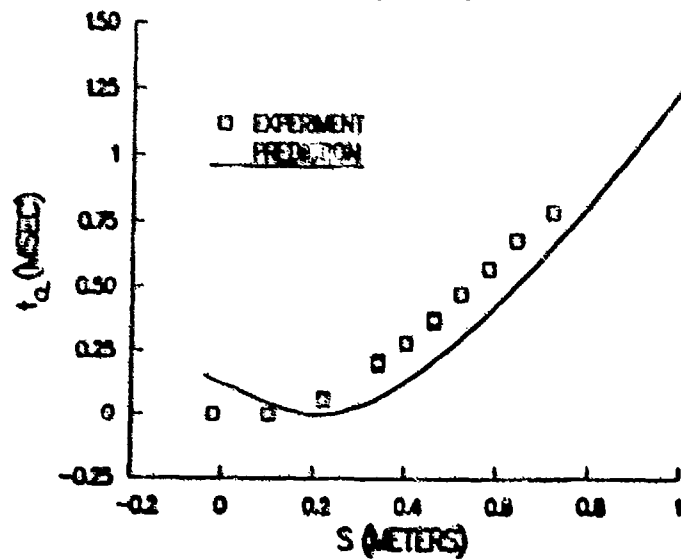
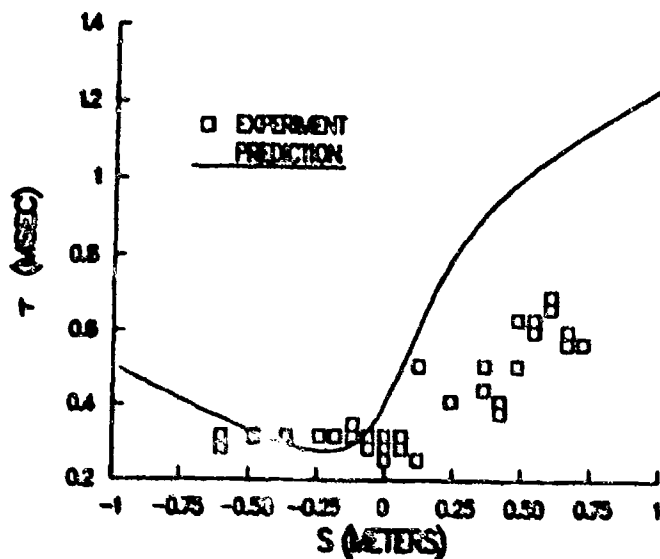
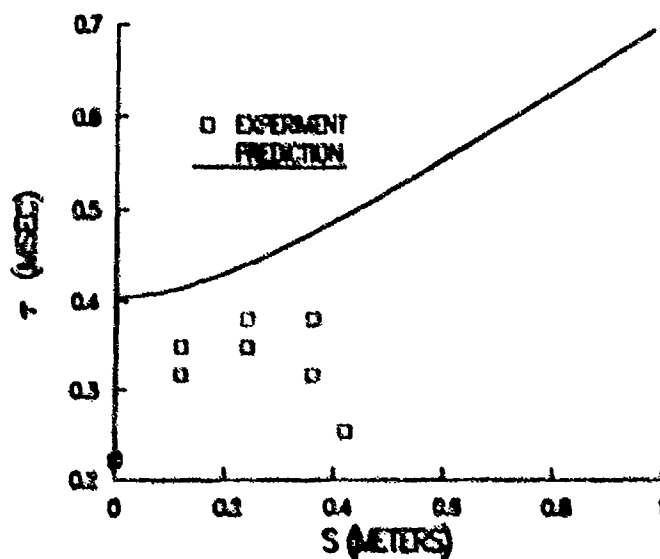


Figure 11. Comparison of Predicted Blast Wave Time of Arrival with Experiment

a. 0° Plate Orientation,
Parallel to Line of
Fire



b. 0° Plate Orientation,
Perpendicular to Line
of Fire



c. -5° Plate Orientation,
Parallel to Line of
Fire

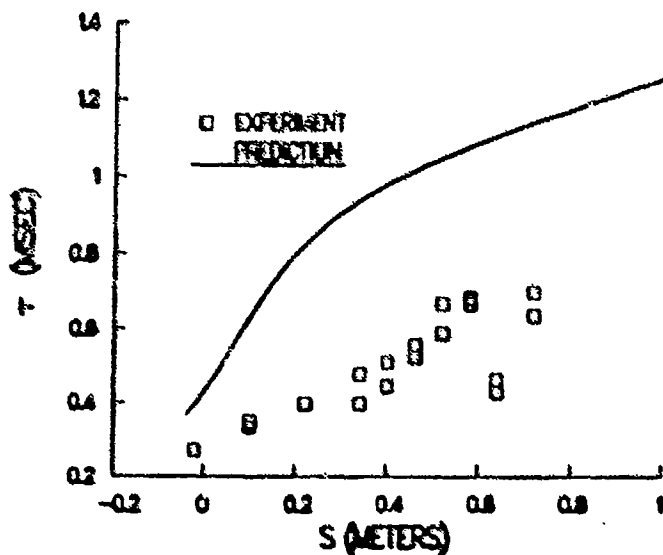


Figure 12. Comparison of Predicted Positive Phase Duration with Experiment

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APPENDIX A

Analysis for Obtaining the Shock Wave Angle of Incidence

We wish to obtain the angle between the incident shock and the contour plane. In Figure A-1, A is the point of interest in the contour plane, $\vec{r}$ is the vector directed from the muzzle to A, θ is the angle between the boreline and $\vec{r}$, ϕ is the angle between the boreline and the contour plane, and h is the distance from the muzzle to the contour plane along a line normal to the plane.

We define $\vec{p}$ as the vector which is directed from the boreline to A and is normal to the shockwave surface. We then have

$$\vec{p} = \vec{r} - \vec{\xi} \quad (\text{A-1})$$

where $\vec{\xi}$ is a vector along the boreline as shown in Figure A-1. The angle between $\vec{r}$ and $\vec{p}$ is designated as η . The components of $\vec{p}$ are found to be

$$p_x = x_A \quad (\text{A-2})$$

$$p_y = y_A - \xi \cos \phi \quad (\text{A-3})$$

$$p_z = z_A - \xi \sin \phi \quad (\text{A-4})$$

The magnitude of $\vec{\xi}$, ξ , is found from the law of sines:

$$\frac{\sin(180^\circ - \theta - \eta)}{r} = \frac{\sin \eta}{\xi} \quad (\text{A-5})$$

Upon rearrangement, Equation (A-5) becomes

$$\xi = \frac{r \sin \eta}{\sin(\theta + \eta)} = \frac{r \sec \theta}{\frac{\tan \theta}{\tan \eta} + 1} \quad (\text{A-6})$$

The cosine of the angle of incidence is given by

$$\cos \alpha_1 = \frac{\vec{p} \cdot \vec{n}}{p} = \frac{-z_A + \xi \sin \phi}{(p_x^2 + p_y^2 + p_z^2)^{1/2}} \quad (A-7)$$

where $\vec{n}$ is the unit normal to the contour plane. To use Equation (A-7) we must first obtain ξ . If n is known, Equation (A-6) may be employed to find ξ . The discussion below describes how n may be found.

Referring again to Figure A-1 we see that

$$\tan n = -\frac{1}{r} \left(\frac{dr}{d\theta} \right)_{t_a} \quad (A-8)$$

where $(dr/d\theta)_{t_a}$ denotes the derivative of r with respect to θ along a contour of time of arrival, t_a . To obtain $(dr/d\theta)_{t_a}$ the following identity is used:

$$\left(\frac{dr}{d\theta} \right)_{t_a} = - \left(\frac{\partial t_a}{\partial \theta} \right)_r / \left(\frac{\partial t_a}{\partial r} \right)_\theta \quad (A-9)$$

Recall that

$$t_a = \frac{\ell'}{a_\infty} [X f(Z) + C_1 + C_2 \cos \theta] \quad (A-10)$$

where

$$X = r/\ell', \quad Z = X^{-1.1}$$

and

$$\ell' = \ell'(\theta) \quad .$$

Hence, the chain rule may be applied to yield

$$\left(\frac{\partial t_a}{\partial \theta}\right)_r = \frac{dt_a}{dX} \left(\frac{\partial X}{\partial \theta}\right)_r + \left(\frac{\partial t_a}{\partial \theta}\right)_X \quad (A-11)$$

$$\left(\frac{\partial t_a}{\partial r}\right)_\theta = \frac{dt_a}{dX} \left(\frac{\partial X}{\partial r}\right)_\theta + \left(\frac{\partial t_a}{\partial r}\right)_X \quad (A-12)$$

Furthermore, by differentiation, we find

$$\left(\frac{\partial X}{\partial \theta}\right)_r = - \frac{r}{(\ell')^2} \frac{d\ell'}{d\theta} \quad (A-13)$$

$$\left(\frac{\partial X}{\partial r}\right)_\theta = \frac{1}{\ell'} \quad (A-14)$$

$$\left(\frac{\partial t_a}{\partial \theta}\right)_X = \frac{t_a}{\ell'} \frac{d\ell'}{d\theta} - \frac{\ell'}{a_\infty} C_2 \sin \theta \quad (A-15)$$

and

$$\left(\frac{\partial t_a}{\partial r}\right)_X = 0 \quad (A-16)$$

The following result is obtained from Reference 8:

$$\frac{dt_a}{dX} = \frac{\ell'}{a_\infty} \left(\frac{\chi^{1.1}}{1 + \chi^{1.1}} \right) \quad (A-17)$$

Equations (A-11) and (A-12) may now be rewritten as

$$\left(\frac{\partial t_a}{\partial \theta}\right)_r = \frac{1}{a_\infty} \frac{d\ell'}{d\theta} \left[\frac{a_\infty t_a}{\ell'} - \chi \left(\frac{\chi^{1.1}}{1 + \chi^{1.1}} \right) \right] - \frac{\ell'}{a_\infty} C_2 \sin \theta \quad (A-18)$$

and

$$\left(\frac{\partial t_a}{\partial r}\right)_\theta = \frac{1}{a_\infty} \left(\frac{\chi^{1.1}}{1 + \chi^{1.1}} \right) \quad (A-19)$$

Substitution of Equations (A-18) and (A-19) into (A-9) yields

$$\left(\frac{dr}{d\theta}\right)_{t_a} = \frac{d\ell'}{d\theta} [X - \bar{t}_a (1 + X^{-1.1})] + C_2 \ell' (1 + X^{-1.1}) \sin\theta \quad (\text{A-20})$$

where

$$\bar{t}_a = \frac{a_\infty t_a}{\ell'} .$$

Finally we obtain

$$\tan \eta = \frac{1}{r} \frac{d\ell'}{d\theta} \left[\bar{t}_a \left(1 + \frac{1}{X^{1.1}}\right) - X \right] - \frac{C_2}{X} \left(1 + \frac{1}{X^{1.1}}\right) \sin\theta. \quad (\text{A-21})$$

In summary, to determine α_1 , we first compute η from Equation (A-21). Equation (A-6) is then used to obtain ξ , which is substituted into Equations (A-2) through (A-4) to determine the components of $\vec{p}$. Finally, Equation (A-7) is used to calculate α_1 . This approach is less time-consuming than direct computation of the gradient of t_a because we make use of dt_a/dX which is available to us from previous analysis.

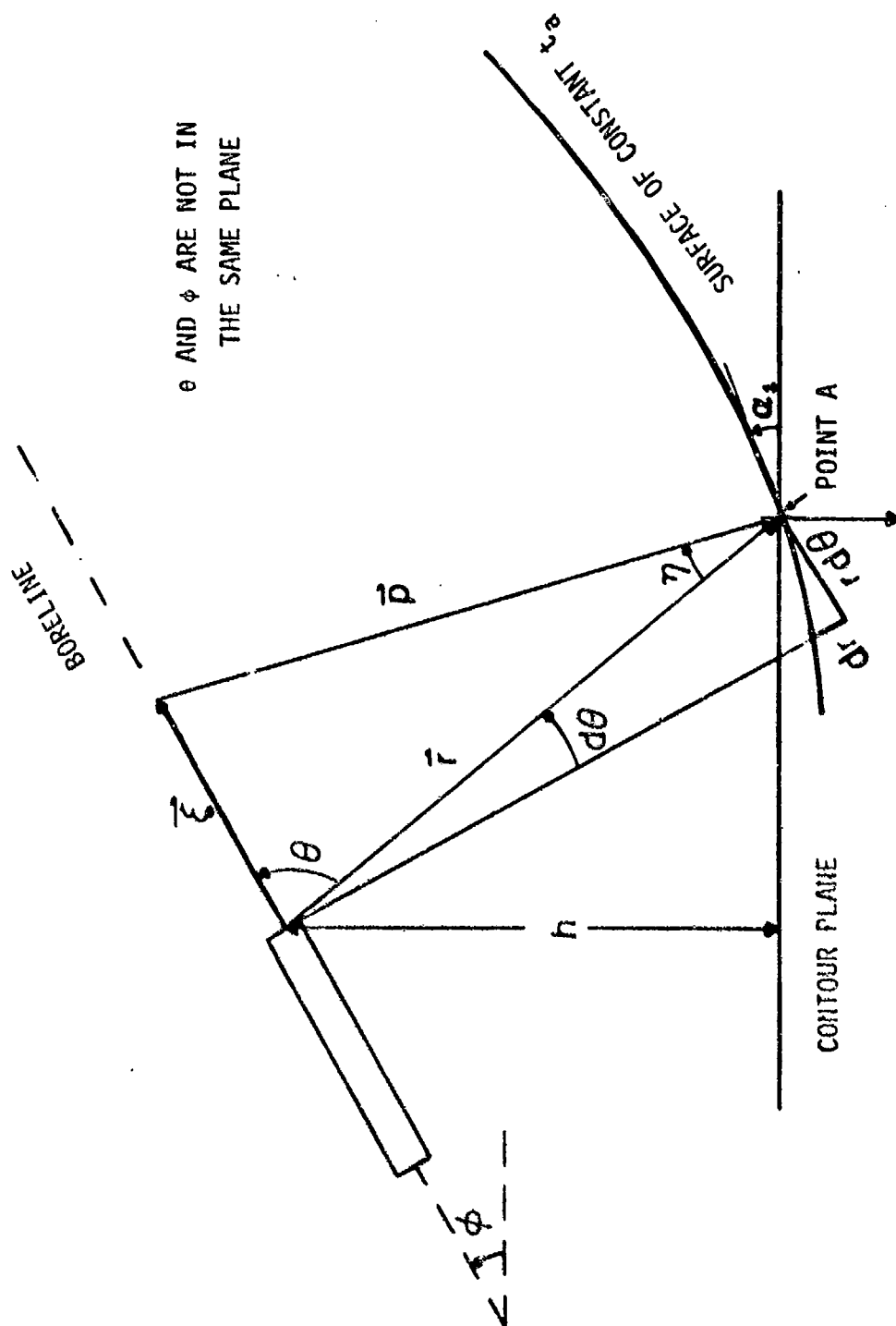


Figure A-1. Geometry of the Shock Wave Angle of Incidence Calculation

APPENDIX B - LISTING OF BLAST

```

0001 C *****
0002 C * BLAST *
0003 C *****
0004 C
0005 C-----
0006 C BLAST GENERATES CONTOUR MAPS OF PEAK INCIDENT OVERPRESSURE,
0007 C PEAK REFLECTED OVERPRESSURE, BLAST WAVE TIME OF ARRIVAL, AND POSITIVE
0008 C PHASE DURATION OF MUZZLE BLAST FROM CANNON. CONTOURS OF THESE QUANTI-
0009 C TIES ARE PLOTTED IN A POLAR COORDINATE SYSTEM WHICH IS LOCATED IN AN
0010 C ARBITRARY PLANE WITH RESPECT TO THE GUN TUBE. THE FREE FIELD BLAST
0011 C QUANTITIES ARE COMPUTED USING SCALING RELATIONS DEVELOPED BY FANSLER
0012 C AND SCHMIDT (ABRL-TR-02504). THE REFLECTED OVERPRESSURE IS COMPUTED
0013 C USING THE ANALYSIS OF HEAPS, FANSLER, AND SCHMIDT.
0014 C THE PROGRAM IS WRITTEN IN FORTRAN 77 WITH A FEW VAX-11 FORTRAN
0015 C STATEMENTS. THE PLOTTING IS DONE USING THE COMMERCIAL SOFTWARE
0016 C PACKAGE, DISSPLA. THE PROGRAM IS DESIGNED TO BE RUN INTERACTIVELY
0017 C ON SEVERAL TYPES OF TERMINALS WITH GRAPHICS CAPABILITY.
0018 C
0019 C THIS PROGRAM WAS DEVELOPED BY THE FLUID PHYSICS BRANCH OF THE LAUNCH
0020 C AND FLIGHT DIVISION OF THE BALLISTIC RESEARCH LABORATORY.
0021 C
0022 C CURRENT VERSION CREATED OCTOBER 84
0023 C-----
0024
0025 PROGRAM BLAST
0026 PARAMETER(NL=40,Q=50,P=100)
0027
0028 C-----
0029 C P AND Q ARE THE HORIZONTAL AND VERTICAL GRID DIMENSIONS,
0030 C RESPECTIVELY. NL IS THE MAXIMUM NUMBER OF CONTOURS THAT
0031 C MAY BE PLOTTED.
0032 C-----
0033
0034 LOGICAL INTBAL,GRIDUP
0035
0036 REAL PSIANQ(11),ANGLIN(11),PSISLP(11),SLOPES(11)
0037 REAL TOL,PI,RTOD,DTOR
0038 REAL UPBND,LOWBND,YVAR,ATM,GAMMA,AMIN,XYFAC,D,PROPM
0039 REAL TRAVEL,BORV,CHAMV,TOTLV,PROJ,PROBB,SPECF,TEMPK,ASUBM
0040 REAL PRATIO,AMBSS,VSUBP,GAMMP,MU,ELEANG,PHI,COSPHI,SINPHI
0041 REAL RINC,USUBY,USYBZ,X,Y,Z,ZHEIGHT,MAXR
0042 REAL R,COSTHE,SINTE,GM1,EXPO,RFACTR,XMASST,DSQ,DONHAF,AREAB
0043 REAL DIVFAC,CHIHET,ENERG,LSCALE,LPRIME,CAPX,CAPZ
0044 REAL PBAR(P,Q),TSUBA(P,Q),TAU(P,Q),PREFL(P,Q)
0045 REAL TNUM,TANETA,XCE,PSUBX,PSUBY,PSUBZ
0046 REAL ALPHA1,PRESIN,XI,PPMAX,CONINC,H(40),PMAX,PMIN,PRMIN
0047 REAL PRMAX,TSAMIN,TSAMAX,TAUMIN,TAUMAX,XSTEP,RATIO(2)
0048 REAL TARGX,TARGY,TARGZ,PBAR1,PBAR2,TSUBA1,TSUBA2
0049 REAL TAU1,TAU2,TINC,T(500),PRESS(500),TMAX,TMIN,TSUBAM
0050
0051 INTEGER TRMNUM,BAUD,MAJOPT,NOGRID,MENU,UNIT
0052 INTEGER POPT,IOPT,KLOP,KLAP,I,J,ISIGN,ICOUNT,NLEVL

```

```

0053      INTEGER FINAL,TEST,LIMIT,FOUND(40),ICNT,NPNTS
0054
0055      CHARACTER ESC/27/
0056      CHARACTER*1 ANS,ANS1,DUMMY,WUNITS
0057      CHARACTER*3 ERASE
0058      CHARACTER*15 FNAME,WFILE
0059      CHARACTER*32 GUN
0060      CHARACTER*38 LABEL1
0061      CHARACTER*25 LABEL2
0062      CHARACTER*26 LABEL3
0063      CHARACTER*79 LABEL6
0064      CHARACTER*75 LABEL7
0065      CHARACTER*39 LABEL8
0066      CHARACTER*49 NAME
0067      CHARACTER*44 NAME1
0068      CHARACTER*45 NAME2
0069      CHARACTER*44 NAME3
0070      CHARACTER*42 NAME4
0071
0072      COMMON/ONE/PBAR1,TSUBA1,TAU1
0073      COMMON/TWO/PBAR2,TSUBA2,TAU2
0074      COMMON/GRID/NLEVL5,H,K,OPEN,XM,YM,ISIGN
0075      COMMON/INC/RINC,MAXR
0076      COMMON/TRIG/RTOD,DTOR,PI
0077      COMMON/REFL/GAMMA,TOL,UPBND,LOWBND,XI
0078      COMMON/LAGRAN/PSIANG,PSISLP,ANGLIN,SLOPES
0079      COMMON/PRESS/PBAR,POPT,KLAP
0080      COMMON/ATMOS/ATM
0081      COMMON WORK(12000),XPLOT(250),YPL0T(250),LSAV
0082
0083      C-----
0084      C THE ELEMENTS OF ARRAY 'ANGLIN' ARE THE ANGLES (RADIAN5) AS A FUNC-
0085      C TION OF INCIDENT OVERPRESSURE AT WHICH THE LINEAR FIT PART OF THE
0086      C REFLECTED OVERPRESSURE CURVE STARTS.  THE ELEMENTS OF 'PSIANG'
0087      C ARE THE INCIDENT OVERPRESSURES CORRESPONDING TO THESE ANGLES.
0088      C THE ELEMENTS OF ARRAY 'SLOPES' ARE THE SLOPES OF THE LINEAR APPROXI-
0089      C MATION.  THE ELEMENTS OF 'PSISLP' ARE THE INCIDENT OVERPRESSURES
0090      C CORRESPONDING TO THESE SLOPES.  THESE FOUR ARRAYS ARE USED IN THE
0091      C LAGRANGIAN INTERPOLATION SUBROUTINE.
0092      C-----
0093
0094      DATA PSIANG/2.,5.,10.,15.,20.,25.,30.,40.,50.,60.,70./
0095      DATA ANGLIN/1.29,1.15,1.06,1.01,.98,.96,.93,.91,.89,.87,.86/
0096      DATA PSISLP/2.,5.,10.,15.,20.,25.,30.,40.,50.,60.,70./
0097      DATA SLOPES/-4.1,-3.,-2.4,-2.1,-2.,-2.,-1.9,-1.8,-1.7,-1.6,
0098      & -1.5/
0099
0100      TOL=.000001
0101      PI=3.141593
0102      RTOD=180./PI
0103      DTOR=PI/180.
0104      UPBND=PI/2

```

```

0105         LOWBND=.01
0106         YVAR=1.013*10.**5
0107         ATM=14.70
0108         GAMMA = 1.40
0109         AMIN=0.
0110         C1 = 9.24
0111         C2 = .94
0112         GRIDUP = .FALSE.
0113
0114 C-----
0115 C  THE CURRENT VERSION HAS FIVE TERMINAL TYPE DISTINCTIONS.
0116 C-----
0117
0118         WRITE(6,*)
0119         WRITE(6,*) ' Specify the type of terminal you are using.'
0120         WRITE(6,*)
0121         WRITE(6,*) ' 0   Retrographics.'
0122         WRITE(6,*) ' 1   Tektronix 4010 or 4051'
0123         WRITE(6,*) ' 2   Tektronix 4014'
0124         WRITE(6,*) ' 3   Hewlett Packard 2623'
0125         WRITE(6,*) ' 4   ID - 100'
0126         WRITE(6,*)
0127         WRITE(6,*) ' Input corresponding integer.'
0128
0129         READ*,TRMNUM
0130 90      IF (TRMNUM .LT. 0 .OR. TRMNUM .GT. 4) THEN
0131             WRITE(6,*) 'Invalid choice. Try again.'
0132             READ*,TRMNUM
0133             GOTO 90
0134         END IF
0135
0136         IF (TRMNUM .EQ. 0 .OR. TRMNUM .EQ. 4) THEN
0137             BAUD = 480
0138         ELSE
0139             BAUD = 960
0140         END IF
0141
0142         NOGRID=1
0143         XYFAC=1.
0144
0145 105     CALL SCLEAR(TRMNUM)
0146         WRITE(6,*)
0147         WRITE(6,*)
0148         WRITE(6,*)
0149         WRITE(6,*)
0150         WRITE(6,*)
0151         WRITE(6,*)
0152         WRITE(6,*)
0153         WRITE(6,*) '                               MAIN MENU '
0154         WRITE(6,*)
0155         WRITE(6,*) ' 1.  Input or read information for initial plots.'
0156         WRITE(6,*) ' 2.  Change the input information.'

```

```

0157      WRITE(6,*) ' 3. Generate the plotting grid or read the grid'
0158      WRITE(6,*) '      from a file.'
0159      WRITE(6,*) ' 4. Plot contours.'
0160      WRITE(6,*) ' 5. Write input information to file for future use.'
0161      WRITE(6,*) ' 6. Save the current grid in a file for future use.'
0162      WRITE(6,*) ' 7. Terminate the program.'
0163      WRITE(6,*)
0164      WRITE(6,*) 'Input the corresponding integer.'
0165      READ*, MENU
0166
0167 110  IF (MENU .LT. 1 .OR. MENU .GT. 7) THEN
0168      WRITE(6,*) 'Invalid response. try again.'
0169      READ*, MENU
0170      GOTO 110
0171  END IF
0172
0173      IF (MENU .EQ. 1) GOTO 1000
0174      IF (MENU .EQ. 2) GOTO 2000
0175      IF (MENU .EQ. 3) GOTO 3000
0176      IF (MENU .EQ. 4) GOTO 4000
0177      IF (MENU .EQ. 5) GOTO 5000
0178      IF (MENU .EQ. 6) GOTO 3500
0179      IF (MENU .EQ. 7) GOTO 6000
0180
0181 1000 CALL SCLEAR(TRMNUM)
0182
0183      WRITE(6,*) 'You have chosen to input information for initial plot'
0184      WRITE(6,*)
0185      WRITE(6,*) 'Do you wish to read the information from'
0186      WRITE(6,*) 'a data file? (Y or N)'
0187      READ(*, '(A1)') ANS
0188      IF (ANS .EQ. 'Y') THEN
0189          WRITE(6,*) 'Enter the name of the data file (15 characters)'
0190          READ(*, '(A15)') FNAME
0191          UNIT = 1
0192          OPEN(UNIT = 1, FILE = FNAME, READONLY, STATUS = 'OLD')
0193      ELSE
0194          UNIT = 5
0195      END IF
0196
0197      CALL SCLEAR(TRMNUM)
0198
0199      WRITE(6,*) 'Enter gun nomenclature (32 characters)'
0200      READ(UNIT, '(A32)') GUN
0201      WRITE(6,*)
0202      WRITE(6,*) 'Enter bore diameter of gun (meters).'
0203      READ(UNIT, *) D
0204      WRITE(6,*)
0205      WRITE(6,*) 'Do you wish to use interior ballistic'
0206      WRITE(6,*) 'formulation? (Y or N)'
0207      READ(UNIT, '(A1)') ANS1
0208

```

```

0209         IF (ANS1 .EQ. 'Y') THEN
0210             INTBAL = .TRUE.
0211             WRITE(6,*) 'Enter propellant mass (kg).'
```

0212 READ(UNIT,*) PRCTM

0213 WRITE(6,*)

0214 WRITE(6,*) 'Enter the distance the projectile '

0215 WRITE(6,*) 'travels in bore (meters).'

0216 READ(UNIT,*) TRAVEL

0217 BORV = .25*PI*D*D*TRAVEL

0218 WRITE(6,*)

0219 WRITE(6,*) 'Enter volume of chamber (cubic meters).'

0220 READ(UNIT,*) CHAMV

0221 TOTLV = BORV + CHAMV

0222 WRITE(6,*)

0223 WRITE(6,*) 'Enter projectile mass (kg).'

0224 READ(UNIT,*) PROJ

0225 WRITE(6,*)

0226 WRITE(6,*) 'Enter fraction of propellant burnt.'

0227 READ(UNIT,*) PROPB

0228 WRITE(6,*)

0229

0230 C-----

0231 C THE SPECIFIC FORCE IS EQUAL TO THE GAS COEFFICIENT TIMES

0232 C THE ADIABATIC FLAME TEMPERATURE OF THE PROPELLANT.

0233 C-----

0234

0235 CALL SCLEAR(TRMNUM)

0236 WRITE(6,*) 'Enter specific force. Use MKS units (m*m/s*s) (A),'

0237 WRITE(6,*) 'or English units (ft*lb/lbm) (B). Enter A or B.'

0238 WRITE(6,*)

0239 READ(UNIT, '(A1)') WUNITS

0240 WRITE(6,*)

0241 WRITE(6,*) 'Now enter specific force.'

0242 WRITE(6,*)

0243 READ(UNIT,*) SPECF

0244 IF (WUNITS .EQ. 'B') SPECF = SPECF*2.992

0245 WRITE(6,*)

0246 WRITE(6,*) 'Enter flame temperature (deg. Kelvin).'

0247 WRITE(6,*) 'Default = 3000 K.'

0248 READ(UNIT, '(F12.4)') TEMPK

0249 IF (TEMPK .EQ. 0.0) TEMPK = 3000.0

0250 CALL SCLEAR(TRMNUM)

0251 ELSE

0252 INTBAL = .FALSE.

0253 WRITE(6,*)

0254 WRITE(6,*) 'Enter pre-uncorked sound speed at muzzle (m/s).'

0255 READ(UNIT,*) ASUBM

0256 WRITE(6,*)

0257 WRITE(6,*) 'Enter ratio of pre-uncorked muzzle pressure'

0258 WRITE(6,*) 'to ambient pressure.'

0259 READ(UNIT,*) PRATIO

0260 END IF

```

0261
0262 WRITE(6,*)
0263 WRITE(6,*) 'Enter ambient sound speed (m/s). Default = 340.0 m/s'
0264 READ(UNIT,'(F12.4)') AMBSS
0265 IF (AMBSS .EQ. 0.0) AMBSS = 340.0
0266
0267 WRITE(6,*)
0268 WRITE(6,*) 'Enter exit velocity of projectile.'
0269 READ(UNIT,*) VSUBP
0270
0271 WRITE(6,*)
0272 WRITE(6,*) 'Enter propellant specific heat ratio, gamma.'
0273 WRITE(6,*) 'Default = 1.24.'
0274 READ(UNIT,'(F7.4)') GAMMP
0275 IF (GAMMP .EQ. 0.0) GAMMP = 1.24
0276
0277 WRITE(6,*)
0278 WRITE(6,*) 'Enter momentum index, mu. Default = 0.78'
0279 READ(UNIT,'(F7.4)') MU
0280 IF (MU .EQ. 0.0) MU = 0.78
0281
0282 CALL SCLEAR(TRMNUM)
0283
0284 WRITE(6,*) 'Enter elevation angle of gun (degrees).'
0285 READ(UNIT,*) ELEANG
0286 PHI = DTOR*ELEANG
0287 COSPHI = COS(PHI)
0288 SINPHI = SIN(PHI)
0289
0290 WRITE(6,*) 'Enter the height of the muzzle (meters).'
0291 READ(UNIT,*) ZHEIGHT
0292
0293 CLOSE (UNIT=1)
0294
0295 GOTO 105
0296
0297 2000 CALL SCLEAR(TRMNUM)
0298
0299 WRITE(6,*) 'You have chosen to change information.'
0300 WRITE(6,*)
0301 WRITE(6,*) '          Change of information menu'
0302 WRITE(6,*)
0303 WRITE(6,*) ' 1. Change weapon and flow parameters.'
0304 WRITE(6,*) ' 2. Change the orientation of the gun.'
0305 WRITE(6,*) ' 3. Return to the main menu.'
0306 WRITE(6,*)
0307 WRITE(6,*) 'Enter the corresponding integer.'
0308 READ*,MENU
0309 2010 IF ( MENU .LT. 1 .OR. MENU .GT. 3 ) THEN
0310     WRITE(6,*) 'Invalid response. Try again.'
0311     READ*,MENU
0312     GOTO 2010

```

```

0313         END IF
0314
0315         IF (MENU .EQ. 1) GOTO 2100
0316         IF (MENU .EQ. 2) GOTO 2200
0317         IF (MENU .EQ. 3) GOTO 105
0318
0319 2100 CALL SCLEAR(TRMNUM)
0320
0321 WRITE(6,*) 'You may change any of the following:'
0322 WRITE(6,*)
0323 WRITE(6,*) ' 1. Gun nomenclature      10. Pre-uncorked sound speed '
0324 WRITE(6,*) ' 2. Bore diameter                at the muzzle '
0325 WRITE(6,*) ' 3. Propellant mass * 11. Ratio of pre-uncorked muz-'
0326 WRITE(6,*) ' 4. Inbore travel                zle pressure to ambient '
0327 WRITE(6,*) '      distance *                pressure '
0328 WRITE(6,*) ' 5. Chamber volume * 12. Ambient sound speed'
0329 WRITE(6,*) ' 6. Projectile mass * 13. Projectile exit velocity'
0330 WRITE(6,*) ' 7. Fraction of pro- 14. Specific heat ratio'
0331 WRITE(6,*) '      pellant burnt * 15. Momentum index'
0332 WRITE(6,*) ' 8. Specific force *'
0333 WRITE(6,*) ' 9. Flame temperature *'
0334 WRITE(6,*)
0335 WRITE(6,*) ' or you may                16. Return to preceeding menu'
0336 WRITE(6,*)
0337 WRITE(6,*) '* indicates an interior ballistics parameter.'
0338 WRITE(6,*)
0339 WRITE(6,*) 'Enter corresponding integer.'
0340 READ*,MENU
0341
0342 2110 IF (MENU .LT. 1 .OR. MENU .GT. 16) THEN
0343     WRITE(6,*) 'Invalid response. Try again.'
0344     READ*,MENU
0345     GOTO 2110
0346 END IF
0347
0348 CALL SCLEAR(TRMNUM)
0349
0350 IF (MENU .EQ. 1) THEN
0351     WRITE(6,*) 'Current value is ',GUN
0352     WRITE(6,*) 'Enter new value'
0353     READ(*, '(A32)') GUN
0354 END IF
0355
0356 IF (MENU .EQ. 2) THEN
0357     WRITE(6,*) 'Current value is ',D
0358     WRITE(6,*) 'Enter new value'
0359     READ*,D
0360 END IF
0361
0362 IF (MENU .EQ. 3) THEN
0363     WRITE(6,*) 'Current value is ',PROPM
0364     WRITE(6,*) 'Enter new value'

```

```

0365         READ*,PROPM
0366         ANS1 = 'Y'
0367     END IF
0368
0369     IF (MENU .EQ. 4) THEN
0370         WRITE(6,*) 'Current value is ',TRAVEL
0371         WRITE(6,*) 'Enter new value'
0372         READ*,TRAVEL
0373         BORV = 0.25*PI*D*D*TRAVEL
0374         ANS1 = 'Y'
0375     END IF
0376
0377     IF (MENU .EQ. 5) THEN
0378         WRITE(6,*) 'Current value is ',CHAMV
0379         WRITE(6,*) 'Enter new value'
0380         READ*,CHAMV
0381         ANS1 = 'Y'
0382     END IF
0383
0384     IF (MENU .EQ. 6) THEN
0385         WRITE(6,*) 'Current value is ',PROJ
0386         WRITE(6,*) 'Enter new value'
0387         READ*,PROJ
0388         ANS1 = 'Y'
0389     END IF
0390
0391     IF (MENU .EQ. 7) THEN
0392         WRITE(6,*) 'Current value is ',PROPB
0393         WRITE(6,*) 'Enter new value'
0394         READ*,PROPB
0395         ANS1 = 'Y'
0396     END IF
0397
0398     IF (MENU .EQ. 8) THEN
0399         WRITE(6,*) 'Current value is ',SPECF
0400         WRITE(6,*) 'Use MKS units (m*m/s*s) (A), or English'
0401         WRITE(6,*) 'units (ft*lb/lbm) (B). Enter A or B.'
0402         WRITE(6,*)
0403         READ(*,'(A1)') WUNITS
0404         WRITE(6,*)
0405         WRITE(6,*) 'Now enter new value.'
0406         READ*, SPECF
0407         IF (WUNITS .EQ. 'B') SPECF = SPECF*2.992
0408         ANS1 = 'Y'
0409     END IF
0410
0411     IF (MENU .EQ. 9) THEN
0412         WRITE(6,*) 'Current value is ',TEMPK
0413         WRITE(6,*) 'Enter new value'
0414         READ*,TEMPK
0415         ANS1 = 'Y'
0416     END IF

```

```

0417
0418     IF (MENU .EQ. 10) THEN
0419         WRITE(6,*) 'Current value is ',ASUBM
0420         WRITE(6,*) 'Enter new value'
0421         READ*,ASUBM
0422     END IF
0423
0424     IF (MENU .EQ. 11) THEN
0425         WRITE(6,*) 'Current value is ',PRATIO
0426         WRITE(6,*) 'Enter new value'
0427         READ*,PRATIO
0428     END IF
0429
0430     IF (MENU .EQ. 12) THEN
0431         WRITE(6,*) 'Current value is ',AMBSS
0432         WRITE(6,*) 'Enter new value'
0433         READ*,AMBSS
0434     END IF
0435
0436     IF (MENU .EQ. 13) THEN
0437         WRITE(6,*) 'Current value is ',VSubP
0438         WRITE(6,*) 'Enter new value'
0439         READ*,VSubP
0440     END IF
0441
0442     IF (MENU .EQ. 14) THEN
0443         WRITE(6,*) 'Current value is ',GAMMP
0444         WRITE(6,*) 'Enter new value'
0445         READ*,GAMMP
0446     END IF
0447
0448     IF (MENU .EQ. 15) THEN
0449         WRITE(6,*) 'Current value is ',MU
0450         WRITE(6,*) 'Enter new value'
0451         READ*,MU
0452     END IF
0453
0454     IF (MENU .EQ. 16) GOTO 2000
0455     GOTO 2100
0456
0457 2200 CALL SCLEAR(TRMNUM)
0458     WRITE(6,*) 'Current elevation angle of gun is ',ELEANG,
0459     & ' degrees.'
0460     WRITE(6,*)
0461     WRITE(6,*) 'Enter the new elevation angle.'
0462     READ*, ELEANG
0463     PHI = DTOR*ELEANG
0464     COSPHI = COS(PHI)
0465     SINPHI = SIN(PHI)
0466
0467     WRITE(6,*)
0468     WRITE(6,*) 'The current height of the muzzle is ',ZHEIGHT

```

```

0469      WRITE(6,*)
0470      WRITE(6,*) 'Enter the new height of the muzzle,'
0471      READ*, ZHEIGHT
0472
0473      GOTO 2000
0474
0475      C-----
0476      C IN SECTION 3000 THE USER CHOOSES WHICH QUANTITY HE WANTS PLOTTED.
0477      C THE VALUES OF THIS QUANTITY ARE THEN DETERMINED AT EACH GRID POINT
0478      C IN THE CONTOUR PLANE.
0479      C-----
0480
0481      3000 CALL SCLEAR(TRMNUM)
0482
0483      C-----
0484      C THE USER MAY GENERATE A GRID TO PLOT ALL QUANTITIES, OR HE MAY
0485      C CHOOSE TO EXCLUDE THE REFLECTED OVERPRESSURE. THIS CHOICE IS
0486      C GIVEN BECAUSE THE REFLECTED OVERPRESSURE GRID IS MUCH MORE TIME-
0487      C CONSUMING TO GENERATE THAN THE OTHER QUANTITIES.
0488      C THE USER MAY ALSO READ A GRID THAT WAS PREVIOUSLY GENERATED.
0489      C-----
0490
0491      WRITE(6,*)
0492      WRITE(6,*) 'You may'
0493      WRITE(6,*)
0494      WRITE(6,*) ' 1. Generate a grid of values for '
0495      WRITE(6,*) '           peak incident overpressure,'
0496      WRITE(6,*) '           peak reflected overpressure,'
0497      WRITE(6,*) '           blast wave time of arrival,'
0498      WRITE(6,*) '           positive phase duration.'
0499      WRITE(6,*)
0500      WRITE(6,*) ' 2. Generate a grid of values for all of the'
0501      WRITE(6,*) '           quantities above excluding peak reflected'
0502      WRITE(6,*) '           overpressure.'
0503      WRITE(6,*)
0504      WRITE(6,*) ' 3. Read a previously generated grid from a'
0505      WRITE(6,*) '           data file.'
0506      WRITE(6,*)
0507      WRITE(6,*) ' Enter the corresponding integer. '
0508      READ *, IOPT
0509
0510      IF (IOPT .NE. 3) THEN
0511
0512      C-----
0513      C NEW PAGE.
0514      C-----
0515
0516      CALL SCLEAR(TRMNUM)
0517      KLOP=0
0518      KLAP=0
0519
0520      C-----

```

```

0521 C THE USER DEFINES THE MAXIMUM RADIUS TO BE PLOTTED.
0522 C-----
0523
0524     WRITE(6,*)'Input maximum distance from origin to be plotted
0525     & (meters).'

```

0573 C WHICH POINTS FROM THE ORIGIN OF THE CONTOUR PLANE TO THE POINT IN
 0574 C THE CONTOUR GRID UNDER CONSIDERATION. X,Y, AND Z ARE THE COORDI-
 0575 C NATES OF THIS GRIDPOINT REFERRED TO AN ORIGIN AT THE MUZZLE. THETA
 0576 C IS THE POLAR ANGLE OF THE VECTOR R. THETA IS DETERMINED BY
 0577 C TAKING THE DOT PRODUCT OF R AND U.

0578 C-----

0579
 0580 X=-J*RINC
 0581 IF (I*RINC.LT.MAXR) Y=-(MAXR-I*RINC)
 0582 IF (I*RINC.EQ.MAXR) Y=0.
 0583 IF (I*RINC.GT.MAXR) Y=I*RINC-MAXR
 0584 Z=-ZHEIGH
 0585 R=SQRT(X**2 + Y**2 + Z**2)
 0586 COSTHE=((Y*USUBY)+(Z*USUBZ))/R
 0587 SIN THE=SQRT(1. - COSTHE**2)
 0588 GM1=GAMMP-1.
 0589 EXPO=(3.*GAMMP-1.)/GM1

0590

0591 C-----

0592 C THE SCALING LENGTHS, LSCALE AND LPRIME, ARE DETERMINED.
 0593 C FIRST, INTERIOR BALLISTIC PARAMETERS ARE CONSIDERED.

0594 C-----

0595
 0596 IF (INTBAL) THEN
 0597 PROJ = 1.05*PROJ
 0598 RFACTR = 1.35
 0599 IF(D.LT.0.02) RFACTR = 1.5
 0600 IF(D.GT.0.045) RFACTR = 1.3
 0601 XMASST = PROJ + PROPM/3.
 0602 DSQ = D**2
 0603 DONHAF = SQRT(D)
 0604 AREAB = PI*(D**2)/4.
 0605 DIVFAC = 1.7 + 671.*DONHAF*((DSQ/PROPM)**.86)
 0606 CHIHET=10500.*TOTLV*D*DONHAF*(TEMPK-300.)*RFACTR/AREAB
 0607 & / (VSUBP**2)/XMASST/DIVFAC
 0608 ENERG=((PROPB*PROPM*SPECF)/GM1)-.5*(PROJM+
 0609 & PROPM/3.)*(1.0+CHIHET)*VSUBP**2
 0610 ASUBM=((GAMMP*GM1*ENERG)/(PROPM*(PROPM**2/(3.*PROJM
 0611 &))))**.5
 0612 PRATIO=(GM1*ENERG)/(TOTLV*(1+PROPM/(3.*PROJM)))/YVAR
 0613 END IF

0614

0615 C-----

0616 C NEXT MUZZLE EXIT CONDITIONS FOR SUBSONIC EXIT FLOW.

0617 C-----

0618
 0619 IF (VSUBP.LE.ASUBM) THEN
 0620 LSCALE=D*SQRT((.00862*PRATIO*ASUBM/(GM1*AMBSS))
 0621 & *(1.+GAMMP*GM1/2.)*((2.+GM1*VSUBP/ASUBM)/
 0622 & (GAMMP+1.))**EXPO)
 0623 ELSE
 0624

```

0625 C-----
0626 C FINALLY, MUZZLE EXIT CONDITIONS FOR SUPERSONIC EXIT FLOW.
0627 C-----
0628
0629 LSCALE=D*.0928*SQRT((PRATIO*VSUBP/(GM1*AMBSS))*
0630 & (1.+GAMMP*GM1*.5*(VSUBP/ASUBM)**2))
0631 END IF
0632
0633 C-----
0634 C LPRIME IS CALCULATED.
0635 C-----
0636
0637 LPRIME=LSCALE*((MU*COSTHE)+SQRT(1.-(MU**2)*(SINTHE**2)))
0638 CAPX=R/LPRIME
0639 CAPZ=CAPX**-1.1
0640 IF (CAPX.LT.1.) KLOP=1
0641
0642 C-----
0643 C PBAR IS THE PEAK INCIDENT OVERPRESSURE, TSUBA IS THE BLAST WAVE
0644 C TIME OF ARRIVAL, AND TAU IS THE POSITIVE PHASE DURATION. THESE
0645 C QUANTITIES ARE CALCULATED USING THE SCALING RELATIONS DERIVED BY
0646 C FANSLER AND SCHMIDT.NEW PBAR AND TSUBA EQUATIONS ADDED MARCH,83.
0647 C-----
0648
0649 PBAR(I,J)=2.4*CAPZ
0650
0651 TSUBA(I,J)=R/AMBSS*(1.+10.*CAPZ-.8333*CAPZ**2+.4348*
0652 & CAPZ**3-.2941*CAPZ**4+.2273*CAPZ**5-.1667*CAPZ**6)-
0653 & (LPRIME/AMBSS)*(C1+C2*COSTHE)
0654
0655 TAU(I,J)=(LPRIME/AMBSS)*(1.0 + .13*CAPX)
0656
0657 C-----
0658 C IF IOPT=1 WE GO THROUGH THE REFLECTED OVERPRESSURE CALCULATION.
0659 C THE FIRST STEP IS TO DETERMINE THE SHOCK WAVE ANGLE OF INCIDENCE
0660 C AT EACH GRID POINT.
0661 C-----
0662
0663 IF (IOPT.EQ. 1) THEN
0664
0665 C-----
0666 C ALPHA1 IS THE SHOCK WAVE ANGLE OF INCIDENCE AT THE GRIDPOINT.
0667 C A DETAILED EXPLANATION OF THE ALPHA1 CALCULATION IS IN APPENDIX
0668 C A OF THE REPORT.
0669 C-----
0670
0671 TSABAR = TSUBA(I,J)*AMBSS/LPRIME
0672
0673 C-----
0674 C DLPDTH = DERIVATIVE OF LPRIME WITH RESPECT TO THETA
0675 C DCXDTB = DERIVATIVE OF CAPX WITH RESPECT TO TSUBA BAR
0676 C-----

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```

0677
0678      DLPDTH = -LPRIME*MU*SINTHE/SQRT(1. - MU*MU*SINTHE**2)
0679      DCXDLP = -R/LPRIME**2
0680
0681 C-----
0682 C IF THE TIME OF ARRIVAL EXPRESSION IS CHANGED, DTBDGX MUST ALSO BE
0683 C CHANGED ACCORDINGLY.
0684 C-----
0685
0686      DCXDTB = 1. + CAPZ
0687
0688      TANETA = (DLPDTH/LPRIME)*( DCXDTB*TSABAR/CAPX - 1.0 )
0689      &      + C2*LPRIME*DCXDTB*SINTHE/CAPX
0690
0691      IF (COSTHE .EQ. 0.) THEN
0692          XCE = R*TANETA
0693      ELSE
0694          TANTHE = SINTHE/COSTHE
0695          XCE = (R/COSTHE)/(TANTHE/TANETA + 1.0)
0696      END IF
0697
0698      PSUBX = X
0699      PSUBY = Y - XCE*COSPHI
0700      PSUBZ = Z - XCE*SINPHI
0701      ALPHA1 = ACOS(-PSUBZ/SQRT(PSUBX**2+PSUBY**2+PSUBZ**2))
0702      IF (ALPHA1 .GT. PI/2.) ALPHA1 = PI - ALPHA1
0703      PRESIN=PBAR(I,J)
0704      XI=PRESIN+1.
0705
0706 C-----
0707 C SUBROUTINE REFCAL IS CALLED TO DETERMINE THE REFLECTED
0708 C OVERPRESSURE, PREFL, AT THE GRIDPOINT.
0709 C IF THE ANGLE OF INCIDENCE IS GREATER THAN 1. DEGREE WE USE
0710 C OBLIQUE SHOCK THEORY. IF ANGLE OF INCIDENCE IS LESS THAN
0711 C 1. DEGREE WE USE NORMAL SHOCK RELATIONS.
0712 C-----
0713
0714      IF (ALPHA1 .GT. 0.0174) THEN
0715          CALL REFCAL(PRESIN,PREFL(I,J),ALPHA1)
0716      ELSE
0717          P3 = ( XI**2*(3*GAMMA-1.) - (GAMMA-1.)*XI )/
0718      &      ( XI*(GAMMA-1.) + (GAMMA+1.) )
0719          PREFL(I,J) = P3 - 1.
0720      END IF
0721
0722      END IF
0723      3165      CONTINUE
0724      3160      CONTINUE
0725      CALL BELL
0726      CALL BELL
0727      GRIDUP = .TRUE.
0728      GOTO 105

```

```

0729
0730         ELSE
0731
0732 C-----
0733 C  IF THE USER HAS CHOSEN TO READ A GRID THAT HAS BEEN SAVED
0734 C  THE GRID IS NOW READ FROM THE DATA FILE.
0735 C-----
0736
0737 3200  CALL SCLEAR(TRMNUM)
0738       WRITE(6,*) 'What is the name of the data file?'
0739       READ(*, '(A20)') FNAME
0740       OPEN(UNIT=1, FILE=FNAME, STATUS='OLD')
0741       WRITE(6,*) 'Reading grid from file ', FNAME
0742       READ(1,*) IOPT
0743       READ(1,*) MAXR
0744       IF (IOPT .EQ. 1) THEN
0745         DO 3210 I=1,P
0746           DO 3215 J=1,Q
0747             READ(1,*) PBAR(I,J), PREFL(I,J), TSUBA(I,J), TAU(I,J)
0748 3215         CONTINUE
0749 3210     CONTINUE
0750       END IF
0751       IF (IOPT .EQ. 2) THEN
0752         DO 3220 I=1,P
0753           DO 3225 J=1,Q
0754             READ(1,*) PBAR(I,J), TSUBA(I,J), TAU(I,J)
0755 3225         CONTINUE
0756 3220     CONTINUE
0757       END IF
0758       CLOSE(UNIT=1)
0759       RINC=2.*MAXR/P
0760
0761       CALL BELL
0762       CALL BELL
0763       CALL BELL
0764       GRIDUP = .TRUE.
0765       GOTO 105
0766
0767       END IF
0768
0769 C-----
0770 C  THE USER CAN WRITE THE CURRENT GRID TO A DATA FILE FOR FUTURE
0771 C  USE TO AVOID SPENDING THE TIME GENERATING IT.
0772 C-----
0773
0774 3500  CALL SCLEAR(TRMNUM)
0775       WRITE(6,*)
0776       WRITE(6,*) 'Enter the name you wish to give the file.'
0777       READ(*, '(A20)') FNAME
0778       OPEN(UNIT=1, FILE=FNAME, STATUS='NEW')
0779       WRITE(6,*)
0780       WRITE(6,*) 'Writing grid to file ', FNAME

```

```

0781      WRITE(1,*) IOPT
0782      WRITE(1,*) MAXR
0783      IF (IOPT .EQ. 1) THEN
0784          DO 3505 I=1,P
0785              DO 3510 J=1,Q
0786                  WRITE(1,*) PBAR(I,J),PREFL(I,J),TSUBA(I,J),TAU(I,J)
0787      3510          CONTINUE
0788      3505          CONTINUE
0789      END IF
0790      IF (IOPT .EQ. 2) THEN
0791          DO 3520 I=1,P
0792              DO 3530 J=1,Q
0793                  WRITE(1,*) PBAR(I,J),TSUBA(I,J),TAU(I,J)
0794      3530          CONTINUE
0795      3520          CONTINUE
0796      END IF
0797      CLOSE(UNIT=1)
0798      CALL BELL
0799      CALL BELL
0800      GOTO 105
0801
0802      C-----
0803      C IN SECTION 4000 THE USER PICKS WHICH QUANTITY HE WANTS TO PLOT.
0804      C THE GRID USED MAY BE ONE GENERATED DURING THE CURRENT INTERACTIVE
0805      C SESSION OR IT MAY BE ONE WHICH SAVED FROM A PREVIOUS SESSION.
0806      C THIS FEATURE ALLOWS THE USER TO RUN THE TIME-CONSUMING PART
0807      C OF THE PROGRAM ON A NON-GRAPHICS TERMINAL AND THEN MOVE TO A
0808      C GRAPHICS TERMINAL TO QUICKLY GENERATE THE CONTOUR MAPS.
0809      C THE CONTOUR LEVELS TO BE PLOTTED ARE SPECIFIED
0810      C BY THE USER OR DETERMINED AUTOMATICALLY. THE CONTOURING ALGOR-
0811      C ITHM THEN SEARCHES THROUGH THE GRID TO DETERMINE THE PATH OF
0812      C EACH CONTOUR LEVEL. ONCE THE PATH HAS BEEN DETERMINED, IT IS
0813      C PLOTTED USING THE DISSPLA SUBROUTINES.
0814      C-----
0815
0816      4000  CALL SCLEAR(TRMNUM)
0817          IF (.NOT. GRIDUP) THEN
0818              WRITE(6,*) 'You must generate or read a grid of function'
0819              WRITE(6,*) 'values before plotting. Hit return to return'
0820              WRITE(6,*) 'to main menu. Then choose menu option 3.'
0821              READ(*, '(F3.1)') PAUS
0822              GOTO 105
0823          END IF
0824
0825      C-----
0826      C THE LABELS ARE DEFINED.
0827      C-----
0828
0829      LABEL1='DISTANCE FROM ORIGIN OF PLANE, meters '
0830      LABEL2='ANGLE OF ELEVATION (deg)='
0831      LABEL3='HEIGHT OF MUZZLE (meters)='
0832      LABEL6='YOUR MAXIMUM CONTOUR VALUE IS TOO LARGE, PLEASE

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0833      & TRY AGAIN. IT MUST NOT EXCEED -'
0834      LABEL7='YOUR MAXIMUM CONTOUR VALUE IS TOO SMALL., PLEASE
0835      & TRY AGAIN. IT MUST EXCEED -'
0836      LABEL8='INPUT NEW VALUE (ENTER 0. FOR DEFAULT).'

```

```

0885      READ*,POPT
0886      IF (POPT.EQ. 3) POPT=4
0887      IF (POPT.EQ. 2) POPT=3
0888      END IF
0889
0890  C-----
0891  C THE USER CHOOSES WHETHER HE WANTS TO SPECIFY THE VALUE OF EACH
0892  C CONTOUR OR HAVE THE CONTOUR LEVELS AUTOMATICALLY SCALED STARTING
0893  C WITH A COMPUTER GENERATED MINIMUM VALUE.
0894  C-----
0895
0896      CALL SCLEAR(TRMNUM)
0897      WRITE(6,*)'You may'
0898      WRITE(6,*)
0899      WRITE(6,*)'  1.  Enter the contour values to be plotted.'
0900      WRITE(6,*)'  2.  Have the contour values automatically'
0901      WRITE(6,*)'      calculated based on the minimum and maximum'
0902      WRITE(6,*)'      values of the function in the plotting domain.'
0903      WRITE(6,*)
0904      READ*, MENU
0905      IF (MENU.EQ.1) THEN
0906
0907          CALL SCLEAR(TRMNUM)
0908          WRITE(6,*)'Input contour values to be plotted (mbar or msec,'
0909          WRITE(6,*)'max of 40 values)'
0910          WRITE(6,*)
0911          WRITE(6,*)'If no more inputs, enter 0. '
0912  4101  FORMAT(' ','Contour ',1X,I2)
0913          ICOUNT=0
0914          DO 4135 I=1,40
0915              WRITE(6,*)
0916              WRITE(6,4101) I
0917              READ *, H(I)
0918              IF (POPT.EQ.1.AND.H(I).GE.2.4) THEN
0919                  KLAP=1
0920              ELSE
0921                  KLAP=0
0922              END IF
0923              H(I) = H(I)/1000.
0924              IF(H(I).EQ.0.0) THEN
0925                  NLEVL=ICOUNT
0926                  GO TO 4136
0927              ELSE
0928                  ICOUNT=ICOUNT+1
0929              END IF
0930  4135  CONTINUE
0931
0932  C-----
0933  C IF THE USER INPUTS THE CONTOUR VALUES HIMSELF, THEY ARE
0934  C SORTED INTO INCREASING ORDER.
0935  C-----
0936

```

```

0937 4136 FINAL=NLEVELS
0938 TEST=NLEVELS-1
0939 DO 4140 J=1,TEST
0940 LIMIT=FINAL-1
0941 DO 4145 I=1,LIMIT
0942 IF (H(I).GT.H(I+1)) THEN
0943 TEMP=H(I)
0944 H(I)=H(I+1)
0945 H(I+1)=TEMP
0946 END IF
0947 4145 CONTINUE
0948 FINAL=FINAL-1
0949 4140 CONTINUE
0950
0951 ELSE
0952
0953 C-----
0954 C IF THE CONTOUR VALUES ARE TO BE COMPUTER CHOSEN, THE MAX-
0955 C IMUM AND MINIMUM VALUES IN THE CONTOUR GRID ARE FOUND AND
0956 C THE CONTOUR LEVELS ARE SCALED ACCORDING TO THE INCREMENT.
0957 C-----
0958
0959 WRITE(6,*)
0960 WRITE(6,*) 'Enter the number of contours you want plotted'
0961 WRITE(6,*) '(maximum of 40).'
0962 READ*,NLEVELS
0963 WRITE(6,*)
0964
0965 4250 IF (POPT.EQ.1) THEN
0966 CALL FNDMAX(PBAR,PMAX,POPT)
0967 CALL FNDMIN(PBAR,PMIN,POPT)
0968 PMIN = TWOSIG(1.1*PMIN)
0969 PMAX = .9*PMAX
0970 CINC=(PMAX-PMIN)/(NLEVELS-1)
0971 CINC=ONESIG(CINC)
0972 DO 4255 I=1,NLEVELS
0973 H(I)=PMIN + (I-1)*CINC
0974 IF (H(I) .GT. 2.4) THEN
0975 KLAP = 1
0976 ELSE
0977 KLAP = 0
0978 END IF
0979 4255 CONTINUE
0980 END IF
0981 IF (POPT.EQ.2) THEN
0982 CALL FNDMAX(PREFL,PRMAX,POPT)
0983 CALL FNDMIN(PREFL,PRMIN,POPT)
0984 PRMIN = TWOSIG(1.1*PRMIN)
0985 PRMAX = 0.9*PRMAX
0986 CINC=(PRMAX-PRMIN)/(NLEVELS-1)
0987 CINC=ONESIG(CINC)
0988 DO 4260 I=1,NLEVELS

```

```

0989             H(I)=PRMIN + ((I-1)*CINC)
0990 4260         CONTINUE
0991             END IF
0992             IF (POPT.EQ.3) THEN
0993                 CALL FNDMAX(TSUBA,TSAMAX,POPT)
0994                 CALL FNDMIN(TSUBA,TSAMIN,POPT)
0995                 TSAMIN = TSAMIN*1.1
0996                 TSAMAX = TWOSIG(TSAMAX*.9)
0997                 CINC=(TSAMAX-TSAMIN)/(NLEVL-1)
0998                 CINC=ONESIG(CINC)
0999                 DO 4265 I=1,NLEVL
1000                     H(I)=TSAMAX-((I-1)*CINC)
1001 4265         CONTINUE
1002             END IF
1003             IF (POPT.EQ.4) THEN
1004                 CALL FNDMAX(TAU,TAUMAX,POPT)
1005                 CALL FNDMIN(TAU,TAUMIN,POPT)
1006                 TAUMIN=TAUMIN*1.1
1007                 TAUMAX=TWOSIG(TAUMAX*.9)
1008                 CINC=(TAUMAX-TAUMIN)/(NLEVL-1)
1009                 CINC=ONESIG(CINC)
1010                 DO 4267 I=1,NLEVL
1011                     H(I)=TAUMAX-((I-1)*CINC)
1012 4267         CONTINUE
1013             END IF
1014
1015         END IF
1016
1017 C-----
1018 C FOUND(I)=0 MEANS THAT NO CONTOURS WERE LOCATED AT THE H(I)
1019 C LEVEL. FOUND(I)=1 MEANS THAT CONTOURS WERE LOCATED.
1020 C-----
1021
1022         DO 4173 I=1,NLEVL
1023             FOUND(I)=0
1024 4173     CONTINUE
1025
1026 C-----
1027 C THE USER'S TERMINAL IS READIED FOR THE PLOTS .THE CONTOURS
1028 C WILL BE DRAWN USING DISSPLA VERSION 9.0 COMMANDS. BECAUSE
1029 C OF THE SYMMETRY OF THE PROBLEM, THETA NEED ONLY RANGE FROM
1030 C 0 TO 180 DEGREES.
1031 C-----
1032
1033         IF (TRMNUM.EQ.0 .OR. TRMNUM .EQ. 4) THEN
1034             CALL RETRO (BAUD)
1035         ELSE IF (TRMNUM.EQ.1) THEN
1036             CALL TK4010 (BAUD)
1037         ELSE IF (TRMNUM.EQ.2) THEN
1038             CALL TK4014 (BAUD,1)
1039         ELSE
1040             CALL HP2623 (BAUD)

```

```

1041         END IF
1042         XSTEP=MAXR/5.
1043
1044 C-----
1045 C THE DISSPLA COMMANDS READY THE TERMINAL FOR PLOTTING
1046 C BY FIRST DEFINING THE SUBPLOT AREA THEN CALIBRATING IT
1047 C FOR THE CONTOUR LINES.
1048 C-----
1049
1050         CALL BGNPL(0)
1051         CALL NOCHEK
1052         CALL NOBRDR
1053         CALL SIMPLX
1054         CALL PHYSOR(.1,1.0)
1055         CALL BLOWUP(XYFAC)
1056         CALL TITLE(' $',-100,' ',0,' ',0,10.0,5.0)
1057         CALL FRAME
1058         CALL GRAF(0.0,XSTEP,2.*MAXR,0.0,XSTEP,MAXR)
1059
1060 C-----
1061 C THE CONTOUR SEARCH SUBROUTINE IS CALLED WITH THE APPRO-
1062 C PRIATE QUANTITY TO BE PLOTTED.
1063 C-----
1064
1065         IF (POPT.EQ.1) THEN
1066             CALL CONTOR(PBAR,FOUND)
1067         END IF
1068         IF (POPT.EQ.2) THEN
1069             CALL CONTOR(PREFL,FOUND)
1070         END IF
1071         IF (POPT.EQ.3) THEN
1072             CALL CONTOR(TSUBA,FOUND)
1073         END IF
1074         IF (POPT.EQ.4) THEN
1075             CALL CONTOR(TAU,FOUND)
1076         END IF
1077
1078 C-----
1079 C THE APPROPRIATE HEADING IS PLACED ON THE PLOT.
1080 C-----
1081
1082         IF (POPT.EQ.1) THEN
1083             NCHAR=44
1084             NAME=NAME1
1085         END IF
1086         IF (POPT.EQ.2) THEN
1087             NCHAR=45
1088             NAME=NAME2
1089         END IF
1090         IF (POPT.EQ.3) THEN
1091             NCHAR=44
1092             NAME=NAME3

```

```

1093      END IF
1094      IF (POPT.EQ.4) THEN
1095          NCHAR=42
1096          NAME=NAME4
1097      END IF
1098
1099      CALL HEIGHT(0.22)
1100      CALL MESSAG(%REF(NAME),NCHAR,.75,7.2)
1101      CALL HEIGHT(0.19)
1102
1103      C-----
1104      C THE REMAINING PLOT SPECIFICATIONS ARE WRITTEN ON THE PLOT.
1105      C-----
1106
1107      CALL MESSAG(%REF(GUN),32,4.5,6.8)
1108      CALL MESSAG(%REF(LABEL2),25,4.5,6.5)
1109      CALL REALNO(%REF(ELEANG),2,8.6,6.5)
1110      CALL MESSAG(%REF(LABEL3),26,4.5,6.2)
1111      CALL REALNO(%REF(ZHEIGHT),2,8.6,6.2)
1112      CALL MESSAG('ASUBM(m/s)=',11,0.0,6.8)
1113      CALL REALNO(%REF(ASUBM),1,2.0,6.8)
1114      CALL MESSAG('PRATIO=',7,0.0,6.5)
1115      CALL REALNO(%REF(PRATIO),1,2.0,6.5)
1116      CALL MESSAG('VSUBP(m/s)=',11,0.0,6.2)
1117      CALL REALNO(%REF(VSUBP),1,2.0,6.2)
1118      CALL MESSAG('GAMMA=',6,0.0,5.9)
1119      CALL REALNO(%REF(GAMMP),2,2.0,5.9)
1120      CALL MESSAG('MU= ',6,0.0,5.6)
1121      CALL REALNO(%REF(MU),2,2.0,5.6)
1122      IF (INTBAL) THEN
1123          CALL MESSAG('PROPELLANT MASS(kg)=',20,4.5,5.9)
1124          CALL REALNO(%REF(PROPM),5,7.7,5.9)
1125          CALL MESSAG('PROJECTILE MASS(kg)=',20,4.5,5.6)
1126          CALL REALNO(%REF(PROJM),4,7.7,5.6)
1127          CALL MESSAG('SPECIFIC FORCE(      )=',24,0.0,5.2)
1128          CALL MIXALF('INSTRUCTION')
1129          CALL MESSAG('m(EH.6)2(EXHX)/s(EH.6)2(EXHX)$',100,
1130      & 2.00,5.2)
1131          CALL RESET('MIXALF')
1132          CALL REALNO(%REF(SPECF),104,3.20,5.2)
1133      END IF
1134      CALL MESSAG(%REF(LABEL1),36,2.25,-.75)
1135      CALL ENDGR(0)
1136      CALL HEIGHT(.25)
1137      IF (NOGRID.EQ.0) THEN
1138          CALL YCONUM
1139          CALL TITLE(' $',-100,' ',1,' ',1,10.0,5.0)
1140          CALL POLAR(DTOR,XSTEP,5.0,0.0)
1141          GO TO 4122
1142      END IF
1143      CALL TITLE(' $',-100,' ',1,' ',0,10.0,5.0)
1144

```

```

1145 C-----
1146 C THE ACTUAL CONTOUR LINES ARE DRAWN IN THE LINEAR MODE.
1147 C NOW, THE POLAR MODE IS CALLED IN ORDER TO SUPERIMPOSE
1148 C THE DISTANCE SCALE AND ADD THE GRID IF ACTIVATED.
1149 C-----
1150
1151 CALL POLAR(DTOR,XSTEP,5.0,0.0)
1152 RATIO(1)=1.
1153 RATIO(2)=1.
1154 CALL MRSCOD(.3,2,RATIO)
1155 CALL GRID(-30,1)
1156 4122 CALL ENDPL(0)
1157
1158 IF (TRMNUM.EQ.0) CALL XRETRO (480)
1159 IF (TRMNUM.EQ.3) PRINT*,ESC//'*dA'
1160 IF (TRMNUM.EQ.4) THEN
1161     CALL XRETRO(480)
1162     PRINT*,ESC//'*2'
1163 END IF
1164 CALL DONEPL
1165
1166 C-----
1167 C TO ERASE THE PLOT AND RETURN TO PROGRAM EXECUTION, THE USER
1168 C MUST PRESS 'RETURN'.
1169 C-----
1170
1171 WRITE(6,*)
1172 CALL SCLEAR(TRMNUM)
1173 IF (POPT.EQ.1.AND.KLAP.EQ.1) THEN
1174     WRITE(6,*)
1175     WRITE(6,*)'The scaling relations used in this program were'
1176     WRITE(6,*)'derived using pressure data of no more than'
1177     WRITE(6,*)'2.4 atm. However, this graph exceeds this pressure'
1178     WRITE(6,*)'and these higher pressure predictions may be'
1179     WRITE(6,*)'considered less accurate.'
1180     WRITE(6,*)
1181     WRITE(6,*)'Press return to continue.'
1182     READ(5,*) DUMMY
1183 END IF
1184 IF (POPT.EQ.3.AND.KLAP.EQ.1) THEN
1185     WRITE(6,*)
1186     WRITE(6,*)'Some of the contours exceed the data range used'
1187     WRITE(6,*)'in deriving the scaling relations. Therefore,'
1188     WRITE(6,*)'The lower time values may be less accurate'
1189     WRITE(6,*)
1190     WRITE(6,*)'Press return to continue.'
1191     READ(5,*(A1)) DUMMY
1192 END IF
1193
1194 GOTO 4000
1195
1196 4230 CALL SCLEAR(TRMNUM)

```

```

1197
1198 C-----
1199 C THE PLOT SIZE CAN BE ALTRED.
1200 C-----
1201
1202     WRITE(6,*)
1203     WRITE(6,*)
1204     WRITE(6,*)'Input factor for changing graph size.'
1205     WRITE(6,*)'Enter 1.0 to obtain the default size.'
1206     WRITE(6,*)
1207     READ *,XYFAC
1208     GOTO 4000
1209
1210 4300  CALL SCLEAR(TRMNUM)
1211
1212 C-----
1213 C THE USER CAN ELIMINATE OR REACTIVATE THE POLAR GRID THAT IS
1214 C SUPERIMPOSED ON THE PLOT.
1215 C-----
1216
1217     WRITE(6,*)
1218     WRITE(6,*)
1219     WRITE(6,*)'A polar grid is by default superimposed on the'
1220     WRITE(6,*)'contour maps. To erase this grid, enter OFF.'
1221     WRITE(6,*)
1222     WRITE(6,*)'If the grid is already deactivated, enter ON.'
1223     WRITE(6,*)'Hit return for no change.'
1224     WRITE(6,*)
1225     READ(5, '(A3)') ERASE
1226     IF (ERASE.EQ.'OFF') NOGRID=0
1227     IF (ERASE.EQ.'ON ') NOGRID=1
1228     GO TO 4000
1229
1230 C-----
1231 C SECTION 5000 WRITES THE INPUT INFORMATION TO A FILE FOR
1232 C FUTURE USE.
1233 C-----
1234
1235 5000  CALL SCLEAR(TRMNUM)
1236     WRITE(6,*) 'Enter the name you wish to give the file.'
1237     READ(*, '(A15)') WFILE
1238
1239     OPEN (UNIT=1, FILE=WFILE, STATUS='NEW')
1240     WRITE(1, '(A32)') GUN
1241     WRITE(1, *) D
1242     WRITE(1, '(A1)') ANS1
1243     IF (ANS1 .EQ. 'Y') THEN
1244         WRITE(1, *) PROPM
1245         WRITE(1, *) TRAVEL
1246         WRITE(1, *) CHAMV
1247         WRITE(1, *) PROJ
1248         WRITE(1, *) PROPB

```

```

1249      WRITE(1, '(A1)') WUNITS
1250      WRITE(1, *) SPECIF
1251      WRITE(1, *) TEMPK
1252      ELSE
1253          WRITE(1, *) ASUBM
1254          WRITE(1, *) PRATIO
1255      END IF
1256      WRITE(1, *) AMBSS
1257      WRITE(1, *) VSUBP
1258      WRITE(1, *) GAMMP
1259      WRITE(1, *) MU
1260      WRITE(1, *) ELEANG
1261      WRITE(1, *) ZHEIGH
1262      CLOSE(UNIT=1)
1263
1264      GOTO 105
1265
1266      6000 CONTINUE
1267
1268      STOP
1269      END

```

```

0001
0002      C-----
0003      C SUBROUTINE CONTOR SEARCHES FOR THE BEGINNING OF CONTOURS BY COM-
0004      C PARING THE VALUE OF THE FUNCTION AT ADJACENT GRID SQUARES. IT IS
0005      C CALLED BY THE MAIN PROGRAM ONCE THE FUNCTIONAL VALUES AT ALL THE
0006      C GRIDPOINTS HAVE BEEN DETERMINED.
0007      C-----
0008
0009      SUBROUTINE CONTOR(GRIDPT, FOUND)
0010      PARAMETER(NL=40, Q=50, P=100)
0011      INTEGER XM(P), YM(Q), UNUSED(P, Q), F(WND(NL), OPEN
0012      INTEGER POPT, PP, QQ
0013      REAL H(NL), GRIDPT(P, Q), PBAR(P, Q), MAXR
0014      COMMON/GRID/NLEVL, H, K, OPEN, XM, YM, KNIGN
0015      COMMON/INC/RINC, MAXR
0016      COMMON/PRESS/PBAR, POPT, KLAP
0017      COMMON WORK(12000), XPLT(250), YPLT(250),
0018      $ LSAV, KSAV, NOSTOR(NL), MSAV
0019
0020      HFACT = 1000.0
0021
0022      PP = P
0023      QQ = Q
0024
0025      DO 10 I=1, P
0026      490  XM(I)=1
0027      DO 20 I=1, Q

```

```

0028      420      YM(I)=I
0029              JM=Q-1
0030              IM=P-1
0031
0032      C-----
0033      C ALL CONTOURS AT EACH LEVEL ARE DRAWN BEFORE MOVING ON TO THE NEXT
0034      C LEVEL.
0035      C-----
0036      C-----
0037      C THE 'XPLOT' AND 'YPLOT' VALUES WHICH HAVE BEEN STORED IN
0038      C THEIR RESPECTIVE ARRAYS DURING SUBROUTINE PLOT ARE FED
0039      C INTO DISSPLA'S CONTOUR SETUP OPTION 'CONCRV', ALONG WITH
0040      C THE APPROPRIATE PRESSURE LEVEL.
0041      C-----
0042              CALL BCOMON(12000)
0043              CALL CONBGN
0044              MSAV = 1
0045              DO 430 K=1,NLEVL
0046              KSAV=K
0047              LSAV=0
0048
0049      C-----
0050      C THE ARRAY UNUSED IS INITIALIZED FOR THE CONTOUR LEVEL.  UNUSED(I,J)=
0051      C 1 MEANS THAT THE I,J GRIDPOINT WILL BE USED IN DRAWING THE CONTOURS
0052      C AT THIS LEVEL.  UNUSED(I,J)=0 MEANS THAT THE I,J GRIDPOINT IS NOT
0053      C SIGNIFICANT.  AT EACH CONTOUR LEVEL, THE BOUNDARY OF THE GRID IS
0054      C SCANNED FOR A POINT WHERE A CONTOUR CROSSES INTO THE GRID WITH THE
0055      C HIGHER FUNCTIONAL VALUES ON THE RIGHT.  THIS CONDITION PREVENTS THE
0056      C PROGRAM FROM RELOCATING CONTOURS IT HAS ALREADY DRAWN.  THE SCAN OF
0057      C THE GRID BOUNDARY BEGINS IN THE LOWER LEFT CORNER AND PROCEEDS COUN-
0058      C TERCLOCKWISE.
0059      C
0060      C IF AN INTERSECTION WITH THE GRID BOUNDARY IS FOUND, SUBROUTINE FOL-
0061      C LOW IS CALLED TO FOLLOW THIS CONTOUR THROUGH THE GRID UNTIL IT
0062      C EXITS FROM THE GRID.
0063      C-----
0064
0065              DO 440 J=2,JM
0066                  DO 445 I=2,IM
0067                      UNUSED(I,J)=0
0068                      IF (GRIDPT(I-1,J).LT.H(K).AND.GRIDPT(I,J).GE.H(K))
0069      &                      UNUSED(I,J)=1
0070
0071      445          CONTINUE
0072      440          CONTINUE
0073      OPEN=1
0074
0075      C-----
0076      C FIRST, THE BOTTOM EDGE OF THE GRID IS SCANNED.
0077      C-----
0078
0079              DO 450 I=2,P

```

```

0080         IF (GRIDPT(I-1,1).LT.H(K).AND.GRIDPT(I,1).GE.H(K)) THEN
0081             FOUND(K)=1
0082             CALL FOLLOW(GRIDPT,I,1,-1,0,UNUSED)
0083             CALL CONCRV(XPLOT(1),YPLOT(1),LSAV,HFACT*H(K))
0084             LSAV = 0
0085         END IF
0086     450     CONTINUE
0087
0088     C-----
0089     C THE RIGHT EDGE IS SCANNED.
0090     C-----
0091
0092         DO 460 J=2,Q
0093             IF (GRIDPT(P,J-1).LT.H(K).AND.GRIDPT(P,J).GE.H(K)) THEN
0094                 FOUND(K)=1
0095                 CALL FOLLOW(GRIDPT,PP,J,0,-1,UNUSED)
0096                 CALL CONCRV(XPLOT(1),YPLOT(1),LSAV,HFACT*H(K))
0097                 LSAV = 0
0098             END IF
0099     460     CONTINUE
0100
0101     C-----
0102     C THE TOP EDGE IS SCANNED.
0103     C-----
0104
0105         DO 470 L=1,IM
0106             I=P-L
0107             IF (GRIDPT(I+1,Q).LT.H(K).AND.GRIDPT(I,Q).GE.H(K)) THEN
0108                 FOUND(K)=1
0109                 CALL FOLLOW(GRIDPT,I,QQ,1,0,UNUSED)
0110                 CALL CONCRV(XPLOT(1),YPLOT(1),LSAV,HFACT*H(K))
0111                 LSAV = 0
0112             END IF
0113     470     CONTINUE
0114
0115     C-----
0116     C THE LEFT EDGE IS SCANNED.
0117     C-----
0118
0119         DO 480 L=1,JM
0120             J=Q-L
0121             IF (GRIDPT(1,J+1).LT.H(K).AND.GRIDPT(1,J).GE.H(K)) THEN
0122                 FOUND(K)=1
0123                 CALL FOLLOW(GRIDPT,1,J,0,1,UNUSED)
0124                 CALL CONCRV(XPLOT(1),YPLOT(1),LSAV,HFACT*H(K))
0125                 LSAV = 0
0126             END IF
0127     480     CONTINUE
0128
0129     C-----
0130     C ONCE ALL THE OPEN CONTOURS AT LEVEL H ARE FOUND AND FOLLOWED TO
0131     C COMPLETION, THE ARRAY UNUSED IS SEARCHED FOR ANY CLOSED CONTOURS

```

```

0132 C OF HEIGHT H. IF A CLOSED CONTOUR IS FOUND, SUBROUTINE FOLLOW IS
0133 C CALLED TO FOLLOW IT UNTIL IT RETURNS TO THE POINT WHERE IT WAS
0134 C FOUND.
0135 C-----
0136         MSAV = 2
0137         OPEN=0
0138         DO 490 L=2,JM
0139             J=Q-L+1
0140             DO 500 M=2,IM
0141                 I=P-M+1
0142                 IF (UNUSED(I,J).EQ.1) THEN
0143                     FOUND(K)=1
0144                     CALL FOLLOW(GRIDPT,I,J,-1,0,UNUSED)
0145                     CALL CONCRV(XPLOT(1),YPLOT(1),LSAV,HFACT*H(K))
0146                     LSAV = 0
0147                 END IF
0148             500      CONTINUE
0149         490      CONTINUE
0150     430      CONTINUE
0151     CALL CONEND
0152
0153 C-----
0154 C NEXT, THE DISSPLA PARAMETERS ARE SET TO DRAW SOLID CONTOUR
0155 C LINES AND LABEL THEM WHERE POSSIBLE. THE 'CONTUR' COMMAND
0156 C ACTUALLY DRAWS THE LINES USING THE DATA STORED IN 'CONCRV'.
0157 C-----
0158
0159         CALL HEIGHT(.16)
0160         CALL CONLIN(0,'SOLID','LABELS',1,4)
0161         CALL CONANG(90.)
0162         CALL CONMIN(4.5)
0163         CALL CONTUR(1,'LABELS','DRAW')
0164         RETURN
0165         END

```

```

0001
0002 C-----
0003 C SUBROUTINE FOLLOW FOLLOWS A CONTOUR THROUGH THE GRID ONCE IT HAS
0004 C BEEN FOUND BY CHECKING THE SIDES OF THE GRID SQUARES TO DETERMINE
0005 C WHICH SIDE THE CONTOUR PASSES THROUGH. IT FINDS THE POINT OF
0006 C INTERSECTION USING LINEAR INTERPOLATION BETWEEN THE ADJACENT GRID-
0007 C POINTS. CONTROL DOES NOT RETURN TO SUBROUTINE CONTOR UNTIL
0008 C THE CONTOUR EITHER EXITS FROM THE GRID OR RETURNS TO THE POINT
0009 C IN THE GRID WHERE IT WAS FIRST FOUND. WHEN SUBROUTINE FOLLOW
0010 C DETERMINES HOW THE CONTOUR PASSES THROUGH A GRID SQUARE, SUBROU-
0011 C TINE PLOT IS CALLED TO STORE THE X AND Y VALUES LATER USED FOR
0012 C THE ACTUAL PLOTTING.
0013 C-----
0014

```

```

0015      SUBROUTINE FOLLOW(GRIDPT,IIG,JJG,IIA,JJA,UNUSED)
0016      PARAMETER(NL=40,Q=50,P=100)
0017      INTEGER IG,JG,IA,JA,OPEN,K,LAST,FIRST,TE,XM(P),YM(Q),
0018      & NLEVL,UNUSED(P,Q)
0019      REAL GRIDPT(P,Q),H(NL),Z,ZA,ZB,ZC,X,Y,
0020      & RINC,T,MAXR
0021      COMMON/GRID/NLEVL,H,K,OPEN,XM,YM,ISIGN
0022      COMMON/INC/RINC,MAXR
0023      COMMON WORK(12000),XPLOT(250),YPLOT(250),
0024      & LSAV,KSAV,NOSTOR(NL),MSAV
0025
0026      C-----
0027      C THE PARAMETERS IG,JG,IA, AND JA ARE USED IN VARIOUS COMBINATIONS
0028      C AS THE SUBSCRIPTS FOR THE ARRAYS XM AND YM. THE VALUES OF THESE
0029      C SUBSCRIPTS DETERMINE WHICH GRID POINTS ARE CONSIDERED IN ANY PARTI-
0030      C CULAR LINEAR INTERPOLATION.
0031      C-----
0032
0033      IG=IIG
0034      JG=JJG
0035      IA=IIA
0036      JA=JJA
0037
0038      C-----
0039      C FIRST=1 INDICATES THAT A NEW CONTOUR HAS JUST BEEN FOUND; FIRST=0
0040      C MEANS THAT THE PLOTTING OF THE CONTOUR IS ALREADY IN PROGRESS.
0041      C LAST=1 INDICATES THAT THE END OF A CONTOUR HAS BEEN REACHED; LAST=0
0042      C MEANS THAT THE CONTOUR IS NOT YET FINISHED.
0043      C-----
0044
0045      FIRST=1
0046      LAST=0
0047
0048      C-----
0049      C THE LOCATION OF THE POINT T WHERE THE CONTOUR PASSES BETWEEN THE
0050      C POINTS (I,J) AND (I+IA,J+JA) IS CALCULATED USING LINEAR INTERPOLATION.
0051      C-----
0052
0053      Z=GRIDPT(IG,JG)
0054      ZA=GRIDPT(IG+IA,JG+JA)
0055      605 T=0.
0056      IF(Z.NE.ZA) T=(Z-H(K))/(Z-ZA)
0057      X=XM(IG)-T*(XM(IG)-XM(IG+IA))
0058      Y=YM(JG)-T*(YM(JG)-YM(JG+JA))
0059
0060      C-----
0061      C TESTS ARE NOW PERFORMED TO DETERMINE IF T IS THE LAST POINT ON THE
0062      C CONTOUR.
0063      C-----
0064
0065      IF (OPEN.EQ.1) GOTO 610
0066      IF (IA.EQ.-1.AND.UNUSED(IG,JG).EQ.0) LAST=1

```

```

0067      GOTO 650
0068      610  IF (FIRST.EQ.1) GOTO 660
0069          IF (JA.EQ.0) GOTO 620
0070          GOTO 630
0071      620  IF (JG.EQ.1.OR.JG.EQ.Q) LAST=1
0072      630  IF (JA.NE.0) GOTO 640
0073          GOTO 650
0074      640  IF (IG.EQ.1.OR.IG.EQ.P) LAST=1
0075      650  IF (LAST.EQ.1) GOTO 660
0076          IF (IA.EQ.-1) UNUSED(IG,JG)=0
0077
0078      C-----
0079      C THE COORDINATES OF T ARE OUTPUT TO SUBROUTINE PLOT.
0080      C-----
0081
0082      660  LSAV=LSAV+1
0083          CALL PLOT(X,Y,FIRST)
0084
0085      C-----
0086      C COMPARISONS ARE NOW MADE TO DETERMINE WHICH OF THE CELL SIDES
0087      C THE CONTOUR CROSSES NEXT. THE VALUES OF Z, ZA, IG, JG, IA,
0088      C AND JA ARE ADJUSTED BEFORE CONTINUING TO FIND A NEW POINT, T.
0089      C-----
0090
0091          IF (LAST.EQ.1) THEN
0092              NOSTOR(KSAV)=LSAV
0093              RETURN
0094          END IF
0095          ZB=GRIDPT(IG+JA,JG-IA)
0096          IF (ZB.GE.H(K)) GOTO 670
0097          ZA=ZB
0098          TE=IA
0099          IA=JA
0100          JA=-TE
0101          GOTO 690
0102      670  ZC=GRIDPT(IG+IA+JA,JG-IA+JA)
0103          IF (ZC.GE.H(K)) GOTO 680
0104          Z=ZB
0105          ZA=ZC
0106          IG=IG+JA
0107          JG=JG-IA
0108          GOTO 690
0109      680  Z=ZC
0110          IG=IG+IA+JA
0111          JG=JG-IA+JA
0112          TE=JA
0113          JA=IA
0114          IA=-TE
0115      690  FIRST=0
0116          GOTO 605
0117          END

```

```

0001
0002 C-----
0003 C SUBROUTINE PLOT STORES THE X AND Y VALUES IN TWO 2 DIMENSIONAL
0004 C ARRAYS CALLED XPLOT AND YPLOT. THESE VALUES WILL BE USED IN THE
0005 C CALL TO CONTUR FOR THE ACTUAL PLOTTING.
0006 C-----
0007
0008     SUBROUTINE PLOT(X,Y,FIRST)
0009     PARAMETER(NL=40,Q=50,P=100)
0010     INTEGER FIRST
0011     REAL MAXR
0012     COMMON/INC/RINC,MAXR
0013     COMMON WORK(12000),XPLOT(250),YPLOT(250),
0014     & LSAV,KSAV,NOSTOR(NL),MSAV
0015     XPLOT(LSAV)=(RINC*X)
0016     YPLOT(LSAV)=(RINC*Y)
0017     RETURN
0018     END

```

```

0001
0002 C-----
0003 C SUBROUTINE FNDMAX FINDS THE MAXIMUM VALUE OF ANY OF THE
0004 C FUNCTIONS FOR WHICH CONTOURS ARE PLOTTED.
0005 C-----
0006
0007     SUBROUTINE FNDMAX(VALS1,MAXVAL,POPT)
0008     PARAMETER(NL=40,Q=50,P=100)
0009     INTEGER POPT
0010     REAL VALS1(P,Q),MAXVAL
0011     MAXVAL=0.
0012     J=1
0013     DO 710 I=1,P
0014         DO 720 J=1,Q
0015             IF (POPT.EQ.1.AND.I.GE.45.AND.I.LE.55
0016             &     .AND.J.LE.5) GOTO 720
0017             IF (VALS1(I,J).GT.MAXVAL) MAXVAL=VALS1(I,J)
0018         720     CONTINUE
0019     710     CONTINUE
0020     RETURN
0021     END

```

```

0001
0002 C-----
0003 C SUBROUTINE FNDMIN FINDS THE MINIMUM VALUE OF ANY OF THE

```

```

0004 C FUNCTIONS FOR WHICH CONTOURS ARE PLOTTED.
0005 C-----
0006
0007 SUBROUTINE FNDMIN(VALS2,MINVAL,POPT)
0008 PARAMETER(NL=40,Q=50,P=100)
0009 INTEGER POPT
0010 REAL VALS2(P,Q),MINVAL
0011 MINVAL=100000.
0012 DO 810 I=1,P
0013     DO 820 J=1,Q
0014         IF(POPT.EQ.3.AND.I.GE.45.AND.I.LE.55.AND.J.LE.5)
0015             & GO TO 820
0016         IF(POPT.EQ.4.AND.I.GE.45.AND.I.LE.55.AND.J.LE.5)
0017             & GO TO 820
0018         IF (VALS2(I,J).LT.MINVAL) MINVAL=VALS2(I,J)
0019     820 CONTINUE
0020 810 CONTINUE
0021 RETURN
0022 END

```

```

0001
0002 C-----
0003 C SUBROUTINE REFCAL IS CALLED BY THE MAIN PROGRAM TO DETERMINE
0004 C THE REFLECTED OVERPRESSURE, PREREF AT EACH GRIDPOINT IN THE CONTOUR
0005 C GRID. FIRST A CHECK IS MADE TO SEE IF REGULAR REFLECTION IS
0006 C POSSIBLE. IF IT IS POSSIBLE, THE REGULAR REFLECTION CALCULATION
0007 C PROCEEDS. IF REGULAR REFLECTION DOES NOT OCCUR SUBROUTINE
0008 C NONREG IS CALLED TO DETERMINE THE REFLECTED OVERPRESSURE.
0009 C-----
0010
0011 SUBROUTINE REFCAL(PRESIN,PREREF,ALPHA1)
0012 REAL MACHN1,MACHN2,LOWBND,PSIANG(11),ANGLIN(11),SLOPES(11)
0013 REAL PSISLP(11)
0014 COMMON/REFL/GAMMA,TOL,UPBND,LOWBND,XI
0015 COMMON/TRIG/RTOD,DTOR,PI
0016 COMMON/LAGRAN/PSIANG,PSISLP,ANGLIN,SLOPES
0017 CALL PRELIM(ALPHA1,PRESIN,DELTA,MACHN1,MACHN2,DELMAX)
0018 IF (DELTA.GE.0.90*DELMAX) THEN
0019     CALL NONREG(DELMAX,PRESIN,ALPHA1,MACHN1,MACHN2,PREREF)
0020     RETURN
0021 END IF
0022 ALPMAX=FALMAX(MACHN2,GAMMA)
0023 CALL ITRATE(0,ALPHA2,DELTA,LOWBND,ALPMAX,MACHN2,PRESIN)
0024 QUOTNT=(2.*GAMMA*(MACHN2**2*(SIN(ALPHA2))**2-1.))/
0025 & (GAMMA+1.)+1.
0026 PREREF=QUOTNT*XI-1.
0027 RETURN
0028 END

```

```

0001
0002 C-----
0003 C SUBROUTINE PRELIM PERFORMS THE INITIAL OBLIQUE SHOCK CALCULATIONS FOR
0004 C THE REGULAR REFLECTION SOLUTION. MN1 IS THE STREAMLINE VELOCITY IN
0005 C FRONT OF THE INCIDENT SHOCK. DELANG IS THE FLOWSTREAM DEFLECTION
0006 C ANGLE. MN2 IS THE STREAMLINE VELOCITY BEHIND THE INCIDENT SHOCK.
0007 C DELMA IS THE MAXIMUM FLOWSTREAM DEFLECTION ANGLE FOR REGULAR REFLECTION.
0008 C-----
0009
0010 SUBROUTINE PRELIM(ANGINC,PRESIN,DELANG,MN1,MN2,DELMA)
0011 REAL MN1,MN2,MN,LOWBND
0012 COMMON/REFL/GAMMA,TOL,UPBND,LOWBND,XI
0013 SINANG=SIN(ANGINC)
0014 MN1=(SQRT(((GAMMA+1.)/(2.*GAMMA))*PRESIN+1.))/
0015 & SINANG
0016 MN=MN1*SINANG
0017 DELANG=ATAN(1./(TAN(ANGINC)*(((GAMMA+1.)*
0018 & MN1**2*.5/(MN**2-1.))-1.)))
0019 MN2=(SQRT(((GAMMA-1.)*XI+(GAMMA+1.))/(2*GAMMA*XI)))
0020 & /SIN(ANGINC-DELANG)
0021 IF (MN2.LT.1.) MN2=1.
0022 DELMA=(0.7698*(SQRT(MN2**2-1.))**3)/((GAMMA+1.)*MN2**2)
0023 RETURN
0024 END

```

```

0001
0002 C-----
0003 C SUBROUTINE NONREG DETERMINES THE REFLECTED OVERPRESSURE WHEN
0004 C REGULAR REFLECTION DOES NOT OCCUR.
0005 C-----
0006
0007 SUBROUTINE NONREG(DELMAX,PRESIN,ALPHA1,MACHN1,MACHN2,
0008 & PREREF)
0009 REAL LOWBND,MACHN1,MACHN2,PSIANG(11),ANGLIN(11),SLOPES(11)
0010 REAL PSISLP(11)
0011 COMMON/TRIG/RTOD,DTOR,PI
0012 COMMON/REFL/GAMMA,TOL,UPBND,LOWBND,XI
0013 COMMON/LAGRAN/PSIANG,PSISLP,ANGLIN,SLOPES
0014 COMMON/ATMOS/ATM
0015
0016 C-----
0017 C FIRST, THE ANGLE OF INCIDENCE, ALPHD1, WHERE REGULAR REFLECTION
0018 C STOPS IS DETERMINED BY CALLING SUBROUTINE ALMAX. NEXT, THE
0019 C ANGLE OF INCIDENCE, STTANG, WHERE THE LINEAR APPROXIMATION BEGINS
0020 C IS DETERMINED BY SUBROUTINE LAGRNG.
0021 C-----
0022

```

```

0023      CALL ALMAX(ALPHD1,PRESIN)
0024      CALL LAGRNG(ATM*PRESIN,STTANG,PSIANG,ANGLIN)
0025      ALPHD2=ALPHD1-.001
0026
0027      C-----
0028      C THE FOLLOWING SECTION OF CODE PERTAINS TO THE CASE WHEN ALPHA1
0029      C IS IN THE REGION WHERE THE CUBIC POLYNOMIAL IS USED TO APPROXI-
0030      C MATE THE REFLECTED OVERPRESSURE. THE SLOPE, SLOPE1, AT ALPHD1
0031      C IS DETERMINED BY FINITE DIFFERENCE. THE SLOPE, SLOPE2, AT STTANG
0032      C IS DETERMINED BY SUBROUTINE LAGRNG. SUBROUTINE CUBIC IS CALLED
0033      C TO DETERMINE THE CUBIC EQUATION AND EVALUATE IT AT ALPHA1 TO OBTAIN
0034      C THE REFLECTED OVERPRESSURE.
0035      C-----
0036
0037      IF (ALPHA1.GT.ALPHD2.AND.ALPHA1.LT.STTANG) THEN
0038      CALL PRELIM(ALPHD1,PRESIN,DELTA,MACHN1,MACHN2,DELMAX)
0039      ALPHM1=FALMAX(MACHN2,GAMMA)
0040      CALL ITRATE(0,ALPHP1,DELTA,LOWBND,ALPHM1,MACHN2,PRESIN)
0041      QUOTNT=(2.*GAMMA*(MACHN2**2*(SIN(ALPHP1))**2-1.))/
0042      & (GAMMA+1.)+1.
0043      PREFD1=QUOTNT*XI-1.
0044      CALL PRELIM(ALPHD2,PRESIN,DELTA,MACHN1,MACHN2,DELMAX)
0045      ALPHM2=FALMAX(MACHN2,GAMMA)
0046      CALL ITRATE(0,ALPHP2,DELTA,LOWBND,ALPHM2,MACHN2,PRESIN)
0047      QUOTNT=(2.*GAMMA*(MACHN2**2*(SIN(ALPHP2))**2-1.))/
0048      & (GAMMA+1.)+1.
0049      PREFD2=QUOTNT*XI-1.
0050      SLOPE1=(PREFD1-PREFD2)/(.001*PRESIN)
0051      CALL LAGRNG(ATM*PRESIN,SLOPE2,PSISLP,SLOPES)
0052      VALSTT=FLINE(PRESIN,STTANG)
0053      CALL CUBIC(ALPHD2,PREFD2/PRESIN,SLOPE1,STTANG,VALSTT,SLOPE2,
0054      & ALPHA1,PREREF)
0055      PREREF=PREREF*PRESIN
0056      END IF
0057
0058      C-----
0059      C IF ALPHA1>STTANG, THEN THE LINEAR APPROXIMATION IS USED TO DETERMINE
0060      C THE REFLECTED OVERPRESSURE.
0061      C-----
0062
0063      IF (ALPHA1.GT.ALPHD1.AND.ALPHA1.GE.STTANG) PREREF=
0064      & FLINE(PRESIN,ALPHA1)*PRESIN
0065      RETURN
0066      END

0001
0002      C-----
0003      C SUBROUTINE ITRATE PERFORMS AN ITERATIVE PROCEDURE TO DETER-
0004      C MINE THE SHOCK WAVE ANGLE OF INCIDENCE, ANGLE, FOR A GIVEN

```

```

0005 C FLOW DEFLECTION ANGLE, ANGLE2. THE FUNCTION WHICH IS ITER-
0006 C ATED IS F. A SOLUTION HAS BEEN FOUND WHEN F=0.
0007 C-----
0008
0009 SUBROUTINE ITRATE(L,ANGLE,ANGLE2,ANGLOW,ANGLHI,
0010 & MN2,PRESIN)
0011 INTEGER SIGN,SIGNH,SIGNL
0012 REAL MN2,ANG(20),VAL(20),LOWBND
0013 COMMON/TRIG/RTOD,DTOR,PI
0014 COMMON/REFL/GAMMA,TOL,UPBND,LOWBND,XI
0015 ANGLEL=ANGLOW
0016 ANGLEH=ANGLHI
0017
0018 C-----
0019 C THE RANGE OF VALUES FOR ANGLE1 IS DIVIDED INTO 20 EQUAL INTER-
0020 C VALS AND F IS EVALUATED AT EACH INTERVAL. THE SMALLEST VALUE OF
0021 C F IS FOUND. THE ARGUMENT ANGLE FOR THIS VALUE OF F BECOMES ANGLE
0022 C AND THE ANGLES TO THE LEFT AND RIGHT OF THIS POINT BECOME ANGLEL
0023 C AND ANGLEH RESPECTIVELY.
0024 C-----
0025
0026 ANGINC=(ANGLEH-ANGLEL)/19.
0027 DO 910 I=1,20
0028 ANG(I)=ANGLEL+(I-1)*ANGINC
0029 VAL(I)=F(L,ANG(I),ANGLE2,MN2,GAMMA,PRESIN)
0030 910 CONTINUE
0031 VALMIN=1000000.
0032 DO 920 I=1,20
0033 IF (ABS(VAL(I)).LT.VALMIN) THEN
0034 VALMIN=ABS(VAL(I))
0035 IMIN=I
0036 END IF
0037 920 CONTINUE
0038 ILEFT=IMIN-1
0039 IRIGHT=IMIN+1
0040 IF (IMIN.EQ.20) IRIGHT=IMIN
0041 IF (IMIN.EQ.1) ILEFT=IMIN
0042 ANGLEL=ANG(ILEFT)
0043 ANGLEH=ANG(IRIGHT)
0044 ANGLE=(ANGLEH-ANGLEL)/2.+ANGLEL
0045
0046 C-----
0047 C THE SIGNS OF ANGLEL, ANGLE, AND ANGLEH ARE COMPARED TO
0048 C DETERMINE WHETHER THE ZERO OF F IS GREATER OR LESS THAN
0049 C ANGLE. SUPPOSE IT IS DETERMINED THAT THE ROOT IS LESS THAN
0050 C ANGLE. THE INTERVAL FROM ANGLEL TO ANGLE IS DIVIDED
0051 C IN HALF AND ANGLE BECOMES ANGLEH AND THE MIDDLE POINT
0052 C BECOMES ANGLE. F IS EVALUATED AND THE SIGNS ARE AGAIN
0053 C COMPARED. THE PROCESS REPEATS UNTIL ABS[F(ANGLEL)-
0054 C F(ANGLEH)]<TOL.
0055 C-----
0056

```

```

0057      900  VALUEL=F(L,ANGLEL,ANGLE2,MN2,GAMMA,PRESIN)
0058          VALUEH=F(L,ANGLEH,ANGLE2,MN2,GAMMA,PRESIN)
0059          VALUE=F(L,ANGLE,ANGLE2,MN2,GAMMA,PRESIN)
0060          IF (VALUEH.LT.0.) SIGNH=-1
0061          IF (VALUEH.GE.0.) SIGNH=1
0062          IF (VALUEL.LT.0.) SIGNL=-1
0063          IF (VALUEL.GE.0.) SIGNL=1
0064          IF (VALUE.LT.0.) SIGN=-1
0065          IF (VALUE.GE.0.) SIGN=1
0066          IF (SIGN.EQ.SIGNL) THEN
0067              TEMP=ANGLE
0068              ANGLE=ANGLE+(ANGLEH-ANGLE)/2.
0069              ANGLEL=TEMP
0070          END IF
0071          IF (SIGN.EQ.SIGNH) THEN
0072              TEMP=ANGLE
0073              ANGLE=ANGLE-(ANGLE-ANGLEL)/2.
0074              ANGLEH=TEMP
0075          END IF
0076          DIF=ABS(VALUEH-VALUEL)
0077          IF (DIF.GT.TOL) GOTO 900
0078          RETURN
0079          END

```

```

0001
0002      C-----
0003      C SUBROUTINE ALMAX DETERMINES THE MAXIMUM ANGLE OF INCIDENCE, ALPHD1,
0004      C FOR ANY INCIDENT OVERPRESSURE, PRESIN.
0005      C-----
0006
0007          SUBROUTINE ALMAX(ALPHD1,PRESIN)
0008              REAL MACHN1,MACHN2
0009              COMMON/TRIG/RTOD,DTOR,PI
0010              DO 1010 I=30,90,5
0011                  ALPHCH=DTOR*I
0012                  CALL PRELIM(ALPHCH,PRESIN,DELTA,MACHN1,MACHN2,DELMAX)
0013                  DELMAX=0.90*DELMAX
0014                  IF (DELTA.GT.DELMAX) THEN
0015                      DO 1020 J=I-5,I
0016                          ALPHCH=DTOR*J
0017                          CALL PRELIM(ALPHCH,PRESIN,DELTA,MACHN1,MACHN2,
0018                              & DELMAX)
0019                          DELMAX=0.90*DELMAX
0020                          IF (DELTA.GT.DELMAX) THEN
0021                              DO 1030 K=1,10
0022                                  ALPHCH=DTOR*((J-1)+.1*K)
0023                                  CALL PRELIM (ALPHCH,PRESIN,DELTA,MACHN1,
0024                                      & MACHN2,DELMAX)
0025                                  DELMAX=0.90*DELMAX

```

```

0026         IF (DELTA.GT.DELMAX) THEN
0027             ALPHD1=DTOR*((J-1)+.1*(K-1))
0028             RETURN
0029         END IF
0030     1030     CONTINUE
0031     END IF
0032     1020     CONTINUE
0033     END IF
0034     1010     CONTINUE
0035     END

```

```

0001
0002 C-----
0003 C SUBROUTINE CUBIC FORMS AND EVALUATES THE THIRD DEGREE POLYNOMIAL
0004 C WHICH FITS THE MIDDLE SECTION OF THE REFLECTED OVERPRESSURE VS.
0005 C ANGLE OF INCIDENCE CURVES.
0006 C-----
0007
0008     SUBROUTINE CUBIC(A,D,F,F,I,J,X,Y)
0009     REAL I,J,K,L
0010     COMMON/REFL/GAMMA,TOL,UPBND,LOWBND,XI
0011     B=A**2/2.
0012     C=A**3/6.
0013     G=F**2/2.
0014     H=F**3/6.
0015     K=G-B
0016     L=A-F
0017     COEFF4=(L*(I-D+E*L)+(J-E)*(K+A*L))/(L*(H-C+B*L)+K*(K+A*L))
0018     COEFF3=((I-D+E*L)-(H-C+B*L)*COEFF4)/(K+A*L)
0019     COEFF2=E-A*COEFF3-B*COEFF4
0020     COEFF1=D-A*COEFF2-B*COEFF3-C*COEFF4
0021     Y=(X**3)*COEFF4/6.+(X**2)*COEFF3/2.+X*COEFF2+COEFF1
0022     RETURN
0023     END

```

```

0001
0002 C-----
0003 C SUBROUTINE LAGRNG PERFORMS LAGRANGIAN INTERPOLATION TO DETER-
0004 C MINE THE VALUE, Y, OF A FUNCTION AT ARGUMENT, X. THE ELEMENTS
0005 C OF ARRAY FUNCT ARE THE TABULATED FUNCTIONAL VALUES FOR THE COR-
0006 C RESPONDING ARGUMENTS IN ARGUM.
0007 C-----
0008
0009     SUBROUTINE LAGRNG(X,Y,ARGUM,FUNCT)
0010     REAL ARGUM(11),FUNCT(11),DIFF(11),A(11)
0011

```

```

0012 C-----
0013 C FIRST, THE FOUR VALUES IN ARRAY ARGUM NEAREST IN ABSOLUTE VALUE
0014 C TO X ARE SELECTED ALONG WITH THE CORRESPONDING ELEMENTS OF FUNCT.
0015 C THESE ARE THE OPTIMUM POINTS TO USE TO FORM A THIRD DEGREEE
0016 C LAGRANGIAN POLYNOMIAL TO THE FUNCTION AT X.
0017 C-----
0018
0019 DO 1110 I=1,11
0020     DIFF(I)=ABS(X-ARGUM(I))
0021 1110 CONTINUE
0022     SORTED=0
0023     LAST=11
0024     DO WHILE (SORTED.NE.1.AND.LAST.GE.2)
0025         SORTED=1
0026         LIMIT=LAST-1
0027         DO 1120 I=1,LIMIT
0028             IF (DIFF(I).GT.DIFF(I+1)) THEN
0029                 SORTED=0
0030                 TEMP1=DIFF(I)
0031                 TEMP2=ARGUM(I)
0032                 TEMP3=FUNCT(I)
0033                 DIFF(I)=DIFF(I+1)
0034                 ARGUM(I)=ARGUM(I+1)
0035                 FUNCT(I)=FUNCT(I+1)
0036                 DIFF(I+1)=TEMP1
0037                 ARGUM(I+1)=TEMP2
0038                 FUNCT(I+1)=TEMP3
0039             END IF
0040 1120     CONTINUE
0041         LAST=LAST-1
0042     END DO
0043     Y=0.
0044 1125 CONTINUE
0045
0046 C-----
0047 C THE THIRD DEGREE POLYNOMIAL IS FORMED AND EVALUATED AT X TO
0048 C DETERMINE Y.
0049 C-----
0050
0051 DO 1130 K=1,4
0052     A(K)=1.
0053     DO 1140 J=1,4
0054         IF (J.NE.K) THEN
0055             A(K)=A(K)*(X-ARGUM(J))/(ARGUM(K)-ARGUM(J))
0056         END IF
0057 1140     CONTINUE
0058     Y=Y+A(K)*FUNCT(K)
0059 1130 CONTINUE
0060     RETURN
0061 END

```

```

0001
0002
0003
0004 C-----
0005 C FUNCTION FLINE FORMS AND EVALUATES THE LINEAR FIT SECTION OF
0006 C THE REFLECTED OVERPRESSURE CURVES. PRESIN IS THE INCIDENT OVER-
0007 C PRESSURE AND ANGINC IS THE INCIDENT WAVE ANGLE AT WHICH THE
0008 C LINEAR EQUATION IS EVALUATED.
0009 C-----
0010
0011 REAL FUNCTION FLINE(PRESIN,ANGINC)
0012 REAL M,PSIANG(11),PSISLP(11),ANGLIN(11),SLOPES(11)
0013 COMMON/TRIG/RTOD,DTOR,PI
0014 COMMON/LAGRAN/PSIANG,PSISLP,ANGLIN,SLOPES
0015 COMMON/ATMOS/ATM
0016
0017 C-----
0018 C SUBROUTINE LAGRNG IS CALLED TO DETERMINE THE SLOPE, M
0019 C-----
0020
0021 CALL LAGRNG(ATM*PRESIN,M,PSISLP,SLOPES)
0022 FLINE=M*ANGINC-M*PI/2.+1.
0023 RETURN
0024 END

```

```

0001
0002
0003 C-----
0004 C SUBROUTINE SCLEAR ERASES THE SCREEN AND SENDS THE CURSOR HOME
0005 C IF USING A RETRO VT, HP2623, OR TEKTRONIKS TERMINAL.
0006 C-----
0007
0008 SUBROUTINE SCLEAR(TRMNUM)
0009 INTEGER TRMNUM
0010 INTEGER*4 CHANNEL,STAT
0011 CHARACTER ESC/27/
0012 COMMON/IO/CHANNEL
0013 IF(TRMNUM.EQ.0.OR.TRMNUM.EQ.4) THEN
0014 IAA=LIB$ERASE_PAGE(1,1)
0015 IDA=SCR$SET_CURSOR($VAL(1),$VAL(1))
0016 ELSE IF(TRMNUM.EQ.3) THEN
0017 CALL ASSIGN_CHANNEL
0018 CALL OUTPUT(ESC// 'H'//ESC// 'J')
0019 CALL DEASSIGN_CHANNEL
0020 ELSE IF (TRMNUM.EQ.2) THEN
0021 CALL ASSIGN_CHANNEL
0022 CALL OUTPUT(ESC//CHAR(12))

```

```

0023          CALL DEASSIGN_CHANNEL
0024          DO 1555 I=1,50
0025          DO 1550 J=1,10000
0026      1550          CONTINUE
0027      1555          CONTINUE
0028          END IF
0029          RETURN
0030          END

```

```

0001
0002      C-----
0003      C THE FOLLOWING SUBROUTINES ARE USED TO CLEAR THE SCREEN ON THE
0004      C HP2623 AND TEKTRONIKS TERMINALS USING SYSTEM SERVICE COMMANDS.
0005      C-----
0006
0007          SUBROUTINE INPUT(TYPEIN)
0008          INCLUDE '($IODEF)'
0009          CHARACTER*(*) TYPEIN
0010          INTEGER*4 QUAD(2)
0011          INTEGER*4 CHANNEL,STAT,SYS$QIOW
0012          DATA QUAD/2*0/
0013
0014          STAT=SYS$QIOW(,,$VAL(CHANNEL),$VAL(IO$_TTYREADALL.OR.IO$_M_NOECHO)
0015      +          ,,,,,$REF(TYPEIN),$VAL(LEN(TYPEIN))),,QUAD,,,,)
0016          IF (STAT) RETURN
0017          PRINT*, 'READ ERROR ',STAT
0018          CALL DEASSIGN_CHANNEL
0019          STOP
0020          END

```

```

0001
0002      C-----
0003      C SUBROUTINE OUTPUT
0004      C-----
0005
0006          SUBROUTINE OUTPUT(TYPEOUT)
0007          COMMON/IO/CHANNEL
0008          INCLUDE '($IODEF)'
0009          CHARACTER*(*) TYPEOUT
0010          INTEGER*4 CHANNEL,STAT,SYS$QIOW
0011
0012          STAT=SYS$QIOW(,,$VAL(CHANNEL),$VAL(IO$_WRITEBLK.OR.IO$_M_NOFORMAT)
0013      +          ,,,,,$REF(TYPEOUT),$VAL(LEN(TYPEOUT))),,$VAL(0),,,)
0014          IF (STAT) RETURN
0015          PRINT*, 'WRITE ERROR',STAT
0016          CALL DEASSIGN_CHANNEL

```

```

0017          STOP
0018          END

```

```

0001
0002      C-----
0003      C SUBROUTINE ASSIGN
0004      C-----
0005
0006          SUBROUTINE ASSIGN_CHANNEL
0007          COMMON/IO/CHANNEL
0008          INTEGER*4 SYS$ASSIGN,CHANNEL,STAT
0009          STAT=SYS$ASSIGN('TT',CHANNEL,,)
0010          IF (STAT) RETURN
0011              PRINT*, 'DEVICE ASSIGNMENT ERROR ',STAT
0012              STOP
0013          END

```

```

0001
0002      C-----
0003      C SUBROUTINE DEASSIGN
0004      C-----
0005
0006          SUBROUTINE DEASSIGN_CHANNEL
0007          COMMON/IO/CHANNEL
0008          INCLUDE'($IODEF)'
0009          INTEGER*4 SYS$DASSGN,CHANNEL,STAT
0010
0011          STAT=SYS$DASSGN($VAL(CHANNEL))
0012          IF (.NOT.STAT) PRINT*, 'DEVICE DEASSIGN ERROR ',STAT
0013          RETURN
0014          END

```

```

0001
0002      C-----
0003      C FUNCTION FALMAX DETERMINES THE REFLECTED SHOCK WAVE ANGLE FOR
0004      C MAXIMUM STREAM DEFLECTION BEHIND THE REFLECTED SHOCK.
0005      C-----
0006
0007          FUNCTION FALMAX(MACHN2,GAMMA)
0008          REAL MACHN2
0009          SINSQA=(1./(4.*GAMMA*MACHN2**2))*((GAMMA+1.)*MACHN2**2-
0010          & 3.+GAMMA+SQRT((GAMMA+1.)*((GAMMA+1.)*MACHN2**4-
0011          & 2.*(3.-GAMMA)*MACHN2**2+(GAMMA+9.))))

```

```

0012     FALMAX=ASIN(SQRT(SINSQA))
0013     RETURN
0014     END

```

```

0001
0002 C-----
0003 C FUNCTION F IS THE FUNCTION EVALUATED IN SUBROUTINE ITRATE TO
0004 C DETERMINE THE REFLECTED SHOCK WAVE ANGLE FOR A GIVEN FLOW DEFLEC-
0005 C TION ANGLE.
0006 C-----
0007
0008     FUNCTION F(L,ARGUM,KNOWN,VEL,GAMMA,PRESS)
0009     REAL KNOWN
0010     VELTEM=VEL
0011     IF (L.EQ.1) VELTEM=(SQRT(((GAMMA+1.)/(2.*GAMMA))*
0012 & PRESS+1.))/SIN(ARGUM)
0013     F=2.*(VELTEM**2*(SIN(ARGUM))**2-1.)/(TAN(ARGUM)*
0014 & (VELTEM**2*(GAMMA+COS(2.*ARGUM))+2.))-TAN(KNOWN)
0015     RETURN
0016     END

```

```

0001
0002 C-----
0003 C ONESIG CONVERTS X TO ONE SIGNIFICANT FIGURE.
0004 C-----
0005
0006     FUNCTION ONESIG(X)
0007
0008     IF ( X .GT. 9. ) THEN
0009         DO 10 I=1,10
0010             X = X/10.
0011             IF (X .LT. 9.) THEN
0012                 X = ANINT(X)*(10.**I)
0013                 ONESIG = X
0014                 RETURN
0015             END IF
0016 10      CONTINUE
0017     END IF
0018     IF ( X .GE. .9 .AND. X .LE. 9. ) THEN
0019         ONESIG = ANINT(X)
0020         RETURN
0021     END IF
0022     IF ( X .LT. .9 ) THEN
0023         DO 20 I=1,10
0024             X = X*10.
0025             IF ( X .GT. .9 ) THEN

```

```

0026             X = ANINT(X)/(10.**I)
0027             ONESIG = X
0028             RETURN
0029             END IF
0030 20          CONTINUE
0031             END IF
0032
0033             END

```

```

0001
0002 C-----
0003 C  TWOSIG CONVERTS X TO TWO SIGNIFICANT FIGURES.
0004 C-----
0005
0006             FUNCTION TWOSIG(X)
0007
0008             IF ( X .GT. 99.0 ) THEN
0009                 DO 10 I=1,10
0010                     X = X/10.
0011                     IF (X .LT. 99.0) THEN
0012                         X = ANINT(X)*(10.**I)
0013                         TWOSIG = X
0014                         RETURN
0015                     END IF
0016 10          CONTINUE
0017             END IF
0018             IF ( X .GE. 9.9 .AND. X .LE. 99.0 ) THEN
0019                 TWOSIG = ANINT(X)
0020                 RETURN
0021             END IF
0022             IF ( X .LT. 9.9 ) THEN
0023                 DO 20 I=1,10
0024                     X = X*10.
0025                     IF ( X .GT. 9.9 ) THEN
0026                         X = ANINT(X)/(10.**I)
0027                         TWOSIG = X
0028                         RETURN
0029                     END IF
0030 20          CONTINUE
0031             END IF
0032
0033             END

```

LIST OF SYMBOLS

A_e	area of bore
a_m	propellant sound speed at muzzle immediately before projectile ejection
a_∞	ambient sound speed
B	fraction of propellant burnt
C	propellant mass
D	bore diameter of gun
E	internal energy of propellant gas immediately prior to projectile ejection
h	distance from the origin of the contour plane to the muzzle
λ	scale length for explosion
λ'	effective scaling length that varies with angle from boreline
m_p	projectile mass
m_1	effective projectile mass accounting for bore friction ($\approx 1.05 m_p$)
M	Mach number of incident shock
M_1	streamline Mach number in front of incident shock
M_2	streamline Mach number behind incident shock
$\vec{n}$	unit vector normal to contour plane
$\vec{P}$	vector directed from the boreline to the field point of interest that is normal to the shockwave surface
p_m	muzzle pressure for propellant immediately before projectile ejection
p_∞	ambient pressure
p_I	pressure behind incident shock
p_R	pressure behind reflected shock
$\overline{P}$	incident overpressure (atm)
$\overline{P}_R$	reflected overpressure (atm)
$\vec{r}$	vector directed from muzzle to field point of interest

LIST OF SYMBOLS (CONTINUED)

r	magnitude of $\vec{r}$
R	gas constant
t_a	blast wave time of arrival
T_m	propellant temperature at muzzle immediately before uncorking
T_a	adiabatic flame temperature of propellant
T_{mean}	mean temperature of propellant gas
$\vec{u}$	unit vector parallel to boreline
U	combined volume of chamber and bore
V_p	exit velocity of projectile
x	coordinate having origin at the muzzle with the direction defined as perpendicular to the boreline and parallel to the contour plane. Shown in Figure 1.
y	coordinate having origin at the muzzle with the direction parallel to the contour plane and being in the vertical plane encompassing the boreline. Shown in Figure 1.
z	coordinate having origin at the muzzle with direction perpendicular to the contour plane. Positive direction corresponds to increasing distance from contour plane as shown in Figure 1.
Z	$(r/l')^{1.1}$
α_1	wave angle of incident shock
α_2	wave angle of reflected shock
γ	specific heat ratio
δ_1	flow deflection angle through incident shock
δ_2	flow deflection angle through reflected shock
δ_{max}	maximum stream deflection consistent with regular shock reflection
n	angle between $\vec{r}$ and $\vec{P}$
θ	polar angle from boreline to field point
μ	momentum index
$\vec{\xi}$	vector along boreline designating apparent origin of blast wave

LIST OF SYMBOLS (CONTINUED)

π	cubic polynomial used in the approximation of the reflected pressure coefficient curves
τ	blast wave positive phase duration
ϕ	angle between boreline and contour plane
χ	ratio of heat losses to kinetic energy
Ω	roughness factor

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