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TANGENT OGIVE NOSE AERODYNAMIC HEATING PROGRAM: NQLDW019

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GODDARD SPACE FLIGHT CENTER
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Sounding Rocket Division

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ABSTRACT

NQLDW019 is a digital computer program, written in Fortran IV for the IBM 360/91, which calculates the aerodynamic heating and shear stresses at the wall for tangent ogive noses that are slender enough to maintain an attached nose shock through that portion of flight during which heat transfer from the boundary layer to the wall is significant. The lower entropy of the attached nose shock combined with the inclusion of the streamwise pressure gradient yields a reasonable estimate of the actual flow conditions. Both laminar and turbulent boundary layers are examined and an approximation of the effects of (up to) moderate angles of attack is included in the analysis.

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TANGENT OGIVE NOSE AERODYNAMIC HEATING PROGRAM: NQLDW019

INTRODUCTION

The common use of the slender tangent ogive shape for sounding rocket "nose cones" has led to development of the aerodynamic heating program (NQLDW019) presented in this report. The slenderness of the ogives of interest results in an attached nose shock wave through periods of supersonic and hypersonic flight during which significant aerodynamic heating is experienced. The low entropy-jump across the oblique shock wave as opposed to the entropy-jump across the normal shock wave associated with "blunt bodies" results in an increase of heat transfer to the ogive for a constant flight condition. This is similar to the case of the cone heating as compared to that on a blunt, axisymmetric body. However, unlike the cone case, the ogive body has a definite (first order) pressure gradient along the surface streamlines. A blunt body analysis program is treated in Reference (1) and a conical analysis program in Reference (2). The present program considers the in-between (tangent ogive) case in which the nose shock is oblique but there is a body pressure gradient.

The effects of moderate angle-of-attack (local body angle plus angle-of-attack of 30 to 35 degrees) are approximated by the program. There is also an option by which the user can elect to input his own pressure distribution instead of allowing the program to calculate the pressures. Finally, the ARDC 1959 atmosphere will normally be used by the program but the user may elect to input the pre-nose shock (free stream) temperature and pressure in order to analyze a wind tunnel condition. The fluid medium, however, must always be air.

THEORY

The theory of NQLDW019 is derived from a combination of the analytical methods of References (1) and (2) with a few new approximations and assumptions. The pertinent geometry along with the most important items of nomenclature are shown in Figures 1 and 2. The tangent ogive and flow geometry are completely specified to the program by the three input values: XX5, YY5 and α (identified in Figure 1). The effects of (up to) moderate angles-of-attack are accounted for by assuming the local flow to be similar to that on a cone of half-angle equal to the ogive local surface angle. The applicable free stream conditions can be derived by inputting the vehicle altitude and employing the 1959 ARDC atmosphere or by electing to define the pre-nose shock air properties by specifying two thermodynamic variables — the pressure and the temperature — then obtaining all the other properties from the real gas (equilibrium) Mollier approximations of Hansen (Reference 3).

The program always solves for the heating and shear data at 15 stations, 10 of which are equally spaced along the ogive and the last five on a downstream cylinder. The user may elect (by setting IPRESS = 1) to input the local-to-stagnation-point pressure ratio at each of the 15 points and the program will get the entropy on the nose at the first station (ONE) and expand isentropically to the input pressures at the local points. Note that this solution assumes a constant entropy (at the post-nose-shock value) over the entire body.

In the alternate solution (IPRESS = 0), the program calculates the downstream-of-the-conical-nose-shock properties including pressure and entropy (point 1, Figure 1) and then, using these data as initial values, passes through a real gas

Prandtl Meyer expansion of $\Delta\theta$ degrees to get the pressure at point 2 (Figure 1). This pressure and the point 1 entropy are then used with the air properties of Reference (3) to define all external-to-boundary-layer properties at point 2. The program now considers the local surface angle at point 2 to be a cone half-angle and calculates a new cone (external to boundary layer) entropy at point 2 which it uses in the same manner as just described to expand by the real gas Prandtl-Meyer routine through $\Delta\theta$ degrees to obtain the point 3 pressure at the point 2 entropy. In this way, the properties at each point on the ogive are derived at the approximate entropy of the immediate upstream point.

This method represents an attempt to approximate the entropy gradient across the shock layer. Note that the entropies so derived are conservatively lower, the farther aft one goes on the ogive. Moreover, the greatest conservatism in the predictions of the local heat transfer rate occurs at point 10. For all points downstream of 10, the entropy is left at the point 10 calculated value and the pressures are assumed to be the arithmetic average of the free stream (ahead of the nose shock) and the point just upstream of the point being studied. Mathematically:

$$SR(11) = SR(12) = SR(13) = SR(14) = SR(15) = SR(10) \tag{1}$$

and

$$P(11) = [P_\infty + P(10)]/2. \tag{2}$$

$$P(12) = [P_\infty + P(11)]/2. \tag{3}$$

$$P(13) = [P_\infty + P(12)]/2. \tag{4}$$

$$P(14) = [P_\infty + P(13)]/2. \tag{5}$$

$$P(15) = [P_\infty] \tag{6}$$

Of course, the real gas Prandtl-Meyer expansion is used only up to and including point 11. From point 11 to points 12, 13, 14, and 15, the entropy is constant and isentropic expansion to the local pressures indicated in Equations (2) through (6) defines the local flow properties. The program contains a check that never allows the calculated pressure to go below 80% of the free stream pressure — as would sometimes result from the Prandtl-Meyer expansion technique described.

It should be emphasized that while the entropy values for the program-calculated pressure option (IPRESS = 0) are low (yielding conservatively high heat transfer rates), the pressures that result from the Prandtl-Meyer expansion technique are also normally on the low side. This tends to decrease the predicted heat transfer rates. The two effects tend to offset each other.

Geometric Calculations

The input to NQLDW019 is greatly simplified by the fact that the program treats a fixed number of stations on a fixed geometry, the tangent ogive followed by a cylinder. In specifying the magnitude of X (XX5 in the program) and Y (YY5 in the program) and the angle-of-attack, α, all necessary geometric input has been supplied and the program is able to generate the geometric details required by means of the following equations (the nomenclature of which is defined in Figure 2):

Given only X and Y (XX5 and YY5),

$$R = \frac{X^2 + Y^2}{2Y} \tag{7}$$

$$\theta = \text{Tan}^{-1}\left[\frac{X}{R - Y}\right] = \text{Tan}^{-1}\left[\frac{2XY}{X^2 - Y^2}\right] \tag{8}$$

$\Delta\theta$ is defined as

$$\Delta\theta = 0.1[\theta] \tag{9}$$

In order to calculate the "flow deflection" distance, r (i), define

$$\phi(i) = PHI(i) = \theta + \alpha - \frac{\sum_0^i \Delta\theta}{2} \tag{10}$$

and thence (from the right triangle of Figure 2)

$$r(i) = 2R \sin\left[\frac{\sum_0^i \Delta\theta}{2}\right] \sin\phi(i) \tag{11}$$

The surface coordinate distance (boundary layer build-up distance) is

$$X(i) = R\,[i\,(\Delta\theta)] \tag{12}$$

<u>Assumptions</u>

The following basic assumptions are applicable to NQLDW019:

(1) The shock layer entropy gradient effect on the external-to-boundary layer flow properties around the ogive is approximated by assuming the local external flow to have originated just downstream of a shock wave generated by a cone of the same half-angle as the local surface angle $(\theta + \alpha)$. This tends to predict increasingly lower (than the true local value) entropies as one considers points farther downstream on the ogive. The predicted heat transfer, therefore, is expected to become increasingly conservative as the farther downstream stations are treated. (See Figure A4.)

(2) In the alternate method in which pressures are input and the entropy is constant at the post nose shock (point 1) value, the calculated entropy is expected to be higher than the actual values for downstream points, again the error growing with distance downstream. Accordingly, lower heat transfer rates downstream should result from the entropy effect of the pressure-input option. Note that one cannot conclude from this that the heat rate distributions from this method are actually conservative because their magnitudes in this option are also highly dependent upon the magnitudes of the pressures that are input. The above remarks refer to the entropy effect alone (as though the pressures by either method were equal).

(3) It is assumed that the increase in heat transfer rate caused by the thinning of the boundary layer (resulting from the crossflow) at any station on the ogive nose can be approximated by the use of Equations (29) and (30), substituting the local surface angle (θ) for the cone half angle, θ_c. The validity of this local similarity assumption has not been established independently at this writing.

(4) Except where the local Mach number is low enough to trigger the perfect gas Prandtl-Meyer or oblique shock routines, the analyses assume air in chemical and thermodynamic equilibrium.

Heat Transfer Rate and Shear Stress on Body

The boundary layer heat transfer rate and shear stresses at the wall are calculated by means of (a) the Eckert and Tewfik adaptation of Lee's momentum integral equation (Reference 4) and the use of Reynolds analogy for the laminar case, and (b) the Flat Plate Reference Enthalpy Method described in Reference (5) (also applying Reynolds analogy) for the turbulent boundary layer case. The programmed equations are:

(1) Laminar heat rate (ratioed to the spherical nose stagnation point heat rate)

$$\frac{\dot{q}_{(x)}}{\dot{q}_{(0)}} = \left[\frac{k^*_{(x)}}{k^*_{(0)}}\right]\left[\frac{H^*_{(x)}}{H^*_{(0)}}\right]\left[\frac{h_{rec} - h_{(w)}}{h_{(0)} - h_{(w)}}\right]\left[\frac{C_{p_{w(0)}}}{C_{p_{w(x)}}}\right] \quad \text{[QRATL]} \tag{13}$$

where the starred quantities are evaluated at local pressure and reference enthalpy, h^*.

$$h^* = h_{ref} = \frac{h_{(e)} + h_{(w)}}{2} + 0.22\sqrt{P_{r(e)}}\,(h_{(0)} - h_{(w)}) \tag{14}$$

$$h_{rec} = h_{(e)}[\,1 - (P_r^*)^{½} + h_{(0)}(P_r^*)^{½}\,] \quad \text{(Laminar B. L.)} \tag{15}$$

or

$$h_{rec} = h_{(e)}[1 - (P_r^*)^{1/3} + h_{(0)}(P_r^*)^{1/3}] \quad \text{(Turbulent B. L.)} \tag{16}$$

In Equation (13), $H^*(x)$ is given by:

$$H^*_{(x)} = \left[\frac{\rho^*_{(x)}}{\rho_{(0)}}\right]\left[\frac{V_{(x)}}{V_{(\infty)}}\right](r_{(x)})^N \Bigg/ \left\{\int_0^x \left[\frac{\rho^*_{(x)}\,\mu^*_{(x)}}{\rho_{(0)}\,\mu_{(0)}}\right]\left[\frac{V_{(x)}}{V_{(\infty)}}\right](r_{(x)})^{2N}\,dx\right\}^{½} \tag{17}$$

N = 0 for 2 dimensional and N = 1 for axisymmetric flow (hence N = 1 for the case considered) and

$$H^*_{(0)} = \left[\frac{2 \frac{\rho^*_{(x)}}{\rho_{(0)}} \left(\frac{dv}{dx}\right)_{(0)}}{V_{(\infty)} (\mu^*_{(0)}/\mu_{(0)})} \right]^{1/2} (1 + N)^{1/2} \tag{18}$$

is the stagnation point value.

Note that $(dv/dx)_{(0)}$ is given the Newtonian (circular nose) value

$$\left(\frac{dv}{dx}\right)_{(0)} = \frac{\sqrt{2}}{R_N} \left[\frac{P_{(0)} - P_{(\infty)}}{\rho_{(0)}} \right]^{1/2} \tag{19}$$

The turbulent heating equation is:

$$\dot{q}_{Turb} = \frac{0.03(g)^{\frac{1}{3}} (1+N)^{.2} (k^*_{(x)})^{2/3} (\rho^*_{(x)} V_{(x)})^{.8} \left[\left(1 - \sqrt[3]{P^*_r}\right) h_{(x)} + \sqrt[3]{P^*_r}\, h_0 - h_w \right]}{\left(\mu^*_{(x)}\right)^{7/15} \left(C^*_{p_0}\right)^{2/3} x^{.2}} \tag{20}$$

Using Reynolds analogy, the laminar and turbulent shear stress and friction coefficients are calculated from:

$$C_{f_{Lam}} = \frac{2\, \dot{q}_{Lam} \left(P^*_{r(x)}\right)^{2/3}}{\rho_{(x)} V_{(x)} (h_{rec} - h_{(w)}) g} \tag{21}$$

$$C_{f_{Turb}} = \frac{2\, \dot{q}_{Turb} \left(P^*_{r(x)}\right)^{2/3}}{\rho_{(x)} V_{(x)} (h_{rec} - h_{(w)}) g} \tag{22}$$

$$\tau_{Lam} = 0.5\, C_{f_{Lam}} \rho_{(x)} V^2_{(x)} \tag{23}$$

$$\tau_{Turb} = 0.5\, C_{f_{Turb}} \rho_{(x)} V^2_{(x)} \tag{24}$$

The local Reynolds number is calculated from

$$R_{e_{(x)}} = \frac{\rho_{(x)} V_{(x)} X}{\mu_{(x)}} \tag{25}$$

and the momentum thickness Reynolds number is (see Reference 1)

$$R_{e_{(\theta)}} = \frac{0.87 \, f''_{(w)}}{C_{f_{(w)}}} \, \frac{\rho_{(w)} \mu_{(w)}}{\rho_{(x)} \mu_{(x)}} \tag{26}$$

in which the Cohen and Reshotko's (Reference 6) velocity gradient parameter, $f''_{(w)}$, is curve fitted by the following two equations (valid for favorable pressure gradients):

(a) $C_f R_e / N_u > 2$

$$f''_{(w)} = 0.0508 \left[C_f R_e / N_u\right]^2 + 0.1332 \left[C_f R_e / N_u\right] \tag{27}$$

(b) $0 \leq C_f R_e / N_u \leq 2$

$$f''_{(w)} = 0.011627 \left[C_f R_e / N_u\right]^2 + 0.25644 \left[C_f R_e / N_u\right] - 0.089787 \tag{28}$$

Shock and Expansion Routines

The real gas oblique shock routine for hypersonic flow and the method of accounting for the pressure and entropy gradients across the shock layer for conical flow are given in Appendix B of Reference (2). This hypersonic analysis becomes invalid in the medium to low supersonic range so an alternate supersonic conical shock calculation method (see Appendix C of Reference 2) is automatically actuated upon failure of the hypersonic analysis.

Similarly, a real gas (applicable for hypersonic Mach number ranges) Prandtl-Meyer expansion routine (Figure 4, Reference 1) is valid only down to local Mach numbers somewhere between 2 and 3. As with the cone shock calculations, the real gas Prandtl-Meyer analysis is backed-up by a perfect gas routine (Appendix D, Reference 2) which is automatically called when failure of the real gas method is sensed. Note that in either the shock or expansion analysis for low supersonic flow, the perfect gas assumption is quite valid.

Crossflow Corrections

The derivation of the effects of crossflow on a cone at moderate angle-of-attack is given in Reference (2). The resulting equations are:

$$QRATL = \left[\frac{\dot{q}_{with\ crossflow}}{\dot{q}_{without\ crossflow}}\right]_{Laminar}$$

$$= \left[\frac{1 + \dfrac{2\,Tan\,(\theta_c + \alpha)}{Tan\,\theta_c}}{3}\right]^{1/2} \qquad (29)$$

and

$$QRATT = \left[\frac{\dot{q}_{with\ crossflow}}{\dot{q}_{without\ crossflow}}\right]_{Turbulent}$$

$$= 0.85\ (1 + K_2)^{0.2} \qquad (30)$$

where

$$K_2 = 1.25 \left[\frac{Tan\ (\theta_c + \alpha)}{Tan\ \theta_c}\right]$$

These equations are used to estimate the effects of crossflow on the ogive nose. Both equations are solved at each station on the ogive assuming the local surface angle, θ, to be the "cone half angle", θ_c. Note that when the angle-of-attack, α, goes to zero, both QRATL and QRATT go to one. Finally, it must be remembered that even when properly used (for cone flow) Equations (29) and (30) are valid only for $(\theta_c + \alpha)$ values up to approximately 35 degrees. As the deflection angle plus angle-of-attack exceeds this range, the crossflow begins to dominate the aeroheating phenomenon and a better analytical prediction derives from a two-dimensional, blunt body method like that of Reference (1). Obviously, the cross-over point for the applicability of either theory is not clearly defined.

Hemi-Spherical Nose Stagnation Heating

There are two reasons for including the calculation of the hemi-spherical nose calculation in this program. First, the post normal shock flow properties are required for the laminar boundary layer heat rate calculation of Equation (13) and also the stagnation heat rate is specifically required to redimensionalize the heat ratio of this equation to get the absolute value of the local laminar heat rate. The second reason lies in the fact that the stagnation point heat transfer is often desired as a general heat transfer parameter for evaluating the effects of trajectory parameters, vehicle weight, etc., upon the vehicle thermal environment.

Note that the nose radius selected as a program input enters into the solution of Equation (13) only via the $H^*_{(0)}$ term (Equation 18) in the form of the stagnation point velocity gradient (Equation 19). The same nose radius is also used in the stagnation point heating rate (Equation 31) so it is clear that all data relative to body points 1 through 15 are totally independent of the value of RN which is input.

For this reason it is suggested that a value of RN = 1 foot be input because this is commonly used as a heat indicator.

The stagnation point heat rate is calculated by the equation of Fay and Riddell (Reference 10) with the Lewis number assumed equal to unity:

$$\dot{q}_{\substack{STAG\\POINT}} = 0.76\,g\,(P_r)^{-.6}\,(\rho_{(w)}\mu_{(w)})^{.1}\,(\rho_{(x)}\mu_{(x)})^{.4}\,(h_{(0)} - h_{(w)})\left(\frac{dv}{dx}\right)^{1/2}_{(0)} \qquad (31)$$

Detachment of Nose Shock Wave

The method of estimating the point 1 conditions by assuming the conical nose shock wave that would result from a cone of half-angle equal to the angle shown as $(\theta + \alpha)$ in Figure 2 does introduce a possible problem. If $(\theta + \alpha)$ at any given freestream Mach number is greater than some critical flow deflection angle, δ_{c_r}, the nose shock will detach and the analytical methods of NQLDW019 will become invalid. In order to protect against this possibility (which can arise from either too blunt an ogive, too large an angle-of-attack, or a combination of the two), the critical conical flow deflection angle as a function of free stream Mach number is taken from chart 5 of Reference (7). These data are curve-fitted in five regions of free stream Mach number:

$$1.05 \le M_\infty < 1.5$$

$$1.5 \le M_\infty < 3.0$$

$$3.0 \le M_\infty < 5.0$$

$$5.0 \le M_\infty < 10.0$$

$$10.0 \le M_\infty < 100.0$$

Thus, for each problem, the nose apex flow deflection angle (including angle-of-attack) and the free stream Mach number are known. The program uses the free stream Mach number in the appropriate region (curve-fitted equation) to obtain the maximum allowable flow deflection angle, δ_{c_r}. This angle is then compared with the actual deflection angle $(\theta + \alpha)$ at the nose and if $\delta_{c_r} < (\theta + \alpha)$, the program is halted and the following warning is printed out:

"NOSE SHOCK IS DETACHED. USE BLUNT BODY PROGRAM
THE FREE STREAM MACH NO. = (Number Given)
THE ACTUAL DEFLECTION ANGLE = (Number Given)
THE DEFLECTION ANGLE FOR DETACHMENT = (Number Given)
GO TO NEXT PROBLEM"

Note that this same printout will occur if the free stream Mach number should inadvertently be input as less than 1.05. Of course, only the nose point need be checked in this manner because all points downstream of the nose point have effective deflection angles less than that for point 1.

INPUT

For convenience, the program input is summarized in Figure 3. Once the basic theory and operation of the program are understood, this figure provides complete input data definition and the format in which it is input, including the dimensions of the variables.

The input for NQLDW019 consists of from 3 to 10 cards, depending upon the options selected. The 10 possible input cards are contained within 6 card types. The three card types which must always be present are card types 1, 2, and 5. Card types 3, 4, and 6 are optional.

Card Type 1 — (1 card per problem; always required)

The single digit, NTUN, is placed in column 2 of card number 1. If NTUN is input as "0", the program will assume the 1959 ARDC atmosphere. If NTUN is input as "1", the user must enter (in card type 3) the pre-nose shock values of the free stream pressure (lb_f/ft^2) and temperature (°K). Columns 3 through 74 of card type 1 may be given any alpha-numeric message which will be printed in the output as a problem title.

Card Type 2 — (1 card per problem; always required)

Columns 1 through 13 contain the vehicle altitude (ft). The vehicle velocity (ft/sec) is given in columns 14 through 26. Columns 27-39 contain the radius of a hemispherical nose (ft), the stagnation point heat rate of which is used to non-dimensionalize the local body heat rates. The wall temperature assumed at this stagnation point is input in columns 40-52. Note that the hemispherical stagnation point is hypothesized solely to provide a non-dimensionalizer for the pressure and heat transfer rate and does not actually exist on the vehicle. The (constant) distance between stations 10 and 11, 11 and 12, 12 and 13, 13 and 14, and 14 and 15 (dx) is input in columns 53-65. The preceding five inputs are all floating point (decimal point required) in the fields defined above.

The constant, ITW, is entered (fixed point, right justified) in columns 66-69. If a temperature (in °K) is entered in this field, card type 4 (cards no. 4, 5, and 6) is omitted from the input. If ITW is entered as zero (in column 69) or left blank, then card type 4 must be included.

The next item on card type 2 is IPRESS which is entered in column 70. If given the value "0" (zero), the program will calculate the pressures at all stations and no type 6 cards are input. If given the value "1" (one), the user must supply the local pressure ratios at all stations by entering cards number 8, 9, and 10 (Card Type 6).

LLL is input in column 71. If given the value zero (or left blank) no automatic dumps will occur in subroutine ITER. If 1 is placed in column 71 the dumps will be permitted. This column is normally given the zero entry.

Column 72 contains the counter "LONG". If left blank or given a zero, the short printout will result. If given the digit 1, the complete printout will result. Examples of both the short and the long printout are given in sample problems 1 and 2.

A zero in column 73 will allow program diagnostics for exponential over and underflow (which normally will not effect the program solutions but which clutter up the printout needlessly). The digit 1 in column 73 will suppress these diagnostics. Normally, one will use the digit 1 unless the diagnostics are specifically desired.

Finally, if column 74 is zero or left blank the output will be given in English units. If a 1 is put in this column the printout will be in the International System of Units (metric); see sample problems 3A and 3B.

Card Type 3 — (1 card per problem; enter only when NTUN = 1 on Card Type 1)

Columns 1-15 contain the pre-nose shock value of the pressure (free stream) in lb_f/ft^2 and columns 16-30, the corresponding temperature (°K).

Card Type 4 — (3 cards per problem; enter only when ITW = 0 on Card No. 2)

These cards contain, in fields of 15 (five fields to a card), the wall temperature at each of the 15 stations (°K).

Card Type 5 — (1 card per problem; always required)

The vehicle body geometry specifications are given in three consecutive fields of 15 (starting in column 1). XX5, the centerline length of the tangent ogive (ft), YY5, the cylindrical aft-section body radius (ft), and ALPHA, the vehicle angle-of-attack (degrees). Note that these items are called out in Figures 1 and 2.

Card Type 6 — (3 cards per problem; enter only when IPRESS = 1 in Card Type 2)

Again, three cards, each having 5 fields of 15 columns (consecutive, starting in column 1), are used to input the local to stagnation point pressure ratios at each of the 15 stations. If IPRESS = 0, these three cards are omitted and the program will calculate its own pressure distribution and the entropy at each station on the ogive will be calculated. If these cards are included in the input (i.e., IPRESS = 1), the program calculates the entropy at point 1 and assumes this value to pertain to all downstream stations.

Note that all cards which are entered for any problem MUST be entered in the order shown in Figure 3. Of course, it is perfectly permissible to omit any cards not required for the particular case in question.

OUTPUT

Four choices are available for output control. If the counter "IMETRC" is set equal to zero, the printout is all given in English (engineering) units.

"IMETRC" is entered as one, the printout will be in metric units as defined in Reference 11. Note that the first item of output is the problem title and this is always followed by a statement of which system of units is applicable for that problem. The English units are given in the symbol table first, followed by the metric units when applicable. Metric units are "applicable" only when a quantity is printed out in metric units; that is, the program does all calculations in the English units and converts to the metric system when called upon to do so by the "IMETRC" counter. Caution: ALL INPUT must be given in the English system of units as defined in the first parenthetical expressions in the symbol table and also in Figure 3. Temperatures, however, are always in degrees Kelvin (in either system of units) for this program.

Initial Conditions (Long or Short)

This block is always given and it includes the input values of altitude, velocity, nose radius (for spherical nose non-dimensionalizing data), wall temperature at the stagnation point on the spherical nose, the values assigned to the counters NTUN, ITW, IPRESS, LLL, and LONG, vehicle angle-of-attack (alpha) and the ogive geometry (the centerline length of the ogive and the radius of the base of the ogive nose). The flow deflection distances at each of the 15 stations and the X coordinate distances to these points as calculated by the program are also given in this block.

Free Stream Conditions (Long or Short)

The free stream Mach number, enthalpy, temperature, velocity, pressure, specific heat ratio and density are listed for the input altitude condition.

Stream Deflection at Ogive Nose (Long or Short)

In this line, the stream deflection angle at the ogive nose (TH1) is given along with that value of the nose deflection angle (TH2) at which the nose shock would separate.

The printout up to this point is the same, regardless of whether the long or the short form is requested.

Post Nose Shock Data (Long)

This group of printout lists, for conditions at each of the 11 ogive points, the shock wave angle associated with the local body deflection angle as well as the pressure, temperature and entropy downstream of this shock.

Local Surface Data (Long)

The external-to-boundary-layer values of pressure, temperature and entropy are given at each of the fifteen points on the body. Also for each point, the ratios of heat rate at the actual angle-of-attack to that at zero degrees angle-of-attack for both a laminar and a turbulent boundary layer are given.

Stagnation Point Data for Spherical Nose (Long or Short)

This block contains local, reference and wall values of the thermal and transport properties of air at the stagnation point of a spherical nose of radius, RN. The heat transfer rate to this stagnation point is also given.

Local Station Data (Long)

This series of blocks lists the wall, reference and external-to-the-boundary-layer thermal and transport properties of air at each of the 15 stations on the body.

Heat and Shear Data (Long or Short)

For stations 2 through 15, the laminar and turbulent convective heat rates, X or surface coordinate distance, ratios of laminar and turbulent heat rates to nose stagnation values, friction forces and coefficients (laminar and turbulent), recovery enthalpy, local and momentum thickness Reynolds numbers and two diagnostic parameters "CFRENU" and "ROMURT" are listed.

The units for the data printed out are defined in the Symbol section of this report. They depend, of course, on the value of "IMETRC" that has been input.

SYMBOLS

C_f = friction coefficient (local) (-)

C_p = specific heat of air (Btu/lbm °K) (J/kg °K)

$(dv/dx)_{(0)}$ = Newtonian velocity gradient at the stagnation point on a circular nose (sec^{-1}) (see Eq. 19)

f'' (w) = velocity gradient parameter from Reference (6) (see Eqs. 27 and 28)

g = acceleration of gravity (32.174 ft/sec^2)

h = enthalpy (Btu/lbm) (J/kg)

$H_{(0)}^*$ = defined by Equation (18)

$H_{(x)}^*$ = defined by Equation (17)

IPRESS = a counter; set = 0 if program is to calculate its own pressure distribution; set = 1 if user wishes to input his own pressure distribution. (-)

ITW = a counter; set = 0 when each station location is to be given a wall temperature value TW (I); set = TEMP (in fixed point) when all station location temperatures are to be given the same value

TW (I) = TEMP (°K)

k = coefficient of thermal conductivity (Btu/ft sec °K) (J/m s °K)

N = a constant; set = 0 for one dimensional flow; set = 1 for axisymmetric flow (= 1 throughout this program)

Nu = Nusselt Number (-)

P (I) = pressure at stations 1 through 15 (atmospheres, except where otherwise noted)

P_r = Prandtl Number (-)

PX PO (I) = the local to stagnation point pressure ratio at each of the 15 station locations (-)

q = heat transfer rate (Btu/ft^2 sec) (W/m^2)

QRATL = ratio of heat transfer with crossflow to that without crossflow for a laminar boundary layer (see Eq. 29) (-)

QRATT = ratio of heat transfer with crossflow to that without crossflow for a turbulent boundary layer (see Eq. 30) (-)

R = tangent ogive radius of curvature (see Figures 1 and 2) (ft) (m)

R_e or $R_{e_{(x)}}$ = local Reynolds number (Eq. 25) (-)

$R_{e_{(\theta)}}$ = local momentum thickness Reynolds number (Eq. 26) (-)

R_N = spherical nose radius (for calculation of blunt body stagnation point heat transfer rate) (ft)

r (I) or r (X) = the flow deflection distance defined by Eq. (11) and shown in Figures 1 and 2 (ft) (m) [r (I) = r (i) = r (x)]

SR (I) = the non-dimensionalized (S/R, where R here is the gas constant for air) entropy of the local flow at stations 1 through 15 (-)

TWI = the wall temperature at the spherical nose stagnation point (°K)

TW (I) = the wall temperature at each of the 15 stations (°K)

V = velocity (ft/sec) (m/sec)

VINFY = velocity of the vehicle (ft/sec) (m/sec)

X = XX5 = tangent ogive longitudinal dimension (shown in Figures 1 and 2) (ft) (m)

X (I) = surface coordinate distance along streamline from nose tip to each station (ft) (m)

NTUN = a counter; set = 0, the program uses standard atmosphere properties at ZALT; set = 1, the user must input the free stream (ahead of nose shock) pressure and temperature, thereby specifying all free stream properties of air

Y = YY5 = tangent ogive base radius, shown in Figures 1 and 2 (ft) (m)

ZALT = the vehicle altitude (ft) (m)

α = ALPHA = the vehicle angle-of-attack (deg. or rad.) (rad.)

δ_{cr} = the flow deflection angle (conical flow) at which the nose shock becomes detached for a given free stream Mach number (deg. or rad.)

θ = the local surface deflection angle; also, the central angle turned by the tangent ogive radius, R, to define the complete ogive (see Figures 1 and 2) (deg. or rad.)

θ_c = cone half angle (deg. or rad.) (rad.)

μ = viscosity coefficient (lbf sec/ft^2) (NS/m^2)

ρ = density of air (lbm sec^2/ft^4 = slugs/ft^3) (kg/m^3)

τ = boundary layer shear stress at the wall (lbf/ft^2) (N/m^2)

ϕ (I) = angle defined by Eq. (10) and shown in Figure 2 (deg. or rad.) (rad.) [ϕ (I) = ϕ (i)]

SUBSCRIPTS

e = local, external to the boundary layer value

Lam = considers a laminar boundary layer

rec = evaluated at recovery conditions

ref = evaluated at reference conditions (see superscript)

Turb = considers a turbulent boundary layer

x = at a position X ft from nose tip along a surface streamline (same as e)

w = evaluated at local pressure and wall temperature

o = at stagnation point for a spherical nose of Radius, R_N

∞ = free stream (ahead of nose shock) value

SUPERSCRIPT

* = property evaluated at local pressure and reference enthalpy

UNITS ABBREVIATIONS

Btu = British thermal units (E = engineering or English units)

#m or lbm = pound, mass (E)

#f or lbf = pound, force (E)

°K = degree Kelvin (m = metric units)

J = Joules (m)

kg = kilogram (m)

N = Newton (m)

ft = foot (E)

s or sec = second of time (E and m)

slug = #m sec^2/ft^4 (E)

w = watts (m)

Note that 1 $Joule/m^2 s = 1 \; watt/m^2$

TABLE OF UNITS

ITEM			ENGLISH	METRIC
A	=	Area	ft^2	m^2
C_p	=	specific heat	Btu/lbm °K	J/kg °K
ρ	=	density	lbm/ft^3	kg/m^3
h	=	enthalpy	Btu/lbm	J/kg
S/R	=	non-dimensionalized Entropy	—	—
x	=	distance	ft	m
τ	=	shear stress	lbf/ft^2	N/m^2
μ	=	viscosity	lbf sec/ft^2	Ns/m^2
T	=	temp. as used here	°K	°K
$\dot{q}$	=	heat rate	Btu/ft^2 sec	W/m^2
Q	=	heat quantity	Btu	J
P	=	pressure	lbf/ft^2	N/m^2
k	=	thermal conductivity	Btu ft/ft^2 sec °K	J/m s °K

REFERENCES

1. "Digital Utilization Program FB147 — General Aerodynamic Heating", by L. D. Wing, Report No. ER-109, October 1967, Technical Services Division, Fairchild Hiller Corporation

2. "Aerodynamic Heating for Wedge/Wedge or Cone/Cone at Angles of Attack from Zero to Approximately 40°", by L. D. Wing, Report No. ER-116, November 1968, Technical Services Division, Fairchild Hiller Corporation

3. "Approximations for the Thermodynamic and Transport Properties of High Temperature Air", by C. F. Hansen, NASA Technical Report R-50, 1959

4. "Use of Reference Enthalpy in Specifying the Laminar Heat Transfer Distribution Around Blunt Bodies in Dissociated Air", by E. R. G. Eckert and O. E. Tewfik, Journal of the Aero/Space Sciences, Pg. 464, Vol. 27, No. 6, June 1960

5. "Evaluation of Several Hypersonic Turbulent Heat Transfer Analyses by Comparison with Experimental Data", by P. A. Libby and R. J. Cresci, WADC Technical Note 57-72, July 1957, ASTIA DOC. NO. AD 118093

6. "Similar Solutions for the Compressible Laminar Boundary Layer with Heat Transfer and Pressure Gradient", by C. B. Cohen and E. Reshotko, NACA Report 1293, 1956

7. "Equations, Tables, and Charts for Compressible Flow", NASA Ames Research Staff, NACA Report 1135, 1953

8. "Free Flight Aerodynamic Heating Data to Mach Number 10.4 for a Modified Von Karman Nose Shape", by Wm. M. Bland, Jr. and K. A. Collie, NASA TND 889, May 1961

9. "10 Element One Dimensional Structural Heating Programs", by L. D. Wing, Document X-721-69-454, August 1969, NASA Goddard Space Flight Center, Greenbelt, Maryland

10. "Theory of Stagnation Point Heat Transfer in Dissociated Air", by J. A. Fay and F. R. Riddell, Journal of the Aero/Space Sciences, Pg. 73, Vol. 25, No. 2, February 1958

11. "The International System of Units — Physical Constants and Conversion Factors", by E. A. Mechtly, NASA SP-7012, 1964, Scientific and Technical Information Division, NASA, Washington, D. C.

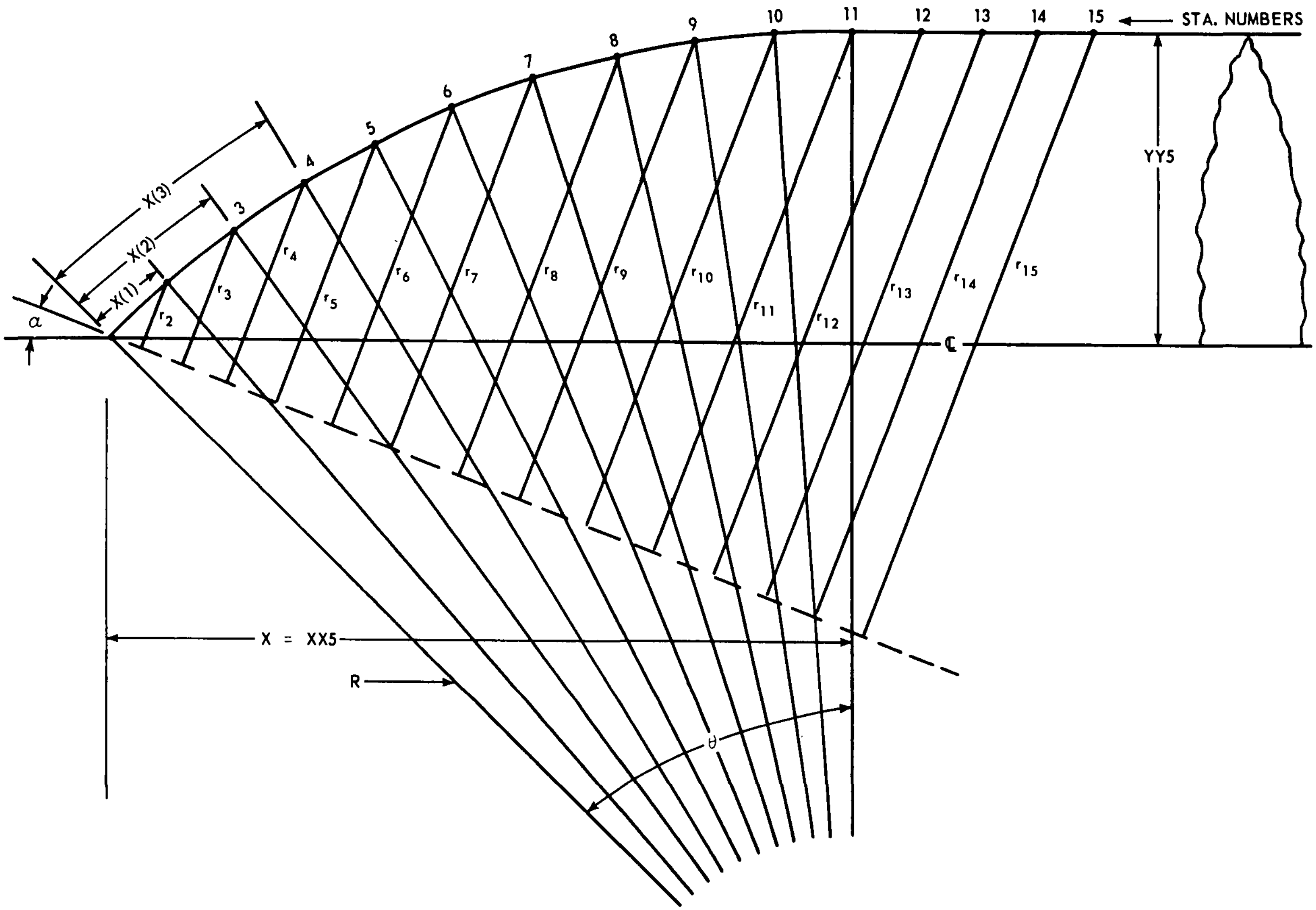

Figure 1. Geometry of Tangent Ogive Nose

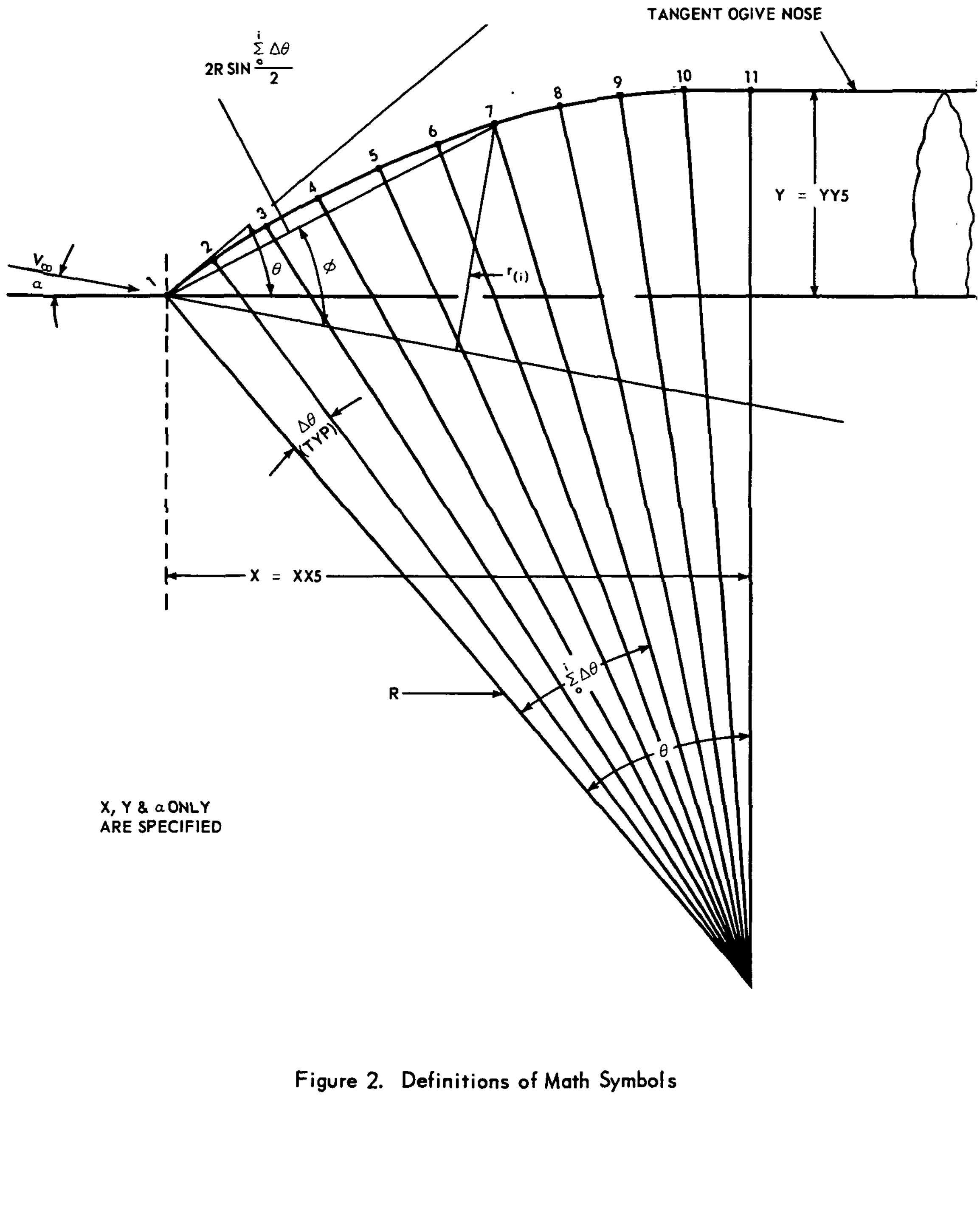

Figure 2. Definitions of Math Symbols

GODDARD SPACE FLIGHT CENTER

FORTRAN CODING RECORD

PROGRAM | PROGRAMMER | DATE | PUNCHING INSTRUCTIONS | GRAPHIC | PUNCH | PAGE OF | CARD ELECTRO NUMBER

STATEMENT NUMBER | CONT | FORTRAN STATEMENT | IDENTIFICATION SEQUENCE

```
NTUN (column 2)                                                      IPRESS, LLL, LØNG, LDW, IMETRC (columns 72-76)
                                                                     CARD NO.
                              TITLE                                                              1
 ZALT (FT)   VINFY (FT/SEC)     RN (FT)      TWI (°K)       DX (FT)       ITW                   2
 PXPØ (1)    PXPØ (2)           PXPØ (3)     PXPØ (4)       PXPØ (5)                            3
 PXPØ (6)    PXPØ (7)           PXPØ (8)     PXPØ (9)       PXPØ (10)                           4
 PXPØ (11)   PXPØ (12)          PXPØ (13)    PXPØ (14)      PXPØ (15)                           5
 TW (1) (°K) TW (2)             TW (3)       TW (4)         TW (5)                              6
 TW (6)      TW (7)             TW (8)       TW (9)         TW (10)                             7
 TW (11)     TW (12)            TW (13)      TW (14)        TW (15)                             8
 XX5 (FT)    YY5 (FT)           ALPHA (DEG)  NOTE: INPUT SEQUENCE MUST BE AS SHOWN IN THIS FIGURE 9
PINFY (LBF/FT^2)  TINFY (°K)                                                                    10
```

NTUN = 0 FOR 1959 ARDC ATMOSPHERE
NTUN = 1 FOR PINFY & TINFY TO BE INPUT } FIXED POINT IN COLUMN 2
ZALT = VEHICLE ALTITUDE (FT) FLOATING POINT
VINFY = VEHICLE VELOCITY (FT/SEC) FLOATING POINT
RN = NOSE RADIUS FOR SPHERICAL NOSE – USED TO GET NONDIMENSIONALIZING STAGNATION POINT HEAT RATE. (NORMALLY USE RN = 1. (FT) FLOATING POINT)
TWI = WALL TEMPERATURE AT THE STAGNATION POINT (°K) FLOATING POINT
DX = DISTANCE BETWEEN STATIONS 11, 12, 13, 14 AND 15 ON THE CYLINDRICAL AFT BODY (THIS IS CONSTANT) (FT) FLOATING POINT
ITW = 0 WHEN EACH STATION IS TO BE GIVEN A DIFFERENT WALL TEMPERATURE (CARDS 6, 7 AND 8 MUST BE ENTERED). = CONSTANT WHEN ALL STATIONS ARE TO HAVE TWALL = CONSTANT (THE DESIRED INPUT VALUE) (°K) FIXED POINT, RIGHT JUSTIFY
IPRESS = 0 FOR PROGRAM TO CALCULATE ITS OWN PRESSURES, = 1 FOR INPUT PRESSURES (CARDS 3, 4, 5 MUST BE ENTERED.) FIXED POINT
LDW = 0 FOR NO SUPPRESSION OF DIAGNOSTICS; = 1 FOR SUPPRESSION OF DIAGNOSTICS.
LLL { = 0 FOR NO DUMP IN SUBROUTINE ITER; = 1 FOR DUMP IN SUBROUTINE ITER } ← FIXED POINT

LONG { = 0 FOR SHORT PRINTOUT; = 1 FOR LONG PRINTOUT } FIXED POINT
PINFY & TINFY = PRESSURE AND TEMP. AHEAD OF NOSE SHOCK ENTERED ONLY WHEN NTUN = 1 (lBF/FT², °K) FLOATING POINT
TW(I) = WALL TEMP. AT EACH STA (I = 1, 15), ENTER ONLY IF ITW = 0 ON CARD 2 FLOATING POINT
XX5 = LENGTH OF TANGENT – OGIVE NOSE (TIP TO POINT OF TANGENCY) (FT) FLOATING POINT
YY5 = RADIUS OF CYLINDRICAL AFT BODY (FT) FLOATING POINT
ALPHA = VEHICLE ANGLE OF ATTACK (DEG.) FLOATING POINT
PXPØ (I) = RATIO OF LOCAL TO STAG. PT. PRESSURE TO BE INPUT FOR EACH STATION ONLY WHEN IPRESS = 1 ON CARD 2. FLOATING POINT
IMETRC = 0 FOR PRINTOUT IN ENGLISH UNITS; = 1 FOR PRINTOUT IN METRIC UNITS FIXED POINT (NOTE THAT INPUT IS ALWAYS IN ENGLISH UNITS)

N.B. WHATEVER RN IS INPUT, THE PROGRAM GETS QSTPT AT THIS RN AND USES THIS VALUE TO NONDIMENSIONALIZE THE LAM. & TURB. LOCAL HEAT RATES

GSFC 6-1(12/69)

Figure 3. Summary of Input for NQLDW010 – The Ogive Nose Heating Program

APPENDIX A

A COMPARISON OF THE FLIGHT MEASURED DATA OF REFERENCE (8) WITH THE THEORY OF NQLDW019 AND NQLDW112 (REFERENCE 9)

In order to test the theory used in NQLDW019, flight data from NASA TND 889 (Reference 8) is used. The vehicle nose of Figure A-1 was flown on a four stage vehicle with a temperature history measured on the inside of the 0.032 inch inconel wall at the position marked "point A" on the sketch. The velocity and altitude histories of the test vehicle through the significant heating portion of flight (during which valid temperature data were recorded) are shown in Figure A-2. Using these trajectory data and the nose configuration of Figure A-1, the laminar and turbulent heat rate, recovery enthalpy, momentum thickness Reynolds number and the local Reynolds number data of Figure A-3 were calculated by NQLDW019, electing the option which allows the program to determine its own local pressures.

These data were then used as input to the 10 element, one dimensional structural heating program (NQLDW112, Reference 9) to obtain the temperature histories shown as solid lines in Figure A-4. Note that the cases of a fully turbulent boundary layer and of transition at local Reynolds numbers of 2.8, 5.0 and 10.0 million are shown. The flight recorded temperature data are shown as circled points.

In general, the agreement between theory and flight data is quite good. The data indicate that transition from turbulent to laminar flow probably occurred at a calculated local Reynolds number of seven to eight million. It is emphasized that this local Reynolds number is defined as

$$R_{e_{x_{(TR)}}} = \frac{\rho_{(x)} V_{(x)} X}{\mu_{(x)}} \quad \text{(A1)}$$

where the sub x values are taken at the outer edge of the boundary layer at point A. Inasmuch as the manner of approximating the effects of the entropy gradient through the shock layer results in more or less fictitious values of the local entropy at any given point, caution must be used in comparing the transition Reynolds number as defined by Equation (A1) with transition Reynolds numbers from other sources which do not make the same local entropy value assumptions.

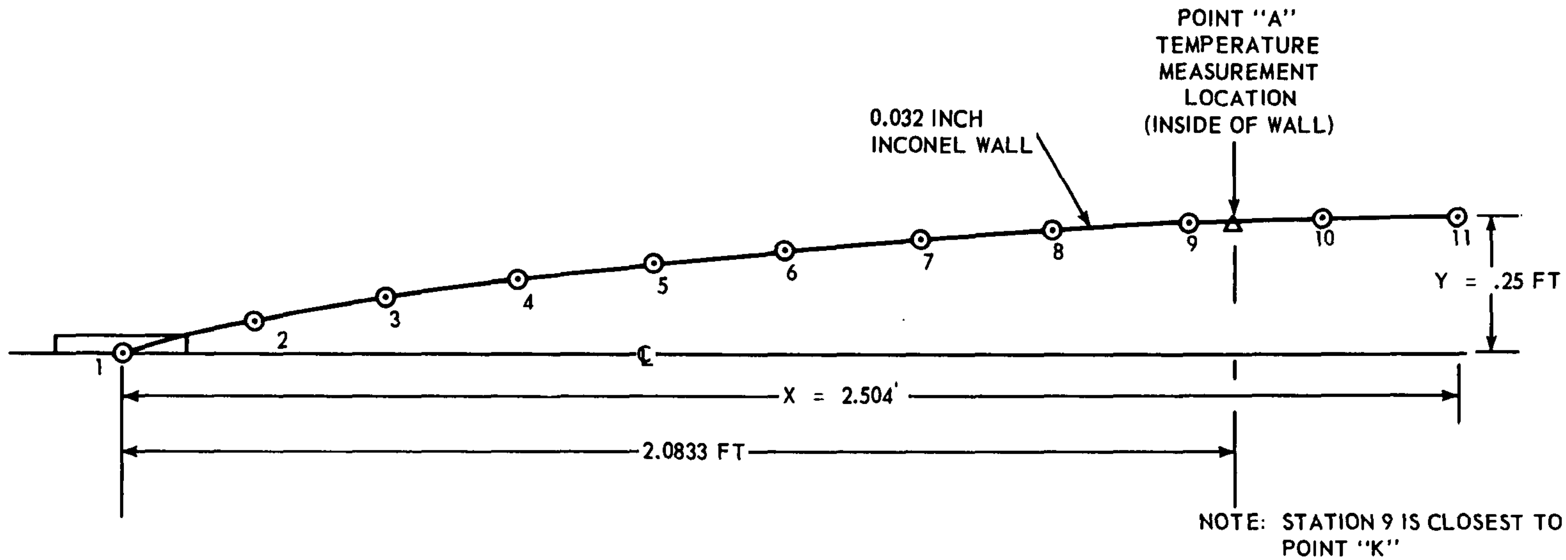

Figure A-1. Sketch of Vehicle Nose for Ref. 8 Flight Data

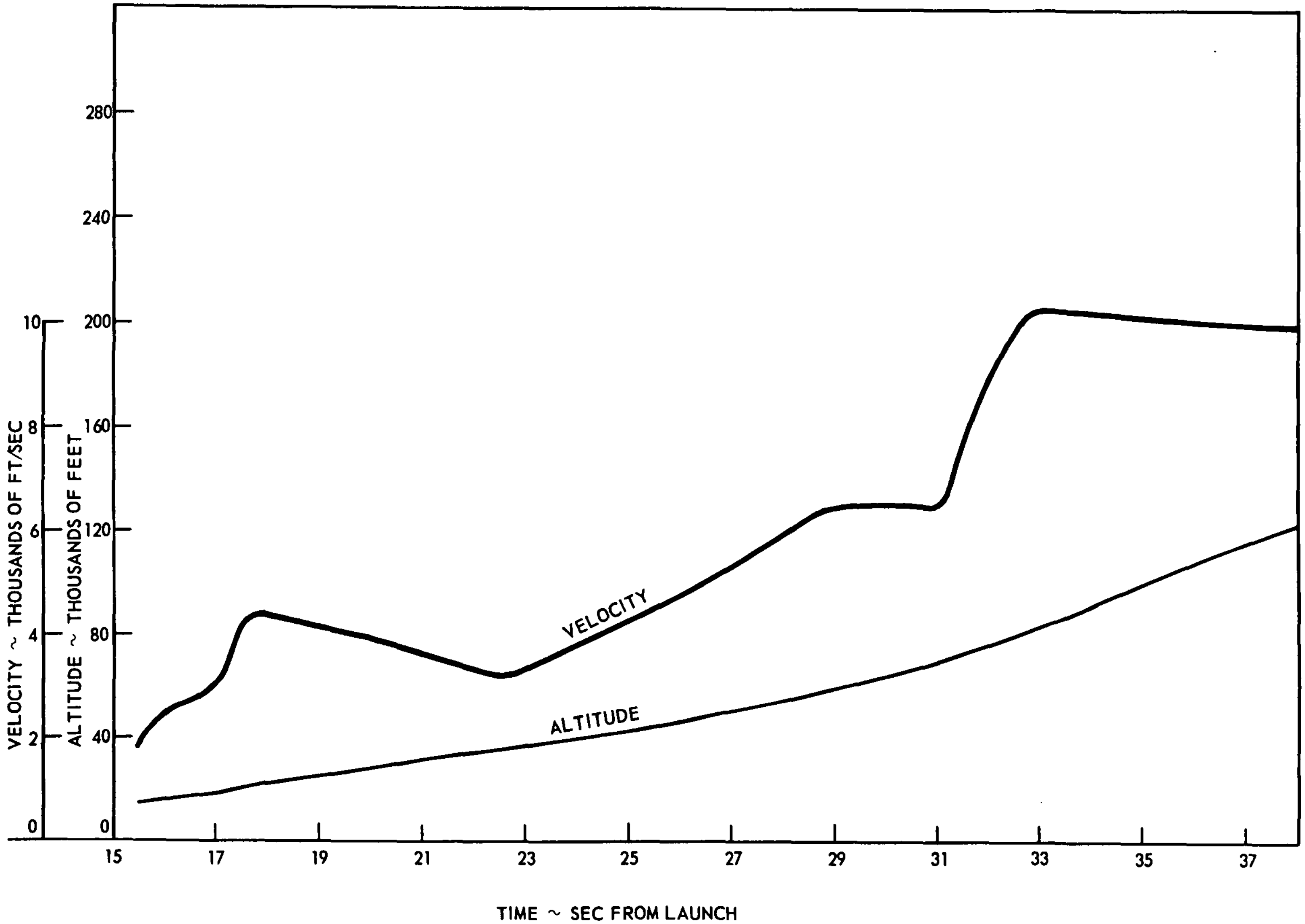

Figure A-2. Velocity and Altitude Histories for the Flight of the Vehicle of Figure 1 through the Significant Aeroheating Portion of Flight

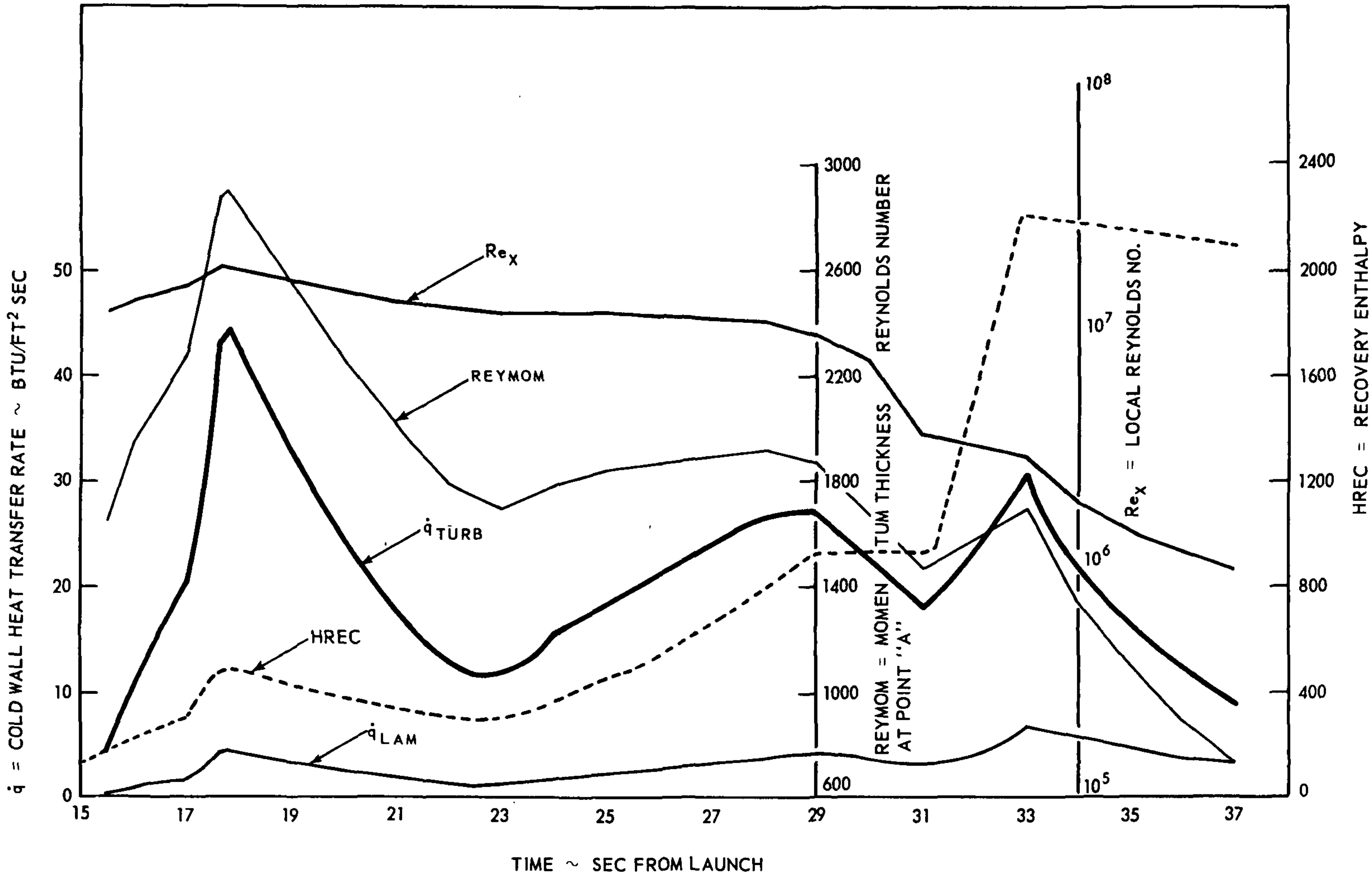

Figure A-3. Laminar and Turbulent Heat Transfer Rates, Recovery Enthalpy, Local Reynolds Number and Momentum Thickness Numbers at Point "A"

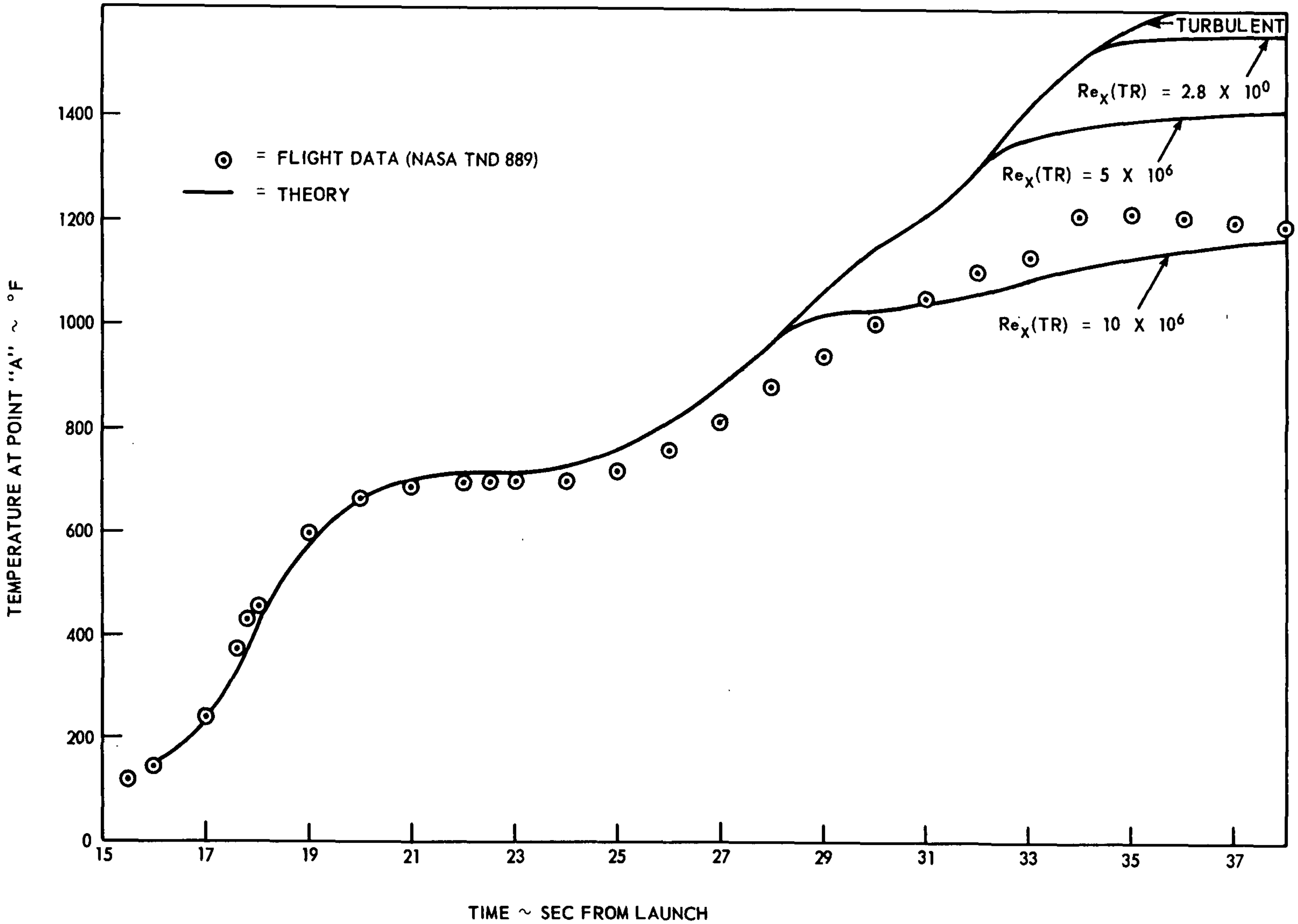

Figure A-4. Comparison of Flight with Theoretical Data Using the Theory of NQLDW019 to Predict the Heat Rate History

APPENDIX B

PROGRAM LISTING AND SAMPLE PROBLEMS — NQLDW019

The following pages present a listing of the main program and all the required (non-library) subroutines. Identification of each subroutine by name is accompanied by a brief description of its function. In addition, the printout of four sample problems is given.

A. SUBROUTINES

The listings of the following eight non-library subroutines follow the listing of the main program. The first seven subroutines are written in Fortran IV but the eighth subroutine is in assembler language.

1. Subroutine ITER

The purpose of ITER is to take a known (input) pressure and enthalpy and an estimated temperature and, in conjunction with the real-gas Mollier subroutine (which can be entered only with a pressure and temperature) return the actual temperature which matches the input pressure and enthalpy.

2. Subroutine TBLALT

TBLALT is entered with an altitude (feet) to obtain (using the 1959 ARDC atmosphere) such properties of air as density, thermal conductivity, speed of sound, temperature, entropy, enthalpy, specific heat, etc., at the entry altitude.

3. Subroutine BLOG

This minuscule routine merely prevents the ALOG function from being called with a negative argument.

4. Subroutine ANAPRP

This subroutine, called with a pressure and a temperature, supplies Hansen's approximations (see Reference 3 of main report) of the thermal and transport properties of air in equilibrium for the entry pressure and temperature conditions.

5. Subroutine POLY

This is a subroutine which, in conjunction with data input (in the case of this program, the data defines the stream deflection angle at which shock wave separation from the body occurs), permits the required interpolation of the input data.

6. Subroutine CONSHK

CONSHK takes input data which include stream deflection angle, free stream velocity, Mach number, specific heat ratio, density, pressure and enthalpy and returns the shock wave angle and all the downstream-of-shock air properties. The program considers real gas (air in chemical and thermodynamic equilibrium) properties where applicable. When the real gas routine fails (usually because of very high pressure or low stream Mach number), it is automatically supplanted by a perfect gas analysis and the switch is noted in the printout.

7. Subroutine RGPM

This subroutine is similar to CONSHK except that it provides air properties downstream of a real gas (or perfect gas if the real gas case fails) Prandtl-Meyer expansion.

8. Subroutine SPIE

This subroutine is used solely for the purpose of suppressing certain diagnostics in the 360/91 system which, in the case of this program, serve no useful purpose but do clutter up the program printout. The user elects to call the suppression by entering the counter LDW = 1 in the input. If LDW is set equal to zero or left blank, no suppression of diagnostics will occur.

B. SAMPLE PROBLEMS

The printout for four sample problems is given in order to illustrate typical electives. Problems 1 and 2 are identical except that in Problem 1 the "long printout" is elected and Problem 2 shows the "short printout". In both problems the ogive geometry and flight conditions are the same:

XX5	=	2.741	ft.
YY5	=	0.5	ft.
α	=	10.	deg.
Velocity	=	4,000	ft/sec
Altitude	=	50,000.	ft.

Both Problems 1 and 2 give output data in English units.

Problems 3A and 3B are, again, identical except 3A gives the output in English units and 3B gives the same data in metric units. (Note that temperatures are always given in degrees Kelvin, regardless of which system of units is called.) In sample Problems 3A and 3B the input data are:

XX5	=	3.0	ft.
YY5	=	0.6	ft.

α	=	0.	deg.
Velocity	=	25,000.	ft/sec
Altitude	=	300,000.	ft.

In all four sample problems the ARDC 1959 atmosphere is used and the program computes the local pressures.

```
C   NOLDW019    THE OGIVE NOSE AEROHEATING PROGRAM  AUGUST 20, 1970
C
C
C OSTPT = THE HEAT TRANSFER RATE TO THE SPHERICAL NOSE OF RADIUS, RN.
C     LOCAL LAMINAR AND TURBULENT HEAT RATES ARE NONDIMENSIONALIZED
C     (OXQOLAM AND OXQOTURB) BY BEING DIVIDED BY OSTPT.  THUS, RN IS
C     NORMALLY INPUT AS 1 FOOT BUT CAN BE INPUT AS ANY ARBITRARY
C     WITHOUT ADVERSELY EFFECTING OXQOLAM,OXQOTURB,QLOCLAM,OR QLOCTURB.
C
C  LONG = 0 FOR THE SHORT PRINTOUT
C       = 1 FOR THE LONG PRINTOUT
C     LOW=0 FOR NO SUPRESSION OF DIAGNOSTICS,=1 FOR SUPRESSION OF SAME
C     IMETRC=0(OR BLANK) FOR PRINTOUT IN ENGLISH UNITS. =1 FOR PRINTOUT
C                       IN METRIC UNITS
C
C  IPRESS = 0 FOR PROGRAM TO CALCULATE ITS OWN PRESSURES
C         = 1 FOR USER TO INPUT PRESSURES ON CARDS 8, 9, AND 10.
C
C  ITW = 0 WHEN EACH STATION IS TO BE GIVEN A DIFFERENT WALL TEMPERATURE
C     (CARDS 4, 5, AND 6 MUST BE ENTERED)
C      = 'CONSTANT' WHEN ALL STATION WALL TEMPERATURES ARE TO BE
C        SET AT THE 'CONSTANT' VALUE
C     NTEST2 = 1-FOR FIRST STEP OF NORMAL SHOCK TEMP.ITER.,2-FOR FORCED
C     CONVERGENCE ROUTINE ON TEMP. AFTER SHOCK ITER.
C     NTUN = 0--1959 ARDC ATMOS.. 1-FREE STREAM PROPERTIES ARE INPUT
C     I = COUNTER FOR STATIONS.  I=0 IS STAGNATION POINT.  I=1 IS AT THE
C        OGIVE NOSE.  I=11 IS AT THE OGIVE-CYL. SHOULDER
C     NSTUP = COUNTER ON ENTHALPY ITERATION
C     NSTOP1 = COUNTER ON DENSITY ITERATION
C     LI = COUNTER FOR RETURN FROM ANOPRP---1,2,3,4
C          NTUN = 0 FOR PROGRAM TO USE1959 ATMOSPHERE
C          = 1 FOR USER TO INPUT PINFY (LBM/SQ.FT) AND TINFY (DEG.K)
C          (CARD 10)
C          TWI = STAGNATION POINT WALL TEMPERATURE (DEG. K)
C          DX = DISTANCE BETWEEN STATIONS 11-12,12-13,13-14,AND 14-15(FT)
C          ITW = 0 WHEN EACH STATION IS TO BE GIVEN A DIFFERENT WALL
C               TEMPERATURE (CARDS NO.S 6,7,AND 8 MUST BE INPUT)
C          = C WHEN ALL TEMPERATURES OF WALL ARE TO HAVE THE VALUE OF 'C'
C          IPRESS = 0 FOR PROGRAM TO CALCULATE LOCAL PRESSURES
C          = 1 WHEN LOCAL PRESSURES ARE TO BE INPUT  (CARDS 3,4,AND 5
C               MUST BE ENTERED)
C          LLL = 0 FOR NO DUMP IN SUBROUTINE ITER
C              = 1 FOR DUMP IN ITER
C          LONG = 0 FOR SHORT PRINTOUT
C               = 1 FOR LONG PRINTOUT
C          XX5 = LENGTH OF TANGENT-OGIVE (TIP TO POINT OF TANGENCY,
C                    MEASURED ALONG AXIS OF SYMMETRY)  (FT)
C          YY5 = RADIUS OF CYLINDRICAL AFT-BODY AT JUNCTION WITH
C                    TANGENT-OGIVE    (FT)
C          ALPHA = VEHICLE ANGLE OF ATTACK  (DEG)
C          PXPU(I) = THE LOCAL-TO-STAGNATION POINT PRESSURE RATIOS AT
C                    EACH STATION,I,AS INPUT ON CARDS 3,4,AND 5
C                         (WHEN IPRESS = 1 ONLY).
C     NOTE THAT THE ENTROPY IS IN NON-DIMENSIONALIZED FORM, SR=S/R
0001       DIMENSION   XM27R(15),HRECLM(15),HRECTM(15)
0002       DIMENSION HW7(15),CPW7(15),HREF7(15),TKREF7(15),VISRX7(15),
          1RHORX7(15),        TKX7(15),VISCX7(15),HX7(15),VX7(15),AAX7(15),
          2RHOX7(15), CPX7(15)
0003       DIMENSION  TETSM(15)
0004       DIMENSION RRM(15),XXM(15)
0005       DIMENSION X(15),PXPU(15),R(15),TW(15),Y(50),SAVF(19),INFO(18)
0006       DIMENSION  DTW(15),DP(15),DRX(15),P(15),T(15),TKS(15)
0007       DIMENSION VS(15),HS(15),H(15),CP(15),RHO(15),AA(15),VISC(15),
          1TK(15),V(15),PR(15)
0008       DIMENSION TKX(16),VISCX(16),PRX(16),ZX(16),HX(16),VX(16),
          1CPCVX(16),AX(16),RHOX(16),CPX(16),R1(21),V1(21),RO1(21),
          2VIS1(21),RO2(21),VIS2(21),V2(21),R2(21),RO(21)
0009       DIMENSION PHIX(15),RHOW(15),VISCW(15)
0010       DIMENSION  SR(15),PS(15),SRS(15),TS(15),CPS(15),RHOS(15),PRS(15),
          1AS(15),VISCS(15),TETSHK(15),CPCV(15),Z(15),XM(15),
          2CPCVS(15),XMS(15)
0011       DIMENSION HREFX(16),HW(16),CPW(16),PRREFX(16),TKREFX(16),VISCRX(16
          1),RHORX(16),TREFX(16),ZREFX(16),CPCVRX(15),PSIL(16),PSIT(16),
          2HRECL(16),HRECT(16),ZS(16)
0012       COMMON/DRRAY/QRATL(15),QRATT(15),PHI(15)
0013       COMMON /ARRAY/A(23)
0014       LOGICAL  J
0015  1111 GO TO 1
0016     1 READ(5,1000,END=P005)NTUN,(INFO(I),I=1,18)
0017       WRITE(6,1112) INFO
0018       READ(5,1001)ZALT,VINFY,RN,TWI,DX,ITW,IPRESS,LLL,LONG,LOW,IMETRC
0019       IF (IMETRC)889,889,890
0020   889 WRITE(6,893)
0021   893 FORMAT(///20X,'NOTE THAT PRINTOUT IS IN ENGLISH UNITS')
0022       GO TO 892
0023   890 WRITE(6,891)
0024   891 FORMAT(///20X,'NOTE THAT PRINTOUT IS IN METRIC UNITS')
0025   892 CALL SPIE(LOW)
0026       IF(LONG-1)870,871,871
0027   871 IF(IMETRC)874,874,875
0028   874 WRITE(6,1113)
0029       GO TO 870
0030   875 WRITE(6,876)
0031       WRITE(6,930)
0032   930 FORMAT(/2X,'HEAT RATES ARE IN WATTS/SQ.METER')
0033   876 FORMAT(///6X,'VISC=NEWTON SEC/SQ.METER'15X,'CP=JOULES/KGM DEGK'/6X
          1,'T OR TREF=DEGK'24X,'RHO OR RHOR=KGM/CU.METER'/6X,'H OR HREF=JOUL
          2E/KGM'14X,'PSI=NEWT/SQ.M'/6X,'TK OR TKREF=JOULE/METER SEC DEGK'6X
          3,'TAUW=NEWTONS/SQ.METER'/6X,'SYMBOL ENDS IN X = LOCAL EXTERNAL-TO-
          4B.LAYER VALUE'/6X,'SYMBOL ENDS IN L = B.LAYER FLOW IS LAMINAR'/
          56X,44HSYMBOL ENDS IN T = B.LAYER FLOW IS TURBULENT//3X,12HDEFINITI
          6ONS-/6X,31HC = LOCAL VEL./FREE STREAM VEL./6X,34HCPCV = GAMMA = SP
          7ECIFIC HEAT RATIO/6X,27HPR OR PREF = PRANDTL NUMBER/6X,29HPSI = H
          8RECOVERY MINUS H WALL/6X,26HZ = COMPRESSIBILITY FACTOR/6X,33HCF =
```

```
     9FRICTION COEFFICIENT AT WALL/6X,24HTAUW = WALL SHEAR STRESS/6X,102MAIN1050
     1HREYX = REYNOLDS NO. BASED ON LOCAL (EXTERNAL-TO-B.LAYER) PROPERTIMAIN1060
     2ES AND SURFACE DIST. FROM STAG. POINT/6X,44HREYMOM  = MOMENTUM THIMAIN1070
     3CKNESS REYNOLDS NUMBER/2X,65H(WHEN REYMOM IS NEG., HEAT RATE IS NEMAIN1080
     4G. SO REYMOM HAS NO MEANING)//6X,57HROMURT = (RHO * MU)WALL  /  (RMAIN1090
     5HO * MU)EXTERNAL TO B.LAYER)                                      MAIN1100
  870 X(1)=0.                                                           MAIN1110
      PXPO(1) = 1.0                                                     MAIN1120
      R(1) = 0.0                                                        MAIN1130
      NPOS=15                                                           MAIN1140
      NTEST4 = 0                                                        MAIN1150
      IZ1 = -4                                                          MAIN1160
      IZ2 = -4                                                          MAIN1170
      IZ3 = -4                                                          MAIN1180
      IZ4 = -4                                                          MAIN1190
      IZ5 = -4                                                          MAIN1200
      IF(IMETRC)877,877,878                                             MAIN1210
  878 ZALTM=ZALT*.3048                                                  MAIN1220
      VINFM=VINFY*.3048                                                 MAIN1230
      RNM=RN*.3048                                                      MAIN1240
      WRITE(6,1060)ZALTM,VINFM,RNM,TWI,NTUN,ITW,IPRESS,LLL,LONG         MAIN1250
      GO TO 879                                                         MAIN1260
  877 WRITE(6,1060)ZALT,VINFY,RN,TWI,NTUN  ,        ITW,IPRESS,LLL,LONG MAIN1270
 1060 FORMAT(/2X,'INIT. CONDITIONS '/2X,'ZALT='E14.6,2X,'VINFY='E14.6,  MAIN1280
     12X,'RN='E14.6,2X,'TWI='E14.6/2X,'NTUN  ='I3,13X  ,                MAIN1290
     2'ITW='I4,3X,'IPRESS='I4/2X,'LLL='I1,3X,'LONG='I1)                 MAIN1300
C  CALCULATE SURFACE COORDINATE AND FLOW DEFLECTION DISTANCES AT EACH STMAIN1310
  879 IF(IPRESS)741,741,740                                             MAIN1320
  740 READ(5,9922)(PXPO(I),I=1,15)                                      MAIN1330
 9922 FORMAT(5E15.6/5E15.6/5E15.6)                                      MAIN1340
  741 ZFT=ZALT                                                          MAIN1350
      I=0                                                               MAIN1360
      IF(ITW-1)3,2,2                                                    MAIN1370
    3 READ(5,9000)  (TW(I),  I=1,15)                                    MAIN1380
 9000 FORMAT(5E15.6/5E15.6/5E15.6)                                      MAIN1390
      GO TO 5                                                           MAIN1400
    2 DO 4  I=1,15                                                      MAIN1410
    4 TW(I)=ITW                                                         MAIN1420
    5 READ(5,9710)XX5,YY5,ALPHA                                         MAIN1430
      IF(IMETRC)880,880,881                                             MAIN1440
  881 XX5M=XX5*.3048                                                    MAIN1450
      YY5M=YY5*.3048                                                    MAIN1460
      ALPHAM=ALPHA/57.295                                               MAIN1470
      WRITE(6,1061)XX5M,YY5M,ALPHAM                                     MAIN1480
      GO TO 882                                                         MAIN1490
  880 WRITE(6,1061)XX5,YY5,ALPHA                                        MAIN1500
 1061 FORMAT(/2X,'INPUT X, Y, ALPHA'/2X,'XX5='E14.6,2X,'YY5='E14.6,2X,  MAIN1510
     1'ALPHA(DEG)='E14.6)                                               MAIN1520
  882 ALPHA=ALPHA/57.295                                                MAIN1530
 9710 FORMAT(3E15.6)                                                    MAIN1540
      RZ=(XX5**2+YY5**2)/(2.*YY5)                                       MAIN1550
      XTHETA=(ATAN(XX5/(RZ-YY5)))                                       MAIN1560
      XXTETA=XTHETA+ALPHA                                               MAIN1570
      DELTET=.1*XTHETA                                                  MAIN1580
      DELX=RZ*DELTET                                                    MAIN1590
      X(1)=0.                                                           MAIN1600
      R(1)=0.                                                           MAIN1610
      DO 7  I=2,11                                                      MAIN1620
      XII=I-1                                                           MAIN1630
      X(I)=XII*DELX                                                     MAIN1640
      ZZ1=(XII*DELTET)/2.                                               MAIN1650
      PHIX(I)=XXTETA-ZZ1                                                MAIN1660
    7 R(I)=2.*RZ*SIN(ZZ1)*SIN(PHIX(I))                                  MAIN1670
      ZZ2=DX*SIN(ALPHA)                                                 MAIN1680
      R(12)=R(11)+ZZ2                                                   MAIN1690
      R(13)=R(12)+ZZ2                                                   MAIN1700
      R(14)=R(13)+ZZ2                                                   MAIN1710
      R(15)=R(14)+ZZ2                                                   MAIN1720
      X(12)=X(11)+DX                                                    MAIN1730
      X(13)=X(12)+DX                                                    MAIN1740
      X(14)=X(13)+DX                                                    MAIN1750
      X(15)=X(14)+DX                                                    MAIN1760
      DO 884 I=1,15                                                     MAIN1770
      IF(IMETRC)5747,5747,883                                           MAIN1780
  883 RRM(I)=R(I)*.3048                                                 MAIN1790
      XXM(I)=X(I)*.3048                                                 MAIN1800
      WRITE(6,5748)RRM(I),XXM(I),I                                      MAIN1810
      GO TO 884                                                         MAIN1820
 5747 WRITE(6,5748)R(I),X(I),I                                          MAIN1830
  884 CONTINUE                                                          MAIN1840
 5748 FORMAT(/2X,'R(I)='E14.6,10X,'X(I)='E14.6,5X,'I='I3)               MAIN1850
      IF(NTUN)1173,6,1173                                               MAIN1860
 1173 READ(5,1002) PINFY,TINFY                                          MAIN1870
      GO TO 1759                                                        MAIN1880
    6 CALL TBLALT       (ZFT,PENG,SPWT,RHO,RHOSLG,VPART,XMFP,ACCG,FREQ, MAIN1890
     1XMU,ETA,THCOND,SMA,TEMPR,HBTU,SS,AMOL)                            MAIN1900
      TINFY=TEMPR/1.8                                                   MAIN1910
      PINFY=PENG                                                        MAIN1920
 1759 PINF=PINFY/2116.2                                                 MAIN1930
      L=1                                                               MAIN1940
      PP=PINF                                                           MAIN1950
      TT=TINFY                                                          MAIN1960
      GO TO 6500                                                        MAIN1970
 6502 HINFY=129.0816*A(8)                                               MAIN1980
      RHOSLG=.002507*A(3)                                               MAIN1990
      RHOINF=RHOSLG                                                     MAIN2000
      SMA=1140.*A(6)                                                    MAIN2010
      XMINFY=VINFY/SMA                                                  MAIN2020
      XMINF=XMINFY                                                      MAIN2030
      GAMINF=A(14)                                                      MAIN2040
      HT=HINFY+(VINFY**2/50123.)                                        MAIN2050
      CON1 = VINFY **2                                                  MAIN2060
      CON2 = RHOSLG * CON1 / PINFY                                      MAIN2070
      CON1 = CON1 /(HINFY * 50123.0)                                    MAIN2080
```

```
      I = 1
      RHORAT=.2
      NSTOP1 = 0
C
C     ITERATION SCHEME FOR PO-PRESSURE AT STAGNATION POINT-EFNS 10-15
C
   10 SAV1 = RHORAT
      PTWO = ((1.0-SAV1)*CON2+1.0)*PINFY
      HTWO = HINFY *((1.0-SAV1**2)*CON1+1.0)
      NSTOP = 0
      NTEST2=1
      GO TO (11,12),I
   11 TTWO = PTWO/RHOSLG * RHORAT /3086.48
      I = 2
      IF(TTWO-15000.0) 12,405,405
  405 TTWO = TTWO/4.0
   12 PTWO = PTWO/2116.2
   13 L=2
      PP=PTWO
      TT=TTWO
      GO TO 6500
    9 HTWO1 =129.0816*A(8)
      DHTWO=HTWO-HTWO1
      NSTOP = NSTOP+1
      IF(ABS(DHTWO/HTWO) - .00005)111,111,110
  110 IJK=110
      IF(NSTOP-25) 200,299,299
  200 IF(NTEST2 - 1) 115,222,115
  222 DTDHTO=1./(.123406*A(4))
  113 TTWO1 = TTWO + DTDHTO * DHTWO
      IF(TTWO1-15000.0)1131,1131,1130
 1130 TTWO1=15000.0
 1131 IF(TTWO1-100.0)112,112,114
  112 DHTWO = DHTWO / 2.0
 1120 IF(ABS(DTDHTO * DHTWO)-1.0)750,750,113
  750 KLM=750
      IF(IZ1)751,751,999
  751 RHORAT = .80 * RHORAT
      IZ1=IZ1+1
      I = 1
      GO TO 10
  114 TTWO3=TTWO
      TTWO=TTWO1
      DHTHR = DHTWO
      NTEST2 = NTEST2 + 1
      IF(TTWO-15000.) 13,13,1140
 1140 TTWO = 15000.
      GO TO 13
  115 TTWO2 =(TTWO3*DHTWO - TTWO *DHTHR)/(DHTWO-DHTHR)
      IF(TTWO2-15000.0)1151,1151,1150
 1150 TTWO2=15000.0
 1151 TTWO3=TTWO
      TTWO = TTWO2
      DHTHR = DHTWO
      IF(TTWO2-100.) 116,116,13
  116 DHTWO = DHTWO / 2.0
      IF(ABS(DHTWO)-1.0) 752,752,115
  752 KLM = 752
      IF(IZ2) 753,753,999
  753 RHORAT = .80*RHORAT
      IZ2 = IZ2 +1
      I = 1
      GO TO 10
  111 RHOTWO =A(3) * .002507
      SRTWO = A(2)
      NSTOP1 = NSTOP1+1
   14 RHORAT = RHOSLG/RHOTWO
      IF(ABS(RHORAT-SAV1)-.0001) 15,15,199
  199 IJK = 199
      IF(NSTOP1-25) 10,299,299
   15 VTWO = RHORAT * VINFY
      CON1 = VTWO * VTWO
      PO = PTWO +(RHOTWO*CON1)/4232.4
      PON = PO
      HTT=HTWO1+CON1/50123.
      NSTOP = 0
   17 TO = TTWO
      NTEST2 = 1
      NTEST3 = 1
      GO TO 18
C
C     ITERATION SCHEME FOR TO-TEMPERATURE AT STAGN. POINT-EFNS 16-20
C
   16 IF (NTEST3.EQ.2) GO TO 170
  165 DTDHO = 1./CPR
  160 TO1 = TO + DTDHO * DHO
      IF (TO1-100.) 161,161,180
  161 DHO = DHO / 2.0
      KLM = 161
      IF(ABS(DTDHO * DHO) - 1.0) 999,999,160
  180 TO3 = TO
      TO = TO1
      DH3 = DHO
      NTEST3 = 2
   18 L=3
      PP=PO
      TT=TO
      GO TO 6500
 6501 HO=129.0816*A(8)
      CPR=.123406*A(4)
      DHO=HTT-HO
      NSTOP = NSTOP+1
      IF(ABS(DHO/HT) - .00005) 20,20,201
  201 IJK=201
```

```
      IF(NSTOP-25)16,299,299
  170 TO2 = (TO3*DHO - TO*DH3) / (DHO - DH3)
      TO1 = TO2
      IF(TO1 - 100.) 171,171,180
  171 DHO = DHO / 2.
      IF(ABS(DHO)-1.0) 172,172,170
  172 KLM=172
      IF(IZ5) 173,173,999
  173 IZ5 = IZ5 +1
      GO TO 170
   20 RHOO = .002507*A(3)
      PRO=A(16)
      CPCVO=A(14)
      CPO=CPR
      TKO=SQRT(TO)
      VISCO=A(10)*TKO*2.209698E-8
      TKO =A(11)  *TKO*3.28521E-7
      SRO=A(2)
      ZTWO = 224.0/VINFY
      ZO=A(9)
      AO=1140.*A(6)
      TET=XXTETA+DELTET
      JX=0
      IF(IMETRC)885,885,886
  886 VI222=VINFY*.3048
      RH222=RHOINF*515.379
      H2222=2324.44*HINFY
      WRITE(6,887)XMINF,VI222,GAMINF,RH222,H2222,PINF,TINFY
  887 FORMAT(/2X,'FREE STREAM CONDITIONS'/2X,'XMINF='E14.6,2X,'VINFY='E1
     14.6,2X,'GAMINF='E14.6,2X,'RHOINF='E14.6/2X,'HINFY='E14.6,2X,'PINF=
     2'E14.6,1X,'(ATMOS.)'2X,'TINFY='E14.6)
      GO TO 888
  885 WRITE(6,4471)XMINF,VINFY,GAMINF,RHOINF,HINFY,PINF,PINFY,TINFY
 4471 FORMAT(/2X,'FREE STREAM CONDITIONS'/2X,'XMINF='E14.6,2X,'VINFY='E1
     14.6,2X,'GAMINF='E14.6,2X,'RHOINF='E14.6/2X,'HINFY='E14.6,2X,'PINF=
     2'E14.6,1X,'(ATMOS)'2X,'PINFY='E14.6,1X,'(PSF)'/2X,'TINFY='E14.6)
  888 CONTINUE
      DO 794  I=1,11
      TET=TET-DELTET
      X24=1./XMINF
      IF(TET)4061,4061,4060
 4061 TETS=ARSIN(X24)
      P(11)=PINF*((2.*GAMINF*(XMINF**2)*(X24**2)-(GAMINF-1.))/(GAMINF+1.
     1))
      V(11)= VINFY*COS(TETS)
      H(11)=HT-(V(11)**2/50123.)
      TESS=H(11)/.432
      IF(LLL-1)4050,4051,4051
 4050 J=.TRUE.
      GO TO 4052
 4051 J=.FALSE.
 4052 IITER=6
      PP=P(11)
      I75=4052
      IF(PP-PINF)4078,4079,4079
 4078 PP=.8*PINF
 4079 TT=TESS
      HC=H(11)
      CALL ITER(PP,TT,HC,IITER,J)
      IF(IITER.LE.0) GO TO 4053
      GO TO 4054
 4053 WRITE(6,4070) I75
 4070 FORMAT(/2X,'FAILURE IN ITER CALLED BY MAIN,STMT NO.='2X,I4)
      GO TO 1
 4054 T(11)=TT
      PS(11)=PP
      CALL ANAPRP (PP,TT,&1111)
      GO TO 4062
 4060 PINFY=PINF
      CALL CONSHK (TET,XMINF,VINFY,GAMINF,RHOINF,HINFY,PINFY,LLL,JX,PP,
     1TT,TETS,IZ29,K51)
      JX=1
      IF(K51)6363,6363,6364
 6363 GO TO 1
 6364 CONTINUE
      IF(IZ29)790,790,791
  790 WRITE(6,792)
  792 FORMAT(/2X,'FAILURE IN ITER CALLED BY CONSHK')
      GO TO 1
  791 CONTINUE
      CALL ANAPRP(PP,TT,&1111)
      PS(I)=PP
 4062 SRS(I)=A(2)
      TS(I)=TT
      ZS(I)=A(9)
      CPS(I)=.123406*A(4)
      RHOS(I)=.002507*A(3)
      PRS(I)=A(16)
      AS(I)=1140.*A(6)
      VISCS(I)=A(10)*TT**.5*2.20968E-8
      TKS(I)=A(11)*TT**.5*3.28521E-7
      HS(I)=129.0816*A(8)
      VS(I)=224.*SQRT(HT-HS(I))
C  TETSHK = SHOCK ANGLE IN DEGREES
      TETSHK(I)=TETS*57.295
      CPCVS(I) =A(14)
      XMS(I) = VS(I)/AS(I)
      IF(LONG-1)794,895,895
  895 IF(IMETRC)897,897,896
  896 TETSM(I)=TETSHK(I)/57.295
      WRITE(6,795)I,I,TETSM(I),PS(I) ,TS(I),SRS(I)
      GO TO 794
  897 WRITE(6,795)I,I,TETSHK(I),PS(I),TS(I),SRS(I)
  794 CONTINUE
```

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  795 FORMAT(/2X,'I='I2/
     1       2X,'THETA SHOCK FOR POINT'1X,I2, 1X,'='E14.6/2X,'PS(1)='
     1E15.6,2X,'TS(1)='E15.6,2X,'SPS(1)='F15.6)
C   END OF CONSHK CALCULATIONS FOR POINTS 1 - 10
C   PROCEED TO SUBROUTINE RGPM AND GET LOCAL PROP.S AT STA.S
C
  441 IF(IPRESS-1)361,360,360
  360 SRCON=SRS(1)
      WRITE(6,365)SRS(1)
  365 FORMAT(/2X,'ISENTROPIC EXPANSION TO INPUT PRESSURE AT (PT.1) ENTRO
     1PY = 'E14.6)
      GO TO 9921
  361 P1=PS(1)
      P(1)=PS(1)
      T1=TS(1)
      T(1)=TS(1)
      SR1=SRS(1)
      SR(1)=SRS(1)
      TK(1)=TKS(1)
      VISC(1)=VISCS(1)
      PR(1)=PRS(1)
      Z(1)=ZS(1)
      V(1)=VS(1)
      CPCV(1)=CPCVS(1)
      AA(1)=AS(1)
      RHO(1)=RHOS(1)
      XM(1)=XMS(1)
      CP(1)=CPS(1)
      H(1)=HS(1)
       A1=AS(1)
      RHO1=RHOS(1)
      CP1=CPS(1)
      H1=HS(1)
      V7=VS(1)
      XM1=XMS(1)
      CPCV1=CPCVS(1)
      VISC1=VISCS(1)
      TK1=TKS(1)
      DELVX=(VINFY-VS(1))/100.
      DXXX=DELVX
      DTHETA=DELTET
      GO TO 9920
C   IF PXPO IS INPUT,GET PRESS. & ENTROPY FOR EACH STATION
 9921 DO 8700  I=1,15
      P(I)=PXPO(I)*PO
 8700 SR(I)=SRS(1)
      GO TO 8740
 9920 DO 797  I=1,10
      IB=1
      CALL RGPM (P1,T1,SR1,V7,A1,RHO1,CP1,H1,VISC1,TK1,DTHETA,HT,
     1CPCV1,XM1,XXTETA,DELVX,ALPHA,IB,P2,T2,K50)
      IF(K50)2970,2970,2971
 2970 GO TO 1
 2971 CONTINUE
      P(I+1)=P2
      T(I+1)=T2
      D11=SQRT(T2)
      TK(I+1)=D11*A(11)*3.28512E-7
      VISC(I+1)=D11*A(10)*2.209698E-8
      PR(I+1)=A(16)
      Z(I+1)=A(9)
      SR(I+1)=SRS(I+1)
      H(I+1)=129.0816*A(3)
      V(I+1)=224.*SQRT(HT-H(I+1))
      CPCV(I+1)=A(14)
      AA(I+1)=1140.*A(6)
      RHO(I+1)=.002507*A(3)
      XM(I+1)=V(I+1)/AA(I+1)
      CP(I+1)=.123406*A(4)
      P1=P(I+1)
      T1=T(I+1)
      SR1=SRS(I+1)
      V7=V(I+1)
      DELVX=DXXX
      A1=AA(I+1)
      RHO1=RHO(I+1)
      CP1=CP(I+1)
      H1=H(I+1)
      CPCV1=CPCV(I+1)
      XM1=XM(I+1)
      VISC1=VISC(I+1)
  797 TK1=TK(I+1)
C
C   NOW WE HAVE THE LOCAL FLOW PROPERTIES FOR POINTS 1 - 11
C
      DO 798  I=1,11
      IF (PXPO(I)-.009)8702,8702,798
 8702 PXPO(I)=.009
  798 PXPO(I)=P(I)/PO
      IF(ALPHA)861,860,861
  861 P(12)=P(11)
      P(13)=P(11)
      P(14)=P(11)
      P(15)=P(11)
      GO TO 862
  860 P(12)=(PINFY+P(11))/2.
      P(13)=(PINFY+P(12))/2.
      P(14)=(PINFY+P(13))/2.
      P(15)= PINFY
  862 T(12)=T(11)
      T(13)=T(11)
      T(14)=T(11)
      T(15)=T(11)
      SR(12)=SR(11)
```

```
      SR(13)=SR(11)
      SR(14)=SR(11)
      SR(15)=SR(11)
      PXPO(12)=P(12)/PO
      PXPO(13)=P(13)/PO
      PXPO(14)=P(14)/PO
      PXPO(15)=P(15)/PO
      DO 520 I=12,15
      TK(I)=TK(11)
      VISC(I)=VISC(11)
      PR(I)=PR(11)
      Z(I)=Z(11)
      SR(I)=SR(11)
      H(I)=H(11)
      V(I)=V(11)
      CPCV(I)=CPCV(11)
      AA(I)=AA(11)
      RHO(I)=RHO(11)
      XM(I)=XM(11)
  520 CP(I)=CP(11)
      GO TO 371
 8740 TQ1=TS(1)
      DTHETA=DELTET
      XXTETA=XXTETA+DTHETA
      DO 43  I=1,10
      COUNT=I
      PHI(I)=XXTETA-COUNT*DTHETA
      IF (ALPHA)40,40,41
   40 QRATT(I)=1.
      QRATL(I)=1.
      GO TO 44
   41 RR1=2.*TAN(PHI(I))
      RR2=TAN(PHI(I)-ALPHA)
      RR3=RR1/RR2
      RR4=1.+RR3
      RR5=RR4/3.
      QRATL(I)=SQRT(RR5)
      RR6=RR1/2.
      RR7=RR6/RR2
      XK22=1.25*RR7
      RR8=(1.+XK22)**.2
   43 QRATT(I)=.85*RR8
   44 CONTINUE
      DO 45 I=11,15
      QRATL(I)=QRATL(10)
   45 QRATT(I)=QRATT(10)
      TESTA=0.
      DO 378 I=1,15
      TQ=TQ1
      PQ=P(I)
      CALL ANAPRP (PQ,TQ)
      SRTRY=A(2)
      DSR=SRCON-SRTRY
      IF(ABS(DSR/SRCON)-.0005)370,370,372
  372 TZ1=.99*TQ
      TZ2=1.01*TQ
      CALL ANAPRP (PQ,TZ1)
      SRZ1=A(2)
      CALL ANAPRP (PQ,TZ2)
      SRZ2=A(2)
      DT=TZ2-TZ1
      DSRZ=SRZ2-SRZ1
      DTDSRZ=DT/DSRZ
      TQ1=DTDSRZ*DSR+TQ1
      TESTA=TESTA+1.
      IF(TESTA-30.)375,375,376
  376 WRITE(6,377)
  377 FORMAT(/2X,'FAILURE IN CONST. SR EXPANSION TO LOCAL PRESS.  GO TO
     1NEXT PROBLEM')
      GO TO 1
  375 CONTINUE
  370 T(I)=TQ1
      SR(I)=SRS(1)
      TK(I)=A(11)*T(I)**.5*3.28512E-7
      VISC(I)=A(10)*T(I)**.5*2.209698E-8
      PR(I)=A(16)
      Z(I)=A(9)
      H(I)=129.0816*A(8)
      V(I)=224.*SQRT(HT-H(I))
      CPCV(I)=A(14)
      AA(I)=1140.*A(6)
      RHO(I)=.002507*A(3)
      XM(I)=V(I)/AA(I)
  378 CP(I)=.123406*A(4)
  371 IF(LONG-1)8701,440,440
  440 DO 1705 I=1,15
 1705 WRITE(6,1700)I,P(I),T(I),SR(I),QRATL(I),QRATT(I)
 1700 FORMAT(/2X,'I='I2,3X,'P(I)='E14.6,3X,'T(I)='E14.6,3X,
     1'SR(I)='E14.6/3X,'QRATL(I)='E14.6,3X,'QRATT(I)='E14.6)
C     GET STAGNATION POINT DATA
 8701 TT=TWI
      PP=PO
      CALL ANAPRP (PP,TT,&1111)
      TWO=TWI
      HWO=129.0816*A(8)
      RHOWO=.002507*A(3)
      VISCWO=A(10)*(TT**.5)*2.209698E-8
      DVDXO=(1./RN)*SQRT((4232.4*(PO-PINF))/RHOO)
      CPWO=.123406*A(4)
      QSTPT=.76*(1./PRO**.6)*((RHOWO*VISCWO)**.1)*((RHOO*VISCO)**.4)*(HO
     1-HWO)*SQRT(DVDXO)*32.174
      HREFO=.5*(HO+HWO)
      TEST=HREFO/.432
      HZ=HREFO
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0515        TZ=TEST                                                              MAIN6250
0516        PZ=PO                                                                MAIN6260
0517        J=.TRUE.                                                             MAIN6270
0518        ILL=1                                                                MAIN6280
0519        CALL ITER (PZ,TZ,HZ,ILL,J)                                           MAIN6290
0520        TREFO=TZ                                                             MAIN6300
0521        VISCRO=A(10)*TZ**.5*2.209698F-8                                      MAIN6310
0522        TKREFO=A(11)*TZ**.5*3.28512F-7                                       MAIN6320
0523        ZREFO=A(9)                                                           MAIN6330
0524        PRREFO=A(16)                                                         MAIN6340
0525        CPREFO=.123406*A(4)                                                  MAIN6350
0526        RHORO=.002507*A(3)                                                   MAIN6360
0527        CPCVRO=A(14)                                                         MAIN6370
0528        IF(IMETRC)900,900,901                                                MAIN6380
0529    901 HREFOM=HREFO*2324.4444                                               MAIN6390
0530        VISROM=VISCRO*47.880258                                              MAIN6400
0531        TKROM=TKREFO*43.2394                                                 MAIN6410
0532        CPRFOM=CPREFO*2324.4444                                              MAIN6420
0533        RHOROM=RHORO*515.379                                                 MAIN6430
0534        RN2M=RN*.3048                                                        MAIN6440
0535        RHOOM=RHOO*515.379                                                   MAIN6450
0536        TKOM=TKO*43.23943                                                    MAIN6460
0537        VISCOM=VISCO*47.880258                                               MAIN6470
0538        CPOM=CPO*2324.4444                                                   MAIN6480
0539        AOM=AO*.3048                                                         MAIN6490
0540        VISWOM=VISCWO*47.880258                                              MAIN6500
0541        HWOM=HWO*2324.4444                                                   MAIN6510
0542        CPWOM=CPWO*2324.4444                                                 MAIN6520
0543        QSTPTM=QSTPT*11348.9                                                 MAIN6530
0544        HOM=HO*2324.4444                                                     MAIN6540
0545        HTM=HT*2324.4444                                                     MAIN6550
0546        RHOWOM=RHOWO*515.379                                                 MAIN6560
0547        WRITE(6,800)HREFOM,TREFO,VISROM,TKROM,ZREFO,PRREFO,CPRFOM,RHOROM,    MAIN6570
           1CPCVRO,RN2M,TO,PO   ,RHOOM,SRO,TKOM,VISCOM,DVDXO,ZO,CPOM,AOM,TWO,    MAIN6580
           2VISWOM,HWOM,CPWOM,PRO,QSTPTM,HOM,HTM,RHOWOM                          MAIN6590
0548        GO TO 902                                                            MAIN6600
0549    900 WRITE(6,800)HREFO,TREFO,VISCRO,TKREFO,ZREFO,PRREFO,CPREFO,RHORO,     MAIN6610
           1CPCVRO,RN,    TO,PO,RHOO,SRO,TKO,VISCO,DVDXO,ZO,CPO,AO,TWO,VISCWO,   MAIN6620
           2HWO,CPWO,PRO,QSTPT,HO,HT,RHOWO                                       MAIN6630
0550    800 FORMAT(/2X,'STAGNATION POINT DATA FOR SPHERICAL NOSE'//2X,'HREFO =MAIN6640
           1'E12.6,2X,'TREFO ='E12.6,2X,'VISCRO='E12.6,2X,'TKREFO='E12.6/        MAIN6650
           22X,'ZREFO ='E12.6,2X,'PRREFO='E12.6,2X,'CPREFO='E12.6,2X,'RHORO ='MAIN6660
           3E12.6/2X,'CPCVRO='E12.6,2X,'RN     ='E12.6,2X,'TO     ='E12.6/2X,    MAIN6670
           4'PO     ='E12.6,2X,'RHOO  ='E12.6,2X,'SRO   ='E12.6,2X,'TKO    ='E12MAIN6680
           5.6/2X,'VISCO ='E12.6,2X,'DVDXO ='E12.6,2X,'ZO     ='E12.6,2X,        MAIN6690
           6'CPO    ='E12.6/2X,'AO     ='E12.6,2X,'TWO    ='E12.6,2X,'VISCWO='E12MAIN6700
           7.6,2X,'HWO   ='E12.6/2X,'CPWO  ='E12.6,2X,'PRO    ='E12.6/10X,'QSTPMAIN6710
           8T='E14.6,2X,'= NOSE STAGNATION POINT HEAT RATE'/                     MAIN6720
           92X,'HO='E14.6,5X,'HT='E14.6,5X,'RHOWO='E14.6)                        MAIN6730
      C      THIS COMPLETES THE CALCULATION OF THE SPHERICAL (REFERENCE) NOSE    MAIN6740
      C      STAGNATION POINT DATA                                               MAIN6750
      C                                                                          MAIN6760
      C      NOW GET ALL REFERENCE QUANTITIES FOR POINTS 1 THROUGH 15            MAIN6770
      C                                                                          MAIN6780
0551    902 CONTINUE                                                             MAIN6790
0552        XINT=0.                                                              MAIN6800
0553        DO 841 I=1,15                                                        MAIN6810
0554        CALL ANAPRP (P(I),TW(I),&1111)                                       MAIN6820
0555        HW(I)=129.0816*A(8)                                                  MAIN6830
0556        CPW(I)=.123406*A(4)                                                  MAIN6840
0557        RHOW(I)=.002507*A(3)                                                 MAIN6850
0558        VISCW(I)=A(10)*TW(I)**.5*2.209698E-8                                 MAIN6860
0559        HREFX(I)=(H(I)+HW(I))*.5+.22*SQRT(PR(I))*(HO-H(I))                   MAIN6870
0560        TEST=HREFX(I)/.432                                                   MAIN6880
0561        TR=TEST                                                              MAIN6890
0562        J=.TRUE.                                                             MAIN6900
0563        ILL=2                                                                MAIN6910
0564        HR=HREFX(I)                                                          MAIN6920
0565        CALL ITER (P(I),TR,HR,ILL,J)                                         MAIN6930
0566        PRREFX(I)=A(16)                                                      MAIN6940
0567        TKREFX(I)=A(11)*TR**.5*3.28512E-7                                    MAIN6950
0568        VISCRX(I)=A(10)*TR**.5*2.209698E-8                                   MAIN6960
0569        RHORX(I)=.002507*A(3)                                                MAIN6970
0570        TREFX(I)=TR                                                          MAIN6980
0571        ZREFX(I)=A(9)                                                        MAIN6990
0572        CPCVRX(I)=A(14)                                                      MAIN7000
0573        PSIL(I)=H(I)*(1.-SQRT(PRREFX(I)))+HO*(SQRT(PRREFX(I)))-HW(I)         MAIN7010
0574        PSIT(I)=H(I)*(1.-PRREFX(I)**.333)+HO*PRREFX(I)**.333-HW(I)           MAIN7020
0575        IF(LONG-1)841,802,802                                                MAIN7030
0576    802 IF(IMETRC)910,910,911                                                MAIN7040
0577    911 HW7(I)=HW(I)*2324.4444                                               MAIN7050
0578        CPW7(I)=CPW(I)*2324.4444                                             MAIN7060
0579        HREF7(I)=HREFX(I)*2324.4444                                          MAIN7070
0580        TKREF7(I)=TKREFX(I)*43.2394                                          MAIN7080
0581        VISRX7(I)=VISCRX(I)*47.880258                                        MAIN7090
0582        RHORX7(I)=RHORX(I)*515.379                                           MAIN7100
0583        TKX7(I)=TK(I)*43.2394                                                MAIN7110
0584        VISCX7(I)=VISC(I)*47.880258                                          MAIN7120
0585        HX7(I)=H(I)*2324.4444                                                MAIN7130
0586        VX7(I)=V(I)*.3048                                                    MAIN7140
0587        AAX7(I)=AA(I)*.3048                                                  MAIN7150
0588        RHOX7(I)=RHO(I)*515.379                                              MAIN7160
0589        CPX7(I)=CP(I)*2324.4444                                              MAIN7170
0590        WRITE(6,803)I,HW7(I),CPW7(I),HREF7(I),PRREFX(I),TKREF7(I),VISRX7(IMAIN7180
           1),RHORX7(I),TREFX(I),ZREFX(I),CPCVRX(I),  P(I),T(I),TKX7(I),VISCX7MAIN7190
           2(I),PR(I),Z(I),SR(I),HX7(I),VX7(I),CPCV(I),AAX7(I),RHOX7(I),XM(I),MAIN7200
           3CPX7(I)                                                              MAIN7210
0591        GO TO 841                                                            MAIN7220
0592    910 WRITE(6,803)I,HW(I),CPW(I),HREFX(I),PRREFX(I),TKREFX(I),VISCRX(I),MAIN7230
           1RHORX(I),TREFX(I),ZREFX(I),CPCVRX(I),P(I),T(I),TK(I),VISC(I),        MAIN7240
           2PR(I),Z(I),SR(I),H(I),V(I),CPCV(I),AA(I),RHO(I),XM(I),CP(I)          MAIN7250
0593    803 FORMAT(//2X,'WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW MAIN7260
           1PROPERTIES AT STATION = 'I2/2X,'HW(I)     ='E12.6,2X,'CPW(I)   ='    MAIN7270
           2E12.6,2X,'HREFX(I) ='E12.6,2X,'PRREFX(I)='E12.6/2X,'TKREFX(I)='      MAIN7280
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                 1F14.6/5X,'OXQOLAM='E14.6,3X,'OXQOTURB='E14.6,3X,'CFLAM='E14.6,3X, MAIN8330
                 2'CFTURB='E14.6/2X,'TAULAM='E14.6,3X,'TAUTURB='E14.6,3X,'CFRENU='   MAIN8340
                 3E14.6,3X,'ROMURT='E14.6/3X,'REX='E14.6,3X,'REYMOM='E14.6/          MAIN8350
                 43X,'HRECL='E14.6,5X,'HRECT='F14.6)                                 MAIN8360
 0685       6500 IF(TT-100.)9810,9810,9811                                           MAIN8370
 0686       9810 TT=200.                                                             MAIN8380
 0687       9811 CALL ANAPRP (PP,TT,&1111)                                           MAIN8390
 0688            GO TO(6502,9,6501),L                                                MAIN8400
 0689        299 WRITE (6,1010)IJK                                                   MAIN8410
 0690       1010 FORMAT(41H NON-CONVERGENCE OF ITERATION SCHEME IJK=I3)              MAIN8420
 0691            GO TO 1                                                             MAIN8430
 0692        999 WRITE (6,9999)KLM                                                   MAIN8440
 0693       9999 FORMAT(47H TEMPERATURE OUTSIDE RANGE OF MOLLIER DATA KLM=I3)        MAIN8450
 0694            GO TO 1                                                             MAIN8460
 0695       1000 FORMAT (I2, 18A4)                                                   MAIN8470
 0696       1001 FORMAT(5E13.8,I4,5I1)                                               MAIN8480
 0697       1002 FORMAT (2E15.8)                                                     MAIN8490
 0698       1112 FORMAT (1H1/27X,18A4)                                               MAIN8500
 0699       1113 FORMAT( ////6X,17HVISC=LB-SEC/SQ.FT,24X,15HCP=BTU/LB-DEG.K/6X,17HTMAIN8510
                 1 OR TREF = DEG.K,26X,25HRHO OR RHOR = SLUGS/CU.FT/6X,18HH OR HREF MAIN8520
                 2= BTU/LB,25X,12HPSI = BTU/LB/6X,30HTK OR TKREF = BTU/FT-SEC-DEG.K MAIN8530
                 313X,15HTAUW = LB/SQ.FT//6X,50HSYMBOL ENDS IN X = LOCAL EXTERNAL-TOMAIN8540
                 4-B.LAYER VALUE/6X,42HSYMBOL ENDS IN L = B.LAYER FLOW IS LAMINAR/  MAIN8550
                 56X,44HSYMBOL ENDS IN T = B.LAYER FLOW IS TURBULENT//3X,12HDEFINITIMAIN8560
                 6ONS-/6X,31HC = LOCAL VEL./FREE STREAM VEL./6X,34HCPCV = GAMMA = SPMAIN8570
                 7ECIFIC HEAT RATIO/6X,27HPR OR PREF = PRANDTL NUMBER/6X,29HPSI = H MAIN8580
                 8RECOVERY MINUS H WALL/6X,26HZ = COMPRESSIBILITY FACTOR/6X,33HCF = MAIN8590
                 9FRICTION COEFFICIENT AT WALL/6X,24HTAUW = WALL SHEAR STRESS/6X,102MAIN8600
                 1HREYX = REYNOLDS NO. BASED ON LOCAL (EXTERNAL-TO-B.LAYER) PROPERTIMAIN8610
                 2ES AND SURFACE DIST. FROM STAG. POINT/6X,44HREYMOM  = MOMENTUM THIMAIN8620
                 3CKNESS REYNOLDS NUMBER/2X,65H(WHEN REYMOM IS NEG., HEAT RATE IS NEMAIN8630
                 4G. SO REYMOM HAS NO MEANING)//6X,57HROMURT = (RHO * MU)WALL  /  (RMAIN8640
                 5HO * MU)EXTERNAL TO B.LAYER)                                      MAIN8650
 0700       8005 STOP                                                                MAIN8660
 0701            END                                                                 MAIN8670
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COMMON BLOCK /DRRAY / MAP SIZE 84

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
QRATL	0	QRATT	3C	PHI	78				

COMMON BLOCK /ARRAY / MAP SIZE 5C

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
A	0								

SUBPROGRAMS CALLED

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
IBCOM#	4EC	SPIE	4F0	TBLALT	4F4	ITER	4F8	ANAPRP	4FC
CONSHK	500	FRXPR#	504	RGPM	508	ATAN	50C	SIN	510
SQRT	514	ARSIN	518	COS	51C	TAN	520		

SCALAR MAP

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
NTUN	7B4	I	7B8	ZALT	7BC	VINFY	7C0	RN	7C4
TWI	7C8	DX	7CC	ITW	7D0	IPRESS	7D4	LLL	7D8
LONG	7DC	LOW	7E0	IMETRC	7E4	NPOS	7E8	NTEST4	7EC
IZ1	7F0	IZ2	7F4	IZ3	7F8	IZ4	7FC	IZ5	800
ZALTM	804	VINFM	808	RNM	80C	ZFT	810	XX5	814
YY5	818	ALPHA	81C	XX5M	820	YY5M	824	ALPHAM	828
RZ	82C	XTHETA	830	XXTETA	834	DELTCT	838	DELX	83C
XII	840	ZZ1	844	ZZ2	848	PINFY	84C	TINFY	850
PENG	854	SPWT	858	RHOSLG	85C	VPART	860	XMFP	864
ACCG	868	FREQ	86C	XMU	870	ETA	874	THCOND	878
SMA	87C	TEMPR	880	HBTU	884	SS	888	AMOL	88C
PINF	890	L	894	PP	898	TT	89C	HINFY	8A0
RHOINF	8A4	XMINFY	8A8	XMINF	8AC	GAMINF	8B0	HT	8B4
CON1	8B8	CON2	8BC	RHORAT	8C0	NSTOP1	8C4	SAV1	8C8
PTWO	8CC	HTWO	8D0	NSTOP	8D4	NTEST2	8D8	TTWO	8DC
HTWOI	8E0	DHTWO	8E4	IJK	8E8	DTDHTO	8EC	TTWO1	8F0
KLM	8F4	TTWO3	8F8	DHTHR	8FC	TTWO2	900	RHOTWO	904
SRTWO	908	VTWO	90C	PO	910	PON	914	HTT	918
TO	91C	NTEST3	920	DTDHO	924	CPR	928	TO1	92C
DHO	930	TO3	934	DH3	938	HO	93C	TO2	940
RHOO	944	PRO	948	CPCVO	94C	CPO	950	TKO	954
VISCO	958	SRO	95C	ZTWO	960	ZO	964	AO	968
TET	96C	JX	970	VI222	974	RH222	978	H2222	97C
X24	980	TETS	984	TESS	988	J	98C	IITER	990
I75	994	HC	998	IZ29	99C	K51	9A0	SRCON	9A4
P1	9A8	T1	9AC	SR1	9B0	A1	9B4	RHO1	9B8
CP1	9BC	H1	9C0	V7	9C4	XM1	9C8	CPCV1	9CC
VISC1	9D0	TK1	9D4	DELVX	9D8	DXXX	9DC	DTHETA	9E0
I8	9E4	P2	9E8	T2	9EC	K50	9F0	DII	9F4
TQ1	9F8	COUNT	9FC	RR1	A00	RR2	A04	RR3	A08
RR4	A0C	RR5	A10	RR6	A14	RR7	A18	XK22	A1C
RR8	A20	TESTA	A24	TQ	A28	PQ	A2C	SRTRY	A30
DSR	A34	TZ1	A38	TZ2	A3C	SRZ1	A40	SRZ2	A44
DT	A48	DSRZ	A4C	DTDSRZ	A50	TWO	A54	HWO	A58
RHOWO	A5C	VISCWO	A60	DVDXD	A64	CPWO	A68	QSTPT	A6C
HREFO	A70	TEST	A74	HZ	A78	TZ	A7C	PZ	A80
ILL	A84	TREFO	A88	VISCRO	A8C	TKREFO	A90	ZREFO	A94
PRREFO	A98	CPREFO	A9C	RHORO	AA0	CPCVRO	AA4	HREFOM	AA8
VISROM	AAC	TKROM	AB0	CPRFOM	AB4	RHOROM	AB8	RN2M	ABC
RHOOM	AC0	TKOM	AC4	VISCOM	AC8	CPOM	ACC	AOM	AD0
VISWOM	AD4	HWOM	AD8	CPWOM	ADC	QSTPTM	AE0	HOM	AE4
HTM	AE8	RHOWOM	AEC	XINT	AF0	TR	AF4	HR	AF8
DAXX	AFC	XD	B00	XRO1	B04	XRO2	B08	DRO	B0C
XVIS1	B10	XVIS2	B14	DVIS	B18	XV1	B1C	XV2	B20
DV	B24	XR1	B28	XR2	B2C	DR	B30	K	B34
DINT	B38	II	B3C	F	B40	HXSTAR	B44	CB1	B48
CB2	B4C	REX	B50	Z25	B54	Z26	B58	HOSTAR	B5C
HORAT	B60	Z27	B64	Z28	B68	Z29	B6C	QXQOL	B70
QLOCL	B74	CX1	B78	CX2	B7C	CX3	B80	CX4	B84

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     3E12.6,2X,'VISCRX(I)='E12.6,2X,'RHORX(I) ='E12.6,2X,'TREFX(I) ='     MAIN7290
     4E12.6/2X,'ZREFX(I) ='E12.6,2X,'CPCVRX(I)='E12.6,2X,'PX(I)    ='     MAIN7300
     5E12.6,2X,'TX(I)    ='E12.6/2X,'TKX(I)    ='E12.6,2X,'VISCX(I) ='     MAIN7310
     6E12.6,2X,'PRX(I)   ='E12.6,2X,'ZX(I)     ='E12.6/2X,'SRX(I)   ='     MAIN7320
     7E12.6,2X,'HX(I)    ='E12.6,2X,'VX(I)     ='E12.6,2X,'CPCVX(I) ='     MAIN7330
     8E12.6/2X,'AAX(I)   ='E12.6,2X,'RHOX(I)   ='E12.6,2X,'XM(I)    ='     MAIN7340
     9E12.6,2X,'CPX(I)   ='E12.6)                                         MAIN7350
  841 CONTINUE                                                            MAIN7360
      DO 801 I=1,14                                                       MAIN7370
      DAXX=X(I+1)-X(I)                                                    MAIN7380
      XD=DAXX/20.                                                         MAIN7390
      XRO1=RHORX(I)                                                       MAIN7400
      XRO2=RHORX(I+1)                                                     MAIN7410
      DRO=((XRO2-XRO1)/DAXX)*XD                                           MAIN7420
      XVIS1=VISCRX(I)                                                     MAIN7430
      XVIS2=VISCRX(I+1)                                                   MAIN7440
      DVIS=((XVIS2-XVIS1)/DAXX)*XD                                        MAIN7450
      XV1=V(I)                                                            MAIN7460
      XV2=V(I+1)                                                          MAIN7470
      DV=((XV2-XV1)/DAXX)*XD                                              MAIN7480
      XR1=R(I)                                                            MAIN7490
      XR2=R(I+1)                                                          MAIN7500
      DR=((XR2-XR1)/DAXX)*XD                                              MAIN7510
      R1(1)=XR1                                                           MAIN7520
      V1(1)=XV1                                                           MAIN7530
      RO1(1)=XRO1                                                         MAIN7540
      VIS1(1)=XVIS1                                                       MAIN7550
      DO 810 K=1,20                                                       MAIN7560
      RO2(K)=RO1(K)+DRO                                                   MAIN7570
      RO1(K+1)=RO2(K)                                                     MAIN7580
      VIS2(K)=VIS1(K)+DVIS                                                MAIN7590
      VIS1(K+1)=VIS2(K)                                                   MAIN7600
      V2(K)=V1(K)+DV                                                      MAIN7610
      V1(K+1)=V2(K)                                                       MAIN7620
      R2(K)=R1(K)+DR                                                      MAIN7630
      R1(K+1)=R2(K)                                                       MAIN7640
      RO(K)=(RO2(K)+RO1(K))/2.                                            MAIN7650
      VIS2(K)=(VIS2(K)+VIS1(K))/2.                                        MAIN7660
      V2(K)=(V2(K)+V1(K))/2.                                              MAIN7670
      R2(K)=(R2(K)+R1(K))/2.                                              MAIN7680
      DINT=((RO(K)*VIS2(K))/(RHOO*VISCO))*(V2(K)/VINFY)*(R2(K)**2)        MAIN7690
     1*XD                                                                 MAIN7700
  810 XINT=XINT+DINT                                                      MAIN7710
      II=I+1                                                              MAIN7720
      F=(RHORX(II)/RHOO)*(V(II)/VINFY)*R(II)                              MAIN7730
C                                                                         MAIN7740
      HXSTAR=F/(SQRT(XINT))                                               MAIN7750
      CB1=SQRT(PRREFX(II))                                                MAIN7760
      CB2=(PRREFX(II)**.3333)                                             MAIN7770
      HRECL(II)=H(II)*(1.-CB1)+HO*CB1                                     MAIN7780
      HRECT(II)=H(II)*(1.-CB2)+HO*CB2                                     MAIN7790
      REX=RHO(II)*V(II)*X(II)/VISC(II)                                    MAIN7800
      Z25=4*DVDXO*(RHORO/RHOO)                                            MAIN7810
      Z26=VINFY*(VISCRO/VISCO)                                            MAIN7820
      HOSTAR=SQRT(Z25/Z26)                                                MAIN7830
      HORAT=HXSTAR/HOSTAR                                                 MAIN7840
      Z27=TKREFX(II)/TKREFO                                               MAIN7850
      Z28=(HRECL(II)-HW(II))/(HO-HWO)                                     MAIN7860
      Z29=CPWO/CPW(II)                                                    MAIN7870
      QXQOL=Z27*HORAT*Z28*Z29                                             MAIN7880
      QLOCL=QXQOL*QSTPT                                                   MAIN7890
      CX1=(1.-CB2)*H(II)+(CB2*HO)-HW(II)                                  MAIN7900
      CX2=(RHORX(II)*V(II))**.8                                           MAIN7910
      CX3=TKREFX(II)**.6667                                               MAIN7920
      CX4=.03*(32.174**.3333)*(2.**.2)                                    MAIN7930
      XNUM5=CX1*CX2*CX3*CX4                                               MAIN7940
      CX5=VISCRX(II)**.46667                                              MAIN7950
      CX6=CPREFO**.6667*(X(II)**.2)                                       MAIN7960
      XDEN5=CX5*CX6                                                       MAIN7970
      QLOCT=(XNUM5/XDEN5)*QRATT(II)                                       MAIN7980
      QXQOT=QLOCT/QSTPT                                                   MAIN7990
      CTT=PRREFX(II)**.6667                                               MAIN8000
      CFLAM=(2.*QLOCL*CTT)/(RHO(II)*V(II)*PSIL(II)*32.174)                MAIN8010
      CFTURB=(2.*QLOCT*CTT)/(RHO(II)*V(II)*PSIT(II)*32.174)               MAIN8020
      TAULAM=.5*CFLAM*RHO(II)*V(II)**2                                    MAIN8030
      TAUTUR=.5*CFTURB*RHO(II)*(V(II)**2)                                 MAIN8040
      CFRENU=(CFLAM*REX*TK(II)*PSIL(II))/(QLOCL*X(II)*CP(II))             MAIN8050
      IF(CFRENU-2.)815,815,816                                            MAIN8060
  815 FPRIME=.0508*(CFRENU**2)+.1332*CFRENU                               MAIN8070
      GO TO 817                                                           MAIN8080
  816 FPRIME=.0116267*(CFRENU**2)+.25644*CFRENU-.089787                   MAIN8090
  817 ROMURT=(RHOW(II)*VISCW(II))/(RHO(II)*VISC(II))                      MAIN8100
      REYMUM=(.87*FPRIME*ROMURT)/CFLAM                                    MAIN8110
      IKK=I+1                                                             MAIN8120
      IF(IMETRC)950,950,951                                               MAIN8130
  951 QLOCLM=QLOCL*11348.9                                                MAIN8140
      QLOCTM=QLOCT*11348.9                                                MAIN8150
      XM278(IKK)=X(IKK)*.3048                                             MAIN8160
      TAULM=TAULAM*47.880258                                              MAIN8170
      TAUTM=TAUTUR*47.880258                                              MAIN8180
      REXM=REX*.3048                                                      MAIN8190
      REYMM=REYMUM*.3048                                                  MAIN8200
      HRECLM(II)=HRECL(II)*2324.4444                                      MAIN8210
      HRECTM(II)=HRECT(II)*2324.4444                                      MAIN8220
      WRITE(6,818)IKK,QLOCLM,QLOCTM,XM278(IKK),QXQOL,QXQOT,CFLAM,CFTURB,MAIN8230
     1TAULM,TAUTM,CFRENU,ROMURT,REXM,REYMM,HRECLM(II),HRECTM(II)          MAIN8240
      GO TO 801                                                           MAIN8250
  950 WRITE(6,818)IKK,QLOCL,QLOCT,X(IKK),                                 MAIN8260
     1QXQOL,QXQOT,CFLAM,CFTURB,TAULAM,                                    MAIN8270
     1TAUTUR,CFRENU,ROMURT,REX,REYMUM,HRECL(II),HRECT(II)                 MAIN8280
  801 CONTINUE                                                            MAIN8290
      GO TO 1                                                             MAIN8300
  818 FORMAT(//2X,'STATION NO. ='I2/5X,'QLOCLAM='E14.6,5X,'QLOCTURB='     MAIN8310
     1E14.6,5X,'X='                                                       MAIN8320
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XNUM5	B88	CX5	B8C	CX6	B90	XDEN5	B94	QLOCT	B98
QXQOT	B9C	CTT	BA0	CFLAM	BA4	CFTURB	BA8	TAULAM	BAC
TAUTUR	BB0	CFRENU	BB4	FPRIME	BB8	RUMURT	BBC	REYMOM	BC0
IKK	BC4	QLOCLP	BC8	QLOCTM	BCC	TAULM	BD0	TAUTM	BD4
REXM	BD8	REYMM	BDC						

ARRAY MAP

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
XM278	BF0	HRECLM	C1C	HRECTM	C58	HW7	C94	CPW7	CD0
HREF7	D0C	TKREF7	D48	VISRX7	D84	RHORX7	DC0	TKX7	DFC
VISCX7	E38	HX7	E74	VX7	FB0	AAX7	EEC	RHOX7	F28
CPX7	F64	TETSM	FA0	RRM	FDC	XXM	1018	X	1054
PXPO	1090	R	10CC	TW	1108	Y	1144	SAVE	120C
INFO	1258	DTW	12A0	DP	120C	DRX	1318	P	1354
T	1390	TKS	13CC	VS	1408	HS	1444	H	1480
CP	14BC	RHO	14F8	AA	1534	VISC	1570	TK	15AC
V	15E8	PR	1624	TKX	1660	VISCX	16A0	PRX	16E0
ZX	1720	HX	1760	VX	17A0	CPCVX	17F0	AX	1820
RHOX	1860	CPX	18A0	R1	18E0	V1	1934	RO1	1988
VIS1	19DC	RO2	1A30	VIS2	1A84	V2	1AD8	R2	1B2C
RO	1B80	PHIX	1BD4	RHOW	1C10	VISCW	1C4C	SR	1C88
PS	1CC4	SRS	1D00	TS	1D3C	CPS	1D78	RHOS	1DB4
PRS	1DF0	AS	1E2C	VISCS	1E68	TETSHK	1EA4	CPCV	1EE0
Z	1F1C	XM	1F58	CPCVS	1F94	XMS	1FD0	HREFX	200C
HW	204C	CPW	208C	PRREFX	20CC	TKREFX	210C	VISCRX	214C
RHORX	218C	TREFX	21CC	ZREFX	220C	CPCVRX	224C	PSIL	228C
PSIT	22CC	HRECL	230C	HRECT	234C	ZS	238C		

FORMAT STATEMENT MAP

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
893	23CC	891	23F8	930	2429	876	2450	1060	27D6
9922	2858	9000	286B	1061	287E	9710	288F	5748	28C6
887	28E9	4471	2970	4070	2A0D	792	2A40	795	2A67
365	2AC1	377	2B06	1700	2B4F	800	2BA0	803	2D8A
818	2F7F	1010	3069	9999	3098	1000	30C0	1001	30D5
1002	30E2	1112	30E9	1113	30F5				

```
*OPTIONS IN EFFECT*  ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,MAP
*OPTIONS IN EFFECT*  NAME = MAIN    , LINECNT =       58
*STATISTICS*    SOURCE STATEMENTS =      701,PROGRAM SIZE =    26216
```

```
             C
             C      SUBROUTINE ITER TO FIND TEMP AT GIVEN ENTHALPY(FIXED PRESS)
             C
 0001               SUBROUTINE ITER(P,T,H,I,J)
             C              -THIS ROUTINE IS GIVEN A PRESSURE,ENTHALPY,AND A
             C               TEMPERATURE GUESS. IT USES AN ITERATION TECHNIQUE TO
             C               FIND THE CORRECT TEMPERATURE TO ENTER ANAPRP SUBROUTINE
             C               WITH TO GET THE GIVEN ENTHALPY -
             C                  P = PRESSURE  (LBF/SQFT)
             C                  T = TEMPERATURE (DEG.K).  ENTER WITH GUESS FOR T
             C                      AND RETURN WITH CORRECT T VALUE
             C                  H = ENTHALPY (BTU/LBM)
             C                  I = ENTRY POINT NUMBER
             C                  J = TRUE IF NO PRINTOUT OF ITERATIONS IS DESIRED
             C
             C
 0002               DIMENSION G(5)
 0003               DIMENSION X(4)
 0004               COMMON/ARRAY/A(23)
 0005               DOUBLE PRECISION X
 0006               LOGICAL  J
 0007               ITEN = 0
 0008               G(4) = T
 0009            10 IF(G(4).GE.100.) GO TO 20
 0010               G(4)=100.
 0011               GO TO 30
 0012            20 IF (G(4) .GT. 15000.) G(4) = 15000.
 0013            30 CALL ANAPRP(P,G(4),&5003)
 0014          5003 A(4)=A(4)*.123406
 0015               A(8)= A(8) * 129.0816
 0016               G(2)= G(4) + (H-A(8))/A(4)
 0017               ITEN = ITEN +1.
 0018               IF (J) GO TO 40
 0019               WRITE (6,5000) I,ITEN,G(4),G(2),H,A(8)
 0020            40 IF(ABS((A(8)-H)/H) .LE. 0.0001) GO TO 80
 0021               IF(ITEN .GT. 1) GO TO 50
 0022               G(3) = G(4)
 0023               G(4) = G(2)
 0024               GO TO 60
 0025            50 IF(ITEN .GT. 25) GO TO 70
 0026               DO 55  K=1,4
 0027            55 X(K) = G(K)
 0028               G(5) = (X(2)*X(3)-X(1)*X(4)) /(X(2)+X(3)-X(1)-X(4))
 0029               G(3) = G(4)
 0030               G(4) = G(5)
 0031            60 G(1)= G(2)
 0032               GO TO 10
             C
             C              -ERROR EXIT (ITER. COUNT OVER 25)
             C
 0033            70 WRITE (6,5001)
 0034               WRITE (6,5002) P,T,H,I,J,(A(K),K=1,23)
 0035               I=-1
 0036               RETURN
             C
             C      NORMAL RETURN EXIT
```

```
            C
0037           80 T= G(4)
0038              A(4)=A(4)/.123406
0039              A(8)=A(8)/129.0816
0040         5000 FORMAT (10HOENTRY PT.I2,12H   ITER. NO.I3, 9H   T(I) =1PE14.6,
                X          9H   T(0) =E14.6, 9H   H(I) =E14.6, 9H   H(0) =E14.6)
0041         5001 FORMAT (38HOERROR EXIT -- ITERATION COUNT OVER 25)
0042         5002 FORMAT (4HOP =1PE14.6, 6H   T =E14.6,6H   H =E14.6,6H   I =I2,
                X   6H   J =I3/14H ARRAY(1-23) =/(6E20.6))
0043/             RETURN
0044              END
                          COMMON BLOCK /ARRAY   / MAP SIZE        5C
SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION
A              0


                          SUBPROGRAMS CALLED
SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION
ANAPRP        FC       IBCOM#       100


                          SCALAR MAP
SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION
ITEN         110       T            114       P            118       H            11C       J            120
I            124       K            128


                          ARRAY MAP
SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION
G            12C       X            140


                          FORMAT STATEMENT MAP
SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION     SYMBOL    LOCATION
 5000        160        5001        18A        5002        1E4

   *OPTIONS IN EFFECT*  ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,MAP
   *OPTIONS IN EFFECT*  NAME = ITER    , LINECNT =        58
   *STATISTICS*    SOURCE STATEMENTS =        44,PROGRAM SIZE =      1526
   *STATISTICS*  NO DIAGNOSTICS GENERATED


            C
            C      SUBROUTINE TBLALT
            C
0001               SUBROUTINE TBLALT(ZFT,PENG,SPWT,RHO,RHOSLG,VPART,XMFP,ACCG,FREQ,
                  1XMU,ETA,THCOND,SMA,TEMPR,HBTU,SS,AMOL)
0002               DIMENSION XALT(12),TMP(12),PB(12),XLM(12)
            C      DIMENSION XALT(12),TMB(12),PB(12),XLM(12)
0003               IF(ITEST-19876)13,12,13
0004            13 XALT(1)=0.0
0005               XALT(2)=11000.0
0006               XALT(3) = 25000.0
0007               XALT(4)=47000.0
0008               XALT(5)=53000.0
0009               XALT(6)= 79000.0
0010               XALT(7)=90000.0
0011               XALT(8)=105000.0
0012               XALT(9)=160000.0
0013               XALT(10)=170000.0
0014               XALT(11)=200000.0
0015               XALT(12)=700000.0
0016               TMB(1)=288.16
0017               TMB(2)=216.66
0018               TMB(3)=216.66
0019               TMB(4)=282.66
0020               TMB(5)=282.66
0021               TMB(6)=165.66
0022               TMB(7)=165.66
0023               TMB(8)=225.66
0024               TMB(9)=1325.66
0025               TMB(10)=1425.66
0026               TMB(11)=1575.66
0027               TMB(12)=3325.66
0028               PB(1)=2.1162170E03
0029               PB(2)=4.7267616E02
0030               PB(3)=5.1975447E01
0031               PB(4)=2.5153891E00
0032               PB(5)=1.2177534E00
0033               PB(6)=2.1077554E-02
0034               PB(7)=2.1906667E-03
0035               PB(8)=1.5556518E-04
0036               PB(9)=2.6480315E-06
0037               PB(10)=2.0654640E-06
0038               PB(11)=1.8688358E-06
0039               PB(12)=1.2730206E-09
0040               XLM(1)=-0.0065
0041               XLM(2)=0.0
0042               XLM(3)=0.0030
0043               XLM(4)=0.0
0044               XLM(5)=-0.0045
0045               XLM(6)=0.0
0046               XLM(7)=0.0040
0047               XLM(8)=0.0200
0048               XLM(9)=0.0100
0049               XLM(10)=0.0050
0050               XLM(11)=0.0035
0051               XLM(12)=0.0
0052               ITEST=19876
0053            12 ZMET=0.3048*ZFT
0054               ALT = ZMET /(1.0 + ZMET /6.356776E6)
0055               DO 1 I = 1,12
0056               IF(XALT(I)-ALT) 1,2,3
```

```
0057          1 CONTINUE                                                         TBAL0620
0058          2 TM = TMB(I)                                                      TBAL0630
0059            PENG = PB(I)                                                     TBAL0640
0060            GO TO 6                                                          TBAL0650
0061          3 TM = TMB(I-1) + XLM(I-1) * (ALT - XALT(I-1))                     TBAL0660
0062            IF (XLM(I-1))4,5,4                                               TBAL0670
0063          4 PENG = PB(I-1) *(TMB(I-1)/(TMB(I-1)+XLM(I-1)*(ALT-XALT(I-1))))   TBAL0680
             1  **(3.416479E-2 /XLM(I-1))                                        TBAL0690
0064            GO TO 6                                                          TBAL0700
0065          5 PENG=PB(I-1)*(2.7183**(-3.416479E-2*(ALT-XALT(I-1))/TMB(I-1)))   TBAL0710
0066          6 IF(ALT-90000.0) 7,8,8                                            TBAL0720
0067          7 AMOL=28.966                                                      TBAL0730
0068            GO TO 11                                                         TBAL0740
0069          8 IF(ALT-180000.0) 9,10,10                                         TBAL0750
0070          9 AMOL=22.0-5.04483574*ATAN((ALT-22.E4)/25.E3)                     TBAL0760
0071            GO TO 11                                                         TBAL0770
0072         10 AMOL=27.106-7.93569710*ATAN((ALT-18.E4)/14.E4)                   TBAL0780
0073         11 ACCG = 1.399046E16/(2.0852629E7+ZFT)**2                          TBAL0790
0074            TEMPK=TM*AMOL/28.966                                             TBAL0800
0075            TEMPR=1.8*TEMPK                                                  TBAL0810
0076            PMET = 4882.8*PENG                                               TBAL0820
0077            HBTU = 99.53 + 0.2396 * (TEMPR-400.0)                            TBAL0830
0078            SB=0.06865*(1.8568E01+2.7512E-02*TEMPR-3.5545E-05*TEMPR**2+2.0107 TBAL0840
             1     E-08*TEMPR**3)                                                TBAL0850
0079            SS=SB+0.06886*ALOG(211.6217/PENG)                                TBAL0860
0080            RHO=PENG*AMOL/(1545.0*TEMPR)                                     TBAL0870
0081            SPWT=RHO*ACCG                                                    TBAL0880
0082            RHOSLG=RHO/32.174                                                TBAL0890
0083            SQRTTM=SQRT(TM)                                                  TBAL0900
0084            VPART=88.704621*SQRTTM                                           TBAL0910
0085            XMFP=26.4135609E-7*AMOL*TM/PMET                                  TBAL0920
0086            FREQ=3.3583060E7*PMET/(AMOL*SQRTTM)                              TBAL0930
0087            A=TEMPK**1.5                                                     TBAL0940
0088            XMU=.9797309E-06*A/(TEMPK+110.4)                                 TBAL0950
0089            ETA=XMU/RHO                                                      TBAL0960
0090            THCOND=4.25E-7*A/(TEMPK+245.4*10.0**(-12.0/TEMPK))               TBAL0970
0091         30 SMA=65.772018*SQRTTM                                             TBAL0980
0092            RETURN                                                           TBAL0990
0093            END                                                              TBAL1000
                          SUBPROGRAMS CALLED
SYMBOL    LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION
FRXPR#       FC        ATAN        100       ALOG        104       SQRT        108


                          SCALAR MAP
SYMBOL    LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION
ITEST       13C        ZMET        140       ZFT         144       ALT         148       I           14C
TM          150        PENG        154       AMOL        158       ACCG        15C       TEMPK       160
TEMPR       164        PMET        168       HBTU        16C       SB          170       SS          174
RHO         178        SPWT        17C       RHOSLG      180       SQRTTM      184       VPART       188
XMFP        18C        FREQ        190       A           194       XMU         198       ETA         19C
THCOND      1A0        SMA         1A4


                          ARRAY MAP
SYMBOL    LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION
XALT        1A8        TMB         1D8       PB          208       XLM         238


  *OPTIONS IN EFFECT*  ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,MAP
  *OPTIONS IN EFFECT*  NAME = TBLALT  , LINECNT =       58
  *STATISTICS*    SOURCE STATEMENTS =       93,PROGRAM SIZE =     2682
  *STATISTICS*  NO DIAGNOSTICS GENERATED


           C                                                                     BLOG0010
           C    FUNCTION BLOG(X)                                                 BLOG0020
           C                                                                     BLOG0030
0001            FUNCTION BLOG(X)                                                 BLOG0040
0002            BLOG = ALOG(ABS(X))                                              BLOG0050
0003            RETURN                                                           BLOG0060
0004            END                                                              BLOG0070
                          SUBPROGRAMS CALLED
SYMBOL    LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION
ALOG         90


                          EQUIVALENCE DATA MAP
SYMBOL    LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION
BLOG         A0


                          SCALAR MAP
SYMBOL    LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION
X            A4


  *OPTIONS IN EFFECT*  ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,MAP
  *OPTIONS IN EFFECT*  NAME = BLOG    , LINECNT =.      58
  *STATISTICS*    SOURCE STATEMENTS =        4,PROGRAM SIZE =      328
  *STATISTICS*  NO DIAGNOSTICS GENERATED


           C                                                                     ANAP0010
           CANAPRX         FORTRAN 4 VERSION OF ANAPRP SUBROUTINE                ANAP0020
           C                                                                     ANAP0030
0001             SUBROUTINE ANAPRP(P,T,*)                                        ANAP0040
0002             CALL NOUNFL                                                     ANAP0050
           C                      P = PRESSURE (LB/SQFT)                         ANAP0060
           C                      T = TEMPERATURE (DEG.K)                        ANAP0070
           C                                                                     ANAP0080
           C              - THE RESULTS APPEAR IN A COMMON ARRAY(/ARRAY/A(23)).  ANAP0090
           C               A(1) = HTR                                            ANAP0100
```

```
      C              A(2) = SR                                          ANAP0110
      C              A(3) = RHO                                         ANAP0120
      C              A(4) = CPRP                                        ANAP0130
      C              A(5) = CPR                                         ANAP0140
      C              A(6) = AA1P                                        ANAP0150
      C              A(7) = AA1                                         ANAP0160
      C              A(8) = HH1                                         ANAP0170
      C              A(9) = Z                                           ANAP0180
      C              A(10)= VISCOL                                      ANAP0190
      C              A(11)= TLMBOP                                      ANAP0200
      C              A(12)= TLMBDA                                      ANAP0210
      C              A(13)= DENV                                        ANAP0220
      C              A(14)= CPCV                                        ANAP0230
      C              A(15)= DVPR                                        ANAP0240
      C              A(16)= PRP                                         ANAP0250
      C              A(17)= PR                                          ANAP0260
      C              A(18)= ZT                                          ANAP0270
      C              A(19)= PF                                          ANAP0280
      C              A(20)= XE                                          ANAP0290
      C              A(21)= CF                                          ANAP0300
      C              A(22)= EC                                          ANAP0310
      C              A(23)= VNF                                         ANAP0320
      C                                                                 ANAP0330
0003        COMMON /ARRAY/A(23)                                         ANAP0340
0004        EQUIVALENCE(A(1),HRT),(A(2),SR),(A(3),RHO),(A(4),CPRP),     ANAP0350
           1        (A(5),CPR),(A(6),AA1P),(A(7),AA1),(A(8),HH1),       ANAP0360
           2        (A(9),Z),(A(10),VISCOL),(A(11),TLMBOP),(A(12),TLMBDA),ANAP0370
           3        (A(13),DENV),(A(14),CPCV),(A(15),DVPR),(A(16),PRP), ANAP0380
           4        (A(17),PR),(A(18),ZT),(A(19),PF),(A(20),XE),        ANAP0390
           5        (A(21),CF),(A(22),FC),(A(23),VNE)                   ANAP0400
0005        PP=P                                                        ANAP0410
0006        TT=T                                                        ANAP0420
0007        TR=TT/1000.                                                 ANAP0430
0008        GT=BLOG(TT)                                                 ANAP0440
0009        GTR=.43429*GT-3.0                                           ANAP0450
0010        IF(TT)7010,7010,7011                                        ANAP0460
0011   7010 WRITE(6,200)                                                ANAP0470
0012    200 FORMAT(/2X,'A NO-NO HAS BEEN PERPETRATED. THE ENTRY TEMPERATURE ISANAP0480
           1ZERO OR NEGATIVE')                                          ANAP0490
0013        RETURN 1                                                    ANAP0500
0014   7011 CONTINUE                                                    ANAP0510
0015        SQT=SQRT(TT)                                                ANAP0520
0016        C=0.16                                                      ANAP0530
0017        IF(TT-10000.)10,10,20                                       ANAP0540
0018     10 IF(TT-2000.)20,15,15                                        ANAP0550
0019     15 C=C-0.04*SIN((TT-2000.)/1274.0)                             ANAP0560
0020     20 VO=2740./TT                                                 ANAP0570
0021        V1=3390./TT                                                 ANAP0580
0022        V2 =2270./TT                                                ANAP0590
0023        V3 =11390./TT                                               ANAP0600
0024        V4 =18990./TT                                               ANAP0610
0025        V5 =228./TT                                                 ANAP0620
0026        V6 =326./TT                                                 ANAP0630
0027        V7 =22800./TT                                               ANAP0640
0028        V8 =48600./TT                                               ANAP0650
0029        V9 =27700./TT                                               ANAP0660
0030        V10 =41500./TT                                              ANAP0670
0031        V11 =38600./TT                                              ANAP0680
0032        V12 =58200./TT                                              ANAP0690
0033        V13 =70.6/TT                                                ANAP0700
0034        V14 =188.9/TT                                               ANAP0710
0035        V15 =22000./TT                                              ANAP0720
0036        V16 =47000./TT                                              ANAP0730
0037        V17 =67900./TT                                              ANAP0740
0038        V18 =175./TT                                                ANAP0750
0039        VD1=29500./TT                                               ANAP0760
0040        VD2 =56600./TT                                              ANAP0770
0041        VI1 =158000./TT                                             ANAP0780
0042        VI2 =168300./TT                                             ANAP0790
0043        VF1 =75500./TT                                              ANAP0800
0044        EVO =EXP(-VO)                                               ANAP0810
0045        EV1 =EXP(-V1)                                               ANAP0820
0046        EV2 =EXP(-V2)                                               ANAP0830
0047        EV3 =EXP(-V3)                                               ANAP0840
0048        EV4 =EXP(-V4)                                               ANAP0850
0049        EV5 =EXP(-V5)                                               ANAP0860
0050        EV6 =EXP(-V6)                                               ANAP0870
0051        EV7 =EXP(-V7)                                               ANAP0880
0052        EV8 =EXP(-V8)                                               ANAP0890
0053        EV9 =EXP(-V9)                                               ANAP0900
0054        EV10 =EXP(-V10)                                             ANAP0910
0055        EV11 =EXP(-V11)                                             ANAP0920
0056        EV12 =EXP(-V12)                                             ANAP0930
0057        EV13 =EXP(-V13)                                             ANAP0940
0058        EV14 =EXP(-V14)                                             ANAP0950
0059        EV15 =EXP(-V15)                                             ANAP0960
0060        EV16 =EXP(-V16)                                             ANAP0970
0061        EV17 =EXP(-V17)                                             ANAP0980
0062        EV18 =EXP(-V18)                                             ANAP0990
0063        TGT = 2.5*GT                                                ANAP1000
0064        RGT = 3.5*GT                                                ANAP1010
0065        WO = 1.-EVO                                                 ANAP1020
0066        W1 = 1.-EV1                                                 ANAP1030
0067        W2 = 1.-EV2                                                 ANAP1040
0068        W3 = 3.+2.*EV3+EV4                                          ANAP1050
0069        W4 = 5.+3.*EV5+EV6+5.*EV7+EV8                               ANAP1060
0070        W5 = 4.+10.*EV9+6.*EV10                                     ANAP1070
0071        W6 = 4.+10.*EV11+6.*EV12                                    ANAP1080
0072        W7=1.+3.*EV13+5.*EV14+5.*EV15+EV16+5.*EV17                  ANAP1090
0073        W8 = 2.+2.*EV18                                             ANAP1100
      C                                                                 ANAP1110
      C      PARTITION FUNCTIONS Q P(I)                                 ANAP1120
      C                                                                 ANAP1130
0074        GOPN2=RGT-0.42-BLOG(W1)                                     ANAP1140
```

```
      GQPO2=RGT+0.11-BLOG(W2)+BLOG(W3)
      GQPNO=RGT+0.53-BLOG(W0)+BLOG(W8)-VD1-VD2+VF1
      GQPN = TGT+0.3+BLOG(W5)-VD2
      GQPO = TGT+0.5+BLOG(W4)-VD1
      GQPNP= TGT+0.3+BLOG(W7)-VI2-VD2
      GQPOP = TGT+0.5+BLOG(W6)-VI1-VD1
      GQPE = TGT-14.24
C
C     FIRST DERIVATIVES----DW(I)=T*D LN W(I)/DT=T*D LN Q P(I)/DT
C                           -T*D(0.5*5(OR 7) LN T)/DT
C
      DW0 = V0*EV0/W0
      DW1 = V1*EV1/W1
      DW2 = V2*EV2/W2
      DW3 = (2.*V3*EV3+V4*EV4)/W3
      DW4 = (3.*V5*EV5+V6*EV6+5.*V7*EV7+V8*EV8)/W4
      DW5 = (10.*V9*EV9+6.*V10*EV10)/W5
      DW6=(10.*V11*EV11+6.*V12*EV12)/W6
      DW7 =(3.*V13*EV13+5.*V14*EV14+5.*V15*EV15+V16*EV16+5.*V17*
     1EV17)/W7
      DW8 = 2.*V18*EV18/W8
C
C     SECOND DERIVATIVES----DDW(I)=D(T**2*D LN W(I)/DT/DT-(DW(I))**2
C
      DDW3 =(2.*V3**2*EV3+V4**2*EV4)/W3
      DDW4 =(3.*V5**2*EV5+V6**2*EV6+5.*V7**2*EV7+V8**2*EV8)/W4
      DDW5 =(10.*V9**2*EV9+6.*V10**2*EV10)/W5
      DDW6 =(10.*V11**2*EV11+6.*V12**2*EV12)/W6
      DDW7 =(3.*V13**2*EV13+5.*V14**2*EV14+5.*V15**2*EV15+V16**2*
     1EV16+5.*V17**2*EV17)/W7
      DDW8 = V18 * DW8
C
C     VIBRATIONAL
C
      VN0 = V0/2.
      VN2= V1/2.
      VO2 = V2/2.
C
C     C V(I)
C
      CVN0V =1.+(2.*VN0/(EXP(VN0)-EXP(-VN0)))**2
      CVN2V =1.+(2.*VN2/(EXP(VN2)-EXP(-VN2)))**2
      CVO2V =1.+(2.*VO2/(EXP(VO2)-EXP(-VO2)))**2
      CVN2T =1.5
      CVO2T =1.5+DDW3-DW3**2
      CVN0T =1.5+DDW8-DW8**2
      CVN0  =CVN0V+CVN0T
      CVN2  =CVN2V+CVN2T
      CVO2  =CVO2V+CVO2T
      CVN= 1.5 + DDW5-DW5**2
      CVO = 1.5 +DDW4 - DW4**2
      CVNP = 1.5 + DDW7 - DW7**2
      CVOP=1.5+DDW6-DW6**2
      CVE = 1.5
C
C     DERIVATIVES OF PARTITION FUNCTIONS----D QP(I) = T * D QP(I)/DT
C                                                   = H(I)/RT
C
      DQPN2 = 3.5 +DW1
      DQPO2 = 3.5 +DW2+DW3
      DQPNO = 3.5+DW0+DW8+VD1+VD2-VF1
      DQPN = 2.5+DW5+VD2
      DQPO = 2.5+DW4+VD1
      DQPNP=2.5+DW7+VI2+VD2
      DQPOP = 2.5+DW6+VI1+VD1
      DQPE = 2.5
      GKPO2 = GQPO+GQPO-GQPO2
      IF(ABS(GKPO2)-70.0) 35,35,30
   30 GEPSO2=-1.5+.5*GKPO2-.5*BLOG(PP)
      EPSO2 = EXP(GEPSO2)
      EPSN2 = 1.0E-35
      EPSON = 1.0E-35
      GO TO 70
   35 GKPN2 = GQPN+GQPN-GQPN2
      IF(ABS(GKPN2)-70.0) 45,45,40
   40 GKPN2 = -70.0
   45 GKPN = GQPNP+GQPE-GQPN
      IF(ABS(GKPN)-70.) 55,55,50
   50 GKPN=-70.
   55 GKPO = GQPOP+GQPE-GQPO
      IF(ABS(GKPO)-70.0) 65,65,60
   60 GKPO = -70.0
   65 CONTINUE
      VKPO2 = EXP(GKPO2)
      VKPN2 = EXP(GKPN2)
      VKPN=EXP(GKPN)
      VKPO = EXP(GKPO)
      VKPON=0.2*VKPO+0.8*VKPN
      IF(.64+.8*(1.+4.*PP/VKPO2))7012,7013,7013
 7012 CALL PDUMP(PP,VKPON,5)
      RETURN 1
 7013 CONTINUE
      EPSO2 = (-0.8+SQRT(0.64+0.8*(1.0+4.0*PP/VKPO2)))/(2.0*(1.0+4.0*PP/
     1VKPO2))
      IF(.16+3.84*(1.+4.*PP/VKPN2))7014,7015,7015
 7014 CALL PDUMP(PP,EPSO2,5)
      RETURN 1
 7015 CONTINUE
      EPSN2 = (-0.4+SQRT (0.16+3.84*(1.0+4.0*PP/VKPN2)))/(2.0*(1.0+4.0*P
     1P/VKPN2))
      IF(1.+PP/VKPON)7016,7017,7017
 7016 CALL PDUMP(PP,EPSN2,5)
      RETURN 1
 7017 CONTINUE
```

```
0158          EPSON = 1.0/SQRT(1.0+PP/VKPON)                                     ANAP2190
0159       70 EPS = EPSO2+EPSN2+2.0*EPSON                                        ANAP2200
0160          ZZ=1.0+EPS                                                         ANAP2210
0161          DKPN2 = 2.0*DOPN-DOPN2                                             ANAP2220
0162          DKPO2=2.0*DOPO - DOPO2                                             ANAP2230
0163          DKPNO = 19.22+GTR*(-32.432+15.2976*GTR)                            ANAP2240
0164          DKPN =DOPNP+DOPE-DOPN                                              ANAP2250
0165          DKPO =DOPOP+DOPE-DOPO                                              ANAP2260
0166          DKPON=0.2*DKPO+0.8*DKPN                                            ANAP2270
0167          IF (EPSO2 .EQ.0.0) GO TO 71                                        ANAP2280
0168          DEPSO2 = DKPO2/(2.0/EPSO2-1.0/(1.0+EPSO2)+1.0/(0.2-EPSO2+1.0E-30))ANAP2290
0169       72 DEPSN2=DKPN2/(2.0/EPSN2-1.0/(1.2+EPSN2)+1.0/(0.8-EPSN2+1.0E-30))  ANAP2300
0170          DEPSON=DKPON/(2.0/EPSON-1.0/(1.0+EPSON)+1.0/(1.0-EPSON+1.0E-30))  ANAP2310
0171          DZEO2 = -DEPSO2                                                    ANAP2320
0172          DZEN2 = -DEPSN2                                                    ANAP2330
0173          DZEO  = 2.0*DEPSO2-0.4*DEPSON                                      ANAP2340
0174          DZEN  = 2.0*DEPSN2-1.6*DEPSON                                      ANAP2350
0175          DZEE  = 2.0*DEPSON                                                 ANAP2360
0176          IF (EPSO2.EQ.0.0) GO TO 73                                         ANAP2370
0177          REPSO2=(DKPO2-1.0)/(2.0/EPSO2+1.0/(0.2-EPSO2+1.0E-30))            ANAP2380
0178          CALL OVERFL(IXZY)                                                  ANAP2390
0179          IF(IXZY-2)500,501,500                                              ANAP2400
0180      500 CALL PDUMP(PP,VMFP,5)                                              ANAP2410
0181      501 CONTINUE                                                           ANAP2420
0182       74 REPSN2=(DKPN2-1.0)/(2.0/EPSN2+1.0/(0.8-EPSN2+1.0E-30))            ANAP2430
0183          REPSON=(DKPON-1.0)/(2.0/EPSON+1.0/(1.0-EPSON+1.0E-30))            ANAP2440
0184          RZEO2 = -REPSO2                                                    ANAP2450
0185          RZEN2 = -REPSN2                                                    ANAP2460
0186          RZEO =2.0*REPSO2-0.4*REPSON                                        ANAP2470
0187          RZEN =2.0*REPSN2-1.6*REPSON                                        ANAP2480
0188          RZEE =2.0*REPSON                                                   ANAP2490
0189          ZTP= 0.0                                                           ANAP2500
0190          ZTC= 0.0                                                           ANAP2510
        C                                                                        ANAP2520
        C     REACTION SPECIFIC HEATS                                            ANAP2530
        C                                                                        ANAP2540
0191          CPRR = 0.0                                                         ANAP2550
0192          CVRR = 0.0                                                         ANAP2560
0193          IF(TT-399.0) 80,75,75                                              ANAP2570
0194       75 CPRR = DOPO2*DZEO2+DOPN2*DZEN2+DOPO*DZEO+DOPN*DZEN+DZEE*(0.2*DOPOPANAP2580
             1+0.8*DOPNP+DOPE)                                                   ANAP2590
0195          CVRR =(DOPO2-1.0)*RZEO2+(DOPN2-1.0)*RZEN2+(DOPO-1.0)*RZEO+(DOPN-1.ANAP2600
             10)*RZEN+RZEE*(0.2*(DOPOP-1.0)+0.8*(DOPNP-1.0)+(DOPE-1.0))         ANAP2610
        C                                                                        ANAP2620
        C     DERIVATIVES                                                        ANAP2630
        C                                                                        ANAP2640
0196          ZTP=(DEPSO2+DEPSN2+2.0*DEPSON)                                     ANAP2650
0197          ZTC=(REPSO2+REPSN2+2.0*REPSON)                                     ANAP2660
        C                                                                        ANAP2670
        C     MOLE FRACTIONS                                                     ANAP2680
        C                                                                        ANAP2690
0198       80 XO2=(0.2-EPSO2)/ZZ                                                 ANAP2700
0199          XN2 = (0.80-EPSN2)/ZZ                                              ANAP2710
0200          XO = (2.0*EPSO2-0.40*EPSON)/ZZ                                     ANAP2720
0201          XN = (2.0*EPSN2-1.60*EPSON)/ZZ                                     ANAP2730
0202          XE = 2.0*EPSON/ZZ                                                  ANAP2740
0203          GP=0.43429*BLOG(PP)                                                ANAP2750
0204          XNO =-4.431+GTR*((11.981+GP* (-0.479+0.0557*GP))+(-11.527+GP*(1.64ANAP2760
             1 7-0.1723*GP))*GTR)                                                ANAP2770
0205          XNOP =-24.196+GP*(-0.242-0.016*GP)+GTR*((47.730+GP*(-2.00+0        ANAP2780
             1.146*GP))+(-27.295+GP*(2.865-0.258*GP))*GTR)                       ANAP2790
0206          XNO = EXP(XNO/0.43429)                                             ANAP2800
0207          XNOP= EXP(XNOP/0.43429)                                            ANAP2810
0208          XN2 = XN2-0.8*(XNO+XNOP)                                           ANAP2820
0209          XO2 = ABS(XO2-0.2*(XNO+XNOP))                                      ANAP2830
0210          XNP = 0.8 * XE                                                     ANAP2840
0211          XOP = 0.2 * XE                                                     ANAP2850
0212          XE  = XE+XNOP/2.0                                                  ANAP2860
        C                                                                        ANAP2870
        C     ENTHALPY                                                           ANAP2880
        C                                                                        ANAP2890
0213          HRT =ZZ*(XN2*DOPN2+XO2*DOPO2+XNO*DOPNO+XN*DOPN+XO*DOPO+XE*(0.80*DOANAP2900
             1PNP+0.20*DOPOP+DOPE))                                              ANAP2910
0214          SO2 = GOPO2+DOPO2                                                  ANAP2920
0215          SN2 = GOPN2+DOPN2                                                  ANAP2930
0216          SNO = GOPNO+DOPNO                                                  ANAP2940
0217          SO  = GOPO+DOPO                                                    ANAP2950
0218          SN  = GOPN+DOPN                                                    ANAP2960
0219          SOP = GOPOP+DOPOP                                                  ANAP2970
0220          SNP = GOPNP+DOPNP                                                  ANAP2980
0221          SE  = GOPE +DOPE                                                   ANAP2990
        C                                                                        ANAP3000
        C     ENTROPY                                                            ANAP3010
        C                                                                        ANAP3020
0222          SR=ZZ*(XO2*SO2+XN2*SN2+XNO*SNO+XO*SO+XN*SN+XE*(0.80*SNP+0.20*SOP+SANAP3030
             1E)-XO2*BLOG(XO2)-XN2*BLOG(XN2)-XO*BLOG(XO)-XN*BLOG(XN)-2.0*XE*BLOGANAP3040
             2(XE)-BLOG(PP))                                                     ANAP3050
        C                                                                        ANAP3060
        C     DENSITY                                                            ANAP3070
        C                                                                        ANAP3080
0223          RHO = 273.0* PP/(TT*ZZ)                                            ANAP3090
        C                                                                        ANAP3100
        C     PARTIAL SPECIFIC HEATS                                             ANAP3110
        C                                                                        ANAP3120
0224          CVRP=ZZ*(XN2*CVN2+XO2*CVO2+XNO*CVNO+XN*CVN+XO*CVO+XE*(0.80*CVNP+0.ANAP3130
             12*CVOP+CVE))                                                       ANAP3140
0225          CPRP=ZZ*(XN2*(CVN2+1.0)+XO2*(CVO2+1.0)+XNO*(CVNO+1.0)+XN*(CVN+1.0)ANAP3150
             1+XO*(CVO+1.0)+XE*(0.8*(CVNP+1.0)+0.20*(CVOP+1.0)+(CVE+1.0)))      ANAP3160
        C                                                                        ANAP3170
        C     TOTAL SPECIFIC HEATS                                               ANAP3180
        C                                                                        ANAP3190
0226          CPR = CPRP+CPRR                                                    ANAP3200
0227          CVR = CVRP+CVRR                                                    ANAP3210
        C                                                                        ANAP3220
```

```
C       GAMMA
C
        CPCV = CPR/CVR
        AARP = CPCV*(ZTC+ZZ)/(ZTP+ZZ)
        IF(ZZ*TT*AARP)7018,7019,7019
 7018 CALL PDUMP(PP,AARP,5)
        RETURN 1
 7019 CONTINUE
        AA1  = 0.0488*SQRT(ZZ*TT*AARP)
        IF(ZZ*TT*CPRP/CVRP)7020,7021,7021
 7020 CALL PDUMP(PP,AA1,5)
        RETURN 1
 7021 CONTINUE
        AA1P = 0.0488*SQRT(ZZ*TT*CPRP/CVRP)
        Z=ZZ
        GRHO=.43429*BLOG(RHO)
        X1= XN2+XO2+XNO
        X2= XN+XO
        X3= XNP+XOP
        X4=XE
        CV1R =(XN2*CVN2+XO2*CVO2+XNO*CVNO)/X1
        IF(X2.EQ.0.0) GO TO 81
        CV2R =(XN*CVN+XO*CVO)/X2
   82 CV3R =(XNP*CVNP+XOP*CVOP)/X3
        VNE   =2.69E19*XE*PP*273.0/TT
        CSD11=29.1+GTR*(-12.3+2.6864*GTR)
        CSD12=26.29+GTR*(-16.363+3.9445*GTR)
        CSD22=23.37+GTR*(-17.36+5.2349*GTR)
        CSD23=68.65+GTR*(-52.466+12.435*GTR)
        CSD24=9.0
        IF(TR**3/(2.*VNE))7022,7023,7023
 7022 CALL PDUMP(PP,CSD24,5)
        RETURN 1
 7023 CONTINUE
        CSD33=44160.*(BLOG(2.615E8*SQRT(TR**3/(2.*VNE)))-.961)/TR**2
        CSD34=CSD33
        CSD44=CSD33
        CSV11=34.54+GTR*(-15.546+2.031*GTR)
        CSV22=26.4+GTR*(-20.759+6.4549*GTR)
        CSV33=CSD33+22030.0/TR**2
        CSV44=CSV33
        DELTA1=0.696+TR*(-0.06235+0.002428*TR)
        DELTA2=0.768+TR*(-0.1672+TR*(0.011957-0.000282*TR))
        DELTA=DELTA1-(DELTA1-DELTA2)*(GRHO+5.)/6.
        PART1 = 1.0/(0.0235*CSV11+1.45* X2 *0.016*CSD12/X1)
        IF(X2.EQ.0.0) GO TO 83
        PART2=1.0/(0.03325*CSV22+1.45*(X1*0.032*CSD12/X2+X3*0.0277*CSD23/X
       12+X4*0.000242*CSD24/X2))
   84 PART3=1.0/(0.03325*CSV33+1.45*(X2*0.0277*CSD23/X3+0.000242*CSD34))
        PART4=1.0/(5.38*CSV44+1.45*(X2*6.34*CSD24/X4+6.34*CSD34))
        VISCOL=PART1+PART2+PART3+PART4
        PART5=1.0/(0.02332*CSV11+C*0.276*X2*CSD12/X1)
        IF(X2.EQ.0.0) GO TO 85
        PART6=1.0/(0.0165*CSV22+C*(0.186*X1*CSD12/X2+0.1915*X3*CSD23/X2+0.
       100338*X4*CSD24/X2))
   86 PART7=1.0/(0.0165*CSV33+C*(0.1915* X2*CSD23/X3+0.00338*CSD34))
        PART8=1.0/(0.000102*CSV44+C*(0.00133*X2*CSD24/X4+0.00133*CSD34))
        VLMIX=PART5+PART6+PART7+PART8
        PART9=11.45*(CV1R-1.5)/(CSV11*(1.0+0.818*X2*CSD12/(X1*CSD11)))
        IF(X2.EQ.0.0) GO TO 87
        PART10=16.16*(CV2R-1.5)/(CSV22*((1.0+1.156*X1*CSD12/(X2*CSD22))+X3
       1*CSD23/(X2*CSD22)+0.00875*X4*CSD24/(X2*CSD22)))
   88 PART11=16.19*(CV3R-1.5)/(CSV33*(X2*CSD23/(X3*CSD33)+1.00875))
        EUCKEN=PART9+PART10+PART11
        RLO2=DKPO2**2/(0.0596*CSD12*(XO/XO2+4.0*XO2/XO+4.0+4.0*XN2/XO)+0.0
       1729*CSD11*4.0*XN2/XO)
        RLN2O2=DKPNO**2/(0.0729*CSD11*((XO2+XNO)/XN2+(XN2+XNO)/XO2+4.0*(XN
       12+XO2)/XNO+6.0)+0.0596*CSD12*(XN/XN2+XN/XO2+4.0*XN/XNO))
        RLN2=DKPN2**2/(0.0596*CSD12*(XN/XN2+4.0*XN2/XN+4.0+XO/XN2)+0.0516*
       1CSD22*4.0*XO/XN)
        RLN=DKPN**2/(0.0516*CSD23*(XE/XN+XN/XNP+2.)+0.000451*CSD24*(XE/XN+
       1XN/XE+2.)+0.0516*CSD33*(XOP/XNP)*0.8)
        IF(1.0E-5-EPSO2) 114,114,116
  114 IF(ABS(0.2-EPSO2)-EPSN2) 115,115,117
  115 IF(ABS(0.8-EPSN2)-EPSON) 119,119,118
  116 CNDR=0.0
        GO TO 120
  117 CNDR=RLO2+RLN2O2+RLN2
        GO TO 120
  118 CNDR=RLN2+RLN2O2+RLN+RLO2
        GO TO 120
  119 CNDR=RLN+RLN2
  120 TLMBDA=VLMIX+EUCKEN+CNDR
        TLMBDP=VLMIX+EUCKEN
        IF(TT-399.0) 125,130,130
  125 VISCOL=0.889+0.37*TR
        TLMBDA=1.029+0.76*TR
        TLMBDP=TLMBDA
  130 HH1=HRT*TT/1050.0
        DENV=17.3*VISCOL/(Z*SQT)
        PRP=0.2668*CPRP*VISCOL/TLMBDP
        PR=0.2668*CPR*VISCOL/TLMBDA
        IF(VNE)7024,7025,7025
 7024 CALL PDUMP(PP,R,5)
        RETURN 1
 7025 CONTINUE
        PF=56400.0*SQRT(VNE)
        VMFP=1.0E16/(VNE*(X1/X4*(-0.0763*TR**2+1.384*TR+3.002)+X2/X4*(13.0
       1*GTR**2-35.48*GTR+31.89)+4.0/3.0*(1.0-DELTA)*CSD34))
        CF=6.215E5 * SQT/VMFP
        EC=2.820E-4*VNE/CF
        DVPR=DENV/PR
 1234 ZT=ZZ*TT
        RETURN
```

```
      71 DEPSO2=DKPO2/(-1.0+1./(.2+1.0E-30))                             ANAP4270
         GO TO 72                                                        ANAP4280
      73 REPSO2=(DKPO2-1.0)/(1.0/(.2+1.0E-30))                           ANAP4290
         GO TO 74                                                        ANAP4300
      81 CV2R=0.0                                                        ANAP4310
         GO TO 82                                                        ANAP4320
      83 PART2=1.0/(0.03325*CSV22)                                       ANAP4330
         GO TO 84                                                        ANAP4340
      85 PART6=1.0/(0.0165*CSV22)                                        ANAP4350
         GO TO 86                                                        ANAP4360
      87 PART10=16.18*(CV2R-1.5)/(CSV22)                                 ANAP4370
         GO TO 88                                                        ANAP4380
         END                                                             ANAP4390
```

COMMON BLOCK /ARRAY / MAP SIZE 5C

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
A	0	HRT	0	SR	4	RHO	8	CPRP	C
CPR	10	AA1P	14	AA1	18	HH1	1C	Z	20
VISCOL	24	TLMBDP	28	TLMBDA	2C	OENV	30	CPCV	34
DVPR	38	PRP	3C	PR	40	Z1	44	PF	48
XE	4C	CF	50	EC	54	VNF	58		

SUBPROGRAMS CALLED

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
NOUNFL	254	ALOG	258	IBCOM#	25C	PDUMP	260	OVERFL	264
SQRT	268	SIN	26C	EXP	270				

SCALAR MAP

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
PP	3E8	P	3EC	TT	3F0	T	3F4	TR	3F8
GT	3FC	GTR	400	SCT	404	C	408	VO	40C
V1	410	V2	414	V3	418	V4	41C	V5	420
V6	424	V7	428	V8	42C	V9	430	V10	434
V11	438	V12	43C	V13	440	V14	444	V15	448
V16	44C	V17	450	V18	454	VD1	458	VD2	45C
VI1	460	VI2	464	VF1	468	EVO	46C	EV1	470
EV2	474	EV3	478	EV4	47C	EV5	480	EV6	484
EV7	488	EV8	48C	EV9	490	EV10	494	EV11	498
EV12	49C	EV13	4A0	EV14	4A4	EV15	4A8	EV16	4AC
EV17	4B0	EV18	4B4	TGT	4B8	RGT	4BC	WO	4C0
W1	4C4	W2	4C8	W3	4CC	W4	4D0	W5	4D4
W6	4D8	W7	4DC	W8	4E0	GQPN2	4E4	GOPO2	4E8
GQPNO	4EC	GQPN	4F0	GOPO	4F4	GQPNP	4F8	GOPOP	4FC
GOPE	500	DWO	504	DW1	508	DW2	50C	DW3	510
DW4	514	DW5	518	DW6	51C	DW7	520	DW8	524
DDW3	528	DDW4	52C	DDW5	530	DDW6	534	DDW7	538
DDW8	53C	VNO	540	VN2	544	VO2	548	CVNOV	54C
CVN2V	550	CVO2V	554	CVN2T	558	CVO2T	55C	CVNOT	560
CVNO	564	CVN2	568	CVO2	56C	CVN	570	CVO	574
CVNP	578	CVOP	57C	CVE	580	DQPN2	584	DQPO2	588
DQPNO	58C	DQPN	590	DQPO	594	DQPNP	598	DQPOP	59C
DQPE	5A0	GKPO2	5A4	GEPSO2	5A8	EPSO2	5AC	EPSN2	5B0
EPSON	5B4	GKPN2	5B8	GKPN	5BC	GKPO	5C0	VKPO2	5C4
VKPN2	5C8	VKPN	5CC	VKPO	5D0	VKPON	5D4	EPS	5D8
ZZ	5DC	DKPN2	5E0	DKPO2	5E4	DKPNO	5E8	DKPN	5EC
DKPO	5F0	DKPON	5F4	DEPSO2	5F8	DEPSN2	5FC	DEPSON	600
DZEO2	604	DZEN2	608	DZEO	60C	DZEN	610	DZEE	614
REPSO2	618	IXZY	61C	VMFP	620	REPSN2	624	REPSON	628
RZEO2	62C	RZEN2	630	RZEO	634	RZEN	638	RZEE	63C
ZTP	640	ZTC	644	CPRR	648	CVRR	64C	XO2	650
XN2	654	XO	658	XN	65C	GP	660	XNO	664
XNOP	668	XNP	66C	XOP	670	SO2	674	SN2	678
SNO	67C	SO	680	SN	684	SOP	688	SNP	68C
SE	690	CVRP	694	CVR	698	AARP	69C	SRHO	6A0
X1	6A4	X2	6A8	X3	6AC	X4	6B0	CV1R	6B4
CV2R	6B8	CV3R	6BC	CSD11	6C0	CSD12	6C4	CSD22	6C8
CSD23	6CC	CSD24	6D0	CSD33	6D4	CSD34	6D8	CSD44	6DC
CSV11	6E0	CSV22	6E4	CSV33	6E8	CSV44	6EC	DELTA1	6F0
DELTA2	6F4	DELTA	6F8	PART1	6FC	PART2	700	PART3	704
PART4	708	PART>	70C	PART6	710	PART7	714	PART8	718
VLMIX	71C	PART9	720	PART10	724	PART11	728	EUCKEN	72C
RLO2	730	RLN2O2	734	RLN2	738	RLN	73C	CVDR	740
R	744								

FORMAT STATEMENT MAP

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
200	748								

```
*OPTIONS IN EFFECT*  IO,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,MAP
*OPTIONS IN EFFECT*  NAME = ANAPRP   , LINECNT =       58
*STATISTICS*    SOURCE STATEMENTS =       334,PROGRAM SIZE =     10866
*STATISTICS*  NO DIAGNOSTICS GENERATEO
```

```
C                                                                        POLY0010
CSUBROUTINE POLY                                                         POLY0020
C                                                                        POLY0030
      SUBROUTINE POLY(A,N,X,P,XMIN,XMAX)                                 POLY0040
      DIMENSION A(21)                                                    POLY0050
      S=((2.*X)-(XMAX+XMIN))/(XMAX-XMIN)                                 POLY0060
      P=0.                                                               POLY0070
      N1=N+1                                                             POLY0080
      DO 1 I=1,N1                                                        POLY0090
      II=N1+1-I                                                          POLY0100
    1 P=P*S+A(II)                                                        POLY0110
      RETURN                                                             POLY0120
      END                                                                POLY0130
```

```
                                   SCALAR MAP
SYMBOL    LOCATION        SYMBOL   LOCATION       SYMBOL    LOCATION       SYMBOL    LOCATION       SYMBOL    LOCATION
S               94        X              98       XMAX            9C       XMIN            A0       P               A4
N1              A8        N              AC       I               B0       II              B4

                                   ARRAY MAP
SYMBOL    LOCATION        SYMBOL   LOCATION       SYMBOL    LOCATION       SYMBOL    LOCATION       SYMBOL    LOCATION
A               B8

   *OPTIONS IN EFFECT*  ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,MAP
   *OPTIONS IN EFFECT*  NAME = POLY     , LINECNT =       58
   *STATISTICS*    SOURCE STATEMENTS =       10,PROGRAM SIZE =      550
   *STATISTICS*  NO DIAGNOSTICS GENERATED


             C                                                                  CNSK0010
             C      SUBROUTINE CONSHK                                           CNSK0020
             C                                                                  CNSK0030
 0001               SUBROUTINE CONSHK (TET,XMINF,VINFY,GAMINF,RHOINF,HINFY,PINFY,LLL, CNSK0040
                   1JX,PP,TT,TETS,IZ29,K51)                                     CNSK0050
 0002               DIMENSION  XT2(51)                                          CNSK0060
 0003               DIMENSION COEF(5),COEFF(5,5),NDEG(5),XMAX(5),XMIN(5)        CNSK0070
 0004               COMMON /ARRAY/A(23)                                         CNSK0080
 0005               DATA COEFF/17.4921875,16.696205,2.65781257,-6.346205,0.,43.718005,CNSK0090
                   1    7.91310851,-3.27146657,1.43995064,-.601292207,52.8000001,    CNSK0100
                   2    2.36647676,-.849623186,.28352329,-.100376848,55.9640625,     CNSK0110
                   3    1.27135383,-.414062554,-.221353822,0.,57.0167813,-1.21994631, CNSK0120
                   4    .0332183853,1.56994653,0./,NDEG/3,4,4,3,3/,XMAX/1.5,3.,5.,10.,CNSK0130
                   5   100./,XMIN/1.05,1.5,3.,5.,10./                           CNSK0140
 0006               LOGICAL  J                                                  CNSK0150
 0007               KKK1=1                                                      CNSK0160
 0008               J25=0                                                       CNSK0170
 0009               KK=0                                                        CNSK0180
 0010               TH2=0.                                                      CNSK0190
 0011               DEL=.01                                                     CNSK0200
 0012               HT=HINFY + (VINFY**2/50123.)                                CNSK0210
 0013               N=1                                                         CNSK0220
 0014               VINF=VINFY                                                  CNSK0230
 0015               K51=1                                                       CNSK0240
             CCHECK CONE HALF ANGLE (TET) TO ASSURE THAT AT XMINF THE CONE NOSE SHOCKCNSK0250
             C      WILL NOT SEPARATE.  IF IT DOES, CUT PROGRAM, PRINT WARNING AND GO CNSK0260
             C      TO NEXT PROBLEM.                                            CNSK0270
             C                                                                  CNSK0280
             C  TH1 = ACTUAL DEFLECTION ANGLE IN DEGREES                        CNSK0290
             C      TH2 = MAXIMUM ALLOWABLE TH1 AT XMINF (IN DEGREES)           CNSK0300
 0016               IZ29=1                                                      CNSK0310
 0017               XXTETA=TET                                                  CNSK0320
 0018               TH1=XXTETA*57.295                                           CNSK0330
 0019               D=XMINF                                                     CNSK0340
 0020               IF(JX)1721,7366,1721                                        CNSK0350
 0021          7366 IF(D-1.05)7355,7341,7341                                    CNSK0360
 0022          7341 IF(D-1.5)7342,7343,7343                                     CNSK0370
 0023          7342 ISEC=1                                                      CNSK0380
 0024               GO TO 6680                                                  CNSK0390
 0025          7343 IF(D-3.)7344,7345,7345                                      CNSK0400
 0026          7344 ISEC=2                                                      CNSK0410
 0027               GO TO 6680                                                  CNSK0420
 0028          7345 IF(D-5.)7346,7347,7347                                      CNSK0430
 0029          7346 ISEC=3                                                      CNSK0440
 0030               GO TO 6680                                                  CNSK0450
 0031          7347 IF(D-10.)7348,7349,7349                                     CNSK0460
 0032          7348 ISEC=4                                                      CNSK0470
 0033               GO TO 6680                                                  CNSK0480
 0034          7349 ISEC=5                                                      CNSK0490
 0035          6680 DO 6670 I=1,5                                               CNSK0500
 0036          6670 COEF(I)=COEFF(I,ISEC)                                       CNSK0510
 0037               CALL POLY(COEF       ,NDEG(ISEC),D,TH2,XMIN(ISEC),XMAX(ISEC))   CNSK0520
 0038               IF(TH2-TH1)7340,6671,6671                                   CNSK0530
 0039          7355 WRITE(6,7356)                                               CNSK0540
 0040          7356 FORMAT(/2X,'FREE STREAM MACH NO. IS LESS THAN 1.05')        CNSK0550
 0041               RETURN                                                      CNSK0560
 0042          7340 WRITE(6,6673)D,TH1,TH2                                      CNSK0570
 0043          6673 FORMAT(/2X,'NOSE SHOCK IS DETACHED.  USE BLUNT BODY PROGRAM'/   CNSK0580
                   12X,'THE FREE STREAM MACH NO. = 'E14.6/2X,'THE ACTUAL DEFLECTION ANCNSK0590
                   2GLE = 'E14.6/2X,'THE DEFL. ANGLE FOR DETACHMENT = 'E14.6/2X,    CNSK0600
                   3'GO TO NEXT PROBLEM')                                       CNSK0610
 0044               K51=-1                                                      CNSK0620
 0045               RETURN                                                      CNSK0630
 0046          6671 CONTINUE                                                    CNSK0640
 0047               WRITE(6,7360)  TH1,TH2                                      CNSK0650
 0048          7360 FORMAT(/2X,             'TH1='E14.6,2X,'TH2='E14.6/2X,'WHERE TH1= CNSK0660
                   1POINT 1 STREAM DEFLECTION ANGLE,DEGREES.  TH2=STREAM DEFLECTION ANCNSK0670
                   2GLE AT POINT 1 WHICH CAUSES SEPARATION OF SHOCK WAVE')      CNSK0680
 0049          1721 IF((XMINF*SIN(TET))-3.)30,30,31                             CNSK0690
 0050            31 SINTHS=1.0027*SIN(TET)+.5567/XMINF                          CNSK0700
 0051               TETS=ARSIN(SINTHS)                                          CNSK0710
 0052             6 SINTS=SINTHS                                                CNSK0720
             C       ESTIMATE PTWO AND TTWO                                     CNSK0730
 0053               PTWO=PINFY*((2.*GAMINF*(XMINF**2)*(SINTS**2)-(GAMINF-1.))/(GAMINF+CNSK0740
                   X1.))                                                        CNSK0750
 0054               VT = VINFY * COS(TETS)                                      CNSK0760
 0055               HTWO = HT-(VT**2/50123.)                                    CNSK0770
 0056               TTWO = HTWO/.432                                            CNSK0780
 0057               IF(TTWO-15000.) 8,8,7                                       CNSK0790
 0058             7 TTWO = 15000.                                               CNSK0800
 0059             8 IF(TTWO-50.)9,9,10                                          CNSK0810
 0060             9 TTWO=50.                                                    CNSK0820
 0061            10 P = PTWO                                                    CNSK0830
 0062               T = TTWO                                                    CNSK0840
 0063               L=1                                                         CNSK0850
 0064               GO TO 6000                                                  CNSK0860
```

```
 1110 RHOTWO =.002507* A(3)
      RHORAT = RHOINF/RHOTWO
      CP2=.123406*A(4)
C
C     OBLIQUE SHOCK ROUTINE
C
      NTEST4=0
      NTEST5=0
 6080 K=1
      NTEST6=0
      NTEST7=0
      XM=PINFY*((1.-RHORAT)*GAMINF*(XMINF**2)*(SINTS**2)+1.)-PTWO
      YE=HINFY*((1.-RHORAT**2)*((GAMINF-1.)/2.)*(XMINF**2)*(SINTS**2)+1.
     1)-HTWO
      F=XM**2+YE**2
      IF(F-10.)6030,6030,6001
 6001 P2A=PTWO+DEL*PTWO
      P2B=PTWO-DEL*PTWO
      T2A=TTWO+DEL*TTWO
      T2B=TTWO-DEL*TTWO
      P=PTWO
      T=T2A
      L=2
      GO TO 6000
C     AT PTWO AND T2A
 6004 RHO21=.002507*A(3)
      H21=129.0816*A(8)
      P=PTWO
      T=T26
      L=3
      GO TO 6000
C     AT PTWO AND T2B
 6005 RHO22=.002507*A(3)
      H22=129.0816*A(8)
      P=P2A
      T=TTWO
      L=4
      GO TO 6000
C     AT P2A AND TTWO
 6006 RHO23=.002507*A(3)
      H23=129.0816*A(8)
      P=P2B
      T=TTWO
      L=5
      GO TO 6000
C     AT P2B AND TTWO
 7331 RHO24=.002507*A(3)
      H24=129.0816*A(8)
      DHDPCT=(H23-H24)/(P2A-P26)
      DRDPCT=(RHO23-RHO24)/(P2A-P2B)
      DRDTCP=(RHO21-RHO22)/(T2A-T26)
      DHDTCP=(H21-H22)/(T2A-T26)
      XYZ=XMINF**2*SINTS**2
      XYZZ=GAMINF*XYZ
      XYZZZ=((GAMINF-1.)/2.)*XYZ
      DMDPCT=PINFY*(XYZZ*(RHOINF/RHOTWO**2)*DRDPCT)-1.
      DMDTCP=PINFY*(XYZZ*(RHOINF/RHOTWO**2)*DRDTCP)
      DEDPCT=HINFY*(XYZZZ*(2.*RHOINF**2/RHOTWO**3)*DRDPCT)-DHDPCT
      DEDTCP=HINFY*(XYZZZ*(2.*RHOINF**2/RHOTWO**3)*DRDTCP)-DHDTCP
      DELTP=(DMDTCP*YE-DEDTCP*XM)/(DMDPCT*DEDTCP-DMDTCP*DEDPCT)
      DELTT=(DEDPCT*XM-DMDPCT*YE)/(DMDPCT*DEDTCP-DMDTCP*DEDPCT)
      PTWO=PTWO+DELTP
      IF(PTWO)8713,8713,8714
 8713 PTWO=.00001
 8714 CONTINUE
      TTWO=TTWO+DELTT
      IF(TTWO-50.)6970,6971,6971
 6970 TTWO=50.
 6971 IF(TTWO-15000.)6972,6972,6973
 6973 TTWO=15000.
 6972 CONTINUE
      KK=KK+1
      XT2(KK)=DELTT
      P=PTWO
      T=TTWO
      L=6
      GO TO 6000
 6007 HTWO=129.0816*A(8)
      RHOTWO=.002507*A(3)
      SR2=A(2)
      CPTWO=.123406*A(4)
      CP2=CPTWO
      RHORAT=RHOINF/RHOTWO
      XM=PINFY*((1.-RHORAT)*GAMINF*(XMINF**2)*(SINTS**2)+1.)-PTWO
      YE=HINFY*((1.-RHORAT**2)*((GAMINF-1.)/2.)*(XMINF**2)*(SINTS**2)+1.
     1)-HTWO
      F=XM**2+YE**2
      NTEST6=NTEST6+1
      IF(F-10.)6030,6030,6606
 6606 IJK=6606
      IF(KKK1-3)740,740,54
  740 IF(KK-3)54,52,52
   52 ALL1=ABS(XT2(KK))
      ALL2=ABS(XT2(KK-2))
      IF((ABS(ALL1-ALL2)/ALL1)-.035)50,50,54
   50 DEL=DEL/2.
      KKK1=KKK1+1
      J25=J25+1
      IF(J25-20)6001,6001,56
   56 IJK=J25
      GO TO 6050
   54 IF(NTEST6-50)6001,6001,6050
 6050 WRITE(6,6051)IJK
 6051 FORMAT(/2X,'NON-CONVERGENCE AT IJK='I4/3X,'GO TO PERFECT GAS SHOCK
     1 ROUTINE')
```

```
      GO TO 30
 6030 ZYX=TAN(TETS)
      TETCI=(((1+N)-RHORAT)*ZYX)/((1+N)+RHORAT*(ZYX**2))
      TETCI=ATAN(TETCI)
      DTETS=TET-TETCI
      NTEST5=NTEST5+1
      IF(ABS(DTETS/TET)-.002)7716,7716,7841
 7841 TETS=TETS+DTETS
      SINTS=SIN(TETS)
      NTEST6=0
      IF(NTEST5-25)6001,6001,7731
 7731 IJK=7841
      GO TO 6050
 7716 PC=PTWO+((RHOINF*VINF**2*RHORAT*SIN(TETS)**2)/4232.4)
 7164 TC=TTWO
 7189 P=PC
      T=TC
      L=7
      GO TO 6000
 7161 SRC=A(2)
      NTEST7=NTEST7+1
      CPRP=.123406*A(4)
      DSR=SR2-SRC
      IF(ABS(DSR/SR2)-.0005)7162,7162,7163
 7163 DTC=(TC/CPRP)*DSR*.123406
      TC=TC+(DTC/4.)
      IF(NTEST7-35)7169,7169,7170
 7170 IJK=7163
      GO TO 6050
 7169 IF(TC-50.)7165,7165,7166
 7165 TC=50.-(.85*NTEST7)
 7166 IF(TC-15000.)7189,7189,7168
 7168 TC=15000.
      GO TO 7189
 7162 P=PC
      T=TC
      GO TO 6999
   30 A1=4.*(SIN(TET)**2)
      WRITE(6,5050)
 5050 FORMAT(//2X,'USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS')
      A2=SQRT(XMINF**2-1.)
      A3=SIN(TET)
      A4=A2*A3
      XNOM1=2.5+8.*A4
      DEN1=1.+16.*A4
      A5=XNOM1/DEN1
      CP=A1*A5
      A6=VINF**2
      A7=RHOINF/2.
      PC=((CP/2116.2)*A6*A7)+PINFY
      XNHER=.40835*(XMINF*SIN(TET))-.08167
      IF(XNHER)33,33,34
   33 XNHER=0.
   34 HC=EXP(XNHER)*HINFY
      HT=HINFY+VINFY**2/50123.
      A10=50123.*(HT-HC)
      VC=SQRT(A10)
      A11=XMINF**2-1.
      A12=GAMINF+1.
      A13=A3**2
      A14=.5*A12*A11*A13
      A15=1.+A14
      A16=SQRT(A15)
      SINTS=(1.-COS(TET)+A16)/XMINF
      TETS=ARSIN(SINTS)
      T=HC/.432
      IF(T-50.)5061,5061,5062
 5061 T=50.
 5062 CONTINUE
      IF(TET)960,960,961
  960 P=PINFY
      T=TINFY
      GO TO 6999
  961 IF(LLL-1)43,44,44
   43 J=.TRUE.
      GO TO 45
   44 J=.FALSE.
   45 IITER=5
      P=PC
      CALL ITER(P,T,HC,IITER,J)
      IF(IITER.LE.0) GO TO 6899
      GO TO 6999
 6899 IZ29=-1
      RETURN
 6999 L=8
 6000 PP=P
      TT=T
      IF(TT-50.)650,651,651
  650 TT=50.
      GO TO 652
  651 IF(TT-15000.)652,652,653
  653 TT=15000.
  652 CONTINUE
      IF(P-PINFY)4000,4000,4001
 4000 P=PINFY
 4001 CONTINUE
      CALL ANAPRP(P,T,&1111)
      GO TO(1110,6004,6005,6006,7331,6007,7161,6035),L
 6035 RETURN
 1111 K51=-1
      WRITE(6,2999)L
 2999 FORMAT(/2X,'FAILURE IN ANAPRP CALLED FROM CONSHK WITH L='I3)
      RETURN
      END
```

COMMON BLOCK /ARRAY / MAP SIZE 5C

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
A	0								

SUBPROGRAMS CALLED

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
POLY	2EC	IBCOM#	2F0	ITER	2F4	ANAPRP	2F8	SIN	2FC
ARSIN	300	COS	304	TAN	308	ATAN	30C	SQRT	310
EXP	314								

SCALAR MAP

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
KKK1	3A4	J25	3A8	KK	3AC	TH2	3B0	DEL	3B4
HT	3B8	HINFY	3BC	VINFY	3C0	N	3C4	VINF	3C8
K51	3CC	1229	3D0	XXTETA	3D4	TET	3D8	TH1	3DC
D	3F0	XMINF	3E4	JX	3E8	ISFC	3EC	I	3F0
SINTHS	3F4	TETS	3F8	SINTS	3FC	PTWO	400	PINFY	404
GAMINF	408	VT	40C	HTWO	410	TTWO	414	P	418
T	41C	L	420	RHOTWO	424	RHORAT	428	RHOINF	42C
CP2	430	NTEST4	434	NTEST5	438	K	43C	NTEST6	440
NTEST7	444	XM	448	YE	44C	F	450	P2A	454
P2B	458	T2A	45C	T2B	460	RHO21	464	H21	468
RHO22	46C	H22	470	RHO23	474	H23	478	RHO24	47C
H24	480	DHOPCT	484	DRDPCT	488	DRDTCP	48C	DHDTCP	490
XYZ	494	XYZZ	498	XYZZZ	49C	DHDPCT	4A0	DHDTCP	4A4
DEDPCT	4A8	DEDTCP	4AC	DELTP	4B0	DELTT	4B4	SR2	4B8
CPTWO	4BC	IJK	4C0	ALL1	4C4	ALL2	4C8	ZYX	4CC
TETCI	4D0	DTETS	4D4	PC	4D8	TC	4DC	SRC	4E0
CPRP	4E4	DSR	4E8	DTC	4EC	A1	4F0	A2	4F4
A3	4F8	A4	4FC	XNOM1	500	DEN1	504	A5	508
CP	50C	A6	510	A7	514	XNMER	518	HC	51C
A10	520	VC	524	A11	528	A12	52C	A13	530
A14	534	A15	538	A16	53C	TINFY	540	LLL	544
J	548	ITTER	54C	PP	550	TT	554		

ARRAY MAP

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
XT2	558	COEF	624	COEFF	638	NDEG	69C	XMAX	6B0
XMIN	6C4								

FORMAT STATEMENT MAP

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
7356	6D8	6673	705	7360	7C4	6051	863	5050	8A7
2999	8DF								

```
*OPTIONS IN EFFECT*  ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,MAP
*OPTIONS IN EFFECT*  NAME = CONSHK  , LINECNT =       58
*STATISTICS*    SOURCE STATEMENTS =      263,PROGRAM SIZE =     6652
*STATISTICS*  NO DIAGNOSTICS GENERATED
```

```
           C                                                                    RGPM0010
           C   REAL AND PERFECT GAS PRANDTL-MEYER EXPANSION SUBROUTINE          RGPM0020
           C                                                                    RGPM0030
0001             SUBROUTINE RGPM(P1,T1,SR1,V7,A1,RHO1,CP1,H1,VISC1,TK1,DTHETA,HT, RGPM0040
                1CPCV1,XM1,XXTETA,DELVX,ALPHA,IB,P2,T2,K50)                     RGPM0050
0002             COMMON/DRRAY/QRATL(15),QRATT(15),PHI(15)                       RGPM0060
0003             COMMON /ARRAY/A(23)                                            RGPM0070
0004             ZZZ1=1.                                                        RGPM0080
0005             ZZZ2=1.                                                        RGPM0090
0006             K50=1                                                          RGPM0100
0007             K75=1                                                          RGPM0110
0008             XN20=1.                                                        RGPM0120
0009             XN21=1.                                                        RGPM0130
0010             V1=V7                                                          RGPM0140
0011             NSTOP1=0                                                       RGPM0150
0012             THETA1=0.                                                      RGPM0160
0013             CON23=SQRT(V1**2-A1**2)/(A1*V1)                                RGPM0170
0014             CON17=RHO1*V1                                                  RGPM0180
0015             CON16=CON17                                                    RGPM0190
0016             CON22=CON23                                                    RGPM0200
0017             DELV=DELVX                                                     RGPM0210
0018             NXX=0                                                          RGPM0220
0019             IX1=0                                                          RGPM0230
0020             IX2=0                                                          RGPM0240
0021             NXY=0                                                          RGPM0250
0022          84 V2=V1+DELVX                                                    RGPM0260
0023             NSTOP=0                                                        RGPM0270
0024             NSTOP1=NSTOP1+1                                                RGPM0280
0025             IF(NSTOP1-51)85,85,585                                         RGPM0290
0026         225 WRITE(6,5000) IJK                                              RGPM0300
0027        5000 FORMAT(///2X,'NONCONVERGENCE AT IJK='I4)                       RGPM0310
0028             K50=-1                                                         RGPM0320
0029             RETURN                                                         RGPM0330
0030          85 CON15=V2*V2                                                    RGPM0340
0031             H2=HT-(CON15/50123.)                                           RGPM0350
0032             CON21=V2-V1                                                    RGPM0360
0033             P2=P1-(CON16*CON21)/2116.2                                     RGPM0370
0034             IF(P2)170,170,171                                              RGPM0380
0035         170 P2=.9*P1                                                       RGPM0390
0036         171 CON20=H2-H1                                                    RGPM0400
0037             T2=T1+(CON20)/CP1                                              RGPM0410
0038             L=1                                                            RGPM0420
0039             P=P2                                                           RGPM0430
0040             T=T2                                                           RGPM0440
0041             IF(P)585,585,4901                                              RGPM0450
0042        4901 IF(T-100.)4902,4903,4903                                       RGPM0460
0043        4902 T=100.                                                         RGPM0470
```

```
      GO TO 6000
 4903 IF(T-15000.)4904,4904,4905
 4905 T=15000.
 4904 GO TO 6000
   86 CP2=.123406* A(4)
      RHO2 = .002507 * A(3)
      CPA=(CP1+CP2)/2.
      T2=T2+(CON20)/CPA
      IF(T2-100.)8910,8910,8911
 8910 T2=100.
      GO TO 88
 8911 IF(T2-15000.)88,88,8912
 8912 T2=15000.
      GO TO 88
   87 RHO2 = .002507 * A(3)
   88 CON17=RHO2*V2
      RHOAVA=(CON16+CON17)/2.
      P2=P1-(RHOAVA*(CON21/2116.2))
      L=2
      P=P2
      T=T2
      IF(P)585,585,4906
 4906 IF(T-100.)4907,4908,4908
 4907 T=100.
      GO TO 6000
 4908 IF(T-15000.)4909,4909,4910
 4910 T=15000.
 4909 GO TO 6000
  585 WRITE(6,8340)
 8340 FORMAT(//2X,'REAL GAS P-M ROUTINE FAILED (VEL. TOO LOW) - PROGRAM
     1HAS SWITCHED TO PERFECT GAS P-M EXPANSION')
      DELNU=DTHETA
      T2EST=T1
      AL1=XM1**2
      AL2=CPCV1*AL1
      AL3=AL1-1.
      AL4=(AL2/SQRT(AL3))*DELNU
      AL5=CPCV1+1.
      AL6=AL5*AL1**2
      AL7=4.*AL3
      AL8=4.*AL3**2
      AL9=AL2*((AL6-AL7)/AL8)*(DELNU**2)
      AL10=AL2/(2.*AL3**3.5)
      AL11=((CPCV1+1.)/6.)*(AL1**4)
      AL12=((5.+7.*CPCV1-2.*CPCV1**2)/6.)*AL1**3
      AL13=1.6667*AL5*AL1**2
      AL14=-2.*AL1+1.3333
      AL15=AL10*(AL11-AL12+AL13+AL14)*(DELNU**3)
      P2R=P1*(1.-AL4+AL9-AL15)
      P=P2R
      T=T2EST
      SR=SR1
      NSTOP9=0
      L=3
      GO TO 6000
  573 DSR=SR-A(2)
      CP2R=.123406*A(4)
      IF(ABS(DSR/SR)-.0005)574,574,575
  575 NSTOP9=NSTOP9+1
      IJK=573
      IF(NSTOP9-50)576,576,225
  576 T=T+(T/CP2R)*DSR*.123406*.25
      IF(T-15000.)577,577,578
  578 T=15000.
      GO TO 579
  577 IF(T-50.)580,579,579
  580 T=50.-XN20
      XN20=XN20-1.
  579 GO TO 6000
  574 P2=P2R
      T2=T
      D15=SQRT(T2)
      TK2=D15*A(11)*3.28512E-7
      VISC2=D15*A(10)*2.209698E-8
      PR2=A(16)
      Z2=A(9)
      SR2=A(2)
      H2=129.0816*A(8)
      V2=224.*SQRT(HT-H2)
      CPCV2=A(14)
      A2=1140.*A(6)
      XM2=V2/A2
      RHO2=.002507*A(3)
      GO TO 97
   89 DSR2=SR1-A(2)
      CP2=.123406*A(4)
      SR2=A(2)
      IF(ABS(DSR2/SR1)-.0005)92,92,90
   90 NSTOP=NSTOP+1
      IF(NSTOP-40)91,91,585
   91 T2=T2+(T2/CP2)*DSR2*.123406*.25
      T=T2
      IF(T-15000.)912,912,911
  911 T=15000.
  912 IF(T-50.)913,913,914
  913 T=50.-XN21
      XN21=XN21+1.
  914 L=4
      P=P2
      GO TO 6000
   92 CP2 =.123406 * A(4)
      RHO2=.002507 * A(3)
      A2=1140. * A(6)
   93 CON23=SQRT(CON15-A2**2)/(A2*V2)
```

```
      DTETA=(DELVX/2.)*(CON22+CON23)
      D1=DTHETA-DTETA
      IF(ABS(D1/DTHETA)-.001)97,97,61
   61 IF(NXX-1)62,63,63
   62 IF(D1)64,65,65
   64 IX1=-1
      GO TO 63
   65 IX2=1
   63 NXX=NXX+1
      IF(IX1+IX2)66,67,66
   66 IF(D1)68,69,69
   68 IX1=-1
      DELVX=DELVX-DELV
      GO TO 84
   69 IX2=1
      DELVX=DELVX+DELV

   67 IF(D1)70,71,71
   70 IF(ZZZ1+ZZZ2)7161,7160,7160
 7160 DELVX=DELVX-.095*DELV
      ZZZ1=-1.
      GO TO 7162
 7161 DELVX=DELVX-.004*DELV
      GO TO 7162
   71 IF(ZZZ1+ZZZ2)7163,7164,7164
 7164 DELVX=DELVX+.095*DELV
      ZZZ2=-1.
      GO TO 7162
 7163 DELVX=DELVX+.004*DELV
 7162 NXY=NXY+1
      IF(NXY-50)84,84,7170
 7170 WRITE(6,7171)
 7171 FORMAT(/2X,'FAILURE OF CONVERGENCE OF THETA IN RGPM, STMNT 70 OR 7
     11')
      K50=-1
      RETURN
 6000 CALL ANAPRP(P,T,&1111)
      GO TO(86,89,573,87),L
C  CALCULATE LAM AND TURB QRATIOS     QRATL AND QRATT
   97 IF(IB-1)4370,4370,4371
 4371 RETURN
 4370 XXTETA=XXTETA+DTHETA
      DO 1950 I=1,11
      COUNT=I
      PHI(I)=XXTETA-COUNT*DTHETA
      IF(ALPHA)740,740,742
  742 IF(I-11)741,743,743
  743 QRATL(11)=QRATL(10)
      QRATT(11)=QRATT(10)
      GO TO 1950
  740 QRATL(I)=1.
      QRATT(I)=1.
      GO TO 1950
  741 RR1=2.*TAN(PHI(I))
      RR2=TAN(PHI(I)-ALPHA)
      RR3=RR1/RR2
      RR4=1.+RR3
      RR5=RR4/3.
      QRATL(I)=SQRT(RR5)
      RR6=RR1/2.
      RR7=RR6/RR2
      XK22=1.25*RR7
      RR8=(1.+XK22)**.2
      QRATT(I)=.85*RR8
 1950 CONTINUE
      XXTETA=XXTETA-DTHETA
      DO 1951  I=12,15
      QRATL(I)=QRATL(11)
 1951 QRATT(I)= QRATT(11)
      RETURN
 1111 K50=-1
      WRITE(6,2995)
 2995 FORMAT(/2X,'FAILURE IN ANAPRP,CALLED BY RGPM')
      WRITE(6,4931)
 4931 FORMAT(/2X,'ZOUNDS AND GADZOOKS, THE VERY LEAST'/2X,
     1'ONE MIGHT EXPECT FROM THIS TUBELESS BEAST'/2X,
     2'IS THE CURTESY OF A PROMPT REPLY'/2X,
     3'AND A LITTLE HELP TO FATHOM WHY'/2X,
     4'(WITH THE PERFECT LOGIC THIS PROGRAM ENTAILED)'/2X,
     5'THE IBM 360 FAILED')
      RETURN
      END
```

COMMON BLOCK /DRRAY / MAP SIZE 84

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
QRATL	0	QRATT	3C	PHI	78				

COMMON BLOCK /ARRAY / MAP SIZE 5C

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
A	0								

SUBPROGRAMS CALLED

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
IBCOM#	2A8	FRXPR#	2AC	ANAPRP	2B0	SQRT	2B4	TAN	2B8

SCALAR MAP

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
ZZZ1	300	ZZZ2	304	K50	308	K75	30C	XN20	310
XN21	314	V1	318	V7	31C	NSTOP1	320	THETA1	324
CON23	328	A1	32C	CON17	330	RHO1	334	CON16	338
CON22	33C	DELV	340	DELVX	344	NXX	348	IX1	34C
IX2	350	NXY	354	V2	358	NSTOP	35C	IJK	360

```
CON15        364      H2          368      HT          36C      CON21       370      P2          374
P1           378      CON20       37C      H1          380      T2          384      T1          388
CP1          38C      L           390      P           394      T           398      CP2         39C
RHO2         3A0      CPA         3A4      RHOAVA      3A8      DELNU       3AC      DTHETA      380
T2EST        3B4      AL1         3B8      XM1         3BC      AL2         3C0      CPCV1       3C4
AL3          3C8      AL4         3CC      AL5         3D0      AL6         3D4      AL7         3D8
AL8          3DC      AL9         3E0      AL10        3E4      AL11        3E8      AL12        3EC
AL13         3F0      AL14        3F4      AL15        3F8      P2R         3FC      SR          400
SR1          404      NSTOP9      408      DSR         40C      CP2R        410      D15         414
TK2          418      VISC2       41C      PR2         420      Z2          424      SR2         428
CPCV2        42C      A2          430      XM2         434      DSR2        438      DTETA       43C
D1           440      IB          444      XXTETA      448      I           44C      COUNT       450
ALPHA        454      RR1         458      RR2         45C      RR3         460      RR4         464
RR5          468      RR6         46C      RR7         470      XK22        474      RR8         478
VISC1        47C      TK1         480

                                FORMAT STATEMENT MAP
SYMBOL    LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION     SYMBOL   LOCATION
  5000       484         8340      4A5         7171      5D8         2995      549         4931      570


   *OPTIONS IN EFFECT*  ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,MAP
   *OPTIONS IN EFFECT*  NAME = RGPM    , LINECNT =       58
   *STATISTICS*    SOURCE STATEMENTS =      221,PROGRAM SIZE =     5244
   *STATISTICS*  NO DIAGNOSTICS GENERATED
```

```
SPIE                                      EXTERNAL SYMBOL DICTIONARY
SYMBOL    TYPE ID  ADDR  LENGTH LD ID                                                            11.19  3/03/71

SPIE       SD  01 000000 0000D8
YECH       LD     0000A8          01
R1         LD     0000C8          01
```

```
  LOC  OBJECT CODE    ADDR1 ADDR2  STMT   SOURCE STATEMENT                                         F30SEP69    3/03/71

                                    2 * 9/17/68 - L.F.H.                                                    SPIE0020
                                    3 * MOD. 3/07/69 - L.F.H.                                               SPIE0030
                                    4 *                                                                     SPIE0040
                                    5 * USAGE...CALL SPIF( LDW )                                            SPIE0050
                                    6 *      WHERE LDW IS A PARAMETER CALLING FOR SETTING A NEW P.I.E. OR RE-  SPIE0060
                                    7 * SETTING THE OLD P.I.E. DEPENDING ON WHETHER IT IS .GT. ZERO OR .LT.  SPIE0070
                                    8 * ONE, RESPECTIVELY.  IF THE NEW P.I.E. HAS BEEN SET, IT REMAINS IN    SPIE0080
                                    9 * EFFECT ON SUBSEQUENT CALLS ON SPIF WITH LDW .GT. ZERO; THE OLD P.I.E. SPIE0090
                                   10 * IS RESET IF A SUBSEQUENT CALL ON SPIE HAS LDW .LT. ONE.              SPIE0100
                                   11 *                                             ...GOOD LUCK-L.F.H.     SPIE0110
                                   12 *                                                                     SPIE0120
000000                             13 SPIE     CSECT                                                        SPIE0130
                                   14          ENTRY YECH,R1                                                SPIE0140
000000                             15          USING *,15                                                   SPIE0150
000000 47F0 F054          00054    16          B     S100                                                   SPIE0160
000004 F5E207C9C540                17          DC    CL6'5SPIE '                                            SPIE0170
00000C                             18 SAREA    DS    18F                                                    SPIE0180
000054 90EC D00C          0000C    19 S100     STM   14,12,12(13)                                           SPIE0190
                                   20 *                                                                     SPIE0200
000058 41C0 F00C          0000C    21          LA    12,SAREA                                               SPIE0210
00005C 50DC 0004          00004    22          ST    13,4(12)                                               SPIE0220
000060 50CD 0008          00008    23          ST    12,8(13)                                               SPIE0230
000064 18DC                        24          LR    13,12                                                  SPIE0240
                                   25 *                                                                     SPIE0250
000066 0520                        26          BALR  2,0                                                    SPIE0260
000068                             27          USING *,2                                                    SPIE0270
                                   28          DROP  15                                                     SPIE0280
                                   29 *                                                                     SPIE0290
000068 5831 0000          00000    30          L     3,0(1)                                                 SPIE0300
00006C 5843 0000          00000    31          L     4,0(3)                                                 SPIE0310
000070 5940 2068          000D0    32          C     4,=F'1'                                                SPIE0320
000074 4740 2042          000AA    33          BL    S300                                                   SPIE0330
                                   34 *                                                                     SPIE0340
000078 5840 2064          000CC    35          L     4,FLAG                                                 SPIE0350
00007C 5940 2068          000D0    36          C     4,=F'1'                                                SPIE0360
000080 4780 2034          0009C    37          BE    S200                                                   SPIE0370
000084 D203 2064 2068 000CC 000D0  38          MVC   FLAG,=F'1'                                             SPIE0380
                                   39 *                                                                     SPIE0390
                                   40          SPIE  YECH,((1,15))                                          SPIE0400
00008A                             41+         CNOP  2,4
00008A 4110 202E          00096    42+         LA    1,*+12 LOAD BRANCH ADDRESS
00008E 0511                        43+         BALR  1,1 BRANCH AROUND PARAMS.
000090 0F                          44+         DC    B'00001111' PROGRAM MASK BITS
000091 0000A8                      45+         DC    AL3(YECH) EXIT ROUTINE ADDRESS
000094 7F                          46+         DC    B'01111111'
000095 FF                          47+         DC    B'11111111' INTERUPTION MASK
000096 0A0E                        48+         SVC   14 ISSUE SPIE SVC
000098 5010 2060          000C8    49          ST    1,R1                                                   SPIE0410
                                   50 *                                                                     SPIE0420
00009C 58DC 0004          00004    51 S200     L     13,4(12)                                               SPIE0430
0000A0 98EC D00C          0000C    52          LM    14,12,12(13)                                           SPIE0440
0000A4 92FF D00C    0000C          53          MVI   12(13),X'FF'                                           SPIE0450
0000A8 07FE                        54 YECH     BCR   15,14                                                  SPIE0460
                                   55 *                                                                     SPIE0470
0000AA 5840 2064          000CC    56 S300     L     4,FLAG                                                 SPIE0480
0000AE 5940 206C          000D4    57          C     4,=F'0'                                                SPIE0490
0000B2 4780 2034          0009C    58          BE    S200                                                   SPIE0500
0000B6 5810 2060          000C8    59          L     1,R1                                                   SPIE0510
                                   60          SPIE  MF=(E,(1))                                             SPIE0520
0000BA 0A0E                        61+         SVC   14 ISSUE SPIE SVC
0000BC D703 2064 2064 000CC 000CC  62          XC    FLAG,FLAG                                              SPIE0530
0000C2 47F0 2034          0009C    63          B     S200                                                   SPIE0540
                                   64 *                                                                     SPIE0550
0000C8                             65 R1       DS    F                                                      SPIE0560
```

```
000OCC 00000000                       66 FLAG     DC     F'0'                                               SPIE0570
0000D0                                67          LTORG                                                     SPIE0580
0000D0 00000001                       68                 =F'1'
0000D4 00000000                       69                 =F'0'
                                      70          END                                                       SPIE0590


SPIE                                          RELOCATION DICTIONARY

 POS.ID   REL.ID   FLAGS   ADDRESS                                                                           3/03/71

   01       01      08      000091


SPIE                                        CROSS-REFERENCE

SYMBOL    LEN   VALUE  DEFN      REFERENCES                                                                   3/03/71

FLAG     00004 0000CC 00066    0035  0038  0056  0062  0062
R1       00004 0000C8 00065    0014  0049  0059
SAREA    00004 00000C 00018    0021
SPIE     00001 000000 00013
S100     00004 000054 00019    0016
S200     00004 00009C 00051    0037  0058  0063
S300     00004 0000AA 00056    0033
YECH     00002 0000A8 00054    0014  0045


NO STATEMENTS FLAGGED IN THIS ASSEMBLY
*STATISTICS*     SOURCE RECORDS (SYSIN) =    59       SOURCE RECORDS (SYSLIB) =    488
*OPTIONS IN EFFECT*   LIST, NODECK, LOAD, NORENT, XREF, NOTEST, ALGN, OS, LINECNT =  55
   96 PRINTED LINES


F128-LEVEL LINKAGE EDITOR OPTIONS SPECIFIED MAP,LIST
           VARIABLE OPTIONS USED - SIZE=(153600,6144)                  DEFAULT OPTION(S) USED

                                            MODULE MAP

  CONTROL SECTION                    ENTRY

    NAME     ORIGIN  LENGTH            NAME    LOCATION     NAME    LOCATION     NAME    LOCATION     NAME    LOCATION

  MAIN          00    6668
  ITER        6668     5F6
  TBLALT      6C60     A74
  BLOG        76E0     148
  ANAPRP      7828    2A72
  POLY        A2A0     226
  CONSHK      A4C8    19FC
  RGPP        BEC8    147C
  TNING       D348     1F4
  SPIE        D540      D8
                                     YECH        05E8     R1         0608
  IHCSLUG *   D618     1B6
                                     ALOG10      D618     ALOG       D630
  IHCSASCN*   D7D0     1DF
                                     ARCOS       D7D0     ARSIN      D7E6
  IHCSATN2*   D9B0     1C8
                                     ATAN2       D9B0     ATAN       D9C4
  IHCSSCN *   DB80     1D9
                                     COS         DB80     SIN        DB98
  IHCFRXPR*   DD60     183
                                     FRXPR#      DD60
  IHCECOMH*   DEE8     F31
                                     IBCOM#      DEE8     FDIOCS#    DFA4     INTSWTCH   EE06
  IHCCOMH2*   EE20     581
                                     SEQDASD     F0BC
  NOUNFL  *   F3A8      1C
  IHCSSQRT*   F3C8     145
                                     SQRT        F3C8
  IHCSTNCT*   F510     266
                                     COTAN       F510     TAN        F526     QTAN       F698
  IHCFCVTH*   F778    1195
                                     ADCON#      F778     FCVAOUTP   F822     FCVLOUTP   F8B2     FCVZOUTP   FA02
                                     FCVIOUTP    FDA8     FCVEOUTP  102AA     FCVCOUTP  104C4     INT6SWCH  107AB
  IHCEFNTH*  10910     512
                                     ARITH#     10910     ADJSWTCH  10C7C
  IHCSEXP *  10E28     192
                                     EXP        10E28
  IHCEFIOS*  10FC0    1368
                                     FIOCS#     10FC0     FIOCSBEP  10FC6
  IHCERRM *  12328     58C
                                     ERRMON     12328     IHCERRE   12340
  IHCUOPT *  128E0     328
  IHCFOVER*  12C10      50
                                     OVERFL     12C10
  IHCFDUMP*  12C60     201
                                     DUMP       12C60     PDUMP     12C76
  IHCETRCH*  12E68     28E
                                     IHCTRCH    12E68     ERRTRA    12F70
  IHCUATBL*  130F8     638
  DRRAY      13730      84
  ARRAY      137E8      5C

 ENTRY ADDRESS        00
 TOTAL LENGTH      13848

****GSFC      DOES NOT EXIST BUT HAS BEEN ADDED TO DATA SET
```

SAMPLE PROB. NO.1 TW=300,RN=1,IPRESS=0, LONG PRINTOUT

NOTE THAT PRINTOUT IS IN ENGLISH UNITS

```
VISC=LB-SEC/SQ.FT                          CP=BTU/LB-DEG.K
T OR TREF = DEG.K                            RHO OR RHOR = SLUGS/CU.FT
H OR HREF = BTU/LB                           PSI = BTU/LB
TK OR TKREF = BTU/FT-SEC-DEG.K               TAUW = LB/SQ.FT

SYMBOL ENDS IN X = LOCAL EXTERNAL-TO-B.LAYER VALUE
SYMBOL ENDS IN L = B.LAYER FLOW IS LAMINAR
SYMBOL ENDS IN T = B.LAYER FLOW IS TURBULENT

DEFINITIONS-
   C = LOCAL VEL./FREE STREAM VEL.
   CPCV = GAMMA = SPECIFIC HEAT RATIO
   PR OR PREF = PRANDTL NUMBER
   PSI = H RECOVERY MINUS H WALL
   Z = COMPRESSIBILITY FACTOR
   CF = FRICTION COEFFICIENT AT WALL
   TAUW = WALL SHEAR STRESS
   REYX = REYNOLDS NO. BASED ON LOCAL (EXTERNAL-TO-B.LAYER) PROPERTIES AND SURFACE DIST. FROM STAG. POINT
   REYMOM  = MOMENTUM THICKNESS REYNOLDS NUMBER
(WHEN REYMOM IS NEG., HEAT RATE IS NEG. SO REYMOM HAS NO MEANING)

   ROMURT = (RHO * MU)WALL  /  (RHO * MU)EXTERNAL TO B.LAYER

INIT. CONDITIONS
ZALT=  C.500000E 05   VINFY=  0.400000E 04   RN=  0.100000E 01   TWI=  0.300000E 03
NTUN  =  0              ITW= 300    IPRESS=   0
LLL=0    LONG=1

INPUT X, Y, ALPHA
XX5=  0.274100E 01   YY5=  0.500000E 00   ALPHA(DEG)=  0.100000E 02

R(I)=  C.0                 X(I)=  C.0             I=  1

R(I)=  0.138545E 00        X(I)=  0.280140E 00    I=  2

R(I)=  0.268216E 00        X(I)=  0.560281E 00    I=  3

R(I)=  0.388844E 00        X(I)=  0.840421E 00    I=  4

R(I)=  0.500272E 00        X(I)=  0.112056E 01    I=  5

R(I)=  0.602355E 00        X(I)=  0.140070E 01    I=  6

R(I)=  0.694960E 00        X(I)=  0.168084E 01    I=  7

R(I)=  0.777967E 00        X(I)=  0.196098E 01    I=  8

R(I)=  0.851267E 00        X(I)=  0.224112E 01    I=  9

R(I)=  0.914765E 00        X(I)=  0.252126E 01    I= 10

R(I)=  0.968379E 00        X(I)=  0.280140E 01    I= 11

R(I)=  0.105520E 01        X(I)=  0.330140E 01    I= 12

R(I)=  0.114203E 01        X(I)=  0.380140E 01    I= 13

R(I)=  0.122885E 01        X(I)=  0.430140E 01    I= 14

R(I)=  0.131568E 01        X(I)=  0.480140E 01    I= 15

FREE STREAM CONDITIONS
XMINF=  0.412856E 01   VINFY=  0.400000E 04   GAMINF=  0.139990E 01   RHOINF=  0.363638E-03
HINFY=  0.932242E 02   PINF=  0.115115E 00 (ATMOS)   PINFY=  0.243606E 03 (PSF)
TINFY=  0.216660E 03

TH1=  0.306756E 02   TH2=  0.530907E 02
WHERE TH1= POINT 1 STREAM DEFLECTION ANGLE,DEGREES.  TH2=STREAM DEFLECTION ANGLE AT POINT 1 WHICH CAUSES SEPARATION OF SHOCK WAVE

USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I= 1
THETA SHOCK FOR POINT  1 =  0.388944E 02
PS(I)=    0.915685E 00   TS(I)=    0.470289E 03   SRS(I)=    0.255451E 02

USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I= 2
THETA SHOCK FOR POINT  2 =  0.363815E 02
PS(I)=    0.825032E 00   TS(I)=    0.446408E 03   SRS(I)=    0.254637E 02

USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I= 3
THETA SHOCK FOR POINT  3 =  0.339604E 02
PS(I)=    0.738147E 00   TS(I)=    0.423239E 03   SRS(I)=    0.253858E 02

USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I= 4
THETA SHOCK FOR POINT  4 =  0.316190E 02
```

```
PS(I)=   0.655463E 00  TS(I)=   0.400832E 03  SRS(I)=   0.254121E 02

USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I= 5
THETA SHOCK FOR POINT  5 =  0.293392E 02
PS(I)=   0.577389E 00  TS(I)=   0.379227E 03  SRS(I)=   0.252433E 02

USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I= 6
THETA SHOCK FOR POINT  6 =  0.271816E 02
PS(I)=   0.504307E 00  TS(I)=   0.358453E 03  SRS(I)=   0.251802E 02

USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I= 7
THETA SHOCK FOR POINT  7 =  0.250958E 02
PS(I)=   0.436579E 00  TS(I)=   0.338534E 03  SRS(I)=   0.251233E 02

USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I= 8
THETA SHOCK FOR POINT  8 =  0.231116E 02
PS(I)=   0.374535E 00  TS(I)=   0.319482E 03  SRS(I)=   0.250731E 02

USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I= 9
THETA SHOCK FOR POINT  9 =  0.212441E 02
PS(I)=   0.318475E 00  TS(I)=   0.301302E 03  SRS(I)=   0.250297E 02

USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I=10
THETA SHOCK FOR POINT 10 =  0.195143E 02
PS(I)=   0.268670E 00  TS(I)=   0.283994E 03  SRS(I)=   0.249923E 02

USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I=11
THETA SHOCK FOR POINT 11 =  0.179502E 02
PS(I)=   0.225361E 00  TS(I)=   0.267550E 03  SRS(I)=   0.249591E 02

I= 1   P(I)=  0.915685E 00   T(I)=  0.470289E 03   SR(I)=  0.255451E 02
 QRATL(I)=  0.117525E 01   QRATT(I)=  0.105637E 01

I= 2   P(I)=  0.804810E 00   T(I)=  0.452165E 03   SR(I)=  0.254637E 02
 QRATL(I)=  0.119880E 01   QRATT(I)=  0.106062E 01

I= 3   P(I)=  0.704205E 00   T(I)=  0.425735E 03   SR(I)=  0.253858E 02
 QRATL(I)=  0.120604E 01   QRATT(I)=  0.106599E 01

I= 4   P(I)=  0.612310E 00   T(I)=  0.400173E 03   SR(I)=  0.253121E 02
 QRATL(I)=  0.122839E 01   QRATT(I)=  0.107291E 01

I= 5   P(I)=  0.528953E 00   T(I)=  0.376131E 03   SR(I)=  0.252433E 02
 QRATL(I)=  0.125813E 01   QRATT(I)=  0.108204E 01

I= 6   P(I)=  0.453791E 00   T(I)=  0.353016E 03   SR(I)=  0.251802E 02
 QRATL(I)=  0.129923E 01   QRATT(I)=  0.109451E 01

I= 7   P(I)=  0.386670E 00   T(I)=  0.331440E 03   SR(I)=  0.251233E 02
 QRATL(I)=  0.135924E 01   QRATT(I)=  0.111241E 01

I= 8   P(I)=  0.327129E 00   T(I)=  0.310846E 03   SR(I)=  0.250731E 02
 QRATL(I)=  0.145457E 01   QRATT(I)=  0.114014E 01

I= 9   P(I)=  0.274745E 00   T(I)=  0.291439E 03   SR(I)=  0.250297E 02
 QRATL(I)=  0.162959E 01   QRATT(I)=  0.118893E 01

I=10   P(I)=  0.229602E 00   T(I)=  0.273422E 03   SR(I)=  0.249923E 02
 QRATL(I)=  0.206912E 01   QRATT(I)=  0.130106E 01

I=11   P(I)=  0.189402E 00   T(I)=  0.256184E 03   SR(I)=  0.249591E 02
 QRATL(I)=  0.206912E 01   QRATT(I)=  0.130106E 01

I=12   P(I)=  0.189402E 00   T(I)=  0.256184E 03   SR(I)=  0.249591E 02
 QRATL(I)=  0.206912E 01   QRATT(I)=  0.130106E 01

I=13   P(I)=  0.189402E 00   T(I)=  0.256184E 03   SR(I)=  0.249591E 02
 QRATL(I)=  0.206912E 01   QRATT(I)=  0.130106E 01

I=14   P(I)=  0.189402E 00   T(I)=  0.256184E 03   SR(I)=  0.249591E 02
 QRATL(I)=  0.206912E 01   QRATT(I)=  0.130106E 01

I=15   P(I)=  0.189402E 00   T(I)=  0.256184E 03   SR(I)=  0.249591E 02
 QRATL(I)=  0.206912E 01   QRATT(I)=  0.130106E 01

STAGNATION POINT DATA FOR SPHERICAL NOSE

HREFO =0.270774E 03  TREFO =0.622497E 03  VISCRO=0.620202E-06  TKREFO=0.122102E-04
ZREFO =0.100000E 01  PRREFO=0.740697E 00  CPREFO=0.453686E 00  RHORO =0.283532E-02
CPCVRO=0.137364E 01  RN    =0.100000E 01  TO    =0.925830E 03
PO    =0.257883E 01  RHOO  =0.190636E-02  SRO   =0.270285E 02  TKO   =0.168865E-04
VISCO =0.816003E-06  DVDXO =0.233376E 04  ZO    =0.100000E 01  CPO   =0.483059E 00
AO    =0.196178E 04  TWO   =0.300000E 03  VISCWO=0.382730E-06  HWO   =0.129114E 03
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CPWO  =0.432809E 00  PRO   =0.750234E 00
      QSTPT=  0.162914E 02  = NOSE STAGNATION POINT HEAT RATE
HO=  0.412434E 03     HT=  0.412439E 03     RHOWO=  0.586327E-02


WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  1
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.205576E 03  PRREFX(I)=0.735258E 00
TKREFX(I)=0.994262E-05  VISCRX(I)=0.515954E-06  RHORX(I) =0.131648E-02  TREFX(I) =0.476044E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.138879E 01  PX(I)      =0.915685E 00  TX(I)      =0.470299E 03
TKX(I)     =0.985364E-05  VISCX(I) =0.511675E-06  PRX(I)     =0.735079E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.255451E 02  HX(I)      =0.203050E 03  VX(I)      =0.324134E 04  CPCVX(I) =0.138929E 01
AAX(I)     =0.142201E 04  RHOX(I)    =0.133760E-02  XM(I)      =0.227941E 01  CPX(I)     =0.440406E 00


WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  2
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.203089E 03  PRREFX(I)=0.735083E 00
TKREFX(I)=0.985474E-05  VISCRX(I)=0.511745E-06  RHORX(I) =0.117102E-02  TREFX(I) =0.470377E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.138929E 01  PX(I)      =0.804810E 00  TX(I)      =0.452165E 03
TKX(I)     =0.957211E-05  VISCX(I) =0.498115E-06  PRX(I)     =0.734542E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.254637E 02  HX(I)      =0.195110E 03  VX(I)      =0.330223E 04  CPCVX(I) =0.139082E 01
AAX(I)     =0.139511E 04  RHOX(I)    =0.121819E-02  XM(I)      =0.236700E 01  CPX(I)     =0.439164E 00


WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  3
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.199473E 03  PRREFX(I)=0.734833E 00
TKREFX(I)=0.972690E-05  VISCRX(I)=0.505592E-06  RHORX(I) =0.104292E-02  TREFX(I) =0.462130E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.138999E 01  PX(I)      =0.704205E 00  TX(I)      =0.425735E 03
TKX(I)     =0.916127E-05  VISCX(I) =0.478043E-06  PRX(I)     =0.733812E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.253858E 02  HX(I)      =0.183569E 03  VX(I)      =0.338877E 04  CPCVX(I) =0.139286E 01
AAX(I)     =0.135472E 04  RHOX(I)    =0.113208E-02  XM(I)      =0.250146E 01  CPX(I)     =0.437527E 00


WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  4
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.195985E 03  PRREFX(I)=0.734599E 00
TKREFX(I)=0.960313E-05  VISCRX(I)=0.499618E-06  RHORX(I) =0.922734E-03  TREFX(I) =0.454163E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.139066E 01  PX(I)      =0.612310E 00  TX(I)      =0.400173E 03
TKX(I)     =0.876379E-05  VISCX(I) =0.458275E-06  PRX(I)     =0.733067E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.253121E 02  HX(I)      =0.172445E 03  VX(I)      =0.347014E 04  CPCVX(I) =0.139458E 01
AAX(I)     =0.131423E 04  RHOX(I)    =0.104723E-02  XM(I)      =0.264044E 01  CPX(I)     =0.436155E 00


WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  5
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.192812E 03  PRREFX(I)=0.734392E 00
TKREFX(I)=0.949046E-05  VISCRX(I)=0.494151E-06  RHORX(I) =0.810065E-03  TREFX(I) =0.446908E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.139125E 01  PX(I)      =0.528958E 00  TX(I)      =0.375131E 03
TKX(I)     =0.837721E-05  VISCX(I) =0.440622E-06  PRX(I)     =0.735501E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.252433E 02  HX(I)      =0.162013E 03  VX(I)      =0.354477E 04  CPCVX(I) =0.139597E 01
AAX(I)     =0.127477E 04  RHOX(I)    =0.962497E-03  XM(I)      =0.278071E 01  CPX(I)     =0.435060E 00


WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  6
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.189772E 03  PRREFX(I)=0.734200E 00
TKREFX(I)=0.938232E-05  VISCRX(I)=0.488883E-06  RHORX(I) =0.705941E-03  TREFX(I) =0.439951E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.139180E 01  PX(I)      =0.453791E 00  TX(I)      =0.353016E 03
TKX(I)     =0.800729E-05  VISCX(I) =0.423317E-06  PRX(I)     =0.737776E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.251802E 02  HX(I)      =0.152005E 03  VX(I)      =0.361490E 04  CPCVX(I) =0.139708E 01
AAX(I)     =0.123547E 04  RHOX(I)    =0.879789E-03  XM(I)      =0.292593E 01  CPX(I)     =0.434186E 00


WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  7
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.186957E 03  PRREFX(I)=0.734026E 00
TKREFX(I)=0.928201E-05  VISCRX(I)=0.483978E-06  RHORX(I) =0.610473E-03  TREFX(I) =0.433501E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.139229E 01  PX(I)      =0.386670E 00  TX(I)      =0.331440E 03
TKX(I)     =0.766067E-05  VISCX(I) =0.406966E-06  PRX(I)     =0.740241E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.251233E 02  HX(I)      =0.142681E 03  VX(I)      =0.367904E 04  CPCVX(I) =0.139793E 01
AAX(I)     =0.119748E 04  RHOX(I)    =0.798457E-03  XM(I)      =0.307231E 01  CPX(I)     =0.433524E 00


WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  8
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.184289E 03  PRREFX(I)=0.733862E 00
TKREFX(I)=0.918685E-05  VISCRX(I)=0.479306E-06  RHORX(I) =0.523862E-03  TREFX(I) =0.427385E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.139274E 01  PX(I)      =0.327129E 00  TX(I)      =0.310846E 03
TKX(I)     =0.732820E-05  VISCX(I) =0.391151E-06  PRX(I)     =0.742895E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.250731E 02  HX(I)      =0.133792E 03  VX(I)      =0.373917E 04  CPCVX(I) =0.139857E 01
AAX(I)     =0.115995E 04  RHOX(I)    =0.720263E-03  XM(I)      =0.322355E 01  CPX(I)     =0.433024E 00


WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  9
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.181793E 03  PRREFX(I)=0.733706E 00
TKREFX(I)=0.909775E-05  VISCRX(I)=0.474913E-06  RHORX(I) =0.445952E-03  TREFX(I) =0.421657E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.139315E 01  PX(I)      =0.274745E 00  TX(I)      =0.291439E 03
TKX(I)     =0.701303E-05  VISCX(I) =0.376035E-06  PRX(I)     =0.745654E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.250297E 02  HX(I)      =0.125424E 03  VX(I)      =0.379490E 04  CPCVX(I) =0.139904E 01
AAX(I)     =0.112335E 04  RHOX(I)    =0.645207E-03  XM(I)      =0.337821E 01  CPX(I)     =0.432660E 00


WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 10
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.179491E 03  PRREFX(I)=0.733555E 00
TKREFX(I)=0.901553E-05  VISCRX(I)=0.470841E-06  RHORX(I) =0.376424E-03  TREFX(I) =0.416369E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.139352E 01  PX(I)      =0.229002E 00  TX(I)      =0.273422E 03
TKX(I)     =0.671841E-05  VISCX(I) =0.361791E-06  PRX(I)     =0.748427E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.249923E 02  HX(I)      =0.117661E 03  VX(I)      =0.384587E 04  CPCVX(I) =0.139937E 01
AAX(I)     =0.108920E 04  RHOX(I)    =0.573221E-03  XM(I)      =0.353417E 01  CPX(I)     =0.432405E 00


WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 11
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.177300E 03  PRREFX(I)=0.733405E 00
TKREFX(I)=0.893731E-05  VISCRX(I)=0.466951E-06  RHORX(I) =0.315141E-03  TREFX(I) =0.411335E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.139386E 01  PX(I)      =0.189402E 00  TX(I)      =0.256184E 03
TKX(I)     =0.643430E-05  VISCX(I) =0.347945E-06  PRX(I)     =0.751256E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.249591E 02  HX(I)      =0.110237E 03  VX(I)      =0.389400E 04  CPCVX(I) =0.139960E 01
AAX(I)     =0.105342E 04  RHOX(I)    =0.505998E-03  XM(I)      =0.369652E 01  CPX(I)     =0.432227E 00
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WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 12
HW(I)      =0.129114E 03  CPW(I)      =0.432809E 00  HREFX(I) =0.177300E 03  PRREFX(I)=0.733405E 00
TKREFX(I)=0.893731E-05  VISCRX(I)=0.466951E-06  RHORX(I) =0.315141E-03  TREFX(I) =0.411335E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.139336E 01  PX(I)      =0.189402E 00  TX(I)      =0.256184E 03
TKX(I)     =0.643430E-05  VISCX(I) =0.347945E-06  PRX(I)     =0.751256E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.249591E 02  HX(I)       =0.110237E 03  VX(I)       =0.389400E 04  CPCVX(I) =0.139960E 01
AAX(I)     =0.105342E 04  RHOX(I)    =0.505998E-03  XM(I)       =0.369652E 01  CPX(I)     =0.432227E 00

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 13
HW(I)      =0.129114E 03  CPW(I)      =0.432809E 00  HREFX(I) =0.177300E 03  PRREFX(I)=0.733405E 00
TKREFX(I)=0.893731E-05  VISCRX(I)=0.466951E-06  RHORX(I) =0.315141E-03  TREFX(I) =0.411335E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.139336E 01  PX(I)      =0.189402E 00  TX(I)      =0.256184E 03
TKX(I)     =0.643430E-05  VISCX(I) =0.347945E-06  PRX(I)     =0.751256E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.249591E 02  HX(I)       =0.110237E 03  VX(I)       =0.389400E 04  CPCVX(I) =0.139960E 01
AAX(I)     =0.105342E 04  RHOX(I)    =0.505998E-03  XM(I)       =0.369652E 01  CPX(I)     =0.432227E 00

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 14
HW(I)      =0.129114E 03  CPW(I)      =0.432809E 00  HREFX(I) =0.177300E 03  PRREFX(I)=0.733405E 00
TKREFX(I)=0.893731E-05  VISCRX(I)=0.466951E-06  RHORX(I) =0.315141E-03  TREFX(I) =0.411335E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.139336E 01  PX(I)      =0.189402E 00  TX(I)      =0.256184E 03
TKX(I)     =0.643430E-05  VISCX(I) =0.347945E-06  PRX(I)     =0.751256E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.249591E 02  HX(I)       =0.110237E 03  VX(I)       =0.389400E 04  CPCVX(I) =0.139960E 01
AAX(I)     =0.105342E 04  RHOX(I)    =0.505998E-03  XM(I)       =0.369652E 01  CPX(I)     =0.432227E 00

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 15
HW(I)      =0.129114E 03  CPW(I)      =0.432809E 00  HREFX(I) =0.177300E 03  PRREFX(I)=0.733405E 00
TKREFX(I)=0.893731E-05  VISCRX(I)=0.466951E-06  RHORX(I) =0.315141E-03  TREFX(I) =0.411335E 03
ZREFX(I) =0.100000E 01  CPCVRX(I)=0.139336E 01  PX(I)      =0.189402E 00  TX(I)      =0.256184E 03
TKX(I)     =0.643430E-05  VISCX(I) =0.347945E-06  PRX(I)     =0.751256E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.249591E 02  HX(I)       =0.110237E 03  VX(I)       =0.389400E 04  CPCVX(I) =0.139960E 01
AAX(I)     =0.105342E 04  RHOX(I)    =0.505998E-03  XM(I)       =0.369652E 01  CPX(I)     =0.432227E 00

STATION NO. = 2
   QLOCLAM=  0.158883E 02     QLOCTURB=  0.778355E 02      X=  0.280140E 00
   QXOOLAM=  0.975283E 00   QXOOTURB=  0.477769E 01   CFLAM=  0.792548E-03   CFTURB=  0.373697E-02
TAULAM=  0.526409E 01   TAUTURB=  0.248209E 02   CFRENU=  0.221545E 01   ROMURT=  0.115808E 01
 REX=  0.226238E 07   REYMOM=  0.680641E 03
 HRECL=  0.381437E 03      HRECT=  0.391246E 03

STATION NO. = 3
   QLOCLAM=  0.103266E 02     QLOCTURB=  0.629021E 02      X=  0.560281E 00
   QXOOLAM=  0.633864E 00   QXOOTURB=  0.386105E 01   CFLAM=  0.543620E-03   CFTURB=  0.317992E-02
TAULAM=  0.333366E 01   TAUTURB=  0.206703E 02   CFRENU=  0.221715E 01   ROMURT=  0.113617E 01
 REX=  0.449631E 07   REYMOM=  0.974494E 03
 HRECL=  0.379757E 03      HRECT=  0.390097E 03

STATION NO. = 4
   QLOCLAM=  0.770624E 01     QLOCTURB=  0.535571E 02      X=  0.840421E 00
   QXOOLAM=  0.473024E 00   QXOOTURB=  0.328744E 01   CFLAM=  0.430961E-03   CFTURB=  0.286981E-02
TAULAM=  0.271733E 01   TAUTURB=  0.130950E 02   CFRENU=  0.221894E 01   ROMURT=  0.111402E 01
 REX=  0.666437E 07   REYMOM=  0.120651E 04
 HRECL=  0.378136E 03      HRECT=  0.389929E 03

STATION NO. = 5
   QLOCLAM=  0.605536E 01     QLOCTURB=  0.464223E 02      X=  0.112056E 01
   QXOOLAM=  0.371689E 00   QXOOTURB=  0.284949E 01   CFLAM=  0.362841E-03   CFTURB=  0.265964E-02
TAULAM=  0.219412E 01   TAUTURB=  0.160830E 02   CFRENU=  0.221118E 01   ROMURT=  0.108904E 01
 REX=  0.867673E 07   REYMOM=  0.139465E 04
 HRECL=  0.376615E 03      HRECT=  0.387948E 03

STATION NO. = 6
   QLOCLAM=  0.487763E 01     QLOCTURB=  0.405976E 02      X=  0.140070E 01
   QXOOLAM=  0.299399E 00   QXOOTURB=  0.249196E 01   CFLAM=  0.315349E-03   CFTURB=  0.250444E-02
TAULAM=  0.181273E 01   TAUTURB=  0.143564E 02   CFRENU=  0.220398E 01   ROMURT=  0.106390E 01
 REX=  0.105234E 08   REYMOM=  0.156113E 04
 HRECL=  0.375155E 03      HRECT=  0.386940E 03

STATION NO. = 7
   QLOCLAM=  0.397772E 01     QLOCTURB=  0.357025E 02      X=  0.168084E 01
   QXOOLAM=  0.244160E 00   QXOOTURB=  0.219149E 01   CFLAM=  0.279929E-03   CFTURB=  0.239276E-02
TAULAM=  0.151265E 01   TAUTURB=  0.123299E 02   CFRENU=  0.219629E 01   ROMURT=  0.103901E 01
 REX=  0.121326E 08   REYMOM=  0.170983E 04
 HRECL=  0.373792E 03      HRECT=  0.386014E 03

STATION NO. = 8
   QLOCLAM=  0.326273E 01     QLOCTURB=  0.316191E 02      X=  0.196098E 01
   QXOOLAM=  0.200273E 00   QXOOTURB=  0.194084E 01   CFLAM=  0.251747E-03   CFTURB=  0.231906E-02
TAULAM=  0.126758E 01   TAUTURB=  0.116768E 02   CFRENU=  0.218812E 01   ROMURT=  0.101385E 01
 REX=  0.135019E 08   REYMOM=  0.184646E 04
 HRECL=  0.372492E 03      HRECT=  0.385128E 03

STATION NO. = 9
   QLOCLAM=  0.268002E 01     QLOCTURB=  0.284032E 02      X=  0.224112E 01
   QXOOLAM=  0.164505E 00   QXOOTURB=  0.174345E 01   CFLAM=  0.228570E-03   CFTURB=  0.229857E-02
TAULAM=  0.106191E 01   TAUTURB=  0.106739E 02   CFRENU=  0.217971E 01   ROMURT=  0.988760E 00
 REX=  0.145927E 08   REYMOM=  0.197364E 04
 HRECL=  0.371267E 03      HRECT=  0.384290E 03

STATION NO. =10
   QLOCLAM=  0.219739E 01     QLOCTURB=  0.266572E 02      X=  0.252126E 01
   QXOOLAM=  0.134880E 00   QXOOTURB=  0.163627E 01   CFLAM=  0.209102E-03   CFTURB=  0.240300E-02
TAULAM=  0.886422E 00   TAUTURB=  0.101868E 02   CFRENU=  0.217134E 01   ROMURT=  0.964157E 00
 REX=  0.153631E 08   REYMOM=  0.209339E 04
 HRECL=  0.370127E 03      HRECT=  0.383516E 03
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STATION NO. =11
   QLOCLAM=  0.179514E 01      QLOCTURB=  0.227577E 02      X=  0.280140E 01
   QXQOLAM=  0.110189E 00   QXQOTURB=  0.139591E 01   CFLAM=  0.191971E-03   CFTURB=  0.230174E-02
TAULAM=  0.736455E 00   TAUTURB=  0.833014E 01   CFRENU=  0.216286E 01   ROMURT=  0.939319E 00
 REX=  0.158639E 08   REYMOM=  0.221640E 04
 HRECL=  0.369035E 03      HRECT=  0.382764E 03


STATION NO. =12
   QLOCLAM=  0.172836E 01      QLOCTURB=  0.220223E 02      X=  0.330140E 01
   QXQOLAM=  0.105690E 00   QXQOTURB=  0.135177E 01   CFLAM=  0.184829E-03   CFTURB=  0.222737E-02
TAULAM=  0.709059E 00   TAUTURB=  0.854482E 01   CFRENU=  0.216286E 01   ROMURT=  0.939319E 00
 REX=  0.186953E 08   REYMOM=  0.229531E 04
 HRECL=  0.369035E 03      HRECT=  0.382764E 03


STATION NO. =13
   QLOCLAM=  0.166742E 01      QLOCTURB=  0.214099E 02      X=  0.380140E 01
   QXQOLAM=  0.102349E 00   QXQOTURB=  0.131418E 01   CFLAM=  0.178312E-03   CFTURB=  0.216542E-02
TAULAM=  0.684058E 00   TAUTURB=  0.830718E 01   CFRENU=  0.216286E 01   ROMURT=  0.939319E 00
 REX=  0.215267E 08   REYMOM=  0.237971E 04
 HRECL=  0.369035E 03      HRECT=  0.382764E 03


STATION NO. =14
   QLOCLAM=  0.161178E 01      QLOCTURB=  0.204872E 02      X=  0.430140E 01
   QXQOLAM=  0.989343E-01   QXQOTURB=  0.129210E 01   CFLAM=  0.172363E-03   CFTURB=  0.211256E-02
TAULAM=  0.661233E 00   TAUTURB=  0.810430E 01   CFRENU=  0.216286E 01   ROMURT=  0.939319E 00
 REX=  0.243582E 08   REYMOM=  0.246136E 04
 HRECL=  0.369035E 03      HRECT=  0.382764E 03


STATION NO. =15
   QLOCLAM=  0.156088E 01      QLOCTURB=  0.204329E 02      X=  0.480140E 01
   QXQOLAM=  0.959097E-01   QXQOTURB=  0.125421E 01   CFLAM=  0.166919E-03   CFTURB=  0.206661E-02
TAULAM=  0.640350E 00   TAUTURB=  0.792810E 01   CFRENU=  0.216286E 01   ROMURT=  0.939319E 00
 REX=  0.271896E 08   REYMOM=  0.254215E 04
 HRECL=  0.369035E 03      HRECT=  0.382764E 03


                    NO.2 (SAME AS NO.1 BUT TESTS SHORT PRINTOUT)


             NOTE THAT PRINTOUT IS IN ENGLISH UNITS

INIT. CONDITIONS
ZALT=  0.500000E 05   VINFY=  0.400000E 04   RN=  0.100000E 01   TWI=  0.300000E 03
NTUN  =  0              ITW= 300    IPRESS=    0
LLL=0    LONG=0

INPUT X, Y, ALPHA
XX5=  0.274100E 01   YY5=  0.500000E 00   ALPHA(DEG)=  0.100000E 02

R(I)=  0.0                 X(I)=  0.0                I=  1

R(I)=  0.139545E 00        X(I)=  0.280140E 00       I=  2

R(I)=  0.268216E 00        X(I)=  0.560281E 00       I=  3

R(I)=  0.388844E 00        X(I)=  0.840421E 00       I=  4

R(I)=  0.500272E 00        X(I)=  0.112056E 01       I=  5

R(I)=  0.602355E 00        X(I)=  0.140070E 01       I=  6

R(I)=  0.694960E 00        X(I)=  0.168084E 01       I=  7

R(I)=  0.777967E 00        X(I)=  0.196098E 01       I=  8

R(I)=  0.851267E 00        X(I)=  0.224112E 01       I=  9

R(I)=  0.914765E 00        X(I)=  0.252126E 01       I= 10

R(I)=  0.968379E 00        X(I)=  0.280140E 01       I= 11

R(I)=  0.105520E 01        X(I)=  0.330140E 01       I= 12

R(I)=  0.114203E 01        X(I)=  0.380140E 01       I= 13

R(I)=  0.122885E 01        X(I)=  0.430140E 01       I= 14

R(I)=  0.131568E 01        X(I)=  0.480140E 01       I= 15

FREE STREAM CONDITIONS
XMINF=  0.412856E 01  VINFY=  0.400000E 04  GAMINF=  0.139990E 01  RHOINF=  0.363638E-03
HINFY=  0.932242E 02  PINF=  0.115115E 00 (ATMOS)  PINFY=  0.243606E 03 (PSF)
TINFY=  0.216660E 03

TH1=  0.306756E 02  TH2=  0.530907E 02
WHERE TH1= POINT 1 STREAM DEFLECTION ANGLE,DEGREES.  TH2=STREAM DEFLECTION ANGLE AT POINT 1 WHICH CAUSES SEPARATION OF SHOCK WAVE

USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

STAGNATION POINT DATA FOR SPHERICAL NOSE

HREFO =0.270774E 03  TREFO =0.622497E 03  VISCRO=0.620202E-05  TKREFO=0.122162E-04
ZREFO =0.100000E 01  PRREFO=0.740687E 00  CPREFO=0.453686E 00  RHCRO =0.283532E-02
CPCVRO=0.137364E 01  RN    =0.100000E 01  TO     =0.925838E 03
PO    =0.257883E 01  RHOO  =0.190636E-02  SRO    =0.270285E 02  TKO   =0.168865E-04
VISCO =0.816003E-06  DVDXO =0.233876E 04  ZO     =0.100000E 01  CPO   =0.483059E 00
AO    =0.196178E 04  TWO   =0.300000E 03  VISCWO=0.382730E-06  HWO   =0.129114E 03
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CPWO  =0.432809E 00  PRO   =0.750294E 00
       QSTPT= 0.162914E 02  = NOSE STAGNATION POINT HEAT RATE.
HO= 0.412434E 03     HT= 0.412439E 03     RHOWO= 0.588327E-02

STATION NO. = 2
   QLOCLAM= 0.158888E 02      QLOCTURB= 0.778355E 02      X= 0.280140E 00
   QXQOLAM= 0.975283E 00   QXQOTURB= C.477769E 01   CFLAM= 0.792548E-03   CFTURB= 0.373697E-02
TAULAM= 0.526409E 01   TAUTURB= 0.248209E 02   CFRENU= 0.221545E 01   ROMURT= 0.115808E 01
 REX= 0.226238E 07   REYMOM= 0.680641E 03
 HRECL= 0.381437E 03     HRECT= 0.391246E 03

STATICN NO. = 3
   QLOCLAM= 0.103266E 02      QLOCTURB= 0.629021E 02      X= 0.560281E 00
   QXQOLAM= 0.633864E 00   QXQOTURB= 0.386105E 01   CFLAM= 0.543620E-03   CFTURB= 0.317992E-02
TAULAM= 0.353366E 01   TAUTURB= 0.206703E 02   CFRENU= 0.221715E 01   ROMURT= 0.113617E 01
 REX= 0.449631E 07   REYMOM= 0.974494E 03
 HRECL= 0.379757E 03     HRECT= 0.390097E 03

STATION NO. = 4
   QLOCLAM= 0.770624E 01      QLOCTURB= 0.535571E 02      X= 0.840421E 00
   QXQOLAM= 0.473024E 00   QXQOTURB= 0.328744E 01   CFLAM= 0.430961E-03   CFTJRB= 0.286981E-02
TAULAM= 0.271733E 01   TAUTURB= 0.180950E 02   CFRENU= 0.221894E 01   ROMURT= 0.111402E 01
 REX= 0.666437E 07   REYMOM= 0.120651E 04
 HRECL= 0.378136E 03     HRECT= 0.388989E 03

STATION NO. = 5
   QLOCLAM= 0.605536E 01      QLOCTURB= 0.464223E 02      X= 0.112056E 01
   QXQOLAM= 0.371689F 00   QXQOTURB= 0.284949E 01   CFLAM= 0.362841E-03   CFTURB= 0.265964E-02
TAULAM= 0.219412E 01   TAUTURB= 0.160830E 02   CFRENU= 0.221118E 01   ROMURT= 0.108904E 01
 REX= 0.867673E 07   REYMOM= 0.139465E 04
 HRECL= 0.376615E 03     HRECT= 0.387948E 03

STATION NO. = 6
   QLOCLAM= 0.487763E 01      QLOCTURB= 0.405976E 02      X= 0.140070E 01
   QXQOLAM= 0.299398E 00   QXQOTURB= C.249196E 01   CFLAM= 0.315349E-03   CFTURB= 0.250444E-02
TAULAM= 0.181273E 01   TAUTURB= 0.143964E 02   CFRFNU= 0.220398E 01   ROMURT= 0.105390E 01
 REX= 0.105234E 08   REYMOM= 0.156113E 04
 HRECL= 0.375155E 03     HRECT= 0.386949E 03

STATION NO. = 7
   QLOCLAM= 0.397772E 01      QLOCTURB= 0.357025E 02      X= 0.168084E 01
   QXQOLAM= 0.244160E 00   QXQOTURB= 0.219149E 01   CFLAM= 0.279929E-03   CFTURB= 0.239276E-02
TAULAM= 0.151265E 01   TAUTURB= 0.129298E 02   CFRENU= 0.219629E 01   ROMURT= 0.103901E 01
 REX= 0.121326E 08   REYMOM= 0.170988E 04
 HRECL= 0.373792E 03     HRECT= 0.386018E 03

STATION NO. = 8
   QLOCLAM= 0.326273E 01      QLOCTURB= 0.316191E 02      X= 0.196098E 01
   QXQOLAM= 0.200273E 00   QXQOTURB= 0.194084E 01   CFLAM= 0.251747E-03   CFTURB= 0.231906E-02
TAULAM= 0.126758E 01   TAUTURB= 0.116768E 02   CFRENU= 0.218812E 01   ROMURT= 0.101385E 01
 REX= 0.135019E 08   REYMOM= 0.184646E 04
 HRECL= 0.372492E 03     HRECT= 0.385128E 03

STATION NO. = 9
   QLOCLAM= 0.268002E 01      QLOCTURB= 0.284032E 02      X= 0.224112E 01
   QXQOLAM= 0.164505E 00   QXQOTURB= 0.174345E 01   CFLAM= 0.228570E-03   CFTURB= 0.229857E-02
TAULAM= 0.106191E 01   TAUTURB= 0.106789E 02   CFRENU= 0.217971E 01   ROMURT= 0.988760E 00
 REX= 0.145927E 08   REYMOM= 0.197364E 04
 HRECL= 0.371267E 03     HRECT= 0.384290E 03

STATION NO. =10
   QLOCLAM= 0.219739E 01      QLOCTURB= 0.266572E 02      X= 0.252126E 01
   QXQOLAM= 0.134880E 00   QXQOTURB= 0.163627E 01   CFLAM= 0.209102E-03   CFTURB= 0.240300E-02
TAULAM= 0.886422E 00   TAUTURB= 0.101868E 02   CFRENU= 0.217134E 01   ROMURT= 0.964157E 00
 REX= 0.153631E 08   REYMOM= 0.209339E 04
 HRECL= 0.370127E 03     HRECT= 0.383510E 03

STATION NO. =11
   QLOCLAM= 0.179514E 01      QLOCTURB= 0.227577E 02      X= 0.280140E 01
   QXQOLAM= 0.110189E 00   QXQOTURB= 0.139691E 01   CFLAM= 0.191971E-03   CFTURB= 0.230174E-02
TAULAM= 0.736455E 00   TAUTURB= 0.883014E 01   CFRENU= 0.216286E 01   ROMURT= 0.939319E 00
 REX= C.158639E 08   REYMOM= 0.221040E 04
 HRECL= 0.369035E 03     HRECT= 0.382764E 03

STATION NO. =12
   QLOCLAM= 0.172836E 01      QLOCTURB= 0.220223E 02      X= 0.330140E 01
   QXQOLAM= 0.106090E 00   QXQOTURB= 0.135177E 01   CFLAM= 0.184829E-03   CFTURB= 0.222737E-02
TAULAM= 0.709059E 00   TAUTURB= 0.854482E 01   CFRENU= 0.216286E 01   ROMURT= 0.939319E 00
 REX= 0.186953E 08   REYMOM= 0.229581E 04
 HRECL= 0.369035E 03     HRECT= 0.382764E 03

STATION NO. =13
   QLOCLAM= 0.166742E 01      QLOCTURB= 0.214099E 02      X= 0.380140E 01
   QXQOLAM= 0.102349E 00   QXQOTURB= 0.131418E 01   CFLAM= 0.178312E-03   CFTURB= 0.216542E-02
TAULAM= 0.684058E 00   TAUTURB= 0.830718E 01   CFRENU= 0.216286E 01   ROMURT= 0.939319E 00
 REX= 0.215267E 08   REYMOM= 0.237971E 04
 HRECL= 0.369035E 03     HRECT= 0.382764E 03

STATION NO. =14
   QLOCLAM= 0.161178E 01      QLOCTURB= 0.208872E 02      X= 0.430140E 01
   QXQOLAM= 0.989343E-01   QXQOTURB= 0.128210E 01   CFLAM= 0.172363E-03   CFTURB= 0.211256E-02
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TAULAM=  0.661234E 00   TAUTURB=  0.219439E 01   CFRENU=  0.216286E 01   ROMURT=  0.939319E 00
 REX=  0.243582E 08   REYMOM=  0.246186E 04
 HRECL=  0.369035E 03      HRECT=  0.382764E 03


STATION NO. =15
   QLOCLAM=  0.156988E 01      QLOCTURB=  0.264329E 02      X=  0.480145E 01
   QXCOLAM=  0.958097E-01   CXROTURB=  0.125421E 01   CFLAM=  0.166919E-03   CFTURB=  0.706661E-02
TAULAM=  0.640350E 00   TAUTURB=  0.772810E 01   CFRENU=  0.216236E 01   ROMURT=  0.939319E 00
 REX=  0.271896E 08   REYMOM=  0.254215E 04
 HRECL=  0.369035E 03      HRECT=  0.382764E 03


                         PROBLEM NO.3A  ALPHA = 0 DEG


                NOTE THAT PRINTOUT IS IN ENGLISH UNITS



    VISC=LB-SEC/SQ.FT                               CP=BTU/LB-DEG.K
    T OR TREF = DEG.K                                 RHO OR RHOR = SLUGS/CU.FT
    H OR HREF = BTU/LB                                PSI = BTU/LB
    TK OR TKREF = BTU/FT-SEC-DEG.K                    TAUW = LB/SQ.FT

    SYMBOL ENDS IN X = LOCAL EXTERNAL-TO-B.LAYER VALUE
    SYMBOL ENDS IN L = B.LAYER FLOW IS LAMINAR
    SYMBOL ENDS IN T = B.LAYER FLOW IS TURBULENT

 DEFINITIONS-
    C = LOCAL VEL./FREE STREAM VEL.
    CPCV = GAMMA = SPECIFIC HEAT RATIO
    PR OR PREF = PRANDTL NUMBER
    PSI = H RECOVERY MINUS H WALL
    Z = COMPRESSIBILITY FACTOR
    CF = FRICTION COEFFICIENT AT WALL
    TAUW = WALL SHEAR STRESS
    REYX = REYNOLDS NO. BASED ON LOCAL (EXTERNAL-TO-B.LAYER) PROPERTIES AND SURFACE DIST. FROM STAG. POINT
    REYMOM  = MOMENTUM THICKNESS REYNOLDS NUMBER
(WHEN REYMOM IS NEG., HEAT RATE IS NEG. SO REYMOM HAS NO MEANING)

    ROMURT = (RHO * MU)WALL  /  (RHO * MU)EXTERNAL TO B.LAYER

INIT. CONDITIONS
ZALT=  0.300000E 06   VINFY=  0.250000E 05   RN=  0.100000E 01   TWI=  0.300000E 03
NTUN  =  0                  ITW= 300   IPRESS=   0
LLL=0    LONG=1

INPUT X, Y, ALPHA
XX5=  0.300000E 01   YY5=  0.600000E 00   ALPHA(DEG)=  0.0

R(I)=  0.0                      X(I)=  0.0                I=  1

R(I)=  0.112796E 00             X(I)=  0.307937E 00       I=  2

R(I)=  0.214196E 00             X(I)=  0.615874E 00       I=  3

R(I)=  0.304042E 00             X(I)=  0.923811E 00       I=  4

R(I)=  0.382193E 00             X(I)=  0.123175E 01       I=  5

R(I)=  0.448529E 00             X(I)=  0.153968E 01       I=  6

R(I)=  0.502945E 00             X(I)=  0.184762E 01       I=  7

R(I)=  0.545356E 00             X(I)=  0.215556E 01       I=  8

R(I)=  0.575698E 00             X(I)=  0.246350E 01       I=  9

R(I)=  0.593922E 00             X(I)=  0.277143E 01       I= 10

R(I)=  0.600000E 00             X(I)=  0.307937E 01       I= 11

R(I)=  0.600000E 00             X(I)=  0.357937E 01       I= 12

R(I)=  0.600000E 00             X(I)=  0.407937E 01       I= 13

R(I)=  0.600000E 00             X(I)=  0.457937E 01       I= 14

R(I)=  0.600000E 00             X(I)=  0.507937E 01       I= 15

FREE STREAM CONDITIONS
XMINF=  0.294579E 02   VINFY=  0.250000E 05   GAMINF=  0.139999E 01   RHOINF=  0.411946E-08
HINFY=  0.715226E 02   PINF=  0.100052E-05 (ATMOS)   PINFY=  0.211729E-02 (PSF)
TINFY=  0.166227E 03

TH1=  0.226196E 02   TH2=  0.574145E 02
WHERE TH1= POINT 1 STREAM DEFLECTION ANGLE,DEGREES.   TH2=STREAM DEFLECTION ANGLE AT POINT 1 WHICH CAUSES SEPARATION OF SHOCK WAVE

I= 1
THETA SHOCK FOR POINT  1 =  0.237483E 02
PS(I)=   0.189321E-03   TS(I)=    0.241872E 04   SRS(I)=    0.438444E 02

I= 2
THETA SHOCK FOR POINT  2 =  0.214909E 02
PS(I)=   0.155953E-03   TS(I)=    0.229989E 04   SRS(I)=    0.428594E 02

NON-CONVERGENCE AT IJK=6606
 GO TO PERFECT GAS SHOCK ROUTINE


USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS
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I= 3
THETA SHOCK FOR POINT  3 =  0.200855F 02
PS(I)=   0.121566F-03  TS(I)=   0.267146E 04  SRS(I)=   0.465375E 02

I= 4
THETA SHOCK FOR POINT  4 =  0.170065F 02
PS(I)=   0.379711F-04  TS(I)=   0.201895E 04  SRS(I)=   0.410735E 02

I= 5
THETA SHOCK FOR POINT  5 =  0.147258F 02
PS(I)=   0.734085E-04  TS(I)=   0.176562E 04  SRS(I)=   0.402640E 02

I= 6
THETA SHOCK FOR POINT  6 =  0.123958F 02
PS(I)=   0.522054F-04  TS(I)=   0.137477E 04  SRS(I)=   0.394506E 02

I= 7
THETA SHOCK FOR POINT  7 =  0.100145E 02
PS(I)=   0.342811E-04  TS(I)=   0.991177E 03  SRS(I)=   0.385253E 02

I= 8
THETA SHOCK FOR POINT  8 =  0.763493F 01
PS(I)=   0.201289E-04  TS(I)=   0.662442E 03  SRS(I)=   0.375143E 02


USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I= 9
THETA SHOCK FOR POINT  9 =  0.532997F 01
PS(I)=   0.936327E-05  TS(I)=   0.395070E 03  SRS(I)=   0.364173E 02


USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I=10
THETA SHOCK FOR POINT 10 =  0.315149F 01
PS(I)=   0.328271E-05  TS(I)=   0.246259E 03  SRS(I)=   0.358055E 02

I=11
THETA SHOCK FOR POINT 11 =  0.194535E 01
PS(I)=   0.800413E-06  TS(I)=   0.199615E 03  SRS(I)=   0.364816E 02


REAL GAS P-M ROUTINE FAILED (VEL. TOO LOW) - PROGRAM HAS SWITCHED TO PERFECT GAS P-M EXPANSION


REAL GAS P-M ROUTINE FAILED (VEL. TOO LOW) - PROGRAM HAS SWITCHED TO PERFECT GAS P-M EXPANSION

I= 1   P(I)=  0.189321E-03   T(I)=  0.241872E 04   SR(I)=  0.438444E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I= 2   P(I)=  0.130382E-03   T(I)=  0.235227E 04   SR(I)=  0.428594E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000F 01

I= 3   P(I)=  0.887868E-04   T(I)=  0.220975E 04   SR(I)=  0.465375E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000F 01

I= 4   P(I)=  0.597246E-04   T(I)=  0.246920E 04   SR(I)=  0.410735E 02
 QRATL(I)=  0.100000F 01   QRATT(I)=  0.100000E 01

I= 5   P(I)=  0.407269E-04   T(I)=  0.181828E 04   SR(I)=  0.402640E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I= 6   P(I)=  0.250207E-04   T(I)=  0.140459E 04   SR(I)=  0.394506E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I= 7   P(I)=  0.152313E-04   T(I)=  0.102147E 04   SR(I)=  0.385253E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I= 8   P(I)=  0.776323E-05   T(I)=  0.672617E 03   SR(I)=  0.375143E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I= 9   P(I)=  0.318059E-05   T(I)=  0.395777E 03   SR(I)=  0.364173E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I=10   P(I)=  0.965904E-06   T(I)=  0.207697E 03   SR(I)=  0.358055E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I=11   P(I)=  0.132649E-06   T(I)=  0.989484E 02   SR(I)=  0.364816E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I=12   P(I)=  0.566582E-06   T(I)=  0.989484E 02   SR(I)=  0.364816E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I=13   P(I)=  0.783549F-06   T(I)=  0.989484E 02   SR(I)=  0.364816E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I=14   P(I)=  0.892032E-06   T(I)=  0.989484E 02   SR(I)=  0.364816E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I=15   P(I)=  0.100052E-05   T(I)=  0.989484E 02   SR(I)=  0.364816E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

STAGNATION POINT DATA FOR SPHERICAL NOSE

HREFO =0.633441E 04  TREFO =0.460406F 04  VISCRO=0.267232E-05  TKREFO=0.695580F-04
ZREFO =0.136719E 01  PRREFO=0.727619F 00  CPREFO=0.589244E 00  RHORO =0.129205E-06
CPCVRO=0.116345E 01  RN    =0.100000E 01  TO    =0.526012E 04
PO    =0.118832E-02  RHOO  =0.874659E-07  SRJ   =0.613390E 02  TKO   =0.962225F-04
VISCO =0.315039E-05  DVDXO =0.757980E 04  ZO    =0.176773E 01  CPO   =0.662273E 00
AO    =0.655106F 04  TWO   =0.300000E 03  VISCWO=0.382730E-06  HWO   =0.129114E 03
CPWO  =0.432809E 00  PRO   =0.696954E 00
      QSTPT=  0.196654E 02  = NOSE STAGNATION POINT HEAT RATE
HO=  0.125397E 05     HT=  0.125408E 05     RHOWO=  0.271100F-05
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WALL, REFFRENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  1
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.318168E 04  PRREFX(I)=0.773936E 00
TKREFX(I)=0.466045E-04  VISCRX(I)=0.199795E-05  RHORX(I) =0.334177E-07  TREFX(I) =0.322690E 04
ZREFX(I) =0.120158E 01  CPCVRX(I)=0.127516E 01  PX(I)      =0.189321E-03  TX(I)      =0.241872E 04
TKX(I)     =0.348373E-04  VISCX(I) =0.160528E-05  PRX(I)     =0.812763E 00  ZX(I)      =0.111649E 01
SRX(I)     =0.438444E 02  HX(I)      =0.208853E 04  VX(I)      =0.229010E 05  CPCVX(I) =0.114870E 01
AAX(I)     =0.334063E 04  RHOX(I)    =0.479816E-07  XM(I)      =0.685529E 01  CPX(I)     =0.548750E 00

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  2
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.314351E 04  PRREFX(I)=0.776945E 00
TKREFX(I)=0.457295E-04  VISCRX(I)=0.196961E-05  RHORX(I) =0.234611E-07  TREFX(I) =0.316620E 04
ZREFX(I) =0.120129E 01  CPCVRX(I)=0.128131E 01  PX(I)      =0.130382E-03  TX(I)      =0.235227E 04
TKX(I)     =0.340120E-04  VISCX(I) =0.157245E-05  PRX(I)     =0.813045E 00  ZX(I)      =0.110442E 01
SRX(I)     =0.428594E 02  HX(I)      =0.196078E 04  VX(I)      =0.230405E 05  CPCVX(I) =0.114487E 01
AAX(I)     =0.327223E 04  RHOX(I)    =0.343490E-07  XM(I)      =0.704123E 01  CPX(I)     =0.547147E 00

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  3
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.301670E 04  PRREFX(I)=0.787767E 00
TKREFX(I)=0.428524E-04  VISCRX(I)=0.187727E-05  RHORX(I) =0.170529E-07  TREFX(I) =0.297037E 04
ZREFX(I) =0.119966E 01  CPCVRX(I)=0.130513E 01  PX(I)      =0.987868E-04  TX(I)      =0.220975E 04
TKX(I)     =0.325472E-04  VISCX(I) =0.150193E-05  PRX(I)     =0.804632E 00  ZX(I)      =0.106398E 01
SRX(I)     =0.465375E 02  HX(I)      =0.157777E 04  VX(I)      =0.234538E 05  CPCVX(I) =0.113619E 01
AAX(I)     =0.309841E 04  RHOX(I)    =0.258456E-07  XM(I)      =0.756963E 01  CPX(I)     =0.542493E 00

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  4
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.331287E 04  PRREFX(I)=0.765225E 00
TKREFX(I)=0.485330E-04  VISCRX(I)=0.205415E-05  RHORX(I) =0.101238E-07  TREFX(I) =0.334624E 04
ZREFX(I) =0.120662E 01  CPCVRX(I)=0.120240E 01  PX(I)      =0.597246E-04  TX(I)      =0.246920E 04
TKX(I)     =0.354794E-04  VISCX(I) =0.163273E-05  PRX(I)     =0.816791E 00  ZX(I)      =0.116861E 01
SRX(I)     =0.410735E 02  HX(I)      =0.250710E 04  VX(I)      =0.224378E 05  CPCVX(I) =0.115713E 01
AAX(I)     =0.347666E 04  RHOX(I)    =0.141659E-07  XM(I)      =0.645382E 01  CPX(I)     =0.552209E 00

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  5
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.277220E 04  PRREFX(I)=0.808276E 00
TKREFX(I)=0.376813E-04  VISCRX(I)=0.170711E-05  RHORX(I) =0.892364E-08  TREFX(I) =0.261756E 04
ZREFX(I) =0.119333E 01  CPCVRX(I)=0.122989E 01  PX(I)      =0.407269E-04  TX(I)      =0.181828E 04
TKX(I)     =0.288347E-04  VISCX(I) =0.130823E-05  PRX(I)     =0.772627E 00  ZX(I)      =0.100559E 01
SRX(I)     =0.402640E 02  HX(I)      =0.922114E 03  VX(I)      =0.241450E 05  CPCVX(I) =0.119266E 01
AAX(I)     =0.271841E 04  RHOX(I)    =0.152446E-07  XM(I)      =0.888204E 01  CPX(I)     =0.529826E 00

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  6
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.267646E 04  PRREFX(I)=0.815463E 00
TKREFX(I)=0.360459E-04  VISCRX(I)=0.165183E-05  RHORX(I) =0.574996E-08  TREFX(I) =0.250538E 04
ZREFX(I) =0.118872E 01  CPCVRX(I)=0.119396E 01  PX(I)      =0.250207E-04  TX(I)      =0.140459E 04
TKX(I)     =0.236286E-04  VISCX(I) =0.109133E-05  PRX(I)     =0.763490E 00  ZX(I)      =0.100005E 01
SRX(I)     =0.394506E 02  HX(I)      =0.654303E 03  VX(I)      =0.244217E 05  CPCVX(I) =0.131184E 01
AAX(I)     =0.239162E 04  RHOX(I)    =0.121912E-07  XM(I)      =0.102114E 02  CPX(I)     =0.514301E 00

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  7
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.260221E 04  PRREFX(I)=0.820648E 00
TKREFX(I)=0.348638E-04  VISCRX(I)=0.161100E-05  RHORX(I) =0.363098E-08  TREFX(I) =0.242315E 04
ZREFX(I) =0.118461E 01  CPCVRX(I)=0.117474E 01  PX(I)      =0.152313E-04  TX(I)      =0.102147E 04
TKX(I)     =0.182793E-04  VISCX(I) =0.873687E-06  PRX(I)     =0.754248E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.385253E 02  HX(I)      =0.453886E 03  VX(I)      =0.246216E 05  CPCVX(I) =0.133577E 01
AAX(I)     =0.205496E 04  RHOX(I)    =0.102053E-07  XM(I)      =0.119815E 02  CPX(I)     =0.490937E 00

WALL, REFFRENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  9
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.253321E 04  PRREFX(I)=0.825817E 00
TKREFX(I)=0.336850E-04  VISCRX(I)=0.156971E-05  RHORX(I) =0.192122E-08  TREFX(I) =0.234042E 04
ZREFX(I) =0.118165E 01  CPCVRX(I)=0.116202E 01  PX(I)      =0.776323E-05  TX(I)      =0.672617E 03
TKX(I)     =0.129849E-04  VISCX(I) =0.654175E-06  PRX(I)     =0.742734E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.375143E 02  HX(I)      =0.293558E 03  VX(I)      =0.247895E 05  CPCVX(I) =0.136807E 01
AAX(I)     =0.168758E 04  RHOX(I)    =0.789934E-08  XM(I)      =0.146894E 02  CPX(I)     =0.458682E 00

WALL, REFFRENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  9
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.248098E 04  PRREFX(I)=0.831071E 00
TKREFX(I)=0.325244E-04  VISCRX(I)=0.152846E-05  RHORX(I) =0.816468E-09  TREFX(I) =0.225816E 04
ZREFX(I) =0.118068E 01  CPCVRX(I)=0.115470E 01  PX(I)      =0.318059E-05  TX(I)      =0.395277E 03
TKX(I)     =0.868292E-05  VISCX(I) =0.454809E-06  PRX(I)     =0.733905E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.364173E 02  HX(I)      =0.170319E 03  VX(I)      =0.249139E 05  CPCVX(I) =0.139489E 01
AAX(I)     =0.130630E 04  RHOX(I)    =0.550711E-08  XM(I)      =0.190720E 02  CPX(I)     =0.435916E 00

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 10
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.249713E 04  PRREFX(I)=0.835534E 00
TKREFX(I)=0.317020E-04  VISCRX(I)=0.149903E-05  RHORX(I) =0.253185E-09  TREFX(I) =0.219950E 04
ZREFX(I) =0.118710E 01  CPCVRX(I)=0.116541E 01  PX(I)      =0.965904E-06  TX(I)      =0.207697E 03
TKX(I)     =0.561903E-05  VISCX(I) =0.307579E-06  PRX(I)     =0.760015E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.358055E 02  HX(I)      =0.893672E 02  VX(I)      =0.249953E 05  CPCVX(I) =0.139993E 01
AAX(I)     =0.948421E 03  RHOX(I)    =0.318288E-08  XM(I)      =0.263491E 02  CPX(I)     =0.431976E 00

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 11
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.251833E 04  PRREFX(I)=0.841117E 00
TKREFX(I)=0.306930E-04  VISCRX(I)=0.146258E-05  RHORX(I) =0.357048E-10  TREFX(I) =0.212758E 04
ZREFX(I) =0.119511E 01  CPCVRX(I)=0.121493E 01  PX(I)      =0.132649E-06  TX(I)      =0.989484E 02
TKX(I)     =0.360830E-05  VISCX(I) =0.203454E-06  PRX(I)     =0.782771E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.364816E 02  HX(I)      =0.425747E 02  VX(I)      =0.250422E 05  CPCVX(I) =0.140000E 01
AAX(I)     =0.654776E 03  RHOX(I)    =0.917510E-09  XM(I)      =0.382455E 02  CPX(I)     =0.431921E 00

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 12
HW(I)      =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.251833E 04  PRREFX(I)=0.836697E 00
TKREFX(I)=0.315308E-04  VISCRX(I)=0.149289E-05  RHORX(I) =0.148883E-09  TREFX(I) =0.218719E 04
ZREFX(I) =0.119083E 01  CPCVRX(I)=0.118120E 01  PX(I)      =0.566582E-06  TX(I)      =0.989484E 02
TKX(I)     =0.360830E-05  VISCX(I) =0.203454E-06  PRX(I)     =0.782771E 00  ZX(I)      =0.100000E 01
SRX(I)     =0.364816E 02  HX(I)      =0.425747E 02  VX(I)      =0.250422E 05  CPCVX(I) =0.140000E 01
AAX(I)     =0.654776E 03  RHOX(I)    =0.917510E-09  XM(I)      =0.382455E 02  CPX(I)     =0.431921E 00
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WALL, REFFRENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 13
HW(I)     =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.251833E 04  PRREFX(I)=0.835555E 00
TKREFX(I)=0.317491E-04  VISCRX(I)=0.150074E-05  RHORX(I) =0.204632E-09  TREFX(I) =0.220272E 04
ZREFX(I) =0.118970E 01  CPCVRX(I)=0.117631E 01  PX(I)     =0.783549E-06  TX(I)     =0.989484E 02
TKX(I)    =0.360830E-05  VISCX(I) =0.203454E-06  PRX(I)    =0.782771E 00  ZX(I)     =0.100000E 01
SRX(I)    =0.364816E 02  HX(I)     =0.425747E 02  VX(I)     =0.250422E 05  CPCVX(I) =0.140000E 01
AAX(I)    =0.654776E 03  RHOX(I)   =0.917510E-09  XM(I)     =0.382455E 02  CPX(I)    =0.431921E 00

WALL, REFFRENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 14
HW(I)     =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.251833E 04  PRREFX(I)=0.835081E 00
TKREFX(I)=0.318401E-04  VISCRX(I)=0.150401E-05  RHORX(I) =0.232378E-09  TREFX(I) =0.220919E 04
ZREFX(I) =0.118924E 01  CPCVRX(I)=0.117461E 01  PX(I)     =0.892032E-06  TX(I)     =0.989484E 02
TKX(I)    =0.360830E-05  VISCX(I) =0.203454E-06  PRX(I)    =0.782771E 00  ZX(I)     =0.100000E 01
SRX(I)    =0.364816E 02  HX(I)     =0.425747E 02  VX(I)     =0.250422E 05  CPCVX(I) =0.140000E 01
AAX(I)    =0.654776E 03  RHOX(I)   =0.917510E-09  XM(I)     =0.382455E 02  CPX(I)    =0.431921E 00

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 15
HW(I)     =0.129114E 03  CPW(I)     =0.432809E 00  HREFX(I) =0.251833E 04  PRREFX(I)=0.834649E 00
TKREFX(I)=0.319233E-04  VISCRX(I)=0.150700E-05  RHORX(I) =0.260030E-09  TREFX(I) =0.221511E 04
ZREFX(I) =0.118884E 01  CPCVRX(I)=0.117326E 01  PX(I)     =0.100052E-05  TX(I)     =0.989484E 02
TKX(I)    =0.360830E-05  VISCX(I) =0.203454E-06  PRX(I)    =0.782771E 00  ZX(I)     =0.100000E 01
SRX(I)    =0.364816E 02  HX(I)     =0.425747E 02  VX(I)     =0.250422E 05  CPCVX(I) =0.140000E 01
AAX(I)    =0.654776E 03  RHOX(I)   =0.917510E-09  XM(I)     =0.382455E 02  CPX(I)    =0.431921E 00

STATION NO. = 2
   QLOCLAM=  0.149112E 02      QLOCTURB=  0.326321E 01      X=  0.307937E 00
   QXQOLAM=  0.758246E 00   QXQOTURB=  0.165937E 00   CFLAM=  0.887218E-01   CFTURB=  0.187418E-01
TAULAM=  0.308905E 00   TAUTURB=  0.170875E 00   CFRENU=  0.207683E 01   ROMURT=  0.210774E 01
 REX=  0.154986E 03   REYMOM=  0.101883E 02
 HRECL=  0.112855E 05      HRECT=  0.116862E 05

STATION NO. = 3
   QLOCLAM=  0.815033E 01      QLOCTURB=  0.218918E 01      X=  0.615874E 00
   QXQOLAM=  0.414451E 00   QXQOTURB=  0.111322E 00   CFLAM=  0.637766E-01   CFTURB=  0.165451E-01
TAULAM=  0.453363E 00   TAUTURB=  0.117613E 00   CFRENU=  0.211799E 01   ROMURT=  0.199710E 01
 REX=  0.248567E 03   REYMOM=  0.137716E 02
 HRECL=  0.113072E 05      HRECT=  0.117019E 05

STATION NO. = 4
   QLOCLAM=  0.480823E 01      QLOCTURB=  0.133543E 01      X=  0.923811E 00
   QXQOLAM=  0.244502E 00   QXQOTURB=  0.679079E-01   CFLAM=  0.705294E-01   CFTURB=  0.189089E-01
TAULAM=  0.251502E 00   TAUTURB=  0.674276E-01   CFRENU=  0.204646E 01   ROMURT=  0.225467E 01
 REX=  0.179842E 03   REYMOM=  0.134526E 02
 HRECL=  0.112833E 05      HRECT=  0.116837E 05

STATION NO. = 5
   QLOCLAM=  0.343609E 01      QLOCTURB=  0.111893E 01      X=  0.123175E 01
   QXQOLAM=  0.174728E 00   QXQOTURB=  0.568935E-01   CFLAM=  0.448065E-01   CFTURB=  0.141148E-01
TAULAM=  0.199104E 00   TAUTURB=  0.627211E-01   CFRENU=  0.224384E 01   ROMURT=  0.178307E 01
 REX=  0.346560E 03   REYMOM=  0.188398E 02
 HRECL=  0.113668E 05      HRECT=  0.117441E 05

STATION NO. = 6
   QLOCLAM=  0.210486E 01      QLOCTURB=  0.749938E 00      X=  0.153968E 01
   QXQOLAM=  0.107034E 00   QXQOTURB=  0.381350E-01   CFLAM=  0.340719E-01   CFTURB=  0.117512E-01
TAULAM=  0.123869E 00   TAUTURB=  0.427217E-01   CFRENU=  0.228414E 01   ROMURT=  0.164205E 01
 REX=  0.420045E 03   REYMOM=  0.233380E 02
 HRECL=  0.113872E 05      HRECT=  0.117584E 05

STATION NO. = 7
   QLOCLAM=  0.130231E 01      QLOCTURB=  0.499017E 00      X=  0.184762E 01
   QXQOLAM=  0.662237E-01   QXQOTURB=  0.253754E-01   CFLAM=  0.250495E-01   CFTURB=  0.929556E-02
TAULAM=  0.774867E-01   TAUTURB=  0.287544E-01   CFRENU=  0.232191E 01   ROMURT=  0.149157E 01
 REX=  0.531372E 03   REYMOM=  0.294416E 02
 HRECL=  0.114029E 05      HRECT=  0.117635E 05

STATION NO. = 8
   QLOCLAM=  0.681757E 00      QLOCTURB=  0.289558E 00      X=  0.215556E 01
   QXQOLAM=  0.346679E-01   QXQOTURB=  0.147243E-01   CFLAM=  0.168683E-01   CFTURB=  0.694216E-02
TAULAM=  0.409418E-01   TAUTURB=  0.168497E-01   CFRENU=  0.236780E 01   ROMURT=  0.131173E 01
 REX=  0.645245E 03   REYMOM=  0.394151E 02
 HRECL=  0.114222E 05      HRECT=  0.117829E 05

STATION NO. = 9
   QLOCLAM=  0.287787E 00      QLOCTURB=  0.141397E 00      X=  0.246350E 01
   QXQOLAM=  0.146342E-01   QXQOTURB=  0.719017E-02   CFLAM=  0.101836E-01   CFTURB=  0.485177E-02
TAULAM=  0.174052E-01   TAUTURB=  0.829234E-02   CFRENU=  0.240644E 01   ROMURT=  0.110878E 01
 REX=  0.743169E 03   REYMOM=  0.563277E 02
 HRECL=  0.114466E 05      HRECT=  0.117999E 05

STATION NO. =10
   QLOCLAM=  0.890375E-01      QLOCTURB=  0.539093E-01      X=  0.277143E 01
   QXQOLAM=  0.452764E-02   QXQOTURB=  0.274133E-02   CFLAM=  0.544198E-02   CFTURB=  0.319715E-02
TAULAM=  0.541073E-02   TAUTURB=  0.317885E-02   CFRENU=  0.233208E 01   ROMURT=  0.861480E 00
 REX=  0.716846E 03   REYMOM=  0.787081E 02
 HRECL=  0.114699E 05      HRECT=  0.118160E 05

STATION NO. =11
   QLOCLAM=  0.122969E-01      QLOCTURB=  0.109418E-01      X=  0.307937E 01
   QXQOLAM=  0.625309E-03   QXQOTURB=  0.556402E-03   CFLAM=  0.260611E-02   CFTURB=  0.225239E-02
TAULAM=  0.749755E-03   TAUTURB=  0.647992E-03   CFRENU=  0.227436E 01   ROMURT=  0.620461E 00
 REX=  0.347760E 03   REYMOM=  0.114665E 03
 HRECL=  0.115040E 05      HRECT=  0.118394E 05
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STATION NO. =12
   QLOCLAM=  0.523401E-01     QLOCTURB=  0.334956E-01      X=  0.357937E 01
   QXQULAM=  0.264154E-02    QXQOTURB=  0.170328E-02   CFLAM=  0.110830E-01   CFTURB=  0.688308E-02
TAULAM=  0.318849E-02   TAUTURB=  0.198020E-02   CFRENU=  0.226639E 01   ROMURT=  0.265018E 01
 REX=  0.404226E 03   REYMOM=  0.114653E 03
 HRECL=  0.114738E 05      HRECT=  0.118187E 05


STATION NO. =13
   QLOCLAM=  0.718731E-01     QLOCTURB=  0.421579E-01      X=  0.407937E 01
   QXQULAM=  0.365481E-02    QXQOTURB=  0.214376E-02   CFLAM=  0.152158E-01   CFTURB=  0.865920E-02
TAULAM=  0.437743E-02   TAUTURB=  0.249117E-02   CFRENU=  0.226432E 01   ROMURT=  0.366503E 01
 REX=  0.460692E 03   REYMOM=  0.115359E 03
 HRECL=  0.114660E 05      HRECT=  0.118133E 05


STATION NO. =14
   QLOCLAM=  0.811148E-01     QLOCTURB=  0.456351E-01      X=  0.457937E 01
   QXQOLAM=  0.412476E-02    QXQOTURB=  0.232063E-02   CFLAM=  0.171707E-01   CFTURB=  0.937186E-02
TAULAM=  0.493984E-02   TAUTURB=  0.269620E-02   CFRENU=  0.226347E 01   ROMURT=  0.417247E 01
 REX=  0.517158E 03   REYMOM=  0.116323E 03
 HRECL=  0.114628E 05      HRECT=  0.118111E 05


STATION NO. =15
   QLOCLAM=  0.901037E-01     QLOCTURB=  0.489302E-01      X=  0.507937E 01
   QXQOLAM=  0.458185E-02    QXQOTURB=  0.248855E-02   CFLAM=  0.190719E-01   CFTURB=  0.100483E-01
TAULAM=  0.548680E-02   TAUTURB=  0.289079E-02   CFRENU=  0.226269E 01   ROMURT=  0.467989E 01
 REX=  0.573624E 03   REYMOM=  0.117412E 03
 HRECL=  0.114598E 05      HRECT=  0.118091E 05


                         PROBLEM NO.3B ALPHA = 0 DEG   WITH PRINTOUT IN METRIC UNITS


                 NOTE THAT PRINTOUT IS IN METRIC UNITS


    VISC=NEWTON SEC/SQ.METER                   CP=JOULES/KGM DEGK
    T OR TREF=DEGK                            RHO OR RHOR=KGM/CU.METER
    H OR HREF=JOULE/KGM                  PSI=NEWT/SQ.M
    TK OR TKREF=JOULE/METER SEC DEGK        TAUW=NEWTONS/SQ.METER
    SYMBOL ENDS IN X = LOCAL EXTERNAL-TO-B.LAYER VALUE
    SYMBOL ENDS IN L = B.LAYER FLOW IS LAMINAR
    SYMBOL ENDS IN T = B.LAYER FLOW IS TURBULENT

 DEFINITIONS-
    C = LOCAL VEL./FREE STREAM VEL.
    CPCV = GAMMA = SPECIFIC HEAT RATIO
    PR OR PREF = PRANDTL NUMBER
    PSI = H RECOVERY MINUS H WALL
    Z = COMPRESSIBILITY FACTOR
    CF = FRICTION COEFFICIENT AT WALL
    TAUW = WALL SHEAR STRESS
    REYX = REYNOLDS NO. BASED ON LOCAL (EXTERNAL-TO-B.LAYER) PROPERTIES AND SURFACE DIST. FROM STAG. POINT
    REYMOM  = MOMENTUM THICKNESS REYNOLDS NUMBER
(WHEN REYMOM IS NEG., HEAT RATE IS NEG. SO REYMOM HAS NO MEANING)

    ROMURT = (RHO * MU)WALL  /  (RHO * MU)EXTERNAL TO B.LAYER

HEAT RATES ARE IN WATTS/SQ.METER

INIT. CONDITIONS
ZALT=  0.914399E 05  VINFY=  0.762000E 04  RN=  0.304800E 00  TWI=  0.300000E 03
NTUN  =  0              ITW= 300    IPRESS=   0
LLL=0   LONG=1

INPUT X, Y, ALPHA
XX5=  0.914400E 00  YY5=  0.182880E 00  ALPHA(DEG)=  0.0

R(I)=  0.0                   X(I)=  0.0                I=  1

R(I)=  0.343803E-01          X(I)=  0.938591E-01       I=  2

R(I)=  0.652870E-01          X(I)=  0.187718E 00       I=  3

R(I)=  0.926719E-01          X(I)=  0.281577E 00       I=  4

R(I)=  0.116492E 00          X(I)=  0.375437E 00       I=  5

R(I)=  0.136712E 00          X(I)=  0.469296E 00       I=  6

R(I)=  0.153297E 00          X(I)=  0.563155E 00       I=  7

R(I)=  0.166225E 00          X(I)=  0.657014E 00       I=  8

R(I)=  0.175473E 00          X(I)=  0.750873E 00       I=  9

R(I)=  0.181027E 00          X(I)=  0.844732E 00       I= 10

R(I)=  0.182880E 00          X(I)=  0.938591E 00       I= 11

R(I)=  0.182880E 00          X(I)=  0.109099E 01       I= 12

R(I)=  0.182880E 00          X(I)=  0.124339E 01       I= 13

R(I)=  0.182880E 00          X(I)=  0.139579E 01       I= 14

R(I)=  0.182880E 00          X(I)=  0.154819E 01       I= 15
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FREE STREAM CONDITIONS
XMINF=  0.294579E 02  VINFY=  0.762000E 04  GAMINF=  0.139999E 01  RHOINF=  0.212308E-05
HINFY=  0.166250E 06  PINF=  0.100052E-05 (ATMOS.)  TINFY=  0.166227E 03

TH1=  0.226196E 02  TH2=  0.574145E 02
WHERE TH1= POINT 1 STREAM DEFLECTION ANGLE,DEGREES.  TH2=STREAM DEFLECTION ANGLE AT POINT 1 WHICH CAUSES SEPARATION OF SHOCK WAV

I= 1
THETA SHOCK FOR POINT  1 =  0.414491E 00
PS(I)=   0.189321E-03  TS(I)=   0.241872E 04  SRS(I)=   0.438444E 02

I= 2
THETA SHOCK FOR POINT  2 =  0.375090E 00
PS(I)=   0.155953E-03  TS(I)=   0.229989E 04  SRS(I)=   0.428594E 02

NON-CONVERGENCE AT IJK=6606
 GO TO PERFECT GAS SHOCK ROUTINE


USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I= 3
THETA SHOCK FOR POINT  3 =  0.350563E 00
PS(I)=   0.121566E-03  TS(I)=   0.267146E 04  SRS(I)=   0.465375E 02

I= 4
THETA SHOCK FOR POINT  4 =  0.296323E 00
PS(I)=   0.979711E-04  TS(I)=   0.201895E 04  SRS(I)=   0.410735E 02

I= 5
THETA SHOCK FOR POINT  5 =  0.257017E 00
PS(I)=   0.734085E-04  TS(I)=   0.176562E 04  SRS(I)=   0.402640E 02

I= 6
THETA SHOCK FOR POINT  6 =  0.216351E 00
PS(I)=   0.522054E-04  TS(I)=   0.137877E 04  SRS(I)=   0.394506E 02

I= 7
THETA SHOCK FOR POINT  7 =  0.174788E 00
PS(I)=   0.342811E-04  TS(I)=   0.991177E 03  SRS(I)=   0.385253E 02

I= 8
THETA SHOCK FOR POINT  8 =  0.133256E 00
PS(I)=   0.201289E-04  TS(I)=   0.662442E 03  SRS(I)=   0.375143E 02


USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I= 9
THETA SHOCK FOR POINT  9 =  0.930268E-01
PS(I)=   0.936327E-05  TS(I)=   0.395070E 03  SRS(I)=   0.364173E 02


USES SUPERSONIC RATHER THAN HYPERSONIC ANALYSIS

I=10
THETA SHOCK FOR POINT 10 =  0.550045E-01
PS(I)=   0.328271E-05  TS(I)=   0.246259E 03  SRS(I)=   0.358055E 02

I=11
THETA SHOCK FOR POINT 11 =  0.339532E-01
PS(I)=   0.800413E-06  TS(I)=   0.199615E 03  SRS(I)=   0.364816E 02

REAL GAS P-M ROUTINE FAILED (VEL. TOO LOW) - PROGRAM HAS SWITCHED TO PERFECT GAS P-M EXPANSION

REAL GAS P-M ROUTINE FAILED (VEL. TOO LOW) - PROGRAM HAS SWITCHED TO PERFECT GAS P-M EXPANSION

I= 1   P(I)=  0.189321E-03    T(I)=  0.241872E 04    SR(I)=  0.438444E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I= 2   P(I)=  0.130382E-03    T(I)=  0.235227E 04    SR(I)=  0.428594E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I= 3   P(I)=  0.887868E-04    T(I)=  0.220975E 04    SR(I)=  0.465375E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I= 4   P(I)=  0.597246E-04    T(I)=  0.246920E 04    SR(I)=  0.410735E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I= 5   P(I)=  0.407269E-04    T(I)=  0.181828E 04    SR(I)=  0.402640E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I= 6   P(I)=  0.250207E-04    T(I)=  0.140459E 04    SR(I)=  0.394506E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I= 7   P(I)=  0.152313E-04    T(I)=  0.102147E 04    SR(I)=  0.385253E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I= 8   P(I)=  0.776323E-05    T(I)=  0.672617E 03    SR(I)=  0.375143E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I= 9   P(I)=  0.318059E-05    T(I)=  0.395277E 03    SR(I)=  0.364173E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I=10   P(I)=  0.965904E-06    T(I)=  0.207697E 03    SR(I)=  0.358055E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I=11   P(I)=  0.132649E-06    T(I)=  0.989484E 02    SR(I)=  0.364816E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I=12   P(I)=  0.566582E-06    T(I)=  0.989484E 02    SR(I)=  0.364816E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01
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I=13   P(I)=  0.783549E-06   T(I)=  0.989484E 02   S(I)=  0.364816E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I=14   P(I)=  0.892032E-06   T(I)=  0.989484E 02   S(I)=  0.364816E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

I=15   P(I)=  0.100052E-05   T(I)=  0.989484E 02   S(I)=  0.364816E 02
 QRATL(I)=  0.100000E 01   QRATT(I)=  0.100000E 01

STAGNATION POINT DATA FOR SPHERICAL NOSE

HREFO =0.147240E 08  TREFO =0.460406E 04  VISCRO=0.127951E-03  TKRFFO=0.293809E-02
ZREFO =0.136719E 01  PRREFO=0.727619E 00  CPREFO=0.136967E 04  RHORO =0.665898E-04
CPCVRO=0.116345E 01  RN    =0.304800E 00  TO    =0.526012E 04
PO    =0.118832E-02  RHOO  =0.450781E-04  SRO   =0.613390E 02  TKO   =0.416051E-02
VISCO =0.150841E-03  DVDXO =0.757980E 04  ZO    =0.176773E 01  CPO   =0.153942E 04
AO    =0.199676E 04  TWO   =0.300000E 03  VISCWO=0.183252E-04  HWO   =0.300119E 06
CPWO  =0.100604E 04  PRO   =0.696954E 00
       QSTPT=  0.223180E 06  = NOSE STAGNATION POINT HEAT RATE
HO=  0.291479E 08     HT=  0.291505E 08     RHOWO=  0.139719E-02

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  1
HW(I)     =0.300119E 06  CPW(I)    =0.100604E 04  HREFX(I) =0.739564E 07  PRREFX(I)=0.773936E 00
TKREFX(I)=0.201515E-02  VISCRX(I)=0.956621E-04  RHORX(I) =0.172228E-04  TREFX(I) =0.322690E 04
ZREFX(I) =0.120158E 01  CPCVRX(I)=0.127516E 01  PX(I)     =0.169321E-03  TX(I)     =0.241872E 04
TKX(I)    =0.150634E-02  VISCX(I) =0.768613E-04  PRX(I)    =0.812763E 00  ZX(I)     =0.111649E 01
SRX(I)    =0.438444E 02  HX(I)     =0.485467E 07  VX(I)     =0.698022E 04  CPCVX(I) =0.114870E 01
AAX(I)    =0.101822E 04  RHOX(I)   =0.247287E-04  XM(I)     =0.685529E 01  CPX(I)    =0.127554E 04

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  2
HW(I)     =0.300119E 06  CPW(I)    =0.100604E 04  HREFX(I) =0.730691E 07  PRREFX(I)=0.776945E 00
TKREFX(I)=0.197732E-02  VISCRX(I)=0.943055E-04  RHORX(I) =0.120913E-04  TREFX(I) =0.316620E 04
ZREFX(I) =0.120129E 01  CPCVRX(I)=0.128131E 01  PX(I)     =0.130382E-03  TX(I)     =0.235227E 04
TKX(I)    =0.147066E-02  VISCX(I) =0.752891E-04  PRX(I)    =0.813045E 00  ZX(I)     =0.110442E 01
SRX(I)    =0.428594E 02  HX(I)     =0.455772E 07  VX(I)     =0.702274E 04  CPCVX(I) =0.114487E 01
AAX(I)    =0.997374E 03  RHOX(I)   =0.177027E-04  XM(I)     =0.704123E 01  CPX(I)    =0.127181E 04

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  3
HW(I)     =0.300119E 06  CPW(I)    =0.100604E 04  HREFX(I) =0.701216E 07  PRREFX(I)=0.787767E 00
TKREFX(I)=0.185291E-02  VISCRX(I)=0.898841E-04  RHORX(I) =0.378870E-05  TREFX(I) =0.297037E 04
ZREFX(I) =0.119966E 01  CPCVRX(I)=0.130513E 01  PX(I)     =0.887868E-04  TX(I)     =0.220975E 04
TKX(I)    =0.140732E-02  VISCX(I) =0.719127E-04  PRX(I)    =0.804632E 00  ZX(I)     =0.106398E 01
SRX(I)    =0.465375E 02  HX(I)     =0.366745E 07  VX(I)     =0.714873E 04  CPCVX(I) =0.113619E 01
AAX(I)    =0.944396E 03  RHOX(I)   =0.133203E-04  XM(I)     =0.756963E 01  CPX(I)    =0.126099E 04

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  4
HW(I)     =0.300119E 06  CPW(I)    =0.100604E 04  HREFX(I) =0.770059E 07  PRREFX(I)=0.765225E 00
TKREFX(I)=0.209854E-02  VISCRX(I)=0.983535E-04  RHORX(I) =0.521760E-05  TREFX(I) =0.334624E 04
ZREFX(I) =0.120662E 01  CPCVRX(I)=0.120240E 01  PX(I)     =0.597246E-04  TX(I)     =0.246920E 04
TKX(I)    =0.153411E-02  VISCX(I) =0.781757E-04  PRX(I)    =0.816791E 00  ZX(I)     =0.116861E 01
SRX(I)    =0.410735E 02  HX(I)     =0.582762E 07  VX(I)     =0.683902E 04  CPCVX(I) =0.115713E 01
AAX(I)    =0.105969E 04  RHOX(I)   =0.730079E-05  XM(I)     =0.645382E 01  CPX(I)    =0.128358E 04

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  5
HW(I)     =0.300119E 06  CPW(I)    =0.100604E 04  HREFX(I) =0.644383E 07  PRREFX(I)=0.808276E 00
TKREFX(I)=0.162932E-02  VISCRX(I)=0.817368E-04  RHORX(I) =0.459905E-05  TREFX(I) =0.261756E 04
ZREFX(I) =0.119333E 01  CPCVRX(I)=0.122989E 01  PX(I)     =0.407269E-04  TX(I)     =0.181828E 04
TKX(I)    =0.124680E-02  VISCX(I) =0.626385E-04  PRX(I)    =0.772627E 00  ZX(I)     =0.100559E 01
SRX(I)    =0.402640E 02  HX(I)     =0.214340E 07  VX(I)     =0.735939E 04  CPCVX(I) =0.119266E 01
AAX(I)    =0.828570E 03  RHOX(I)   =0.785673E-05  XM(I)     =0.888204E 01  CPX(I)    =0.123155E 04

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  6
HW(I)     =0.300119E 06  CPW(I)    =0.100604E 04  HREFX(I) =0.622127E 07  PRREFX(I)=0.815463E 00
TKREFX(I)=0.155873E-02  VISCRX(I)=0.790900E-04  RHORX(I) =0.296341E-05  TREFX(I) =0.250538E 04
ZREFX(I) =0.118872E 01  CPCVRX(I)=0.119396E 01  PX(I)     =0.250207E-04  TX(I)     =0.140459E 04
TKX(I)    =0.102169E-02  VISCX(I) =0.522531E-04  PRX(I)    =0.763490E 00  ZX(I)     =0.100005E 01
SRX(I)    =0.394506E 02  HX(I)     =0.152089E 07  VX(I)     =0.744373E 04  CPCVX(I) =0.131184E 01
AAX(I)    =0.728965E 03  RHOX(I)   =0.628307E-05  XM(I)     =0.102114E 02  CPX(I)    =0.119546E 04

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  7
HW(I)     =0.300119E 06  CPW(I)    =0.100604E 04  HREFX(I) =0.604870E 07  PRREFX(I)=0.820648E 00
TKREFX(I)=0.150749E-02  VISCRX(I)=0.771349E-04  RHORX(I) =0.187133E-05  TREFX(I) =0.242315E 04
ZREFX(I) =0.118481E 01  CPCVRX(I)=0.117474E 01  PX(I)     =0.152313E-04  TX(I)     =0.102147E 04
TKX(I)    =0.790341E-03  VISCX(I) =0.418324E-04  PRX(I)    =0.754248E 00  ZX(I)     =0.100000E 01
SRX(I)    =0.385253E 02  HX(I)     =0.106666E 07  VX(I)     =0.750467E 04  CPCVX(I) =0.133577E 01
AAX(I)    =0.626353E 03  RHOX(I)   =0.525959E-05  XM(I)     =0.119815E 02  CPX(I)    =0.114116E 04

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  8
HW(I)     =0.300119E 06  CPW(I)    =0.100604E 04  HREFX(I) =0.588831E 07  PRREFX(I)=0.825817E 00
TKREFX(I)=0.145652E-02  VISCRX(I)=0.751580E-04  RHORX(I) =0.990158E-06  TREFX(I) =0.234042E 04
ZREFX(I) =0.118165E 01  CPCVRX(I)=0.116202E 01  PX(I)     =0.776323E-05  TX(I)     =0.672617E 03
TKX(I)    =0.561461E-03  VISCX(I) =0.313221E-04  PRX(I)    =0.742734E 00  ZX(I)     =0.100000E 01
SRX(I)    =0.375143E 02  HX(I)     =0.682359E 06  VX(I)     =0.755584E 04  CPCVX(I) =0.136807E 01
AAX(I)    =0.514373E 03  RHOX(I)   =0.407115E-05  XM(I)     =0.146894E 02  CPX(I)    =0.106618E 04

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION =  9
HW(I)     =0.300119E 06  CPW(I)    =0.100604E 04  HREFX(I) =0.576689E 07  PRREFX(I)=0.831071E 00
TKREFX(I)=0.140634E-02  VISCRX(I)=0.731828E-04  RHORX(I) =0.420790E-06  TREFX(I) =0.225816E 04
ZREFX(I) =0.118068E 01  CPCVRX(I)=0.115470E 01  PX(I)     =0.318059E-05  TX(I)     =0.395277E 03
TKX(I)    =0.375440E-03  VISCX(I) =0.217764E-04  PRX(I)    =0.733905E 00  ZX(I)     =0.100000E 01
SRX(I)    =0.364173E 02  HX(I)     =0.395896E 06  VX(I)     =0.759376E 04  CPCVX(I) =0.139489E 01
AAX(I)    =0.398162E 03  RHOX(I)   =0.283825E-05  XM(I)     =0.190720E 02  CPX(I)    =0.101326E 04
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WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 10
HW(I)     =0.300119E 06  CPW(I)     =0.100604E 04  HREFX(I) =0.580445E 07  PRREFX(I)=0.835534E 00
TKREFX(I)=0.137078E-02  VISCRX(I)=0.717741E-04  RHORX(I) =0.130486E-06  TREFX(I) =0.219950E 04
ZREFX(I) =0.119710E 01  CPCVRX(I)=0.116541E 01  PX(I)      =0.965904E-06  TX(I)      =0.207697E 03
TKX(I)    =0.242963E-03  VISCX(I) =0.147270E-04  PRX(I)     =0.760015E 00  ZX(I)      =0.100000E 01
SRX(I)    =0.359055E 02  HX(I)      =0.207729E 06  VX(I)      =0.761857E 04  CPCVX(I) =0.139993E 01
AAX(I)    =0.269139E 03  RHOX(I)    =0.164039E-05  XM(I)      =0.263491E 02  CPX(I)     =0.100410E 04

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 11
HW(I)     =0.300119E 06  CPW(I)     =0.100604E 04  HREFX(I) =0.585372E 07  PRREFX(I)=0.841117E 00
TKREFX(I)=0.132715E-02  VISCRX(I)=0.700287E-04  RHORX(I) =0.184015E-07  TREFX(I) =0.212758E 04
ZREFX(I) =0.119511E 01  CPCVRX(I)=0.121493E 01  PX(I)      =0.132549E-06  TX(I)      =0.989484E 02
TKX(I)    =0.156021E-03  VISCX(I) =0.974142E-05  PRX(I)     =0.782771E 00  ZX(I)      =0.100000E 01
SRX(I)    =0.364816E 02  HX(I)      =0.989625E 05  VX(I)      =0.763287E 04  CPCVX(I) =0.140000E 01
AAX(I)    =0.199576E 03  RHOX(I)    =0.472865E-06  XM(I)      =0.382455E 02  CPX(I)     =0.100398E 04

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 12
HW(I)     =0.300119E 06  CPW(I)     =0.100604E 04  HREFX(I) =0.585372E 07  PRREFX(I)=0.836697E 00
TKREFX(I)=0.136337E-02  VISCRX(I)=0.714798E-04  RHORX(I) =0.767310E-07  TREFX(I) =0.218719E 04
ZREFX(I) =0.119063E 01  CPCVRX(I)=0.118120E 01  PX(I)      =0.566582E-06  TX(I)      =0.989484E 02
TKX(I)    =0.156021E-03  VISCX(I) =0.974142E-05  PRX(I)     =0.782771E 00  ZX(I)      =0.100000E 01
SRX(I)    =0.364816E 02  HX(I)      =0.989625E 05  VX(I)      =0.763287E 04  CPCVX(I) =0.140000E 01
AAX(I)    =0.199576E 03  RHOX(I)    =0.472865E-06  XM(I)      =0.382455E 02  CPX(I)     =0.100398E 04

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 13
HW(I)     =0.300119E 06  CPW(I)     =0.100604E 04  HREFX(I) =0.585372E 07  PRREFX(I)=0.835555E 00
TKREFX(I)=0.137281E-02  VISCRX(I)=0.718558E-04  RHORX(I) =0.105466E-06  TREFX(I) =0.220272E 04
ZREFX(I) =0.118970E 01  CPCVRX(I)=0.117631E 01  PX(I)      =0.783549E-06  TX(I)      =0.989484E 02
TKX(I)    =0.156021E-03  VISCX(I) =0.974142E-05  PRX(I)     =0.782771E 00  ZX(I)      =0.100000E 01
SRX(I)    =0.364816E 02  HX(I)      =0.989625E 05  VX(I)      =0.763287E 04  CPCVX(I) =0.140000E 01
AAX(I)    =0.199576E 03  RHOX(I)    =0.472865E-06  XM(I)      =0.382455E 02  CPX(I)     =0.100398E 04

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 14
HW(I)     =0.300119E 06  CPW(I)     =0.100604E 04  HREFX(I) =0.585372E 07  PRREFX(I)=0.835081E 00
TKREFX(I)=0.137674E-02  VISCRX(I)=0.720123E-04  RHORX(I) =0.119763E-06  TREFX(I) =0.220919E 04
ZREFX(I) =0.118924E 01  CPCVRX(I)=0.117461E 01  PX(I)      =0.892032E-06  TX(I)      =0.989484E 02
TKX(I)    =0.156021E-03  VISCX(I) =0.974142E-05  PRX(I)     =0.782771E 00  ZX(I)      =0.100000E 01
SRX(I)    =0.364816E 02  HX(I)      =0.989625E 05  VX(I)      =0.763287E 04  CPCVX(I) =0.140000E 01
AAX(I)    =0.199576E 03  RHOX(I)    =0.472865E-06  XM(I)      =0.382455E 02  CPX(I)     =0.100398E 04

WALL, REFERENCE, AND EXTERNAL-TO-BOUNDARY-LAYER FLOW PROPERTIES AT STATION = 15
HW(I)     =0.300119E 06  CPW(I)     =0.100604E 04  HREFX(I) =0.585372E 07  PRREFX(I)=0.834649E 00
TKREFX(I)=0.138035E-02  VISCRX(I)=0.721555E-04  RHORX(I) =0.134014E-06  TREFX(I) =0.221511E 04
ZREFX(I) =0.118884E 01  CPCVRX(I)=0.117326E 01  PX(I)      =0.100052E-05  TX(I)      =0.989484E 02
TKX(I)    =0.156021E-03  VISCX(I) =0.974142E-05  PRX(I)     =0.782771E 00  ZX(I)      =0.100000E 01
SRX(I)    =0.364816E 02  HX(I)      =0.989625E 05  VX(I)      =0.763287E 04  CPCVX(I) =0.140000E 01
AAX(I)    =0.199576E 03  RHOX(I)    =0.472865E-06  XM(I)      =0.382455E 02  CPX(I)     =0.100398E 04

STATION NO. = 2
   QLOCLAM=  0.169225E 06     QLOCTURB=  0.370339E 05     X=  0.938591E-01
   QXQOLAM=  0.758246E 00   QXQOTURB=  0.165937E 00   CFLAM=  0.887218E-01   CFTURB=  0.187418E-01
TAULAM=  0.387306E 02   TAUTURB=  0.818154E 01   CFRENU=  0.207683E 01   ROMURT=  0.210774E 01
 REX=  0.472397E 02   REYMOM=  0.310541E 01
 HRECL=  0.262326E 08      HRECT=  0.271639E 08

STATION NO. = 3
   QLOCLAM=  0.924973E 05     QLOCTURB=  0.248448E 05     X=  0.187718E 00
   QXQOLAM=  0.414451E 00   QXQOTURB=  0.111322E 00   CFLAM=  0.637766E-01   CFTURB=  0.165451E-01
TAULAM=  0.217071E 02   TAUTURB=  0.563134E 01   CFRENU=  0.211799E 01   ROMURT=  0.199710E 01
 REX=  0.757632E 02   REYMOM=  0.419758E 01
 HRECL=  0.262829E 08      HRECT=  0.272004E 08

STATION NO. = 4
   QLOCLAM=  0.545681E 05     QLOCTURB=  0.151557E 05     X=  0.281577E 00
   QXQOLAM=  0.244502E 00   QXQOTURB=  0.679079E-01   CFLAM=  0.705294E-01   CFTURB=  0.189089E-01
TAULAM=  0.120420E 02   TAUTURB=  0.322845E 01   CFRENU=  0.204646E 01   ROMURT=  0.225467E 01
 REX=  0.548157E 02   REYMOM=  0.410037E 01
 HRECL=  0.262275E 08      HRECT=  0.271580E 08

STATION NO. = 5
   QLOCLAM=  0.389959E 05     QLOCTURB=  0.126975E 05     X=  0.375437E 00
   QXQOLAM=  0.174728E 00   QXQOTURB=  0.568735E-01   CFLAM=  0.448065E-01   CFTURB=  0.141148E-01
TAULAM=  0.953314E 01   TAUTURB=  0.300310E 01   CFRENU=  0.224384E 01   ROMURT=  0.178307E 01
 REX=  0.105631E 03   REYMOM=  0.574237E 01
 HRECL=  0.264215E 08      HRECT=  0.272984E 08

STATION NO. = 6
   QLOCLAM=  0.238878E 05     QLOCTURB=  0.851096E 04     X=  0.469296E 00
   QXQOLAM=  0.107034E 00   QXQOTURB=  0.381350E-01   CFLAM=  0.340719E-01   CFTURB=  0.117512E-01
TAULAM=  0.593089E 01   TAUTURB=  0.204553E 01   CFRENU=  0.228414E 01   ROMURT=  0.164205E 01
 REX=  0.128030E 03   REYMOM=  0.711343E 01
 HRECL=  0.264688E 08      HRECT=  0.273318E 08

STATION NO. = 7
   QLOCLAM=  0.147798E 05     QLOCTURB=  0.566329E 04     X=  0.563155E 00
   QXQOLAM=  0.662237E-01   QXQOTURB=  0.253754E-01   CFLAM=  0.250495E-01   CFTURB=  0.929556E-02
TAULAM=  0.371008E 01   TAUTURB=  0.137677E 01   CFRENU=  0.232191E 01   ROMURT=  0.149157E 01
 REX=  0.161962E 03   REYMOM=  0.897379E 01
 HRECL=  0.265053E 08      HRECT=  0.273575E 08
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STATION NO. = 8
   QLOCLAM=  0.773719E 04      QLOCTURB=  0.328616E 04      X=  0.657014E 00
   QXQOLAM=  0.346679E-01   QXQOTURB=  0.147243E-01   CFLAM=  0.168683E-01   CFTURB=  0.694216E-02
TAULAM=  0.196030E 01   TAUTURB=  0.806766E 00   CFRENU=  0.236780E 01   ROMURT=  0.131173E 01
 REX=  0.196671E 03   REYMOM=  0.120137E 02
 HRECL=  0.265502E 08      HRECT=  0.273888E 08

STATION NO. = 9
   QLOCLAM=  0.326607E 04      QLOCTURB=  0.160470E 04      X=  0.750873E 00
   QXQOLAM=  0.146342E-01   QXQOTURB=  0.719017E-02   CFLAM=  0.101836E-01   CFTURB=  0.485177E-02
TAULAM=  0.833367E 00   TAUTURB=  0.397039E 00   CFRENU=  0.240644E 01   ROMURT=  0.110873E 01
 REX=  0.226518E 03   REYMOM=  0.171687E 02
 HRECL=  0.266071E 08      HRECT=  0.274282E 08

STATION NO. =10
   QLOCLAM=  0.101048E 04      QLOCTURB=  0.611811E 03      X=  0.844732E 00
   QXQOLAM=  0.452764E-02   QXQOTURB=  0.274133E-02   CFLAM=  0.544188E-02   CFTURB=  0.319715E-02
TAULAM=  0.259067E 00   TAUTURB=  0.152204E 00   CFRENU=  0.233208E 01   ROMURT=  0.861480E 00
 REX=  0.218495E 03   REYMOM=  0.239902E 02
 HRECL=  0.266612E 08      HRECT=  0.274655E 08

STATION NO. =11
   QLOCLAM=  0.139557E 03      QLOCTURB=  0.124178E 03      X=  0.938591E 00
   QXQOLAM=  0.625309E-03   QXQOTURB=  0.556402E-03   CFLAM=  0.260611E-02   CFTURB=  0.225239E-02
TAULAM=  0.358984E-01   TAUTURB=  0.310260E-01   CFRENU=  0.227436E 01   ROMURT=  0.620461E 00
 REX=  0.105997E 03   REYMOM=  0.349498E 02
 HRECL=  0.267404E 08      HRECT=  0.275200E 08

STATION NO. =12
   QLOCLAM=  0.594002E 03      QLOCTURB=  0.380138E 03      X=  0.109099E 01
   QXQOLAM=  0.266154E-02   QXQOTURB=  0.170328E-02   CFLAM=  0.110830E-01   CFTURB=  0.688308E-02
TAULAM=  0.152665E 00   TAUTURB=  0.948125E-01   CFRENU=  0.226639E 01   ROMURT=  0.265018E 01
 REX=  0.123208E 03   REYMOM=  0.349463E 02
 HRECL=  0.266703E 08      HRECT=  0.274719E 08

STATION NO. =13
   QLOCLAM=  0.815681E 03      QLOCTURB=  0.478446E 03      X=  0.124339E 01
   QXQOLAM=  0.365481E-02   QXQOTURB=  0.214376E-02   CFLAM=  0.152158E-01   CFTURB=  0.865920E-02
TAULAM=  0.209593E 00   TAUTURB=  0.119278E 00   CFRENU=  0.226432E 01   ROMURT=  0.366503E 01
 REX=  0.140419E 03   REYMOM=  0.351614E 02
 HRECL=  0.266522E 08      HRECT=  0.274594E 08

STATION NO. =14
   QLOCLAM=  0.920563E 03      QLOCTURB=  0.517919E 03      X=  0.139579E 01
   QXQOLAM=  0.412476E-02   QXQOTURB=  0.232063E-02   CFLAM=  0.171707E-01   CFTURB=  0.937186E-02
TAULAM=  0.236521E 00   TAUTURB=  0.129095E 00   CFRENU=  0.226347E 01   ROMURT=  0.417247E 01
 REX=  0.157630E 03   REYMOM=  0.354551E 02
 HRECL=  0.266446E 08      HRECT=  0.274543E 08

STATION NO. =15
   QLOCLAM=  0.102258E 04      QLOCTURB=  0.555395E 03      X=  0.154819E 01
   QXQOLAM=  0.458185E-02   QXQOTURB=  0.248855E-02   CFLAM=  0.190719E-01   CFTURB=  0.100483E-01
TAULAM=  0.262709E 00   TAUTURB=  0.138412E 00   CFRENU=  0.226269E 01   ROMURT=  0.467989E 01
 REX=  0.174841E 03   REYMOM=  0.357871E 02
 HRECL=  0.266378E 08      HRECT=  0.274496E 08
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