An Experimental Investigation of the Mixing and Combustion
of an Underexpanded H₂ Jet in Supersonic Flow

By

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ABSTRACT

The interaction of an underexpanded hydrogen jet coaxially injected into supersonic flow is investigated experimentally. Experimental results are discussed and analyzed. Comparisons are made between the experimental results and theoretical predictions computed using an analytical technique. Changes to improve the theory are suggested.
ACKNOWLEDGEMENTS

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\( C \_p \) nondimensional specific heat, \( C\_p /C\_p\_\infty \)

\( H \) nondimensional total enthalpy, \( H^*/C\_p\_\infty T\_\infty \)

\( h \) Nondimensional static enthalpy, \( h^*/C\_p T\_\infty \)

\( Le \) Lewis number

\( M \) Mach number

\( m_i \) molecular weight of \( i^{th} \) specie, \( \frac{kg}{kmole} \)

\( n \) coordinate normal to streamlines

\( p \) nondimensional pressure, \( p^*/(\rho\_\infty Q\_\infty^2) \)

\( Pr \) Prandtl number

\( p_{t2} \) pitot pressure, \( N/m^2 \)

\( q \) nondimensional velocity, \( q^*/Q\_\infty \)

\( Re \) freestream Reynolds number, \( \frac{\rho\_\infty Q\_\infty R\_1}{\mu\_\infty} \)

\( r_j \) radius of jet at injector's exit (used as reference dimension), 0.3175 cm

\( s \) coordinate along streamlines

\( S_1, S_2, S_3 \) forcing functions defined in text

\( T \) nondimensional temperature, \( T^*/T\_\infty \)

\( U_1, U_2 \) nondimensional velocities normal to the shock wave in Rankine-Hugoniot equations, \( U_1^*/Q\_\infty; U_2^*/Q\_\infty \)

\( V \) nondimensional velocity, \( V^*/Q\_\infty \)

\( V_{t1}, V_{t2} \) nondimensional tangential velocities in Rankine-Hugoniot equations, \( V_{t1}^*/Q\_\infty; V_{t2}^*/Q\_\infty \)

\( W \) molecular weight of mixture, \( \frac{kg}{kmole} \)
the production rate of oxygen at 1000 K and the local pressure of \( \dot{W}_1^* \)

nondimensional species production team, \( \dot{W}_1/\dot{W}_0 \)

nondimensional coordinate along nozzles' axis

nondimensional coordinate normal to nozzles' axis

mass fraction of \( i^{th} \) species

ratio of specific heats

flow angle, radians

nondimensional density, \( \rho^*/\rho_{\infty} \)

nondimensional absolute viscosity, \( \mu^*/\mu_{\infty} \)

Mach angle, radians

equivalence ratio; the ratio of the actual \( \dot{m}_{H_2} \) to that required for stoichiometric reaction,

\[
\frac{\dot{m}_{H_2}}{0.029157 \dot{m}_{air}}
\]

(The fictitious \( \phi \)'s for nitrogen test medium are computed as if the test stream were air.)

Subscripts:

CL

centerline

f

frozen state

i

pertaining to specie i

j

jet

t

test stream vessel stagnation condition

\( \infty \)

freestream nozzle exit conditions

Superscripts:

*  
dimensional variable

x
SUMMARY

An experimental data base for the injection, mixing, and combustion of an underexpanded hydrogen jet in a supersonic test stream has been obtained. Experimental pitot pressure data have been compared with theoretical predictions.

The experimental tests were conducted with both air and nitrogen as test media which led to reacting and nonreacting flows, respectively. Tests were conducted in a free-jet and in a ducted mode. Theoretical values were computed using two different viscosity models and a wide range of Prandtl number (0.7 to 1.4) with a Lewis number of 1.

The comparison of the experimental and theoretical data indicates that the theory is inadequate for predicting the flow field resulting from the injection of an underexpanded (hydrogen) jet into supersonic flow. Suggestions are made for improving the theory.
CHAPTER 1

INTRODUCTION

The hydrogen fueled supersonic combustion ramjet (scramjet) engine is envisioned as the prime candidate to fill the propulsion requirements for future hypersonic aircraft. However, feasible scramjet engines face problems in several technological areas. (Status evaluations of the scramjet concept may be found in references 1, 2, 3, and 4.) Three such areas are of concern in this work. These are the injection, mixing, and combustion of hydrogen. Note that the last two are directly related to the first by the following sequence: injection controls mixing and mixing controls combustion. As a result, fuel injection holds an important position in the total scramjet problem. Thus, it is not surprising that numerous fuel injection schemes have been investigated in both cold and hot supersonic flows. Simplicity in flow field modeling has made parallel coaxial injection the scheme most widely investigated (references 5, 6, and 7 present investigations of this type).

These previous investigations of coaxial injection were limited to cases where injector exit pressure matched the test stream static pressure. These matched pressure cases were selected primarily because the theory available was designed to handle them.

On the other hand, recent theory (see references 8 and 9) is designed to handle more complex underexpanded (jet pressure greater than the test stream static pressure) injection. The significance of such a theory becomes apparent when one notes that any practical scramjet engine
is likely to use hydrogen injection by an underexpanded jet.

In fact, all scramjet engines must be capable of operating with underexpanded injection, although this may not be the primary type of injection. However, a search of the literature indicated that there was very little information on an underexpanded hydrogen jet coaxially injected into supersonic flow. Particular information, such as data on the underexpansion (exit) shock wave's affect on the hydrogen mixing and combustion, is completely lacking. The present investigation was therefore undertaken to experimentally determine some of the fundamental characteristics of the mixing and combustion of an underexpanded hydrogen jet in supersonic flow. In addition, the theory of reference 8 was tested by comparing experimental data with theoretical data computed using the computer program (reference 9) based on the theory of reference 8.
CHAPTER II

APPARATUS AND INSTRUMENTATION

Facility and Test Conditions

The experimental portion of this work was conducted in the Langley 11-Inch Ceramic-Heated Tunnel. This facility, described in reference 10, has a bed of zirconia pebbles which is heated by the combustion products from a propane burner. The products from the burner are passed through the bed until the desired stagnation temperature is reached. The hot test gas is obtained by passing the test medium (air or nitrogen) through the heated pebbles. In this manner, test gas total temperatures up to 2530 K (maximum usage temperature of the zirconia pebbles) can be furnished with a maximum stagnation pressure of 4 MN/m².

For the purpose of the present tests, the facility was fitted with the Mach 2 test stream nozzle which is a scaled version of one given in reference 11. This axisymmetric nozzle was constructed of stainless-steel and cooled by about 6 kg/sec of water. The facility was operated in two modes, a free-jet mode and a ducted mode. In the ducted mode, the ducting around the supersonic flow formed a circular combustor. A schematic of the facility (in the ducted mode configuration) is given in figure 1. The free-jet mode configuration is obtained by removing the constant area duct which extends from plane A-A to plane B-B of figure 1. In each configuration, the exit plane of the Mach 2 hydrogen injector nozzle was 0.3175 cm downstream of the exit plane of the test stream nozzle. Tests were conducted with both air and nitrogen as test media.
Figure 1 - Schematic of the coaxial supersonic combustion apparatus.
and for all tests the total temperature of the test stream was 2167 K, with a nozzle exit (static) temperature of 1338 K. This temperature was high enough to give ignition without a pilot flame or ignitor. The stagnation pressure ranged from 0.759 to 0.858 MN/m², which gave rise to test gas flow rates of 1.23 to 1.39 kg/sec and nozzle exit (static) pressures of 0.099 to 0.112 MN/m².

A summary of the test conditions is presented in Table I.

Hydrogen Injector

The hydrogen injector, which was mounted coaxial with the main nozzle, is a 0.953 cm (3/8 in) stainless-steel tube with a 5° conical nozzle at the exit. This nozzle, with a 0.635 cm exit diameter and 0.488 cm throat diameter, gives a nominal exit Mach number of 2. The injector exit lip thickness is 0.159 cm.

This injector lip of finite thickness introduces the problem of wake effects in the base region of the injector. However, it is considered to be a good compromise between the ideal and technically practical nozzle. Ideally, for ease of analysis, the injector should have an infinitely thin lip, and parallel flow at its exit. Unfortunately, the contoured nozzle needed to fulfill these ideal conditions cannot be built and a compromise must be sought. If the requirement of parallel flow is dropped, the infinitely thin lip can be approached by at least two designs. One is the boattail conical type nozzle given in figure 2. This design produces two undesirable results. First, the boattail causes the test flow to expand to a lower pressure, and second, the expansion
Table 1

<table>
<thead>
<tr>
<th>$X_{r_j}$</th>
<th>$P_{r0}$</th>
<th>$P_{\infty}$</th>
<th>$\frac{P_1}{P_{\infty}}$</th>
<th>Re x $10^4$</th>
<th>$\dot{m}$</th>
<th>$\dot{m}_{H_2}$</th>
<th>Test Type</th>
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<td>1±.5</td>
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<td>0.103</td>
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<td>2.446</td>
<td>1.302</td>
<td>0.015</td>
<td>A-FJ</td>
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<td>0.794</td>
<td>0.103</td>
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<td>2.460</td>
<td>1.307</td>
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<tr>
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<td>0.104</td>
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<td>2.451</td>
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<td>1.5±.5</td>
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<td>0.102</td>
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<td>2.657</td>
<td>1.388</td>
<td>0.016</td>
<td>N-D</td>
</tr>
</tbody>
</table>

A - Air  
FJ - Free Jet  
N - Nitrogen  
D - Ducted  
$X_{r_j}$ = Duct Length
Figure 2.- Half cross section of a nozzle having a very thin lip and boattail.
turns the flow (near the injector) so that it is no longer parallel with the rest of the test stream. The other design is the one of figure 3, where the boattail has been eliminated. Unfortunately, this design suffers from the increased chance of separation of boundary layer on the injector. Such separation of boundary layer would be caused by interaction with the exit shock and the jet flow. If a nozzle of this design is cut off (see figure 3), the resulting nozzle has a finite lip thickness with a base region. Although the wake effects of this region cannot be computed close to the base, the probability of boundary layer separation is reduced. This result is obtained from the fact that the boundary layer can bleed into the wake and the compression effects of the divergent flow are eased. It was felt that the exit thickness (0.159 cm) of the injector chosen was sufficient to prevent separation but small enough to get a far field (several $r_j$'s) solution for the wake region. It is also pointed out that the experimental data of reference 12 indicates that the jet spreads better when injected from a blunt body of this type. Increased spreading (mixing) suggests better burning. This design was therefore adopted for the present investigations.

The cooling needed to protect the injector during each test is provided by the injectant (hydrogen). In the present tests, the hydrogen supplied at ambient temperature was heated to a total temperature of approximately 470 K as it cooled the injector before injection into the stream. With this total temperature, and stagnation pressures ranging from 1.59 to 1.94 MN/m$^2$, the injector supplied hydrogen mass flow rates of 0.015 to 0.018 kg/sec. The resulting equivalence ratio, based on
Figure 3.- Half cross section of a nozzle with no boattail but with a very thin lip. (Cutting the tip off this nozzle as indicated by the vertical line produces an injector of the type used in the present work.)
total flow in the test stream nozzle, varied from 0.381 to 0.467 and the exit (static) pressures ranged from 0.203 to 0.248 MN/m$^2$. The injector exit pressure was therefore about 2 times the test stream static pressure for each test, and the injected hydrogen was thus underexpanded.

**Circular Combustor**

In the ducted mode, constant area ducts of four different lengths (9.53, 12.70, 30.48, and 45.72 cm) were individually attached to the facility nozzle to form circular combustors. These combustors, constructed of stainless-steel, are uncooled (heat sink) and have numerous pressure orifices for measuring static pressure. The orifices are arranged in three rows (designated P, Q, and R in figure 4) that run axially along the duct with each row spaced 120° apart. A schematic of the 12.7 cm combustor, accompanied by a table summarizing the orifice locations for all four ducts, is given in figure 4.

**Pitot Probes**

The pitot probes used in the present tests were of two different designs. One design is a modified version of a probe developed by the Applied Physics Laboratory of Johns Hopkins University and reported in reference 13. It has an outside diameter of 0.635 cm and a tip half-angle of 30° (see figure 5 for details of probe tip). The other design is a slightly modified version of a probe described in reference 14. It has an outside tip of 0.914 cm and a tip half-angle of 20° (see figure 6 for details of probe).
Figure 4.- Half section of 12.7 cm length duct (‘ken in the plane bisecting the pressure taps of Row P) with axial locations for all four ducts.
Figure 5.- Cross section of the modified Johns Hopkins' probe.
Figure 6.- Half-section of the modified Eggers' probe.
Probes of both designs were water-cooled by a no return method. In this method, water is supplied through a single passage in the main body of the probe, sprayed against the rear of the probe tip, and then injected into the test stream at a location behind the pressure sensing region. Once in the test stream, the water is swept downstream over the probe body furnishing further cooling.

Pitot-pressure profiles were obtained with a single moving probe which was driven perpendicularly across the flow field at a rate of approximately 0.5 cm/sec by a dc motor. Comparisons of pitot pressures taken at the same points with the probe moving and stationary indicated that response of the pressure transducer was sufficient to give accurate measurements while moving. In addition, probes of either design gave the same results for identical test conditions.

Photographs and Shadowgraphs

Data obtained in the form of photographic records were of two types: black and white movies, and shadowgraphs. The movies were taken at a frame rate that varied from 20 to 64 frames/sec. They were used to check the pitot probe alignment and vibration. The shadowgraphs were taken at a constant frame rate of 24 frames/sec. They were used to define the flow quality and are quite valuable for analyzing the flow field.

Photographic records of both types were obtained on 16 mm black and white movie film with an ASA number of 400 (Lin number of 27). The total photographic records will not be included in this work. However, an example of the shadowgraphs are given in figure 7.
(a) Test stream and jet.

(b) Flow-up of wave structure.

Figure 7. - Shadowgraph of the test stream and jet in the free-jet mode with combustion.
Example of Pitot Test Data

Although the majority of the test data is to be presented in Chapter IV, the exit pitot surveys are introduced here to provide a feel for the experimental data. In figures 8 and 9, radial exit pitot pressure profiles for the free-jet reacting and nonreacting cases are given respectively. Both profiles have the same general shape, however their peak (centerline) values are not equal. The nonreacting peak value is less than the reacting, since it is taken at an axial location slightly downstream of the axial location of the reacting case. The solid line of both figures is a straight line connection of adjacent data points intended as a guide to the data trend.

Since both cases have the same shape, only one discussion will be offered. This discussion uses the letters common to both of these figures, and the flow schematic of figure 10. The pitot pressure varies radially in the following manner. The pressure decrease in going from points a to b is due partly to the radial travel across the conical jet flow field, and partly to an expansion fan from the injector lip. Both processes result in higher Mach numbers, and thus lower pitot pressures. The small peak at c is the result of the shock wave which terminates the expansion fan. The decrease in pressure from c to d is due to the shock wave indicated at c and the fact that d is in the base region of the injector. The shock indicated at c is a curved shock which extends from the injector lip at the exit to the centerline at a slightly downstream location. Thus, much of the region c to d is behind the curved shock, whose strength varies from a minimum near the
Figure 8. Pitot profile at exit of injector ($x/r_j = 1 \pm .5$) with air test medium.
Figure 9. Pitot profile at exit of injector ($x/R_j = 1.5 \pm 0.5$) with nitrogen test medium.
Figure 10.- A schematic of the free-jet flow field with various prominent features at the survey location labeled.
injector lip to a maximum at the centerline. The strength variation in this region produces a radial pitot pressure profile which varies in the same direction (minimum to maximum), whereas the radial Mach number profile varies in the opposite direction. In idealized flow, \( d \) would be the location of a slip line separating the test stream and jet flow. In the present work, the radial region near \( d \) is probably a mixing boundary. Point \( e \) is the underexpansion or exit shock wave which extends from the injector's outer lip to the test stream boundary, where it is reflected as an expansion fan. Therefore, the region \( d \) to \( e \) is similar but in opposite sense to the region \( c \) to \( d \). The region from \( e \) to \( f \) is the test stream without any interaction. The dip from \( f \) to \( g \) is an indication of the free-jet test stream interacting with the ambient air.

It may be surmised from the above discussion that the flow field resulting from the underexpanded injection of hydrogen into supersonic flow is quite complex. As a consequence, the theoretical treatment by necessity must be rather sophisticated. The theory used for comparison in this work is that of reference 8, and is outlined in the next chapter.
CHAPTER III

THEORY

General Governing Equations

The basic governing equations are the well known "viscous-inviscid" equations used in higher order boundary layer and viscous flow field analysis with finite rate chemistry terms included. These "viscous-inviscid" equations are supplemented by the Rankine-Hugoniot and Prandtl-Meyer relations to facilitate the computation of shock and expansion conditions respectively. The basic equations are given in Appendix A along with a limited discussion of how they are applied. The reader interested in a more thorough delineation of the equations and the numerical application may consult references 15, 16, and 17.

Viscosity Models

The program as published in reference 9 had a turbulent eddy viscosity model referred to as the "Ferri-Kleinstei" model. This model, which was developed in references 18 and 19, has viscosity variation in the axial direction only. However, it was felt that Eggers' viscosity model (see reference 20), which varies both axially and radially, may be more accurate. Thus, it was decided that the program would be run with both models individually incorporated.

Ferri-Kleinstei Model

In this model, the turbulent eddy viscosity undergoes an axial variation from the jet exit to the end of the potential core. The length
of the potential core is defined as: the distance $\chi$ from the jet exit to the downstream location where the mass fraction of hydrogen on the centerline becomes less than 0.99. The viscosity is then assumed to be constant for all locations downstream of the potential core length $\chi$.

The viscosity is computed, for stream locations $(x/r_j)$ less than $\chi$, with the nondimensional equation,

$$\mu = K_1 \text{Re} \left( \frac{\rho q}{(\rho q)} \right)_{\text{max}} - (\rho q)_{\text{min}} \left( \frac{x}{r_j} + K_3 \right)$$  \hspace{1cm} (1)$$

where, $K_1 = 7.5 \times 10^{-4}$ and $K_3 = 100$.

For stream locations equal to or greater than $\chi$

$$\mu = K_1 \text{Re} \left( \frac{\rho q}{(\rho q)} \right)_{\text{max}} - (\rho q)_{\text{min}} \chi + K_3$$  \hspace{1cm} (2)$$

and since $\mu$ is constant downstream of the length $\chi$, equation 2 is executed once. The resulting value of $\mu$ is stored for future downstream calculations.

Eggers' Model

There are two viscosity models generally referred to as Eggers' model, thus one must be careful to specify the model intended. The two models, which are similar in mathematical structure, are called Z-difference and kinematic Z-difference models by Eggers (reference 6). In the Z-difference model (see reference 20) the absolute viscosity varies axially only and is computed using the nondimensional equation,

$$\mu = KZ (\rho q)_{CL}$$  \hspace{1cm} (3)$$

In the kinematic Z-difference model, the kinematic viscosity varies axially and is computed using the nondimensional equation,
The absolute viscosity is obtained by multiplying the kinematic viscosity (of equation 4) by the local density which varies radially. Thus, the absolute viscosity varies both axially and radially, and is computed with the equation,

\[ \nu = \rho_{local} K Z (q)_{CL} \]  

In all three equations (3-5), the empirical constant \( K \) has a value of 0.01. The quantity \( Z \) is defined as the radial distance between the points where the local velocities are \( U_1 \) and \( U_2 \) as given by the equations,

\[ U_1 = U_a + 0.95 (U_{CL} - U_a) \]  

and,

\[ U_2 = U_a + 0.5 (U_{CL} - U_a) \]  

where \( U_a \) equal the stream velocity external to the jet.

It is the model computed by use of equation 5 that is referred to as the Eggers' model in this work.
CHAPTER IV

RESULTS AND DISCUSSION

The experimental data and theoretical predictions of the present study are presented in dimensionless form. All pressures are nondimensionalized by dividing by the test stream stagnation pressure ($P_{t_0}$). Similarity, dimensionless coordinates and lengths are obtained by division by the hydrogen jet radius ($r_j$) at the exit of the injector. It is also noted that all theoretical calculations were performed with a Lewis number of 1.

Free-jet Data

Radial pitot pressure surveys were taken at several axial stations for the free-jet mode and at the end of the ducts when operating in the ducted mode. The pitot pressure data (surveys) for each mode of operation can be subdivided into reacting and nonreacting cases. In the reacting cases, the test stream is air, and in the nonreacting cases the test stream is nitrogen.

The data for the free-jet reacting cases given in figure 11 are typical and will be discussed. The pitot surveys were made at axial locations ($x/r_j$) of 1, 19, 30, 40, 56, and 80. The data for the axial location $x/r_j$ equal one were previously presented in figure 8, and will not be covered here. The prominent features, such as high jet centerline pressure bounded by jet mixing boundaries, present at the $x/r_j = 1$ location extend downstream. In fact, the high centerline pressure is present for the $x/r_j = 19$, 30, and 40 locations. However, the mixing
Figure 11: Experimental and theoretical Pitot profiles at various axial locations for the reacting free-jet mode (Ferrini-Kleinert viscosity model).
Figure 11 - Continued.
Figure 11.- Concluded
region has engulfed the centerline at the $x/r_j = 56$ location and the centerline is not discernible. The regions of no interaction, previously discussed in the section on the pitot sample, have become tenuous at the $x/r_j = 56$ location. This demise of these regions is attributed to the fact that free-jet test mixing boundary spreads inward to meet the jet-test-stream mixing region which spreads outward.

Other details of the data are given in the following discussion, in which theoretical predictions are compared with the data.

The theoretical calculations at the free-jet test stream boundary were not expected to agree with the experimental data, since the program does not have the necessary theory for handling the test stream mixing boundary. The program takes a constant pressure boundary approach which is sufficient for mathematical consistency, but improper for actual boundary conditions. This approach does not affect the accuracy of the calculations performed for the region inside the test stream mixing boundary since this region is supersonic. Thus, the boundary disturbances cannot be transmitted to the internal region of interest, and the calculations should be in agreement with the experimental data. Unfortunately, an actual comparison of the theoretical calculations and the experimental data does not show such agreement. In figure 11, for example, there is a comparison of the experimental pitot pressure data to theoretical calculations performed with the Ferri-Kleinstein viscosity model. The test stream is air, and the theoretical data are for Prandtl numbers of 0.7 and 1.4. As expected, there is no agreement in the region of the test stream mixing boundary. For axial locations $x/r_j = 19$ and 30 where there is a
region of test stream not affected by the mixing boundary or jet inter-
action, the agreement is excellent. (At \(x/r_j = 19\) these regions extend
from \(y/r_j = -7.5\) to \(-4\) and from \(y/r_j = 4\) to \(9\).) This agreement indi-
cates that the constant pressure boundary approach does not affect the
accuracy of the program for the region internal to the test stream mixing
boundary. However, the only other semblance of agreement is at the
centerline region \(y/r_j = \pm 1\) and that is not complete. For example,
the centerline differences between the experimental and theoretical
values \(Pr = 0.7\) are given in Table 2.

<table>
<thead>
<tr>
<th>(x/r_j)</th>
<th>(\beta \text{ difference } @ \xi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>13</td>
</tr>
<tr>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>80</td>
<td>10</td>
</tr>
</tbody>
</table>

This erratic agreement on the centerline suggests that the analytical
technique does not handle the wave structure internal to the jet (see
figure 7).

Theoretical jet mixing (spreading) effects, as indicated by pitot
pressure, are much too large at all the axial locations (this may be
observed by comparing the theoretical and experimental widths of the
region of interaction in figure 11).
In figure 12, the theoretical data computed using the Eggers' viscosity model (and Prandtl number of 0.7, 1.0, and 1.4) are compared to the same experimental data given in figure 11. As can be seen, the agreement with this viscosity model is about the same as that of the Ferri-Kleinlein model. Likewise, the discussion of figure 11 is in general true of figure 12.

The nonreacting free-jet case, resulting from the use of nitrogen as the test medium, is presented in figure 13. The theoretical results obtained with each of the viscosity models are so close together that only the theoretical results obtained with Eggers' model will be presented. In this figure, only the theoretical results obtained with a Prandtl number of 1 are offered since this gives the best agreement. At an axial location of \( x/r_j = 19 \) theoretical and experimental results have the same general shapes. The numerical agreement, however, is quite poor in the near centerline region \( y/r_j = \pm 1.5 \). In addition, the shape agreement is short lived and disappears by the time an axial location of 40 is reached. For all values of \( x/r_j \geq 40 \) the experimental data have a minimum at the centerline and the theoretical have a maximum. That is, the theoretical data exhibit a valley in the near centerline region. These results indicate that the theoretical near centerline Mach numbers are too low, thus producing pitot pressures which are too high. This contrary behavior of the theoretical predictions is probably due to improper handling of the jet wave structure.

The expected disagreement for the test stream mixing boundary is also present. Furthermore, the region of no test stream interaction (for
Figure 12.- Experimental and theoretical pitot profiles at various axial locations for the reacting free-jet (Eggers' viscosity model).
Figure 12.—Continued.
Figure 13. - Nonreacting free-jet pitot profiles at various axial locations. (Theoretical curve represents both viscosity models, and a Prandtl number of 1.)
Figure 13.- Continued.
Figure 13.- Continued.
example at $x/r_j = \pm 7.0$ to $\pm 2.0$ gives excellent agreement between the experimental and theoretical values of pitot pressures.

Ducted Data (Circular Combustors)

The experimental data for the ducted case are presented in figures 14, 15, and 16. Figure 14 presents the pitot surveys made at the exit of the four ducts using air test medium (reacting case). Figure 15 gives similar data for the nonreacting case (nitrogen test medium). Figure 16 gives the static pressures measured along the various ducts. The static pressure measurements and exit pitot profiles were made simultaneously for each duct. The same technique was used for both air and nitrogen test gas.

The program was unable to calculate the flow field for even the shortest (length = 30 $r_j$) duct, therefore a comparison between the experimental and theoretical data cannot be made. The inability of the program to compute the flow field for the ducted cases stemmed from the fact that the underexpanded shock wave, which reflects from the duct wall, is unable to traverse the region of test stream jet interaction. The flow angle computed for the jet and its interaction with the test stream were inconsistent with the shock wave and the rest of the flow field. The reflected shock is not suspect since it is fully compatible with the portion of the test stream which has not interacted with the jet.

An Evaluation of the Analytical Tool

The utility of the analytical tool as applied here appears quite limited with either of the two viscosity models employed. This is not
Figure 14. - Lateral pitot pressure distributions at the exits of the four ducts. (Test medium, Air)
Figure 15.- Lateral pitot pressure distributions at the exits of the four ducts. (Test medium, Nitrogen)
to imply that the inadequacy of the program is due to the viscosity models employed. In fact, the similar results obtained with the two different models indicate that the fault lies in handling the internal (jet) flow, and its interaction with the test stream. This hypothesis is further supported by the fact that the spreading as indicated by theoretical pitot pressure is excessive for the reacting case (see figures 11 and 12). Similarly, pitot pressure was consistently overpredicted by the program for the nonreacting case, particularly in the near centerline region which is highly dependent on the jet flow.

Another failing of the program is that it did not detect the fact that the expansion fan is terminated by an intersecting shock front. A discussion of why there is an intersecting shock terminating the fan can be found in reference 21, and one may refer to the discussion of figures 7 and 8 for the location of the shock. The program has incorporated in it a subprogram which checks the entire flow field at one axial location before each downstream marching step is taken, to see if a pressure gradient exists. If a pressure gradient of sufficient strength is encountered, it inserts an embedded shock wave. Thus, it must be concluded that the computed jet flow did not produce the pressure gradient necessary for shock wave insertion.

It should be noted that all of the shortcomings of the analytical approach, detected by the present work, are associated with the divergent internal (conical jet) flow and its interaction with the test stream. Thus, there is the possibility that it can be successfully applied to the case of underexpanded jets whose flow divergence is small at the injector.
exit.

It is felt that the analytical predictions can be improved by replacing the present method of handling the jet flow with a characteristic expansion network. This network, which would require considerable effort to implement, would be terminated by an intersecting shock front. The intersecting shock may require little additional effort since the sub-program previously mentioned may insert the required shock once the proper jet flow is computed by means of an expansion network. An improved program, which correctly handles the jet flow by an expansion network, would be very useful and probably effective in analyzing underexpanded jets.
CHAPTER V

CONCLUDING REMARKS

One of the major technological problems facing the scramjet engine concept is the ability to successfully predict the flow field resulting from the injection, mixing, and combustion of hydrogen fuel. Such predictions are necessary for good design of major components of the engine (i.e. fuel injectors, the combustor, and the exit nozzle). Of particular importance here is the ability to predict the flow field resulting from underexpanded injection of hydrogen. More fundamental, however, is the need for experimental data on an underexpanded H₂ jet in a supersonic flow.

The present work has accomplished the task of furnishing a small data base on the coaxial injection of an underexpanded H₂ jet into supersonic flow. The data obtained are for a Mach 2 test stream of air or nitrogen, and a Mach 2 hydrogen jet whose exit pressure is approximately twice the test stream static pressure. Since the air or nitrogen test stream has a static temperature of 1338 K, data with and without combustion is provided. In addition, the facility was operated in a free-jet mode and in a ducted mode furnishing data for four different duct lengths. The free-jet data consist of radial pitot profiles at various axial locations. The ducted data consist of radial pitot profiles at the duct ends and static pressures measured along the duct walls. In addition, the present work tested the utility of an analytical technique designed to predict the flow field resulting from the injection of
an underexpanded jet into supersonic flow. The theory is tested by comparing experimental data with theoretical predictions. The theoretical calculations, which cover a wide range of Prandtl number (0.7 to 1.4), were unable to correctly predict the experimental results.
REFERENCES


APPENDIX A

THEORY

General Governing Equations

The basic governing equations are the well known "viscous-inviscid" equations used in higher order boundary layer and viscous flow field analysis (see references 15, 16, and 17) with the finite rate chemistry terms included. These equations are evolved from the full Navier-Stokes equations by assuming that the transport effects depend only on gradients normal to the streamlines. (The normal momentum equations are kept in the inviscid form.)

These equations, written in nondimensional form for an intrinsic coordinate system (with $s$ along the streamlines and $n$ normal to the streamlines), are as follows for axisymmetric flow.

Global Continuity:

$$\frac{\partial (\rho q)}{\partial s} + \rho q \frac{\partial U}{\partial n} + \frac{\rho q}{y} \sin \theta = 0$$

(A1)

S-Momentum:

$$\rho q \frac{\partial q}{\partial s} + \frac{\partial p}{\partial s} = S_1$$

(A2)

where,

$$S_1 = \frac{1}{Re} \left[ \frac{\partial}{\partial n} \left( \mu \frac{\partial q}{\partial n} \right) + \mu \left( \cos \theta \right) \frac{\partial q}{\partial n} \right]$$

V-Momentum:

$$\rho q^2 \frac{\partial \theta}{\partial s} + \frac{\partial p}{\partial n} = n$$

(A3)
Energy:
\[ \rho q (C_p) \frac{\partial T}{\partial s} - q \frac{\partial p}{\partial s} = S_2 - \sum W_i h_i \]  
(A4)

where,
\[ S_2 = \frac{1}{\text{Re} \ (y - 1) M^2} \left[ \frac{\partial}{\partial n} \left( \frac{\mu}{\text{Pr}} \frac{\partial T}{\partial n} \right) + \frac{\mu}{y \text{Pr}} \frac{C_p}{\partial n} \right] \frac{\partial T}{\partial n} + \frac{\mu (Le)}{\text{Pr}} \frac{\partial T}{\partial n} \sum C_{p_i} \frac{\partial \alpha_i}{\partial n} + (y - 1) M^2 \mu \left( \frac{\partial q}{\partial n} \right)^2 \]

Species Conservation:
\[ \rho q \frac{\partial \alpha_i}{\partial s} = S_{\alpha_i} + W_i \]  
(A5)

where,
\[ S_{\alpha_i} = \frac{1}{\text{Re} \ (y - 1) M^2} \left[ \frac{\partial}{\partial n} \left( \frac{\mu_0}{\text{Pr}} \frac{\partial \alpha_i}{\partial n} \right) + \mu \frac{\mu_0 \text{cos} \theta}{y \text{Pr}} \frac{\partial \alpha_i}{\partial n} \right] \]

State:
\[ p = \frac{W_0 \rho T}{\gamma_0 M^2 W} \]  
(A6)

where,
\[ W = \left[ \sum \frac{x_i}{m_i} \right]^{-1} \]

For supersonic flow fields, the above equations (A1 to A6) have a dual mathematical nature (see reference 15). That is, they exhibit features of both hyperbolic and parabolic systems. The analytical tool of reference 9, therefore, uses a numerical scheme employing a characteristic network in conjunction with a boundary layer type network to yield a coupled solution. This scheme is thoroughly discussed in reference 17,
and will not be fully covered here. However, the following description of the approach used by the scheme is offered.

Essentially, the approach finds a characteristic solution which feels the effects of diffusion and finite rate chemistry. This is done by treating the diffusive and chemistry terms as forcing functions in the "compatibility relation" along characteristics. Treating these terms as forcing functions results in the characteristic directions of the viscous system being exactly those of the inviscid system. Namely, the frozen Mach line (Cz)

$$\frac{dy}{dx} = \tan (\Theta \pm \bar{u}_f)$$  \hspace{2cm} (A7)

and thus the streamlines are defined by the equation

$$\frac{dy}{dx} = \tan \Theta$$  \hspace{2cm} (A8)

The compatibility relation can be shown to be (see reference 17 for an excellent derivation)

$$\frac{\sin \bar{u}_f \cos \bar{u}_f}{\gamma_\infty P} \frac{dp}{dx} + \left[ \frac{\sin \Theta}{y} + \frac{S_{1f}}{\rho q^2} \right]$$

$$\frac{(\gamma_f - 1)}{\gamma_\infty P} \frac{S_2}{\gamma_f (\alpha_\infty^2 - 1) \omega_\infty^2 pq} + \sum W_i h_i$$  \hspace{2cm} (A9)

$$\frac{W}{\rho q} \left( \frac{S_{3f}}{m_f} + \frac{w_1}{m_i} \right) \frac{\sin \bar{u}_f}{\cos (\Theta \pm \bar{u}_f)} dx = 0$$

The program of reference 9 is designed to analyze the mixing and combustion of an underexpanded $H_2$ jet; therefore, it is apparent that the equations previously presented are not sufficient. Since the jet is
underexpanded, it has an exit pressure greater than the test stream static pressure and must expand into the test stream. The expanded jet, however, is seen by the test stream as an obstruction and an exit shock wave is generated. In addition, embedded shocks caused by combustion compression are possible downstream. The equations required to perform the expansion and shock calculations are also incorporated into the program (reference 9).

The expansion was assumed to be isentropic, two dimensional, and inviscid in the limit of vanishing radial distance with respect to the injector lip. These assumptions allowed the use of the following isentropic relations (Prandtl-Meyer expansion) near the injector's lip.

1. State $\frac{P}{\rho^\gamma}$ = constant  \hspace{1cm} (A1c)
2. Energy $h + \frac{1}{2} \nu^2$ = constant  \hspace{1cm} (A11)
3. Momentum $\frac{dp}{\rho} + \frac{1}{2} \frac{d\nu^2}{d}$ = 0  \hspace{1cm} (A12)
4. Compatibility $\frac{1}{\gamma} (\eta + p) \pm \frac{d\Theta}{\cos \mu \sin \mu} = 0$  \hspace{1cm} (A13)

In the case of the shock wave, it was assumed that the chemistry was frozen across the shock and that it was two dimensional (the 2-D shock is an exact solution for the conical shock if there is no angle attack). Thus, the following Rankine-Hugoniot relations were incorporated into the program. They are:

1. Continuity $\rho_1 \nu_1 = \rho_2 \nu_2$  \hspace{1cm} (A14)
2. Normal Momentum $p_1 + \rho_1 (\nu_1)^2 = p_2 + \rho_2 (\nu_2)^2$  \hspace{1cm} (A15)
3. Tangential Momentum $\nu_1 = \nu_2$  \hspace{1cm} (A16)
4. Energy $H = h + \frac{1}{2} (\nu^2)$ = constant  \hspace{1cm} (A17)

where, $h = \sum \alpha_i h_i(T)$
Exit (Underexpansion) Shock

As previously stated, when the jet expands into the test stream an exit (underexpansion) shock wave is generated. The idealized flow resulting from such an interaction is depicted in figure A1.

Although it can easily be deduced that the pressures \( p \)'s, and flow angles \( \theta \)'s are equal on either side of the slip line separating the regions 1 and 2 of this figure, it is not possible to calculate them by a direct method. Fortunately, the downstream conditions can be calculated by the iterative process that follows. A shock angle is chosen (an angle slightly larger than \( \sin^{-1}(1/M_{\infty}) \) is a good choice) and the downstream properties \( (p_1, T_1, \theta_1, \text{etc.}) \) are computed. The jet is then expanded from its exit pressure to the pressure \( p_2 = p_1 \). If the flow angle \( \theta_2 \) associated with this pressure does not equal the flow angle \( \theta_1 \) downstream of the shock wave, a new shock angle is selected and the above procedure is repeated until convergence is obtained. The stream properties \( (p, \theta) \) for which convergence is obtained are the properties existing across the slip line of figure A1.
Figure A1. A schematic of the flow field resulting from the interaction of the test stream and the underexpanded jet.
APPENDIX B

MODIFIED COMPUTER PROGRAM

The original program of reference 9 has been streamlined and modified to the extent that it is not readily recognized as essentially the same program. Numerically, both old and new versions give the same mathematical results for the cases they are both able to handle. (The original program was not able to handle shock waves which ran from the outer boundary toward the centerline, and various other subtleties.) The version given here has the Ferri-Kleinstein viscosity model as did the original of reference 9.
A3977

PROGRAM CHAR

MAIN PROGRAM FOR CHARACTERISTICS WITH SHEAR
COMMON/AB/EPP,EPT
COMMON/AC/180D,FIN
COMMON/AL/AG,EEM
COMMON/AM/JSUB,JSUB
COMMON/AB/LA/7,55,EMI,INF
COMMON/AC/TOCHEM
COMMON/BE/XMASS(55)
COMMON/CG/JUP,EUP,GUP,DTPRI(55),DUP,EUP,TP PRI(55),TPRI(55)
COMMON/CK/MTMOLE(7)
COMMON/DB/RETB(4),156
COMMON/DE/EM
COMMON/DP/YN(55)
COMMON/ED/CPIN,RC
COMMON/EP/EM(55),GM(55),P(55),TH(55),Y(55)
COMMON/EG/EIN,PX,LEC
COMMON/EF/GAMINF,w(17),PINF
COMMON/FE/DEL
COMMON/GE/AD,ROC,UN,VISINF
COMMON/GF/DLY,RVISA,KOUNT,VISA
COMMON/GK/DELX
COMMON/HJ/KOUNT,LL,NPT
COMMON/HL/ALPHA,BETA
COMMON/HP/ALP(7),55),CPH(7,55),CPH(55),EMN(55),GMN(55),MN(7,55),
ILP(55),ON(55),ON(55),ON(55),ON(55),THN(55),TH(55),WHM(55)
COMMON/HB/ACTAN(4),IEMBED
COMMON/CF/LAP_B(7),PHI(55)
COMMON/FC/UX(55),x(55)
COMMON/FC/ALP(7),IFUEL,PRES
COMMON/FP/IJ/CHEM,N(55),T(55)
COMMON/Q(A,H(55),Q(55),RHO(55),XWX(55)
COMMON/QR/RHOP(2),WOD(7,55),WODTC(7),WP(2),XMP(2)
COMMON/PC/HP,BP,AP1,AP2
COMMON/RS/GPS,PS,THS,THSL,THSC
COMMON/ST/13,1,2,3,4,KP,FIRST,STAR
COMMON/TS/DVacey,DWOCI,IFS,MM,VI,VI
COMMON/UW/1111,HEX,IPRESS,IPRESU,ISSUB
COMMON/VT/1ACH(7,55),JCH(55),VI,VISD,VS
COMMON/WV/ICONT,IAH,KT,THBPN,THBP
COMMON/WH/NPTS,W,RE,XBP,XJ
COMMON/XG/XG

BEGIN INPUTTING PARAMETERS

ORIGINAL PAGE 55
OF POOR QUALITY
WRITE(*,480)
112 FORMT(1S,5X,9E13.5)
480 FORMT(1H1)
C J=0 YMC DIMENSIONAL
C J=1 AXISYMMETRIC
C SPECIES 1 IS N
C SPECIES 2 IS O
C SPECIES 3 IS H2O
C SPECIES 4 IS H2
C SPECIES 5 IS O2
C SPECIES 6 IS OH
C SPECIES 7 IS H2
WMOLE(1)=1.009
WMOLE(2)=16.
WMOLE(3)=16.016
WMOLE(4)=2.016
WMOLE(5)=32.0
WMOLE(6)=17.008
WMOLE(7)=26.014
FAS=WMOLE(4)/16.
J22=0
X08=0.
IDG=0
DEL=0.
DO 8220 I=1,4
BETA(I)=0.
BET(A(I))=0.
I3(I)=0
8220 CONTINUE
IFS=0
MSP=7
R0=1.987
R0D=R0*3.087*32.22.2205*1000.
EP=1.E-10
EP=1.E-10
EP=1.E-10
I=1.0
N=6
EXX=1.E-06
I3=0
KFIRST=-1
KG=10000
JCONV=0
INPTSH=0
363 CONTINUE
CALL INDATA
C *************************************** MAKE INITIAL SHEAR
VISD=VISD(X8P)
CFF=8.
CALL SHEAR(CFF, VISW)

CONTINUE
CALL EMBC
  W**S=VISD=WISC=WIS=VXIS=VIS(VX)
  XVIS=DVISC=DVISB=DVISB=0.
DO 7188 K=1,NPTS
  DO 7199 J=1,NSP
  7199 XS(IJ)=1.0**K*ALP*I*K*/MTMOL(E)
   FUAIR=1.00**K*XS(1)+2.*XS(4)+2.*XS(3)*XS(6)/16.*(XS(12)+XS(13)
   +2.*XS(5)+XS(15)+2.*XS(7))
   PHI(K)=FUAIR/82.0161

CONTINUE
IF(KOUNT.EQ.0)GO TO 407
IF(I11.EQ.1)GO TO 407
IF(KOUNT.EQ.KOUNT)GO TO 407
IF((KOUNT.EQ.KOUNT).NE.KOUNT)GO TO 179
407 WRITE(6,408)KOUNT
408 FORMAT(7H1KOUNT=I5)
  WRITE(6,526)X(I1)
526 FORMAT(5HSH X = E13.5)
DO 4485 I23=1,4
  IF(BET0(I23),E0.0)GO TO 4485
  IF(BET(I23),LT.1)
   WRITE(6,848)I23,BET0(I23)
4484 FORMAT(5HSHX20EMBEDDED SHOCK TYPE = E11.3)
  WRITE(6,848)I23,BET0(I23)
4484 FORMAT(5HSHX20EMBEDDED SHOCK TYPE = E11.3)
  WRITE(6,233)I11,10X,7MBETA = +E11.3
233 FORMAT(10X,7MBETA = +E11.3)
4485 CONTINUE
VISW=VISD*VISW
WRITE(6,7222)VISW
7222 FORMAT(10X,11HVISCOSITY =E13.5,15H(LB*SEC/FT**2))
WRITE(6,5267)
5267 FORMAT(5HSHX3HPIT+,11X,1MY,12X,1M1,12X,1MH,12X,1MP,11X,2MTH,11X,
  1HPHI11X3HPIT++HGM9X5HPIT)
DO 70 I=1,NPTS
  P(I)=P0/PIN
70 FORMAT(5H0=P(I)/PIN
    P0=P(I)PRES*(GAMMA(I)+1.15*EM(I)**2)**GAMMA(I)/(GAMMA(I)-1.1)
    A*(2.*GAMMA(I)/GAMMA(I)+1.15*EM(I)**2-((GAMMA(I)-1.1)/GAMMA(I)+1.1)**(1/2))
    0.1-GAMMA(I))
    WRITE(6,112)I,Y(I),T(I),P(I),TH(I),EM(I),PHO(I),GAMMA(I),PITOT
    T(I),I=1,NPTS)
DO 71 I=1,NPTS
71 FORMAT(5HP(K)=P(I)/PIN
WRITE(6,150)
150 FORMAT(5H0=P(K)/PIN
  6HALP(1),7X,6HALP(2),7X,
26HALP(3),7X,6HALP(4),7X,6HALP(5),7X,6HALP(6),7X,6HALP(7),7X,3HPHI
2.1X,1HW)
WRITE(6,112) (I, (ALP(J), J=1,7), PHI(I), W(I), I=1,NPTS)

179 CONTINUE
   IF(KOUNT.GE.KKKK) GO TO 1572
   IF(TIII.EQ.1) GO TO 1572
   ALPHA=1.0
   BETA=0.0
   CALL STEPVIS(B)
   IF(TIII.EQ.1) GO TO 407
   IF(KOUNT.EQ.KFIPST.OR.I13.NE.1) GO TO 300
   CALL PUNCH
   DO 331 I=JSUBL,JSUBU
      Y(PRI(I))=Y(I)
      THPRI(I)=TH(I)
   CONTINUE
300 CONTINUE
   CALL CHEM(FAS)
8242 CONTINUE
   ICONT=0
   IEND=L
   K=1
   L=2
807 IF(L.GE.JSUBL.AND.L.LE.JSUBL) GO TO 956
888 K=L
   IF(L.EQ.NPTS) GOTO 612
   IF(L.EQ.JSUBL.AND.ICONT.EQ.1) GO TO 1622
   IF(BETB(1).EQ.0..AND.BETB(2).EQ.0..AND.BETB(3).EQ.0..AND.BETB(4).
      .EQ.0.) GO TO 777
   IF(BETB(1).GT.0. OR.BETB(3).GT.5.) 777
   777 IF(K.EQ.IS(2). OR.K.EQ.IS(4)) GO TO 8236
   IF(K.NE.IS(1)-1) 18231, 775
8231 IF(K.NE.IS(3)-1) GO TO 11
    775 MMM=1
    K=IS(1)
    KT=K
    GO TO 8232
11 IF(K.NE.IS(3)-1) GO TO 22
773 MMM=3
    K=IS(3)
    KT=K
    GO TO 8232
22 IF(K.NE.IS(2)) GO TO 33
    MMM=2
    GO TO 8232
33 IF(K.NE.IS(4)) GO TO 44
    MMM=4
    GO TO 8232
44 IF(K.EQ.IS(2)+1.OR.K.EQ.IS(4)+1) GO TO 8888, 8234
88888 K=K+1
   L=K
   KT=L-1
   GO TO 8234
8232 L=K
8230 IFS=1
   IPOI=1
   ALSV=ALPHA
   BESV=BETA
   IF (BET(1).EQ.0..AND.BET(2).EQ.0..AND.BETA(3).EQ.0..AND.BETA(4).EQ.0) GO TO 772
   IF (BET(1).GT.0..OR.BET(3).GT.0) GO TO 772
   KTSAV=KT
772 CALL CPOINT
   TMHE=THN(K)
   ALPHA=.5
   BET(1)=.5
   IF (BET(1).EQ.0..AND.BETA(2).EQ.0..AND.BETA(3).EQ.0..AND.BETA(4).EQ.0) GO TO 2194
   IF (BET(1).GT.0..OR.BET(3).GT.0) GO TO 2194
   K=KTSAV
215 CALL "POINT"
   IF (K .LT. 0) GO TO 2195
   WRITE(6,9191)
   WRITE(6,2196)
2196 FORMAT(4H ERROR IN CPOINT ITERATION FOR SHOCK IN CHAR)
   STOP
2195 ERTHD=ABS(TMHE-THN(K))
   IF (BET(1).EQ.0..AND.BET(2).EQ.0..AND.BETA(3).EQ.0..AND.BETA(4).EQ.0) GO TO 771
   IF (BET(1).GT.0..OR.BET(3).GT.0) GO TO 771
   KT=KTSAV
771 IF (ERTHD.GT.ETXX) GO TO 2194
   ALPHA=ALS
   BET(1)=BES
   IF (K.EQ.IS(2)) MMH=2
   IF (K.EQ.IS(4)) MMH=4
   IF (IFS=2)
      CALL MSHCCK(MMH)
   IFS=0
   K=K+1
   L=L+1
   GO TO 887
8234 CONTINUE
   IPOI=1
   ALSV=ALPHA
   BESV=BETA
CALL CPOIAT
KT=L-1
THDE=THN(K)
ALPHA=+.5
BETA=+.5

2621 CALL CPCIAT
KT=L-1
IPOI=IPOI+1
IF(IPOI.LT.20)GO TO 2A92
WRITE(6,9191)

9191 FORMAT(1H1)
WRITE(6,2197) K

2197 FORMAT(3H ERROR IN STANDARD CPOINT ITERATION IN CHAR AT POINT I2) STOP

2622 ERTHO=ABS(THDE-THN(K))
THDE=THN(K)
IF(ERTHO.GT.EXXX) GO TO 2631
ALPHA=ALSV
BETA=BEVS
C
*********************************************************************** INCREASE COUNTERS DO NEXT C POINT

902 CONTINUE
K=K+1
IF(L.EQ.NPTS) GO TO 7676
L=L+1
IF(ICCNT.EQ.1) GO TO 8A8
GO TO 8A7
C
NOZZLE WALL CALCULATION

612 CONTINUE
IPOI=1
ALSV=ALPHA
BEVS=BETA
CALL LPCIAT(NPTS,1.)
K=NPTS
THDE=THN(K)
IF(1) IPRESU.EQ.0) THDE=PN(K)
ALPHA=+.5
BETA=+.5

2607 CALL LPCIAT(NPTS,1.)
K=NPTS
IPOI=IPOI+1
IF(IPOI.LT.20)GO TO 2608
WRITE(6,9191)
WRITE(6,2198)

2198 FORMAT(3H ERROR IN NOZZLE WALL CALCULATION ITERATION IN CHAR) STOP

2608 ERTHO=ABS(THDE-THN(K))
IF(1) IPRESU.EQ.0) ERTHO=ABS(1.-THDE/PN(K))
THDE=THN(K)
IF(1) IPRESU.EQ.0) THDE=PN(K)
IF(ERTHD.GT.EXXX) GO TO 2607
ALPHA=ALSY
BETA=ESV
C COMPLETE FIRST POINT
7676 CONTINUE
IF(JSUBU.EQ.1) GO TO 1620
CALL LPCINT(1,0.)
K=1
IPOI=1
ALSY=ALPHA
BESV=BETA
THDE=THN(K)
IF(IPRESS.EQ.1.0.) THDE=PN(K)
ALPHA=.5
BETA=.5
2609 CALL LPCINT(1,0.)
K=1
IPOI=IPOI+1
IF(IPOI.LT.70) GO TO 2610
WRITE(6,9191)
WRITE(6,2199)
2199 FORMAT(39w ERROR IN FIRST POINT ITERATION IN CHAR)
STOP
2610 ERTHD=ABS(THDE-THN(K))
IF(IPRESS.EQ.1.0.) ERTHD=THDE-PN(K)
THDE=THN(K)
IF(IPRESS.EQ.0) THDE=PN(K)
IF(ERTHD.GT.EXXX) GO TO 2619
ALPHA=ALSY
BETA=ESV
C SUBSONIC PRESSURE ITERATION
1600 CONTINUE
IF(JSUBU.EQ.0) GO TO 1622
IF(IINCNT.EQ.1) GO TO 1622
IF(I113.NE.1.OR.KOUNT.NE.KFIRST) GO TO 1777
CALL DPDTH(THS,JSUBU)
CALL DPDTH(THSU,JSUBU+1)
CALL CPLTH(THSL,JSUBU-1)
CALL TMSS(TMSS)
AUP=Y(JSUBU)
BUP=TAN(TH(JSUBU))
IF(IREGI.NE.0.AND.JSUBU.EQ.J22) GO TO 6375
CUP=THS/COS(TH(JSUBU))**3
DUP=(THS**3*TAN(TH(JSUBU))*THS/THS)/COS(TH(JSUBU))**4
EUP=-4.095
GO TO 6376
6375 CONTINUE
CUP=0.
DUP=-1.

ORIGINAL PAGE OF POOR QUALITY
EUP=2.
0376 CONTINUE
DO 391 JSUB=JSUAV
381 CALL DPCTM(DISPRII(I)),I
1777 CONTINUE
CALL SSCANIG(TOG)
IF(ING.GT.2) GO TO 1622
I=1
IPUNCH=1
GO TO 677
1622 CONTINUE
IF(ISUB.EQ.0) GO TO 359
IF(JCCNV.EQ.1) GO TO 360
IF(EMN(I).EQ.KK0) GO TO 361
IF(NPTSM.EQ.0) NPTSM=NPTS
INPTS=1
REWINC=7
GO TO 363
360 NPTS=NPTSM
INPTS=2
359 DO 357 I=1,NPTS
II=NPTS-I+1
IF(EHII(I).GT.EMST) GO TO 357
IF(ISUB.GT.1) GO TO 355
ISUB=1
WRITE(*,354)
354 FORMAT(3H1) SUBSONIC REGION ENCOUNTERED
EMST=EMSUE
EMSUE=1.15
API=0
IREGI=0
GO TO 359
355 N=II+1
IF(IREGI.EQ.1) X=JSUAV
GO TO 359
357 CONTINUE
IREGI=2
GO TO 361
358 CONTINUE
IF(JCCNV.EQ.0) GO TO 1417
JCCNV=0
DO 1418 I=1,NPTS
II=NPTS-I+1
IF(EMN(I).GT.EMST) GO TO 1418
GO TO 1417
1418 CONTINUE
IREGI=2
II=0
EMSUE=EMST
K00=K00+1
ABCS=YN(I)
ABCD=YN(I)
BBOD=TAK(THN(I))
CROD=1.

GO TO 361
1417 CONTINUE
APC=PN(I)
AP2=(PN(I)-PN(I1)-AP1*(YN(K)-YN(I1)))/(YN(K)-YN(I1))**2
DO 356 I=1,K
PN(I)=APB+AP1*(YN(I1)-YN(I))*AP2*(YN(I1)-YN(I))**2
NCHN(I1)=GEM*WN(I)*PN(I)/TN(I)
IF (I.EQ.1) GO TO 356
XJ1=1.+XJ
I1=I-1
YFUN=(YN(I1)**XJ1-YN(I1)**XJ1)/XJ
YEF=(NCHN(I1)**XJ1)**COS(THN(I1))**NCHN(I1)**QN(I1)**COS(THN(I1))/Z.
YMASS(I1)**XMASS(I1)*YFUN*YFUN
356 CONTINUE
DS=2.*DFLX/(COS(TP(K))**COS(THN(K)))
PS=(PN(K)-P(K))/DS
GPM5=(GAM(K)**PN(K)**FMN(K)**2-GAM(K)**P(K)**FMN(K)**2)/DS
OS=2.*DFLX/(COS(TP(K))**COS(THN(K)))
361 CONTINUE
C COMPUTE SHEAR
WISE=WIS(XAPM)
CFF=3.
 CALL SHEAR2(CFF,WISE)
C *****************************************************/RESET ALPHA AND BETA
IF (IAME.EQ.0) GO TO 396
IF (BETAS.GT.1.5) GO TO 396
ALPHA=0.5
BETA=1.5
GO TO 8282
8396 CONTINUE
C ****************************************************STEP TAKEN OUTPUT
J22=J22L
CALL PSET
GO 1431 I=1+4
1431 BETAS=BETAN(I)
KOUN1=KCLNT+1
GO TO 6785
1572 IF (PUNCM>.EQ.0.0)) CALL EXIT
CALL PUNCH
CALL EXIT
END
SUBROUTINE EMBED
COMMON/ACIBOD,PIN
COMMON/ALGAR,GEM
COMMON/AX/JSJPL,JSJAU
COMMON/BX/ALP(7,55),EMINF,WINF
COMMON/CX/XMASS(55)
COMMON/DX/CP(7,55),CPX(55)
COMMON/EX/WTMOLE(7)
COMMON/ODY/BETA(4),IS14)
COMMON/ED/CP(NP,RC
COMMON/EF/EEM(55),GAM(55),P(55),TH(55),Y(55)
COMMON/EZ/GAMINF,H1(71),RINF
COMMON/GK/DSLY
COMMON/H/ALPHA,BETA
COMMON/HM/ALPN(7,55),CPN(7,55),CPYN(55),EMN(55),EMN(55),EMN(55),EMN(55),EMN(55),
COMMON/H/M/ALPN(7,55),CPN(7,55),CPYN(55),EMN(55),EMN(55),EMN(55),EMN(55),EMN(55),
COMMON/KF/RTAN(4),IFKFO
COMMON/LC/V(55),X(55)
COMMON/P/JCMEQ,MSP,T(55)
COMMON/QA/Q(7,55),A(55),RH(55),XMU(55)
COMMON/R/RCR(55)
COMMON/T/H/ALPN(7,55),CALC(55),DAH(55),DCP(55),DDALP(7,55),DTAU(55),
COMMON/HM/NPTS,RF,X,PH
DATA EPPRES,1,E=047
ITHETA=C.
PHETA=C.
ALPHA=1.
PET=0.
OELX=1.
DO 550 M=1,2
IF(I=I,GE,0) GO TO 500
IMPNTS=2
DO 1 I=2,IM
IF(I,GE,JSJAU,ANC,I,LT,JSJAU) GO TO 1
L=I
I=I-1
TI=1
J=I+2
T1=Y(I+1)-Y(I)
T11=Y(I-2)-Y(I)
T12=Y(I+1)-Y(I)
IF(I=TOL,LT=1,E=C4,OR.T11,LT=1,E=C4,OR.T12,LT=1,E=C4) GO TO 1
D=Y(II)+Y(I)
IF(MV2) GO TO 200
XP2=XOH1(ALPH,BET,YH(I+1),XMU(I+1),0,0,0,1)
XP1=XOH1(ALPH,BET,YH(I+1),XMU(I+1),0,0,0,1)
GO TO 201
CONTINUE
XP2=XOH1(ALPH,BET,YH(I+1),XMU(I+1),0,0,0,1)
XP1=YH1(ALPH,BET,YH(I+1),XMU(I+1),0,0,0,1)
201 DZLAM=XP1-XP2
    IF(DZLAM.LT.1.E-10) GO TO 1
    DT=2/CDZLAM
    IF(DI) 1,1,7
7   IF(GI.GT.10.*DELX) GO TO 1
    P1S=P(I1)+P(I1)
    P2S=P(I2)+P(I2)
    P3S=P(I3)+P(I3)
    P4S=P(I4)+P(I4)
    T1=P(I1)-P(I2)
    T2=P(I2)-P(I3)
    T3=P(I3)-P(I4)
    T4=P1S-P2S
    T5=P2S-P3S
    T6=P3S-P4S
    T7=P1S-P(I1)-P2S*P(I2)
    T8=P2S*P(I2)-P3S*P(I3)
    T9=P3S*P(I3)-P4S*P(I4)
    CALL SOLVE(T1,T2,T3,T4,T5,T6,T7,T8,T9,DT)
    CALL SOLVE(T1,T2,T3,T4,T5,T6,T7,T8,T9,DX)
    CALL SOLVE(T1,T2,T3,T4,T5,T6,T7,T8,T9,DO)
    G=DX/E
    C=DC/E
    D=DD/E
    A=1+P(I1)*(-B+P(I1)*(C-D*P(I1)))
    T=1.3
    CD=1./A
    VST=A*C*P*RE/D+2.*C*3*CD/D**2
    IF(VST.LT.EY(I1)) OR. YST.GE.Y(I1)) GO TO 1
    YSTP=P-C*C*RE/YD
    IF(VSTP.GE.EPRESS) GO TO 1
    IS(M)=I+1
    IF(M/2).GT.EQ.M) IS(M)=1
    XP5=XP1
    XP6=XP2
    GO TO 501
    1 CONTINUE
    GO TO 500

501 ISM=IS(M)
    BET0(M)=(ATAN(XP5)+ATAN(XP6))/2.
    WRITE(16,506)
    FORMAT(13L28X,19HEMBEDDED SHOCK TYPE I2/#13X,2HIS ,5X,4HRETA )
    WRITE(16,506) IS(M),BET9(M)
506 FORMAT(10X,IS,E11.2)
    L=1
    IF(M/2).LT.EQ.M) L=-1
    ISMM=ISM-L
    ISP=ISM+L
73

\[ \text{RAT} \left( \frac{(Y(I) - Y(ISP))}{(Y(ISM) - Y(ISP))} \right) \]
\[ X \text{ (ISM)} = X \text{ (ISP) + RAT(X)} \text{ (ISM) - X (ISP)} \]
\[ Y \text{ (ISM)} = Y \text{ (ISP) + RAT(Y)} \text{ (ISM) - Y (ISP)} \]
\[ Q \text{ (ISM)} = Q \text{ (ISP) + RAT(Q)} \text{ (ISM) - Q (ISP)} \]
\[ P \text{ (ISM)} = P \text{ (ISP) + RAT(P)} \text{ (ISM) - P (ISP)} \]
\[ T \text{ (ISM)} = T \text{ (ISP) + RAT(T)} \text{ (ISM) - T (ISP)} \]
\[ TH \text{ (ISM)} = TH \text{ (ISP) + RAT(TH)} \text{ (ISM) - TH (ISP)} \]
\[ AQ \text{ (ISM)} = AQ \text{ (ISP) + RAT(AQ)} \text{ (ISM) - AQ (ISP)} \]
\[ TAU \text{ (ISM)} = TAU \text{ (ISP) + RAT(TAU)} \text{ (ISM) - TAU (ISP)} \]
\[ LQ \text{ (ISM)} = LQ \text{ (ISP) + RAT(LQ)} \text{ (ISM) - LQ (ISP)} \]
\[ DCX(N \text{ (ISM)} = DCX \text{ (ISP) + RAT(DCX)} \text{ (ISM) - DCX (ISP)} \]
\[ DTAU \text{ (ISM)} = DTAU \text{ (ISP) + RAT(DTAU)} \text{ (ISM) - DTAU (ISP)} \]
\[ XMAS \text{ (ISP)} = XMAS \text{ (ISM) + RAT(XMAS) (ISM) - XMAS (ISP)} \]
\[ CPX(ISM) = 0, \]
\[ WI(ISM) = C \]

CALL THERMO(1(ISM),1,CP1)

DO 100 KI=1,NISP

JI=KI

ALP(KI,ISM)=ALP(KI,ISM)+RAT(ALP(KI,ISM)-ALP(KI,ISM))

DALP(KI,ISM)=DALP(KI,ISM)+RAT(DALP(KI,ISM)-DALP(KI,ISM))

DDALP(KI,ISM)=DDALP(KI,ISM)+RAT(DDALP(KI,ISM)-DDALP(KI,ISM))

\[ H(JI,ISM) = H(JI) \]

CP(JI,ISM)=CP(JI,ISM)

WI(ISM)=ALP(JI,ISM)-WETWOLE(JI)

CPX(ISM)=CPX(ISM)+ALP(JI,ISM)*GPM(JI,ISM)

H(JI,ISM)=H(JI,ISM)

ALNF(KI,ISM)+ALP(KI,ISM)

100 CONTINUE

WI(ISM)=1/WI(ISM)

RISM=R(C/R(ISM))

GAM(ISM)=CPX(ISM)/R(IISM)*GPM

RHI(ISM)=R(ISM)*W(IISM)*GEM(T(IISM))

R1=1/R(IISM)

EM(IISM)=G(IISM)*EMINF*SQR(T(GAM*GAM(ISM)*RI*T(IISM))

XUL(IISM)=XUL(IISM)

Q NI(ISP)=Q (ISM)

R NI(ISP)=0 (ISM)

T NI(ISP)=T (ISM)

P NI(ISP)=P (ISM)

W NI(ISP)=W (ISM)

TH NI(ISP)=TH (ISM)

RHO NI(ISM)=RHO (ISM)

GAM NI(ISP)=GAM(ISP)

IF (JSUBL.GT.ISSM)) JSUBL=JSUBL+1

IF (JSUBU.GT.ISM)) JSUBU=JSUBU+1

DO 101 KK=1,4

IF (IS(KK).GT.ISM)) IS(KK)=IS(KK)+1

101 CONTINUE

IEMBED=1

ORIGINAL PAGE IS OF POOR QUALITY
CALL HSHOCK(K)
IEMBED=1
X(ISM)=X(ISM)
Y(ISM)=Y(ISM)
XMAX(ISM)=XMAX(ISM)
W(ISM)=W(ISM)
P(ISM)=P(ISM)
Q(ISM)=Q(ISM)
T(ISM)=T(ISM)
D(ISM)=D(ISM)
TH(ISM)=TH(ISM)
EM(ISM)=EM(ISM)
RM(ISM)=RM(ISM)
CPX(ISM)=CPX(ISM)
GM(ISM)=GM(ISM)
XMUT(ISM)=XMUT(ISM)
DO 1313 K=1,5
P(KL,ISM)=P(KL,ISM)
CP(KL,ISM)=CP(KL,ISM)
ALPHA(KL,ISM)=ALPHA(KL,ISM)
CONTINUE
1313 CONTINUE
NR=0.
RE=0.
XEP=0.
CALL SHEAL(K=0.)
CONTINUE
END
SUBROUTINE SOLVE(A11,A12,A13,A21,A22,A23,A31,A32,A33,DEL)
DEL=A11*A22*A33-A12*A21*A33-A13*A23*A31+A13*A21*A32-A22*A31
END
SUBROUTINE HSHOCK(K)
COMMON/AL,GAM,GEN
COMMON/BBY,_P(7,55),EMINF,INF
COMMON/EBY,S14,S2A,STAT
COMMON/RCH,TH,MB,XX,Y
COMMON/CJ/COON(7,55),XM(55)
COMMON/CJ/CP(7,55),CPK(7),CPX(55)
COMMON/DB/DE(4),IS14
COMMON/LP/PN(55)
COMMON/CP/CPIN,RO
COMMON/EF/EM(55),GM(55),P(55),TH(55),Y(55)
COMMON/EG/EGP,PRE,PK
COMMON/EF/GAMINF,PI(47),RINF
COMMON/EF/DEF
COMMON/CG/DEL
COMMON/ML/ALPHA,BETA
COMMON/HH/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
ILS(55),QRN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
COMMON/HQ/BE(14),MM9E(1)
COMMON/FQ/JCHEM,NSP,T(55)
COMMON/FA/HT(7,55),Q(55),PM(55),XHU(55)
COMMON/HS/RHOP(2),ROHT(7,55),WDOTC(17),WMP(2),XHUP(2)
COMMON/SC/BN(55),DALPN(7,55),DBQN(55),DQPN(55),DUPNP(1)
COMMON/SM/TAUN(55),TAUN(55)
COMMON/SI/I3,IREI,KS,KFIRST,KKQ,PSTAR
COMMON/TS/OVISB,CVISC,IFS,MMS,VISB,VISC
COMMON/TV/BQ(55),JALP(7,55),DBQ(55),DQPN(55),DUPNP(1),QT(55)
COMMON/TU/TAU(55)
COMMON/TV/ALPP(7,2),PF1,RO(2),OACHP(7,2),DALPP(7,2),DBQ(2),
10CPX(2),DUPNP(1),DUPNP(2),OTUNP(2),DTCMP(2),GMP(2),PP(2),PP(2),
2TAUNP(2),THUP(2),IT(2),YP(2)
COMMON/VV/CONT,E(N0,KT,THBP,N)
DIMENSION DUMM(7)
I=IS(K)
I=I+1
BET=QETB(Q)
I1=1
XXX=1
ICCC=0
I=1
IF(K/2) NE.K L=-1
M=IS(K) L
IF(BETA,NE.0.1) GO TO P210
TAUNP(1)=TAU(M)
BQNM(1)=BQN(M)
DQPN(1)=DQPN(M)
DBNQ(1)=DBNQ(M)
CPXN(1)=CPXN(M)
DO 212 J=1,NSP
DALPN(J,M)=DALP(J,M)
212 CONTINUE
211 CONTINUE
210 CONTINUE
IF(BET.EQ.0.1) BETA=QETB(Q)
4 IT=1
CA=0
SA=0
VT=QN(I) *COS(BET-THN(I))
UI=QN(I) *CA*SIN(BET-THN(I))
UI=RAOS(1)
XMS=RHON(I) *U1
GN=GAMM(I)
GP1=GN+1.
GM1=GN-1.
RNI=I/RNI(I)
XM1=U1**2*CMINF**2*(GAM/GAMM(I)*RNI/TN(I))
XM=1./XM1
IF(IT.EQ.1)U2=U1*(GM1*XMI+2.)/GP1*OM
5 RH2P=XMS/L2
P2H=XMS*(U1-U2)+PN(I)
V2=VT*2
V1=V2+U1*2
V2=V2+U2*2
H6=0.
DO 1400 J=1,NSP
1400 H6=H6+(I-1)*ALPM(J,I)+H6
H2=H6*(V1-V21/2.*EIN
I11=1
T1=TN(I)
IF(I11.EQ.1)T2=T1(12.*GM1*XMI-GP1)*(GM1*XMI+2.)/(2.*GP1)*OM
IF(T2.EQ.T1)GO TO 8250
CALL THERMO(T2,H1,GP1)
H2P=0.
DO 9251 J=1,NSP
9251 H2P=H2P+ALPM(J,1)*H11(J)
ERR1=H2P-HEP/HE
IF(ALPM(I,J).LT.1.E-08) GO TO 8252
I11=I11+1
IF(I11.GT.15) GO TO 8253
IF(I11.GT.2) GO TO 8204
ERR2=ERR1
T22=T2
T2=T2+1.01
GO TO 8255
8253 WRITE(6,9191)
9191 FORMAT(151)
WRITE(G,E205)
8255 FORMAT(* ERROR IN TEMPERATURE LOOP IN HSHOCK*)
STOP
9254 DUM=T22-ERR2*(T2-T22)/ERR1-ERR2
ERR2=ERR1
T22=T2
T2=DUM
GO TO 8260
8260 CONTINUE
QM2=P2H*W1(M1)*GMF/T2
ER=ER+2.*RH2P/RMD(I)
IF(ABS(ER).LT.1.E-9)GO TO 7
IT=IT+1
IF(IT.GT.15)GO TO 190
IF(I.T.GE.2)GO TO 5
E(2)=EP
U(2)=U2
V(2)=U2*SG
GO TO 5
100 WRITE(6,9191)
WRITE(6,200)
200 FORMAT(1X,'ERROR IN MUGNIOOL LOOP IN MSHOCK')
STOP
6 DUM=U22-ER2*U2-U221/1(EP-ER2)
ER2=ER
U2=U2
V2=DUM
GO TO 5
7 CONTINUE
CB=DCS(BET)
SR=SIN(BET)
IF(KK/2.*EQ.0.1)U2=-U2
Q=U2*CA
U=VT+CA-0.2*CA
V=T+CA*0.2*CA
P=2.ATAN(MU/MV)
Q=SQRT(UV*UV+MV*MV)
IF(IIFMBC.EQ.1)GC TO 7535
YM(C)=YH1+*5*(TAN(BET(1)) TAN(BET(2)))*DCL
DEL=1.
IF(BET(1).LE.90...AND.BET(1).EQ.C..AND.BET(2).EQ.D...AND.BET(4).EQ.E..AND.BET(9).EQ.F.
EQ.G.)GC TO 777
IF(BET(1).GT.0...AND.BET(3).EQ.G..AND.BET(4).EQ.H..AND.BET(9).EQ.I..AND.BET(10).EQ.J.)
777 CALL LPOINT(M+1.,C.)
GO TO 775
776 IF(M=MN/2.EQ.MM)CALL LPOINT(M,C.)
775 DEL=.
SIA=0.
S24=C.
S34=C.
GAMB=GAMF(1)
PB=PP(1)
GQ=QP(1)
RHQ=PHQ(1)
TMA=TMP(1)
WR=WP(1)
XMU*XMP(1)
YH=VP(1)
A1=F1(P)
A2=F2(M,SIA,S24,S34)
IF(JCHM.EQ.1)GO TO 7254
A3=0.
GO TO 7257
7254 TP= (TP1 + TP2) / 2.
DTCHP(1) = DTCHP(1) / 2.
DO 1552 J=1,NSP
1552 DUMM(J) = CAHP(J, 1) / 2.
A3 = F3 (TP1, DTCHP(1), TP(1), T2, TP(1), PHE2, DUMM, HPA(1), WN(M))
7257 CONTINUE
OPT = 1.
IF (K / 2) * 2. EQ. X) OPT = 1.
A4 = F4 (BETA, OPT, XMUP(1), THP(1), XMUN(M), TP(N(M)))
A2 = (A2 + A3) * A4
PSH = PPH(1) * OPT * (PH2-THP1) - A2 * DELX / A1
ER3 = (PSH - P2M) / P1M)
IF (ABS(ER3), LT, 1, E-31) GO TO 19
IT1 = IT1 + 1
IF (IT1 GT 15) GO TO 1C1
IT1 = IT1 + 1
IF (IT1 EQ. 2) GO TO 1430
IF (ER1 EQ. ER3, LT, 1, E-06) GO TO 1492
IF (ABS(ER1), GT, ABS(ER3)) GO TO 1430
IF (ICCC EQ. 1) GO TO 103
XXX = -1.
ICCC = 1
IT1 = IT1 - 1
1430 ER1 = ER3
ET1 = BET
ET = BET + .01 * (IT1 - 1) * BET * XXX
GO TO 15
1492 BET2 = (BET - BET1) * 20.
EP1 = ER3
BET1 = BET
BET = BET + BET2
GO TO 15
113 WRITE (6, 9191)
WRITE (6, 220)
220 FORMAT (*) ERROR IN SHOCK ANGLE IN HSHOCK*)
STOP
14 DUN = BET1-ER1 * (BET - BET1) / (ER3-ER1)
ER1 = ER3
ET1 = BET
BET = DUN
15 YN(M) = Y(M) + .5 * (TAN(RET1(K)) + TAN(BET1)) * DX
IS = IS(K)
YN = .5)
KS = IS(K)
LS = KS
KT = KT + 1
IF (KT EQ. 2 OR KT EQ. 4) KT = KT + 1
CALL CPOINT
GO TO 4
19 BETAN(K) = BE
  YN(M) = .5*(TAN(BETAN(K)) + TAN(5ETAN(K)))*DELX*Y(M)
  TS = TS(K)
  YN(55) = YN(M)

3535 CONTINUE
  FN(M) = Z2H
  QN(M) = Q2
  THN(M) = RHE2
  RHOM(M) = RHE2
  TH(M) = T2
  RN(M) = RC/THN(M)
  CPXN(M) = 3.
  DO 1451 J = 1, VS
     HN(J,M) = H1(J)
     CPN(J,M) = CP1(J)
  CPXN(M) = CPXN(M) + ALPH(N,J,M)*CPN(J,M)
  GAM(M) = (FXN(M))/(|CPXN(M) - RN(M)/CPN)
  QN(M) = 1./QH(M)
  CPN(M) = QH(M)*EPINF*SCRT(GAR/CAMN(M)*GRT/THN(M))
  IF (EM(M) .LT. 1.0G11) GO TO 1462
  YMUN(M) = ZMP/EMN(M)

1451 CONTINUE
  RETURN
END

SUBROUTINE SWITCH(J, K)
COMMON/B/A/ALP(7,55), EINF, WINF
COMMON/BE/XMASS(55)
COMMON/CJ,CP(7,55), CP(7), CPX(55)
COMMON/EK/EM(55), GAM(55), P(55), TH(55), Y(55)
COMMON/EX/WM(55), X(55)
COMMON/PS/JCHEM, NSP, T(55)
COMMON/QD, H(7,55), Q(55), RHO(55), XMU(55)
COMMON/RH/Y(55)
COMMON/TV/8Q(55), CALP(7,55), 08Q(55), QCPX(55), ODALP(7,55), OTA(55),
1TAU(55)
  X (J) = Y (K)
  Y (J) = Y (K)
  D (J) = D (K)
  P (J) = P (K)
  T (J) = T (K)
  W (J) = W (K)
  R (J) = R (K)
  EM (J) = EM (K)
  TN (J) = TH (K)
  8Q (J) = 8Q (K)
  TAU (J) = TAU (K)
  DBQ (J) = DBQ (K)
  GAM (J) = GAM (K)
RHC (J) = RMX (K)
XMU (J) = XMX (K)
CPX (J) = CPX (K)
DCPX (J) = DCPX (K)
DTAU (J) = DTAU (K)
XMASK (J) = XMASK (K)
DC 108 JJJ = L
H (JJJ,K) = H (JJJ,K)
CP (JJJ,K) = CP (JJJ,K)
ALP (JJJ,K) = ALP (JJJ,K)
DALP (JJJ,K) = DALP (JJJ,K)
DALP (JJJ,K) = DALP (JJJ,K)
IF B CONTINUE
RETURN
END
SUBROUTINE PM (P, K, IFAN, KOPT, KCP)
COMMON/AL (LP, 55), CP (LP, 55)
COMMON/GL (LP, 55), CP (LP, 55)
COMMON/CPX, X (LP, 55)
COMMON/CP, PP, XLE
COMMON/CPX, XLE
COMMON/P, NN, NN
COMMON/CC, CP, X, X
COMMON/CC, CP, X
COMMON/RC, X (55)
COMMON/R, X (55)
II = L
Q = A (I) / F (III) / FLOAT (IFAN - 1)
IF E = FAN
II = 0.
DO 2 JJ = 1, MPS
H6 = H6 + H (JJ, M) * ALP (JJ, K)
DO 11 LL = 1, NFF
N = LL - 14
IF (IY / 2) / 2. EQ. K X = N - LL + 1
K = N + 1
II = K
YY (II) = Y (K)
P (II) = P (K) / EXP (CP)
ALMR = G (P, GAM (K))
RHO (II) = R (II) / EXP (ALMR)
S = 2. * GAM (K) / GAM (K) - 1.
Q = G (P) / RHO (II) - P (K) / RHO (K)
Q (II) = S (II) / (Q (II) + QQ)
QQ (II) = QQ (II)
H2 = H2 + QQ / 2. * EIN
III = 1
IIII = 1
T1=T(K,K)
IF(T1.EQ.1) T2=T1-.99
8260 CALL THE' (T2,H1,CP1)
H2P=D.
DO 4 J=1,Nsp
   ALP(J,N)=ALP(J,KK)
4 H2P=H2P+ALP(J,N)*H1(J)
ERPI=(H2-H2P)/H6
IF(ABS(ERPI).LT.1.E-08) GO TO 8202
III=III+1
IF(III.GT.15) GO TO 8263
IF(III.GT.2) GO TO 8204
ERR2=ERR1
T2=T2-
T2=T2*.99
GO TO 8260
8203 WRITE(6,9191)
9191 FORMAT(1,H1)
WRITE(6,8205)
8205 FORMAT(* ERROR IN TEMPERATURE LCCC IN PK*)
STOP
8204 DUM=T2-ERR2*(T2-T22)/(ERR1-ERR2)
   ERR2=ERR1
   T22=T2
   T2=DUM
GO TO 8209
8209 CONTINUE
T(N)=T2
M(N)=G.
CPX(N)=0.
DO 5 J=1,Nsp
   CP(J,N)=CP1(J)
5 H(J,N)=H1(J)
   CPX(N)=CPX(N)+ALP(J,N)*CP1(J)
   M(N)=M(N)+ALP(J,N)/MTMOLE(N)
   W(N)=1./M(N)
   R(N)=RG/M(N)
   GAMN=CPX(N)/(CPX(N)-R(N)/CP1)
   ORN=1./R(N)
   EMN=Q(N)/EMINF*SQRT(GAMN*ORN/T(N))
   XM(N)=2*UM1EM(N)
   TH(N)=TH(KK)-OPT*ALMP(1)*COS(XMU*X)+SIN(XMU*KK)+COS(XMUIN))**SI
   IN(XM(N,1))**.5
   M6=M2
1 CONTINUE
RETURN
END
SUBROUTINE CHEMFA3
COMMON/BA/ALP(17,55),WINF,WINF
COMMON/CA/WDOTN(7,55),XN(55)
COMMON/CB/ETB(4),IS(4)
COMMON/CP/YN(55)
COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
COMMON/H/DALCH(:,),NTCHEM
COMMON/HP/ALPER(7),PHI(55)
COMMON/PC/PN(55),X(55)
COMMON/PJ/CHEM,NVP,1(55)
COMMON/QB/VT(7,55),Q(55),XQHO(55),XQUN(55)
COMMON/QS/MOP(2),WDOT(7,55),WDOTC(7),WPI(2),XMUP(2)
COMMON/VT/DACH(7,55),OTCH(55),QVISO,VI50
COMMON/XV/NPTS,RE,XP,XJ
COMMON/YZ/ARRAY,CHEMCFG,CPRESU,EMSUB,RTS,XSIFP
IF(JCHEM.EQ.0) GO TO 9551
****** CHEMISTRY PACKAGE **********
DO 9355 L=1,NPTS
DO 99 M=1,4
IF(IST(M).LT.0) GO TO 99
IF(LT(LT(L=1))).GO TO 99
IF(1+M)/2-2.0 L=1,4,4,1 ITEST=IIS(M)
IF(L.EQ.ITEST.OR,L.EQ.ITEST+1) GO TO A398
A9 CONTINUE
FAT=ABS(PHI(I))
IF(1+M.LT.2).OR.(FAT.GT.100.0) GO TO 8399
D(L)=SQRT((YNS(L)-X(K))**2+2*(YNS(L)-Y(K))**2)*RTM
DO 8350 J=1,NSP
M=ALPER(J)
CALL HODOT(TK1,P(K),Q(K),PHO(K),ALP9,NX,L)
A381 J=1,NSP
A381 DACH(J,L)=DALCH(J)
OTCH(L)=CTCHEM
GO TO 8355
A398 DICH(L)=0.
DO 8399 J=1,NSP
WDOT(J,L)=0.
WDOTN(J,L)=0.
A399 DACH(J,L)=0.
A355 CONTINUE
GO TO 4000
A351 DC 6100 L=1,NPTS
DICH(L)=0.
DO 8352 J=1,NSP
WDOT(J,L)=0.
WDOTN(J,L)=0.
A352 DACH(J,L)=0.
6100 CONTINUE
4000 CONTINUE
RETURN
END
SUBROUTINE SHAKE(I,ASHEAR)
COMMON/CJ,CA(1755),CP(1755),CPX(155)
COMMON/CF,KMOLE(17)
COMMON/ET,EM(155),EA(155),PHI(155),TH(155),Y(155)
COMMON/GK,DEL
COMMON/PEW(155),X(155)
COMMON/EG,JN=G,ASP,T(155)
COMMON/DA/H,7.733,1.0(155),DESC(155),X/MU(155)
COMMON/SS,AL1,AL2/012,RA02,GA02,CH1,CH2,081,DP2,031,032,DT1,DT2,DV
A1,DV2,PF1,FP2,T4,T2,T1,TH2,V1,V2,Y2,TAU
COMMON/MM,IEL,IEX1,X,1ST,KK0,PS1,PP
COMMON/T0/0.7,1.55,0.75,0.55,0.75,0.55,0.75,0.55,0.75,1.55,0.75
COMMON/TVIT,DT(1755),OTM(155),OTC(155),OTD(155),MDM(155)
COMMON/TVV/YVIS,Y,RH,KG
COMMON/VJ/VIS1,V2,RE*V8,YJ
DIMENSION S3D(17)
K=1
V1=V2=VIS
VIS=VIS
T41=TA2=TAU(K)
OT1=OT2=OTAU(K)
Y1=Y2=YG(K)
X1=X2=TH(K)
S1=51(XJ,RE)
CH2=1.
DO 10 J=1,N
10 CH2=CH2*DALP(J,K)*CP(J,K)
B1=BC2=EG(K)
C1=G2=CPX(K)
DB1=DE2=DQ0(K)
PF1=PF2=DPX(K)
CM1=CP2=CH2D
S20=SZ(XJ,RE)
SJD=J
DO 20 J=1,N
20 AL2=AL2+DALP(J,K)
DOI=D2C=DALP(J,K)
S3D(J)=S1(XJ,RE)
26 S3D=T3ET+S3E(J)/MTMOLF(J)
PK=1./PK
SH1=SH1/GAM(K)*PK/YKK**2
SH2=SH2/GAM(K)*L*SH2*GA*PK**K
SH3=SH3/W+PK*SH3/K
IF(JJ,EG,(G)) SH4=0.
IF(JJ,EG,(K)) GO TO 40
SH4=SH4+1.
GO TO 30
SH4=TH2/YK(2)

ORIGINAL PAGE IS
OF POOR QUALITY
GO TO 40
30 SH4 = SIN(TH(K)) / Y(K)
40 CONTINUE
   OD = 1 / DELX
   SM = -DTCK(K) / T(K) * OD * COS(TH(K))
   DUM = 0.
   DO 50 J = 1, NYP
   50 DUM = DUM + DM(J) / XMOL(J)
   SM = W4(2) * DUM / DELX * COS(TH(K))
   SH = SH1 + SH2 + SH3 + SH4 + SH5 + SH6
   ASHEAR = -GAM(K) * P(K) * EM(K)**2 * SH
   RETURN
END
SUBROUTINE PRESS(K, P, TH, TMN)
COMMON/AC/I900, P
COMMON/WY, APRESS, APRESU
COMMON/WY/ABODS, EPRESS, DPRESS
P = APRESS + X*(BPRESS + CPRESS*X)
RETURN
END
FUNCTION VIS(4)
COMMON/VB/ALP(7, 55), EMINF, WINF
COMMON/DB/BET8(4), IS(4)
COMMON/FV/XK1, XK3, XPOT
COMMON/JQ/M(7, 55), Q(55), RH(55), XM(55)
COMMON/WV/PMTS, RE, XBP, XJ
DATA IVIS, ID, IDM = 1
IDM = 1
IF(IS(1) .LT. 0) IDD = IS(4) + 1
IF(IS(3) .GT. 0) IDM = IS(3) - 1
DUM = 0.
RU = RH0(1) * IDD
IF(I = 10) IDM = 1
IF(I = 10) IDM = 1
DUM = ABS(1 + (1 - C4) / RU)
IF(I = -LT, DUM = 1) GO TO 10
DUM = DUM
10 CONTINUE
IF(ALP(4, 1) .GT. 99) GO TO 30
IF(ALP(4, 1) .LT. 1, E-39, ANC, XBP, LT, XPOT) GO TO 30
IF(VIS, EQ, 1) VIS1 = XX1 * RE * XBP * DUM * XX3
IF(VIS, EQ, 0) IMPTI(E, 0, 1, 9696) XBP, VIS1
9696 FORMAT(12H VISCOSITY MODEL SWITCHED AT X = 0.3, 144, VISCOSITY = ,
1F15.5)
VIS1 = 1
XVIS=XVIS1
GO TO 45
30 CONTINUE
XVIS/XK1*RF*XBP*UM1*XK3
40 CONTINUE
RETURN
END
SUBROUTINE COWL
COMMON/BA/ALP(7,55),EMINF,MM#
COMMON/CJ/CP(7,55),CP1(7),CPX(55)
COMMON/OB/BE(4),I3(4)
COMMON/OE/MM
COMMON/EF/E(55),P(55),T(55),Y(55)
COMMON/HJ/KOUNT,LZ,NPT
COMMON/HL/ALPHA,BETA
COMMON/HP/ALPH(55),CPN(7,55),CPXN(55),EMN(55),THM(55),WM(55),XMUN(55)
COMMON/HP/RE(55),(55),RN(55),THN(55),TMN(55),WMN(55),XMUN(55)
COMMON/HP/RETA(4),IEMB:0
COMMON/HE/EM(55),X(55)
COMMON/HC/CSME=,NSP,1(55)
COMMON/HI/CSCH=,RHO(55),PUN(55)
COMMON/HR/CM(55),CM(55),EM(55),THM(55),WM(55),XMUN(55)
COMMON/HT/BO(55),DALP(7,55),DCP(55),DCP X(55),DDALP(7,55),DTA(55),
ITAU(55)
COMMON/W/NPTS,RF,XBP,XJ
ALPHA=1.
BETA=6.
NPTSS=NFT
NPT=NPT-3
2002 WRITE(6,9191)
9191 FORMAT(1H1)
WRITE(6,2004)
2004 FORMAT(1H1,"F7.7 ERR? IN INPUT DATA - NO PRESSURE DIFFERENCE ACROSS 
SPLITTER PLATE/23H SET INPUT - INTACT = 0")
STOP
2003 CPT=1.
K=4
IS(K)=NPTSS-1
L=IS(K)
M=LM+MM
GO TO 2005
2005 CPT=-1.
K=3
IS(K)=NPT+MM
M=NPT
L=LM+MP
2005 IFAN=MM-2
KOPT=CPT*145
N13=NPTS*SS-2*K+1
IF(KK) .EQ. K .AND. N13>=NPTS
GO TO 30
K5=NPTS-K+1-N12
J5=K5+1
CALL SWITCH(JF,K5)
300 CONTINUE
NPTS=NPTS+1
DO 311 I11=1,4
IF(I11.EQ.K) GO TO 311
IF(I11.GT.K) I11=I11-1
311 CONTINUE
LL=LL+1
TAU(LL)=0.
PN(L)L=PL(L)
WN(L)L=1/(LL)
N(L)L=(LL)
T(L)L=TT(L)
R(L)L=RR(L)
PHON(L)L=RH02(L)
GAMA(L)L=GAMN(L)
AQ(LL)L=0.
CPX1(L,L)L=0.
DTAU(LL)L=0.
DBO(LL)L=0.
CPX(L,L)L=0.
WN(L,L)=1
DC 2956 J1+1,NSP
MNEJ,LL=M11,L1
DLP(J1,LL)=0.
DDALP(J1,LL)=0.
2856 ALP(J1+1)=ALP(J1)
ITT=1
PET=PET-(TM(L)+OPT*XU(L1)*1.71
8100 BE=E8(K)
20.7 IE=IE+1
CALL SMCK(K,E)
IE=IE+1
KK=LL+KCFP
P(LL)=P N(L,L)
Q(LL)=Q N(L,L)
T(LL)=T N(L,L)
W(LL)=W N(L,L)
R(LL)=R N(L,L)
TH(LL)=TH N(L,L)
EM(LL)=EM N(L,L)
XMUL(L,L)=XMULN(L,L)
GAM(L,L)=GAMNL(L,L)
RH01(L,L)=RH01N(L,L)
CPX(LLL)=CPXN(LLL)
P (KK)=F N(LLL)
Q (KK)=C N(LLL)
T (KK)=T N(LLL)
W (KK)=W N(LLL)
R (KK)=R N(LLL)
TH (KK)=TH N(LLL)
EM (KK)=EM N(LLL)
WNU(KK)=WNUN(LLL)
GM(KK)=GNMN(LLL)
RHO(KK)=RMON(LLL)
CPX(KK)=CPXN(LLL)
DO 200J=1,NSP
H (J,LL)=H N(J,LL)
CP (J,LL)=CP N(J,LL)
ALP(J,LL)=ALPN(J,LL)
2008 ALP(J,K)=ALPN(J,LL)
X(LL)=X(L)
X(KK)=X(L)
THS=TH(KK)
CALL PH(X,L,IFAN,K,CP,SNM)
IF (K/2) .EQ. N .AND. IFAN .LE. IFAN+1
TPHN=TH(NNN)
ERR=THS-TPHN
IF (ABS(EE1-LT.1.E-06) .LE. 15
IT=IT+1
IF (IT.GT.15) GO TO 12
IF (IT.GT.29) GO TO 14
ERR=ERR
BET1=BET
BET2=BET1*AM1+1
BETB(K)=BET
GOTO 290
10? WRITE(6,203)
203 FORMAT(* ERROR IN BETA SHOCK IN CHNL*)
CALL EXIT
14 SUM=ERR1*ERR1*ERR1*ERR1*ERR1
BET=SUM
BET1=BET
BETB(K)=BET
GOTO 290
15 CONTINUE
RETURN
END
SUBROUTINE DPOINT(K,' ')

COMMON/V/A,N/GEN
COMMON/OL/BL,ALP(7,55),EMINF,WINF
COMMON/OL/BL,CPX(55)
COMMON/K1/CX,T(7,55),CPX(17),CPX(55)
COMMON/QY/VN(55)
COMMON/EY,EM(55),GAM(55),P(55),TH(55),Y(55)
COMMON/EY,GAMINF,H1(7),PINF
COMMON/GK/DLX
COMMON/PG/W(55),X(55)
COMMON/PG/JCHEN,K,NSP,T(55)
COMMON/GA/H1(7,55),Q(55),PHO(55),XMU(55)
COMMON/YU/BO(55),DALP(7,55),DQP(55),DCPX(55),DOALP(7,55),DQAU(55),
1TAU(55)
COMMON/V/ALPP(7,2),RET,ROP(2),DAGHP(7,2),DALPP(7,2),DBQP(2),
1'PXP(2)',DALP(7,2),DTAUP(2),CTCHP(2),GAM(2),PP(2),QP(2),
2'AUP(2),TP(2),TP(2),YP(2)
COMMON/V/T/DAH(7,55),DTCH(55),DVISD,VISD
IT=1
16 RAT=(YD-YF(1))/YP(2)-YP(1)
ALAM=ABS(TAN(THP(1)))+RAT*(TAN(THP(2))-TAN(THP(1))
YAT=YN(1)-ALAM*DELX
ERR=ABS(YAT-YD)/YP(2)-YP(1))
IF(ERR.LE.0.05) GO TO 18
YD=YAT
IT=IT+1
IF(IT.LE.10) GO TO 16
WRITE(E,9191)
9191 FORMAT(1H1)
WRITE(E,202)
STOP
18 YDK1=YD
P(K)=P(1)+RAT*(P(2)-P(1))
Q(K)=Q(1)+RAT*(Q(2)-Q(1))
T(K)=T(1)+RAT*(T(2)-T(1))
TH(K)=TH(1)+RAT*(TH(2)-TH(1))
B(K)=B(1)+RAT*(B(2)-B(1))
TAU(K)=TAU(1)+RAT*(TAU(2)-TAU(1))
DCPX(K)=DCPX(1)+RAT*(DCPX(2)-DCPX(1))
DQAU(K)=DQAU(1)+RAT*(DQAU(2)-DQAU(1))
DTCH(K)=DTCH(1)+RAT*(DTCH(2)-DTCH(1))
CPX(K)=0.
WRITE(E,2)
CALL THERMOT(K),H1,CPX
DO 1 J=1,NSP
H(J,K)=H(J)
1
IF (EM(I).GT.EMSUB) GO TO 910
JSUBL=1
ISUB=1
GO TO 806

910 CONTINUE
GO TO 806

806 CONTINUE
DO 902 I=1,NPTS
II=NPTS+I+1
IF (EM(II).GT.EMSUB) GO TO 902
JSUBL=II+1
GO TO 881

902 CONTINUE

801 CONTINUE
IF (ISUB.EQ.0) GO TO 10
II=1
KFIRST=KCUNT
10 CONTINUE

JDUM=JSUBL-1
NP2=NPTS-1
DO 499 K=1,NP2
DEY=Y(K+1)-Y(K)
IF (DEY.LT.1.E-08) GO TO 499
IF (K.GE.JSUBL AND K.LT.JDUM) GO TO 498
EM1=XM1(I+0...+TH(K),XMU(K),G0..)
EM2=XM2(I+0...+TH(K+1),XMU(K+1),J..1)
DELX(K)=1.*TH(K)/((EM1-EM2)
IF (BET(11).EQ.0..AND.BET(12).EQ.0..AND.BET(3).EQ.0..AND.BET(4)) AEQ.0.) GO TO 499
IF (BET(11).GT.0..OR.BET(3).GT.) GO TO 499
IF (K.EQ.IS(1).OR.K.EQ.IS(3)) DELX(K)=DELX(K-1)
IF (K.EQ.IS(2).OR.K.EQ.IS(4)) DELX(K-1)=DELX(K-2)
GO TO 499

499 DELX(K)=1.E+06

499 CONTINUE
DELX=DELX(K)
DO 501 K=2,NP2
IF (DELX(K).LT.0..DELX) DELX=DELX(K)
501 CONTINUE

501 CONTINUE
IF (BET(11).EQ.0..AND.BET(2).EQ.0..AND.BET(3).EQ.0..AND.BET(4)) AEQ.0.) GO TO 777
IF (BET(11).GT.0..OR.BET(3).GT.) 777,776

777 DCHAR=DELX
GO TO 775

776 DCHAR=2.*DELX
777 IF (XLE.EQ.0..OR.VIS.EQ.0.) GO TO 50
WI=1./VIS
DELV=5.*PR*RE*VIS/XLE
GO TO 51
50  DELY=1.
51  DO 502 K=1,NPTS
      DELVI=1.*E**1;
      IF(K.NE.1) DELY=Y(K)-Y(K-1)
      IF(K.NE.NPTS) DELYY=Y(K+1)-Y(K)
      IF(K.EQ.1) DELY=DELY
      IF(K.EQ.NPTS) CELY=DELY
      IF(IDELY.LT.DEUY) DELY=DELY
      IF(IDELY.LT.1.E-08) GO TO 502
      DELVI=DELV=RHO(K)*Q(K)*DELY**2*COS(TH(K))
502  DEX=DELVI
      DELVI=DELVI
      DO 504 K=2,NPTS
504  IF(IDELY(K).LT.DEUX) DELX=DELY(K)
           DSHEAR=DELY(K)
           DEX=X(1.+DSHEAR+1.+DSHEAR)
           DELX=DEX/STEP
           IF(ISPZ.EQ.1) GO TO 4
           ISPZ=1
           CALL SPACE(ISPZ)
           IF(IINI.EQ.1) RETURN
           IF(ISPZ.EQ.1) GO TO 10
10  CONTINUE
           IF(IJCHRM.EQ.0) GO TO 4275
           DO 505 I=1,NPTS
               DTST=CIII*UIN*E-7/RTH
               DTST=CHMPC*DTST
505  IF(IDELX.GT.DTST) DELX=DTST
           CONTINUE
           IF(IINI.EQ.1.OR.KOLNT.NE.KFIRST) GO TO 4545
           KKK=KOUNT+26
1545  CONTINUE
           IF(E(JSUBU).LT.1.051) KKK=KOUNT+1
           XWT=XBP*ELX
           RA=1./RAE
           IF(XWT.LT.XW(IN)) GO TO 741
           IF(XWT.EQ.XW(NSAVE)) GO TO 5209
           THBP=0.
           XBP=XW(NSAVE)
           YBP=YW(NSAVE)
           IINI=1
           GO TO 5210
5209  CALL TBL(XMT,THBP,XW,THW,NSAVE)
           GO TO 5204
741  THBP=THBP+DELX*COS(THBP)*0A
5204  DELX=DELX*COS(THBP)*COS(THBP)+COS(THBP))/2.
           XBP=XWT
           YBP=YBP+XWT(SIN(THBP)+SIN(THBP))*0.5*DELX/COS(THBP)
           CONTINUE
GO 5211 I=1,NPTS
X(NI)=XBP
Y(NI)=Y(1)+TAN(TH(1))*DLX
5211 TH(NI)=TH(1)
IF(INC0.EQ.1) CALL ROXY(XN(1),YN(1),TH(1),1)
IF(IPRES.EQ.1) CALL PRESS(XN(1),PN(1),TH(1),THN(1))
IF(IPRES.EQ.1) PN(NPTS)=PN(1)*(APRES*PN(NPTS)+BPRES*)
1X(NPTS)
IF(IPRESL.EQ.1) RETURN
IF(Y(NPTS).EQ.YBP) GO TO 6211
CALL ROXY(XW,Y(NPTS),TH(NPTS)+1)
X(NPTS)=XWT
RETURN
6211 X(NPTS)=XBP
Y(NPTS)=YBP
TH(NPTS)=THBP
RETURN
END
SUBROUTINE SSONIC(IDIG)
COMMON/AC/IACD,F
COMMON/AX/JAXJ,AJU0
COMMON/AC/XM(A55)
COMMON/CG/UP,UB,UP,OTSPRI(55),DU,UE,UP,ICONX,THPRI(55),YPRI(55)
COMMON/DY/YN(55)
COMMON/KE/EN(55),CN(55),N(55),TH(55),Y(55)
COMMON/GK/DELX
COMMON/HJ/KOUNT,LL,APT
COMMON/HL/ALPHA,BETA
COMMON/H/ALPHA(55),CPH(55),CPXN(55),EMN(55),GN(55),MN(55),MN(55),IL(55),PN(55),RN(55),TN(55),TN(55),TN(55),TN(55)
COMMON/IG/AG,AP,BP
COMMON/ST/13,1RFII,KT,KNP,KPSTAP
COMMON/Y/IIK,ER,IPRES,IPRES,ISUB
COMMON/Y/XCONT,IKONT,KT,THAP,THBP
COMMON/NE/NPTS,RE,KNP,J
DIMENSIC ED(2),ERE(2),FRTH(2)
DATA LKIP/1,LNE/1,LP/0,LW/0,LJUMP*/7
DATA DTHT/0,
IF(IIDJ.EQ.1.OR.KOUNT.EQ.KFIRST) GC TO 1777
KKF=KEP
CALL OPCTHTHMSBOT(JSUBL)
GTH=1(YSUBL)
GTH=1(YSUBL)
IF(REQ.EQ.0)GTH=THS9C/CTH(XSUBL)**3
IF(REQ.EQ.0)GTH=(CTH+GTH)*DEL
DT=0THQ
XKF=XMMA(JSUBL)
1777 CONTINUE
K=JSUBL
93

DQ=XBPW=XKF
OS=1.56
QQ=1.62
YN(K)=ATAN(DUP+CUP+QQ*QQ+DUP+DQ+DQ**2+DUP*DQ+DQ**3+DUP+DQ**3+DQ)
THN(K)=ATAN(DUP+CUP+QQ+DQ**2+DUP*DQ+DQ**3+DUP+DQ**3)
DS=2.*DELX/(COS(TH(K))+COS(THN(K)))
THM=THM(K)
YGH=YN(K)
IBOO=IBCC
IBOD=1
IPRES1=IPRESS
IPRESS=0
IPRE U1=IPRESU
IPRESU=0
ALSV=ALPHA
BESV=BETA
CALL LPINT(JSUBU,0.)
K=JSUBU
THN(K)=THM
YN(K)=YGH
ALPHA=.5
BETA=.5
CALL LPCINT(JSUBU,0.)
ALPHA=ALSV
BETA=BESV
K=JSUBU
THN(K)=THM
YN(K)=YGH
IBOD=IBOO
IPRESS=IPRES1
IPRESU=IPREU1
DS=2.*DELX/(COS(TH(K))+COS(THN(K)))
PSA=(PN(K)-P(K))/DS
THSA=(CUP*DUP+CUP+DUP+DQ**2+DUP*DQ+DQ**3+DUP+DQ**3)
PNH=GAH(K)*PN(K)*COSN(K)**2+THSA
PY=CCS(THN(K))**2+PSA
K=JSUBL
DQ=XBPW=XKF
YN(K)=ATAN(DTHB+DTHB+CUP+DTHB+DQ**2+DTHB+DQ**3+DQ)
THN(K)=ATAN(DTHB+DTHB+CUP+DTHB+DQ**2+DTHB+DQ**3+DQ)
DS=2.*DELX/(COS(TH(K))+COS(THN(K)))
PY=AP1
ITE1=1
IET=0
1790 AP2=(PY-PYB)*.5/(YN(JSUBU)-YN(K))
AP0=PN(JSUBU)-.5*(PYB+PYU)*(YN(JSUBU)-YN(K))
AP1=PYB
PN(K)=AP0
ICONT=1
IEND=0
KP=K
L=K
KT=K
PSTAR=PN(K)
YN=YN(K)
THG=THN(K)
CALL CPC1AT
YN(K)=YNH
THN(K)=THG
PNB=GAMN(K)*PN(K)*EMN(K)**2*THS0
PYB=COS(THN(K))*PNB
ET=PYE-PYB
IF(ABS(ET).LT.1.E-06) GO TO 1709
ET=ET+1
IF(ET.LT.20) GO TO 6532
WRITE(*,6533)
6533 FORMAT(* ET LOOP IN SSONIC*)
STOP
6532 CONTINUE
ERET=ITE1=ET
IF(ITE1.LT.1) GO TO 358
ITE1=2
PYB=PYB
PY2=PYB
GO TO 1790
358 PYB=PYB-ERET(1)*(PYB-PY2)/(ERET(2)-ERET(1))
PYB=PYB
ERET(1)=ERET(2)
PYB=PYB
GO TO 1790
1709 CONTINUE
ICGT=1
IEND=0
JSUBL=JSUBL+1
JSUBU=JSUBU+1
DO 1734 K=JSUBL,JSUBU-1
K=JSUBU-K+1
THN(K)=Th(K)
YN(K)=TAN(THN(K))**DELX*Y(K)
PN(K)=AP0*AP1*(YN(K)-YN(JSUBL))+AP2 *(YN(K)-YN(JSUBL))**2
KIP=1
ME=1
KP=K
L=K
KT=K
PSTAR=PN(K)
QS=2.*DELX/COS(TH(K))+COS(THN(K)))
YN(K)=Y(K)+.5*(TAN(TH(K))+TAN(THN(K)))*DELX
YN(K)=YN(K)
THGH=THN(K)
CALL CPCINT
YN(K)=YN(K)
THN(K)=THGH
YN(K)=YN(K)+.5*(TAN(TH(K))+TAN(THN(K)))*DELX
KP=KP+1
TERM=(RHON(KP)*QN(KP)*COS(THN(KP))+RHON(KP)*QN(KP)*COS(TH(N(KP)))/2.
XMOM=XMASS(KP)+TERM*(YN(K)**(1.0+XJ)-YN(K)**(1.0+XJ))/XJ
QJ=1.0+XJ
YN(K)=YN(K)**(1.0+QJ)*XMAS(K)-XMASS(KP)/TERM**(1.0/QJ)
1734 CONTINUE
IF(IKOUNT.K,E,KKQ=1) RETURN
XMOM=XMOP=XMSS(JSUBU)
JK=JSUBU+1
DC 347 I=JK,JSUBU
347 XMSS(I)=XMSS(I)+XMOM
JSU1=JSUBU-1
WRITE(6,1418)
1418 FORMAT(1X,*CORRECTED INTERMEDIATE STREAMLINES*/2X,*STREAMLINE NO.
1.07X,8X,*K*12X,Y,11X,*TH*)
DC 36E KK=1,JSU1
K=JSU1+KK
KP=1
ME=1
DTERM=0.
DYM=TAN(THPR(K))
DYAM=CSPR(K)/COS(THPR(K))*3.5
IF(K.EQ.1.002*2=CTH*K,5
XDEL=XBPM*KK
6030 YSTAR=PHRI(K)+DYM*XDEL+D2YDX2*XDEL**2+DTERM*XDEL**3*OS
THSTART=ATAN(DDYDX2)+D2YDX2*XDEL+DTERM*XDEL**2*5
KP=KP+1
TERM=(RHON(KP)*QN(KP)+COS(TH(N(KP))+RHON(KP)*QN(KP)*COS(N(KP)))/2.
XJ=1.0+XJ
XMOM=XMSS(KP)+TERM*(YSTAR*XJ-YN(KP)**(1.0+XJ))/XJ
EZME=XMOM=XMSS(KP)
IF(ABS(EZME))..LT.1.E-06 ) GO TO 6034
KP=KP+1
GO TO (6041,6042),ME
6041 ME=2
DTERM=1*DTERM
DTERM=.01*XDEL**2
GO TO 6032
6042 DTERM=DTERM+DTERM1*(DTERM-DTERM1)/(EZ(K2)-EZ(K1))
DTERM=1*DTERM
DTERM=1*DTERM
EZ(K1)=EZ(K2)
IF (KIF .LE. 20) GO TO 603C
WRITE (6, 6081)
6081 FORMAT (* TOO MANY ITERATIONS FOR ONE POINT IN SSOMIC*) STOP
6034 IF (K .EQ. 1) GO TO 6036
YN(K) = YSTAR
THN(K) = THSTAR
XDEL1 = XCEL / 4.
DO 1419 I = 1, 4
XDE = XDEL1 * FLOAT (I)
XPRTN = X refinement
YPRTN = YPRT
THPRN = ATAN (DYX2 * XDE) / 4.
WRITE (6, 1419) K, XPRT, YPRT, THPRN
1419 FORMAT (A) STOP
CONTINUE
GO TO 386
6036 ERLH = TMSTAR - THN (JSURL)
JCONV = 0
II = 2
ERLH (LME) = ERLH
IF (LJUMP .EQ. 1) GO TO 2501
IF (ABS (ERLH (LME)) .LT. 0.01) GO TO 2501
LKIP = LKIP + 1
GO TO (2502, 2503), LME
2502 LME = 2
DTMB = DTMB
DTMQ = DTMB - 0.5
GO TO 2504
2503 IF (LLICE .EQ. 1) GO TO 2505
IF (ERLH (1) * ERLH (2) .LT. 0.) GO TO 2505
IF (LLICE .EQ. 1) GO TO 2506
LK = 1
RTML = -0.5
IF (ABS (ERLH (2)) .GT. ABS (ERLH (1))) RTML = -PTML
2506 IF (ABS (ERLH (2)) .GT. ABS (ERLH (1)) .AND. LKIP .EQ. 4) GO TO 2537
DTM1 = DTMB
DTM2 = DTMB
DTM3 = DTM1
RTML = RTML
2509 ERLH (1) = ERLH (2)
ERLH (1) = ERLH (2)
IF (LKIP .LE. 10) GO TO 2504
WRITE (6, 2508)
2508 FORMAT (* TOO MANY ITERATIONS IN LOWER WALL LOOP IN SSOMIC*) STOP
2507 PM = ERLH (1) * DTMB**2 - ERLH (2) * DTMB**2 + ERLH (2) * DTMB**2 - ERLHX**1
10MTB**2 + ERLHX**1 * DTM2**2 - ERLH (1) * DTM1**2
PM = ERLH (2) * DTMB**2 - ERLH (1) * DTM1**2 + ERLHX**1 * DTM2**2 - ERLH(2) * DTM1**2
1 + ERLH (1) * DTM1**2 - ERLHX**1 * DTM2**2
DTHQ=PM8/(2.*PMC)
LIJUMP=1
GO TO 2564

2505
LI=1
DTH0=O$TH2-ERTHL(1)*(DTHA-DTHB2)/(ERTHL(2)-ERTHL(1))
DTHB1=DTHB2
DTHB2=THR
DTHQ=CAS
GO TO 25C9

25C1
JCONV=1
LI=8
LKP=1
LME=1
LIQ=1
LICK=1
LIJUMP=0
IREGI=1
DTHQ=0.

25C4 IF(JCCNV.EQ.0) DTHA=DTHQ

386 CONTINUE
RETURN
END
SUBROUTINE BODY(X1,Y,TH,ID)
COMMON/XA/XB,YA,YB,YC,YD,ABCD,E90D,E90C,G90D,IAVE,IPUNCH,J80D,IAVE
X=X1
IF(ID.EQ.1) GO TO 4
IF(ID.EQ.0) GO TO 1
X=X1-X00
Y=AB0D*X*(E90D+)*G90D)
TH=ATAN((E90D+2.)*G90D*X)
GO TO 2
1 Y=0.
TH=0.
GO TO 2
4 Y=EB0D*X*(E90D+)*G90D)
TH=ATAN(E90D+2.)*G90D*X)
2 RETURN
END
SUBROUTINE DPDTH(DTDS,I)
COMMON/AK,JSUBL,JSUBU
COMMON/EF/EM(55),G4M(55),P(55),TH(55),Y(55)
COMMON/RQ/APD,AP1,AP2
CALL SHEAR(I,AP1,AP2)
ASH=ASHEAR
PY=AP1+2.*AP2*(Y(I)-Y(JSUBL))
D2=Y(I+1)-Y(I)
D1=Y(I)-Y(I-1)
DTAUUP(KP)=DTAU(KT)+Q&A1B*Q(DTAU(KT+1)-DTAU(KT))
DBOP(KP)=CQ(KT)+RATB*Q(DBQ(KT+1)-DBQ(KT))
DTCMP(KP)=DTC(KT)+RATB*Q(DTC(KT+1)-DTC(KT))
CPIP(KP)=Q,0
WP(KP)=Q,0
CMP(KP)=Q
CALL THERMO(DP(KP),DP,KP)
DO 4020 J=1,NSP
     ALPP(J,KP)=ALP(J,KT)+RATB*(ALP(J,KT+1)-ALP(J,KT))
     DDALP(J,KP)=DDALP(J,KT)+RATB*(DDALP(J,KT+1)-DDALP(J,KT))
     DCM(KP)=CM(CM(KP)+Q*ALPP(J,KP)*CPE(J))
     CPE(J)=CPE(J)
     WP(KP)=WP(KP)+ALPP(J,KP)/MTMOLE(J)
     DACH(J,KP)=DACH(J,KT)+RATB*(DACH(J,KT+1)-DACH(J,KT))
     IF(KP.EQ.2)GO TO 4020
     WDOT(J,KP)=WDOT(J,KT)+RATB*(WDOT(J,KT+1)-WDOT(J,KT))
4020 CONTINUE
     WP(KP)=1,WP(KP)
     PP(KP)=RC/WP(KP)
     GAMP(KP)=CPE(J)/CP(KP)/CP(KP)*RC/CP(KP)
     XH(J)=1,WP(KP)
     WP(KP)=WP(KP)*WP(KP)*GEW/TP(KP)
     WP(KP)=WP(KP)*EMINP*QRTGAR/GAMP(KP)*RK/TP(KP)
     XH(J)=XH(J)
     IF(KP.FEQ.2)GO TO 501
     KP=2
     IFIFS,EQ.0)KTL=1
     EM2P=XP2(ALPHA,BETA,TH(KT+1),XMU(KT+1),THN1L,THN1L)
     EM2P=XP2(THA,BETA,TH(KT+1),XMU(KT+1),THN1L,THN1L)
     GO TO 531
C GET ALL THE PROPERTIES AT THE C POINT
501 CONTINUE
     IFIFS,EQ.0)GO TO 9500
     Y SS=Y (K)
     P SS=P (K)
     Q SS=Q (K)
     T SS=T (K)
     AO SS=AO (K)
     W SS=W (K)
     TAU SS=TAU (K)
     THO SS=THO (K)
     CP* SS=CPX (K)
     DBQ SS=DBQ (K)
     DTAUS=DTAU(KK)
     DCPXSS=DCP(KK)
     DTCHESS=DTCHE(KK)
     DD 1555 J=1,NSP
CPSS(JI) = CP(J, K)
HSS(JI) = CP(J, K)
ALPSS(JI) = ALP(J, K)
DALPSS(JI) = DALP(J, K)
DACHSS(JI) = DACH(J, K)
1555
DIALPS(JI) = DIALPS(J, K)
CALL EPCHINT(J, K)
K = K

862E CONTINUE
CMZD = 0.0
DO 4338 J = 1, NSP
CMZD = CMZD + DIALPS(JI, K) * CP(J, K)
4338 CONTINUE

IF(ETA(J, K) .LT. IGG) GO TO 4036
TAUN(JI) = TAU(J, K)
BN(JI) = B(J, K)
DOCPX(NJL) = DCPX(J, K)
CTAUN(JI) = DTAU(J, K)
DOG(NJL) = DGQ(J, K)
THKJL = TH(J, K)
DPPX(KL) = CPX(K, K)
TN(JL) = T(K, L) + CTPX(J, K)
WNL = W(N, K)
CMZC = CMZC
DO 4335 J = 1, NSP
DIALPS(J, K) = DIALPS(JI, K)
DIALPS(J, K) = DIALPS(JI, K)
MC(JI) = M(J, K)
WDTIC(JI) = WDTIC(J, K)
4335 CONTINUE

4036 CONTINUE
IF(ETA(J, K) .LT. 0.0) GO TO 3C2
CMZC = 0.0
DO 321 J = 1, NSP
MC(JI) = MC(J, K)
WDTIC(JI) = WDTIC(J, K)
3C1
CMZC = CMZC + DIALPS(J, K) * CP(N, J, L)
3C2 CONTINUE

V1 = VISA
V2 = VISC
DV1 = DVISA
DV2 = DVISI
TA = TAU(J, K)
TA2 = TAU(L)
DT1 = DTAU(J, K)
DT2 = DTAU(L)
EQ = EQ(J, K)
BQ = BQ(J, K)
Y1 = YP1(J, K)
V2=V(N(L))
V1=V(MP(1))
TH2=TH(N(L))
C1=CPX(N(L))
C2=CPX(N(L))
DB1=DPQ(1)
DB2=DPQ(K(L))
PX1=DCPX(N1)
PX2=DCPX(N(L))
CH1=CMC11)
CM2=CM2C
IF (CONT.EQ.1) GO TO 4369
S1A=S11(XJ,RE)
S2A=S21(XJ,RE)
4369 V1=VISD
V1=VISD
TA1=TAU(K)
DT1=DTAU(K)
8G1=OC(K)
T1=TH(K)
TH1=TH(MK)
C1=CPX(K)
DB1=DPQ(K)
PX1=DCPX(K)
CH1=CH2D
S1D=S11(XJ,RE)
S20=S21(XJ,RE)
IF (CONT.EQ.1) GO TO 6427
IF (L.EQ.,MP15) GO TO 6427
V1=VISD
V1=VISD
TA1=TAU(2)
DT1=DTAU(2)
8G1=OC(2)
T1=TH(2)
TH1=TH(2)
C1=CPX(2)
DB1=DPQ(2)
PX1=DCPX(2)
CH1=CMC(2)
S1B=S11(XJ,RE)
S2B=S21(XJ,RE)
6427 CONTINUE
S3AT=0.0
S3BT=0.0
S3D=0.0
00 4040 J=1, NSP
AL2=0ALPM(J,J,L)
002=0ALPM(J,J,L)
IF (ICNT .EQ. 1) GO TO 4311
V1=VISA
DV1=DVISA
AL1=DALPP(J+1)
DI1=DCALPF(J+1)
Q1=QP1(1)
TH1=THP(1)
VI=VP(1)
S3A(J)=S3(XJ,RE)
S3AT=S3AT+3A(J)/WTMOLE(J)

4311
AL1=DALPP(J,KT)
DI1=DCALPF(J,KT)
V1=VISc
DV1=DVISc
Q1=QC(KT)
TH1=TH(KT)
VI=YK(T)
S3D(J)=S3(XJ,RE)
S3DT=S3DT+S3D(J)/WTMOLE(J)
IF (ICNT .EQ. 1) GO TO 494C
IF (L.EQ.4FYS) GO TO 4049
V1=VISc
DV1=DVISc
AL1=DALPP(J,2)
DI1=DCALPF(J,2)
Q1=QP2(1)
TH1=THP(2)
VI=VP(2)
S3P(J)=S3(XJ,RE)
S3ET=S3ET+S3B(J)/WTMOLE(J)
CONTINUE
IF (ICNT .EQ. 1) GO TO 6429
GANB=GMF(1)
P8=PP(1)
08=QP(1)
RHOB=RHOF(1)
THB=THP(1)
W8=WP(1)
XMUB=XMUP(1)
V8=VP(1)
A1=DX(I)
A2=F2(L,S1A,S2A,S3AT)
IF (JCHEM .EQ. 1) GO TO 7252
A3=0.
GO TO 7255
7252 DD 1712 J=1+NSP
1712 DUCNP(J)=(DACHP(J)+DACH(J,K))/2.
DTCHP(1)=(DTCHP(1)+DTCH(K))/2.
TP1=(TL+TP(1)+CTCHL)/2.
A3=F3(TF1,DTCP(1),TP(1),TN(L),THP(1),THN(L),DUMCHP,WP(1),WN(L))
7259 A4=F4(BETA,1,XMUP(1),THP(1),XMUN(L),TN(L))
A2=0.4+3.8*A4
IF(L.EQ.KFTSI) GO TO 6429
GAM=GAPP(2)
P0=PP(2)
Q0=OP(2)
RH0=ROPP(2)
TH0=TP(2)
WB=WP(2)
XM0=XMUP(2)
Y0=YP(2)
T1=F1(L)
B2=F2L(4,5,6,2,3,8)
IF(JCHEM.EQ.1) GO TO 7253
G3=C
GO TO 7255
7253 GO 1713 J=1,NSP
1713 DUMCHP(J)=DACHP(J,2)+DACHP(J,K,1)/2.
DTCP(2)=DTCP(2)*DTCP(2)/DTCH(1)*2.
TP2=(TP(L)+TP(2)+DTCH(L))/2.
93=F3(TP2,DTCP(2),TP(2),TN(L),THP(2),THN(L),DUMCHP,WP(2),WN(L))
7256 B4=F4(BETA,1,XMUP(2),THP(2),XMUN(L),TN(L))
B2=(B2+B3)*B4
6429 CONTINUE
IF(JND.EQ.3) GO TO 630
THN(L)=TN(L)
PK(L)=PP(1)+TP(1)-THN(NPTS)-A2*(X(M(NPTS)-XP(1)))/A1
GO TO 631
630 IF(I$ICNT.EQ.0) THEN
1P(L)=X1*PP(1)+X1*TP(1)-THP(2)-
IF(I$ICNT.EQ.0) THEN
1P(L)=IP$TR
IF(I$ICNT.EQ.0) THEN
1THN(L)=THP(1)-A1*(PN(L)-PP(1)-A2*(XN(L)-XP(1)))
631 CONTINUE
DELS=2.*(XNL-X(K))/(COS(T(K))+COS(TNL))
TERM2=R*P(K)*G(K)
IF(BETA.EQ.1) THEN
2=TERM2+R*ON(L)*QNL)*.5
OT=1/TERM2
QNL=5IC*DELS-PNL*X(K)+OT*G(K)
IF(BETA.EQ.0) THEN
2=CP(XNL)+CPX(K)
DTCHM=DTCHNL+CP(L)-P(K)*(QNL+O(K))/CPX(K)+CPXNL)*E1*OT
DTHM=520*DELS*E1*2./(CPX(K)+CPXNL)*OT
THN(L)=T(K)+DTCHEM+DTHM
CPXNL=0.0
WN(L)=B.0
CALL THERM(TNL,H,1,CP1)
DO 4950 J=1, NSP
DALO(I,J)=SSO(I,J)*DELS*OT
ALPN(J,L)=ALP(J,K) + DALO(I,J) + DACH(J,L)
NH(J,L)=NH(J)
CPNJ(J,L)=CPNJ(J)
NH(L)=NH(L) + ALPN(J,L) + WTMOLE(J)
CPKN(L)=FNKN(L) + ALPN(J,L) + CPNJ(J,L)

4950 CONTINUE

MN(L)=1./NH(L)
RN(L)=RN(L)/MN(L)
GAM(N)(L)=CPKN(L)/(CPKN(L)-RN(N,L)/CPNJ)
ORN=1./RN(L)
RHON(L)=MN(L)/ORN(L)*GW/TN(L)
EM(N)(L)=G(L)*EMINF*QRGAR/GAM(N)L)*ORN/TN(L))
IF(EM(N(L),LT.1.E-001) GO TO 900
7360 XMUK(L)=2*EM(N(L))
980 CONTINUE
IF(IFS.EQ.0) GO TO 1361
Y(K)=Y(K) SS
P(K)=P(K) SS
Q(K)=Q(K) SS
T(K)=T(K) SS
W(K)=W(K) SS
TH(K)=TH(K) SS
BQ(I)=BQ(I) SS
TAU(K)=TAU(K) SS
DBQ(K)=DBQ(K) SS
CPX(K)=CPX(K) SS
RHO(K)=RHO(K) SS
DCKP(K)=DCKP(K) SS
DTAU(K)=DTAU(K) SS
DCHS(K)=DCHS(K) SS
DO 1556 J=1, NSP
ALP(J,K)=ALPS(S(J)
DALP(J,K)=DALPS(J)
DACH(J,K)=DACHS(J)
DDALP(J,K)=DDALPS(J)
CPJ(K)=CPJS(J)
1556 CONTINUE
111 FORMAT(10X,9E..5)
RETURN
END

SUBROUTINE SPACE(ISPP)
COMMON/SC/IMOD, PIN
COMMON/SM/SA,GEN
COMMON/SP/SUBL,JSUB
COMMON/SP/ALP(7,55),EMINF,WINF
COMMON/SD/KAASS(5F)

COMMON/CA/WDTN(7,55),XN(55)
COMMON/CJ/CP(7,55),GP(7,55)
COMMON/CL/WTMOL(7,55)
COMMON/DB/BTEB(4,14)
COMMON/DP/YN(55)
COMMON/Ep/CPIN,PC
COMMON/F/EH(55),GAM(55),P(55),TH(55),Y(55)
COMMON/EP/GAMINF,H(1),RINF
COMMON/G/DELYC
COMMON/H/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),MN(7,55),
IL,PN(55),CN(55),QHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
COMMON/LC/W(55),X(55)
COMMON/PC/JCNM,NSP,D(55)
COMMON/PA/H(7,55),Q(55),RHQ(55),XMU(55)
COMMON/QC/R(55)
COMMON/PJ/AP0,AP1,AP2
COMMON/QG/BN(55),DLPN(7,55),DQN(55),DQPXN(55),DQALPN(7,55),
DQTAUN(55),TAUN(55)
COMMON/R/II3,IREGJ,K,KFIRST,KNKG,PSTAR
COMMON/LC/RL(55),CALP(7,55),DBQ(55),DCPX(55),DQALP(7,55),DQTAU(55),
1TAU(55)
COMMON/UV/UI1,ICR,IPRES,IPRESU,ISUB
COMMON/WV/NPTS,RE,XBP,XJ
COMMON/XV/历史悠久,APRESS,APRESS,APRESS
COMMON/XY/APR,APUS,DELAY,E8003,E8005,INTACT,IPRS,IPUS,ITY0P,
1JODS,MMAX,REHAT,XK2,XX,Y807,YTP
COMMON/YX/ABON,IPRESS,CRESS
COMMON/XY/A8900,A8902,A8900,A8902,A8900,A8902
DIMENSION IS(40),EMAX(55)
XJ2=1.-XJ
XJ1=1.0+XJ
DY=DELAY
DC=1./I=1.4
IF(IS(2),EQ,0) GO TO 1
N=-1
IF(I(2),EQ,1) N=1
IS=IS(1)
DY=ABS(Y(ISI)-Y(ISI+2*N))
IF(DYS<1.2+DY) GO TO 2
C*********** ACC PT ON CONTMIRE SIDE OF SHOCK *****
ISM=ISM(1)
IF(I(2),EQ,1) ISM=ISM(I)+2
DO 3 K=ISM,NPTS
K=NPTS+K
J=K+1
CALL SWITCH(J,K)
3 CONTINUE
NPTS=NPTS+1
ISPP=1
IF(JSUBL.GT.IS(II)) JSUBL=JSUBL+1
IF(JSUBU.GT.IS(II)) JSUBU=JSUBU+1
DC = J=1,4
IF(IS(IJ).GT.IS(II)) IS(IJ)=IS(IJ)+1
4 CONTINUE
IF((I/I/2)*2.3.0.E.1) IS(II)=IS(II)+1
L=ISM=1
M=ISM+1
K=ISM
RAT=.5
P (K)=P (L)+RAT*(P (M)-P (L))
TH (K)=TH (L)+RAT*(TH (M)-TH (L))
X (K)=X (L)+RAT*(X (M)-X (L))
Y (K)=Y (L)+RAT*(Y (M)-Y (L))
Q (K)=Q (L)+RAT*(Q (M)-Q (L))
T (K)=T (L)+RAT*(T (M)-T (L))
RG (K)=RG (L)+RAT*(RG (M)-RG (L))
TAU (K)=TAU (L)+RAT*(TAU (M)-TAU (L))
DBQ (K)=DBQ (L)+RAT*(DBQ (M)-DBQ (L))
DCPX (K)=DCPX (L)+RAT*(DCPX (M)-DCPX (L))
OTAU (K)=OTAU (L)+RAT*(OTAU (M)-OTAU (L))
XMASS (K)=XMASS (L)+RAT*(XMASS (M)-XMASS (L))
CPX(K)=0.
W(K)=0.
CALL THERMO(J1)+M1,CPI
GO TO 5
5 J=1,NSP
ALP (J,K)=ALP (J1)+RAT*(ALP (J,M)-ALP (J1,L))
DALP (J,K)=DALP (J1)+RAT*(DALP (J,M)-DALP (J1,L))
ODALP (J,K)=ODALP (J1)+RAT*(ODALP (J,M)-ODALP (J1,L))
H(J,K)=H(J1)
CP(J,K)=CP(J1)
W(K)=W(K)+ALP(J1,K)/NPOLE(J)
CPX(K)=CFX(K)+ALP(J1,K)*CP(J1,K)
5 CONTINUE
W(K)=1./R(K)
R(K)=O/W(K)
GAM(K)=CFX(K)/CPX(K)-R(K)/CPIN
OR=1./R(K)
RHO(K)=P(K)*W(K)*GEN/T(K)
EM(K)=G(K)*EMINF*SQRT(GAR/GAM(K)*OR/T(K))
XMUK(K)=ZP(EW(K))
2 CONTINUE
YSN=Y(ISI1)+TAN(ABTBI1))*DELX
IF((I/I/2)*2.3.0.E.1) GO TO 6
J=ISI1
K=J+1
EMP=XM2(1.00,0.00,TH(K),XMUK(K),0.00,0.00)
EML=XM2(1.00,0.00,TH(J),XMUK(J),0.00,0.00)
EMP1=XM1(1.00,0.00,TH(K),XMUK(K),0.00,0.00)

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EML1=XM1(I+9)*TH(J)*XMU(J)*C.51.
GO TO 7
6 J=IS(I)
   K=J-1
   EMP=XM1(I+C+11)*XMU(J)*0.5
   EPL=XM1(I+C+11)*TH(K)*XMU(K)*0.
   EM1=XM1(I+9)*TH(J)*XMU(J)*0.5.
   EML1=XM2(I+9)*TH(K)*XMU(K)*0.5.
7 EM3=XM3(I+9)*TH(K)*G.
   YCH=YCH-CEL*EMP*EML+0.5
   YST=YST-DEL*EMP*EML+0.5
   OVT=-N*(YCH-YST)
   IF(BET(1).EQ.0..AND.BET(2).EQ.0..AND.BET(3).EQ.0..AND.BET(4).EQ.0.)GO TO 777
   IF(GST.1.GT.0..OR.BET(1).GT.1.)1775.776
   IF(DYJABS(YJJ-YJ(J)).GT.111)775
   776 IF(N*YK-YCM-L0.315)GO TO 1
   ISIM=IS(I)-1
   IF(ISIM.EQ.NPTS.OR.ISIM.EQ.1)GO TO 1
C******** SUBTRACT PT FROM FREE STREAM SIDE OF SHOCK ****
775 L=K+1
   DO 8 K=L,NPTS
   J=K-1
   CALL SWITCH(J,K)
8 CONTINUE
   NPTS=NPTS-1
   ISPP=1
   IF(JSUB.GT.IS(I))JSUBL=JSUBL+1
   IF(JSUJ.GT.IS(I))JSUJB=JSUJB+1
   GO TO 251
   IF(ISIJ.GT.IS(I))ISIJ=ISIJ+1
9 CONTINUE
   IF(I/I/2*FG.1)IS1=IS(I)-1
   1 CONTINUE
   IF(ITYP.NE.1)GO TO 850
   IF(NPTS.LT.MMAX)GO TO 2121
   1111
   IPUNCH=1
   WRITE(6,9191)
9191 FORMAT(I1)
   WRITE(6,951)
951 FORMAT(WRITE REQUESTED MAXIMUM NUMBER OF FLOW FIELD PTS. EXCEEDED. PUNCH FILE OBTAINED IN PROGRESS). RESUBMIT RUN WITH REDUCED NUMBER OF FLOW FIElD PTS. OR INCREASE INPUT FOR MAXIMUM NUMBER OF PTS. RETURN
850 CONTINUE
   IF(I/I/1.EQ.YMAT.OR.ITYP.EQ.4)GO TO 2130
   IPRESS=1
APRESU=P(IN)/PIN
2100 IF (Y(NPTS) .EQ. YTP.OR.ITYP.EQ.3) GO TO 2101
   IPRESU=1
   APRESU=P(NPTS)/PIN
2101 CONTINUE
   IF (NPTS.LT.MNAX) GO TO 1000
   ISC=0
   DO 700 I=1,N
   700 IF (IS(I).NE.0) ISC=ISC+1
   IF (ITYP.NE.2.OR.ISC.NE.0.OR.ISUB.NE.3) GO TO 701
   YQ=YTP
   IF (Y(NPTS).LE.Y(P-2.*DELTAY) YQ=Y(NPTS)+DELTAY
   IK=1
   IX=1
   NP=NPTS
   IF (NPTS/2*2.NE.NPTS) GO TO 702
   800 J=NPTS+1
   K=NPTS
   CALL SWITCH(J,K)
   Y(J)=YG
   NPTS=NPTS+1
   YFUN=(Y(J)*(XJ2+Y(J))*XJ)-Y(K)*(XJ2+Y(K))*XJ)/XJ
   QQAV=PM0*K*I*K*COS(TH(K))
   XMASS(J)=XMASS(K)+QQAV*YFUN
   IF (NPTS).LT.0
      APRESU=P(NPTS)/FIN
   GO TO 1000
701 APRESU=P(NPTS)/FIN
702 J=1
    DO 703 K=3,NP+2
       J=J+1
       CALL SWITCH(J,K)
703 CONTINUE
   DELTAY=DELTAY*2.
   IF (IK.EQ.2) GO TO 704
   NPTS=NPTS/2+1
   GO TO 1000
751 IF (ITYP.NE.3.OR.IS(I).EQ.0.OR.ISUB.NE.0.OR.ISG.NE.1) GO TO 303
   IK=2
   NP=IS(3)-1
   IF (NP/2*2.NE.NP) GO TO 702
   IG=1
   IF (Y(1).LE.YBOT+2.*DELTAY+1.E-03) GO TO 706
   YT=YBOT
   GO TO 707
706 YT=Y(1)-DELTAY
707 DO 708 KK=1,NPTS
    K=NPTS+1-KK
    J=KK
   CALL SWITCH(J,K)

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7C8 CONTINUE
NPTS=NPTS+1
DO 729 I=1,4
7C9 IF(IS(I),NE,0) IS(I)=IS(I)+1
IF(ISUB.EQ.0) GO TO 710
JSUBL=JSUEL+1
JSUBL=JSUEL+1
710 Y(I)=YI
YFUN=F(I) *(XJ2+Y2(I) *(XJ1-Y1(I) *(XJ2+Y2(I) *(XJ1))/XJ1
RQAV=RHO(I2) *Q(I2) *COS(TH(I2))
XMASS(I)=XMASS(I2) -RQAV*YFUN
TH(I)=0.
APRE5=P(I1) /PIN
GO TO (711,987),IQ
711 NP=NP+1
GO TO 702
764 IS=N/2+2
IF(IS(I3)-ISN3) IS=IS(I3)
IS(N3)=ISN3
DO 705 K=ISS,NPTS
J=K-10
CALL SWITCH(J,K)
7C5 CONTINUE
NPTS=NPTS-ID
GO TO 1000
303 ICT=ISC
ITC=ICP=IPTS
IF(IS(I3),NE,0) ITC=ICP=IS(I3)-1
IBOT=1
IF(IS(I4),NE,0) IBOT=IS(I4)+1
DO=Y(I) *(HCTP)-Y(ICT)
DELTAY=CTY/FLtot(MMAX-(NPTS-ITOP)-IS(I4))/2-ICT)
ID=IBOT
ISN(I)=IS(I1)
ISN(I2)=IS(I2)
ISN(I3)=IS(I3)
ISN(I4)=IS(I4)
JSUBL=JSUBL
JSUBL=JSUBL
IQ=IQ+1
IREG=1
IF(IS(I2),EQ,0) GO TO 501
I*-IS(I2)
GO TO 502
501 IREG=2
IF(ISUB.EQ.0) GO TO 504
IF(JSUBL.EQ.1) GO TO 503
I*=JSUBL
GO TO 502

503 CONTINUE
IEB=JSUBU
IBB=IEB

504 IREG=4
IF(IS(I1).EQ.0) GO TO 505
IT=IS(I1)=1
GO TO 502

505 IREG=5
IF(IS(I3).EQ.0) GO TO 506
IT=IS(I3)=1
GO TO 502

506 IT=NPTS
512 MP=(Y(IT)-Y(I0))/DELTAY
L=1B
JZ=1
DEL=(Y(IT)-Y(I0))/FLOAT(MP)

5032 CONTINUE
J=1B8
K=1B
X N(J)=X (K)
Y N(J)=Y (K)
O N(J)=C (K)
P N(J)=P (K)
T N(J)=T (K)
W N(J)=W (K)
R N(J)=R (K)
EM N(J)=EM (K)
TH N(J)=TH (K)
BQ N(J)=BQ (K)
TAU N(J)=TAU (K)
DBQ N(J)=DBQ (K)
GAM N(J)=GAM (K)
RHO N(J)=RHO (K)
XMU N(J)=XMU (K)
CPX N(J)=CPX (K)
DCPX(N(J)=DCPX (K)
GTAUN(J)=GTAU (K)
XMASS(J)=XMASS(K)
O03108 JJ1=1

H N(JJ,J)=H (JJ,K)
CP N(JJ,J)=CP (JJ,K)
ALP N(JJ,J)=ALP (JJ,K)
DALPH(JJ,J)=DALP (JJ,K)
DDALPH(JJ,J)=DDALP(JJ,K)

3108 CONTINUE
GO TO (2201,2904),JZ

2201 DO 68C KK=1,MP
1=KK*I8B=1
IE=IS(2)+1
IBM=ISM(2)+1
GO TO 501
603 JSUBLH=I+1
IBM=JSUBU
JSUBU=JSUBL+JSUBL-JSURL
IBM=JSUBUN
604 CONTINUE
GO TO 504
605 I=IS(I)+2
IBM=ISM(I)
GO TO 505
606 IF(IS(I),NE.0) ISN(3)=I+2
IF(IS(I),EQ.0) NPTS=I+1
NP=NPTS
IF(IS(I),EQ.0) GO TO 2243
ID=IS(I)-ISM(3)
ISS=IS(I)
DO 2344 K=ISS+1,NPTS
J=K-ID
CALL SWITCH(I,J,K)
2344 CONTINUE
NPTS=NPTS-ID
NP=ISH(I)+1
IF(ISUE,EQ.0) GO TO 2903
JZ=2
JZIC=JSUEL-1
JZI=JSUBN-1
2904 JZI=JZI+1
JZI=JZIC+1
IF(JZI,GE,JSUBUN) GO TO 2903
IBM=JZI
IB=JZIC
GO TO 5932
2903 CONTINUE
DO 2244 I=1001,NP
J=I
K=I
X (J)=XN (K)
Y (J)=YN (K)
Q (J)=QN (K)
P (J)=P N(K)
T (J)=T N(K)
W (J)=W N(K)
R (J)=R N(K)
E (J)=EM N(K)
PH (J)=PH N(K)
R (J)=RQ N(K)
TAU (J)=TAU N(K)
DBQ (J)=DBQ 'K)
GAM (J)=GAM N(K)
RHO (J)=RHO N(K)
XMU (J)=XMU N(K)
CPX (J)=CPX N(K)
DCPX (J)=DCPX N(K)
OTAU (J)=OTAUN(K)
XMASS(J)=XMASS*1(K)
DO4108 JJ=1,NSJ
H (JJ,J)=H *(J,J,K)
CP (JJ,J)=CP W(JJ,K)
ALP (JJ,J)=ALP H(JJ,K)
DALP (JJ,J)=DALP(JJ,K)
DADALP(JJ,J)=DADALP(JJ,K)
4108 CONTINUE
2204 CONTINUE
DO 687 I=1,4
6C7 IS(I)=ISN(I)
JSUBL=JSUBLN
JSUBL=JSUBLN
1000 CONTINUE
IF (ITYP.EQ.3) GO TO 903
IF (YN(NPTS),EQ.YTP) GO TO 903
YQ=YTP
IF (YN(NPTS)*,LE.YTP-1.*DELTAY) YQ=YN(NPTS)+DELTAY
N=2
L=N-1
M=N-1
IF (ABS(P(M)-P(L)) / P(L) .GT. .001) 900, 900, 900
900 IF (ABS(Q(M)-Q(L) ) / Q(L) .LT. .001) 901, 901, 900
901 IF (ABS(T(M)-T(L)) / T(L) .GT. .001) 902, 902, 900
902 IF (ABS(ALP(M)-ALP(L)) .LT. .001*ALP(L) ) 903, 903, 900
903 IF (ITYP-EQ.4) GO TO 907
IF (ITYP-EQ.4) GO TO 907
L=2
M=3
/0=2
I=I+1*GE.YBOT+DELTAY+1.E-03) GO TO 910
YT=YBLT
GO TO 912
910 Y1=Y1-DELTAY
912 IF (ABS(P(M)-P(L)) / P(L) .GT. .001) 904, 904, 707
904 IF (ABS(Q(M)-Q(L) ) / Q(L) .GT. .001) 905, 905, 707
905 IF (ABS(T(M)-T(L)) / T(L) .GT. .001) 906, 906, 707
906 IF (ABS(ALP(M)-ALP(L)) .LT. .001*ALP(L) ) 907, 907, 707
907 CONTINUE
IF (ITYP.EQ.4) GO TO 2102
IF (ITYP.EQ.4) GO TO 2102
IBCD=IBDDS
ABDO=ACCCS
IPRESS=IPRPS
APPRES=APRPS

21C2 IF(ITYP.EQ.3) GO TO 21D3
IF(Y(NPTS),NE,YIP) GO TO 21D3
J00D=J0CCS
E00D=E0CCS
IPRESU=IPS0S
APPRESU=APRPS

21C3 CONTINUE
IF(Y(I),EQ,YBOT,AND,ITYP.EQ.3) ITYP=1
IF(Y(I),EQ,YBOT,AND,ITYP.EQ.2) ITYP=6
IF(Y(NPTS),EQ,YTP,AND,ITYP.EQ.4) ITYP=1
IF(Y(NPTS),EQ,YTP,AND,ITYP.EQ.2) ITYP=3

21D1 CONTINUE
IF(ISUB.EQ.1) RETURN
JSUBL=NPTS+1
JSUBU=NPTS+1
RETURN
END

SUBROUTINE RSET
COMMON/SIL/GAR,GEN
COMMON/BA/ALP(7,55),EMINF,WINF
COMMON/BO/XNAXS(55)
COMMON/CJ*CM(7,55),CP(17),CPX(55)
COMMON/DPMYN(55)
COMMON/EFCPNN(7,55)
COMMON/EF/EM(55),GAN(55),P(55),TH(55),Y(55)
COMMON/EP/GAMINF(47),WINF
COMMON/H/P/ALPN(7,55),CP(17),CPX(55),EMN(55),GANM(55),HN(7,55),
RPN(55),RN(55),RN1(55),RN5(55),RN5(55),RN5(55),XMUN(55)
COMMON/FS/THFP,YPF,YFPN
COMMON/PC/VM(55),X(55)
COMMON/PC/JCMEH,N5P,T(55)
COMMON/QA/CM(7,55),Q(55),RHO(55),XMU(55)
COMMON/RK(55)
COMMON/SC/QQN(55),DALPN(7,55),DNQMN(55),DCPXN(55),DADLPN(7,55),
ODAUN(55),TAUN(55)
COMMON/SD/QQ(55),DALP(7,55),DQQ(55),DCPX(55),DADLP(7,55),DODAUN(55),
1DAUN(55)
COMMON/VCW/ICON,IE,IK,TMBPN,XBPN
COMMON/VW/NPTS,RF,XBP,XJ
DO 511G I=1,NPTS
TH(I)=THN(I)
X(I)=XBPN
Y(I)=YN(I)
Q(I)=QK(I)
P(I)=PN(I)
511G CONTINUE
\[
\begin{align*}
T(i) &= TN(i) \\
RHO(i) &= PHCM(i) \\
EM(i) &= EM(i) \\
XMU(i) &= KPM(i) \\
TAU(i) &= TAUN(i) \\
Q0(i) &= PQA(i) \\
GCPX(i) &= CPRM(i) \\
DTAUI(i) &= DTAI(i) \\
DAPQ(i) &= DEQN(i) \\
Q0437J &= 1, \text{ NSP} \\
ALPJ(i, j) &= ALPNJP(j, i) \\
DALPJ(i, j) &= DALPNJP(j, i) \\
DALP(i, j) &= DALPNJP(j, i) \\
CP(i, j) &= CNP(i, j) \\
HK(i, j) &= HKN(i, j)
\end{align*}
\]

4090 CONTINUE
\[
W(i) = W(i) \\
F(i) = RN(i) \\
GAM(i) = GAPNP(i) \\
CPX(i) = CPXNP(i)
\]

5110 CONTINUE
\[
XJ(i) = 1 + XJ \\
IF(Y(i), EQ, 0) XMN(i) = 0 \\
DO 10 I = 2, NPTS \\
YFUN = Y(i-1, XJ + Y(i, XJ) - Y(i, XJ - Y(i-1, XJ)) / XJ \\
ROQV = RNCM(i)*CM(i)*COS(TH(i)) + RHO(i-1)*CM(i)*COS(TH(i-1)) / 2 \\
XMN(i) = XMNP(i) + ROQV*YFUN
\]

10 CONTINUE
\[
DO M=1, NPTS \\
CPX(i) = CPX(i) \\
CALL THERMOT(i, H1, CP1) \\
DO 8410 I = 1, NPTS \\
CPX(i) = CPX(i) \\
HM(i) = HM(i)
\]

8410 CPX(i) = CM(i) * ALP(i) + CP1(i) \\
RHO(i) = GEW(i) * CM(i) / T(i) \\
GAM(i) = CM(i) - CNP(i) - R(i) / CPN(i) \\
RI = R / RI \\
EMH(i) = CM(i) * CM(i) / SQRT(GAM(i) * R / T(i)) \\
IF(EMH(i), LT, 1, GO TO 8409 \\
XMU(i) = XMU(i)
\]

8409 CONTINUE
\[
XBP = XBP \\
YBP = YBP(NPTS) \\
THBP = TH(NPTS) \\
IF(YBP, EQ, YN(NPTS)) RETURN \\
YBP = YBP \\
THBP = THFA \\
RETURN
\]
END
SUBROUTINE SHEAR1(CFF, VISO)
COMMON/AC1, B00, PIN
COMMON/BA/ALP(7,55), EMINF, WMIF
COMMON/GJ, CP(7, 55), CP1(7), CPX(55)
COMMON/EFF/EPH(55), GA(55), P(55), TH(55), Y(55)
COMMON/PCJ, GCH, NISP, T(55)
COMMON/QJ, QT(7, 55), Q(55), RHO(55), XM(55)
COMMON/SC/QN(55), OALP(7, 55), DQN(55), OCPX(55), DALP(7, 55),
10 OAU(55), TAU(55)
COMMON/WV, NPTS, RE, XAP, XJ
DIMENSION LOCS(4)
K1=0
DO 100 K=1, 8
100
LCSS(K)=0
LAST=NPTS
LAST1=NPTS+1
LAST2=NPTS-1
Y(LAST1)=2.*Y(LAST)-Y(LAST2)
0 (LAST1)=Q(LAST2)
1 (LAST1)=T(LAST2)
CPX(LAST1)=CPX(LAST2)
P(LAST1)=P(LAST2)
TH(LAST1)=TH(LAST2)
TAU(LAST1)=0.
BQ(LAST1)=B.
DQX(LAST1)=D.
DO 6290 J=1, NISP
DALP(J, LAST1)=0.
6290
ALP(J, LAST1)=ALP(J, LAST2)
DO 6292 K=2, LAST
DELY2=Y(K-1)-Y(K)
DELY1=Y(K)-Y(K-1)
IF (DELY2.LT.1.E-06 OR DELY1.LT.1.E-06) GO TO 1301
SUM=DELY1*DELY2
RATIO1=DELY1/DELY2
RATIO2=DELY2/DELY1
SU=1./SUM
RMR=RATIO1-RATIO2
TAU(J)=Q(J+1)*RATIO1-Q(K)+RMR-Q(K-1)*RATIO2)*SU
OD1=1./DELY2
DTAU(J)=2.*Q(J+1)*DELY1*SU-Q(J)+Q(K-1)*DELY2*SU)/DELY1*OD
BQ(J)=T(J+1)-RATIO1-T(K)*RMR-T(K-1)*RATIO2)*SU
BQ(J)=D(J+1)-T(J-1)*DELY1*SU-T(K)+T(K-1)*DELY2*SU)/DELY1*OD
DQX(J)=CPX(J+1)*RATIO1-CPX(K)*RMR-CPX(K-1)*RATIO2)*SU
DO 6291 J=1, NISP
DALF(J, K)=ALP(J, K+1)*RATIO1-ALP(J, K)*RMR-ALP(J, K-1)*RATIO2)*SU
DDALP(J,K)=2.*ALP(J,K+1)\*DELY1\*SU=ALP(J,K)\*ALP(J,K-1)\*DELY2\*SU
1\*DELY1\*CD

6291 CONTINUE
GO TO 6292
1301 KKI=KKI+1
LOGS(KKI)=K

6292 CONTINUE
TAU(1)=0.0
C(V)=Y(1)-Y(1)
IF(INCO.EQ.1)TAU(1)=CFF*PE*RHO(1)**Q(1)**2.5/VISO
PQ(1)=S*C
DCPX(1)=0.
DTAU(1)=Q(2)-C(1)*7.0/(Y(2)-Y(1))**2
IF(INMOD.EQ.1)DTAU(1)=4.*Q(1)**(1)/dy**2-2.*TAU(1)+TAU(2)/DY*
\+CTAU(2)
\+EP(1)=1.0/(T(2)-T(1))**2.0/(Y(2)-Y(1))**2
IF(INCO.EQ.1)DB0(1)=4.*T(2)-T(1)/dy**2-2.*Q(2)/dy+Q(2)
D66293J=1, NSP
DALP(J,1)=0.0
CDALP(J,1)=2.*ALP(J,2)-ALP(J,1)/DY(2)-
\+Y(1)**2
IF(INCO.EQ.1)DDALP(J,1)=4.*(ALP(J,2)-ALP(J,1))/dy**2-2.*GALP(J,2)
\+1(dy+CDALP(J,2)

6293 CONTINUE
DO 103 J=1,8
IF(INCO.EQ.0) GO TO 102
K=LOGS(P)
L=1
IF(K/2)>2.NE,M) L=-1
YNK=Y(K)-Y(K+1)
QK(K)=2.*T(K)-T(K+1)(K+1)\+YNK=Q2(K+1)
TAU(K)=2.*Q(K)-Q(K+1)/YNK\+TAU(K+1)
DCPX(K)=2.*(CPX(KI)-CPX(I))/YNK-DCPX(K+1)
DTAU(K)=2.*TAU(K)-TAU(K+1)/YNK-DTAU(K+1)
DQK(K)=2.*(QK(KI)-Q(K+1))/YNK-DQK(K+1)
DO 103 J=1,NSP
DALP(J,K)=2.*(ALP(J,K)-ALP(J,K+1))/YNK-DALP(J,K+1)

102 CONTINUE
DO 1006 J=1,8
TAUN(J)=TAU(J)
QON(J)=Q(J)
DQNPX(J)=DCPX(J)
DTAUN(J)=CTAU(J)
DQNP(J)=CPQ(J)
DD 7003 J=1,NSP
DALP(J,J)=0
7001 DDALP(J,J)=DDALP(J,I)
119

7000 CONTINUE
   NPTS=LAST
   RETURN
END

SUBROUTINE SHEAR2(CFF, VISD)
COMMON/AC/I00D, PIN
COMMON/DP/VN55)
COMMON/HY/ALPN(7,55), CPN(7,55), CPXN(55), EMN(55), GAMN(35), MN?F, 591,
ILS, P1(55), QA(55), RHN(55), RN(55), TH(55), TN(55), XHUN(55)
COMMON/PC/JCEN, MSP, T(55)
COMMON/SG/B0N(55), DAPN(7,55), DQON(55), DCPXN(55), D0ALPN(7,55),
1DTAUN(55), TAUN(55)
COMMON/MV/NPTS, AE, XP, XJ
DIMEaSLOC310)
KIII=0
DO 106 K=1,8
100 LOC5(K)=6
   LAST=NPTS
   LAST1=NPTS+1
   LAST2=NPTS-1
   YN(LAST1)=2.0*YN(LAST1)-YN(LAST2)
   QN(LAST1)=QN(LAST2)
   TNLAST1=TN(LAST2)
   CPM(k)k LAST1)=CPXN(LAST2)
   PHP(LAST1)=PH(LAST2)
   THN(LAST1)=THN(LAST2)
   TAUN(LAST1)=0.
   BQN(LAST1)=0.
   DCPXN(LAST1)=0.
   DO 300J=1,NSP
      DAPN(J,LAST1)=0.
3001 ALPN(J+LAST1)=ALPN(J,LAST2)
   DO 6002 K=2,LAST
      DELY2=YN(K+1)-YN(K)
      DELY1=YN(K)-YN(K-1)
      IF(DELY1.LT.0.06.OR.DELY1.LT.1.E-06) GO TO 1301
      SUM=DELY1+DELY2
      RATIO1=DELY1/DELY2
      RATIO2=DELY2/DELY1
      SUM=1./SUM
      RR1=1./DELY2
      RMR=RR1*RR1
      TAUN(K)=QN(K+1)*RATIO1-QN(K)*RMR-QN(K-1)*RATIO2*SU
      DTAUN(K)=2.*QN(K+1)*DELY1*SU-QN(K)-QN(K-1)*DELY2*SU/DELY1*OD
      OQN(K)=TH(K+1)-RATIO1-TH(K)*RMR-TH(K-1)*RATIO2*SU
      DQON(K)=2.*TH(K+1)*DELY1*SU-TH(K)+TH(K-1)*DELY2*SU/DELY1*OD
      DCPXN(K)=CPXN(K1)*RATIO1-CPXN(K)+RMR-CPXN(K-1)*RATIO2*SU
   DO 4001 J=1,NSP
      DAPN(J,K)=TALPN(J,K+1)*RATIO1-ALPN(J,K)*RMR-ALPN(J,K-1)*RATIO2

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OF POOR QUALITY
1*SU
  DDALPN(J,K)=2.*[(ALPN(J,K+1)*DELY1*SU-ALPN(J,K)*ALPN(J,K-1)*DELY2
1*SU)/DELY1*00
4081 CONTINUE
  GO TO 6082
1311 KXI=KKI+1
6082 CONTINUE
  FTAUN(1)=G.0
  DIF=Y(2)-YN(1)
  IF(IBCD.EQ.1) TAUN(1)=CFF*PE*RHCHN(1)*QN(1)**2.*5/VISO
  QN(1)=0.0
  OPCXN(1)=0.
  OTAUN(1)=(QN(2)-QN(1))**2./((YN(2)-YN(1))**2.
  IF(IBCD.EQ.1) TAUN(1)=4.*(QN(2)-QN(1))/DY**2-2.*{(TAUN(1)+TAUN(2)
1)/CY+CTAUN(2)
  DQBN(1)=(NY(2)-TN(1))**2./((YN(2)-YN(1))**2.
  IF(IBCD.EQ.1) DQBN(1)=4.*{(YN(2)-YN(1))**2.
  004082J=1, NSP
  DDLPN(J, J)=2.*[(ALPN(J, 2)-ALPN(J, 1))/(YN(2)-
  YN(1))**2.
  IF(IBCD.EQ.1) DDLPN(J, J)=4.*{(ALPN(J,2)-ALPN(J,1))/DY**2-2.*DDLPN
1(J,2)/CY+CDLDPN(J,2)
4082 CONTINUE
  00 131 L=1.0
  IF(LCSEX16.EQ.0) GO TO 132
  K=LCSEX16
  L=1
  IF(M2*2.HE.M) L=1
  YNK=YN(K)-YN(K+L)
  GQBN(K)=2.*{(YN(K)-YN(K+L))/YNK-BG N(K+L)
  TAUN(K)=2.*{(QN(K)-QN(K+L))/YNK-TAUN(K+L)
  DQBN(K)=2.*{(CPNXN(K)-CPXN(K+L))/YNK-DQXN(K+L)
  OTAUN(K)=2.*{(TAUN(K)-TAUN(K+L))/YNK-OTAUN(K+L)
  DQBN(K)=2.*{(QN(K)-QN(K+L))/YNK-QBN(K+L)
  00 102 J=4,NSP
  DDLPN(J,K)=2.*{(ALPN(J,K)-ALPN(J,K+1))/YNK-DDLPN(J,K+1)
70 103 DDLPN(J,K)=2.*{(ALPN(J,K+1)-ALPN(J,K))/YNK-DDLPN(J,K+1)
101 CONTINUE
102 CONTINUE
NPTS=LAST
RETURN
END
SUBROUTINE LPOINT1(I,QPTP)
COMMON/AB/EPP,EPQ,EPT
COMMON/AC/IBOD,PIN
COMMON/AL/GAR,GEN
COMMON/VA/ALP(7,55),EMINF,WINF
COMMON/R8/S18,S2R,S39T
COMMON/R8/CGAMA,PO,QR,HRMC,TH8,W9,XMUB,Y9
COMMON/GMWDTN(7,55),XN(55)
COMMON/CJ/CP(7,55),CP1(71),CPX(55)
COMMON/CJ/KWMOLE(7)
COMMON/Q/K(155)
COMMON/EF/CPIN,40
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COMMON/EF/CPIN,40
COMMON/EF/CPIN,40
COMMON/EF/CPIN,40
COMMON/EF/CPIN,40
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COMMON/EF/CPIN,40
COMMON/EF/CPIN,40
COMMON/EF/CPIN,40
COMMON/EF/CPIN,40
COMMON/EF/CPIN,40
COMM...
8501 CONTINUE
2000 CONTINUE
YB=(Y(K)+Y(I))/2.
KIP4=0
8372 CONTINUE
RATG=(VB-Y(I))/(Y(K)-Y(I))
THM=T(I)+RATG*(TH(K)-TH(I))
XNUH=XNU(I)+RATG*(XNU(K)-XNU(I))
EMZ=XNUH*(ALPHA_BETA*THM*XNUH*THM(I)*XNUH(I))
IF(10PTP.NE.0.) EPZ=EP1L+RATG*(E=1R-EM1L)
YDT=YB
XR=XRF
YB=YN(I)-EM2*DELX
TESTY=(YB-YPT)/(Y(K)-Y(I))
IF(ALMS(0).LT.0.11) GO TO 2371
KIP4=KIP4+1
IF(KIP4.EQ.2D) GO TO 8372
WRITE(6,9191)
WRITE(6,222)
9191 FORMAT(11)
WRITE(6,222)
2020 FORMAT(* UNABLE TO LOCATE Y LOCATION OF CHARACTERISTIC IN LPOINT 1)
STOP
8372 RATG=(VB-Y(I))/(Y(K)-Y(I))
51 THM=T(I)+RATG*(TH(K)-TH(I))
QB=QB(I)+RATG*(QK-Q(I))
PB=P(I)+RATG*(PK-P(I))
TT=T(I)+RATG*(TK-T(I))
TAU=TAU(I)+RATG*(TAUI)-TAU(I))
DB=DB(I)+RATG*(DK-D(I))
DCPX=DCP(I)+RATG*(DCPI)
DTAUR=DTAU(I)+RATG*(DTAUI)-DTAUI)
DBQ=DBQ(I)+RATG*(DBQK)-DBQ(I)
DTCHP(I)=DTCH(I)+RATG*(DTCH(K)-DTCH(I))
DTCHB=DTCH(I)+DTCH(I)*.5
CPX=C-0
MB=8.C
CMB=C.
CMB=C.
CALL THERMO(TT,HE,CP)
DB=40., NSP
ALPBJ=ALP(I,J)+RATG*(ALP(J,K)-ALP(J, I))
DALPI=DALP(J,I)+RATG*(DALP(J,K)-DALP(J, I))
DDALP=DDALP(J,I)+RATG*(DDALP(J,K)-DDALP(J, I))
CM=CM+DALP(J,I)*CP(I)
CM=CM+DALP(J,I)*CP(I)
CM=CM+DALP(J,I)*CP(I)
CM=CM+DALP(J,I)*CP(I)
CM=CM+DALP(J,I)*CP(I)
CM=CM+DALP(J,I)*CP(I)
CM=CM+DALP(J,I)*CP(I)
W=WH+ALPBJ*WTHI
WDOT(J)=HDOT(I,J)+RATG*(WDOT(J,K)-WDOT(J, I))
SCHEDULE

DACNN=DACH(J,I)+RATG*(DACH(J,K)-DACH(J,I))
DACNH=(DACHN+DACH(J,I))/5
DACHP(J,I)=DACHN

4060 CONTINUE
WD=1./NB
RD=RO/NB
GAMO=CPX0/(CPX0-RB/CPX)
OR=1./RB
RHOO=POH0*GEN/TT
EM=QR*EPINF=SQRT(GAR/GAMO*OR/TT
XNU=ZMUL(EM)
IF(DL.EQ.0.) GO TO 8392
Y P(1)=Y 0
X P(1)=X 0
G P(1)=G 0
P P(1)=P 0
T P(1)=TT
W P(1)=W 0
R P(1)=R 0
TH P(1)=TH 0
EN P(1)=EN 0
GQ P(1)=GQ 0
RHO P(1)=RHO 0
XNU P(1)=XNU 0
CPX P(1)=CPX 0
GAM P(1)=GAM 0
TAU P(1)=TAU 0
DBQ P(1)=DBQ 0
DTAUB(1)=DTAUB
DCPX(1)=DCPX(1)
GO 3939 J=1:NSP
ALP P(J,J)=ALP B(J)
DALP P(J,J)=DALP B(J)
3939 GOALPP(J,J)=GOALP B(J)
8392 CONTINUE
IF(BETA ME,0.)GOT04070
TAU(1)=TAU(1)
BQN(1)=BQN(1)
DGPX(I)=DGPX(I)
DTAUN(I)=DTAUN(I)
MN(I)=MN(I)
CM(I)=CM(I)
CPX(I)=CPX(I)
CH2O=CH2O
GO 407 I=1,NSP
DALPN(J,J)=DALP(J,J)
ODALPP(J,J)=ODALP(J,J)
MC(J,J)=M(J,J)
124

4071 CONTINUE

4072 CONTINUE

IF(DEL.EQ.0.0) GO TO 4072

CM2=0.0

DO 4073 J=1,NSP

MC(J)=MN(J,I)

WOOTC(J,J)=WOOTN(J,I)

4073 CM2=CM2+DALPN(J,I)*CPN(J,I)

CONTINUE

V1=VISB

V2=VISC

DV1=DVISE

DV2=DVISC

TA1=TAUE

TA2=TAUN(I)

NT1=DATAE

DT2=DTAUN(I)

Q1=QGB

Q2=QBN(I)

V1=V

V2=Y(N(I)

TH1=TH

TH2=THN(I)

SI1=SI1(XJ,RE)

C1=CPX8

C2=CPN(I)

SB1=SBQ8

CB2=CBQN(I)

PX1=CPXP0

PX2=CPX(I)

CM1=CM28

CM2=CM2

IF(DEL.EQ.0.0)1,2

1 SB9=SB(XJ,RE)

V1=VISB

DV1=DVISE

TA1=TAU(I)

DT1=DATAU(I)

Q1=Q(I)

V1=Y(I)

TH1=TH(I)

SI0=SI1(XJ,RE)

GO TO 56

2 SB9=SB(XJ,RE)

56 IF(DEL.EQ.0.0)3,4

3 V1=VISB

DV1=DVISE

C1=CPX(I)
B1=BC(I)
D1=CE(I)
TA=TAU(I)
TM=THI(I)
Y1=Y(I)
PX1=DCPX(I)
CH1=CHD
S2=S2(XJ,RE)

4 S3BT=0.
S3OT=0.0
D04975J=1, NSP
AL=DALPE(J)
AL2=DALPN(J,,L)
D01=DDALPE(J)
D02=DDALPN(J,,L)
V1=VISB
D1=VISB
B1=GBS
TM=THO
Y1=VA
S3B(J)=S3(XJ,RE)
IF (DEL.EQ.0.15.8
5 V1=VISD
D1=VISD
AL=DALPJ(J,I)
D01=DDALPJ(J,I)
B1=BC(I)
TM=THI(I)
Y1=Y(I)
S3OT=S3(J)+S3(I)+/THOLE(J)
S3BT=S3BT+S3B(J)/THOLE(J)

4075 CONTINUE
IF (DEL.EQ.0.) RETURN
B1=F1(I)
DUM=XJ
I15=0
VAX=VBX(I)
IF(VAX.LT.1.E-9.E.AND.XJ.NE.3.) I15=1
XX=XJ
IF(I15.EQ.1)60,61
60 XJ=0.
61 B3=F2(I,S1B,S2B,S3B)
X=XX
IF(JCHEM.EQ.0) GO TO 7254
B3=0.
GO TO 7257
7254 TP1=TI(I)+DTCH(I)+TT/2.
B3=F3(TP1,STCHB,TT,THN(I),THB,THM(I),DACHB,W8,WN(I))
7257 OPTT=1.
IF(OPTP.NE.0.) OPTT=-1.
B4=F4(126+OPTP,XMUB,TMB,XMUN(I),THN(I))
B2=F2(B2+OPTP)*0.4
IF(OPTP.NE.0.) AND. IPRES U.EQ.0) GO TO 7444
IF(OPTP.NE.0.) AND. IPRES U.EQ.1) GO TO 7482
IF(IBCD.EQ.1) GO TO 7444
IF(IPRESS.EQ.1) GO TO 7482
AX=6.1
IF(I15.EQ.0) GO TO 100
AX=XJ*SIN(XMUB)*SIN(TMB-XMUB)
IF(BETA.GT.0)AX=(AX+XJ*SIN(XMUN(I))
1/STAND(I)-XMUN(I))*.5
AX=1.-AX
100 CONTINUE
PN(I)=PB-(THB*AX+B2*(XN(I)-XB))/B1
GO TO 7445
7482 CONTINUE
KPRESS=KPRESS+1
IF(KPRESS.LT.6) GO TO 3232
IERR=7482
WRITE(6,3131) IERR,I,THN(I),PN(I),YN(I),THB,PB,YB
3131 FORMAT(215,F13.5)
STOP
3232 THDN=THN(I)
KIP=6
THN(I)=THB+OPTT*01*(PN(I)-PB1+OPTT*B2*(XN(I)-XB))
IF(ABS THN(I)-THDN), GT,1.E-64) GO TO 8372
YN(I)=Y(I)+.5*(TAN(IH(I)))*TAN(IH(I)) *DELX
GO TO 7445
7444 PN(I)=PB+OPTT*(THN(I)-THB)/B1-B2*(XN(I)-XB)
7445 CONTINUE
IF(ABS PN(I)+P(I)**LE.EPP) PN(I)+P(I)
DELX=2.*{(XN(I)-X(I)) / C0S(IH(I)) +COS(IH(I))}
TERMS=PHN(I)**Q(I)
IF(BETA.GT 0) TERMS=TERMS+AMON(I)
1*QNI(I)**.5
OT=1./TERMS
QN(I)=SIC*QUE-PN(I)+P(I)**OT*O(I)
IF(AABB(QN(I))=Q(I))**LE.EPQ) QNI(I)=Q(I)
IF(BETA.EQ.0) CPXN(I)=CPX(I)
DTCHMN(I)=CPX(I)+P(I)**Q(N(I)+Q(I)) / (CPX(I)+CPXN(I))**EIN*OT
DTDIFF=SEC*DEL**SIN**2 / (CPX(I)+CPXN(I))**OT
TN(I)=T(I)+DTCHMN+DTDIFF
IF(AABBTMN(I)=T(I))**LE.EPT) TN(I)=T(I)
CPXN(I)=0.0
WN(I)=0.0
CALL THERMO(IH(I),N1,CP1)
D0480J=1, NFP
DALTDF(J,J)=S30(J)*DELS/TERM2
ALPH(J,J)=ALPH(J,J)*DALTDF(J,J)

HN(J,J)=H(J)
CPN(J,J)=CPN(J,J)

WN(J,J)=WN(J,J)+ALPH(J,J)/MTDLE(J)
CPN(J,J)=CPN(J,J)+ALPH(J,J)*CPN(J,J)

CONTINUE

WN(J,J)=1./WN(J,J)
RN(J,J)=RC/WN(J,J)
GAMA(J,J)=CPN(J,J)/(CPN(J,J)-PN(J,J)*CPN(J,J))
DN=1./RN(J,J)
RN0(J,J)=PN(J,J)*GAMA(J,J)*GAMA(J,J)
EMN(J,J)=Q(J,J)*EMINF*SQRT((GAMA(J,J)*Q(R/J,J)))
XMUN(J,J)=ZMU*(EMN(J,J))

RETURN
END

FUNCTION CERY(X1,X2,X3)
COMN=Q/DELT=DEL2, RATE=RAT2, SUM
DERY=(X1*RATE-X2*RAT2-X3*RAT2)/SUM
RETURN
END

SUBROUTINE THSSS(THSS)
COMN=AX/JSUB, JSUAU
COMN=EF/EN(55), GAM(55), P(55), TH(55), Y(55)
COMN=CR/DEL1, DEL2, RATE, RATE, SUM
COMN=RS/GPS, PS, THS, THMSL, THSU
JSUB=JSUB+1
JSUB=JSUB+1
CALL SHER(JSUB, JSMU)
CALL SHER(JSUB, JSMU)
CALL SHER(JSUB, JSMU)

X=0
DEL1=YJSLBP-JJSBUU
DEL2=YJSBUU-JJSBM
SUM=DEL2+DEL1
RATE=DEL1/DEL2
AY=DERY(ASH1, ASH2, ASH3)
COSTH=COSTH(THJSBUU)

TERM1=AY*COSTH
EN=DERY(ENJSUBP)*ENJSUBU*ENJSUBM
TANTH=TAN(THJSBUU)
EMN=EM/COSTH=EMS*TANTH
G贤=GM(ENJSUBU)*P(JSUBU)*EMJSUBU**2
TERM2=2.*COSTH*ENJSUBU*EMN*PS
GPM=DERY(GAMJSUBP)*P(JSUBP)*ENJSUBP**2*GPM*GAMJSUBU*P(JSUBU)
1*ENJSUBM**2
GPM=GPM/COSTH=TANTH
THY=DERY(THJSUBP)*THJSUBU*THJSUBM

RETURN
END
TNNM=TH/V*ST=THS*TANH
TENM=GPM*S*OSTM*OSTH*(EM{JSUBU)*$2-1.1)*THS
THS=DER{THSU,THS,THSL}
TERM5=GPM*SIN{TH,JSUBU)*THS
THYM=DER{TH,JSUBP+1)+TH,JSUBP)*TH,JSUBU)
THYM=DER{TH,JSUBP+1)*TH{JSUBN)+TH{JSUBN-1)}
THNNP=THYM/COSTH=THSU*TAN
THNNN=THYM/COSTH=THSL*TAN
THYM=DER{THNNP,THNN,THNNL}
TERM6=GPM*COSTH*THY
D=GPM*EM{JSUBU)*$2-COSTH*COSTH-1.1)
XNUM=TERM1+TERM2+TERM3+TERM4+TERM5+TERM6
THSS=XNUM/D
RETURN
END
FUNCTION ZMU(EM)
ZMU=ATAM{1.0/SREM{EM+1.01)}
RETURN
END
SUBROUTINE THERMC(TI,M,C8)
COMMON/EDCPIN,RO
COMMON/IRRH,W20,SWFUEL
COMMON/TIN/TIN
DIMENSION WTHOLE(9)
DIMENSION M(7),CP(7)
DIMENSION Q(9),AP(9)
WTHOLE(1)=0.09
WTHOLE(2)=16.0
WTHOLE(3)=16.016
WTHOLE(4)=2.016
WTHOLE(5)=32.0
WTHOLE(6)=17.008
WTHOLE(7)=28.014
WTHOLE(8)=44.011
WTHOLE(9)=WFLUEL
T=T+TIN
C1=RO/CP1\nC2=C1/TIN
DO 10 J=1,9
M=C2/WTHOLE(J)
H2=C1/WTHOLE(J)
CALL COEFF(J,T,TA,CT,CM,DS,DS,F,F,G)
Q(J)=T*(A*TB+5*TCP(C/F,3.0*10-25+E*2*T))
Q(J)=C1/T
AP(J)=A*T*(G+T(D+E*T))
10 CONTINUE
H(1)=Q(1)
```
H(2)=Q(2)
H(3)=RHO*ACOS2*Q(1)
H(4)=Q(4)
H(5)=Q(5)
H(6)=Q(6)
H(7)=Q(7)
C(13)=AP(13)
C(15)=AP(15)
C(17)=AP(17)
C(18)=RHO*AP(3)+ACOS2*AP(4)
C(19)=AP(4)
C(20)=AP(5)
C(21)=AP(6)
C(23)=AP(7)
RETURN
END
SUBROUTINE TOL(T,TEMP,X,Y,N)
DIMENSION X(N),Y(N)
DO 10 J=1,N
  IF(TX-X(J))0,9,10
8  J=J+1
  TEMPy=Y(J)+{Y(J)-Y(J+1)}*{(TX-X(J))-X(J+1)}
10  GO TO 11
9  TEMPy=Y(J)
  GO TO 11
10 CONTINUE
11 RETURN
END
FUNCTION XM1(ALPHA,BETA,TA,XA,TC,XC)
XM1=ALPHA*TAN(TA+X)
IF(BETA.GT.0.) XM1=BETA*TAN((T+C)+X)
RETURN
END
FUNCTION XM2(ALPHA,BETA,TA,XA,TC,XC)
XM2=ALPHA*TAN(TA-T)
IF(BETA.GT.0.) XM2=BETA*TAN((C)+T)
RETURN
END
FUNCTION XM3(ALPHA,BETA,TO,TC)
XM3=A*TAN(TD)
IF(BETA.GT.0.) XM3=A*TAN(TC)
RETURN
END
SUBROUTINE NUCUS(T,PI1,PO1,RHO,ALPHA,DX,L)
COMMON/AC/IBDE+PIN
COMMON/BC/CHMEN
COMMON/CA/HHQTH<.S99) *R(99)
COMMON/GE/RAD,ROU,VIN,VISINF
COMMON/HI/DALCH1,OTCPH
COMMON/PC/ALPHN(7).*IF(4.L,PRES
```
COMMON/QS/RH0I(2),W00T(755),W00TC(7),WP(2),XHUP(2)
COMMON/TN/TIN
DIMENSION ASAVE(7),WTHOLE(7),ALPHA(7)
WTHOLE(1)=1.068
WTHOLE(2)=16.
WTHOLE(3)=19.016
WTHOLE(4)=2.016
WTHOLE(5)=32.6
WTHOLE(6)=17.088
WTHOLE(7)=28.814
TXX=TI
UXX=U1
TERM=RHO1*U1
TT=TT*TN*.001
P1=P1/FH*PRES/2116.
U1=U1*U1
DELTAT=4.E-7
DELTAX=U1*DELTAT
JER=INT(DX/DELTAX)
IF (JER.EQ.0.0) JER=1
DELT=DX#FLOAT(JER)
SAVE=TI
DO 201 J=1,7
201 ASAVE(J)=ALPHA(J)
DT=DELT/41
P=P1
DP=2116./09517.
RH=P*CP/TT*1.0
DO 10 JERRY=1,JER
P=P1
DUM=0.C
DO 96 J=1,7
96 DUN=DUM+ASAVE(J)/WTHOLE(J)
RHO=RH/DUM
IF (ICGCHM.EQ.0.0)
1WRITE(6,250) TI,P,RHO,ASAVE,DT,TN,ALPHN
250 FORMAT(9E18.3) T,J,PRHO,ASAVE,DT,TN
CALL FOCUS(TI,P,RHO,ASAVE,DT,TN)
IF (ICGCHM.EQ.0.0)
1WRITE(6,250) TI,P,RHO,ASAVE,DT,TN,ALPHN
IF (ICGCHM.EQ.0.0)
1WRITE(6,232)
232 FORMAT(//)
IF(JERRY.EQ.1) GO TO 100
DO 110 J=1,7
110 W00T(J,L)=TERM*(ALPHN(J)-ASAVE(J))/DELX
100 CONTINUE
IF(JERRY.EQ.1) GO TO 10
131

TI=TN
DO 20 J=1,7
20 ASAVE(J)=ALPHN(J)
10 CONTINUE
OTCHEP=(TI-TSAVE)*1600./TIN
DO 40 J=1,7
DALCH(J)=ALPHN(J)-ALPHA(J)
40 WCOTN(J,L)=TERM*(ALPHN(J)-ASAVE(J))/DELX
TI=TXX
P1=PKX
U1=UXX
RETURN
END

SUBROUTINE COEFF(I,T,A,B,C,D,E,F,G)
IF(T<1000)GO TO 10
GO TO (15,16,13,11,12,17,14,16,19)*I
10 A = 2.496894E03
  B = 4.193211E-03
  C = -9.611932E-06
  D = 9.512266E-09
  E = -3.203842E-12
  F = -9.672537E-02
  G = -1.411785E00
GO TO 40
15 A = 3.718994E00
  B = -2.5167288E-03
  C = 8.5887353E-06
  D = -8.2960716E-09
  E = 2.7082100E-12
  F = -1.0576766E03
  G = 3.9363724E00
GO TO 40
16 A = 4.1965016E00
  B = -1.7244334E-03
  C = 5.6982316E-06
  D = -4.4930844E-09
  E = 1.4233365E-12
  F = -3.0268778E04
  G = -6.0616246E-01
GO TO 40
13 A = 4.1965016E00
  B = -1.7244334E-03
  C = 5.6982316E-06
  D = -4.4930844E-09
  E = 1.4233365E-12
  F = -3.0268778E04
  G = -6.0616246E-01
GO TO 40
14 A = 3.6916148E00
  B = 0.3312552E-03
  C = 2.1503179E-06
  D = -9.688341E-10
  E = -9.672537E-14
  F = -1.0625336E03
  G = 2.874980E00
GO TO 40
15 A = 2.5000000E00
A = 3.021889E+00
B = 2.1737249E+03
C = 3.7542203E+06
D = -2.9947200E-09
E = 9.0777547E+13
F = 2.5137190E+04
G = 2.6460076E+00
GO TO 40

16
A = 3.021889E+00
B = 2.1737249E+03
C = 3.7542203E+06
D = -2.9947200E-09
E = 9.0777547E+13
F = 2.5137190E+04
G = 2.6460076E+00
GO TO 40

17
A = 3.021889E+00
B = 2.1737249E+03
C = 3.7542203E+06
D = -2.9947200E-09
E = 9.0777547E+13
F = 2.5137190E+04
G = 2.6460076E+00
GO TO 40

18
A = 2.59125
B = 6.43622E-03
C = 7.97796E-06
D = -1.29578E+00
E = 5.03078E-12
F = -9.421.8E
G = E
GO TO 40

20
GO TO (25, 26, 23, 21, 22, 27, 24, 28, 29, 31, 1)

21
A = 3.0436097E+00
B = 6.1187110E+04
C = -1.3993951E+09
D = -2.0331197E+11
E = 2.4593791E+15
F = -8.5491002E+02
G = -1.6481339E+00
GO TO 40

22
A = 3.5976129E+00
133

B = 7.0145603E-04
C = -2.2386670E-07
D = 4.2490159E-11
E = 3.3469204E-15
F = -1.1927918E-03
G = 3.7492659E 00
GO TO 40

23 A = 2.6707532E 00
B = 3.9717115E-03
C = -0.3355137E-07
D = 1.1790853E-10
E = -6.1973568E-15
F = -2.9088894E 04
G = 6.0838391E 09
GO TO 40

24 A = 2.0545711E 00
B = 1.5976316E-03
C = -6.2366254E-07
D = 1.1315849E-10
E = -7.6907878E-15
F = -6.9017465E02
G = 6.3902879E 00
GO TO 40

25 A = 2.5000988E 00
B = 0.0
C = 0.0
D = 0.0
E = 0.0
F = 5.1470497E 04
G = -4.9081096E01
GO TO 4C

26 A = -2.5372567E 00
B = -1.0422198E-05
C = 8.8017926E-09
D = 5.9640261E-12
E = -5.5743600E-16
F = 2.9230007E 04
G = 4.9767942E 00
GO TO 40

27 A = -2.8996544E 00
B = 9.3836861E-04
C = -2.1879904E-07
D = 1.9827855E-11
E = 3.452940E-16
F = 3.8011792E 03
G = 5.5597016E 00
GO TO 40

28 A= 4.1293
B=3.13229E-03
GO TO CO
mi0 027~E-02
C=-3*050
32E-06
Ox60 T7198b40
E=-b
0 501
3%-IC
G=e
0
SO
SETURN
€
N3
FUNCTION S2tXJr6EB
CONNO0E60E IN. PR r XLE
COHMOWSE/4Llr AL2 rBQlrB02
*Cl
rC2
*CHl.CHt
r
OCl
rDBZ. 001
~002 roll
498x442
0012 r OV
173x423
SPQZ
1
IPR
173x498
F=- sn @so 93
bl~CVZ~PXl~PX2~TA1~TA2~TH1~TH2~V1~V2~Y1~Y2
TERM 1 =
Yl eCIWRloRPRW
2*C2 *O BZ*RPR
TERM2=Cl*OVl eBOl*RPR+ CZ*OVZ.BOZ eRPR
TERM~=(V1*BQl~~Hl+V~*0Q~~C~Z~*XLE*~PR
TERM5= (V1*TA1**2+V2*TA2**2)*eIN
IF(X,J.NE.,.) GO TO 10
TERM6=0.
GO TO 2
10 Yf=Vl*Y2
IF(Yf*LE.1,E-10) GO TO 20
TERM6=V1*C1*BO1*PR+V2*C2*DB2*PR
GO TO 2
20 CONTINUE
TERM6=V1*CD1*PR+V2*C2*DA2*PR
S2=(TERM1+TERM2+TERM3+TERM4+TERM5+TERM6)/RE*.5/EIN
RETURN
END
FUNCTION S3(iJ,RF)
COMMON/E,G/EIN,PR,XLE
COMMON/SS/AL1,AL2,BO1,BOQ,C1,C2,CH1,CH2,QP1,QP2,DP1,DPQ,OT1,OT2,OV
A1,DV2,px1,px2,TA1,TA2,TH1,TH2,V1,V2,Y1,Y2
RPR=1/*PR
TERM1=V1*BO1*PR+V2*C2*CO2
TERM2=DV1*AL1+DV2*AL2
IF(X,J.NE.,.) GO TO 10
TERM3=0.
GO TO 2
10 Yf=Y1*Y2
IF(Yf*LE.1,E-10) GO TO 29
TERM3=COS(TH1)*V1*AL1/Y1+COS(TH2)*V2*AL2/Y2
GO TO 2
20 CONTINUE
TERM3=TERM1
2 S3=(TERM1+TERM2+TERM3)*KLE*RPR/RE*.5
RETURN
END
FUNCTION F1(H)
COMMON/Q0/GANM,BP,Q0,RHOB,THB,W0,XMUB,YB
COMMON/HL/ALPHA,BETA
COMMON/HN/ALPN(7,55),CPM(7,55),CPX(55),EHN(55),GAMN(55),HN(7,55),
1L=PN(55),QMN(55),RMON(55),RN(55),TN(55),WN(55),XMUN(55)
RP=1./P0
F1=(*XMUB)*COS(XMUB)/GANB*R0
RP1=1./PN(H)
IF (BETA.GT.0.) F1=(*F1+(*SIN(XMUB)))*COS(XMUB)*1)/GANM(1)*RPN*1.5
RETURN
END
FUNCTION F2(H,S1,S2,S1)
COMMON/Q0/GANB,BP,Q0,RHOB,THB,W0,XMUB,YB
COMMON/YP/YN(55)
COMMON/HL/ALPHA,BETA
COMMON/HN/ALPN(7,55),CPM(7,55),CPX(55),EHN(55),GAMN(55),HN(7,55),
1L=PN(55),QMN(55),RMON(55),RN(55),TN(55),WN(55),XMUN(55)
COMMON/HN/YPN(17,55),YP(17,55),YPN(55),YN(55)
COMMON/YW/HPTS,RE,XBP,XJ
IF (KJ.EQ.0.0) TERM1=0.0
IF (KJ.NE.0.0.) TERM1=(*SIN(XMUB))/YN
IF (KJ.NE.0.0.) ANO=(*BETA.GT.0.) TERM1=.5*(TERM1+(*SINTHB)*YN)
QS=1./Q0**2
TERM2=(*RHOB*QS)
SQ=1./QMN**2
IF (BETA.GT.0.) TERM2=.5*(TERM2+S1/RMON**SQ)
P1=1./Q0
TERM3=S21*(GANB-1.)/GANB*P1/Q0
P2=1./QMN
IF (BETA.GT.0.) TERM3=.5*(TERM3+S1/RMON**SQ)
QD=1./QMN
IF (BETA.GT.0.) TERM4=.5*(TERM4+S31*WN/WHOST**QD)
F2=(*TERM1+TERM2-TERM3-TERM4)
RETURN
END
FUNCTION F4(K,OPT,XMU1,TH1,XMU2,TH2)
F4=(*SIN(XMU1)/COS(TH1+OPT+XMU1)
IF (B.GT.0.) F4=(*F4+(*SIN(XMU2)/COS(TH2+OPT*X MU2)))*.5
RETURN
END
SUBROUTINE HERMAN(YH, YT, A, Y, CI, OB, CC, SCALE)
DIMENSION P(18,10), SNAL8(10), Q(10), A(18,10), Y(7), YH(7), CI(4), FINK(14)
TIM1=DT*2.0
TIM2=DT
T0=TIM2**2
T1=(DT**2-T0)**.5
T2=(DT**3-3.TIM1*T0)/3.0
T3=T0**.5
T4=TIM1*T0/3.0
K=1
DO 10 I=1,4
DO 10 J=1,4
P(K,J)=-A(I,J)*T3
10 P(K+1,J)=-A(I,J)*T1
19 K=K+2
K=1
DO 20 I=1,4
DO 20 J=1,4
P(K,J+4)=-A(I,J)*T4
20 P(K+1,J+4)=-A(I,J)*T2
20 K=K+2
J=1
DO 25 I=1,8,2
S=1./SCALE
P(I,J)=P(I,J)+TIM1*S
P(I,J+4)=P(I,J+4)+T0*S
K=1
DO 20 J=1,4
P(K,J)=P(K,J)+(TIM2-TIM1)*S
P(K,J+4)=P(K,J+4)+2.*T1*S
25 J=J+1
12 CONTINUE
DO 13 I=1,4
DO 13 J=1,0
13 Q(J)=0.0
FINK(1)=Y(1)
FINK(2)=Y(2)
FINK(3)=Y(6)
FINK(4)=Y(3)
K=1
DO 15 I=1,4
DO 15 J=1,4
15 Q(K)=CI(J+1)*FINK(J+1)*(TIM2-TIM1)
Q(K+1)=Q(K)
14 Q(K+1)=Q(K)
K=K+2
DO 16 I=1,4
J=J+1
Q(J+1)=Q(J+1)*CI(J+1)*(TIM2-TIM1)
16 Q(J)=Q(J+1)*CI(J+1)*(TIM2-TIM1)
DO 202 I=1,8
Q(I) = Q(I) / 1.0E-5
DO 292 J = 1, M
292 P(I, J) = P(I, J) / 1.0E-5
CALL CLEM(0, SMAL, P, Q)
CALL SOLY(SMAL, DT, CC, BB, YN)
RETURN
END

SUBROUTINE CLEM(M, X, D)
DIMENSION AT(10, 11), DT(10)
DIMENSION B(10, 10), D(10)
M = M + 1
DO 12 I = 1, M
12 X(I) = 0.0
DO 200 I = 1, M
200 AT(I, I) = C(I)
DO 201 I = 1, M
201 C(I) = 1.0
DO 201 J = 1, M
201 C(J) = 0.0
DO 32 N = 1, M
32 AT(N, N) = AT(N, N) - ABS(SQ(I)) 9.9.0
Q = AT(I, N)
IT = 0
DO 9 I = N + 1, M
IF (ABS(AT(I, N)) >= ABS(SQ(I))) 9.9.0
Q = AT(I, N)
IT = I
9 CONTINUE
IF (IT = N) STOP 77, 7C
DO 71 J = N + 1, M
71 TEMP = AT(N, J)
AT(N, J) = AT(IT, J)
AT(IT, J) = TEMP
7 DO 10 I = 1, M
10 AT(N, I) = AT(N, I) / C
10 IF (M = N) 50, 50 + 10
N1 = N + 1
DO 30 I = 1, M
30 AT(I, N) = AT(I, N) - AT(N, J) * 0
32 CONTINUE
50 X(M) = AT(N, N + 1)
DO 65 N = 2, M
NR = N + 1
Q = AT(NR, N + 1)
DO 60 I = NR, M
60 Q = AT(NR, I) * Y(I)
65 X(NR) = Q / AT(NR, NR)
RETURN
END
SUBROUTINE SOL1(SMALB, DT, CC, BB, Y, YN)
DIMENSION SMALB(10), Y(7), YN(7)
TIME=DT
TNX=TIME**2
YN(1)=YN(1)+SMALB(1)*TIME+SMALB(5)*TNX
YN(2)=YN(2)+SMALB(2)*TIME+SMALB(6)*TNX
YN(3)=YN(3)+SMALB(3)*TIME+SMALB(7)*TNX
YN(4)=YN(4)+SMALB(4)*TIME+SMALB(8)*TNX
YN(5)=CC*YN(1)+YN(6)*.5-YN(3)
YN(6)=BB-YN(2)+YN(6)*YN(3)*.5
RETURN
END
FUNCTION S1(XJ, RE)
COMMON/SS/AL1, AL2, AQ1, AQ2, C1, C2, CM1, CM2, DB1, DB2, D1, D2, DT2, DQ
A1, DQ2, PX1, PX2, TA1, TA2, TH1, TH2, V1, V2, Y1, Y2
TERM1=V1*DT1+V2*DT2
TERM2=DV1*TA1+DV2*TA2
IF(XJ, ME, 0) GO TO 10
TERM3=0.
GO TO 2
10 Y1=Y1+Y2
IF(Y1, LE, 1.E-10) GO TO 20
TERM3=COS(TH1)*V1*TA1/Y1+COS(TH2)*V2*TA2/Y2
GO TO 2
20 CONTINUE
TERM3=TERM1
2 S1=TERM1+TERM2+TERM3/RE+.5
RETURN
END
SUBROUTINE PUNCH
COMMON/AC/IBOD, FIN
COMMON/BA/ALP(1, 55), EMNF, MIF
COMMON/DE/ETB(4), IS(4)
COMMON/EF/EMF(5), GAM(55), P(55), TH(55), Y(55)
COMMON/EG/EIN, PR, XLE
COMMON/FH/KX1, KX2, XP
COMMON/JL/J0, J1, J2, J3, J4, J5
COMMON/MJ/K0, JN, NPT
COMMON/PC/ALPHN(7), IFUEL, PRES
COMMON/PR/JCHEM, NSP, T(55)
COMMON/TW/TIN
COMMON/VV/MTPS, RE, XP, XJ
COMMON/YX/APS, APUS, DELTAY, E80DS, I80DS, INTACT, IPRS, IPUS, ITYP, 1J80DS, INAX, RHEAT, XX2, XX4, YBOT, YTP
COMMON/YX/ABODS, BPRESS, CPRESS
COMMON/YZ/BPRESU, CHEMFC, CPRESU, ENSUB, RTTH, XSTEP
COMMON/YZ/ABODS, BBOD, BBOD, E80D, E80D, F80D, G80D, IAVE, IPUNCH, J80D, KKKK
REIND 7
100 FORMAT(11E15)
101 FORMAT(18E10.3)
200 FORMAT(15,5X,1PE10.3)
102 FORMAT(7E10.3,F10.5)
103 FORMAT(5F10.5)
104 FORMAT(7E11.4)
   WRITE(7,100) KKKK, LL
   WRITE(7,200) IPUNCH, XSTEP
   INTACT=0
   ISHOCK=0
   DO 1111 I=1,4
1111 IF(IS(I),NE.0) ISHOCK=1
   WRITE(7,101) NPTS, NPT, ITYP, ISHOCK, MMAX, KOUNT
   WRITE(7,100) JCHEM, IAVE,
   INTACT
   WRITE(7,102) I, J, K, L, M, N, SXA, RTH, DELTAY, YBOT, YTP, CHEMF, XB
   R=RE/RTH
   WRITE(7,103) R, Q, PP, XLE, EMINF, TIN, MINF, PRESS
   WRITE(7,100) XBOD, EOBDS, FBOOD, GBOOD
   WRITE(7,100) IPUS, APUS, BPRESS, CPRESS
   WRITE(7,100) ZPUS, APUS, CPRESU, CPRESS
   IF(ISHOCK.EQ.0) GO TO 5
   WRITE(7,100) (IS(I), I=1,4)
   WRITE(7,101) IPUS(I), I=1,4)
5 CONTINUE
   70 10 I=1,NPTS
   A =P(I) /PIN
   ALP7 =ALP(7,1) -ALP4(1) / (1.- RHEAT)
   ALP4 =ALP(4,1) /RHEAT
   WRITE(7,103) I(A), TH(I), EM(I), T(I)
   WRITE(7,103) ALP(I), I, ALP(I), I, ALP(1), I, ALP(4), ALP(5), I, ALP(6), I
17
10 CONTINUE
END

SUBROUTINE INDATA
COMMON/AC/IROD, PIN
COMMON/AL/GAR, GEW
COMMON/AAL, ALP(7,55), EMINF, MINF
COMMON/E0/XMASS(55)
COMMON/CJ/GP(7,55), GP(17), CPX(55)
COMMON/CK/XMOL(7)
COMMON/DB/BET(4), IS(14)
COMMON/ED/CP, IRO
COMMON/EF/EM(55), GAM(55), P(55), TH(55), Y(55)
COMMON/G/EIN, PR, XLE
COMMON/EP/GAMINF, HL(7), RINF
COMMON/FH/X1, X3, XP0T
COMMON/GE/RAD, RUP, VISP, VISA
COMMON/GF/DEL, CVISA, KOUNT, VISA
COMMON/HJ/KOUNT,LL,NPT
COMMON/HK/RCO2,RM20,NFUEL
COMMON/DR/THB,YBP,YBPN
COMMON/FC/M(55),X(55)
COMMON/PC/ALPHN(7),IFUEL,PRES
COMMON/PC/JCHEM,NSP,T(55)
COMMON/CA/H(55),Q(55),RHO(55),X(55)
COMMON/RC/R(55)
COMMON/TW/TIN
COMMON/U/P/I11,IERR,IPRESS,IPRESU,ISUB0
COMMON/W/P,NPRE,RE,XBP,XJ
COMMON/MP/APRESS,APRESU
COMMON/X/P/PR,AP,APAP,DELTAY,EBODS,I80DS,INTACT,IPRS,IPUS,ITYP,
1JBODS,MMAX,ReM1,XX2,XX4,XY0T,ITYP
COMMON/Y/P/4885,0PRESS,CRESSU
COMMON/Z/P/8885,2JCHEM,PC,FRESU,EMSUB,RTH,XSTEP
COMMON/ZY/8885,8885,CDOD,EBODS,EB00,FB25,GAOD,IAVE,IPUNCH,JBODS,KKKK
II=7
ISUB0=0
XBP=0
YBP=10000
TBP=6
RAO=0
IFUEL=1
NFUEL=2.016
100 FORMAT(1615)
101 FORMAT(8E10.0)
464 FORMAT(7F11.4)
260 FORMAT(15S5X,7E10.0)
READ(III,100) KKKK,LL
READ(III,200) IPUNCH,XSTEP
READ(III,100) NPTS,NPRE,ITYP,ISHOCK,MMAX,KOUNT
READ(III,100) JCHEM,IAVE,
INTACT
IF(KOUNT.LT.1) KOUNT=0
KOUNT=KOUNT
WRITE(6,112) KKKK,LL
111 FORMAT(8M4KK =I5,5X,4M11 =I3/)
WRITE(6,112) IPUNCH,XSTEP
112 FORMAT(9H IPUNCH =I2,5X,7HXSTEP =E10.3/)
WRITE(6,113) NPTS,NPRE,ITYP,ISHOCK,MMAX
113 FORMAT(7H NPTS =I5,5X,5NHJT =I2,5X,6HITYP =I2,5X,6ISHOCK =I2,5X,6
1MMAX =I3/)
WRITE(6,114) JCHEM,IAVE,
INTACT
114 FORMAT(8H JCHEM =I2,5X,6HIAVE =I2,5X,
18INTACT =I2/)
IF(ITYP.EQ.2,AND.ITYP.NE.4) GO TO 12
IF(INTACT.EQ.0.AND.ISHOCK.EQ.0) GO TO 12
WRITE(6,91901)
9191 FORMAT(11)
WRITE (6, 102)

102 FORMAT (9H TYPE 2 OR TYPE 4 FLOWS MAY NOT START WITH SHOCKS OR HAVE SHOCKS COMING OFF SPLITTER PLATES/43H RECHECK INPUTS AND SUBMIT WITH PROPER TYPE)
STOP

12 CONTINUE
104 READ (II, 101) XJ, ESMUB, RTH, DELTAY, YBOT, YTP, CHEMFC, XBP
READ (II, 101) RE, PR, XLE, EMINF, TIN, WINF, PRES
READ (II, 200) IBOO, ABOD, dBBD, GBOD
READ (II, 200) IBOD, EBOO, FBOO, GBOD
READ (II, 200) IPRESS, APRESS, BPRESS, CPRESS
READ (II, 200) IPRESU, APRESU, BPRESU, CPRESU
IF (XBP .LT. 0.) XBP = 0.
J = XJ + 5
WRITE (6, 115) XJ, ESMUB, RTH, DELTAY, YBOT, YTP, CHEMFC

115 FORMAT (9H XJ = E10.3,2X,7HESMUB = E10.3,2X,5H RT = E10.3,2X,6H DELTAY
1 = E10.3,2X,6HYBOT = E10.3,2X,5HYTP = E10.3,2X,8H CHEMFC = E10.3,7/
WRITE (6, 116) RE, PR, XLE, EMINF, TIN, WINF, PRES
116 FORMAT (9H RE = E10.3,2X,4H PR = E10.3,2X,5H XLE = E10.3,2X,7H EMINF = E10
1.3,2X,5HTIN = E10.3,2X,6H WINF = E10.3,2X,6H PRES = E10.3,7/
WRITE (6, 117) XPOT, XX1, XX2, XX3, XX4
117 FORMAT (9H XPOT = E10.3,2X,5HXK1 = E10.3,2X,5HXK2 = E10.3,2X,5HXK3 = E10
1.3,2X,5HXK4 = E10.3,7/
WRITE (6, 118) IBOO, ABOD, dBBD, GBOD
118 FORMAT (9H IBOO = E10.3,2X,6HABOD = E10.3,2X,6H DBBD = E10.3,2X,6HGBOD = E10
1.3,7/
WRITE (6, 119) JBOO, EBOO, FBOO, GBOD
119 FORMAT (9H JBOO = E10.3,2X,6H EBOO = E10.3,2X,6H FBOO = E10.3,2X,6H GBOD = E10
1.3,7/
WRITE (6, 120) ^PRESS, APRESS, BPRESS, CPRESS
120 FORMAT (9H IPRES = E10.3,2X,6HAPRESS = E10.3,2X,8H APRESS = E10.3,2X,8H BPRESS = E10.3,2X,8H CPRESS = E10.3,7/
WRITE (6, 121) IPRESU, APRESU, BPRESU, CPRESU
121 FORMAT (9H IPRESU = E10.3,2X,6HAPRESU = E10.3,2X,6HAPRESS = E10.3,2X,8H ARESU = E10.3,2X,8H BRESU = E10.3,2X,8H CPRESU = E10.3,7/

411 IBOOD = IBOO
ABOD = ABOD
IPRS = IPRESS
APRS = APRESS
JBOOD = JBOO
EBOOD = EBOO
IPUS = IPRESU
APUS = APRESU
IF (ISHOCK .EQ. 0) GO TO 5
READ (II, 101) (IS1(1), I = 1, 4)
READ (II, 101) (IS2(1), I = 1, 4)
WRITE (6, 128) (IS1(1), I = 1, 4)
128 FORMAT(8I5) IS(1) =I3,2X,THIS(2) =I3,2X,THIS(3) =I3,2X,THIS(4) =I3/
WRITE(6,129) (BET(1),I=1,4)
129 FORMAT(9X,BET(1) =E10.3,2X,9BET(2) =E10.3,2X,9BET(3) =E10.3,2X,
12X,9BET(4) =E10.3)
5 CONTINUE
DO 10 I=1,NPTS
READ(IN,101) Y(I),P(I),TH(I),EM(I),T(I)
READ(IN,404) (ALP(I),J=1,NSP)
10 CONTINUE
IF(ITYP.EQ.1) GO TO 4201
IB0D=0
JBO0D=0
IF(ITYP.EQ.3) JBO0D=JBO0S
IF(ITYP.EQ.4) IB0D=IB00S
4201 RHEAT=1.
RH20=1.
RC02=0.
4204 WTMOLE(I)=WFUEL
RE=RE*RH
ERR=0
CALL COEFF(5,TIM,AZ,BZ,CZ,DZ,HZ,FZ,GZ)
CP=1/(AZ*TIM*CZ*TIM**2*DZ*TIM**3+HZ*TIM**4)*RO/WTMOLE(5)
CALL COEFF(7,TIM,AZ,BZ,CZ,DZ,HZ,FZ,GZ)
CP=1/(AZ*TIM*CZ*TIM**2*DZ*TIM**3+HZ*TIM**4)*RO/WTMOLE(7)
CP=1.32*CP+1.76*CPII
RINF=RO/INF
GAMINF=1./((1.-RINF/CP))
RINF=RO/INF
UINF=EPINF*SQRT(GAMINF*RINF*TIM)
RF=1./RINF
RHOINF=PRE*RF/TIM
WISHF=RHIINF*UINF*RF/RE
GAM=GAMINF*RINF
GEN=GAMINF*EMINF**2/WINF
EIN= (GAP,NF-1.) * EMINF**2
ENS=1./EMINF**2
FIN=1./GAMINF**ENS
WRITE(6,6090)
6090 FORMAT(///48X,31H PROGRAM VIS - CHAR //60X,7WH ITH
1//4X,3HE MB E D E D O SUBSONIC FLOW//53X,21HS H O
1CK WAVE S//33X,63H AND FINITE RATE HZ - AI
1R CHEMISTRY)
IF(JCHEM.EQ.0.) WRITE(6,5610)
IF(JCHEM.EQ.4.) WRITE(6,5611)
IF(JCHEM.EQ.0.) WRITE(6,5612)
IF(JCHEM.EQ.1.) WRITE(6,5613)
5610 FORMAT(///10X,31HTYPE OF FLOW IS TWO DIMENSIONAL)
5611 FORMAT(///10X,31HTYPE OF FLOW IS AXIASSMETRIC)
5612 FORMAT(10X,19HCHEMISTRY IS FROZEN)

ORIGINAL PAGE IS OF POOR QUALITY
5613 FORMAT(1x,2x,HCHEMISTRY IS FINITE RATE)
WRITE(6,5681) RTH

5680 FORMAT
110x,8-HJET OR NOZZLE RADIUS (RTH) = E13.5,4H FT.
WRITE(6,5681) Eminf,finf,vinf,pres,rhoinf,gaminf,winf,ref,pp,xle

5681 FORMAT(/1x,20x,REFERENCE CONDITIONS/20x,20x-------------/
110x,10HMAC NO. (EMINF) = E13.5/10X,15VELOCITY (VINF) = E13.5,
17H FT/SEC/10X,19TEMPERATURE (TINFIN) = "13.5+18 DEGREES K/10X,17HR
17PRESS (PRES) = E13.5,9 lb/ft**2/10X,18DENSIT) (RHOINF) = E13.5,
172H SLUGS/FT**3/10X,37
1HFOZEN SPECIFIC HEAT RATIO (GAMINF) = E13.5/16X,25MOLECULAR WEIGHT
1T (WINF) = E13.5/18X,22HREYNOLDS NUMBER (RE) = E13.5/10X,21HRANDOL
1NUMBER (PP) = E13.5/10X,20HLENIS NUMBER (XLE) = E13.5
WRITE(6,5682)

5682 FORMAT(/10x,15HOUTPUT HEADINGS/20x,15H--------------/
110x,9H X - X/RTH/10X, 9HY - Y/RTH/10X, 15HQ - VELOCITY/UX/10X,
119HMT - TEMPERATURE/UX/10X,17HP - PRESSURE/PRES/10X,20RMH - DENSITY/UX
1RHOM/UX,19GMAN - SPECIFIC HEAT
1/10X,33YMMASS - NON-DIMENSIONAL MASS FLOW
1/10X,23HPEI - EQUIVALENCE RATIO/10X,
120HSE - MOLECULAR WEIGHT/10X,14MMASS FRACTIONS/15X,18HALP(I) - M/15X
110HALP(2) - O/15X,12HALP(3) - H2O/15X,11HALP(4) - H2/15X,11HALP(5)
1 - 02/15X,11HALP(6) - OH/15X,11HALP(7) - N2

413 DO 1774 I=1,NPTS
X(I)=X0P
P(I)=P(I)*PIN
ALP(I,J)=RHEAT*ALP(I,J)
ALP(I,J)=P(I)*Q4*ALP(I,J)+ALP(7,I)
DO 768 J=1,SP
768 IF(ALP(I,J)+LT.1,IE=10) ALP(I,J)=1,IE=10
ALP(I,J)=1./ALP(I,J)+ALP(2,I)+ALP(3,I)+ALP(4,I)+ALP(5,I)+ALP(6,I)
1)
1774 CONTINUE
DO 8883 I=1,NPIS
CALL THERMIT(I),H1,CP1
CPX(I)=0.0
W(I)=0.0
D1176 J=1,NSP
CPX(J,I)=CP1(J)
CPX(I)=CPX(I)+ALP(I,J)*CP1(J)
W(I)=W(I)+ALP(I,J)/HMOLE1(I)
1770 W(I)=W(I)+ALP(1,I)/HMOLE1(I)
CPX(I)=CPX(I)+ALP(I,I)*CP1(J)
W(I)=W(I)+ALP(I,J)/HMOLE1(I)
R(I)=RCW(I)
GAM(I)=CPX(I)/(CPX(I)-R(I)/CP1)
OM(I)=E/EMINF
OR(I)=E/R(I)
QII=EN(I)*ON/SORT(GAR/GAN(I)*OR/T(I))
IF(EN(I).GT.1.)

1XNU(I)=ATAN(1./SORT(EN(I)**2-1.))
8883 CONTINUE
IF(INTACT.EQ.1) CALL COWL
XJ1=1.+XJ
XNASS(I)=0.
00 1705 I=1,NPTS
IF(I.EQ.1) GO TO 1705
XJ2=1.+XJ
YFUNCTION(I)=Y(I-1)*XJ+Y(I)*XJ1- Y(I-1)*XJ+Y(I-1)*XJ1)/XJ1
RQAV=(RHO(I)*Q(I)*COS(TH(I))+ RHO(I-1)*Q(I-1)*COS(TH(I-1)))/2.
XNASS(I)=XNASS(I-1)+RQAV*YFUNCTION
1705 CONTINUE
DELY=(YBP-Y(I))/FLOAT(NPTS-1)
RETURN
END
FUNCTION F3(TP1,OTC,T1,TCH,M1,MHC)
COMMON/CX/MNMOLE(I)
COMMON/CH/DELX
COMMON/HL/ALPHA&ETA
DIMENSION DA(I)
NSP=7
A=ALPHA
B=ETA
TERM1=OTC/(A-B)*TP1+B*(T1+TCH))
TERM2=0.
00 10 J=1,NSP
TERM2=TERM2+DA(J)/M,NMOLE(I)
10 CONTINUE
TERM5=A*M1*B*MHC
TERM2=TERM2*TERM5
TERM3=A*COS(TCH)+B*COS(THC)
F3=-(TERM1+TERM2)*TERM3/DELX
RETURN
END
SUBROUTINE POGUS(I,PRESSI,RHOI,ALPHI,OT,I,N)
COMMON/PO/ALPHA(I),IFUEL,PRES
DIMENSION ALPH(I),AD(10),CI(10),Y(I),YN(I),ALPHA(I)
DIMENSION T0(I),T1(I),O(I),C(I),D(I),E(I),G(I),Z(I)
T0(1)=6.0
T0(2)=6.0
T0(3)=0.5
T0(4)=0.5
T0(5)=0.5
T0(6)=0.5
T0(7)=0.5
T0(8)=0.5
T1(1)=6.0
T1(2)=6.0
T1(1)=3.0299
T1(4)=4.0960
T1(5)=2.9282
T1(6)=3.6392
T1(7)=2.6888
0(1)=39.7055
0(2)=2.5674
0(3)=3.4962
0(4)=27.6123
0(5)=1.7771
0(6)=3.3496
0(7)=2.2043
C(1)=0.0
C(2)=0.0
C(3)=5.686
C(4)=1.5999
C(5)=1.995
C(6)=1.629
C(7)=1.931
D(1)=0.0
D(2)=0.0
D(3)=-31.7458
D(4)=-34.5288
D(5)=-1.0584
D(6)=1.3119
D(7)=-1.4976
E(1)=1.0
E(2)=0.0
E(3)=6.3657
E(4)=30.9184
E(5)=2.5221
E(6)=4.3679
E(7)=2.6593
G(1)=404.5564
G(2)=29.1774
G(3)=-26.9824
G(4)=-8.086
G(5)=-5.522
G(6)=3.4213
G(7)=-5.961
Z(1)=0.063
Z(2)=1.0
Z(3)=1.13
Z(4)=1.26
Z(5)=2.0
Z(6)=1.063
Z(7)=8.75
PSSS=PRESSI
KASE=1FUEL
IF(KASE.EQ.2) PRESSI=PRESSI*.35
IF(KASE.EQ.3) PRESSI=2*PRESSI
RHO1=RHO1*PRESSI/PSS
KTEST=0
EL0=1.0
DLTI=0.0
EPS=.001
time=1.38725E-5*EL0
t=0.0
PO=PRESSI*1.01325E6
RHO0=PO*1.924665E-13
RHO1=RHO1*.5154/RHO0
PRESSI=1.6
T=TI
HI=0.0
DO 65 I=1,7
   IF(T-T(I)) .GT.62.61.61
      HI=10(I)+E(I)*T**ALPH(I)+HI
      GO TO 65
61 IF(T-T(I)) .GT.62.63.64
      HI=10(I)+E(I)*T**ALPH(I)+HI
      GO TO 65
62 IF(T-T(I)) .GT.63.64.65
      HI=10(I)+E(I)*T**ALPH(I)+HI
      GO TO 65
63 HI=10(I)+E(I)*T**ALPH(I)+HI
64 CONTINUE
92 CONTINUE
JJJ = 25
J=0
T = TI
ISAVE=1
KOUNT=0
RHO=RHO1
DELT=DLTI
GAMMA=DT*DELT+1.
PRESSI-PRESSI
=HI
SUMV=0.
DO 11 I=1,7
   ALPHA(I)=ALPH(I)
   Y(I)=RHO*ALPH(I)/2(I)
   YN(I)=0.0
11 SUMV=SUMV+Y(I)
DUM1=6.67031E-7*RHO*EL0
DUM2=DUM1*RHO0/16.
IF(ALPHA(I).GT.1.E-10) GO TO 6
IF(ALPHA(I).GT.1.E-10) GO TO 6
IF(ALPHA(I).GT.1.E-10) GO TO 30
IF(ALPHA(I).GT.1.E-10) GO TO 30
P5=(1.8517*EXP(-25./T))*DUM1*EXP(-29./7/T)/T
R5=1.1E16*DUM1*R4/16.
B11=-(FS*.5+2.*BS*Y(1))*SUNY
CC1=BS*Y(1)**2*SUNY
CC=CC1+(Y2)*Y(1)*.5
Cl=FS*CC+SUNY+CC1
A11=DELTAY+@11
DUM=C1/A11
YN(1)=DUM+Y(1)*DUM1*EXP(A11*OT)
IF(YN(1)<.LT.0.0) YN(1)=0.0
YN(1)=CC-YN(1)*.5
GO TO 99
39 IF(ALPHA(4).LT.0.E-10) GO TO 6
IF(ALPHA(4).GT.1.E-10) GO TO 6
F8=(5.0E16*EXP(-30.3/T1))*DUM1*EXP(-30.3/T)/T)
B8=6.E16*DUM1*RHO0/16.
B11=IF9*.5+2.*BS*Y(1)*SUNY
CC1=BS*Y(1)**2*SUNY
BB=GAM1A*(Y(1)+Y(1))*.5
Cl=F8*BB*SUNY+CC1
A11=DELTAY+@11
DUM=C1/A11
YN(1)=DUM+Y(1)*DUM1*EXP(A11*OT)
YN(2)=B8-YN(1)*.5
IF(YN(2)<.LT.0.0) YN(2)=0.0
YN(3)=B8-YN(2)*.5
GO TO 99
6 CONTINUE
KOUNT=1
IF(KASE.EQ.2) T=1./(1.106/T-.0497)
IF(KASE.EQ.3) T=1./(1.706/T+.2381)
F1=3.E14*EXP(-.01/T)*DUM1
F2=3.E14*EXP(-.03/T)*DUM1
F3=3.E14*EXP(-.02/T)*DUM1
F4=F3
G1=2.48E13*EXP(-.66/T)*DUM1
G2=1.3E14*EXP(-2.99/T)*DUM1
G3=1.33E15*EXP(-10.95/T)*DUM1
G4=3.12E14*EXP(-12.5/T)*DUM1
T=TSAVE
TS=7
IF(KASE.EQ.2) T=1.241+.05524*T
F6=9.66E18*EXP(-.2Z/T)*DUM1
F7=9.86E16*EXP(-.25/T)*DUM1
B6=1.E17*DUM2
B7=1.E16*DUM2
T=TSAVE
F5=1.55E17*EXP(-.54/T)*DUM1
F8=5.80E16*EXP(-.66/T)*DUM1
B5=1.E16*DUM2
B6=6.E14*DUM2
AD(3,2)=872+F2*CC
AD(3,3)=871+DELTA-F1*CC
AD(3,4)=F9
AD(4,1)=F91
AD(4,2)=992
AD(4,3)=897+F3*CC
AD(4,4)=899+DELTA
CI(1)=CC1+F5+SUMY*CC
CI(2)=CC2+F8+SUMY*83
CI(3)=CC7
CI(4)=CC9
SCALE=0.
DO 50 I=1,4
DO 50 J=1,4
50 SCALE=AMAX1(SCALE,ABS(AD(I,J)))
DO 51 I=1,4
DO 52 J=1,4
51 CI(I)=CI(I)/SCALE
CALL MPANBIN2(TT,AD,Y,CI,BB,CC,SCALE)
90 DO 90 J=1,6
IF(YN(J),GE,0.0) GO TO 90
TT=DT/10.
KTEST=K1TEST+1
IF(KTEST.GT.3) 92,27,27
90 CONTINUE
DUM=0.
DO 1 J=1,6
1 DUM=DUM+YN(J)*Z(J)
RMON=DUM/F.L.-ALPHA(7)
YN(T)=RMON*ALPHA(7)/Z(T)
SUMYN=0.
DO 2 J=1,7
2 SUMYN=SUMYN+YN(J)
3 TT=PRES*SUMYN
DO 4 J=1,6
4 ALPHA(J)=YN(J)*Z(J)/RMON
AH=0.
BH=0.
CH=0.
DO 995 I=1,7
IF(IT-1111) 502,501,501
501 BH=BH+E(I)*ALPHA(I)*5
CH=CH+D(I)*ALPHA(I)
GO TO 505
502 IF(IT-1011) 503,503,504
503 BH=BH+G(I)*ALPHA(I)*5
CH=CH+G(I)*ALPHA(I)
GO TO 505
150

504 AM=AH+CI*ALPHA(I)
505 BM=BH+ALPHA(I)*(CI)*T8(I)-BI(I)**.5
506 CM=CH+ALPHA(I)*(CI+CI)*T8(I)**2
507 CONTINUE
508 CH=CH+H
509 IF(AH) 507,508,507
510 IF(BH/4.2) GO TO 500
511 T=KH+BH/2.
512 CONTINUE (BH-BH*AH*CH)/AH
513 IF(JJ)31,31,22
514 ERR=1T-1T
515 IF((ABS(TT/T-1.0)).LE.EPS) GO TO 27
516 GAM1=GAMMA
517 GAMMA=.98*GAMMA
518 GAM2=GAMMA
519 DELTA=(GAMMA-1.0)/DT
520 JJ=JJ+1
521 IF (JJ-JJ) 84,84,12
522 IF(KOUNT.EQ.1) GO TO 14
523 T=TSAVE
524 GO TO 6
525 ERR2=1T-1T
526 IF((ABS(TT/T-1.0)).LE.EPS) GO TO 27
527 GAMMA=GAM1-ERR1*(GAM2-GAM1)/(ERR2-ERR1)
528 GAM1=GAM2
529 ERR1=ERR2
530 GO TO 130
531 WRITE(6,13)
532 FORMAT(100,23H JJ IS GREATER THAN JJJ)
533 TN=T
534 DO 28 J=1,7
535 ALPN(J)=ALPHA(J)
536 DT=DT*TIME
537 PRINTED=PRINTS
538 RETURN
539 END