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IMPROVEMENTS IN THE CHART D RADIATION-HYDRODYNAMIC CODE I: ANALYTIC EQUATIONS OF STATE

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ABSTRACT

A set of equation-of-state subroutines for in-line hydrodynamic code use is described. The information generated is thermodynamically complete and self-consistent. Any combination of elements may be included. The range of validity is large: temperatures from 100 degrees K to 10^8 degrees K and nearly all important densities. Solids, liquids, vapors, plasmas, and phase mixtures are treated. Simple solid-solid phase transitions are included. An approximate value of the Rosseland mean opacity is calculated.

The routines were written for the CHART D radiation diffusion hydrodynamics code but may easily be included in other codes. With minimal effort an equation of state of any substance can be generated.

Key words: Computer routines for analysis of solids, liquids, vapors, plasmas, phase mixtures, and transitions.

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I. INTRODUCTION

All numerical hydrodynamic codes must contain information about the thermodynamic properties or equations of state concerning the materials they are to describe. There are two general categories for the forms in wide current use. Simple analytic expressions are normally employed in wave propagation codes which are designed to work in the low temperature range. Codes which operate at higher temperatures where radiation effects may be important usually have tabular interpolation routines. Each type has its advantages. The tabular form is capable of accurately describing extremely large ranges but requires extensive data handling and tape and machine storage. The analytic forms, on the other hand, are easy to use but are seldom accurate except in a narrow region.

The CHART D radiation diffusion-hydrodynamic code as described in the author's earlier report[1] contains only the tabular form. While the thermodynamic functions given by the equation-of-state routines are accurate and thermodynamically complete and self-consistent, the effort required to generate a data set, fit the data, and load them on a master file tape is considerable. There are, in addition, separate opacity codes which require considerable computation time to generate a compatible set of information. All told, several weeks could be required to get all of this information into the hydrodynamic code.

In this report a set of analytic equation-of-state subroutines having a wide range of validity are developed to lessen this problem. The methods are not nearly as complex as the detailed equation-of-state studies being conducted at Sandia. However, an effort has been made to select terms that give results similar to those in the more complex calculations, simplify them as much as possible, and code them in an efficient manner. The principle requirements of these routines are to compute the complete thermodynamic properties and the Rosseland mean opacity when given the temperature, density, and some basic material data. The inputs should be kept at a minimum and the speed of evaluation should be compatible with hydrodynamic code requirements. This latter requirement together with storage limitations determine the complexity allowed.

The routines developed are completely compatible with the CHART tabular forms and may be used simultaneously. They are also available for uses in other hydrodynamic codes. Their range of validity is very large compared to the forms used in codes such as PUFF[2] and WONDY[3], and they describe the hydrostats of the solids as well as their current forms. No effort has been made to describe the deviatoric terms for elastic-plastic materials; however, it is easily shown that these terms can be separated from the equilibrium thermodynamic functions (see, for example, reports on the WONDY code[3]).

The speed of evaluation depends on the options and number of elements involved. On the average, the computation time is about 50 percent greater than the tabular form from the author's earlier work.[1] However, this may vary by a factor of 2 in either direction, depending on the circumstances. Generally, the many-element materials at high temperatures and the mixed-phase regions are the slowest, whereas either solids or gases at low temperatures are the fastest.

The material data required as inputs are quite simple. For the most part, the information is the same as that required in the PUFF or WONDY forms and is available in many handbooks. However, the inputs for several specialized calculations, e.g., thermal conduction and solid-solid phase transitions, require some thought for proper inclusion.

There are five different types of equations of state available in the routines: a gaseous form with electronic terms and four forms of various complexity for solid, liquid, gases, and phase mixtures. No molecules are considered. Any number of elements can be included in a material. The overall accuracy seems good when compared to more complex methods.

II. GENERAL FORMULATION OF THE EQUATION OF STATE

The generation of thermodynamically complete and consistent equation-of-state information is most easily accomplished by formulation in terms of one of the thermodynamic potentials in its natural independent variables. For use in hydrodynamic codes, especially if radiation effects are to be included, the logical choice is the Helmholtz free energy F, with density ρ and temperature T as the independent variables. All other thermodynamic functions may be computed from various derivatives of the free energy. The relations of interest in the present work are

$$P = \rho^2 \frac{\partial F}{\partial \rho} , \tag{1}$$

$$S = - \frac{\partial F}{\partial T} , \tag{2}$$

$$E = F + TS , \tag{3}$$

$$C_v = \frac{\partial E}{\partial T} = - T \frac{\partial^2 F}{\partial T^2} , \tag{4}$$

$$\frac{\partial P}{\partial T} = \rho^2 \frac{\partial^2 F}{\partial \rho \partial T} , \tag{5}$$

and

$$\frac{\partial P}{\partial \rho} = 2\rho \frac{\partial F}{\partial \rho} + \rho^2 \frac{\partial^2 F}{\partial \rho^2} , \tag{6}$$

where P is pressure, S is entropy, E is energy, and C_v is constant volume heat capacity. The procedure for treating these variables in hydrodynamic calculations has been discussed by the author.[1]

For stability of the numerical integration of the hydrodynamic equations, the time step is limited by a function containing the sound speed C_s. From the definition

$$C_s = \sqrt{\left(\frac{\partial P}{\partial \rho}\right)_S} \tag{7}$$

and various thermodynamic relations, it can be shown that

$$C_s = \left\{ \left(\frac{\partial P}{\partial \rho}\right)_T + \frac{T\left(\frac{\partial P}{\partial T}\right)_\rho^2}{\rho^2\, C_v} \right\}^{1/2} \quad . \tag{8}$$

A fundamental assumption in the formulation presented here is that the equation of state may be written as a superposition of terms appropriate to various physical phenomena. A basis for this assumption will not be developed here; however, it should be noted that most theoretical equations of state and analysis of experimental data employ similar assumptions. The three major divisions to be made are atomic and electronic interactions at absolute zero temperature, thermal motion of atoms and ions, and thermal motion, excitation, and ionization of electrons. The free energy expressing this division is written as

$$F(\rho,T) = E_c(\rho) + F_n(\rho,T) + F_e(\rho,T) \quad , \tag{9}$$

where the subscript c refers to the zero-temperature isotherm or cold component, n refers to the nuclear or atomic component, and e refers to the electronic component. According to the third law of thermodynamics, the entropy must vanish at zero temperature; hence, the energy and free energy are identical. Both F_n and F_e are defined to vanish at zero temperature.

Each of the thermodynamic functions may be written in a form similar to (9). For example, it follows from (1) that the pressure is given by

$$\begin{aligned} P &= \rho^2 \frac{\partial F}{\partial \rho} = \rho^2 \frac{dE_c}{d\rho} + \rho^2 \frac{\partial F_n}{\partial \rho} + \rho^2 \frac{\partial F_e}{\partial \rho} \\ &= P_c(\rho) + P_n(\rho,T) + P_e(\rho,T) \quad . \end{aligned} \tag{10}$$

In this manner, thermodynamic consistency is insured.

Expressions for the various terms are constructed in the following sections. However, in some regions of the (ρ,T) plane, one of the terms might completely dominate the others. It would be unwise to perform time-consuming calculations on relativity unimportant terms and, where possible, this has been avoided. Only the combined effect is relevant for hydrodynamic code use and should be used to judge accuracy.

III. ZERO-TEMPERATURE ISOTHERM

First consider the equation of state at zero absolute temperature. Since the entropy is zero, the pressure and energy are related by the expression

$$P_c = \rho^2 \frac{dE_c}{d\rho} . \tag{11}$$

Define ρ_{oo} as the density of the solid material at zero temperature and pressure and

$$\eta = \rho/\rho_{oo} \tag{12}$$

as the compression. It should be noted that ρ_{oo} is slightly greater than the normal room temperature density because of thermal expansion. Different forms of description will be used for compressed and expanded states.

For compressed states ($\eta > 1$), there are only two regions where the equation of state is well known. For sufficiently large compressions ($\eta \gtrsim 20$), it is generally assumed that zero-temperature Thomas-Fermi statistical calculations are realistic. At these densities the pressures are sufficient to crumple any electronic energy levels or bands near the edge of the atom into a continuum. Possibly the most realistic of this type of calculation are those of Kirshnits[4] and Kalitkin[5] (TFC) as both quantum and exchange corrections are applied.

Experimental data are available in the region near $\eta = 1$. However, this information is limited to pressure of less than 1 to 10 megabars, depending on the material ($\eta < 2$ or 3) and temperatures and densities along the Hugoniot. Thus there is a wide range of compressions of interest where there are no experimental or theoretical data.

To the upper reaches of experimental data many substances show phase transitions which result in a more closely packed structure and decreased compressibility. This of course leads to kinks or discontinuities in the slope of P_c. In simple materials most of the phase changes observed in Hugoniot data appear to be of the second order, although a few first-order changes are clearly seen. A recent summary by Al'tshuler and Bakanova[6] illustrates much of the current data. For composite materials it should be expected that much more complex structure should be found. Such transitions generally occur at pressures of less than a megabar, although one is reported in aluminum above two megabars.[6] At still higher pressures, transitions accompanied by changes in band populations are possible. However, these should not affect the compressibility to any great extent, since the crystal symmetry is unchanged. Hence, it is expected that P_c should be a smooth function at sufficiently large compressions.

To properly treat these transitions would require not only information along the Hugoniot but also at all temperatures of interest. This is beyond the limits of current experimental techniques. While theoretical models may be constructed, they are far too complex, costly, and unreliable to be employed in the present type of calculation. Here we offered two simplified treatments of the cold compression curve. The first simply interpolates from the experimental data at $\eta = 1$ to the high compression limits. No phase changes are allowed. For simple materials, this procedure has been studied[7] and is probably as accurate as any method available, since simple extrapolations of low- and high-density data tend to merge. For more complex engineering materials, little else can be done because of the almost total lack of data.

In Section IX an alternate method is presented which allows for a single phase transition of either first or second order under very restricted circumstances. This calculation is experimental and should only be used with extreme care, especially when first-order transitions are under consideration.

An interpolation function for the pressure which is both convenient and well-behaved is

$$P_c = C_{32}\eta^{5/3} \exp(-C_{33}\eta^{-1/3}) - (C_{34} + C_{35}\eta^{1/3} + C_{36}\eta^{2/3}), \quad \eta > 1 , \qquad (13)$$

where the subscripts are identical to those used in the computer coding. For large compressions, Eq. (13) is identical to the TFC result, provided the first two coefficients are given by[7]

$$C_{32} = \frac{3h^2}{20\pi M_e} \left(\frac{\pi}{3}\right)^{1/3} \left(\frac{\rho_{oo} Z}{M_a}\right)^{5/3} \qquad (14)$$

and

$$C_{33} = \frac{10\pi M_e e^2}{9h^2} \left\{\frac{18}{5} Z^{1/3} + \frac{11}{(12\pi^2 Z)^{1/3}}\right\} \left(\frac{M_a}{2\rho_{oo}}\right)^{1/3} , \qquad (15)$$

where Z is the atomic number, M_a is atomic mass, h is Planck's constant, M_e is electronic mass, and e is the electronic charge.

In the limiting form for large compressions, C_{32} and C_{33} yield the coefficients of the two leading powers, $\eta^{5/3}$ and $\eta^{4/3}$. The first term is that of a free electron gas. The advantages of writing the two leading powers of η in the form given by the first term in (13) was pointed out by Barnes.[8] However, the exponential coefficient is determined by a slightly different rule in the present calculation.

This term accurately describes the entire Thomas-Fermi calculation for compressions down to about 5 or 10. For smaller values of η it gives a smaller and more realistic pressure than the exact Thomas-Fermi result.

The three remaining coefficients in (13) are determined by experimental data at $\eta = 1$. By definition, the pressure is required to vanish, and the bulk modulus and Gruneisen coefficient are related to its first and second derivatives. The bulk modulus at $\eta = 1$ is given by

$$B_{oo} = \frac{dP_c}{d\eta}\Big|_{\eta=1} . \tag{16}$$

The Gruneisen coefficient

$$\Gamma = \frac{1}{\rho}\left(\frac{\partial P}{\partial E}\right)_\rho \tag{17}$$

can be related to the cold compression curve by use of any of several theoretical models. The three most widely accepted models are of Slater,[9] Dugdale and MacDonald,[10] and free-volume theory.[11] It has been shown that the results of all three calculations can be written in the single expression[12]

$$\Gamma = -\frac{1}{3}(2-t) + \frac{1}{2}\,\frac{\eta^2 \dfrac{d^2P_c}{d\eta^2} + 2\eta\left(1 - \dfrac{2t}{3}\right)\dfrac{dP_c}{d\eta} - \dfrac{2t}{3}\left(1 - \dfrac{2t}{3}\right)P_c}{\eta\dfrac{dP_c}{d\eta} - \dfrac{2t}{3}P_c} , \tag{18}$$

where t = 0, 1, or 2 for Slater, Dugdale and MacDonald, and free-volume relations, respectively. If we define

$$T_\Gamma = t - 1 , \tag{19}$$

the expression of current interest is

$$\Gamma_{oo} = \frac{1}{2B_{oo}}\,\frac{d^2P_c}{d\eta^2}\Big|_{\eta=1} - \frac{1}{3}\,T_\Gamma . \tag{20}$$

It is often observed that the Dugdale and MacDonald form ($T_\Gamma = 0$) is superior for metals, and ionic crystals are best described by the free-volume relations ($T_\Gamma = 1$). However, there are exceptions to both rules; for example, aluminum seems to require the Slater relations ($T_\Gamma = -1$). In Section X a method of determining a proper value of T_Γ from Hugoniot and zero pressure isobar data is given. In the remainder of this section it is assumed that T_Γ is known.

The internal energy is defined to vanish at $\eta = 1$. At any other temperature and density it is positive. Equation (11) can be integrated with the result that

$$E_c = \frac{1}{\rho_{oo}} \int_1^{\eta} P_c \, \eta^{-2} \, d\eta$$

$$= \frac{1}{\rho_{oo}} \left\{ 3C_{32} \mathcal{E}_3(C_{33}\eta^{-1/3}) + \frac{C_{34}}{\eta} + \frac{3C_{35}}{2\eta^{2/3}} + \frac{3C_{36}}{\eta^{1/3}} - C_{37} \right\} \qquad (21)$$

$$, \quad \eta > 1 \quad ,$$

where

$$C_{37} = 3C_{32}\mathcal{E}_3(C_{33}) - C_{34} - \frac{3C_{35}}{2} - 3C_{36} \ , \qquad (22)$$

and

$$\mathcal{E}_3(x) = \int_1^{\infty} t^{-3} \, e^{-xt} \, dt \qquad (23)$$

is the third exponential integral.

In considering the form for expanded states $\eta \leq 1$, there are two main regions to be considered. For slightly expanded states, $0.8 \leqslant \eta \leqslant 1$, and temperatures below melt, a tension exists in the material. Although this is a thermodynamically unstable situation, the relaxation times, except for fracture, are extremely large, and for the present, tensions will be considered stable. Fracture is generally treated as a separate calculation in wave propagation codes and requires hydrostats that extend past the point of fracture.

Of greater importance is the mixed-phase region extending up to the critical point. Because of poor microscopic material models in this region, the form of P_c greatly influences properties near the critical point. It is assumed that the atoms are principally influenced by two-body forces with nearest neighbors. Given the form of this interaction, explicit expressions for the thermodynamic functions can be obtained.[13] However, the determination of macroscopic material properties from microscopic quantities by use of this approach is seldom of sufficient reliability to be used in a calculation of the present type. It is preferable to select a generalized potential form and evaluate any constants directly from known macroscopic quantities. The form chosen is a modified Morse potential. The pressure is given by

$$P_c = C_4 \eta^{2/3} \left\{ e^{C_5 \nu} - e^{C_6 \nu} \right\} , \quad \eta \leq 1 \ , \qquad (24)$$

where

$$\nu = 1 - \eta^{-1/3} \ . \qquad (25)$$

This form was selected over other theoretically justifiable expressions, for example, a Lennard-Jones (6-12), 6-9, or Morse-Coulomb potential, since Eq. (24) seems to yield the most reasonable results under the widest circumstances.

Where (11) is integrated from $\eta=1$, the energy is easily shown to be

$$E_c = \frac{3C_4}{\rho_{oo}}\left\{\frac{1}{C_5}\left(e^{C_5\nu} - 1\right) - \frac{1}{C_6}\left(e^{C_6\nu} - 1\right)\right\} \quad , \eta \le 1 . \tag{26}$$

The lattice separation or zero-temperature sublimation energy is then

$$E_S = \frac{3C_4}{\rho_{oo}}\left\{\frac{1}{C_6} - \frac{1}{C_5}\right\} \quad . \tag{27}$$

As P_c given by (24) clearly vanishes at $\eta=1$, the two remaining conditions to determine the three coefficients are obtained from the bulk modulus and Gruneisen coefficient as given by (16) and (20). This procedure insures that E_c, P_c, $\frac{dP_c}{d\eta}$, and $\frac{d^2P_c}{d\eta^2}$ are continuous at $\eta=1$.

From these relations it may be shown that

$$C_5 = 3\hat{\Gamma} \quad \left\{1 + \sqrt{1 - \frac{B_{oo}}{\rho_{oo}E_S\hat{\Gamma}^2}}\right\} , \tag{28}$$

$$C_6 = 3\hat{\Gamma} \quad \left\{1 - \sqrt{1 - \frac{B_{oo}}{\rho_{oo}E_S\hat{\Gamma}^2}}\right\} , \tag{29}$$

where

$$\hat{\Gamma} = \Gamma_{oo} + \frac{1}{3} T_{\Gamma} \tag{30}$$

and

$$C_4 = 3B_{oo}/(C_5 - C_6) \quad . \tag{31}$$

While, on theoretical grounds, imaginary coefficients might be justifiable, it is clear from (28) and (29) that we must require

$$\frac{B_{oo}}{\rho_{oo}E_S\hat{\Gamma}^2} < 1 \tag{32}$$

$$E_D = 3N_o kT \ , \tag{41}$$

and

$$S_D = - N_o k \ \{3 \ \ell n(\theta/T) - 4\} \quad . \tag{42}$$

The density variation of Γ and θ could be calculated from either the Slater, Dugdale and MacDonald, or free-volume relations, Eq. (18), with the cold compression curve discussed in the last section. However, it is often observed experimentally that, for small compressions, Γ is nearly inversely proportional to the density. This also seems to be a fair approximation to the results of the theoretical models over small ranges. For large compressions the limiting value of Γ for all materials is that of a free electron gas of 2/3. A relation that approaches both limits, is properly behaved in the intermediate region, and leads to much faster evaluation than the above theoretical models is

$$\Gamma = \frac{\Gamma_o \rho_o}{\rho} + C_{24}\left(1 - \frac{\rho_o}{\rho}\right)^2 \ , \ \rho > \rho_o \quad . \tag{43}$$

The coefficient C_{24} should be 2/3 to reach the correct limit as $\rho \to \infty$. However, in problems where only slight compressions are encountered ($\eta \lesssim 1.3$), C_{24} may be set to zero to improve speed. The Debye temperature is found from integration of (38). If θ_o is the reference Debye temperature, then it is easily shown that

$$\theta = \theta_o \left(\frac{\rho}{\rho_o}\right)^{C_{24}} \exp\left\{\Gamma_o(1 - \rho_o/\rho) - \frac{1}{2} C_{24}\left(3 - 4\frac{\rho_o}{\rho} + \frac{\rho_o^2}{\rho^2}\right)\right\} \quad . \tag{44}$$

To properly treat solid-solid phase transitions there would be separate relations for each of the phases with appropriate matching at each phase boundary. For the reasons given in Section III this will not be done in the present calculation.

At sufficiently high temperatures or low densities, the nuclear term should describe an ideal gas. Let us define N_ℓ as the number of atoms per unit mass with atomic number Z_ℓ and m_ℓ as its atomic mass. Clearly, the relation

$$N_o = \sum_\ell N_\ell \tag{45}$$

follows from the definitions. The thermodynamic expressions appropriate to this situation are

$$F_G = -kT \sum_\ell N_\ell \left\{ \ell n\left[\frac{U_\ell (2\pi m_\ell kT)^{3/2}}{N_\ell \rho h^3}\right] + 1 \right\} \ , \tag{46}$$

$$P_G = N_o \rho kT \quad , \tag{47}$$

$$E_G = \frac{3}{2} N_o kT \quad , \tag{48}$$

and

$$S_G = k \sum_{\ell} N_{\ell} \left\{ \ell n \left[\frac{U_{\ell} (2\pi m_{\ell} kT)^{3/2}}{N_{\ell} \rho h^3} \right] + 5/2 \right\} \quad , \tag{49}$$

where U_{ℓ} are the internal partition functions. In the present calculation all U_{ℓ} are taken as unity. For ionized gases, the above expressions should be modified so that the sums include all states of ionization. However, since the treatment of ionization discussed in the later sections is of the average atom type, only one term is required for each atomic number.

The principle difficulty in joining these two theories together is the region of melting. The melting transition is of great current interest in the literature. Unfortunately, none of the current theories is sufficiently simple or completely reliable, and those that do show promise have little experimental information for comparison except in the uninteresting region near zero pressure. Since, in the problems of interest, melting may occur at many megabars of pressure, a more general method is required. The method used here is an interpolation on the free energy on an absolute basis that was suggested by the Russians,[14] but in a somewhat different form. The nuclear free energy is boldy written as

$$F_n = N_o kT \{ 3 \ell n (\theta/T) - 1 + \frac{3}{2} \ell n (1 + \psi)\} \quad , \tag{50}$$

where

$$\psi = \frac{C_{13} \rho^{2/3} T}{\theta^2} \tag{51}$$

and

$$C_{13} = \frac{N_o^{5/3} h^2}{2\pi k} \exp \left\{ \frac{2}{3} \sum_{\ell} \frac{N_{\ell}}{N_o} \ell n \left(\frac{N_{\ell}}{N_o^{5/2} M_{\ell}^{3/2}} \right) \right\} . \tag{52}$$

At low temperatures ($\psi << 1$), Eq. (50) reduces to (39) and the thermodynamics to that of a solid. For sufficiently high temperatures ($\psi >> 1$), gaseous thermodynamics are the result as the limiting form of (46) is obtained. Communal free energy and entropy terms are properly included. The corresponding interpolation equations for pressure, energy, and entropy are

$$P_n = \rho N_o kT \left\{ \frac{3\Gamma + \psi}{1 + \psi} \right\} \quad , \tag{53}$$

$$E_n = \frac{3}{2} N_o kT \left\{ \frac{2 + \psi}{1 + \psi} \right\} \quad , \tag{54}$$

V. ELECTRONIC CONTRIBUTION TO THE EQUATION OF STATE

In nearly all calculations of the equation of state, the electronic contribution is the most complex and costly. There are two methods of determining these terms in common use. At low densities, ionization equilibrium calculations are appropriate and, with valid expressions for electrostatic interactions, can be used at relatively high densities. For high compressions, temperature-dependent Thomas-Fermi calculations are available.

One of the fundamental differences in these two calculations is that, in the former, the average thermodynamics is computed with regard for all possible systems, whereas in the latter the thermodynamics of a single average system is calculated. In spite of this and numerous other differences, it has been found that the two methods, properly employed, are not in serious disagreement. It should be remembered that the electronic term is defined to vanish at zero temperature. Hence the zero-temperature Thomas-Fermi values must be subtracted from the normal calculation of the same density. This eliminates many of the effects of degeneracy. Surprisingly, the largest differences in the two calculations, in regions where electronic terms are important, occurs at relatively high temperatures where the ionization calculation yields an atomic shell structure effect that the Thomas-Fermi calculation does not.

The method used here is the simplest available. The average atom ionization model developed by the Russians, with modifications for low and high degrees of ionization, is of both sufficient accuracy and speed to be used in a calculation of this type. Any number of elements can be treated with a very dependable method. The reader is referred to the excellent text of Zel'dovich and Raizer[15] for a complete discussion. Here, only the information required for numerical evaluation is given.

In the original development of the routines given here, it was planned that the ionization calculation should be used only at low densities and high temperatures. An exact and consistent table of scaled temperature-dependent Thomas-Fermi values* was available. However, once it was discovered that the two calculations were quite similar, the method was changed to the present form. There is a considerable savings in storage requirements, and the problem of switching calculations in a consistent manner is eliminated.

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*Developed by D. J. McCloskey, Sandia Laboratories.

The following notations are used:

Z_ℓ = atomic number of element ℓ

A_ℓ = atomic weight of element ℓ

m_ℓ = atomic mass of element ℓ

C_ℓ = number fraction of element ℓ

N_o = total number of atoms per unit mass

N_ℓ = number of ℓ atoms per unit mass

N_e = number of free electrons per unit mass

N_ℓ^i = number of ℓ atoms per unit mass of net ionic charge i

I_ℓ^i = $i^{\underline{th}}$ ionization potential of element ℓ

$\overline{m}$ = average atomic mass

$\overline{Z}_\ell$ = average ionization number of element ℓ

$\overline{Z}$ = average ionization number

$\overline{A}$ = average atomic weight

Z_m = average atomic number

Self-obvious relations involving these quantities that will later be required are:

$$\sum_\ell C_\ell = 1 \quad , \tag{65}$$

$$\overline{A} = \sum_\ell C_\ell A_\ell \quad , \tag{66}$$

$$m_\ell = A_\ell / N_{av} \quad , \tag{67}$$

$$\overline{m} = \overline{A}/N_{av} = \sum_\ell C_\ell m_\ell \quad , \tag{68}$$

$$Z_m = \sum_\ell C_\ell Z_\ell \quad , \tag{69}$$

$$\overline{Z}_\ell = \sum_i i\ N_\ell^i \quad , \tag{70}$$

$$\overline{Z} = \sum_\ell C_\ell \overline{Z}_\ell \quad , \tag{71}$$

$$N_e = \overline{Z}\ N_o \quad , \tag{72}$$

$$N_\ell = C_\ell/\overline{m} = \sum_i N_\ell^i \quad , \tag{73}$$

and

$$N_o = \sum_\ell N_\ell \quad , \tag{74}$$

where N_{av} is the Avogadro number.

The principle problem in this calculation is determination of the average degree of ionization of the various atoms. Ideal gas relations are used in computing the thermodynamics. No pressure ionization or related effects are considered. The electronic free energy is

$$F_e = - \overline{Z} N_o kT \left\{ \ln\left(\frac{AT^{3/2}}{\rho N_o \overline{Z}}\right) + 1 \right\} + \sum_\ell N_\ell Q(\overline{Z}_\ell) \quad , \tag{75}$$

where

$$A = \frac{2(2\pi M_e k)^{3/2}}{h^3} \simeq 6 \times 10^{21} (\mathrm{ev})^{-3/2} \ \mathrm{cm}^{-3} \quad , \tag{76}$$

$$Q(\overline{Z}_\ell) = \sum_{i=1}^{k} I_\ell^i + (\overline{Z}_\ell - k)\, I_\ell^{k+1} \quad , \tag{77}$$

and $k = k(\ell)$ is the next integer smaller than $\overline{Z}_\ell$. The relations of interest are

$$P_e = \overline{Z} N_o \rho kT \quad , \tag{78}$$

$$E_e = \frac{3}{2} \overline{Z} N_o kT + \sum_\ell N_\ell Q(\overline{Z}_\ell) \quad , \tag{79}$$

$$S_e = \overline{Z} N_o k \left\{ \ln\left(\frac{AT^{3/2}}{\rho N_o \overline{Z}}\right) + 5/2 \right\} \quad , \tag{80}$$

$$C_{ve} = 3/2\, N_o k \left\{ \overline{Z} + T \frac{\partial \overline{Z}}{\partial T} \right\} + \sum_\ell N_\ell\, I_\ell^{k+1} \frac{\partial \overline{Z}_\ell}{\partial T} \quad , \tag{81}$$

$$\frac{\partial P_e}{\partial T} = N_o \rho k \left\{ \overline{Z} + T \frac{\partial \overline{Z}}{\partial T} \right\} \quad , \tag{82}$$

and

$$\frac{\partial P_e}{\partial \rho} = N_o kT \left\{ \overline{Z} + \rho \frac{\partial \overline{Z}}{\partial \rho} \right\} \quad . \tag{83}$$

In an ionization equilibrium calculation, the ionic populations are determined by a set of equations of the form

$$\frac{N_\ell^i}{N_\ell^{i-1}} = K(\rho, T) \quad , \tag{84}$$

subject to the constraints on the total number of particles given by (73). The function $K(\rho,T)$ can be extremely complex in detailed calculations. In the simplest case, the normal Saha equations, it can be shown that[16]

$$K(\rho,T) = \frac{U_\ell^i}{U_\ell^{i-1}} \exp\left\{- \frac{\mu_e + I_\ell^i}{kT}\right\}$$

$$= \frac{U_\ell^i}{U_\ell^{i-1}} \frac{2(2\pi M_e kT)^{3/2}}{\rho N_e h^3} \exp\left(- \frac{I_\ell^i}{kT}\right) \tag{85}$$

by matching chemical potentials through appropriate relations, where U_ℓ^i is the internal partition function, μ_e is the electronic chemical potential, and nondegenerate statistics are assumed. All U_ℓ^i are assumed equal. By combining (76), (84), and (85), it is easily shown that

$$\frac{N_\ell^i}{N_\ell^{i-1}} = \frac{AT^{3/2}}{\rho N_e} \exp\left(- \frac{I_\ell^i}{T}\right) \quad , \tag{86}$$

where both the temperature and ionization potential are in units of electron volts.

The above set of equations may be solved by iteration. However, the Russian method is considerably faster, requires less storage, and usually yields nearly the same result. For reasons that will become clear shortly, there are separate calculations for single- and multi-element materials.

Single-Element Ionization

Let us first consider low and high degrees of ionization. These two cases will be solved exactly, with the assumption that only two ionic species are present. The subscript ℓ, denoting the element number, will be retained for continuity.

For $\bar{Z} \leq 1/2$, it is assumed that only neutral and singly ionized atoms are present. It then follows that

$$N_e = N_\ell^1 = \bar{Z} N_o \quad , \tag{87}$$

$$N_\ell^o = N_o(1 - \bar{Z}) \quad , \tag{88}$$

and

$$\frac{N_\ell^1}{N_\ell^o} = \frac{\overline{Z}}{1 - \overline{Z}} = \frac{K_1}{\overline{Z}} \quad , \tag{89}$$

where

$$K_1 = \frac{AT^{3/2}}{\rho\ N_o} \exp\ (-I_\ell^1/T) \tag{90}$$

and T and I_ℓ^1 are both assumed to be in units of electron volts. Clearly, the desired quantities are

$$\overline{Z} = \frac{1}{2} \{ \sqrt{K_1^2 + 4K_1} - K_1 \} \quad , \tag{91}$$

$$\frac{\partial \overline{Z}}{\partial T} = \frac{K_1}{T} \left\{ \frac{1 - \overline{Z}}{K_1 + 2\overline{Z}} \right\} \left\{ \frac{3}{2} + \frac{I_\ell^1}{T} \right\} \quad , \tag{92}$$

and

$$\frac{\partial \overline{Z}}{\partial \rho} = - \frac{K_1}{\rho} \left\{ \frac{1 - \overline{Z}}{K_1 + 2\overline{Z}} \right\} \quad . \tag{93}$$

When $\overline{Z} \geq Z_\ell - 1/2$, only the ions of net charge Z_ℓ and $Z_\ell - 1$ are present. In this case

$$N_e = \overline{Z}\ N_o = Z_\ell\ N_\ell^{Z_\ell} + (Z_\ell - 1)\ N_\ell^{Z_\ell - 1} \tag{94}$$

and

$$N_o = N_\ell = N_\ell^{Z_\ell} + N_\ell^{Z_\ell - 1} \quad . \tag{95}$$

With the definition

$$K_2 = \frac{AT^{3/2}}{\rho\ N_o} \exp\ (- I_\ell^{Z_\ell}/T) \quad , \tag{96}$$

the result is easily shown to be

$$\overline{Z} = \frac{1}{2} \{ Z_\ell - 1 - K_2 + \sqrt{(Z_\ell - 1 - K_2)^2 - 4K_2\ Z_\ell} \} \quad , \tag{97}$$

$$\frac{\partial \overline{Z}}{\partial T} = \frac{K_2}{T} \left\{ \frac{Z_\ell - \overline{Z}}{2\overline{Z} - K_2 + Z_\ell - 1} \right\} \left\{ \frac{3}{2} + \frac{I_\ell^{Z_\ell}}{T} \right\} \quad , \tag{98}$$

and

$$\frac{\partial \overline{Z}}{\partial \rho} = -\frac{K_2}{\rho}\left\{\frac{Z_\ell - \overline{Z}}{2\overline{Z} - K_2 + Z_\ell - 1}\right\} \quad . \tag{99}$$

If neither of the above calculations apply, the Russian method is used in the range $1/2 < \overline{Z} < Z_\ell - 1/2$. Equation (86) is replaced by an expression of the form

$$\overline{Z} = \frac{AT^{3/2}}{\rho\, N_o} \exp(-\,\overline{I}_\ell/T) \quad , \tag{100}$$

where $\overline{I}_\ell$ is an interpolated ionization potential function. If n is an integer and

$$n - 1/2 \leq \overline{Z} < n + 1/2 \quad , \tag{101}$$

then

$$\overline{I}_\ell = I_\ell^n(n + 1/2 - \overline{Z}) + I_\ell^{n+1}(\overline{Z} + 1/2 - n) \; . \tag{102}$$

The value of $\overline{Z}$ is adjusted by a Newton's iteration until Eqs. (100) and (102) are satisfied. The derivatives are obtained from

$$\frac{\partial \overline{Z}}{\partial T} = \overline{Z}\left\{\frac{3}{2} + \frac{\overline{I}_\ell}{T}\right\} / \left\{T + \overline{Z}\,\Delta\,\overline{I}_\ell\right\} \tag{103}$$

and

$$\frac{\partial \overline{Z}}{\partial \rho} = -\frac{\overline{Z}T}{\rho\{T + \overline{Z}\,\Delta\,\overline{I}_\ell\}} \quad , \tag{104}$$

where

$$\Delta\overline{I}_\ell = I_\ell^{n+1} - I_\ell^n \quad . \tag{105}$$

This is the complete single-element calculation.

Multiple-Element Ionization

The multi-element calculation is similar to the single-element version. Here a value of $\overline{Z}$ is guessed and the values of $\overline{Z}_\ell$ calculated as described below. In general, this set of $\overline{Z}_\ell$ will not yield a value of $\overline{Z}$ by (71) consistent with the assumed value. Again we use a Newton's correction where

$$\Delta\overline{Z} = \frac{\overline{Z} - \sum_\ell C_\ell \overline{Z}_\ell}{\sum_\ell C_\ell \dfrac{\partial Z_\ell}{\partial \overline{Z}} - 1} \tag{106}$$

is the change in $\overline{Z}$ for the next iteration.

For each element the calculation is similar to the previous one, except that both $\overline{Z}$ and $\overline{Z}_\ell$ are included in each relation. The results are, for $\overline{Z}_\ell \leq 1/2$:

$$\overline{Z}_\ell = K_{\ell 1}/(K_{\ell 1} + \overline{Z}) \quad , \tag{107}$$

$$\frac{\partial \overline{Z}_\ell}{\partial \overline{Z}} = \frac{(\overline{Z}_\ell)^2}{K_{\ell 1}} = - \frac{K_{\ell 1}}{(K_{\ell 1} + \overline{Z})^2} \quad , \tag{108}$$

$$\frac{\partial \overline{Z}_\ell}{\partial T} = \frac{\overline{Z}(\overline{Z}_\ell)^2}{K_{\ell 1}\, T} \left\{ \frac{3}{2} + \frac{I_\ell^1}{T} \right\} - \frac{K_{\ell 1}}{(K_{\ell 1} + \overline{Z})^2} \frac{\partial \overline{Z}}{\partial T} \quad , \tag{109}$$

and

$$\frac{\partial \overline{Z}_\ell}{\partial \rho} = - \frac{\overline{Z}(\overline{Z}_\ell)^2}{K_{\ell 1}\rho} - \frac{(\overline{Z}_\ell)^2}{K_{\ell 1}} \frac{\partial \overline{Z}}{\partial \rho} \quad , \tag{110}$$

with

$$K_{\ell 1} = \frac{AT^{3/2}}{\rho\, N_o} \exp\left(- \frac{I_\ell^1}{T}\right) \quad . \tag{111}$$

For $\overline{Z}_\ell \geq Z_\ell - 1/2$:

$$\overline{Z}_\ell = Z_\ell - \frac{\overline{Z}}{\overline{Z} + K_{\ell 2}} \quad , \tag{112}$$

$$\frac{\partial \overline{Z}_\ell}{\partial \overline{Z}} = - \frac{K_{\ell 2}}{(\overline{Z} + K_{\ell 2})^2} \quad , \tag{113}$$

$$\frac{\partial \overline{Z}_\ell}{\partial T} = \frac{\overline{Z}}{(\overline{Z} + K_{\ell 2})^2} \frac{K_{\ell 2}}{T} \left\{ \frac{3}{2} + \frac{I_\ell^{Z_\ell}}{T} \right\} - \frac{K_{\ell 2}}{(\overline{Z} + K_{\ell 2})^2} \frac{\partial \overline{Z}}{\partial T} \quad , \tag{114}$$

and

$$\frac{\partial \overline{Z}_\ell}{\partial \rho} = - \frac{\overline{Z}\, K_{\ell 2}}{\rho(\overline{Z} + K_{\ell 2})^2} - \frac{K_{\ell 2}}{(\overline{Z} + K_{\ell 2})^2} \frac{\partial \overline{Z}}{\partial \rho} \quad , \tag{115}$$

with

$$K_{\ell 2} = \frac{AT^{3/2}}{\rho\, N_o} \exp\left(- I_\ell^{Z_\ell}/T\right) \quad . \tag{116}$$

For $1/2 < \overline{Z}_\ell < Z_\ell - 1/2$:

$$\overline{Z}_\ell = \frac{I_\ell^{n+1}\,(n - 1/2) - I_\ell^n\,(n + 1/2) + T \ln\left(\frac{AT^{3/2}}{\overline{Z}\rho\, N_o}\right)}{\Delta I_\ell^n} \quad , \tag{117}$$

$$\frac{\partial \overline{Z}_\ell}{\partial \overline{Z}} = - \frac{T}{\overline{Z}\, \Delta\, I_\ell^n} \quad , \tag{118}$$

$$\frac{\partial \overline{Z}_\ell}{\partial T} = \left\{ \ell n \left(\frac{AT^{3/2}}{\overline{Z}\rho\, N_o} \right) + \frac{3}{2} - \frac{T}{\overline{Z}} \frac{\partial \overline{Z}}{\partial T} \right\} / \Delta\, I_\ell^n \quad , \tag{119}$$

$$\frac{\partial \overline{Z}_\ell}{\partial \rho} = - \left\{ \frac{T}{\rho} + \frac{T}{\overline{Z}} \frac{\partial \overline{Z}}{\partial \rho} \right\} / \Delta\, I_\ell^n \quad , \tag{120}$$

where n is an integer,

$$n - 1/2 \le \overline{Z}_\ell < n + 1/2 \quad , \tag{121}$$

and

$$\Delta\, I_\ell^n = I_\ell^{n+1} - I_\ell^n \quad . \tag{122}$$

The derivatives of $\overline{Z}$ required in (81), (82), and (83) are calculated by noting in each of the above cases that

$$\frac{\partial \overline{Z}_\ell}{\partial T} = \alpha_\ell + \frac{\partial \overline{Z}_\ell}{\partial \overline{Z}} \frac{\partial \overline{Z}}{\partial T} \tag{123}$$

and

$$\frac{\partial \overline{Z}_\ell}{\partial \rho} = \beta_\ell + \frac{\partial \overline{Z}_\ell}{\partial \overline{Z}} \frac{\partial \overline{Z}}{\partial \rho} \quad , \tag{124}$$

where α_ℓ and β_ℓ are known. Applying (71), we see that

$$\frac{\partial \overline{Z}}{\partial T} = \frac{\Sigma\, C_\ell\, \alpha_\ell}{1 - \Sigma\, C_\ell \frac{\partial \overline{Z}_\ell}{\partial \overline{Z}}} \tag{125}$$

and

$$\frac{\partial \overline{Z}}{\partial \rho} = \frac{\Sigma\, C_\ell\, \beta_\ell}{1 - \Sigma\, C_\ell \frac{\partial \overline{Z}_\ell}{\partial \overline{Z}}} \quad , \tag{126}$$

which completes the multi-element calculation.

VI. TWO-PHASE (LIQUID-VAPOR AND SOLID-VAPOR) EQUATION OF STATE

In nearly all problems involving materials which are initially solid but heated to temperatures above melt, mixed-phase regions of the equation of state are encountered. All too often this important region is ignored.

The two-phase region is treated by a Maxwellian construction on the one-phase thermodynamic surface formulated in the previous sections. Since it is desired that the calculation should be as fast as possible, the electronic terms are not included since they would have little effect except at the highest temperatures and would slow the calculation considerably.

Generally, the method is as follows. First, the critical point is located by a two-variable Newton's iteration. Then, at a set of temperatures determined by the critical and melting temperatures, the two-phase boundary densities are located. This calculation is performed only once. The sets of temperatures and densities are stored for evaluation of two-phase thermodynamic properties as subsequently required. For a typical equation of state, approximately 80 to 110 points are retained.

To determine the conditions at a temperature and density within the two-phase region, boundary densities corresponding to the given temperature are found by interpolation in the stored values. A one-phase calculation is performed at each of the two boundary densities and the mixed-phase thermodynamic functions are computed from the mixture rules.

Below the melting temperature, a tension region is retained. For densities greater than about 0.8 ρ_o (= ρ_{min}) and temperatures below melt, the two-phase calculation is bypassed. This creates a discontinuity in the state surface, but it is in a region that cannot usually be encountered in a proper calculation.

Location of Critical Point

The critical point is located by determining the density, ρ_c, and temperature, T_c, where

$$\frac{\partial P}{\partial \rho} = \frac{\partial^2 P}{\partial \rho^2} = 0 \quad . \tag{127}$$

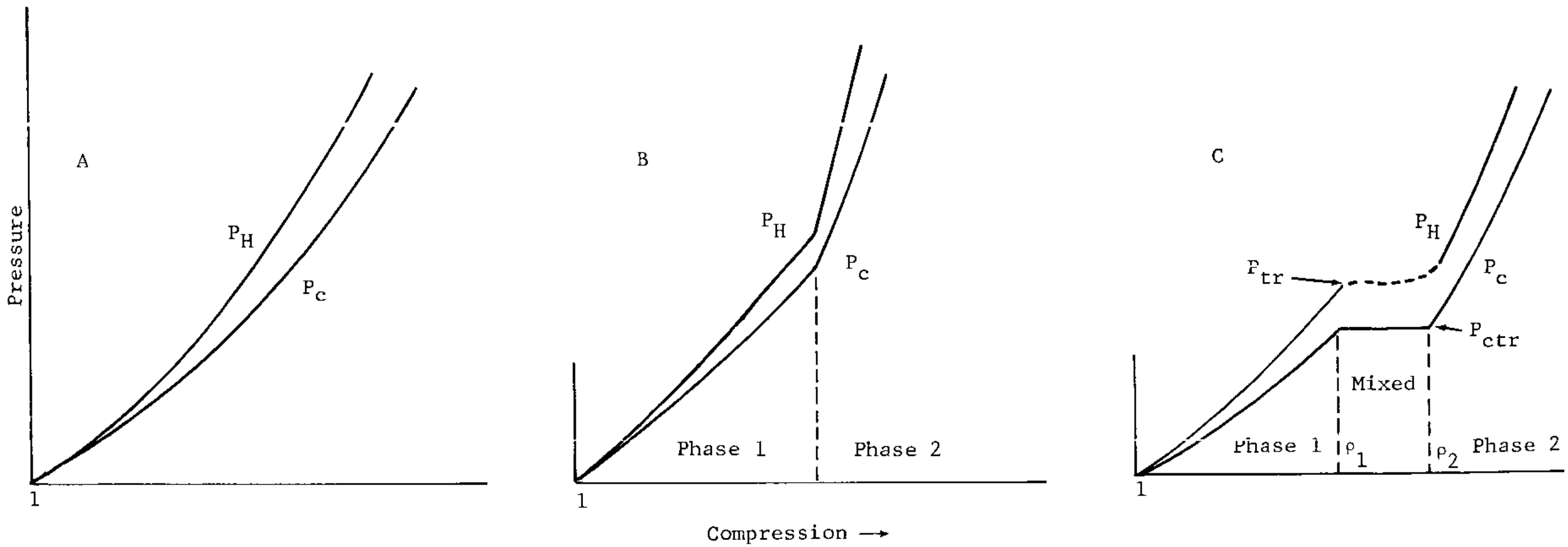

Figure 1. Three types of Hugoniots. Curve A indicates no phase transition, Curve B, second-order phase transition, and Curve C, first-order phase transition.

$$E_c(\eta) = E_c(\eta_1) + \frac{P_{c\,tr}}{\rho_{oo}} \int_{\eta_1}^{\eta} \frac{d\eta}{\eta^2}$$
$$= E_c(\eta_1) + \frac{P_{c\,tr}}{\rho_{oo}} \left\{\frac{\eta-\eta_1}{\eta\eta_1}\right\} , \quad \eta_1 < \eta \le \eta_2 \quad , \tag{162}$$

where $E_c(\eta_1)$ is computed by (21). In this region a unique Hugoniot curve may not be defined. If the thermal components of pressure do not increase with sufficient rapidity, a two-wave shock structure will result. Discussions of this phenomenon are found in Al'tshuler's work.[12]

For $\eta > \eta_2$ the form given by (13) is again employed but with new coefficients in the interpolation terms,

$$P_c(\eta) = C_{32}\eta^{5/3}\exp(-C_{33}\eta^{-1/3}) - \{C_{38}+C_{39}\eta^{1/3}+C_{40}\eta^{2/3}\} \quad ,$$
$$\eta > \eta_2 \quad , \tag{163}$$

where C_{32} and C_{33} are as previously defined. The remaining coefficients are determined by the value of P_c and its first two derivatives at η_2. The energy is given by

$$E_c(\eta) = C_9 + \frac{1}{\rho_{oo}} \{3C_{32}\eta^{2/3}\mathcal{E}_3(C_{33}\eta^{-1/3}) + \frac{C_{38}}{\eta}$$
$$+ \frac{3}{2}\frac{C_{39}}{\eta^{2/3}} + \frac{3C_{40}}{\eta^{1/3}}\} \quad , \tag{164}$$

where

$$C_9 = E_c(\eta_2) - \frac{1}{\rho_{oo}} \{3C_{32}\eta_2^{2/3}\mathcal{E}_3(C_{33}\eta_2^{-1/3})$$
$$+ \frac{C_{38}}{\eta_2} + \frac{3}{2}\frac{C_{39}}{\eta_2^{2/3}} + \frac{3C_{40}}{\eta_2^{1/3}}\} \quad , \tag{165}$$

$\mathcal{E}_3$ is given by (23), and $E_c(\eta_2)$ is computed from (162). For pressures sufficiently high, a well-defined Hugoniot is again formed in this region for compressions somewhat greater than η_2.

Some approximate relations can be given for the form of the Hugoniot for the above relations. However, this calculation has not as yet been fully tested in hydrodynamic code use. The interaction with nonthermodynamic quantities, e.g., artificial viscosity, is not completely known. For this reason only the input quantities will be given here, and it is suggested that this calculation be used only with the greatest care.

Five input quantities are required. Let these be denoted by D_1, D_2, D_3, D_4, and D_5. D_1 is the density ρ_1. If $D_1 < \rho_{oo}$, this calculation is not used. D_2 is the density ρ_2. If $D_2 < D_1$, the value of D_2 is set equal to D_1. This defines a second-order transition. D_3 is the pressure P_{ctr}. If $D_3 \leq 0$, the value of T_T used in Section III is employed to calculate D_3. D_4 is related to $\left.\frac{dP_c}{d\eta}\right|_{\eta_2}$.

If

$$
\begin{aligned}
D_4 > 0 \quad &, \quad \left.\frac{dP_c}{d\eta}\right|_{\eta_2} = D_4 \quad ; \\
D_4 = 0 \quad &, \quad \left.\frac{dP_c}{d\eta}\right|_{\eta_2} = \left(\frac{\eta_2}{\eta_1}\right) \left.\frac{dP_c}{d\eta}\right|_{\eta_1} \quad ; \\
D_4 < 0 \quad &, \quad \left.\frac{dP_c}{d\eta}\right|_{\eta_2} = - D_4 \left.\frac{dP_c}{d\eta}\right|_{\eta_1} \quad .
\end{aligned}
\tag{166}
$$

D_5 is related to $\left.\frac{d^2P_c}{d\eta^2}\right|_{\eta_2}$.

If

$$
\begin{aligned}
D_5 > 0 \quad &, \quad \left.\frac{d^2P_c}{d\eta^2}\right|_{\eta_2} = D_5 \quad ; \\
D_5 = 0 \quad &, \quad \left.\frac{d^2P_c}{d\eta^2}\right|_{\eta_2} = \left(\frac{\eta_2}{\eta_1}\right)^2 \left.\frac{d^2P_c}{d\eta^2}\right|_{\eta_1} \quad ; \\
D_5 < 0 \quad &, \quad \left.\frac{d^2P_c}{d\eta^2}\right|_{\eta_2} = - D_5 \left.\frac{d^2P_c}{d\eta^2}\right|_{\eta_1} \quad .
\end{aligned}
\tag{167}
$$

Note that if D_1 is properly defined but $D_2 = D_3 = D_4 = D_5 = 0$, no transition occurs, since all functions are continuous.

X. COMPUTATION OF INPUT PARAMETERS FROM EXPERIMENTAL DATA

Most of the input parameters are well-defined quantities (see Appendix A). The more difficult may be simply related to directly measurable quantities.

Reference Gruneisen Coefficient

Extensive tables of reference Gruneisen coefficients (Γ_o) are available. However, in some cases the values have been adjusted for special calculations. The value of Γ_o may be expressed in terms of quantities measurable along the zero pressure isobar. Observing the thermodynamic relation

$$\left(\frac{\partial P}{\partial T}\right)_\rho = - \left(\frac{\partial \rho}{\partial T}\right)_P \left(\frac{\partial P}{\partial \rho}\right)_T \quad , \tag{168}$$

it is clear that (17) may be written as

$$\Gamma = \frac{-1}{\rho C_V} \left(\frac{\partial \rho}{\partial T}\right)_P \left(\frac{\partial P}{\partial \rho}\right)_T \quad . \tag{169}$$

The difference in the heat capacity at constant volume C_V and that at constant pressure C_P is given by

$$C_V - C_P = \frac{T}{\rho^2} \left(\frac{\partial \rho}{\partial T}\right)_P^2 \left(\frac{\partial P}{\partial \rho}\right)_T \quad . \tag{170}$$

At the point of reference the above quantities are

$$\left(\frac{\partial P}{\partial \rho}\right)_T = \frac{B_o}{\rho_o} \tag{171}$$

and

$$\left(\frac{\partial \rho}{\partial T}\right)_P = -3\alpha_o \rho_o \quad , \tag{172}$$

where α_o is the coefficient of linear expansion. Thus the reference value of the Gruneisen coefficient is

$$\Gamma_o = \frac{3\alpha_o B_o}{\rho_o C_V} = \frac{3\alpha_o B_o}{\rho_o C_P - 9\alpha_o^2 T_o B_o} \; . \tag{173}$$

All quantities in (173) are measurable at zero pressure.

Experimental Hugoniot Data

It is often observed that experimental Hugoniot data may be expressed in the form

$$U_s = S_o + S_1 U_m \tag{174}$$

within the experimental error. While (174) is not exact, these data may be related to the coefficients encountered in Section III. Consider the initial state i in Section VII to be the reference point o. Equations (147) and (148) may be written in the form

$$P = P_o + \rho_o U_s U_m \tag{175}$$

and

$$\frac{\rho}{\rho_o} = \frac{U_s}{U_s - U_m} \; . \tag{176}$$

Combining these relations it may be shown that

$$\left(\frac{\partial P}{\partial \rho}\right)_s \Bigg|_{\rho_o T_o} = S_o^2 \tag{177}$$

and

$$\left(\frac{\partial^2 P}{\partial \rho^2}\right)_s \Bigg|_{\rho_o T_o} = \frac{2S_o^{\,2}}{\rho_o} (2S_1 - 1) \quad , \tag{178}$$

where the well-known property of second-order tangency between the Hugoniot and reference isentrope has been employed.[15] If it is assumed that the thermal component of pressure is independent of the density near $\rho = \rho_o$, the relation

$$\left(\frac{\partial P}{\partial \rho}\right)_s = \left(\frac{\partial P}{\partial \rho}\right)_T + \frac{T\left[\left(\frac{\partial P}{\partial T}\right)_\rho\right]^2}{\rho^2 \, C_v} \tag{179}$$

may be used to show that

$$\left(\frac{\partial P}{\partial \rho}\right)_s \Bigg|_{\rho_o T_o} = \left(\frac{\partial P}{\partial \rho}\right)_T \Bigg|_{\rho_o T_o} + 3\Gamma_o^2 N_o k T_o \quad , \tag{180}$$

and hence

$$B_o = \rho_o \left\{ S_o^2 - 3\Gamma_o{}^2 N_o k T_o \right\} \quad . \tag{181}$$

In the same manner the second derivatives yield

$$T_\Gamma = -3 \left\{ 1 + \Gamma_o - 2S_1 + \frac{3}{2} \frac{\Gamma_o{}^2 N_o k T_o \rho_o}{B_o} (\Gamma_o - 4S_1) \right\} \tag{182}$$

with the approximation

$$\frac{B_o \; \rho_{oo}{}^2}{B_{oo} \; \rho_o{}^2} \approx 1 \quad , \tag{183}$$

which is generally true to about 5 percent. Thus the two input parameters B_o and T_Γ may be calculated from the experimental Hugoniot data in the form given by (174) and other reference constants. This calculation is included in the input routines. However, because of the approximate nature of (182), slight adjustments might be required for good reproduction.

XI. CODING OF ANALYTIC EQUATION-OF-STATE ROUTINES

The entire analytic equation of state is made up of twelve subroutines. The following list gives the names and principle purpose of each. Only the routines which may be called externally include the argument list. A listing is given in Appendix C.

(1)	ANEOS (T, RHO, P, E, S, CV, DPDT, DPDR, FKROS, CS, KPA, MAT)	Main EOS calculation.
(2)	ANEOS1	Nuclear and cold components.
(3)	ANEOS2 (IGK, NUM, ITAPE, IZETL)	Main setup routine.
(4)	ANION1	Single-element ionization calculation.
(5)	ANION2	Multi-element ionization calculation.
(6)	ANION3	A part of the multi-element ionization calculation.
(7)	ANTWOPH	Evaluates thermodynamic functions in the two-phase regions.
(8)	ANPHASE	Setup for the two-phase calculation.
(9)	EPINT3	Evaluates the third exponential integral.
(10)	ANHUG	Calculates Hugoniots.
(11)	ANPHTR	Setup for phase transitions.
(12)	ANDATA	Contains all constants, such as ionization potentials, required by the other routines.

There are only three external links to these routines. ANEOS is the main calculation entry point. The temperature T and the density RHO must be defined in the calling statement. MAT is the absolute value of the equation-of-state number. All other arguments are computed by the various routines. P is the pressure, E is the energy, S is the entropy, CV is the constant volume heat capacity, DPDT is the pressure derivative with respect to temperature, DPDR is the pressure derivative with respect to density, FKROS is the Rosseland mean absorption coefficient, and CS is the sound speed. The variable KPA is either 1, 2, or 3; 1 indicates a one-phase state, 2 indicates a two-phase state, and 3 indicates that the alternate method of two-phase calculation discussed at the end of Section VI is employed.

ANEOS2 is the main setup routine. The argument IGK may be 1, 2, or 3. The principal initialization calculations occur for IGK = 1. NUM is the number of equations of state and IZETL is an array with the equation-of-state numbers. All data cards are read during this call. When IGK = 2, a complete dump of the calculated constants sufficient to restart the hydrodynamic calculation is produced on tape unit ITAPE. The latter two cases are designed to operate in conjunction with hydrodynamic code restart options.

The only other link to the hydrodynamic code is a COMMON/BIG/ used in subroutines ANHUG and ANDATA for initial data storage. The size of this array depends on the number of library analytic equations of state. In CHART D this space is used to store the tabular equation-of-state data read from tape following the initial analytic equation-of-state calculations.

In the listing shown in Appendix C, the dimensions are set for 20 different equations of state. The storage required for the complete package on a CDC 6600 is approximately 33,000 octal locations.

REFERENCES

1. Thompson, S. L., CHART D: A Computer Program for Calculating Problems of Coupled Hydrodynamic Motion and Radiation Flow in One Dimension, SC-RR-69-613, Sandia Laboratories, Albuquerque, New Mexico, November 1969.

2. Bodie, R. N. and Hormuth, J. E., The Puff 66 and P PUFF 66 Computer Programs, AFWL-TR-66-48, Air Force Weapons Laboratory, Albuquerque, New Mexico, May 1966.

3. Hermann, W., Holzhauser, P., and Thompson, R. J., WONDY - A Computer Program for Calculating Problems of Motion in One Dimension, SC-RR-66-601, Sandia Laboratories, Albuquerque, New Mexico, February 1967.
   Holzhauser, P., and Lawrence, R. J., WONDY III - An Improved Program for Calculating Problems of Motion in One Dimension, SC-DR-68-217, Sandia Laboratories, Albuquerque, New Mexico, June 1968.

4. Kirzhnits, D. A., JETP 32, 115 (1957), [Soviet Physics - JETP 5, 64 (1957)].

5. Kalitkin, N. N., JETP 38, 1534 (1960), [Soviet Physics - JETP 11, 1106 (1960)].

6. Al'tshuler, L. V., and Bakanova, A. A., Usp. Fiz. Nauk 96, 193 (1968), [Soviet Physics - Uspekhi 11, 678 (1969)].

7. Kalitkin, N. N., and Govorukhina, I. A., Fizika Tverdoga Tela 7, 355 (1965), [Soviet Physics - Solid State 7, 287 (1965)].

8. Barnes, J. F., Phys. Rev. 153, 269 (1967).

9. Slater, J. C., Introduction to Chemical Physics (McGraw-Hill Book Co., New York, 1939).

10. Dugdale, J. S., and MacDonald, D. K. C., Phys. Rev. 89, 832 (1953).

11. Hirschfelder, J. O., Curtiss, C. F., and Bird, R. B., Molecular Theory of Gases and Liquids (John Wiley and Sons, New York, 1954).

12. Al'tshuler, L. V., Usp. Fiz. Nauk 85, 197 (1965), [Soviet Physics Uspekhi 8, 52 (1965)].

13. For example, see Pryde, J. A., The Liquid State (Hutchinson, London, 1966).

14. Kormer, S. B., Funtikov, A. I., Urlin, V. D., and Kolesnikova, A. N., JETP 42, 686 (1962), [Soviet Physics - JETP 15, 477 (1962)].

15. Zel'dovich, Ya. B., and Raizer, Yu. P., Physics of Shock Waves and High Temperature Hydrodynamic Phenomena [ed. Hayes, W. D., and Probstein, R. F.] (Academic Press, New York, 1966).

16. Aller, L. H., Astrophysics - The Atmospheres of the Sun and Stars (Ronald Press, New York, 1963).

APPENDIX A

EMPLOYMENT OF ANALYTIC EQUATION-OF-STATE ROUTINES

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EMPLOYMENT OF ANALYTIC EQUATION-OF-STATE ROUTINES

Input Cards for the Analytic Equation of State

There is one set of the following cards for each analytic equation of state. In the CHART D radiation diffusion-hydrodynamic code, these cards follow card set 10 described in Appendix B of Reference 1. Analytic and tabular forms may be simultaneously used, subject only to the total storage limitations and a maximum of twenty different equations of state. Positive equation-of-state numbers are reserved for tabular forms. Analytic equations of state must have a negative number greater than or equal to (-20).

All temperatures below are assumed in units of electron volts.

Card 1. Format (I3, I5, I2 5A10, 2E10.3)

Variable 1. Equation-of-state number.

Variable 2. Library equation-of-state number if desired; otherwise, zero.

Variable 3. Used only with library equation of state. This variable determines the type of analytic calculation (see variable 2, card 2). If out of the range 0 to 4, or library information is only for a gas, this input is ignored.

Variables 4-8. Fifty-column identification label.

Variable 9. The initial density for the Hugoniot calculation. If zero, the calculation is shipped. If negative, the initial density is taken to be the reference density.

Variable 10. The initial temperature for the Hugoniot calculation. If zero, the calculation is shipped. If negative, the initial temperature is taken to be the reference temperature.

The Hugoniot calculation should normally be used only to test new equation-of-state information.

```
**********************************************************
*   If a library equation of state is requested,        *
*   no further data cards are required.                  *
*                                                        *
**********************************************************
```

Cards 2, 3, and 4. Format (8E10.3)

Variable 1. The number of elements in this material.

Variable 2. Switch for type of equation of state.

0. - Solid-gas without electronic terms and without proper treatment of the two-phase region.

1. - Solid-gas with electronic terms but without proper treatment of the two-phase region.

2. - Gas only with electronic terms.

3. - Same as 0., but with a proper treatment of the two-phase region.

4. - Same as 1., but with a proper treatment of the two-phase region.

Options 3 and 4 employ the full treatment of the two-phase region, while 0 and 1 use the alternate method given at the end of Section VI.

Variable 3. Reference density (ρ_o).

Variable 4. Reference temperature (T_o).

Variable 5. Reference pressure (P_o); used only when variables 23 and 24 are zero.

Variable 6. Reference bulk modulus (B_o); used only when variables 23 and 24 are zero.

Variable 7. Reference Gruneisen coefficient (Γ_o).

Variable 8. Reference Debye temperature (θ_o). If zero or negative, code assumes a value of 0.025.

Variable 9. Parameter T_Γ [cf. Eq. (20)];
T_Γ = - 1, Slater theory;
T_Γ = 0, Dugdale and MacDonald theory;
T_Γ = 1, free-volume theory.

Variable 10. Three times the limiting value of the Gruneisen coefficient for large compressions [cf. Eq. (43)], usually either 2 or 0. When a value of 2 is used, $C_{24} = 2/3$.

Variable 11. Zero temperature separation energy (E_S).

Variable 12. Melting temperature (T_{melt}).

Variable 13. Constant in Hugoniot data S_o [cf. Eq. (174)]. See note with variable 14.

Variable 14. Constant in Hugoniot data S_1 [cf. Eq. (174)]. If both S_o and S_1 are greater than 0, the input value of variables 6 and 9 above are ignored (see Section X). If either S_o or S_1 is zero, both are ignored.

Variable 15. Thermal conductivity coefficient (H_o) (see Section VIII). If zero, thermal conduction is not included. Note that the units of $H = H_oT^{C41}$ are ergs/(cm sec eV).

Variable 16. Temperature dependence of thermal conduction coefficient (C_{41}) (see Section VIII).

Variable 17. Lowest allowed solid density (ρ_{min}), usually about 0.8 ρ_o (see Sections III and VI). If zero or negative, code assumes a value of 0.8 ρ_o.

Variable 18. Parameter D_1

Variable 19. Parameter D_2

Variable 20. Parameter D_3

Variable 21. Parameter D_4

Variable 22. Parameter D_5

See Section IX. Normally, all zero except for phase transitions.

Variable 23. Zero pressure - zero temperature density (ρ_{oo}). If zero, code will calculate from the reference point conditions, normally zero.

Variable 24. Zero pressure - zero temperature bulk modulus (B_{oo}). If zero, code will calculate from the reference point conditions, normally zero.

For a gaseous equation of state, variables 5 to 14 and 17 to 24 are read but not used.

Card 5. Format (5(F5.0, E10.3))

There is one set of the following variables for each element in variable 1, card 2.

Variable Odd. Atomic number of element.

Variable Even. Unnormalized atomic number fraction of element.

Printed Output

The normal printed output produced during initiation can be up to four pages in length. Examples are shown in Appendix B. Three of these pages give self-explanatory information concerning the multiphase calculation, zero-temperature isotherm, and Hugoniot if they are requested. The remaining page lists the input cards and calculated constants. Additional listings are given for the phase transition calculations. The variables named ZB are the input variables on the second, third, and fourth cards as given above. The meanings of the elements of the C array are given in the following tabulation.

C. Storage for:

1. η_1 of Eq. (160) if defined for a phase transition; otherwise, large number.
2. η_2 of Eq. (161) if defined for a phase transition.
3. B_{oo} variable 24, card 2 above.
4. Constant in Eq. (24).
5. Constant in Eq. (24).
6. Constant in Eq. (24).
7. P_{ctr} (see Section IX) if defined for a phase transition.
8. $E_c(\eta_1)$ in Eq. (162) if defined for a phase transition.
9. Constant in Eq. (165) if defined for a phase transition.
10. E_S variable 11, card 2 above.
11. ρ_o variable 3, card 2 above.
12. T_o variable 4, card 2 above.
13. Constant in Eq. (52).
14. Constant in Eq. (58).
15. Γ_o variable 7, card 2 above.
16. Constant in Eq. (56).
17. Constant in Eq. (56).
18. T_{melt} variable 12, card 2 above.
19. ρ_{oo} variable 23, card 2 above.

20. P_o variable 5, card 2 above.

21. B_o variable 6, card 2 above.

22. Constant in Eq. (156).

23. ρ_{min} variable 17, card 2 above.

24. Constant in Eq. (43).

25. θ_o variable 8, card 2 above.

26. Z_m [Eq. (69)].

27. N_o [Eq. (74)].

28. Number of elements, variable 1, card 2 above.

29. $\bar{A}$ [Eq. (66)].

30. EOS type switch, variable 2, card 2 above.

31. Internal storage location.

32. Constant in Eq. (13).

33. Constant in Eq. (13).

34. Constant in Eq. (13).

35. Constant in Eq. (13).

36. Constant in Eq. (13).

37. Constant in Eq. (22).

38. Constant in Eq. (163) if defined for a phase transition.

39. Constant in Eq. (163) if defined for a phase transition.

40. Constant in Eq. (163) if defined for a phase transition.

41. Constant in Eq. (153), variable 16, card 2 above.

Library of Analytic Equations of State

The library facilities in these routines are provided only as a convenience to the user so that frequently required equation-of-state information need not be punched for each problem. Basically, the information put on cards 2, 3, 4, and 5 as described above is stored in data statements. Each user should modify the library to meet his requirements. The size of the library determines the dimension required for the COMMON/BIG/ mentioned in Section XI. The first 100 locations of the common block are used in SUBROUTINE ANHUG.

An example of how the library should be treated is given at the end of SUBROUTINE ANDATA listed in Appendix C following the lengthy list of ionization potentials. All information is contained in three arrays which are equivalenced to elements in COMMON/BIG/. The main data block is the array DTAB. The library equation-of-state number is stored in an array TABLE and in the corresponding location in the array TABPL is stored the location of the first element in the DTAB array for this material. The first element in DTAB is a Hollerith constant used for identification. Then, in the above order, is the information contained on cards 2, 3, 4, and 5.

The variable NUMTAB is the total number of library equations of state in the list and should be adjusted with each addition or deletion.

APPENDIX B

EXAMPLES

APPENDIX B

EXAMPLES

The following pages give results of one of the library equations of state shown in Appendix C. Since aluminum is most widely used for illustrative purposes, it was selected for the present calculation. On the next page is reproduced the first printed page of computer output. The meaning of the ZB and C arrays are discussed in Appendix A. The printed symbol COT (ℓ) is the variable C_ℓ and FNI (ℓ) is N_ℓ. Calculated Hugoniot data are shown in Figs. B-1, B-2, and B-3. The thermodynamic functions and Rosseland opacity at constant density are shown in Figs. B-4 through B-7. These plots were produced by a test program.

```
EOS DATA FOR ANALYTIC EOS NUMBER    -3     LIBRARY NUMBER     3      TYPE  4

ALUMINUM

RHUG= -1.0000E+00          THUG= -1.0000E+00


LIBRARY EOS NUMBER      3 ( ALUMINUM    ) IS REQUESTED

ZB( 1)= 1.000000000E+00   ZB(13)= 0.
ZB( 2)= 4.000000000E+00   ZB(14)= 0.
ZB( 3)= 2.700000000E+00   ZB(15)= 0.
ZB( 4)= 2.567785000E-02   ZB(16)= 0.
ZB( 5)= 0.                ZB(17)= 0.
ZB( 6)= 7.630000000E+11   ZB(18)= 0.
ZB( 7)= 2.060000000E+00   ZB(19)= 0.
ZB( 8)= 3.430000000E-02   ZB(20)= 0.
ZB( 9)=-1.000000000E+00   ZB(21)= 0.
ZB(10)= 2.000000000E+00   ZB(22)= 0.
ZB(11)= 1.200000000E+11   ZB(23)= 0.
ZB(12)= 8.000000000E-02   ZB(24)= 0.

C( 1)= 1.000000000+100   C(21)= 7.630000000E+11
C( 2)= 0.                C(22)= 0.
C( 3)= 8.308037864E+11   C(23)= 2.160000000E+00
C( 4)= 6.085688337E+11   C(24)= 6.666666667E-01
C( 5)= 7.227764511E+00   C(25)= 3.430000000E-02
C( 6)= 3.132235489E+00   C(26)= 1.300000000E+01
C( 7)= 0.                C(27)= 2.232285598E+22
C( 8)= 0.                C(28)= 1.000000000E+00
C( 9)= 0.                C(29)= 2.698200000E+01
C(10)= 1.200000000E+11   C(30)= 4.000000000E+00
C(11)= 2.700000000E+00   C(31)= 1.000000000E+00
C(12)= 2.567785000E-02   C(32)= 1.606562223E+13
C(13)= 7.717072014E-05   C(33)= 3.165142243E+00
C(14)= 9.248659981E-04   C(34)= 9.934033095E+11
C(15)= 2.060000000E+00   C(35)=-3.674978173E+12
C(16)=-4.279835391E-01   C(36)= 3.359674857E+12
C(17)= 1.548148148E+00   C(37)= 5.913693881E+12
C(18)= 8.000000000E-02   C(38)= 0.
C(19)= 2.752335237E+00   C(39)= 0.
C(20)= 0.                C(40)= 0.
                         C(41)= 0.

Z( 1)=  13   COT( 1)= 1.00000E+00   FNI( 1)= 2.23229E+22

REFERENCE POINT CONDITIONS
T=  2.567785E-02        RHO=  2.700000E+00
P=  1.500488E+00        E=  2.805208E+09
S=  1.116398E+11        CV=  1.069397E+11
DPDT=  5.934866E+11     DPDR=  2.822157E+11
B0=  7.619824E+11       CS=  5.420491E+05
```

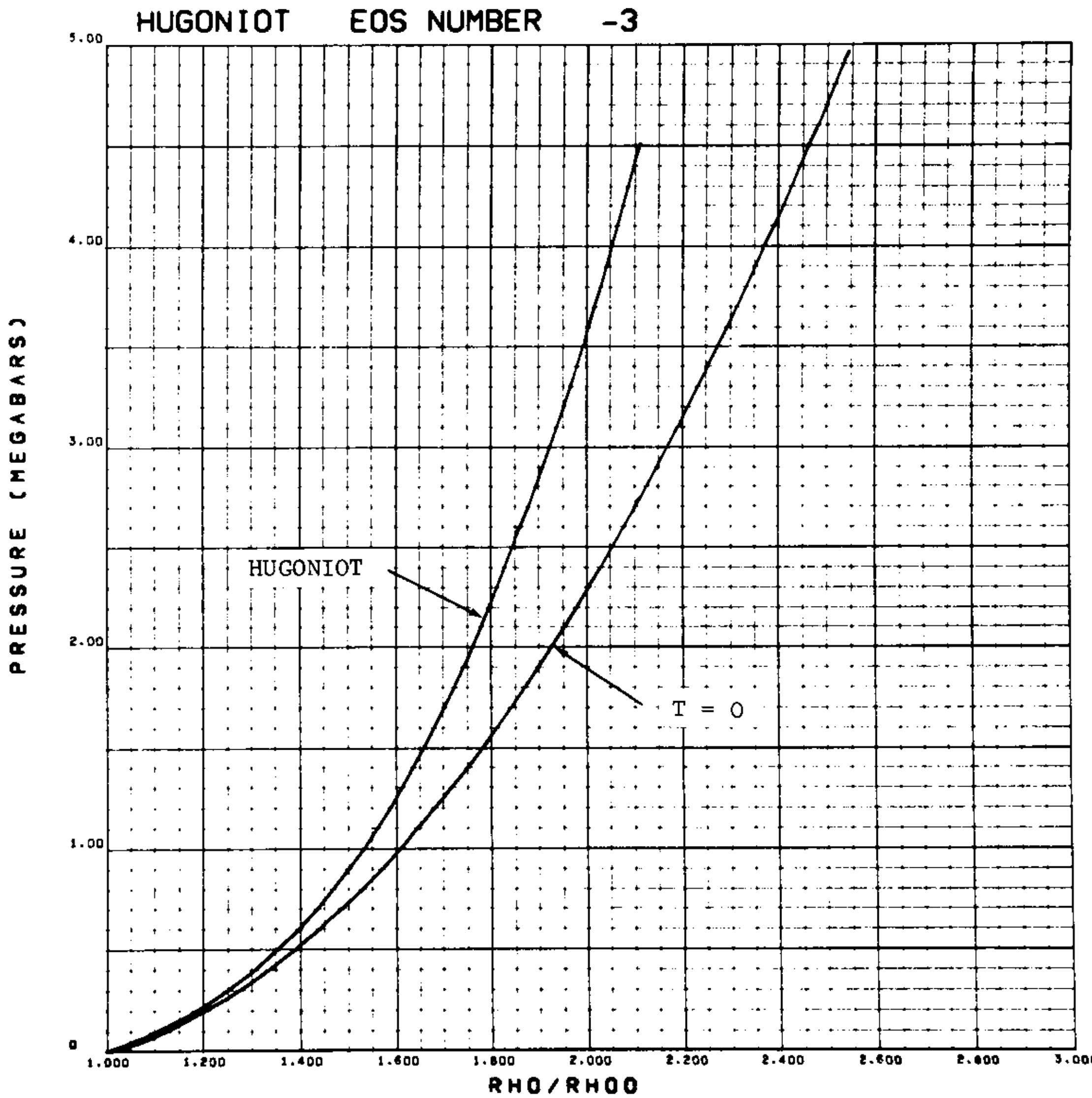
HUGONIOT EOS NUMBER -3
PRESSURE (MEGABARS)
5.00
4.00
3.00
2.00
1.00
0
1.000
1.200
1.400
1.600
1.800
2.000
2.200
2.400
2.600
2.800
3.000
RHO/RHOO
HUGONIOT
T = 0

Figure B-1

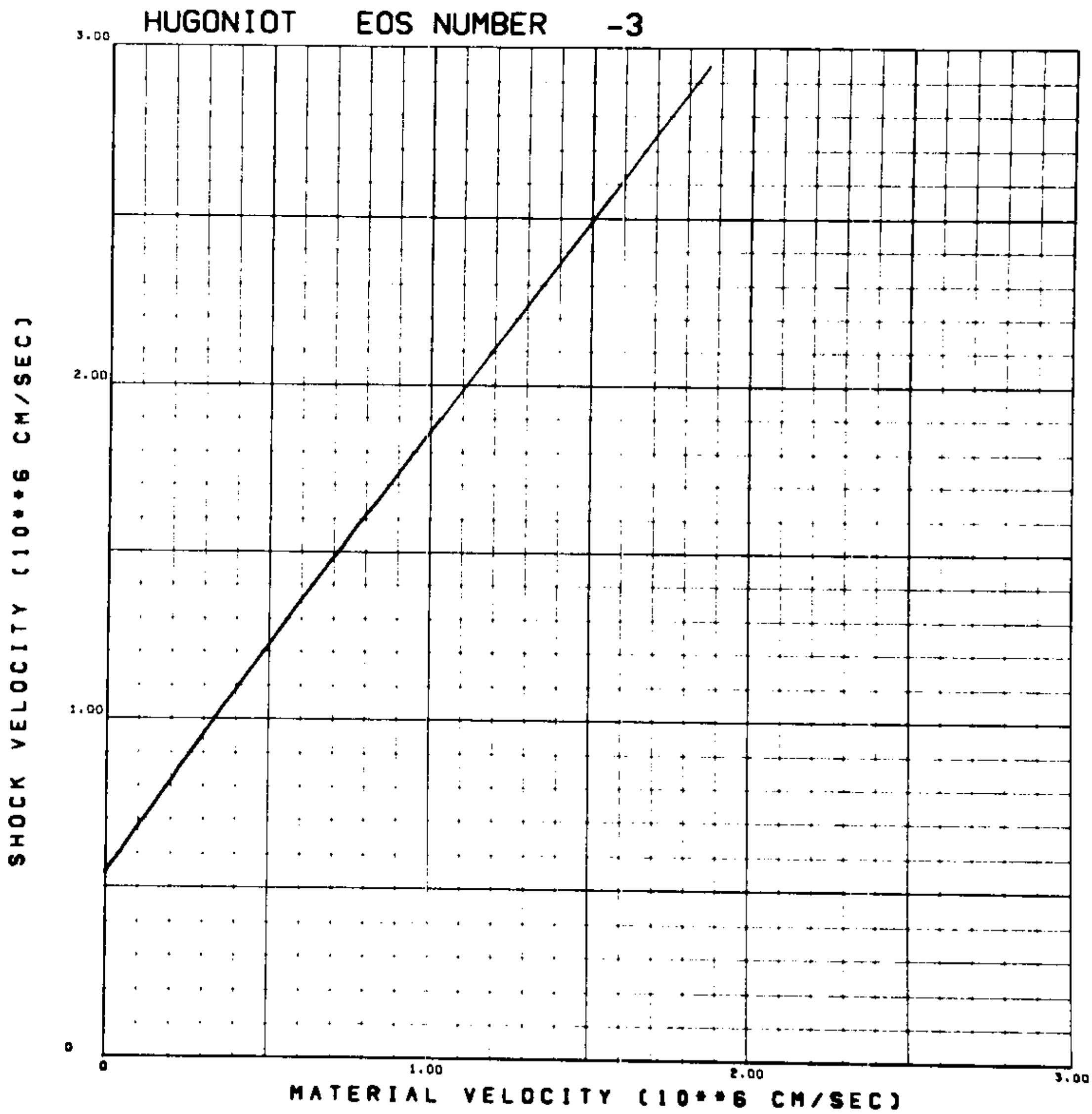
HUGONIOT EOS NUMBER -3
SHOCK VELOCITY (10**6 CM/SEC)
MATERIAL VELOCITY (10**6 CM/SEC)
3.00
2.00
1.00
0
0
1.00
2.00
3.00

Figure B-2

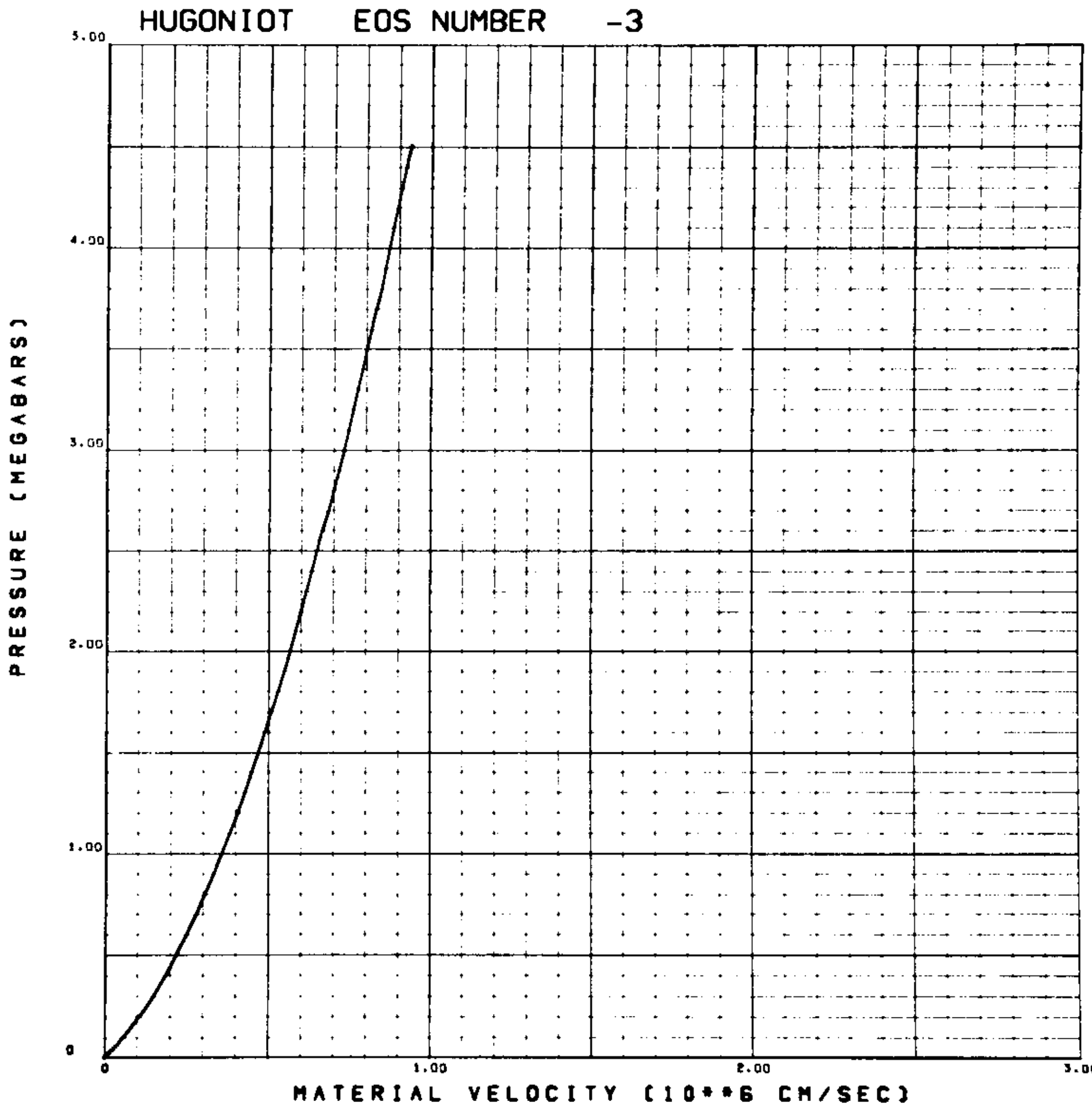
HUGONIOT EOS NUMBER -3
PRESSURE (MEGABARS)
MATERIAL VELOCITY (10**6 CM/SEC)
0
1.00
2.00
3.00
4.00
5.00

Figure B-3

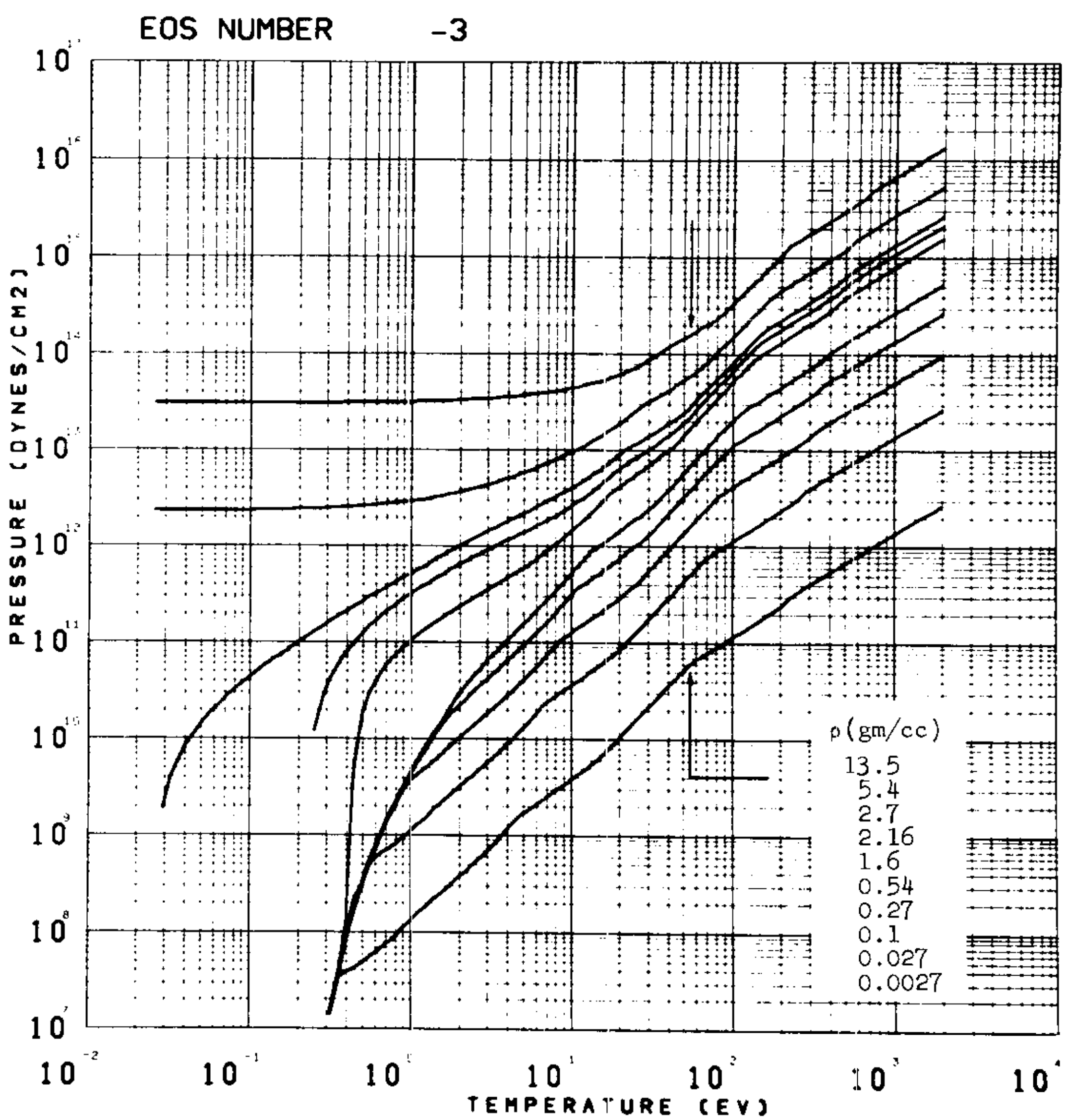
EOS NUMBER -3
PRESSURE (DYNES/CM2)
TEMPERATURE (EV)
ρ(gm/cc)
13.5
5.4
2.7
2.16
1.6
0.54
0.27
0.1
0.027
0.0027

Figure B-4

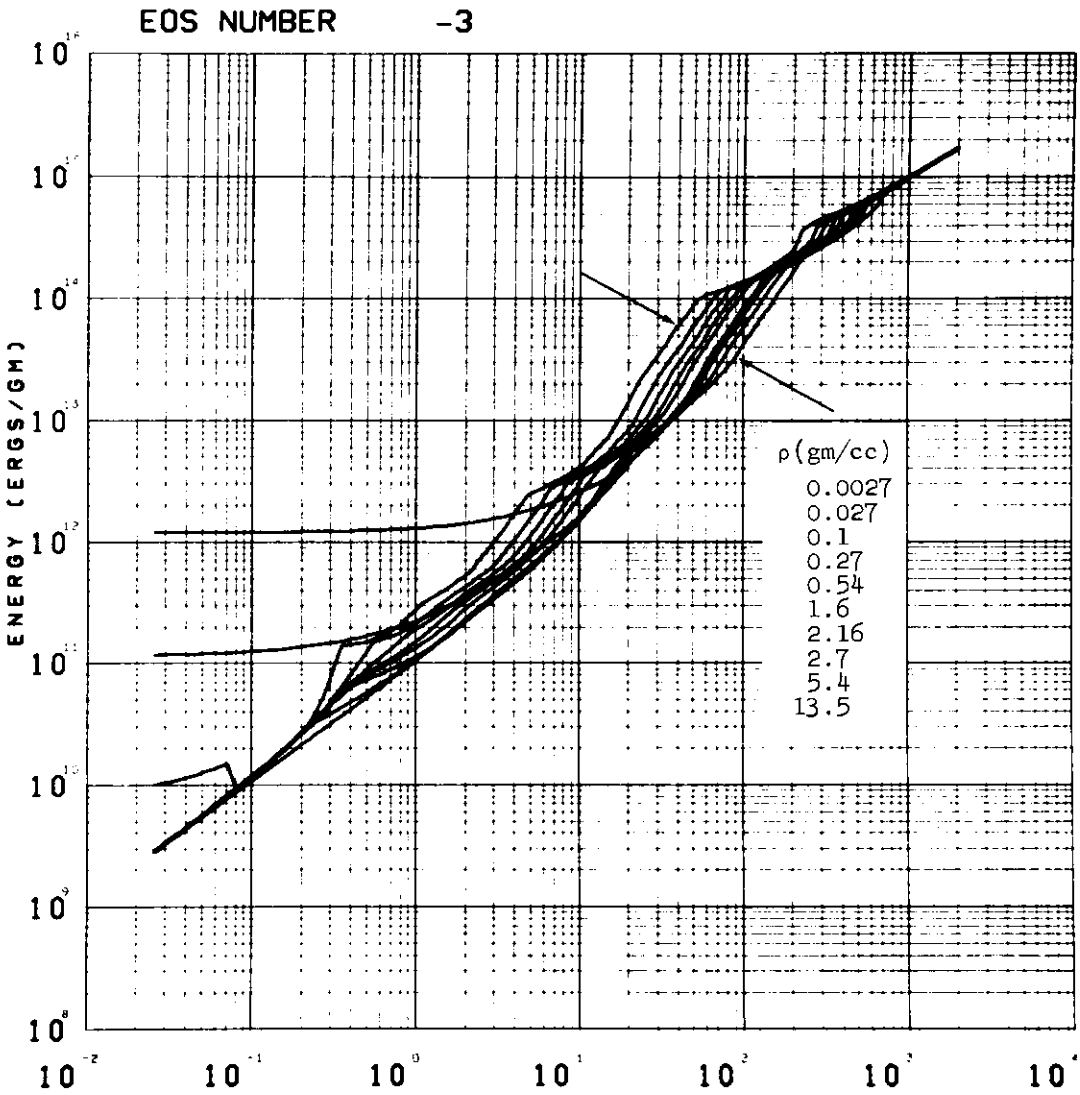
EOS NUMBER -3
ENERGY (ERGS/GM)
TEMPERATURE (EV)
ρ(gm/cc)
0.0027
0.027
0.1
0.27
0.54
1.6
2.16
2.7
5.4
13.5

Figure B-5

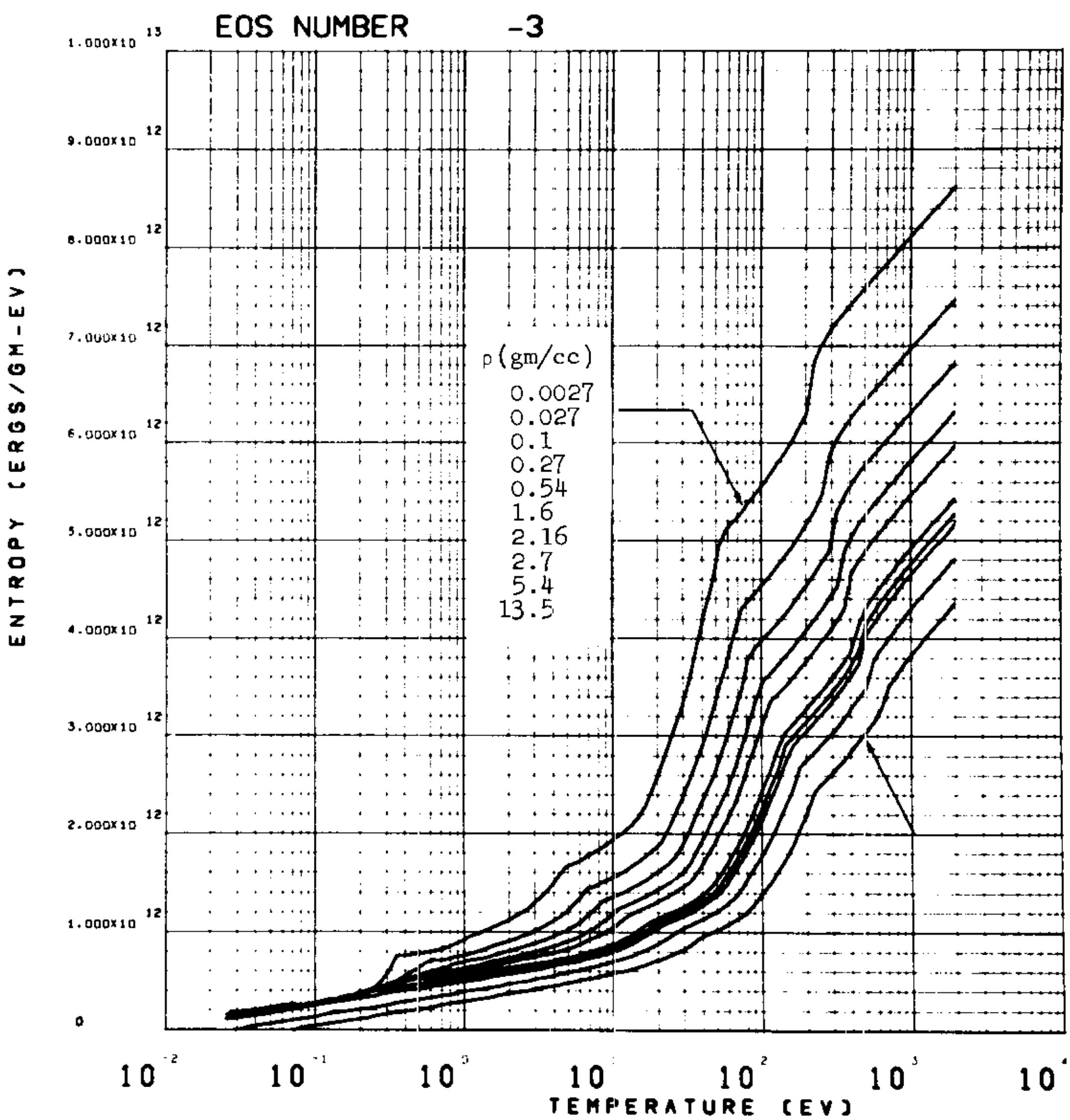
EOS NUMBER -3
ENTROPY (ERGS/GM-EV)
TEMPERATURE (EV)
ρ(gm/cc)
0.0027
0.027
0.1
0.27
0.54
1.6
2.16
2.7
5.4
13.5

Figure B-6

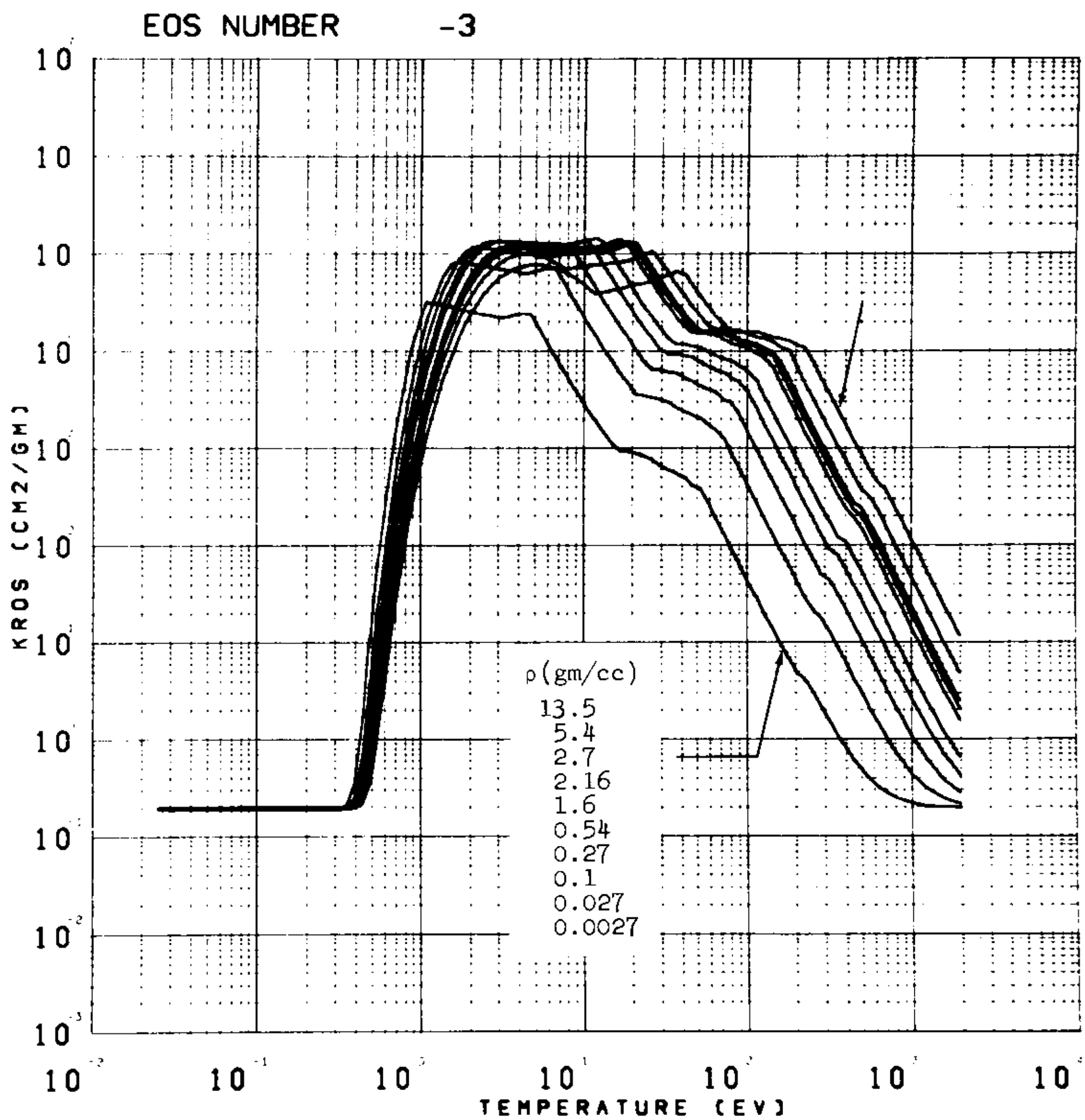
EOS NUMBER -3
KROS (CM2/GM)
TEMPERATURE (EV)
ρ(gm/cc)
13.5
5.4
2.7
2.16
1.6
0.54
0.27
0.1
0.027
0.0027

Figure B-7

APPENDIX C

FORTRAN LISTING

```
      SUBROUTINE ANEOS (T,RHO,P,E,S,CV,DPDT,DPDR,FKROS,CS,KPA,MAT)
C     ANALYTICAL EOS CALCULATION   MAIN ROUTINE
      COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),
     1  RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,
     2  EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)
      T32=T*SQRT(T)
      LOC=LOCSV(MAT)
      NMATS=ACK(LOC+30)
      IF (NMATS.GE.3) GO TO 30
      CALL ANEOS1 (T,RHO,MAT,P,E,S,CV,DPDT,DPDR,LOC)
      IF (P.GE.0.) GO TO 20
      IF (T.GE.ACK(LOC+18)) GO TO 10
      IF (RHO.GE.ACK(LOC+23)) GO TO 20
   10 P=DPDT=DPDR=0.
      KPA=3
      GO TO 60
   20 KPA=1
      GO TO 60
   30 IF (RHO.GE.ACK(LOC+11)) GO TO 50
      IF (T.GE.TCT(MAT)) GO TO 50
      IF (T.GT.ACK(LOC+18)) GO TO 40
      IF (RHO.GE.ACK(LOC+23)) GO TO 50
   40 CALL ANTWOPH (T,RHO,MAT,P,E,S,CV,DPDT,DPDR,LOC,KPA)
      IF (KPA.EQ.2) GO TO 60
   50 CALL ANEOS1 (T,RHO,MAT,P,E,S,CV,DPDT,DPDR,LOC)
      KPA=1
   60 IF (NMATS-3*(NMATS/3)) 80,70,80
   70 FKROS=1.E5
      GO TO 130
   80 IF (T.GT.0.07) GO TO 90
      FKROS=.4*ACK(LOC+26)/ACK(LOC+29)
      ZBAR=0.
      GO TO 130
   90 NMATS=ACK(LOC+28)
      FN=ACK(LOC+27)
      IIZ=ACK(LOC+31)
      IF (NMATS.GT.1) GO TO 100
      Z=ZZS(IIZ)
      CALL ANION1 (T,RHO,Z,FN,PE,EE,SE,CVE,DPTE,DPRE,ZBAR,T32)
      FKROS=(1.E11*RHO*ZBAR**3/(ACK(LOC+29)*T32*T**2)+.4*Z)/ACK(LOC+29)
      GO TO 120
  100 Z=ACK(LOC+26)
      CALL ANION2 (T,RHO,FN,Z,NMATS,IIZ,T32,ZBAR,PE,EE,SE,DPTE,DPRE,CVE)
      Y=0.
      DO 110 I=1,NMATS
  110 Y=Y+COT(IIZ+I-1)*ZB(I)**2
      FKROS=(1.E11*RHO*ZBAR*Y/(ACK(LOC+29)*T32*T**2)+.4*Z)/ACK(LOC+29)
  120 P=P+PE
      E=E+EE
      S=S+SE
      CV=CV+CVE
      DPDT=DPDT+DPTE
      DPDR=DPDR+DPRE
  130 CS=DPDR+(T*DPDT**2)/(CV*RHO**2)
      IF (CS.LT.1.E-20) GO TO 140
```

```
      CS=SQRT(CS)
      GO TO 150
  140 CS=1.E-10
  150 IF (ACK(LOC+22).EQ.0.) RETURN
      Y=ACK(LOC+22)*T**(3.-ACK(LOC+41))/RHO
      FKROS=FKROS*Y/(Y+FKROS)
      RETURN
      END
```

```
      SUBROUTINE ANEOS1 (T,RHO,MAT,P,E,S,CV,DPDT,DPDR,L)
C     AN ANALYTICAL EOS CALCULATION FOR NUCLEAR AND COLD COMPONENTS
      COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),
     1  RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,
     2  FIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)
      FT=BOLTS*ACK(L+27)
      IF (ACK(L+30).NE.2.) GO TO 10
      DPDR=FT*T
      P=DPDR*RHO
      E=1.5*FT*T
      GO TO 50
   10 IF (RHO.GT.1.E-10) GO TO 20
      DPDR=FT*T
      P=RHO*DPDR
      E=ACK(L+10)+1.5*FT*T
      GO TO 50
   20 RSQ=RHO*RHO
      RHO0=ACK(L+11)
      X1=RHO**.3333333333
      RHO00=ACK(L+19)
      X2=RHO/RHO00
      X3=X2**.3333333333
      X4=X2/X3
      X6=1./X3
      IF (X2.GT.1.) GO TO 60
      X5=1.-X6
      X7=EXP(ACK(L+5)*X5)
      X8=EXP(ACK(L+6)*X5)
      P=ACK(L+4)*(X7-X8)*X4
      DPDR=P/(1.5*RHO)+ACK(L+4)*(ACK(L+5)*X7-ACK(L+6)*X8)/(3.*X4*RHO00)
      E=3.*ACK(L+4)*((X7-1.)/ACK(L+5)-(X8-1.)/ACK(L+6))/RHO00
      IF (RHO.GE.RHO0) GO TO 90
      THETA=RHO*ACK(L+16)
      GM=RHO*(ACK(L+17)+THETA)+1.
      GP=ACK(L+17)+2.*THETA
      THETA=ACK(L+14)*RHO*EXP(RHO*(ACK(L+17)+.5*THETA))
   30 PPP=ACK(L+13)*T*(X1/THETA)**2
      IF (PPP.GT.1.E5) GO TO 40
      X3=1./(1.+PPP)
      X4=2.+PPP
      X5=3.*GM+PPP
      EN=1.5*FT*T*X3*X4
      PN=RHO*FT*T*X3*X5
      CV=EN*(1.-PPP*X3/X4)/T
      X6=1.-3.*GM
      DPDT=PN*(1.+PPP*X6*X3/X5)/T
      DPDR=DPDR+PN*(1.+PPP*X3*X6**2/(1.5*X5))/RHO+3.*RHO*FT*X3*GP*T
      S=FT*(4.-3.*ALOG(THETA/T)+1.5*(ALOG(X3)-PPP*X3))
      GO TO 110
   40 DPDR=DPDR+FT*T
      P=P+RHO*FT*T
      E=E+1.5*FT*T
   50 CV=1.5*FT
      DPDT=RHO*FT
      S=FT*(1.5*ALOG(T/ACK(L+13))-ALOG(RHO)+2.5)
```

```
      GO TO 120
   60 X8=ACK(L+33)*X6
      X5=EXP(-X8)
      X7=X5*ACK(L+32)
      IF (X2.GT.ACK(L+1)) GO TO 70
      P=X2*X4*X7-(ACK(L+34)+ACK(L+35)*X3+ACK(L+36)*X4)
      DPDR=(X7*X3*(5.*X3+ACK(L+33))-X6*(ACK(L+35)*X6+2.*ACK(L+36)))/(3.*
     1RHOOO)
      CALL EPINT3 (X8,X5,GM)
      E=(3.*ACK(L+32)*X4*GM+(ACK(L+34)+1.5*ACK(L+35)*X3+3.*ACK(L+36)*X4)
     1/X2-ACK(L+37))/RHOOO
      GO TO 90
   70 IF (X2.GT.ACK(L+2)) GO TO 80
      P=ACK(L+7)
      DPDR=0.
      E=ACK(L+8)+P*(X2-ACK(L+1))/(RHOOO*X2*ACK(L+1))
      GO TO 90
   80 P=X2*X4*X7-(ACK(L+38)+ACK(L+39)*X3+ACK(L+40)*X4)
      DPDR=(X7*X3*(5.*X3+ACK(L+33))-X6*(ACK(L+39)*X6+2.*ACK(L+40)))/(3.*
     1RHOOO)
      CALL EPINT3 (X8,X5,GM)
      E=ACK(L+9)+(3.*ACK(L+32)*X4*GM+(ACK(L+38)+1.5*ACK(L+39)*X3+3.*ACK(
     1L+40)*X4)/X2)/RHOOO
   90 X3=RHOO/RHO
      X4=1.-X3
      X5=ACK(L+24)
      X6=ACK(L+15)
      IF (X5.GT.0.) GO TO 100
      GM=X3*X6
      GP=-GM/RHO
      THETA=ACK(L+25)*EXP(X4*X6)
      GO TO 30
  100 GM=X3*X6+X5*X4**2
      GP=-X3*(X6-2.*X5*X4)/RHO
      THETA=ACK(L+25)*EXP(X4*X6-.5*X5*(3.-X3*(4.-X3)))*(RHO/RHOO)**X5
      GO TO 30
  110 E=E+EN
      P=P+PN
  120 RETURN
      END
```

```
      SUBROUTINE ANEOS2 (IGK,NUM,ITAPE,IZETL)
C     SET UP FOR ANALYTICAL EOS DATA
C     DIMENSIONS ARE SET FOR 20 EQUATIONS OF STATE
C     100 ELEMENTS (AN ELEMENT IS COUNTED ONCE IN EACH EOS)
C     1000 TWO-PHASE BOUNDARY POINTS
      DIMENSION IZETL(1)
      COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),
     1  RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,
     2  EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)
C
      GO TO (10,450,460), IGK
   10 PRINT 470
      IT=0
      IZ=1
      IKPN=1
      DO 430 IQ=1,NUM
      IF (IZETL(IQ).GT.0) GO TO 430
      READ 510, ISE,ISETAB,IZI,(DZB(I),I=1,5),RHUG,THUG
      PRINT 520, ISE,ISETAB,IZI,(DZB(I),I=1,5),RHUG,THUG
      IF (ISE.GE.0) GO TO 30
      IF (ISE.LT.-20) GO TO 30
      DO 20 JJ=1,NUM
      MAT=IZETL(JJ)
      IF (MAT.EQ.ISE) GO TO 40
   20 CONTINUE
   30 PRINT 530, ISE
      STOP 1000
   40 MAT=-MAT
      LOCSV(MAT)=IT
      LOCKP(MAT)=IKPN
      IF (ISETAB.EQ.0) READ 540, (ZB(I),I=1,24)
      IF (ISETAB.NE.0) CALL ANDATA (IT,IZ,ISETAB)
      DO 50 I=1,40
   50 DZB(I)=0.
      DZB(28)=ZB(1)
      DZB(30)=ZB(2)
      DZB(11)=ZB(3)
      DZB(12)=ZB(4)
      DZB(20)=ZB(5)
      DZB(21)=ZB(6)
      DZB(15)=ZB(7)
      DZB(25)=ZB(8)
      TGAM=ZB(9)
      DZB(24)=ZB(10)/3.
      DZB(10)=ZB(11)
      DZB(18)=ZB(12)
      DZB(23)=ZB(17)
      DZB(19)=ZB(23)
      DZB(3)=ZB(24)
      DZB(1)=ZB(18)
      DZB(2)=ZB(19)
      DZB(7)=ZB(20)
      DZB(39)=ZB(21)
      DZB(40)=ZB(22)
      IF (ISETAB.EQ.0) GO TO 60
```

```
      IF (DZB(30).EQ.2.) GO TO 60
      IF (IZI.LT.0) GO TO 60
      IF (IZI.GT.4) GO TO 60
      DZB(30)=IZI
   60 DZB(31)=IZ
      IF (DZB(30).GE.0.) GO TO 80
   70 PRINT 480, DZB(30),(ZB(I),I=1,24)
      STOP
   80 IF (DZB(30).GT.4.) GO TO 70
      IF (DZB(23).LE.0..AND.DZB(30).NE.2.) DZB(23)=0.8*DZB(11)
      IF (DZB(25).LE.0..AND.DZB(30).NE.2.) DZB(25)=0.025
      ACK(IT+41)=ZB(16)
      IF (ZB(15).LE.0.) GO TO 90
      DZB(22)=5.48E12/ZB(15)
      GO TO 100
   90 DZB(22)=0.
  100 DO 110 I=1,12
      J1=I+12
  110 PRINT 550, I,ZB(I),J1,ZB(J1)
      PRINT 560
      J1=DZB(28)
      S=0.
      IZI=IZ+J1-1
      IF (ISETAB.EQ.0) READ 650, (ZZS(I),COT(I),I=IZ,IZI)
      DO 120 I=IZ,IZI
  120 S=S+COT(I)
      DZB(26)=DZB(29)=0.
      S1=0.
      DO 140 I=IZ,IZI
      COT(I)=COT(I)/S
      DZB(26)=DZB(26)+ZZS(I)*COT(I)
      IKK=ZZS(I)
      IKJ=IKK+(IKK*(IKK+1))/2
      IF (EIP(IKJ).NE.0.) GO TO 130
      IF (DZB(30).LT.1.) GO TO 130
      PRINT 580, IKK
      STOP 1017
  130 DZB(29)=DZB(29)+COT(I)*EIP(IKJ-IKK)
  140 S1=S1+COT(I)*EIP(IKJ-IKK)*1.66026E-24
      DZB(27)=0.
      DO 150 I=IZ,IZI
      FNI(I)=COT(I)/S1
  150 DZB(27)=DZB(27)+FNI(I)
      IF (DZB(30).EQ.2.) GO TO 160
      IF (DZB(19).GT.0.) GO TO 160
      IF (DZB(3).GT.0.) GO TO 160
      IF (ZB(13).LE.0.) GO TO 160
      IF (ZB(14).LE.0.) GO TO 160
      S1=3.*DZB(27)*BOLTS*DZB(12)*DZB(15)**2
      DZB(21)=DZB(11)*(ZB(13)**2-S1)
      TGAM=-3.*(DZB(15)+1.-2.*ZB(14)+S1*DZB(11)*(DZB(15)-4.*ZB(14))/(2.*
     1DZB(21)))
  160 S1=0.
      DO 170 I=IZ,IZI
      IKK=ZZS(I)
```

```
      IKK=(IKK*(IKK+1))/2
      S=EIP(IKK)*1.66026E-24
  170 S1=S1+ALOG(FNI(I)/(DZB(27)*(DZB(27)*S)**1.5))*FNI(I)/DZB(27)
      DZB(13)=4.36050E-42*DZB(27)**(5./3.)*EXP(2.*S1/3.)
      IKK=0
      IF (DZB(30).EQ.2) GO TO 320
      DZB(14)=DZB(25)*EXP(1.5-2.*DZB(15))/DZB(11)
      DZB(16)=(1.-2.*DZB(15))/DZB(11)**2
      DZB(17)=(3.*DZB(15)-2.)/DZB(11)
      IF (DZB(19).LE.0.) GO TO 200
      IF (DZB(3).LE.0.) GO TO 200
      GAM=DZB(15)+TGAM/3.
  180 S1=DZB(3)/(DZB(19)*DZB(10)*GAM**2)
      IF (S1.LT.1.) GO TO 190
      S2=GAM*SQRT(1.00001*S1)
      S9=TGAM+3.*(S2-GAM)
      PRINT 590, TGAM,S9
      GAM=S2
      GO TO 180
  190 S2=SQRT(1.-S1)
      DZB(5)=3.*GAM*(1.+S2)
      DZB(6)=3.*GAM*(1.-S2)
      DZB(4)=3.*DZB(3)/(6.*S2*GAM)
      DZB(21)=-7.1
      GO TO 310
  200 S=DZB(13)*DZB(12)*(DZB(11)**(1./3.)/DZB(25))**2
      SPS=S
      I=0
      S1=DZB(20)-DZB(11)*((3.*DZB(15)+S)/(1.+S))*DZB(27)*DZB(12)*BOLTS
      IKK=IKK+1
      IF (IKK.EQ.2) GO TO 220
      IF (DZB(15).EQ.1.) GO TO 210
      S=1.+((2.*DZB(15)-1.)**2-2.)*S1/DZB(21)
      DZB(3)=DZB(21)*(SQRT(S**2+4.*DZB(15)*(DZB(15)-1.)*(1.-2.*S1/DZB(21
     1))**2)-S)*.5/(DZB(15)-1.)
      GO TO 230
  210 DZB(3)=((DZB(21)-2.*S1)**2)/(DZB(21)-S1)
      GO TO 230
  220 CALL ANEOS (DZB(12),DZB(11),S,S2,S3,S4,S5,S6,S7,S8,I,MAT)
      DZB(3)=DZB(3)*DZB(21)/(DZB(11)*S6)
  230 GAM=DZB(15)+TGAM/3.
  240 S2=DZB(3)/(DZB(11)*DZB(10)*GAM**2)
      IF (S2.LT.1.) GO TO 260
      S2=GAM*SQRT(1.00001*S2)
      S9=TGAM+3.*(S2-GAM)
      IF (IKK.GE.2) PRINT 590, TGAM,S9
      GAM=S2
      I=I+1
      IF (I.GT.20) STOP 20
      IF (IKK.GE.2) GO TO 240
      S1=DZB(20)-DZB(11)*((3.*DZB(15)+SPS)/(1.+SPS))*DZB(27)*DZB(12)*BOL
     1TS
      IF (GAM.EQ.1.) GO TO 250
      S=1.+((2.*GAM-1.)**2-2.)*S1/DZB(21)
      DZB(3)=DZB(21)*(SQRT(S**2+4.*GAM*(GAM-1.)*(1.-2.*S1/DZB(21))**2)-S
```

```
   1)*.5/(GAM-1.)
    GO TO 240
250 DZB(3)=((DZB(21)-2.*S1)**2)/(DZB(21)-S1)
    GO TO 240
260 S3=1.
    S4=.9
270 S5=.5*(S3+S4)
    S6=SQRT(1.-S2*S5)
    DZB(5)=3.*GAM*(1.+S6)
    DZB(6)=3.*GAM*(1.-S6)
    S6=6.*GAM*S6
    DZB(4)=S5**(-1./3.)
    IF (S3-S4.LE.1.E-9) GO TO 300
    S6=1.-3.*DZB(3)*(EXP(DZB(5)*(1.-DZB(4)))-EXP(DZB(6)*(1.-DZB(4))))/
   1(DZB(4)**2*S1*S6)
    IF (S6) 280,300,290
280 S4=S5
    GO TO 270
290 S3=S5
    GO TO 270
300 DZB(19)=DZB(11)/S5
    DZB(4)=S1/(S5**(2./3.)*(EXP(DZB(5)*(1.-DZB(4)))-EXP(DZB(6)*(1.-DZB
   1(4)))))
310 S=3.1415926536
    DZB(32)=(3.*6.6252E-27**2/(20.*9.1084E-28*S))*(S/3.)**(1./3.)*(DZB
   1(19)*DZB(26)*DZB(27))**(5./3.)
    DZB(33)=(S*9.1084E-28/.9)*(4.80288E-10/6.6252E-27)**2*(18.*DZB(26)
   1**(1./3.)/5.+11./(12.*S**2*DZB(26))**(1./3.))/(2.*DZB(19)*DZB(27))
   2**(1./3.)
    S2=DZB(33)
    S=DZB(32)*EXP(-S2)
    S9=DZB(15)
    DZB(15)=S9+TGAM/3.
    DZB(34)=S*(6.+3.*DZB(33)+.5*DZB(33)**2)-9.*DZB(3)*DZB(15)
    DZB(35)=3.*DZB(3)*(6.*DZB(15)+1.)-S*(15.+7.*DZB(33)+DZB(33)**2)
    DZB(36)=S*(10.+4.*DZB(33)+.5*DZB(33)**2)-3.*DZB(3)*(3.*DZB(15)+1.)
    DZB(15)=S9
    S1=EXP(-S2)
    CALL EPINT3 (S2,S1,S)
    DZB(37)=3.*DZB(32)*S+DZB(34)+1.5*DZB(35)+3.*DZB(36)
320 DO 330 I=1,40
330 ACK(IT+I)=DZB(I)
    DO 340 I=1,92
    S=I
340 SAVER(I)=ALOG(S+0.5)
    IF (IKK-1) 350,200,350
350 IF (DZB(21).NE.-7.1) GO TO 360
    CALL ANEOS (DZB(12),DZB(11),ACK(IT+20),S,S1,S2,DZB(1),DZB(2),DZB(3
   1),DZB(4),I,MAT)
    ACK(IT+3)=DZB(11)*DZB(2)
360 CALL ANPHTR (DZB,MAT,TGAM)
    DO 370 I=1,40
370 ACK(IT+I)=DZB(I)
    DO 380 I=1,20
    I1=I+20
```

```
  380 PRINT 600, I,ACK(IT+I),I1,ACK(IT+I1)
      I1=41
      PRINT 570, I1,ACK(IT+I1)
      I1=ACK(IT+31)
      I2=ACK(IT+28)
      DO 390 I=1,I2
      PRINT 610, I,ZZS(I1),I,COT(I1),I,FNI(I1)
  390 I1=I1+1
      IF (ACK(IT+12).LE.0.) GO TO 400
      IF (ACK(IT+11).LE.0.) GO TO 400
      CALL ANEOS (ACK(IT+12),ACK(IT+11),S1,S2,S3,S4,S5,S6,DZB(1),DZB(2),
     1I,MAT)
      DZB(3)=ACK(IT+11)*S6
      PRINT 620, ACK(IT+12),ACK(IT+11),S1,S2,S3,S4,S5,S6,DZB(3),DZB(2)
  400 CALL ANPHASE (MAT,IT,IKPN)
      LOCKPL(MAT)=IKPN-1
      PRINT 630, MAT,LOCKP(MAT),MAT,LOCKPL(MAT)
      IF (ACK(IT+30).EQ.2.) GO TO 420
      PRINT 490
      S3=ACK(IT+11)
      S2=S3/25.
      IF (ACK(IT+1).LT.1.E50) S2=(ACK(IT+2)*ACK(IT+19)-S3)/25.
      DO 410 I=1,50
      CALL ANEOS1 (1.E-6,S3,MAT,S4,S5,S6,S7,S8,GAM,IT)
      S6=S3/ACK(IT+19)
      PRINT 500, S3,S4,GAM,S5,S6
  410 S3=S3+S2
  420 IT=IT+41
      IZ=IZI+1
      IF (THUG.LT.0.) THUG=DZB(12)
      IF (RHUG.LT.0.) RHUG=DZB(11)
      CALL ANHUG (MAT,RHUG,THUG)
  430 CONTINUE
      IF (IZ.GT.100) GO TO 440
      IF (IT.GT.820) GO TO 440
      IF (IKPN.GT.1000) GO TO 440
      RETURN
  440 PRINT 640, IZ,IT,IKPN
      STOP 1016
C
C     WRITE RESTART DATA
  450 WRITE (ITAPE) (ACK(I),I=1,4254),(LOCSV(I),I=1,63)
      RETURN
C
C     READ RESTART DATA
  460 READ (ITAPE) (ACK(I),I=1,4254),(LOCSV(I),I=1,63)
      RETURN
C
  470 FORMAT (33H1 ANALYTIC EQUATION OF STATE DATA,//,76H  ROUTINES CODE
     1D BY S.L.THOMPSON, 5231, SANDIA LABORATORY, ALBUQUERQUE, N.M.)
  480 FORMAT (18H0 THERE IS NO TYPE,E12.5,4H EOS,/,(8E13.6))
  490 FORMAT (27H1 ZERO-TEMPERATURE ISOTHERM,//,8X,3HRHO,10X,1HP,9X,4HDP
     1DR,10X,1HE,10X,3HETA)
  500 FORMAT (2X,5E12.4)
  510 FORMAT (I3,I5,I2,5A10,2E10.3)
```

```
520 FORMAT (34H1 EOS DATA FOR ANALYTIC EOS NUMBER,I6,5X,14HLIBRARY NUMAES
   1BER,I5,5X,4HTYPE,I3,//,2X,5A10,//,7H  RHUG=,E12.4,9X,5HTHUG=,E12.4AES
   2,/)                                                                AES
530 FORMAT (7H1 ISE =,I6)                                              AES
540 FORMAT (8E10.3)                                                    AES
550 FORMAT (5H  Z8(,I2,2H)=,E16.3,6H   Z3(,I2,2H)=,E16.9)              AES
560 FORMAT (1X)                                                        AES
570 FORMAT (27X,2HC(,I2,2H)=,E16.9,/)                                  AES
580 FORMAT (34H1 THE IONIZATION POTENTIALS FOR Z=,I4,17H APE NOT IN TAAES
   1BLE)                                                               AES
590 FORMAT (110H0 WARNING - - - THE INPUT PARAMETERS YIELD NONPHYSICAL AES
   1 CONSTANTS FOR THE LOW-DENSITY ZERO-TEMPERATURE ISOTHERM,/,69H  THAES
   2E FORM HAS BEEN CHANGED FOR REALISTIC VALUES        TGAM EFF FROM,AES
   3E12.5,4H TO ,E12.5,/)                                              AES
600 FORMAT (4H  C(,I2,2H)=,E16.9,5H   C(,I2,2H)=,E16.9)                AES
610 FORMAT (4H  Z(,I2,2H)=,F4.0,7H   COT(,I2,2H)=,E12.5,7H   FNI(,I2,2AES
   1H)=,E12.5)                                                         AES
620 FORMAT (28H0 REFERENCE POINT CONDITIONS,/,4H  T=,E14.6,7X,4HRHO=,EAES
   114.6,/,4H  P=,E14.6,7X,2HE=,E14.6,/,4H  S=,E14.6,7X,3HCV=,E14.6,/,AES
   27H  DPDT=,E14.6,4X,5HDPDR=,E14.6,/,5H  B0=,E14.6,6X,3HCS=,E14.6)  AES
630 FORMAT (8H0 LOCKP(,I2,2H)=,I4,11H    LOCKPL(,I2,2H)=,I4)           AES
640 FORMAT (56H1 THERE ARE TOO MANY LAYERS WITH TOO MANY ELEMENTS   IZAES
   1=,I5,5H  IT=,I5,7H  IKPN=,I6)                                      AES
650 FORMAT (5(F5.0,E10.3))                                             AES
    END                                                                AES
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```
      SUBROUTINE ANION1 (T,RHO,Z,FN,P,E,S,CV,DPDT,DPDR,ZBAR,TTT)
C     A SINGLE ELEMENT ANALYTICAL IONIZATION CALCULATION
C     AFTER THE METHOD OF ZELDOVICH AND RAIZER.
      COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),
     1  RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,
     2  EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)
      T32=6.E21*TTT/(RHO*FN)
      IZ=Z
      I1=(IZ*(IZ+1))/2+1
      FLT=ALOG(T32)
      EIU=EIP(I1)
      FIL=EIU/T
      FK1=T32*EXP(-EIL)
      IF (FK1.GT.0.5) GO TO 20
      K=0
      ZBAR=.5*(SQRT(FK1*(FK1+4.))-FK1)
      IF (ZBAR.GT.1.E-6) GO TO 10
      ZBAR=P=E=S=CV=DPDT=DPDR=0.
      GO TO 130
   10 DZBT=FK1*(1.-ZBAR)/(2.*ZBAR+FK1)
      DZBR=-DZBT/RHO
      DZBT=DZBT*(1.5+EIL)/T
      GO TO 100
   20 I2=I1+IZ-1
      EIU=EIP(I2)
      EIL=EIU/T
      FK2=T32*EXP(-EIL)
      IF (FK2.LT.Z-0.5) GO TO 30
      K=IZ-1
      FK1=FK2-Z+1.
      ZBAR=.5*(SQRT(FK1**2+4.*Z*FK2)-FK1)
      DZBT=FK2*(Z-ZBAR)/(2.*ZBAR+FK1)
      DZBR=-DZBT/RHO
      DZBT=DZBT*(1.5+EIL)/T
      GO TO 100
   30 DO 40 I=1,IZ
      K=I-1
      ZBAR=I
      ZBAR=ZBAR+0.5
      EIU=EIP(I1+I)
      FI=EIU/T+SAVER(I)-FLT
      IF (FI.GE.0.) GO TO 50
   40 CONTINUE
      STOP 4040
   50 EIL=EIP(I1+K)
      DLL=(EIU-EIL)/T
      FIBAR=EIU
      ZBARU=ZBAR
      ZBARL=ZBAR-1.
      K=0
   60 FIP=1./ZBAR+DLL
      DZBAR=-FI/FIP
      ZZBAR=ZBAR
      ZBAR=ZBAR+DZBAR
      IF (ABS(DZBAR).LE.1.E-6*ZZBAR) GO TO 90
```

```
   70 K=K+1
      IF (K.GT.100) STOP 4041
      IF (ZBAR.GT.0.) GO TO 80
      ZBAR=ZBAR-.5*DZBAR
      GO TO 70
   80 FIBAR=EIL*(ZBARU-ZBAR)+EIU*(ZBAR-ZBARL)
      FI=FIBAR/T+ALOG(ZBAR)-FLT
      GO TO 60
   90 DZBT=ZBAR/(T+ZBAR*(EIU-EIL))
      DZBR=-T*DZBT/RHO
      DZBT=DZBT*(1.5+FIBAR/T)
      K=ZBAR
  100 ZBARL=FN*BOLTS
      P=ZBAR*ZBARL*RHO*T
      DPDT=RHO*ZBARL*(ZBAR+T*DZBT)
      DPDR=ZBARL*T*(ZBAR+RHO*DZBR)
      E=0.
      IF (K.EQ.0) GO TO 120
      DO 110 I=1,K
  110 E=E+EIP(I1+I-1)
  120 EIL=K
      EIU=EIP(I1+K)
      E=ZBARL*(1.5*ZBAR*T+E+(ZBAR-EIL)*EIU)
      CV=ZBARL*(1.5*(ZBAR+T*DZBT)+EIU*DZBT)
      S=ZBAR*ZBARL*(FLT+2.5-ALOG(ZBAR))
  130 RETURN
      END
```

```
      SUBROUTINE ANION2 (T,RHO,FN,ZBARM,NMATS,IIZ,TTT,ZBAR,P,E,S,DPT,DPR
     1,CV)
C     A MULTIPLE ELEMENT ANALYTICAL IONIZATION CALCULATION
C     AFTER THE METHOD OF ZELDOVICH AND RAIZER.
      COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),
     1  RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,
     2  EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)
      DATA ZRAT/.000045/
      IT=0
      ISK=IIZ-1
      XX=6.E21*TTT/(RHO*FN)
      ZBAR=ZRAT*XX
      IF (ZBAR.LT.1.E-6) GO TO 30
      IF (ZBAR.GT.ZBARM) ZBAR=.99*ZBARM
   10 IT=IT+1
      IF (IT.GT.200) STOP 200
      FLXX=T*ALOG(XX/ZBAR)
      ZC1=ZC2=ZC3=ZC4=ZC5=ZC6=0.
      DO 20 I=1,NMATS
      CALL ANION3 (T,RHO,XX,FLXX,IIZ,ZBAR,I,I1,S,P,E)
      C=COT(ISK+I)
      ZC1=ZC1+C*ZB(I)
      ZC2=ZC2+C*P
      ZC3=ZC3+C*S
      ZC4=ZC4+C*E
      KK=ZB(I)
      C=FNI(ISK+I)*EIP(I1+KK)
      ZC5=ZC5+C*S
   20 ZC6=ZC6+C*P
      DEL=(ZBAR-ZC1)/(ZC2-1.)
      YY=ZBAR+DEL
      IF (YY.GT.1.E-6) GO TO 70
      IF (ZBAR.LE.1.E-6) GO TO 40
      IF (YY.LT.0.) GO TO 60
   30 ZBAR=1.E-6
      GO TO 10
   40 ZBAR=E=P=S=CV=DPR=DPT=ZRAT=0.
      DO 50 I=1,NMATS
   50 ZB(I)=0.
      RETURN
   60 IF (YY.GE.0.) GO TO 70
      YY=YY-.5*DEL
      GO TO 60
   70 IF (YY.LE.ZBARM) GO TO 80
      YY=.7*ZBARM+.3*ZBAR
   80 IF (ABS(YY-ZBAR).LE.1.E-5*(YY+ZBAR)) GO TO 90
      ZBAR=YY
      GO TO 10
   90 E=ZC3/(1.-ZC2)
      S=ZC4/(1.-ZC2)
      ZC1=FN*BOLTS
      P=ZC1*ZBAR*RHO*T
      DPT=ZC1*(ZBAR+T*E)
      CV=1.5*DPT+(ZC5+E*ZC6)*BOLTS
      DPT=RHO*DPT
```

```
      DPR=ZC1*T*(ZBAR+RHO*S)                                            AES  596
      E=0.                                                              AES  597
      DO 120 I=1,NMATS                                                  AES  598
      IZ=ISK+I                                                          AES  599
      C=FNI(IZ)                                                         AES  600
      I1=ZZS(IZ)                                                        AES  601
      I1=(I1*(I1+1))/2                                                  AES  602
      KK=ZB(I)                                                          AES  603
      IF (KK.EQ.0) GO TO 110                                            AES  604
      DO 100 J=1,KK                                                     AES  605
  100 E=E+C*EIP(I1+J)                                                   AES  606
  110 S=KK                                                              AES  607
  120 E=E+C*(ZB(I)-S)*EIP(I1+KK+1)                                      AES  608
      E=1.5*ZBAR*ZC1*T+E*BOLTS                                          AES  609
      S=ZBAR*ZC1*(FLXX/T+2.5)                                           AES  610
      XX=ZBAR/XX                                                        AES  611
      IF (XX.GT.1.E-10) ZRAT=XX                                         AES  612
      RETURN                                                            AES  613
      END                                                               AES  614
```

```
      SUBROUTINE ANION3 (T,RHO,XX,FLXX,IIZ,ZBAR,JKI,I1,AI,BI,DI)
C     A PART OF THE MULTIPLE ELEMENT ANALYTICAL IONIZATION CALCULATION
      COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),
     1  RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,
     2  EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)
      IZ=Z=ZZS(IIZ+JKI-1)
      I1=(IZ*(IZ+1))/2+1
      FK=XX*EXP(-EIP(I1)/T)
      ZBARI=FK+ZBAR
      IF (ZBARI.GT.0.) GO TO 10
      ZBARI=BI=AI=DI=0.
      GO TO 70
   10 ZBARI=FK/(FK+ZBAR)
      IF (ZBARI.GT.0.5) GO TO 30
      IF (ZBARI.LT.1.E-10) GO TO 20
      BI=-ZBARI**2/FK
      AI=-ZBAR*BI*(1.5+EIP(I1)/T)/T
      DI=ZBAR*BI/RHO
      GO TO 70
   20 ZBARI=AI=BI=DI=0.
      GO TO 70
   30 I2=I1+IZ-1
      FK=XX*EXP(-EIP(I2)/T)
      ZBARI=Z-ZBAR/(ZBAR+FK)
      IF (ZBARI.LT.Z-0.5) GO TO 40
      BI=-FK/(FK+ZBAR)**2
      AI=-ZBAR*BI*(1.5+EIP(I2)/T)/T
      DI=ZBAR*BI/RHO
      GO TO 70
   40 DO 50 I=1,IZ
      N=I
      ZBARI=I
      ZBARI=ZBARI+0.5
      EIU=EIP(I1+I)
      FK=FLXX-EIU
      IF (FK) 60,60,50
   50 CONTINUE
      STOP 3030
   60 EIL=EIP(I1+N-1)
      DL=EIU-EIL
      ZBARI=N
      ZBARI=(EIU*(ZBARI-.5)-EIL*(ZBARI+.5)+FLXX)/DL
      BI=-T/(DL*ZBAR)
      AI=(FLXX/T+1.5)/DL
      DI=-T/(RHO*DL)
   70 ZB(JKI)=ZBARI
      RETURN
      END
```

```
      SUBROUTINE EPINT3 (ARG,EXPARG,ANS)
C     DETERMINES THIRD EXPONENTIAL INTEGRAL
C     EXPARG=EXP(-ARG)
C     EXPIN=FIRST EXPONENTIAL INTEGRAL
      DIMENSION CE(5)
      DATA CE0,CE,AE1,AE2,AE3,AE4,BE1,BE2,BE3,BE4/-.57721566,.99999193,-
     1.24991055,.05519968,-.00976004,.00107857,8.5733287,18.059017,8.634
     27609,.26777373,9.5733223,25.632956,21.099653,3.9584969/
      IF (ARG.GT.1.) GO TO 20
      EXPIN=CE0-ALOG(ARG)
      X1=1.
      DO 10 I=1,5
      X1=ARG*X1
   10 EXPIN=EXPIN+X1*CE(I)
      GO TO 40
   20 IF (ARG.LT.100.) GO TO 30
      EXPIN=0.
      GO TO 40
   30 EXPIN=EXPARG*((((ARG+AE1)*ARG+AE2)*ARG+AE3)*ARG+AE4)/(ARG*((((ARG
     1+BE1)*ARG+BE2)*ARG+BE3)*ARG+BE4)))
   40 ANS=.5*(EXPARG-ARG*(EXPARG-ARG*EXPIN))
      RETURN
      END
```

```
      SUBROUTINE ANTWOPH (T,R,MAT,P,E,S,CV,DPDT,DPDR,LOC,KPA)
C     EVALUATES THERMODYNAMIC FUNCTIONS IN THE TWO-PHASE REGION
      COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),
     1 RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,
     2 EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)
      K1=LOCKP(MAT)
      K2=LOCKPL(MAT)
      DO 10 I=K1,K2
      KJ=I+1
      IF (T.GE.TTWO(KJ)) GO TO 20
   10 CONTINUE
      STOP 1543
   20 KK=KJ-1
      TL=TTWO(KJ)
      TU=TTWO(KK)
      IF (KK.GT.K1) GO TO 30
      X1=((TU-T)/(TU-TL))**.3333333333
      R1=RSOL(KK)+(RSOL(KJ)-RSOL(KK))*X1
      IF (R.GE.R1) GO TO 40
      R2=RVAP(KK)-(RVAP(KK)-RVAP(KJ))*X1
      IF (R.LE.R2) GO TO 40
      R1P=(RSOL(KK)-RSOL(KJ))*X1/(3.*(TU-T))
      R2P=(RVAP(KK)-RVAP(KJ))*X1/(3.*(TU-T))
      GO TO 50
   30 DT=TU-TL
      R1=((T-TL)*RSOL(KK)+(TU-T)*RSOL(KJ))/DT
      IF (R.GE.R1) GO TO 40
      R2=((T-TL)*RVAP(KK)+(TU-T)*RVAP(KJ))/DT
      IF (R.GT.R2) GO TO 50
   40 KPA=1
      RETURN
   50 KPA=2
      CALL ANEOS1 (T,R1,MAT,P1,E1,S1,CV1,DPDT1,DPDR1,LOC)
      CALL ANEOS1 (T,R2,MAT,P2,E2,S2,CV2,DPDT2,DPDR2,LOC)
      X3=R1-R2
      X1=(R1-R)/X3
      X2=(R-R2)/X3
      FM1=R1*X2/R
      FM2=R2*X1/R
      E=FM1*E1+FM2*E2
      S=FM1*S1+FM2*S2
      IF (P1.LT.1.E8) GO TO 60
      P=X1*P2+X2*P1
      GO TO 70
   60 P=P2
   70 DPDR=0.
      DPDT=(S2-S1)*(R1*R2/X3)
      IF (KK.EQ.K1) GO TO 80
      X4=(RVAP(KK)-RVAP(KJ))/DT
      X5=(RSOL(KK)-RSOL(KJ))/DT
      GO TO 90
   80 X4=R2P
      X5=R1P
   90 CONTINUE
      X3=-(R1*X1*X4+R2*X2*X5)/(R*X3)
```

```
      X1=CV1+(P1-T*DPDT1)*X5/R1**2                                      AES 741
      X2=CV2+(P2-T*DPDT2)*X4/R2**2                                      AES 742
      CV=X3*(E1-E2)+FM1*X1+FM2*X2                                       AES 743
      RETURN                                                            AES 744
      END                                                               AES 745
```

```
      SUBROUTINE ANPHASE (MAT,IT,IKPN)
C     SET UP FOR TWO-PHASE CALCULATION
      COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),
     1 RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,
     2 EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)
      IF (ACK(IT+30).LE.2.) RETURN
      NTY=0
      KLY=0
   10 KLY=KLY+1
      GO TO (20,30,20,30), KLY
   20 RCT(MAT)=.3*ACK(IT+19)
      TCT(MAT)=2.
      GO TO 40
   30 RCT(MAT)=.15*ACK(IT+19)
      TCT(MAT)=.5
   40 S3=.001
   50 R1=S3*RCT(MAT)
      T1=S3*TCT(MAT)
      KK=-2
      DO 80 I=1,9
      IF (3*((I-1)/3).NE.I-1) GO TO 60
      KK=KK+1
      KN=-2
   60 KN=KN+1
      T2=KK
      T2=TCT(MAT)*(1.+.5*S3*T2)
      R2=KN
      R2=RCT(MAT)*(1.+.5*S3*R2)
      CALL ANEOS1 (T2,R2,MAT,P1,E1,S1,D1,D2,RSOL(IKPN+I),IT)
      IF (KLY.LE.2) GO TO 70
      PRINT 510, T2,R2,P1,E1,S1,RSOL(IKPN+I),I,KK,KN
   70 IF (I.NE.5) GO TO 80
      RSOL(IKPN+10)=P1
      RSOL(IKPN+11)=E1
      RSOL(IKPN+12)=S1
   80 CONTINUE
      D1=RSOL(IKPN+5)
      D2=(RSOL(IKPN+6)-RSOL(IKPN+4))/R1
      D3=(RSOL(IKPN+8)-RSOL(IKPN+2))/T1
      D4=4.*(RSOL(IKPN+6)-2.*RSOL(IKPN+5)+RSOL(IKPN+4))/(R1**2)
      D5=(RSOL(IKPN+9)-RSOL(IKPN+7)-RSOL(IKPN+3)+RSOL(IKPN+1))/(R1*T1)
      DR2=D3*D4-D2*D5
      DR1=(D2*D2-D1*D4)/DR2
      DR2=(D1*D5-D2*D3)/DR2
      IF (KLY.LE.2) GO TO 90
      PRINT 520, RCT(MAT),DR2,TCT(MAT),DR1,D1,D2,D3,D4,D5,NTY,(RSOL(IKPN
     1+I),I=1,9),S3
   90 IF (ABS(DR1).GT.1.E-6*TCT(MAT)) GO TO 100
      IF (ABS(DR2).LE.1.E-6*RCT(MAT)) GO TO 200
  100 IF (ABS(DR1).LE..1*TCT(MAT)) GO TO 110
      DR1=.1*TCT(MAT)*DR1/ABS(DR1)
  110 IF (ABS(DR2).LE..1*RCT(MAT)) GO TO 120
      DR2=.1*RCT(MAT)*DR2/ABS(DR2)
  120 RCT(MAT)=RCT(MAT)+DR2
      TCT(MAT)=TCT(MAT)+DR1
```

```
      IF (S3.EQ.0.0001) GO TO 130
      IF (ABS(DR1).GT.1.E-3*TCT(MAT)) GO TO 130
      IF (ABS(DR2).GT.1.E-3*RCT(MAT)) GO TO 130
      S3=.0001
  130 NTY=NTY+1
      IF (KLY.GT.2) GO TO 150
      IF (NTY-100) 50,10,140
  140 IF (NTY-200) 50,170,170
  150 IF (NTY-300) 50,10,160
  160 IF (NTY-400) 50,180,180
  170 PRINT 530
      GO TO 10
  180 PRINT 540, MAT
  190 ACK(IT+30)=ACK(IT+30)-3.
      RETURN
  200 KN=IKPN+10
      KK=KN+2
      PRINT 550, MAT,RCT(MAT),TCT(MAT),(RSOL(I),I=KN,KK),NTY
      IF (TCT(MAT).GT.ACK(IT+18)) GO TO 210
      PRINT 560, ACK(IT+18)
      GO TO 190
  210 KK=60
      KN=20
      IF (ACK(IT+18).GT.0.15) KN=30
      IF (ACK(IT+18).GT.0.25) KN=40
      KLY=0
      RSOL(IKPN)=RVAP(IKPN)=RCT(MAT)
      TTWO(IKPN)=TCT(MAT)
      PRINT 570
      IK=IKPN+1
      D5=KK
      D5=(TCT(MAT)-ACK(IT+18))/D5
      D6=KN
      D6=ACK(IT+18)/D6
      DO 460 JJJ=1,2
      D4=D5
      JJJJ=KK+10
      T=TCT(MAT)
      IF (JJJ.EQ.1) GO TO 220
      D4=D6
      JJJJ=KN
      T=ACK(IT+18)
  220 DO 460 I=1,JJJJ
      IF (I.EQ.KK-9) D4=.5*D4
      T=T-D4
      IF (T.GT.0.95*TCT(MAT)) GO TO 460
      NQPS=0
  230 IF (I.EQ.KK+10) T=ACK(IT+18)
      IF (RVAP(IK-1).LT.1.E-100) GO TO 470
      IF (T.LT.0.015) GO TO 470
      NTY=0
      R10=R20=RCT(MAT)
      R2=ACK(IT+25)**3*EXP(3.*ACK(IT+15)-1.-ACK(IT+10)/(ACK(IT+27)*BOLTS
     1*T))/(ACK(IT+13)*T)**1.5
      IF (R2.LE.0..AND.NQPS.NE.0) GO TO 470
```

```
      IF (R2.LE.0) R2=1.E-100
      IF (NQPS.NE.0) PRINT 580, R2
      IF (R2.GT..001*ACK(IT+19)) R2=.001*ACK(IT+19)
      R1=ACK(IT+19)
  240 I1=I2=0
  250 CALL ANEOS1 (T,R2,MAT,P2,E2,S2,D1,D2,DP2,IT)
      IF (DP2.GT.0.) GO TO 270
      R20=R2
      R2=.99*R2
      IF (I2.GT.30) R2=.5*R2
      I2=I2+1
      IF (I2-900) 250,250,260
  260 PRINT 490, R2,I2,R1,I1,T,NTY
      GO TO 400
  270 G2=E2-T*S2+P2/R2
  280 CALL ANEOS1 (T,R1,MAT,P1,E1,S1,D1,D2,DP1,IT)
      IF (DP1.GT.0.) GO TO 290
      R10=R1
      R1=1.005*R1
      I1=I1+1
      IF (I1-900) 280,280,260
  290 G1=E1-T*S1+P1/R1
      SP=P1-P2
      SG=G1-G2
      DR1=R1*(SP-R2*SG)/(DP1*(R2-R1))
      DR2=R2*(SP-R1*SG)/(DP2*(R2-R1))
      IF (NQPS.EQ.0) GO TO 300
      PRINT 580, T,R1,DR1,R2,DR2,SP,SG,P1,E1,S1,G1,P2,E2,S2,G2,NTY,I1,I2
     1,DP1,DP2
  300 IF (ABS(DR1).GT.1.E-6*R1) GO TO 310
      IF (ABS(DR2).LE.1.E-6*R2) GO TO 440
  310 IKI=NTY-100*((NTY-1)/100)
      IF (IKI.GT.40) DR1=0.5*DR1
      IF (IKI.GT.50) DR1=.05*DR1
      IF (NTY.LT.80) GO TO 320
      IF (ABS(SP).GT.1.E-2*(ABS(P1)+ABS(P2)+1.E4)) GO TO 320
      IF (ABS(SG).LE.1.E-2*(ABS(G1)+ABS(G2))) GO TO 440
  320 D1=R1+DR1
      IF (D1.GT.R10) GO TO 340
  330 DR1=.5*DR1
      GO TO 320
  340 IF (D1-ACK(IT+19)) 350,350,330
  350 D2=R2+DR2
      IF (D2.GT.0.) GO TO 370
  360 DR2=DR2*.5
      GO TO 350
  370 IF (D2.GE.R20) GO TO 360
      NTY=NTY+1
      R1=D1
      R2=D2
      IF (NTY-100) 240,240,380
  380 IF (NQPS.EQ.0) GO TO 410
      IF (NTY-200) 240,240,390
  390 KLY=KLY+1
      IF (IK.EQ.IKPN+1) GO TO 430
```

```
      IF (KLY.GT.2) GO TO 480
  400 PRINT 500, T
      GO TO 460
  410 NOPS=1
      IF (IK.EQ.IKPN+1) GO TO 420
      IF (KLY-1) 390,390,230
  420 IF (KLY-30) 390,230,230
  430 IF (KLY-32) 460,400,480
  440 RSOL(IK)=R1
      RVAP(IK)=R2
      TTWO(IK)=T
      IK=IK+1
      KLY=0
      IF (T.EQ.ACK(IT+18).AND.R1.LT.ACK(IT+23)) PRINT 590, ACK(IT+23),R1
      IF (T.EQ.ACK(IT+18)) GO TO 450
      IF (5*(I/5).NE.I) GO TO 460
  450 PRINT 600, T,R1,P1,E1,S1,G1,NTY,R2,P2,E2,S2,G2
  460 CONTINUE
  470 RSOL(IK)=ACK(IT+19)
      RVAP(IK)=0.
      TTWO(IK)=0.
      IKPN=IK+1
      RETURN
  480 PRINT 610, T
      GO TO 190
C
  490 FORMAT (21H0 MAXWELL 11,I2 ERROR,3(E13.5,I5))
  500 FORMAT (45H0 TWO-PHASE ITERATION WILL NOT CONVERGE AT T=,E13.5,23H
     1. WILL LEAVE POINT OUT.)
  510 FORMAT (17H CRITICAL ERROR 1,6E13.6,3I5)
  520 FORMAT (17H CRITICAL ERROR 2,9E11.4,I5,/,(10X,3E15.8))
  530 FORMAT (21H CRITICAL POINT ERROR)
  540 FORMAT (68H0 THE CRITICAL POINT ITERATION WILL NOT CONVERGE FOR MA
     1TERIAL NUMBER,I5,26H. WILL CHANGE FORM OF EOS.)
  550 FORMAT (36H1 TWO-PHASE CALCULATION FOR MATERIAL,I5,/,16H  CRITICAL
     1 POINT,/,6H  RHO=,E15.7,9X,2HT=,E15.7,/,4H  P=,E15.7,11X,2HE=,E15.
     27,/,4H  S=,E15.7,11X,4HNTY=,I5,/)
  560 FORMAT (26H0 THE MELTING TEMPERATURE(,E15.7,64H) IS GREATER THAN C
     1RITICAL TEMPERATURE. WILL CHANGE FORM OF EOS.)
  570 FORMAT (22H0 TWO-PHASE BOUNDARIES,/,7X,1HT,9X,6HRHOLIQ,8X,4HPLIQ,9
     1X,4HELIQ,9X,4HSLIQ,9X,4HGLIQ,/,17X,6HRHOVAP,8X,4HPVAP,9X,4HEVAP,9X
     2,4HSVAP,9X,4HGVAP)
  580 FORMAT (15H0 MAXWELL ERROR,7E13.5,/,8E12.4,3I4)
  590 FORMAT (40H0 WARNING - - THE MINIMUM SOLID DENSITY(,E12.5,43H) IS 
     1GREATER THAN THE TRIPLE POINT DENSITY(,E12.5,2H).,/,68H  IMPROPER 
     2SOLID BEHAVIOR WILL RESULT. TO CORRECT USE SMALLER VALUE.,/)
  600 FORMAT (/,6E13.5,/,I13,5E13.5)
  610 FORMAT (45H0 TWO-PHASE ITERATION WILL NOT CONVERGE AT T=,E13.5,26H
     1. WILL CHANGE FORM OF EOS.)
      END
```

```
      SUBROUTINE ANHUG (M,RO,TO)
C     CALCULATES HUGONIOT OF ANALYTICAL EOS
      DIMENSION TS(48), CD(8)
      COMMON /BIG/ B(1)
      EQUIVALENCE (PO,B(1)), (EO,B(2)), (SO,B(3)), (D1,B(4)), (D2,B(5)),
     1 (D3,B(6)), (D4,B(7)), (VO,B(8)), (T,B(9)), (R,B(10)), (P,B(11)),
     2(E,B(12)), (S,B(13)), (CV,B(14)), (PT,B(15)), (PR,B(16)), (F,B(17)
     3), (DF,B(18)), (DR,B(19)), (V,B(20)), (U,B(21)), (TS(1),B(22))
      EQUIVALENCE (CD(1),B(75))
      DATA (TS(I),I=1,48)/.026,.0265,.0275,.0285,.03,.035,.04,.05,.06,.0
     18,.1,.12,.14,.16,.18,.2,.25,.3,.4,.5,.6,.7,.85,1.,1.3,1.5,1.7,2.,2
     2.5,3.,4.,5.,6.,7.,8.5,10.,13.,15.,17.,20.,25.,30.,40.,50.,60.,70.,
     385.,100./
      IF (RO.LE.0.) RETURN
      IF (TO.LE.0.) RETURN
      PRINT 40
      CALL ANEOS (1.E-6,RO,CD(1),CD(2),CD(3),CD(4),CD(5),CD(6),CD(7),CD(
     18),KP,M)
      CALL ANEOS (TO,RO,PO,EO,SO,D1,D2,D3,D4,VO,KP,M)
      D1=0.
      D2=1.
      PRINT 60
      PRINT 50, RO,TO,PO,CD(1),EO,SO,VO,D1,D2
      N=51
      DO 30 I=1,48
      T=TS(I)
      IF (T.LE.TO) GO TO 30
      IF (N.GT.50) R=RO
      N=0
   10 CALL ANEOS (T,R,P,E,S,CV,PT,PR,D1,D2,KP,M)
      F=E-EO+.5*(PO+P)*(RO-R)/(R*RO)
      DF=(P-T*PT)/R**2+.5*PR*(RO-R)/(RO*R)-.5*(PO+P)/R**2
      IF (DF.EQ.0.) GO TO 30
      DR=-F/DF
      IF (ABS(DR).LE.1.E-8*R) GO TO 20
      D1=1.
      IF (DR.LT.0.) D1=-1.
      IF (ABS(DR).GT..5*R) DR=.5*R*D1
      R=R+DR
      N=N+1
      IF (N-50) 10,10,30
   20 V=SQRT((P-PO)/(RO*(1.-RO/R)))
      U=V*(1.-RO/R)
      D1=R/RO
      CALL ANEOS (1.E-6,R,CD(1),CD(2),CD(3),CD(4),CD(5),CD(6),CD(7),CD(8
     1),KP,M)
      PRINT 50, R,T,P,CD(1),E,S,V,U,D1,N
   30 CONTINUE
      RETURN
C
   40 FORMAT (10H1 HUGONIOT)
   50 FORMAT (9E12.4,I3)
   60 FORMAT (9H0     RHO,10X,1HT,11X,1HP,10X,2HPC,11X,1HE,11X,1HS,11X,1
     1HV,11X,1HU,7X,8HRHO/RHOO)
      END
```

```
      SUBROUTINE ANPHTR (C,MAT,TGAM)
C     MODIFIES THE ZERO-TEMPERATURE ISOTHERM OF THE ANALYTICAL EOS
C     FOR A TEMPERATURE INDEPENDENT PHASE TRANSITION
      DIMENSION C(1)
      IF (C(30).EQ.2.) RETURN
      IF (C(1).GT.C(19)) GO TO 20
   10 C(1)=1.E100
      C(2)=C(7)=C(8)=C(9)=C(38)=C(39)=C(40)=0.
      RETURN
   20 S3=C(15)+TGAM/3.
      S1=S3-2.5
      S2=S3+2.5
      S4=EXP(-C(33))*C(32)
      S5=(15.+7.*C(33)+C(33)**2)*S4
      S6=(10.+4.*C(33)+.5*C(33)**2)*S4
      S4=(6.+3.*C(33)+.5*C(33)**2)*S4
      ETA1=C(1)/C(19)
      S7=ETA1**.3333333333
      S8=C(32)*ETA1*S7**2*EXP(-C(33)/S7)
   30 C34=S4-9.*S3*C(3)
      C35=3.*C(3)*(6.*S3+1.)-S5
      C36=S6-3.*C(3)*(3.*S3+1.)
      PTR=S8-(C34+C35*S7+C36*S7**2)
      IF (C(7).EQ.0.) GO TO 70
      IF (ABS(PTR-C(7)).LE.1.E-4*(PTR+C(7))) GO TO 70
      IF (S2-S1.LT.1.E-7) GO TO 70
      IF (PTR-C(7)) 50,70,40
   40 S2=S3
      GO TO 60
   50 S1=S3
   60 S3=.5*(S1+S2)
      GO TO 30
   70 IF (C(2).LT.C(1)) C(2)=C(1)
      ETA2=C(2)/C(19)
      C37=C(37)-C(34)+C34-1.5*(C(35)-C35)-3.*(C(36)-C36)
      S1=C(33)/S7
      S2=EXP(-S1)
      CALL EPINT3 (S1,S2,S4)
      C8=(3.*C(32)*S4*S7**2+C34/ETA1+1.5*C35*S7/ETA1+3.*C36/S7-C37)/C(19
     1)
      DP1=C(32)*S7*(5.*S7+C(33))*EXP(-C(33)/S7)/3.-(C35/S7+2.*C36)/(3.*S
     17)
      DP2=C(32)*((10.+6.*C(33)/S7)/S7+C(33)**2/ETA1)*EXP(-C(33)/S7)/9.+2
     1.*(C35/S7+C36)/(9.*ETA1*S7)
      IF (C(39)) 80,90,100
   80 DP3=-DP1*C(39)
      GO TO 110
   90 DP3=DP1*ETA2/ETA1
      GO TO 110
  100 DP3=C(39)
  110 IF (C(40)) 120,130,140
  120 DP4=-DP2*C(40)
      GO TO 150
  130 DP4=DP2*(ETA2/ETA1)**2
      GO TO 150
```

```
140 DP4=C(40)
150 S1=ETA2**.3333333333
    S2=EXP(-C(33)/S1)
    S4=C(32)*S1*(5.*S1+C(33))*S2-3.*DP3
    S5=9.*ETA2*DP4-C(32)*(10.*S1**2+5.*C(33)*S1+C(33)**2)*S2
    C39=S1*S1*(S5-S4)
    C40=S1*(S4-.5*S5)
    C38=C(32)*S1**2*ETA2*S2-PTR-(C39+C40*S1)*S1
    EN2=C8+PTR*(ETA2-ETA1)/(C(19)*ETA1*ETA2)
    S4=C(33)/S1
    CALL EPINT3 (S4,S2,S5)
    C9=EN2-(3.*C(32)*S5*S1**2+C38/ETA2+(1.5*C39/S1+3.*C40)/S1)/C(19)
    S4=3.*(S3-C(15))
    PRINT 180, PTR,C(7),DP1,DP3,DP2,DP4,C8,EN2,S4,TGAM
    IF (C(7).GT.0.) GO TO 160
    IF (ETA2.GT.ETA1) GO TO 170
    IF (C(39).NE.0.) GO TO 170
    IF (C(40).NE.0.) GO TO 170
    PRINT 190
    GO TO 10
160 IF (ABS(PTR-C(7)).LE.1.E-3*(PTR+C(7))) GO TO 170
    PRINT 200
170 PRINT 210
    C(1)=ETA1
    C(2)=ETA2
    C(7)=PTR
    C(8)=C8
    C(9)=C9
    C(34)=C34
    C(35)=C35
    C(36)=C36
    C(37)=C37
    C(38)=C38
    C(39)=C39
    C(40)=C40
    RETURN
C
180 FORMAT (//,74H  ZERO-TEMPERATURE ISOTHERM HAS BEEN MODIFIED FOR A
   1SOLID PHASE TRANSITION,//,12H  PCTR(CAL)=,E13.6,10X,12HPCTR(INPUT)
   2=,E13.6,/,15H  DPDETA(ETA1)=,E13.6,7X,13HDPDETA(ETA2)=,E13.6,/,17H
   3  D2PDETA2(ETA1)=,E13.6,5X,15HD2PDETA2(ETA2)=,E13.6,/,11H  EC(ETA1
   4)=,E13.6,11X,9HEC(ETA2)=,E13.6,/,11H  TGAMSTAR=,E13.6,11X,5HTGAM=,
   5E13.6)
190 FORMAT (64H0 ALL DEFAULT OPTIONS WERE USED.  NO TRANSITION WILL BE
   1 INCLUDED,/,1H1)
200 FORMAT (54H0 SOMETHING APPEARS TO BE WRONG        CHECK CAREFULLY)
210 FORMAT (1H1)
    END
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      SUBROUTINE ANDATA (IT,IZ,ISETAB)
C     DATA STATEMENTS FOR ANALYTICAL IONIZATICAL CALCULATION
C     ATOMIC WEIGHT OF ELEMENT Z IS (Z*(Z+1))/2
C     FIRST IONIZATION POTENTIAL OF ELEMENT Z IS (Z*(Z+1))/2+1
C     LAST IONIZATION POTENTIAL OF ELEMENT Z IS (Z*(Z+1))/2+Z
      COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),
     1  RSOL(1000),RVAP(1000),TTWO(1000),SAVEP(92),ZB(92),DZB(40),BOLTS,
     2  EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)
      DATA BOLTS/1.60207E-12/
C     Z =  1
      DATA(EIP(I),I=   1,   2)/     1.00801,
     11.3595E+01/
C     Z =  2
      DATA(EIP(I),I=   3,   5)/     4.00280,
     12.4581E+01,5.4403E+01/
C     Z =  3
      DATA(EIP(I),I=   6,   9)/     6.93900,
     15.3900E+00,7.5619E+01,1.2242E+02/
C     Z =  4
      DATA(EIP(I),I=  10,  14)/     9.01300,
     19.3200E+00,1.8206E+01,1.5385E+02,2.1766E+02/
C     Z =  5
      DATA(EIP(I),I=  15,  20)/    10.81200,
     18.2960E+00,2.5149E+01,3.7920E+01,2.5930E+02,3.4013E+02/
C     Z =  6
      DATA(EIP(I),I=  21,  27)/    12.01161,
     11.1256E+01,2.4376E+01,4.7871E+01,6.4476E+01,3.9199E+02,4.8984E+02/
C     Z =  7
      DATA(EIP(I),I=  28,  35)/    14.00730,
     11.4530E+01,2.9593E+01,4.7426E+01,7.7450E+01,9.7863E+01,5.5192E+02,
     26.6683E+02/
C     Z =  8
      DATA(EIP(I),I=  36,  44)/    16.00000,
     11.3614E+01,3.5108E+01,5.4886E+01,7.7394E+01,1.1387E+02,1.3808E+02,
     27.3911E+02,8.7112E+02/
C     Z =  9
      DATA(EIP(I),I=  45,  54)/    18.99920,
     11.7418E+01,3.4980E+01,6.2646E+01,8.7140E+01,1.1421E+02,1.5712E+02,
     21.8514E+02,9.5360E+02,1.1020E+03/
C     Z = 10
      DATA(EIP(I),I=  55,  65)/    20.18400,
     12.1559E+01,4.1070E+01,6.3500E+01,9.7020E+01,1.2630E+02,1.5791E+02,
     22.0720E+02,2.3910E+02,1.1956E+03,1.3604E+03/
C     Z = 11
      DATA(EIP(I),I=  66,  77)/    22.99100,
     15.1380E+00,4.7290E+01,7.1650E+01,9.8880E+01,1.3837E+02,1.7209E+02,
     22.0844E+02,2.6416E+02,2.9978E+02,1.4648E+03,1.6461E+03/
C     Z = 12
      DATA(EIP(I),I=  78,  90)/    24.31300,
     17.6440E+00,1.5031E+01,8.0120E+01,1.0929E+02,1.4123E+02,1.8649E+02,
     22.2490E+02,2.6596E+02,3.2790E+02,3.6736E+02,1.7612E+03,1.9590E+03/
C     Z = 13
      DATA(EIP(I),I=  91, 104)/    26.98200,
     15.9840E+00,1.8823E+01,2.8440E+01,1.1996E+02,1.5377E+02,1.9042E+02,
     22.4138E+02,2.8453E+02,3.3010E+02,3.9350E+02,4.4190E+02,2.0855E+03,
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     32.2990E+03/
C     Z = 14
      DATA(EIP(I),I= 105, 119)/    28.09000,
     18.1490E+00,1.6340E+01,3.3460E+01,4.5130E+01,1.6673E+02,2.0511E+02,
     22.4641E+02,3.0307E+02,3.5096E+02,4.0130E+02,4.7600E+02,5.2320E+02,
     32.4360E+03,2.6660E+03/
C     Z = 15
      DATA(EIP(I),I= 120, 135)/    30.97500,
     11.0484E+01,1.9720E+01,3.0156E+01,5.1354E+01,6.5007E+01,2.2041E+02,
     22.6331E+02,3.0926E+02,3.7160E+02,4.2430E+02,4.7940E+02,5.6030E+02,
     36.1140E+02,2.8150E+03,3.0610E+03/
C     Z = 16
      DATA(EIP(I),I= 136, 152)/    32.06600,
     11.0357E+01,2.3400E+01,3.5000E+01,4.7290E+01,7.2500E+01,8.8029E+01,
     22.8099E+02,3.2880E+02,3.7895E+02,4.4700E+02,5.0580E+02,5.6600E+02,
     36.5100E+02,7.0600E+02,3.2200E+03,3.4820E+03/
C     Z = 17
      DATA(EIP(I),I= 153, 170)/    35.45400,
     11.3010E+01,2.3800E+01,3.9900E+01,5.3500E+01,6.7800E+01,9.6700E+01,
     21.1427E+02,3.4830E+02,4.0070E+02,4.5530E+02,5.3090E+02,5.9300E+02,
     36.6300E+02,7.4900E+02,8.0700E+02,3.6540E+03,3.9310E+03/
C     Z = 18
      DATA(EIP(I),I= 171, 189)/    39.94900,
     11.5755E+01,2.7620E+01,4.0900E+01,5.9790E+01,7.5000E+01,9.1300E+01,
     21.2400E+02,1.4346E+02,4.2260E+02,4.7940E+02,5.3890E+02,6.2100E+02,
     36.8700E+02,7.5500E+02,8.5400E+02,9.1600E+02,4.1150E+03,4.4070E+03/
C     Z = 19
      DATA(EIP(I),I= 190, 209)/    39.10300,
     14.3390E+00,3.1810E+01,4.6000E+01,6.0900E+01,8.2600E+01,9.9700E+01,
     21.1800E+02,1.5500E+02,1.7594E+02,5.0380E+02,5.6400E+02,6.2900E+02,
     37.1700E+02,7.8800E+02,8.7000E+02,9.6600E+02,1.0310E+03,4.6030E+03,
     44.9100E+03/
C     Z = 20
      DATA(EIP(I),I= 210, 230)/    40.08000,
     16.1110E+00,1.1868E+01,5.1210E+01,6.7000E+01,8.4390E+01,1.0900E+02,
     21.2800E+02,1.4330E+02,1.8800E+02,2.1130E+02,5.9180E+02,6.5500E+02,
     37.2700E+02,8.2300E+02,8.9600E+02,9.9100E+02,1.0840E+03,1.1530E+03,
     45.1190E+03,5.4710E+03/
C     Z = 21
      DATA(EIP(I),I= 231, 252)/    44.95600,
     16.5400E+00,1.2800E+01,2.4750E+01,7.3900E+01,9.2000E+01,1.1100E+02,
     21.3900E+02,1.5900E+02,1.8000E+02,2.2600E+02,2.5000E+02,6.8700E+02,
     37.5800E+02,8.3000E+02,9.3000E+02,1.0100E+03,1.1150E+03,1.2100E+03,
     41.2820E+03,5.4833E+03,6.0354E+03/
C     Z = 22
      DATA(EIP(I),I= 253, 275)/    47.90000,
     16.8200E+00,1.3570E+01,2.7470E+01,4.3240E+01,9.9800E+01,1.2000E+02,
     21.4100E+02,1.7200E+02,1.9300E+02,2.1700E+02,2.6600E+02,2.9100E+02,
     37.8800E+02,8.6400E+02,9.4100E+02,1.0460E+03,1.1320E+03,1.2450E+03,
     41.3410E+03,1.4178E+03,6.0493E+03,6.6277E+03/
C     Z = 23
      DATA(EIP(I),I= 276, 299)/    50.94400,
     16.7400E+00,1.4650E+01,2.9400E+01,4.8000E+01,6.5000E+01,1.2900E+02,
     21.5100E+02,1.7400E+02,2.0600E+02,2.3150E+02,2.5800E+02,3.0900E+02,
     33.3600E+02,8.9700E+02,9.7600E+02,1.0570E+03,1.1700E+03,1.2600E+03,
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     41.3800E+03,1.4805E+03,1.5603E+03,6.6438E+03,7.2484E+03/            AES 1229
C     Z = 24                                                              AES 1230
      DATA(EIP(I),I= 300, 324)/    52.00000,                              AES 1231
     16.7640E+00,1.6490E+01,3.0950E+01,5.0300E+01,7.3000E+01,9.1000E+01,AES 1232
     21.6100E+02,1.8500E+02,2.1000E+02,2.4900E+02,2.7200E+02,2.9900E+02,AES 1233
     33.5500E+02,3.8400E+02,1.0130E+03,1.0950E+03,1.1820E+03,1.3010E+03,AES 1234
     41.3950E+03,1.5252E+03,1.6263E+03,1.7097E+03,7.2667E+03,7.8974E+03/AES 1235
C     Z = 25                                                              AES 1236
      DATA(EIP(I),I= 325, 350)/    54.94100,                              AES 1237
     17.4330E+00,1.5636E+01,3.3690E+01,5.3000E+01,7.6000E+01,1.0100E+02,AES 1238
     21.1900E+02,1.9600E+02,2.2200E+02,2.4800E+02,2.8800E+02,3.1500E+02,AES 1239
     33.5000E+02,4.0400E+02,4.3500E+02,1.1360E+03,1.2220E+03,1.3130E+03,AES 1240
     41.4380E+03,1.5380E+03,1.6780E+03,1.7790E+03,1.8660E+03,7.9180E+03,AES 1241
     58.5750E+03/                                                         AES 1242
C     Z = 26                                                              AES 1243
      DATA(EIP(I),I= 351, 377)/    55.84900,                              AES 1244
     17.8700E+00,1.6180E+01,3.0643E+01,5.7000E+01,7.9000E+01,1.0300E+02,AES 1245
     21.3000E+02,1.5100E+02,2.3500E+02,2.6200E+02,2.9000E+02,3.3000E+02,AES 1246
     33.5500E+02,3.9000E+02,4.5700E+02,4.8900E+02,1.2660E+03,1.3540E+03,AES 1247
     41.4500E+03,1.5830E+03,1.6870E+03,1.8370E+03,1.9380E+03,2.0290E+03,AES 1248
     58.5990E+03,9.2810E+03/                                              AES 1249
C     Z = 27                                                              AES 1250
      DATA(EIP(I),I= 378, 405)/    58.93560,                              AES 1251
     17.8600E+00,1.7050E+01,3.3490E+01,5.3000E+01,8.3000E+01,1.0800E+02,AES 1252
     21.3400E+02,1.6400E+02,1.9000E+02,2.9000E+02,3.0500E+02,3.3700E+02,AES 1253
     33.8000E+02,4.1200E+02,4.4400E+02,5.1200E+02,5.4700E+02,1.4030E+03,AES 1254
     41.4950E+03,1.5949E+03,1.7342E+03,1.8429E+03,2.0045E+03,2.1045E+03,AES 1255
     52.1989E+03,9.3098E+03,1.0018E+04/                                   AES 1256
C     Z = 28                                                              AES 1257
      DATA(EIP(I),I= 406, 434)/    58.71000,                              AES 1258
     17.6330E+00,1.8150E+01,3.5160E+01,5.6000E+01,7.9000E+01,1.1200E+02,AES 1259
     21.4000E+02,1.6900E+02,2.0200E+02,2.3300E+02,3.2100E+02,3.5000E+02,AES 1260
     33.8500E+02,4.3000E+02,4.5500E+02,5.0000E+02,5.3000E+02,6.0700E+02,AES 1261
     41.5410E+03,1.6421E+03,1.7465E+03,1.8922E+03,2.0055E+03,2.1789E+03,AES 1262
     52.2779E+03,2.3755E+03,1.0048E+04,1.0782E+04/                        AES 1263
C     Z = 29                                                              AES 1264
      DATA(EIP(I),I= 435, 464)/    63.55000,                              AES 1265
     17.7240E+00,2.0290E+01,3.6830E+01,5.9000E+01,8.2000E+01,1.1000E+02,AES 1266
     21.4000E+02,1.7000E+02,2.0600E+02,2.4100E+02,2.6500E+02,3.7000E+02,AES 1267
     34.0000E+02,4.4100E+02,4.8000E+02,5.2000E+02,5.6000E+02,6.3000E+02,AES 1268
     46.7100E+02,1.6940E+03,1.7960E+03,1.9050E+03,2.0570E+03,2.1750E+03,AES 1269
     52.3600E+03,2.4580E+03,2.5590E+03,1.0813E+04,1.1573E+04/             AES 1270
C     Z = 30                                                              AES 1271
      DATA(EIP(I),I= 465, 495)/    65.37100,                              AES 1272
     19.3910E+00,1.7960E+01,3.9700E+01,6.2000E+01,8.6000E+01,1.1500E+02,AES 1273
     21.4500E+02,1.8000E+02,2.1000E+02,2.5000E+02,2.7935E+02,3.1100E+02,AES 1274
     34.2000E+02,4.5000E+02,4.9000E+02,5.4000E+02,5.8000E+02,6.2000E+02,AES 1275
     47.0000E+02,7.4111E+02,1.8500E+03,1.9555E+03,2.0680E+03,2.2225E+03,AES 1276
     52.3593E+03,2.5473E+03,2.6592E+03,2.7671E+03,1.1665E+04,1.2441E+04/AES 1277
C     Z = 31                                                              AES 1278
      DATA(EIP(I),I= 496, 527)/    69.72000,                              AES 1279
     16.0000E+00,2.0510E+01,3.0700E+01,6.4200E+01,9.0000E+01,1.1800E+02,AES 1280
     21.4400E+02,1.7400E+02,2.1800E+02,2.5500E+02,2.8922E+02,3.2071E+02,AES 1281
     33.6584E+02,4.7072E+02,5.0313E+02,5.4522E+02,5.9701E+02,6.4272E+02,AES 1282
     46.8534E+02,7.7042E+02,8.1423E+02,2.0127E+03,2.1217E+03,2.2379E+03,AES 1283
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     52.3948E+03,2.5503E+03,2.7414E+03,2.8673E+03,2.9821E+03,1.2543E+04,AES 1284
     61.3336E+04/                                                        AES 1285
C      Z = 32                                                            AES 1286
      DATA(EIP(I),I= 528, 560)/    72.60000,                             AES 1287
     17.8800E+00,1.5930E+01,3.4210E+01,4.5700E+01,9.3400E+01,1.1300E+02,AES 1288
     21.4800E+02,1.7700E+02,2.1200E+02,2.6200E+02,2.9525E+02,3.3145E+02,AES 1289
     33.6510E+02,4.2370E+02,5.2445E+02,5.5929E+02,6.0345E+02,6.5704E+02,AES 1290
     47.0845E+02,7.5370E+02,8.4387E+02,8.9038E+02,2.1822E+03,2.2948E+03,AES 1291
     52.4145E+03,2.5739E+03,2.7432E+03,2.9423E+03,3.0821E+03,3.2038E+03,AES 1292
     61.3449E+04,1.4259E+04/                                             AES 1293
C      Z = 33                                                            AES 1294
      DATA(EIP(I),I= 561, 594)/    74.32420,                             AES 1295
     19.8100E+00,1.8630E+01,2.8340E+01,5.0100E+01,6.2600E+01,1.2750E+02,AES 1296
     21.5000E+02,1.8200E+02,2.1800E+02,2.5300E+02,3.0264E+02,3.3851E+02,AES 1297
     33.7671E+02,4.1251E+02,4.8458E+02,5.8121E+02,6.1846E+02,6.6471E+02,AES 1298
     47.2008E+02,7.7721E+02,8.2508E+02,9.2033E+02,9.6955E+02,2.3586E+03,AES 1299
     52.4747E+03,2.5979E+03,2.7598E+03,2.9529E+03,3.1500E+03,3.3037E+03,AES 1300
     63.4324E+03,1.4383E+04,1.5208E+04/                                  AES 1301
C      Z = 34                                                            AES 1302
      DATA(EIP(I),I= 595, 629)/    78.96000,                             AES 1303
     19.7500E+00,2.1500E+01,3.2000E+01,4.3300E+01,6.8000E+01,8.2000E+01,AES 1304
     21.5500E+02,1.8700E+02,2.2300E+02,2.6300E+02,2.9560E+02,3.4631E+02,AES 1305
     33.8480E+02,4.2499E+02,4.6294E+02,5.4849E+02,6.4099E+02,6.8066E+02,AES 1306
     47.2899E+02,7.8616E+02,8.4899E+02,8.9949E+02,9.9982E+02,1.0517E+03,AES 1307
     52.5417E+03,2.6613E+03,2.7881E+03,2.9525E+03,3.1643E+03,3.3645E+03,AES 1308
     63.5321E+03,3.6677E+03,1.5343E+04,1.6185F+04/                       AES 1309
C      Z = 35                                                            AES 1310
      DATA(EIP(I),I= 630, 665)/    79.31200,                             AES 1311
     11.1840E+01,2.1600E+01,3.5900E+01,4.7300E+01,5.9700E+01,8.8600E+01,AES 1312
     21.0300E+02,1.9300E+02,2.2800E+02,2.6600E+02,3.0390E+02,3.4122E+02,AES 1313
     33.9299E+02,4.3411E+02,4.7629E+02,5.1640E+02,6.1541E+02,7.0379E+02,AES 1314
     47.4587E+02,7.9629E+02,8.5525E+02,9.2379E+02,9.7691E+02,1.0823E+03,AES 1315
     51.1370E+03,2.7317E+03,2.8548E+03,2.9851E+03,3.1520E+03,3.3826E+03,AES 1316
     63.5858E+03,3.7673E+03,3.9099E+03,1.6330E+04,1.7189E+04/            AES 1317
C      Z = 36                                                            AES 1318
      DATA(EIP(I),I= 666, 702)/    83.80000,                             AES 1319
     11.3996E+01,2.4560E+01,3.6900E+01,5.2000E+01,6.5000E+01,7.9000E+01,AES 1320
     21.1000E+02,1.2600E+02,2.3400E+02,2.7000E+02,3.1123E+02,3.5082E+02,AES 1321
     33.8986E+02,4.4269E+02,4.8644E+02,5.3061E+02,5.7287E+02,6.8536E+02,AES 1322
     47.6961E+02,8.1411E+02,8.6661E+02,9.2736E+02,1.0016E+03,1.0574E+03,AES 1323
     51.1679E+03,1.2252E+03,2.9284E+03,3.0550E+03,3.1890E+03,3.3583E+03,AES 1324
     63.6076E+03,3.8139E+03,4.0094E+03,4.1588E+03,1.7345E+04,1.8220E+04/AES 1325
C      Z = 37                                                            AES 1326
      DATA(EIP(I),I= 703, 740)/    85.48000,                             AES 1327
     14.1760E+00,2.7500E+01,4.0000E+01,5.2000E+01,7.1000E+01,8.5000E+01,AES 1328
     21.0000E+02,1.3500E+02,1.5100E+02,2.7700E+02,3.1672E+02,3.5948E+02,AES 1329
     34.0076E+02,4.4152E+02,4.9542E+02,5.4179E+02,5.8795E+02,6.3236E+02,AES 1330
     47.5833E+02,8.3845E+02,8.8537E+02,9.3995E+02,1.0025E+03,1.0825E+03,AES 1331
     51.1408E+03,1.2564E+03,1.3164E+03,3.1319E+03,3.2621E+03,3.3996E+03,AES 1332
     63.5714E+03,3.8395E+03,4.0488E+03,4.2582E+03,4.4145E+03,1.8387E+04,AES 1333
     71.9278E+04/                                                        AES 1334
C      Z = 38                                                            AES 1335
      DATA(EIP(I),I= 741, 779)/    87.63000,                             AES 1336
     15.6920E+00,1.1027E+01,4.3000E+01,5.7000E+01,7.2000E+01,9.2000E+01,AES 1337
     21.0700E+02,1.2400E+02,1.6200E+02,1.7900E+02,3.2400E+02,3.6646E+02,AES 1338
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     34.1076E+02,4.5372E+02,4.9620E+02,5.5117E+02,6.0017E+02,6.4832E+02,AES 1339
     46.9488E+02,8.3432E+02,9.1032E+02,9.5965E+02,1.0163E+03,1.0806E+03,AES 1340
     51.1663E+03,1.2273E+03,1.3480E+03,1.4107E+03,3.3423E+03,3.4759E+03,AES 1341
     63.6170E+03,3.7913E+03,4.0781E+03,4.2905E+03,4.5138E+03,4.6771E+03,AES 1342
     71.9456E+04,2.0364E+04/                                            AES 1343
C     Z = 39                                                            AES 1344
      DATA(EIP(I),I= 780, 819)/    88.90800,                            AES 1345
     16.3800E+00,1.2230E+01,2.0500E+01,6.2000E+01,7.7000E+01,9.3000E+01,AES 1346
     21.1600E+02,1.3100E+02,1.4800E+02,1.9100E+02,2.0600E+02,3.7299E+02,AES 1347
     34.1922E+02,4.6505E+02,5.0971E+02,5.5391E+02,6.0994E+02,6.6156E+02,AES 1348
     47.1170E+02,7.6042E+02,9.1332E+02,9.8520E+02,1.0369E+03,1.0957E+03,AES 1349
     51.1618E+03,1.2532E+03,1.3168E+03,1.4426E+03,1.5080E+03,3.5594E+03,AES 1350
     63.6966E+03,3.8412E+03,4.0180E+03,4.3236E+03,4.5390E+03,4.7762E+03,AES 1351
     74.9464E+03,2.0553E+04,2.1477E+04/                                 AES 1352
C     Z = 40                                                            AES 1353
      DATA(EIP(I),I= 820, 860)/    91.22000,                            AES 1354
     16.8400E+00,1.3130E+01,2.2980E+01,3.4330E+01,8.2000E+01,9.9000E+01,AES 1355
     21.1700E+02,1.4100E+02,1.5700E+02,1.7600E+02,2.2200E+02,2.5000E+02,AES 1356
     34.2500E+02,4.7500E+02,5.2237E+02,5.6371E+02,6.1463E+02,6.7173E+02,AES 1357
     47.2597E+02,7.7811E+02,8.2897E+02,9.9536E+02,1.0631E+03,1.1173E+03,AES 1358
     51.1781E+03,1.2460E+03,1.3431E+03,1.4094E+03,1.5402E+03,1.6083E+03,AES 1359
     63.7833E+03,3.9240E+03,4.0722E+03,4.2515E+03,4.5758E+03,4.7943E+03,AES 1360
     75.0454E+03,5.2225E+03,2.1676E+04,2.2616E+04/                      AES 1361
C     Z = 41                                                            AES 1362
      DATA(EIP(I),I= 861, 902)/    92.91000,                            AES 1363
     16.8800E+00,1.4320E+01,2.5040E+01,3.8300E+01,5.0000E+01,1.0300E+02,AES 1364
     21.2500E+02,1.4300E+02,1.6700E+02,1.8500E+02,2.0300E+02,2.4888E+02,AES 1365
     32.8281E+02,4.8379E+02,5.3443E+02,5.8270E+02,6.3074E+02,6.7838E+02,AES 1366
     47.3654E+02,7.9341E+02,8.4753E+02,9.0155E+02,1.0804E+03,1.1440E+03,AES 1367
     51.2006E+03,1.2635E+03,1.3332E+03,1.4360E+03,1.5049E+03,1.6408E+03,AES 1368
     61.7117E+03,4.0140E+03,4.1583E+03,4.3100E+03,4.4918E+03,4.8349E+03,AES 1369
     75.0564E+03,5.3214E+03,5.5054E+03,2.2827E+04,2.3784E+04/           AES 1370
C     Z = 42                                                            AES 1371
      DATA(EIP(I),I= 903, 945)/    95.95000,                            AES 1372
     17.1000E+00,1.6150E+01,2.7130E+01,4.6400E+01,6.1200E+01,6.8000E+01,AES 1373
     21.2600E+02,1.5300E+02,1.6900E+02,1.9700E+02,2.1000E+02,2.3334E+02,AES 1374
     32.7746E+02,3.1732E+02,5.4561E+02,5.9689E+02,6.4606E+02,6.9579E+02,AES 1375
     47.4515E+02,8.0437E+02,8.6387E+02,9.1998E+02,9.7515E+02,1.1685E+03,AES 1376
     51.2280E+03,1.2870E+03,1.3520E+03,1.4235E+03,1.5320E+03,1.6035E+03,AES 1377
     61.7445E+03,1.8180E+03,4.2516E+03,4.3993E+03,4.5546E+03,4.7388E+03,AES 1378
     75.1007E+03,5.3252E+03,5.6042E+03,5.7952E+03,2.4005E+04,2.4978E+04/AES 1379
C     Z = 43                                                            AES 1380
      DATA(EIP(I),I= 946, 989)/    99.00000,                            AES 1381
     17.2800E+00,1.5260E+01,3.1000E+01,4.3000E+01,5.9000E+01,7.6000E+01,AES 1382
     29.4000E+01,1.6100E+02,1.8300E+02,1.9900E+02,2.2400E+02,2.4072E+02,AES 1383
     32.6538E+02,3.0775E+02,3.5353E+02,6.1044E+02,6.6237E+02,7.1244E+02,AES 1384
     47.6385E+02,8.1493E+02,8.7522E+02,9.3735E+02,9.9545E+02,1.0528E+03,AES 1385
     51.2596E+03,1.3149E+03,1.3764E+03,1.4434E+03,1.5167E+03,1.6309E+03,AES 1386
     61.7051E+03,1.8512E+03,1.9274E+03,4.4959E+03,4.6472E+03,4.8060E+03,AES 1387
     74.9927E+03,5.3734E+03,5.6009E+03,5.8938E+03,6.0917E+03,2.5210E+04,AES 1388
     82.6199E+04/                                                       AES 1389
C     Z = 44                                                            AES 1390
      DATA(EIP(I),I= 990,1034)/   101.07000,                            AES 1391
     17.3640E+00,1.6760E+01,2.8460E+01,4.6300E+01,6.3000E+01,8.1000E+01,AES 1392
     21.0000E+02,1.1900E+02,1.9300E+02,2.1600E+02,2.2500E+02,2.5295E+02,AES 1393
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     32.7314E+02,2.9912E+02,3.3973E+02,3.9144E+02,6.7830E+02,7.3086E+02,AES 1394
     47.8184E+02,8.3494E+02,8.8774E+02,9.4910E+02,1.0138E+03,1.0739E+03,AES 1395
     51.1334E+03,1.3537E+03,1.4049E+03,1.4688E+03,1.5379E+03,1.6130E+03,AES 1396
     61.7329E+03,1.8097E+03,1.9609E+03,2.0398E+03,4.7470E+03,4.9018E+03,AES 1397
     75.0642E+03,5.2534E+03,5.6528E+03,5.8834E+03,6.1902E+03,6.3950E+03,AES 1398
     82.6442E+04,2.7448E+04/                                            AES 1399
C      Z = 45                                                           AES 1400
      DATA(EIP(I),I=1035,1080)/   102.91000,                            AES 1401
     17.4600E+00,1.8070E+01,3.1050E+01,4.6000E+01,6.7000E+01,8.5000E+01,AES 1402
     21.0500E+02,1.2600E+02,1.4700E+02,2.2600E+02,2.5000E+02,2.6700E+02,AES 1403
     32.8360E+02,3.0726E+02,3.3457E+02,3.7341E+02,4.3105E+02,7.4918E+02,AES 1404
     48.0238E+02,8.5426E+02,9.0906E+02,9.6357E+02,1.0260E+03,1.0934E+03,AES 1405
     51.1554E+03,1.2171E+03,1.4508E+03,1.4979E+03,1.5642E+03,1.6354E+03,AES 1406
     61.7123E+03,1.8379E+03,1.9173E+03,2.0736E+03,2.1552E+03,5.0049E+03,AES 1407
     75.1632E+03,5.3292E+03,5.5209E+03,5.9390E+03,6.1727E+03,6.4934E+03,AES 1408
     86.7051E+03,2.7701E+04,2.8724E+04/                                 AES 1409
C      Z = 46                                                           AES 1410
      DATA(EIP(I),I=1081,1127)/   106.40000,                            AES 1411
     18.3300E+00,1.9420E+01,3.2920E+01,4.9000E+01,6.6000E+01,9.0000E+01,AES 1412
     21.1000E+02,1.3200E+02,1.5500E+02,1.7800E+02,2.6100E+02,2.7807E+02,AES 1413
     32.9711E+02,3.1594E+02,3.4308E+02,3.7170E+02,4.0879E+02,4.7236E+02,AES 1414
     48.2308E+02,8.7692E+02,9.2970E+02,9.8619E+02,1.0424E+03,1.1059E+03,AES 1415
     51.1759E+03,1.2400E+03,1.3038E+03,1.5510E+03,1.5940E+03,1.6626E+03,AES 1416
     61.7360E+03,1.8146E+03,1.9460E+03,2.0280E+03,2.1893E+03,2.2737E+03,AES 1417
     75.2696E+03,5.4314E+03,5.6010E+03,5.7951E+03,6.2320E+03,6.4687E+03,AES 1418
     86.8034E+03,7.0220E+03,2.8988E+04,3.0127E+04/                      AES 1419
C      Z = 47                                                           AES 1420
      DATA(EIP(I),I=1128,1175)/   107.87400,                            AES 1421
     17.5740E+00,2.1480E+01,3.4820E+01,5.2000E+01,7.0000E+01,8.9000E+01,AES 1422
     21.1600E+02,1.3900E+02,1.6200E+02,1.8700E+02,2.0155E+02,2.7788E+02,AES 1423
     33.0784E+02,3.2893E+02,3.4999E+02,3.8359E+02,4.1054E+02,4.4587E+02,AES 1424
     45.1537E+02,9.0000E+02,9.5448E+02,1.0082E+03,1.0663E+03,1.1243E+03,AES 1425
     51.1888E+03,1.2615E+03,1.3275E+03,1.3935E+03,1.6542E+03,1.6930E+03,AES 1426
     61.7641E+03,1.8395E+03,1.9200E+03,2.0570E+03,2.1417E+03,2.3081E+03,AES 1427
     72.3951E+03,5.5411E+03,5.7065E+03,5.8796E+03,6.0762E+03,6.5319E+03,AES 1428
     86.7716E+03,7.1202E+03,7.3457E+03,3.0302E+04,3.1357E+04/           AES 1429
C      Z = 48                                                           AES 1430
      DATA(EIP(I),I=1176,1224)/   112.41000,                            AES 1431
     18.9910E+00,1.6904E+01,3.7470E+01,5.5000E+01,7.3000E+01,9.4000E+01,AES 1432
     21.1500E+02,1.4600E+02,1.7000E+02,1.9500E+02,2.0986E+02,2.2680E+02,AES 1433
     32.9645E+02,3.3931E+02,3.6244E+02,3.8574E+02,4.1981E+02,4.5108E+02,AES 1434
     44.8464E+02,5.6007E+02,9.7965E+02,1.0351E+03,1.0897E+03,1.1495E+03,AES 1435
     51.2092E+03,1.2748E+03,1.3501E+03,1.4181E+03,1.4862E+03,1.7604E+03,AES 1436
     61.7951E+03,1.8686E+03,1.9461E+03,2.0284E+03,2.1711E+03,2.2584E+03,AES 1437
     72.4299E+03,2.5196E+03,5.8134E+03,5.9883E+03,6.1649E+03,6.3641E+03,AES 1438
     86.8385E+03,7.0813E+03,7.4437E+03,7.6762E+03,3.1643E+04,3.2714E+04/AES 1439
C      Z = 49                                                           AES 1440
      DATA(EIP(I),I=1225,1274)/   114.82000,                            AES 1441
     15.7850E+00,1.8869E+01,2.8030E+01,5.4400E+01,7.7000E+01,9.8000E+01,AES 1442
     21.2000E+02,1.4400E+02,1.7800E+02,2.0400E+02,2.1702E+02,2.3442E+02,AES 1443
     32.5375E+02,3.1673E+02,3.7247E+02,3.9765E+02,4.2318E+02,4.6073E+02,AES 1444
     44.9332E+02,5.2512E+02,5.0648E+02,1.0623E+03,1.1187E+03,1.1742E+03,AES 1445
     51.2357E+03,1.2971E+03,1.3638E+03,1.4417E+03,1.5117E+03,1.5819E+03,AES 1446
     61.8696E+03,1.9002E+03,1.9761E+03,2.0557E+03,2.1397E+03,2.2882E+03,AES 1447
     72.3781E+03,2.5547E+03,2.6471E+03,6.1045E+03,6.2769E+03,6.4571E+03,AES 1448
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     86.6587E+03,7.1519E+03,7.3977E+03,7.7741E+03,8.0135E+03,3.3011E+04,
     93.4099E+04/
C      Z = 50
      DATA(EIP(I),I=1275,1325)/    118.70000,
     17.3420E+00,1.4529E+01,3.0490E+01,4.0720E+01,7.2300E+01,1.0300E+02,
     21.2600E+02,1.5000E+02,1.7600E+02,2.1300E+02,2.2452E+02,2.4074E+02,
     32.6068E+02,2.8240E+02,3.3870E+02,4.0734E+02,4.3456E+02,4.6233E+02,
     45.0334E+02,5.3726E+02,5.6730E+02,6.5458E+02,1.1480E+03,1.2053E+03,
     51.2617E+03,1.3249E+03,1.3880E+03,1.4558E+03,1.5363E+03,1.6083E+03,
     61.6807E+03,1.9818E+03,2.0083E+03,2.0867E+03,2.1683E+03,2.2542E+03,
     72.4083E+03,2.5008E+03,2.6825E+03,2.7777E+03,6.3964E+03,6.5723E+03,
     86.7561E+03,6.9602E+03,7.4721E+03,7.7210E+03,8.1113E+03,8.3576E+03,
     93.4406E+04,3.5511E+04/
C      Z = 51
      DATA(EIP(I),I=1326,1377)/    121.76000,
     18.6390E+00,1.6500E+01,2.5300E+01,4.4100E+01,5.6000E+01,1.0800E+02,
     21.3200E+02,1.5700E+02,1.8400E+02,2.1100E+02,2.3060E+02,2.4674E+02,
     32.6615E+02,2.8863E+02,3.1275E+02,3.6238E+02,4.4391E+02,4.7317E+02,
     45.0317E+02,5.4766E+02,5.8289E+02,6.1117E+02,7.0439E+02,1.2367E+03,
     51.2949E+03,1.3522E+03,1.4172E+03,1.4829E+03,1.5508E+03,1.6339E+03,
     61.7080E+03,1.7825E+03,2.0971E+03,2.1195E+03,2.2002E+03,2.2840E+03,
     72.3716E+03,2.5315E+03,2.6266E+03,2.8133E+03,2.9112E+03,6.6951E+03,
     86.8746E+03,7.0619E+03,7.2684E+03,7.7992E+03,8.0510E+03,8.4553E+03,
     98.7085E+03,3.5829E+04,3.6950E+04/
C      Z = 52
      DATA(EIP(I),I=1378,1430)/    127.61000,
     19.0100E+00,1.8600E+01,3.1000E+01,3.8000E+01,6.0000E+01,7.2000E+01,
     21.3700E+02,1.6400E+02,1.9200E+02,2.2000E+02,2.2810E+02,2.4990E+02,
     32.7066E+02,2.9327E+02,3.1829E+02,3.4480E+02,3.8775E+02,4.8217E+02,
     45.1348E+02,5.4571E+02,5.9367E+02,6.3323E+02,6.5675E+02,7.5589E+02,
     51.3285E+03,1.3876E+03,1.4458E+03,1.5124E+03,1.5790E+03,1.6489E+03,
     61.7346E+03,1.8106E+03,1.8873E+03,2.2154E+03,2.2336E+03,2.3168E+03,
     72.4026E+03,2.4920E+03,2.6576E+03,2.7554E+03,2.9472E+03,3.0478E+03,
     87.0006E+03,7.1836E+03,7.3745E+03,7.5835E+03,8.1330E+03,8.3879E+03,
     98.8061E+03,9.0662E+03,3.7279E+04,3.8416E+04/
C      Z = 53
      DATA(EIP(I),I=1431,1484)/    126.90900,
     11.0454E+01,1.9090E+01,3.2000E+01,4.2000E+01,6.6000E+01,8.1000E+01,
     29.9000E+01,1.7000E+02,2.0000E+02,2.2900E+02,2.3500E+02,2.4690E+02,
     32.7090E+02,2.9628E+02,3.2208E+02,3.4964E+02,3.7855E+02,4.1483E+02,
     45.2214E+02,5.5549E+02,5.8996E+02,6.4139E+02,6.7927E+02,7.0403E+02,
     58.0910E+02,1.4232E+03,1.4833E+03,1.5424E+03,1.6107E+03,1.6790E+03,
     61.7499E+03,1.8383E+03,1.9163E+03,1.9951E+03,2.3367E+03,2.3508E+03,
     72.4364E+03,2.5243E+03,2.6155E+03,2.7368E+03,2.8872E+03,3.0841E+03,
     83.1874E+03,7.3129E+03,7.4994E+03,7.6938E+03,7.9053E+03,8.4736E+03,
     98.7315E+03,9.1636E+03,9.4307E+03,3.8756E+04,3.9909E+04/
C      Z = 54
      DATA(EIP(I),I=1485,1539)/    131.30000,
     11.2129E+01,2.1210E+01,3.2120E+01,3.8300E+01,5.1500E+01,6.4200E+01,
     29.1400E+01,1.0660E+02,1.7520E+02,1.9620E+02,2.1860E+02,2.4230E+02,
     32.6740E+02,2.9360E+02,3.2360E+02,3.5260E+02,3.8270E+02,4.1400E+02,
     44.4360E+02,5.6380E+02,5.9920E+02,6.3590E+02,6.9080E+02,7.3000E+02,
     57.5300E+02,8.6400E+02,1.5210E+03,1.5820E+03,1.6420E+03,1.7120E+03,
     61.7820E+03,1.8540E+03,1.9450E+03,2.0250E+03,2.1060E+03,2.4610E+03,
     72.4710E+03,2.5590E+03,2.6490E+03,2.7420E+03,2.9190E+03,3.0220E+03,
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     83.2240E+03,3.3300E+03,7.6320E+03,7.8220E+03,8.0200E+03,8.2340E+03,
     98.8210E+03,9.0820E+03,9.5280E+03,9.8020E+03,4.0260E+04,4.1430E+04/
C     Z = 55
      DATA(EIP(I),I=1540,1595)/   132.91000,
     13.8930E+00,2.5100E+01,3.5000E+01,4.6000E+01,6.2000E+01,7.4000E+01,
     21.0100E+02,1.2000E+02,1.4430E+02,2.0500E+02,2.2490E+02,2.4863E+02,
     32.7364E+02,3.0009E+02,3.2763E+02,3.5963E+02,3.8998E+02,4.2147E+02,
     44.5411E+02,4.9318E+02,6.1037E+02,6.4710E+02,6.8506E+02,7.4517E+02,
     57.8576E+02,8.1586E+02,9.2476E+02,1.6178E+03,1.6808E+03,1.7431E+03,
     61.8150E+03,1.8870E+03,1.9613E+03,2.0574E+03,2.1396E+03,2.2230E+03,
     72.5628E+03,2.5982E+03,2.6884E+03,2.7807E+03,2.8760E+03,3.0692E+03,
     83.1747E+03,3.3826E+03,3.4910E+03,7.9631E+03,8.1571E+03,8.3599E+03,
     98.5790E+03,9.2258E+03,9.4932E+03,9.9508E+03,1.0231E+04,4.1958E+04,
     $4.3151E+04/
C     Z = 56
      DATA(EIP(I),I=1596,1652)/   137.35000,
     15.2100E+00,1.0001E+01,3.6000E+01,4.9000E+01,6.2000E+01,8.0000E+01,
     29.3000E+01,1.2000E+02,1.4300E+02,1.5700E+02,2.3120E+02,2.5529E+02,
     32.8035E+02,3.0668E+02,3.3447E+02,3.6335E+02,3.9735E+02,4.2905E+02,
     44.6194E+02,4.9591E+02,5.4445E+02,6.5863E+02,6.9669E+02,7.3592E+02,
     58.0123E+02,8.4321E+02,8.8041E+02,9.8721E+02,1.7177E+03,1.7827E+03,
     61.8472E+03,1.9210E+03,1.9951E+03,2.0717E+03,2.1728E+03,2.2572E+03,
     72.3430E+03,2.6675E+03,2.7285E+03,2.8209E+03,2.9154E+03,3.0130E+03,
     83.2225E+03,3.3305E+03,3.5442E+03,3.6550E+03,8.3009E+03,8.4990E+03,
     98.7065E+03,8.9308E+03,9.6374E+03,9.9111E+03,1.0380E+04,1.0667E+04,
     $4.3682E+04,4.4898E+04/
C     Z = 57
      DATA(EIP(I),I=1653,1710)/   138.92000,
     15.6100E+00,1.1430E+01,1.9170E+01,5.2000E+01,6.6000E+01,8.0000E+01,
     21.0000E+02,1.1400E+02,1.4400E+02,1.6500E+02,2.0400E+02,2.5910E+02,
     32.8739E+02,3.1378E+02,3.4142E+02,3.7056E+02,4.0078E+02,4.3678E+02,
     44.6983E+02,5.0411E+02,5.3942E+02,5.9743E+02,7.0860E+02,7.4799E+02,
     57.8848E+02,8.5900E+02,9.0237E+02,9.4667E+02,1.0514E+03,1.8206E+03,
     61.8876E+03,1.9544E+03,2.0301E+03,2.1062E+03,2.1851E+03,2.2913E+03,
     72.3779E+03,2.4661E+03,2.7753E+03,2.8618E+03,2.9564E+03,3.0532E+03,
     83.1531E+03,3.3788E+03,3.4893E+03,3.7089E+03,3.8221E+03,8.6456E+03,
     98.8478E+03,9.0600E+03,9.2895E+03,1.0056E+04,1.0336E+04,1.0817E+04,
     $1.1110E+04,4.5434E+04,4.6674E+04/
C     Z = 58
      DATA(EIP(I),I=1711,1769)/   140.13000,
     16.9000E+00,1.2300E+01,2.0000E+01,3.5000E+01,7.0000E+01,8.5000E+01,
     21.0000E+02,1.2200E+02,1.3700E+02,1.6500E+02,1.8900E+02,2.2523E+02,
     32.8870E+02,3.2118E+02,3.4890E+02,3.7786E+02,4.0834E+02,4.3990E+02,
     44.7790E+02,5.1230E+02,5.4798E+02,5.8462E+02,6.5210E+02,7.6026E+02,
     58.0098E+02,8.4274E+02,9.1846E+02,9.6322E+02,1.0146E+03,1.1172E+03,
     61.9265E+03,1.9955E+03,2.0645E+03,2.1421E+03,2.2203E+03,2.3015E+03,
     72.4127E+03,2.5015E+03,2.5921E+03,2.8862E+03,2.9981E+03,3.0949E+03,
     83.1939E+03,3.2961E+03,3.5381E+03,3.6511E+03,3.8765E+03,3.9921E+03,
     98.9971E+03,9.2033E+03,9.4203E+03,9.6549E+03,1.0481E+04,1.0767E+04,
     $1.1260E+04,1.1560E+04,4.7213E+04,4.8476E+04/
C     Z = 59
      DATA(EIP(I),I=1770,1829)/   140.91300,
     15.8000E+00,1.6786E+01,2.3848E+01,3.3130E+01,4.9317E+01,8.9000E+01,
     21.0600E+02,1.2200E+02,1.4600E+02,1.6200E+02,1.9700E+02,2.1132E+02,
     32.4816E+02,3.2000E+02,3.5667E+02,3.8572E+02,4.1600E+02,4.4782E+02,
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     44.8072E+02,5.2072E+02,5.5647E+02,5.9355E+02,6.3152E+02,7.0847E+02,
     58.1362E+02,8.5567E+02,8.9870E+02,9.7962E+02,1.0258E+03,1.0843E+03,
     61.1848E+03,2.0355E+03,2.1065E+03,2.1777E+03,2.2572E+03,2.3375E+03,
     72.4210E+03,2.5372E+03,2.6282E+03,2.7212E+03,3.0000E+03,3.1375E+03,
     83.2365E+03,3.3377E+03,3.4422E+03,3.7005E+03,3.8160E+03,4.0472E+03,
     94.1652E+03,9.3553E+03,9.5656E+03,9.7873E+03,1.0027E+04,1.0913E+04,
     $1.1206E+04,1.1710E+04,1.2017E+04,4.9020E+04,5.0305E+04/
C      Z = 60
      DATA(EIP(I),I=1830,1890)/   144.25000,
     16.3000E+00,1.6051E+01,2.8371E+01,3.7096E+01,4.7959E+01,6.5334E+01,
     21.1000E+02,1.2800E+02,1.4700E+02,1.7100E+02,1.8357E+02,2.1904E+02,
     32.3533E+02,2.7278E+02,3.5644E+02,3.9387E+02,4.2425E+02,4.5584E+02,
     44.8901E+02,5.2325E+02,5.6525E+02,6.0235E+02,6.4082E+02,6.8013E+02,
     57.6655E+02,8.6869E+02,9.1207E+02,9.5636E+02,1.0425E+03,1.0900E+03,
     61.1556E+03,1.2540E+03,2.1474E+03,2.2204E+03,2.2939E+03,2.3753E+03,
     72.4576E+03,2.5434E+03,2.6647E+03,2.7579E+03,2.8533E+03,3.1424E+03,
     83.2798E+03,3.3810E+03,3.4845E+03,3.5913E+03,3.8658E+03,3.9838E+03,
     94.2209E+03,4.3413E+03,9.7204E+03,9.9347E+03,1.0161E+04,1.0406E+04,
     $1.1352E+04,1.1651E+04,1.2167E+04,1.2480E+04,5.0853E+04,5.2162E+04/
C      Z = 61
      DATA(EIP(I),I=1891,1952)/   147.00000,
     16.0000E+00,1.8016E+01,2.8001E+01,4.1656E+01,5.2043E+01,6.4487E+01,
     28.3050E+01,1.3500E+02,1.5400E+02,1.7300E+02,1.9224E+02,2.0684E+02,
     32.4277E+02,2.6105E+02,2.9911E+02,3.9457E+02,4.3276E+02,4.6447E+02,
     44.9737E+02,5.3189E+02,5.6747E+02,6.1147E+02,6.4992E+02,6.8978E+02,
     57.3043E+02,8.2632E+02,9.2545E+02,9.7016E+02,1.0157E+03,1.1070E+03,
     61.1560E+03,1.2287E+03,1.3250E+03,2.2624E+03,2.3374E+03,2.4131E+03,
     72.4964E+03,2.5808E+03,2.6689E+03,2.7952E+03,2.8906E+03,2.9884E+03,
     83.2879E+03,3.4252E+03,3.5286E+03,3.6343E+03,3.7434E+03,4.0342E+03,
     94.1547E+03,4.3976E+03,4.5204E+03,1.0092E+04,1.0311E+04,1.0542E+04,
     $1.0792E+04,1.1798E+04,1.2103E+04,1.2530E+04,1.2950E+04,5.2714E+04,
     $5.4046E+04/
C      Z = 62
      DATA(EIP(I),I=1953,2015)/   150.36000,
     15.6000E+00,1.1300E+01,3.1432E+01,4.1651E+01,5.6640E+01,6.8690E+01,
     28.2715E+01,1.0247E+02,1.6100E+02,1.8100E+02,1.9434E+02,2.1518E+02,
     32.3181E+02,2.6821E+02,2.8847E+02,3.2714E+02,4.3441E+02,4.7335E+02,
     45.0639E+02,5.4061E+02,5.7647E+02,6.1339E+02,6.5939E+02,6.9919E+02,
     57.4045E+02,7.8243E+02,8.8779E+02,9.8391E+02,1.0299E+03,1.0768E+03,
     61.1733E+03,1.2236E+03,1.3034E+03,1.3976E+03,2.3804E+03,2.4574E+03,
     72.5354E+03,2.6206E+03,2.7070E+03,2.7974E+03,2.9288E+03,3.0264E+03,
     83.1266E+03,3.4364E+03,3.5736E+03,3.6792E+03,3.7872E+03,3.8986E+03,
     94.2056E+03,4.3286E+03,4.5774E+03,4.7026E+03,1.0471E+04,1.0693E+04,
     $1.0929E+04,1.1185E+04,1.2250E+04,1.2562E+04,1.3101E+04,1.3427E+04,
     $5.4602E+04,5.5956E+04/
C      Z = 63
      DATA(EIP(I),I=2016,2079)/   151.96000,
     15.6700E+00,1.1200E+01,2.9377E+01,4.6547E+01,5.7000E+01,7.3323E+01,
     28.7036E+01,1.0264E+02,1.2358E+02,1.8700E+02,2.0165E+02,2.1738E+02,
     32.3982E+02,2.5848E+02,2.9535E+02,3.1758E+02,3.5686E+02,4.7595E+02,
     45.1564E+02,5.5001E+02,5.8555E+02,6.2275E+02,6.6101E+02,7.0901E+02,
     57.5016E+02,7.9282E+02,8.3613E+02,9.5396E+02,1.0441E+03,1.0914E+03,
     61.1395E+03,1.2413E+03,1.2930E+03,1.3799E+03,1.4720E+03,2.5014E+03,
     72.5804E+03,2.6607E+03,2.7478E+03,2.8362E+03,2.9289E+03,3.0654E+03,
     83.1652E+03,3.2678E+03,3.5879E+03,3.7250E+03,3.8328E+03,3.9431E+03,
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     94.0568E+03,4.3800E+03,4.5055E+03,4.7602E+03,4.8878E+03,1.0856E+04,AES 1614
     $1.1083E+04,1.1324E+04,1.1584E+04,1.2709E+04,1.3027E+04,1.3578E+04,AES 1615
     $1.3911E+04,5.6517E+04,5.7895E+04/                                  AES 1616
C      Z = 64                                                            AES 1617
      DATA(EIP(I),I=2080,2144)/   157.25300,                             AES 1618
     16.1600E+00,1.2000E+01,2.9835E+01,4.8541E+01,6.3361E+01,7.4049E+01,AES 1619
     29.1706E+01,1.0708E+02,1.2427E+02,1.4639E+02,2.0732E+02,2.2401E+02,AES 1620
     32.4212E+02,2.6616E+02,2.8635E+02,3.2418E+02,3.4839E+02,3.8829E+02,AES 1621
     45.1918E+02,5.5963E+02,5.9533E+02,6.3218E+02,6.7073E+02,7.1033E+02,AES 1622
     57.6033E+02,8.0283E+02,8.4688E+02,8.9153E+02,1.0158E+03,1.1059E+03,AES 1623
     61.1546E+03,1.2040E+03,1.3109E+03,1.3640E+03,1.4580E+03,1.5480E+03,AES 1624
     72.6254E+03,2.7064E+03,2.7889E+03,2.8779E+03,2.9684E+03,3.0634E+03,AES 1625
     83.2049E+03,3.3069E+03,3.4119E+03,3.7424E+03,3.8794E+03,3.9894E+03,AES 1626
     94.1019E+03,4.2179E+03,4.5574E+03,4.6854E+03,4.9459E+03,5.0759E+03,AES 1627
     $1.1249E+04,1.1479E+04,1.1725E+04,1.1990E+04,1.3175E+04,1.3500E+04,AES 1628
     $1.4062E+04,1.4401E+04,5.8459E+04,5.9860E+04/                       AES 1629
C      Z = 65                                                            AES 1630
      DATA(EIP(I),I=2145,2210)/   158.93000,                             AES 1631
     16.7000E+00,2.0650E+01,2.8106E+01,4.9557E+01,6.8792E+01,8.1875E+01,AES 1632
     29.2797E+01,1.1179E+02,1.2883E+02,1.4759E+02,1.7091E+02,2.2934E+02,AES 1633
     32.4806E+02,2.6857E+02,2.9419E+02,3.1692E+02,3.5472E+02,3.8091E+02,AES 1634
     44.2141E+02,5.6412E+02,6.0532E+02,6.4235E+02,6.8052E+02,7.2041E+02,AES 1635
     57.6135E+02,8.1335E+02,8.5720E+02,9.0265E+02,9.4863E+02,1.0824E+03,AES 1636
     61.1695E+03,1.2195E+03,1.2701E+03,1.3823E+03,1.4368E+03,1.5379E+03,AES 1637
     71.6258E+03,2.7525E+03,2.8355E+03,2.9203E+03,3.0112E+03,3.1037E+03,AES 1638
     83.2010E+03,3.3476E+03,3.4518E+03,3.5592E+03,3.9000E+03,4.0369E+03,AES 1639
     94.1491E+03,4.2639E+03,4.3822E+03,4.7379E+03,4.8684E+03,5.1348E+03,AES 1640
     $5.2672E+03,1.1648E+04,1.1882E+04,1.2132E+04,1.2403E+04,1.3648E+04,AES 1641
     $1.3979E+04,1.4552E+04,1.4898E+04,6.0428E+04,6.1853E+04/            AES 1642
C      Z = 66                                                            AES 1643
      DATA(EIP(I),I=2211,2277)/   162.50000,                             AES 1644
     16.8000E+00,2.0272E+01,3.6227E+01,4.5299E+01,7.0367E+01,9.0132E+01,AES 1645
     21.0209E+02,1.1324E+02,1.3357E+02,1.5227E+02,1.7262E+02,1.9712E+02,AES 1646
     32.5306E+02,2.7381E+02,2.9670E+02,3.2393E+02,3.4868E+02,3.8695E+02,AES 1647
     44.1512E+02,4.5623E+02,6.1075E+02,6.5271E+02,6.9107E+02,7.3055E+02,AES 1648
     57.7179E+02,8.1407E+02,8.6807E+02,9.1327E+02,9.6011E+02,1.0074E+03,AES 1649
     61.1507E+03,1.2347E+03,1.2861E+03,1.3380E+03,1.4553E+03,1.5112E+03,AES 1650
     71.6194E+03,1.7052E+03,2.8826E+03,2.9676E+03,3.0546E+03,3.1474E+03,AES 1651
     83.2420E+03,3.3416E+03,3.4932E+03,3.5996E+03,3.7094E+03,4.0611E+03,AES 1652
     94.1974E+03,4.3118E+03,4.4288E+03,4.5494E+03,4.9214E+03,5.0544E+03,AES 1653
     $5.3266E+03,5.4614E+03,1.2054E+04,1.2292E+04,1.2547E+04,1.2823E+04,AES 1654
     $1.4128E+04,1.4465E+04,1.5050E+04,1.5403E+04,6.2425E+04,6.3872E+04/AES 1655
C      Z = 67                                                            AES 1656
      DATA(EIP(I),I=2278,2345)/   164.93000,                             AES 1657
     16.0000E+00,2.0781E+01,3.4931E+01,5.2392E+01,6.3580E+01,9.2265E+01,AES 1658
     21.1256E+02,1.2400E+02,1.3539E+02,1.5705E+02,1.7741E+02,1.9934E+02,AES 1659
     32.2503E+02,2.7848E+02,3.0126E+02,3.2654E+02,3.5537E+02,3.8215E+02,AES 1660
     44.2088E+02,4.5103E+02,4.9276E+02,6.5908E+02,7.0180E+02,7.4149E+02,AES 1661
     57.8228E+02,8.2487E+02,8.6849E+02,9.2449E+02,9.7104E+02,1.0193E+03,AES 1662
     61.0679E+03,1.2206E+03,1.3017E+03,1.3544E+03,1.4075E+03,1.5301E+03,AES 1663
     71.5874E+03,1.7027E+03,1.7864E+03,3.0157E+03,3.1027E+03,3.1919E+03,AES 1664
     83.2866E+03,3.3833E+03,3.4852E+03,3.6418E+03,3.7504E+03,3.8626E+03,AES 1665
     94.2253E+03,4.3609E+03,4.4775E+03,4.5967E+03,4.7196E+03,5.1079E+03,AES 1666
     $5.2434E+03,5.5214E+03,5.6586E+03,1.2466E+04,1.2709E+04,1.2969E+04,AES 1667
     $1.3250E+04,1.4614E+04,1.4957E+04,1.5554E+04,1.5913E+04,6.4449E+04,AES 1668
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      $6.5919E+04/
C      Z = 68
       DATA(EIP(I),I=2346,2414)/    167.27000,
      16.0000E+00,2.0623E+01,3.5849E+01,5.0678E+01,7.0645E+01,8.2949E+01,
      21.1525E+02,1.3607E+02,1.4665E+02,1.5924E+02,1.8223E+02,2.0426E+02,
      32.2777E+02,2.5464E+02,3.0560E+02,3.3041E+02,3.5808E+02,3.8850E+02,
      44.1732E+02,4.5652E+02,4.8864E+02,5.3098E+02,7.0912E+02,7.5259E+02,
      57.9361E+02,8.3572E+02,8.7965E+02,9.2461E+02,9.8261E+02,1.0305E+03,
      61.0801E+03,1.1301E+03,1.2923E+03,1.3704E+03,1.4244E+03,1.4788E+03,
      71.6066E+03,1.6652E+03,1.7876E+03,1.8692E+03,3.1518E+03,3.2408E+03,
      83.3323E+03,3.4289E+03,3.5276E+03,3.6318E+03,3.7935E+03,3.9043E+03,
      94.0189E+03,4.3925E+03,4.5274E+03,4.6462E+03,4.7677E+03,4.8929E+03,
      $5.2974E+03,5.4354E+03,5.7193E+03,5.8589E+03,1.2886E+04,1.3132E+04,
      $1.3397E+04,1.3683E+04,1.5107E+04,1.5457E+04,1.6065E+04,1.6431E+04,
      $6.6500E+04,6.7993E+04/
C      Z = 69
       DATA(EIP(I),I=2415,2484)/    168.94100,
      16.0000E+00,2.1331E+01,3.6333E+01,5.2006E+01,6.7513E+01,8.9485E+01,
      21.0341E+02,1.3932E+02,1.6068E+02,1.7100E+02,1.8478E+02,2.0911E+02,
      32.3280E+02,2.5789E+02,2.8595E+02,3.3442E+02,3.6126E+02,3.9132E+02,
      44.2334E+02,4.5418E+02,4.9385E+02,5.2795E+02,5.7090E+02,7.6085E+02,
      58.0507E+02,8.4742E+02,8.9085E+02,9.3612E+02,9.8242E+02,1.0424E+03,
      61.0917E+03,1.1427E+03,1.1940E+03,1.3657E+03,1.4407E+03,1.4961E+03,
      71.5517E+03,1.6847E+03,1.7448E+03,1.8743E+03,1.9538E+03,3.2910E+03,
      83.3820E+03,3.4757E+03,3.5742E+03,3.6750E+03,3.7815E+03,3.9482E+03,
      94.0612E+03,4.1782E+03,4.5627E+03,4.6970E+03,4.8180E+03,4.9417E+03,
      $5.0692E+03,5.4900E+03,5.6305E+03,5.9202E+03,6.0622E+03,1.3312E+04,
      $1.3563E+04,1.3832E+04,1.4123E+04,1.5607E+04,1.5963E+04,1.6583E+04,
      $1.6956E+04,6.8578E+04,7.0095E+04/
C      Z = 70
       DATA(EIP(I),I=2485,2555)/    173.04000,
      16.2000E+00,1.2100E+01,3.7750E+01,5.3132E+01,6.9249E+01,8.5435E+01,
      21.0941E+02,1.2495E+02,1.6448E+02,1.8637E+02,1.9563E+02,2.1203E+02,
      32.3769E+02,2.6304E+02,2.8971E+02,3.1897E+02,3.6494E+02,3.9381E+02,
      44.2626E+02,4.5987E+02,4.9275E+02,5.3288E+02,5.6897E+02,6.1252E+02,
      58.1428E+02,8.5926E+02,9.0294E+02,9.4768E+02,9.9430E+02,1.0419E+03,
      61.1039E+03,1.1545E+03,1.2070E+03,1.2596E+03,1.4407E+03,1.5128E+03,
      71.5695E+03,1.6264E+03,1.7646E+03,1.8260E+03,1.9626E+03,2.0400E+03,
      83.4331E+03,3.5261E+03,3.6221E+03,3.7225E+03,3.8253E+03,3.9341E+03,
      94.1059E+03,4.2211E+03,4.3405E+03,4.7359E+03,4.8695E+03,4.9927E+03,
      $5.1187E+03,5.2485E+03,5.6855E+03,5.8285E+03,6.1241E+03,6.2685E+03,
      $1.3745E+04,1.4000E+04,1.4274E+04,1.4570E+04,1.6114E+04,1.6476E+04,
      $1.7108E+04,1.7487E+04,7.0634E+04,7.2223E+04/
C      Z = 71
       DATA(EIP(I),I=2556,2627)/    174.98000,
      16.1000E+00,1.5000E+01,1.9000E+01,5.5256E+01,7.1017E+01,8.7581E+01,
      21.0444E+02,1.3943E+02,1.4758E+02,1.9073E+02,2.1314E+02,2.2197E+02,
      32.4097E+02,2.6797E+02,2.9498E+02,3.2324E+02,3.5367E+02,3.9715E+02,
      44.2806E+02,4.6289E+02,4.9810E+02,5.3301E+02,5.7361E+02,6.1167E+02,
      56.5584E+02,8.6941E+02,9.1515E+02,9.6016E+02,1.0062E+03,1.0542E+03,
      61.1032E+03,1.1672E+03,1.2191E+03,1.2729E+03,1.3269E+03,1.5175E+03,
      71.5865E+03,1.6445E+03,1.7028E+03,1.8461E+03,1.9090E+03,2.0527E+03,
      82.1280E+03,3.5783E+03,3.6733E+03,3.7716E+03,3.8739E+03,3.9787E+03,
      94.0898E+03,4.2667E+03,4.3841E+03,4.5359E+03,4.9121E+03,5.0451E+03,
      $5.1705E+03,5.2988E+03,5.4309E+03,5.8841E+03,6.0296E+03,6.3311E+03,
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     $6.4779E+03,1.4185E+04,1.4444E+04,1.4722E+04,1.5024E+04,1.6627E+04,AES 1724
     $1.6996E+04,1.7640E+04,1.8025E+04,7.2816E+04,7.4379E+04/           AES 1725
C     Z = 72                                                            AES 1726
      DATA(EIP(I),I=2628,2700)/    178.50000,                           AES 1727
     17.0000E+00,1.4900E+01,2.1000E+01,3.1000E+01,7.3850E+01,8.9991E+01,AES 1728
     21.0700E+02,1.2454E+02,1.5253E+02,1.7130E+02,2.1807E+02,2.4101E+02,AES 1729
     32.5000E+02,2.7161E+02,2.9995E+02,3.2862E+02,3.5846E+02,3.9008E+02,AES 1730
     44.3107E+02,4.6401E+02,5.0123E+02,5.3404E+02,5.7497E+02,6.1604E+02,AES 1731
     56.5608E+02,7.0086E+02,8.2624E+02,9.7273E+02,1.0191E+03,1.0664E+03,AES 1732
     61.1158E+03,1.1661E+03,1.2321E+03,1.2854E+03,1.3406E+03,1.3959E+03,AES 1733
     71.5960E+03,1.6620E+03,1.7213E+03,1.7808E+03,1.9294E+03,1.9936E+03,AES 1734
     82.1444E+03,2.2176E+03,3.7265E+03,3.8235E+03,3.9240E+03,4.0282E+03,AES 1735
     94.1351E+03,4.2485E+03,4.4304E+03,4.5500E+03,4.6742E+03,5.0914E+03,AES 1736
     $5.2237E+03,5.3513E+03,5.4818E+03,5.6162E+03,6.0857E+03,6.2337E+03,AES 1737
     $6.5410E+03,6.6902E+03,1.4631E+04,1.4894E+04,1.5178E+04,1.5484E+04,AES 1738
     $1.7148E+04,1.7523E+04,1.8178E+04,1.8570E+04,7.4976E+04,7.6562E+04/AES 1739
C     Z = 73                                                            AES 1740
      DATA(EIP(I),I=2701,2774)/    180.95500,                           AES 1741
     17.8800E+00,1.6200E+01,2.2000E+01,3.3000E+01,4.5000E+01,9.3531E+01,AES 1742
     21.1305E+02,1.2751E+02,1.4573E+02,1.7572E+02,1.9611E+02,2.4649E+02,AES 1743
     32.6996E+02,2.7865E+02,3.0396E+02,3.3362E+02,3.6396E+02,3.9538E+02,AES 1744
     44.2819E+02,4.6668E+02,5.0165E+02,5.4127E+02,5.7967E+02,6.1864E+02,AES 1745
     56.6017E+02,7.0219E+02,7.4758E+02,9.8477E+02,1.0320E+03,1.0797E+03,AES 1746
     61.1284E+03,1.1790E+03,1.2307E+03,1.2987E+03,1.3533E+03,1.4099E+03,AES 1747
     71.4666E+03,1.6761E+03,1.7391E+03,1.7998E+03,1.8606E+03,2.0143E+03,AES 1748
     82.0800E+03,2.2379E+03,2.3090E+03,3.8777E+03,3.9767E+03,4.0795E+03,AES 1749
     94.1856E+03,4.2945E+03,4.4102E+03,4.5972E+03,4.7190E+03,4.8456E+03,AES 1750
     $5.2737E+03,5.4053E+03,5.5351E+03,5.6679E+03,5.8046E+03,6.2903E+03,AES 1751
     $6.4408E+03,6.7540E+03,6.9056E+03,1.5085E+04,1.5352E+04,1.5640E+04,AES 1752
     $1.5952E+04,1.7675E+04,1.8057E+04,1.8723E+04,1.9122E+04,7.7163E+04,AES 1753
     $7.8772E+04/                                                       AES 1754
C     Z = 74                                                            AES 1755
      DATA(EIP(I),I=2775,2849)/    183.86000,                           AES 1756
     17.9800E+00,1.7700E+01,2.4000E+01,3.5000E+01,4.8000E+01,6.1000E+01,AES 1757
     21.1430E+02,1.3120E+02,1.4910E+02,1.6800E+02,2.0000E+02,2.2200E+02,AES 1758
     32.7600E+02,3.0000E+02,3.0900E+02,3.3800E+02,3.6900E+02,4.0100E+02,AES 1759
     44.3400E+02,4.6800E+02,5.0400E+02,5.4100E+02,5.8300E+02,6.2300E+02,AES 1760
     56.6400E+02,7.0600E+02,7.5000E+02,7.9600E+02,1.0450E+03,1.0930E+03,AES 1761
     61.1420E+03,1.1920E+03,1.2440E+03,1.2970E+03,1.3670E+03,1.4230E+03,AES 1762
     71.4810E+03,1.5390E+03,1.7580E+03,1.8180E+03,1.8800E+03,1.9420E+03,AES 1763
     82.1010E+03,2.1580E+03,2.3330E+03,2.4020E+03,4.0320E+03,4.1330E+03,AES 1764
     94.2380E+03,4.3460E+03,4.4570E+03,4.5750E+03,4.7670E+03,4.8910E+03,AES 1765
     $5.0200E+03,5.4590E+03,5.5990E+03,5.7220E+03,5.8570E+03,5.9960E+03,AES 1766
     $6.4980E+03,6.6510E+03,6.9700E+03,7.1240E+03,1.5545E+04,1.5816E+04,AES 1767
     $1.6109E+04,1.6426E+04,1.8209E+04,1.8597E+04,1.9275E+04,1.9680E+04,AES 1768
     $7.9377E+04,8.1039E+04/                                            AES 1769
C     Z = 75                                                            AES 1770
      DATA(EIP(I),I=2850,2925)/    186.30000,                           AES 1771
     17.8700E+00,1.6600E+01,2.6000E+01,3.8000E+01,5.1000E+01,6.4000E+01,AES 1772
     27.9000E+01,1.4108E+02,1.5874E+02,1.7753E+02,1.9719E+02,2.2869E+02,AES 1773
     32.5169E+02,3.1019E+02,3.3594E+02,3.8743E+02,4.1693E+02,4.4830E+02,AES 1774
     44.8068E+02,5.1418E+02,5.4868E+02,5.8505E+02,6.2243E+02,6.6443E+02,AES 1775
     57.0480E+02,7.4618E+02,7.8868E+02,8.3305E+02,8.7930E+02,1.1339E+03,AES 1776
     61.1822E+03,1.2314E+03,1.2818E+03,1.3342E+03,1.3874E+03,1.4558E+03,AES 1777
     71.5122E+03,1.5704E+03,1.6298E+03,1.8494E+03,1.9098E+03,1.9722E+03,AES 1778
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     82.0347E+03,2.1822E+03,2.2494E+03,2.4138E+03,2.4831E+03,4.2363E+03,
     94.3369E+03,4.4414E+03,4.5491E+03,4.6597E+03,4.7769E+03,4.9593E+03,
     $5.0828E+03,5.2113E+03,5.6116E+03,5.7787E+03,5.9106E+03,6.0457E+03,
     $6.1848E+03,6.6422E+03,6.7948E+03,7.1104E+03,7.2643E+03,1.5930E+04,
     $1.6228E+04,1.6547E+04,1.6886E+04,1.8807E+04,1.9217E+04,1.9882E+04,
     $2.0308E+04,8.1834E+04,8.3485E+04/
C     Z = 76
      DATA(EIP(I),I=2926,3002)/   190.20000,
     18.7000E+00,1.7000E+01,2.5000E+01,4.0000E+01,5.4000E+01,6.8000E+01,
     28.3000E+01,9.9000E+01,1.6895E+02,1.8737E+02,2.0705E+02,2.2747E+02,
     32.5847E+02,2.8247E+02,3.4547E+02,3.7297E+02,4.6755E+02,4.9755E+02,
     45.2930E+02,5.6205E+02,5.9605E+02,6.3105E+02,6.6780E+02,7.0555E+02,
     57.4755E+02,7.8830E+02,8.3005E+02,8.7305E+02,9.1780E+02,9.6430E+02,
     61.2246E+03,1.2731E+03,1.3226E+03,1.3733E+03,1.4261E+03,1.4796E+03,
     71.5463E+03,1.6031E+03,1.6616E+03,1.7203E+03,1.9426E+03,2.0033E+03,
     82.0661E+03,2.1291E+03,2.2651E+03,2.3326E+03,2.4963E+03,2.5658E+03,
     94.4436E+03,4.5439E+03,4.6479E+03,4.7551E+03,4.8654E+03,4.9819E+03,
     $5.1546E+03,5.2776E+03,5.4056E+03,5.7671E+03,5.9704E+03,6.1021E+03,
     $6.2374E+03,6.3766E+03,6.7894E+03,6.9416E+03,7.2539E+03,7.4076E+03,
     $1.6322E+04,1.6647E+04,1.6991E+04,1.7354E+04,1.9412E+04,1.9844E+04,
     $2.0495E+04,2.0943E+04,8.4318E+04,8.5989E+04/
C     Z = 77
      DATA(EIP(I),I=3003,3080)/   192.20000,
     19.0000E+00,1.7000E+01,2.7000E+01,3.9000E+01,5.7000E+01,7.2000E+01,
     28.8000E+01,1.0400E+02,1.2100E+02,1.9791E+02,2.1709E+02,2.3766E+02,
     32.5884E+02,2.8934E+02,3.1434E+02,3.8184E+02,4.1109E+02,5.4938E+02,
     45.7988E+02,6.1200E+02,6.4513E+02,6.7963E+02,7.1513E+02,7.5225E+02,
     57.9038E+02,8.3238E+02,8.7350E+02,9.1563E+02,9.5913E+02,1.0043E+03,
     61.0510E+03,1.3169E+03,1.3656E+03,1.4154E+03,1.4665E+03,1.5196E+03,
     71.5734E+03,1.6385E+03,1.6956E+03,1.7544E+03,1.8135E+03,2.0374E+03,
     82.0985E+03,2.1616E+03,2.2251E+03,2.3496E+03,2.4174E+03,2.5805E+03,
     92.6503E+03,4.6540E+03,4.7538E+03,4.8573E+03,4.9642E+03,5.0741E+03,
     $5.1898E+03,5.3530E+03,5.4755E+03,5.6130E+03,5.9257E+03,6.1651E+03,
     $6.2967E+03,6.4321E+03,6.5715E+03,6.9396E+03,7.0915E+03,7.4003E+03,
     $7.5540E+03,1.6720E+04,1.7073E+04,1.7442E+04,1.7828E+04,2.0024E+04,
     $2.0478E+04,2.1116E+04,2.1585E+04,8.6829E+04,8.8520E+04/
C     Z = 78
      DATA(EIP(I),I=3081,3159)/   195.10000,
     19.0000E+00,1.8560E+01,2.8000E+01,4.1000E+01,5.5000E+01,7.5000E+01,
     29.2000E+01,1.0900E+02,1.2700E+02,1.4600E+02,2.2795E+02,2.4790E+02,
     32.6935E+02,2.9130E+02,3.2130E+02,3.4730E+02,4.1930E+02,4.5030E+02,
     46.3290E+02,6.6390E+02,6.9640E+02,7.2990E+02,7.6490E+02,8.0090E+02,
     58.3840E+02,8.7690E+02,9.1890E+02,9.6040E+02,1.0029E+03,1.0469E+03,
     61.0924E+03,1.1394E+03,1.4109E+03,1.4599E+03,1.5099E+03,1.5614E+03,
     71.6149E+03,1.6689E+03,1.7324E+03,1.7899E+03,1.8489E+03,1.9084E+03,
     82.1339E+03,2.1954E+03,2.2589E+03,2.3229E+03,2.4359E+03,2.5039E+03,
     92.6664E+03,2.7364E+03,4.8673E+03,4.9668E+03,5.0698E+03,5.1763E+03,
     $5.2858E+03,5.4008E+03,5.5543E+03,5.6763E+03,5.8033E+03,6.0873E+03,
     $6.3628E+03,6.4943E+03,6.6298E+03,6.7693E+03,7.0328E+03,7.2443E+03,
     $7.5498E+03,7.7033E+03,1.7126E+04,1.7506E+04,1.7900E+04,1.8309E+04,
     $2.0643E+04,2.1119E+04,2.1743E+04,2.2233E+04,8.9367E+04,9.1077E+04/
C     Z = 79
      DATA(EIP(I),I=3160,3239)/   196.97700,
     19.2200E+00,2.0500E+01,3.0000E+01,4.4000E+01,5.8000E+01,7.3000E+01,
     29.6000E+01,1.1400E+02,1.3300E+02,1.5300E+02,1.8587E+02,2.5908E+02,
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     32.7979E+02,3.0213E+02,3.2484E+02,3.5434E+02,3.8134E+02,4.5784E+02,AES 1834
     44.9059E+02,7.1813E+02,7.4963E+02,7.8250E+02,8.1638E+02,8.5188E+02,AES 1835
     58.8838E+02,9.2625E+02,9.6513E+02,1.0071E+03,1.0490E+03,1.0919E+03,AES 1836
     61.1364E+03,1.1823E+03,1.2295E+03,1.5066E+03,1.5559E+03,1.6061E+03,AES 1837
     71.6580E+03,1.7119E+03,1.7661E+03,1.8280E+03,1.8859E+03,1.9451E+03,AES 1838
     82.0050E+03,2.2321E+03,2.2940E+03,2.3579E+03,2.4224E+03,2.5239E+03,AES 1839
     92.5921E+03,2.7540E+03,2.8243E+03,5.0837E+03,5.1828E+03,5.2853E+03,AES 1840
     $5.3915E+03,5.5006E+03,5.6148E+03,5.7587E+03,5.8802E+03,6.0067E+03,AES 1841
     $6.2520E+03,6.5636E+03,6.6950E+03,6.8306E+03,6.9702E+03,7.2491E+03,AES 1842
     $7.4002E+03,7.7023E+03,7.8557E+03,1.7538E+04,1.7946E+04,1.8365E+04,AES 1843
     $1.8796E+04,2.1269E+04,2.1767E+04,2.2377E+04,2.2888E+04,9.1933E+04,AES 1844
     $9.3663E+04/                                                       AES 1845
C     Z = 80                                                            AES 1846
      DATA(EIP(I),I=3240,3320)/   230.60000,                            AES 1847
     11.0430E+01,1.8751E+01,3.4200E+01,4.6000E+01,6.1000E+01,7.7000E+01,AES 1848
     29.4000E+01,1.2000E+02,1.3900E+02,1.5900E+02,1.9125E+02,2.2682E+02,AES 1849
     32.9130E+02,3.1277E+02,3.3600E+02,3.5947E+02,3.8847E+02,4.1647E+02,AES 1850
     44.9747E+02,5.3197E+02,8.0505E+02,8.3705E+02,8.7030E+02,9.0455E+02,AES 1851
     59.4055E+02,9.7755E+02,1.0158E+03,1.0551E+03,1.0971E+03,1.1393E+03,AES 1852
     61.1826E+03,1.2276E+03,1.2738E+03,1.3213E+03,1.6041E+03,1.6536E+03,AES 1853
     71.7041E+03,1.7563E+03,1.8106E+03,1.8651E+03,1.9253E+03,1.9836E+03,AES 1854
     82.0431E+03,2.1033E+03,2.3321E+03,2.3943E+03,2.4586E+03,2.5236E+03,AES 1855
     92.6136E+03,2.6821E+03,2.8433E+03,2.9138E+03,5.3031E+03,5.4019E+03,AES 1856
     $5.5039E+03,5.6096E+03,5.7184E+03,5.8319E+03,5.9661E+03,6.0871E+03,AES 1857
     $6.2131E+03,6.4196E+03,6.7674E+03,6.8986E+03,7.0344E+03,7.1741E+03,AES 1858
     $7.4084E+03,7.5591E+03,7.8579E+03,8.0111E+03,1.7957E+04,1.8392E+04,AES 1859
     $1.8836E+04,1.9291E+04,2.1901E+04,2.2421E+04,2.3018E+04,2.3550E+04,AES 1860
     $9.4526E+04,9.6275E+04/                                            AES 1861
C     Z = 81                                                            AES 1862
      DATA(EIP(I),I=3321,3402)/   294.38000,                            AES 1863
     16.1060E+00,2.0420E+01,2.9800E+01,5.0700E+01,6.4000E+01,8.1000E+01,AES 1864
     29.8000E+01,1.1600E+02,1.4500E+02,1.6600E+02,1.9596E+02,2.3058E+02,AES 1865
     32.6887E+02,3.2461E+02,3.4684E+02,3.7096E+02,3.9519E+02,4.2369E+02,AES 1866
     44.5269E+02,5.3819E+02,5.7444E+02,8.9368E+02,9.2618E+02,9.5980E+02,AES 1867
     59.9443E+02,1.0309E+03,1.0684E+03,1.1071E+03,1.1467E+03,1.1887E+03,AES 1868
     61.2313E+03,1.2749E+03,1.3204E+03,1.3671E+03,1.4148E+03,1.7032E+03,AES 1869
     71.7529E+03,1.8037E+03,1.8563E+03,1.9109E+03,1.9657E+03,2.0243E+03,AES 1870
     82.0829E+03,2.1427E+03,2.2033E+03,2.4337E+03,2.4963E+03,2.5609E+03,AES 1871
     92.6264E+03,2.7049E+03,2.7737E+03,2.9343E+03,3.0051E+03,5.5256E+03,AES 1872
     $5.6239E+03,5.7254E+03,5.8308E+03,5.9392E+03,6.0519E+03,6.1766E+03,AES 1873
     $6.2971E+03,6.4226E+03,6.5903E+03,6.9742E+03,7.1053E+03,7.2412E+03,AES 1874
     $7.3811E+03,7.5707E+03,7.7211E+03,8.0164E+03,8.1696E+03,1.8382E+04,AES 1875
     $1.8845E+04,1.9315E+04,1.9792E+04,2.2540E+04,2.3082E+04,2.3666E+04,AES 1876
     $2.4219E+04,9.7146E+04,9.8914E+04/                                 AES 1877
C     Z = 82                                                            AES 1878
      DATA(EIP(I),I=3403,3485)/   207.20000,                            AES 1879
     17.4150E+00,1.5028E+01,3.1930E+01,4.2310E+01,6.8800E+01,8.4000E+01,AES 1880
     21.0300E+02,1.2200E+02,1.4200E+02,1.7300E+02,2.0100E+02,2.3400E+02,AES 1881
     32.7100E+02,3.1200E+02,3.5900E+02,3.8200E+02,4.0700E+02,4.3200E+02,AES 1882
     44.6000E+02,4.9000E+02,5.8000E+02,6.1800E+02,9.8400E+02,1.0170E+03,AES 1883
     51.0510E+03,1.0860E+03,1.1230E+03,1.1610E+03,1.2000E+03,1.2400E+03,AES 1884
     61.2820E+03,1.3250E+03,1.3690E+03,1.4150E+03,1.4620E+03,1.5100E+03,AES 1885
     71.8040E+03,1.8540E+03,1.9050E+03,1.9580E+03,2.0130E+03,2.0680E+03,AES 1886
     82.1250E+03,2.1840E+03,2.2440E+03,2.3050E+03,2.5370E+03,2.6000E+03,AES 1887
     92.6650E+03,2.7310E+03,2.7980E+03,2.8670E+03,3.0270E+03,3.0980E+03,AES 1888
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     $5.7510E+03,5.8490E+03,5.9500E+03,6.0550E+03,6.1630E+03,6.2750E+03,
     $6.3900E+03,6.5100E+03,6.6350E+03,6.7640E+03,7.1840E+03,7.3150E+03,
     $7.4510E+03,7.5910E+03,7.7360E+03,7.8860E+03,8.1780E+03,8.3310E+03,
     $1.8815E+04,1.9305E+04,1.9800E+04,2.0300E+04,2.3186E+04,2.3750E+04,
     $2.4320E+04,2.4895E+04,9.9793E+04,1.0158E+05/
C      Z = 83
       DATA(EIP(I),I=3486,3569)/   208.98800,
     17.2870E+00,1.6680E+01,2.5560E+01,4.5300E+01,5.6000E+01,8.8300E+01,
     21.0700E+02,1.2700E+02,1.4800E+02,1.6900E+02,2.0356E+02,2.3283E+02,
     32.6524E+02,3.0127E+02,3.4084E+02,3.9803E+02,4.2211E+02,4.4813E+02,
     44.7407E+02,5.1209E+02,5.4289E+02,6.2559E+02,6.7219E+02,1.0171E+03,
     51.0519E+03,1.0877E+03,1.1247E+03,1.1636E+03,1.2034E+03,1.2444E+03,
     61.2863E+03,1.3321E+03,1.3771E+03,1.4231E+03,1.4711E+03,1.5199E+03,
     71.5701E+03,1.8732E+03,1.9251E+03,1.9781E+03,2.0328E+03,2.0898E+03,
     82.1468E+03,2.2127E+03,2.2736E+03,2.3356E+03,2.3987E+03,2.6392E+03,
     92.7042E+03,2.7709E+03,2.8387E+03,2.9454E+03,3.0171E+03,3.1853E+03,
     $3.2586E+03,5.9099E+03,6.0119E+03,6.1169E+03,6.2259E+03,6.3379E+03,
     $6.4546E+03,6.5989E+03,6.7233E+03,6.8528E+03,6.9864E+03,7.4229E+03,
     $7.5581E+03,7.6978E+03,7.8421E+03,8.1184E+03,8.2734E+03,8.5802E+03,
     $8.7403E+03,1.9469E+04,1.9939E+04,2.0416E+04,2.0901E+04,2.3968E+04,
     $2.4521E+04,2.5131E+04,2.5697E+04,1.0270E+05,1.0479E+05/
C      Z = 84
       DATA(EIP(I),I=3570,3654)/   210.00000,
     18.4300E+00,1.9000E+01,2.7000E+01,3.8000E+01,6.1000E+01,7.3000E+01,
     21.1200E+02,1.3200E+02,1.5400E+02,1.7600E+02,2.0181E+02,2.3520E+02,
     32.6575E+02,2.9757E+02,3.3262E+02,3.7077E+02,4.3815E+02,4.6330E+02,
     44.9035E+02,5.1722E+02,5.6527E+02,5.9687E+02,6.7227E+02,7.2747E+02,
     51.0518E+03,1.0886E+03,1.1261E+03,1.1651E+03,1.2058E+03,1.2476E+03,
     61.2906E+03,1.3343E+03,1.3838E+03,1.4308E+03,1.4788E+03,1.5288E+03,
     71.5796E+03,1.6318E+03,1.9441E+03,1.9978E+03,2.0528E+03,2.1093E+03,
     82.1683E+03,2.2273E+03,2.3021E+03,2.3648E+03,2.4288E+03,2.4941E+03,
     92.7431E+03,2.8101E+03,2.8786E+03,2.9481E+03,3.0946E+03,3.1688E+03,
     $3.3453E+03,3.4208E+03,6.0719E+03,6.1779E+03,6.2869E+03,6.3999E+03,
     $6.5159E+03,6.6371E+03,6.8109E+03,6.9396E+03,7.0736E+03,7.2119E+03,
     $7.6649E+03,7.8041E+03,7.9476E+03,8.0961E+03,8.5039E+03,8.6639E+03,
     $8.9854E+03,9.1526E+03,2.0130E+04,2.0580E+04,2.1039E+04,2.1509E+04,
     $2.4756E+04,2.5299E+04,2.5949E+04,2.6505E+04,1.0563E+05,1.0802E+05/
C      Z = 85
       DATA(EIP(I),I=3655,3740)/   211.00000,
     19.3000E+00,2.0000E+01,2.9000E+01,4.1000E+01,5.1000E+01,7.8000E+01,
     29.1000E+01,1.3800E+02,1.6000E+02,1.8300E+02,2.0998E+02,2.3570E+02,
     32.6793E+02,2.9976E+02,3.3099E+02,3.6507E+02,4.0179E+02,4.7936E+02,
     45.0558E+02,5.3366E+02,5.6147E+02,6.1954E+02,6.5194E+02,7.2004E+02,
     57.8384E+02,1.0883E+03,1.1269E+03,1.1561E+03,1.2071E+03,1.2498E+03,
     61.2934E+03,1.3384E+03,1.3840E+03,1.4373E+03,1.4863E+03,1.5363E+03,
     71.5883E+03,1.6409E+03,1.6953E+03,2.0166E+03,2.0723E+03,2.1293E+03,
     82.1875E+03,2.2485E+03,2.3095E+03,2.3931E+03,2.4578E+03,2.5238E+03,
     92.5911E+03,2.8486E+03,2.9176E+03,2.9879E+03,3.0591E+03,3.2454E+03,
     $3.3223E+03,3.5070E+03,3.5848E+03,6.2368E+03,6.3468E+03,6.4598E+03,
     $6.5768E+03,6.6968E+03,6.8227E+03,7.0258E+03,7.1590E+03,7.2975E+03,
     $7.4403E+03,7.9098E+03,8.0532E+03,8.2005E+03,8.3532E+03,8.8923E+03,
     $9.0573E+03,9.3936E+03,9.5680E+03,2.0798E+04,2.1228E+04,2.1669E+04,
     $2.2124E+04,2.5552E+04,2.6034E+04,2.6774E+04,2.7321E+04,1.0859E+05,
     $1.1128E+05/
C      Z = 86
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      DATA(EIP(I),I=3741,3827)/   222.00000,                            AES 1944
     11.0746E+01,2.1000E+01,2.9000E+01,4.4000E+01,5.5000E+01,6.7000E+01,AES 1945
     29.7000E+01,1.1100E+02,1.6600E+02,1.9000E+02,2.1852E+02,2.4505E+02,AES 1946
     32.7069E+02,3.0175E+02,3.3485E+02,3.6550E+02,3.9860E+02,4.3390E+02,AES 1947
     45.2165E+02,5.4895E+02,5.7805E+02,6.0680E+02,6.7490E+02,7.0810E+02,AES 1948
     57.6890E+02,8.4130E+02,1.1264E+03,1.1669E+03,1.2079E+03,1.2509E+03,AES 1949
     61.2954E+03,1.3409E+03,1.3879E+03,1.4354E+03,1.4924E+03,1.5434E+03,AES 1950
     71.5954E+03,1.6494E+03,1.7039E+03,1.7604E+03,2.0909E+03,2.1484E+03,AES 1951
     82.2074E+03,2.2674E+03,2.3304E+03,2.3934E+03,2.4859E+03,2.5524E+03,AES 1952
     92.6204E+03,2.6899E+03,2.9559E+03,3.0269E+03,3.0989E+03,3.1719E+03,AES 1953
     $3.3979E+03,3.4774E+03,3.6704E+03,3.7504E+03,6.4048E+03,6.5188E+03,AES 1954
     $6.6358E+03,6.7568E+03,6.8808E+03,7.0113E+03,7.2438E+03,7.3813E+03,AES 1955
     $7.5243E+03,7.6718E+03,8.1578E+03,8.3053E+03,8.4563E+03,8.6133E+03,AES 1956
     $9.2838E+03,9.4538E+03,9.8048E+03,9.9363E+03,2.1473E+04,2.1883E+04,AES 1957
     $2.2306E+04,2.2746E+04,2.6354E+04,2.6876E+04,2.7606E+04,2.8143E+04,AES 1958
     $1.1158E+05,1.1457E+05/                                            AES 1959
C       Z = 87                                                          AES 1960
      DATA(EIP(I),I=3828,3915)/   223.00000,                            AES 1961
     14.0000E+00,2.2000E+01,3.3000E+01,4.3000E+01,5.9000E+01,7.1000E+01,AES 1962
     28.4000E+01,1.1700E+02,1.3300E+02,1.9700E+02,2.2782E+02,2.5514E+02,AES 1963
     32.8121E+02,3.0676E+02,3.3666E+02,3.7103E+02,4.0109E+02,4.3322E+02,AES 1964
     44.6709E+02,5.6503E+02,5.9341E+02,6.2353E+02,6.5322E+02,7.3134E+02,AES 1965
     57.6534E+02,8.1884E+02,8.9984E+02,1.1663E+03,1.2086E+03,1.2514E+03,AES 1966
     61.2964E+03,1.3428E+03,1.3901E+03,1.4391E+03,1.4885E+03,1.5493E+03,AES 1967
     71.6023E+03,1.6563E+03,1.7123E+03,1.7686E+03,1.8273E+03,2.1669E+03,AES 1968
     82.2263E+03,2.2873E+03,2.3490E+03,2.4140E+03,2.4790E+03,2.5804E+03,AES 1969
     92.6488E+03,2.7188E+03,2.7904E+03,3.0649E+03,3.1379E+03,3.2116E+03,AES 1970
     $3.2864E+03,3.5521E+03,3.6343E+03,3.8355E+03,3.9178E+03,6.5758E+03,AES 1971
     $6.6938E+03,6.8148E+03,6.9398E+03,7.0678E+03,7.2030E+03,7.4648E+03,AES 1972
     $7.6067E+03,7.7542E+03,7.9063E+03,8.4088E+03,8.5605E+03,8.7152E+03,AES 1973
     $8.8765E+03,9.6783E+03,9.8533E+03,1.0219E+04,1.0408E+04,2.2155E+04,AES 1974
     $2.2545E+04,2.2949E+04,2.3374E+04,2.7163E+04,2.7674E+04,2.8444E+04,AES 1975
     $2.8972E+04,1.1459E+05,1.1789E+05/                                 AES 1976
C       Z = 88                                                          AES 1977
      DATA(EIP(I),I=3916,4004)/   226.05000,                            AES 1978
     15.2770E+00,1.0144E+01,3.4000E+01,4.6000E+01,5.8000E+01,7.6000E+01,AES 1979
     28.9000E+01,1.0300E+02,1.4000E+02,1.5600E+02,2.3848E+02,2.6672E+02,AES 1980
     32.9284E+02,3.1845E+02,3.4392E+02,3.7265E+02,4.0830E+02,4.3777E+02,AES 1981
     44.6892E+02,5.0137E+02,6.0950E+02,6.3895E+02,6.7010E+02,7.0072E+02,AES 1982
     57.8887E+02,8.2367E+02,8.6987E+02,9.5947E+02,1.2078E+03,1.2521E+03,AES 1983
     61.2966E+03,1.3436E+03,1.3918E+03,1.4411E+03,1.4921E+03,1.5433E+03,AES 1984
     71.6078E+03,1.6628E+03,1.7188E+03,1.7768E+03,1.8351E+03,1.8958E+03,AES 1985
     82.2446E+03,2.3058E+03,2.3688E+03,2.4323E+03,2.4993E+03,2.5663E+03,AES 1986
     92.6766E+03,2.7468E+03,2.8188E+03,2.8926E+03,3.1756E+03,3.2506E+03,AES 1987
     $3.3261E+03,3.4026E+03,3.7031E+03,3.7928E+03,4.0023E+03,4.0868E+03,AES 1988
     $6.7499E+03,6.8719E+03,6.9969E+03,7.1259E+03,7.2579E+03,7.3976E+03,AES 1989
     $7.6889E+03,7.8351E+03,7.9871E+03,8.1439E+03,8.6629E+03,8.8186E+03,AES 1990
     $8.9771E+03,9.1426E+03,1.0076E+04,1.0256E+04,1.0636E+04,1.0832E+04,AES 1991
     $2.2843E+04,2.3213E+04,2.3599E+04,2.4009E+04,2.7978E+04,2.8479E+04,AES 1992
     $2.9289E+04,2.9808E+04,1.1764E+05,1.2123E+05/                      AES 1993
C       Z = 89                                                          AES 1994
      DATA(EIP(I),I=4005,4094)/   227.00000,                            AES 1995
     16.9000E+00,1.2100E+01,2.0000E+01,4.9000E+01,6.2000E+01,7.6000E+01,AES 1996
     29.5000E+01,1.0900E+02,1.2300E+02,1.6400E+02,1.9276E+02,2.8105E+02,AES 1997
     33.0672E+02,3.3162E+02,3.5678E+02,3.8217E+02,4.0973E+02,4.4666E+02,AES 1998
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     44.7554E+02,5.0572E+02,5.3674E+02,6.5506E+02,6.8558E+02,7.1776E+02,AES 1999
     57.4932E+02,8.4749E+02,8.8309E+02,9.2199E+02,1.0202E+03,1.2511E+03,AES 2000
     61.2972E+03,1.3434E+03,1.3924E+03,1.4426E+03,1.4937E+03,1.5467E+03,AES 2001
     71.5998E+03,1.6681E+03,1.7251E+03,1.7831E+03,1.8431E+03,1.9032E+03,AES 2002
     81.9661E+03,2.3239E+03,2.3871E+03,2.4521E+03,2.5173E+03,2.5863E+03,AES 2003
     92.6553E+03,2.7744E+03,2.8466E+03,2.9206E+03,2.9964E+03,3.2879E+03,AES 2004
     $3.3649E+03,3.4422E+03,3.5204E+03,3.3657E+03,3.9531E+03,4.1708E+03,AES 2005
     $4.2576E+03,6.9269E+03,7.0529E+03,7.1319E+03,7.3149E+03,7.4509E+03,AES 2006
     $7.5953E+03,7.9159E+03,8.0666E+03,8.2231E+03,8.3844E+03,8.9199E+03,AES 2007
     $9.0798E+03,9.2421E+03,9.4118E+03,1.0476E+04,1.0661E+04,1.1057E+04,AES 2008
     $1.1260E+04,2.3538E+04,2.3888E+04,2.4256E+04,2.4651E+04,2.8801E+04,AES 2009
     $2.9291E+04,3.0141E+04,3.0651E+04,1.2070E+05,1.2460E+05/           AES 2010
C      Z = 90                                                           AES 2011
       DATA(EIP(I),I=4095,4185)/   232.04700,                           AES 2012
     16.9500E+00,1.2000E+01,2.0000E+01,2.9200E+01,6.5000E+01,8.0000E+01,AES 2013
     29.4000E+01,1.1500E+02,1.3000E+02,1.4500E+02,2.1200E+02,2.3060E+02,AES 2014
     33.2470E+02,3.4780E+02,3.7150E+02,3.9620E+02,4.2150E+02,4.4790E+02,AES 2015
     44.8610E+02,5.1440E+02,5.4360E+02,5.7320E+02,7.0170E+02,7.3330E+02,AES 2016
     57.6650E+02,7.9900E+02,9.0720E+02,9.4360E+02,9.7520E+02,1.0820E+03,AES 2017
     61.2960E+03,1.3440E+03,1.3920E+03,1.4430E+03,1.4950E+03,1.5480E+03,AES 2018
     71.6030E+03,1.6580E+03,1.7300E+03,1.7890E+03,1.8490E+03,1.9110E+03,AES 2019
     81.9730E+03,2.0380E+03,2.4050E+03,2.4700E+03,2.5370E+03,2.6040E+03,AES 2020
     92.6750E+03,2.7460E+03,2.8740E+03,2.9480E+03,3.0240E+03,3.1020E+03,AES 2021
     $3.4020E+03,3.4810E+03,3.5600E+03,3.6400E+03,4.0250E+03,4.1150E+03,AES 2022
     $4.3410E+03,4.4300E+03,7.1070E+03,7.2370E+03,7.3700E+03,7.5070E+03,AES 2023
     $7.6470E+03,7.7960E+03,8.1460E+03,8.3010E+03,8.4620E+03,8.6280E+03,AES 2024
     $9.1800E+03,9.3440E+03,9.5100E+03,9.6840E+03,1.0880E+04,1.1070E+04,AES 2025
     $1.1480E+04,1.1690E+04,2.4240E+04,2.4570E+04,2.4920E+04,2.5300E+04,AES 2026
     $2.9630E+04,3.0110E+04,3.1000E+04,3.1500E+04,1.2380E+05,1.2800E+05/AES 2027
C      Z = 91                                                           AES 2028
       DATA(EIP(I),I=4186,4277)/   231.00000,                           AES 2029
     16.0000E+00,1.1891E+01,2.1016E+01,3.3121E+01,4.5471E+01,7.8306E+01,AES 2030
     29.2306E+01,1.0601E+02,1.3146E+02,1.4581E+02,1.6116E+02,2.1636E+02,AES 2031
     32.3526E+02,3.3146E+02,3.5506E+02,3.7931E+02,4.0456E+02,4.3046E+02,AES 2032
     44.5741E+02,4.9651E+02,5.2541E+02,5.5526E+02,5.8556E+02,7.1691E+02,AES 2033
     57.4926E+02,7.8321E+02,8.1646E+02,9.2706E+02,9.6426E+02,1.0326E+03,AES 2034
     61.1060E+03,1.3242E+03,1.3732E+03,1.4227E+03,1.4747E+03,1.5277E+03,AES 2035
     71.5822E+03,1.6382E+03,1.6947E+03,1.7682E+03,1.8282E+03,1.8897E+03,AES 2036
     81.9532E+03,2.0167E+03,2.0832E+03,2.4582E+03,2.5247E+03,2.5932E+03,AES 2037
     92.6617E+03,2.7342E+03,2.8067E+03,2.9377E+03,3.0137E+03,3.0912E+03,AES 2038
     $3.1712E+03,3.4777E+03,3.5582E+03,3.6392E+03,3.7212E+03,4.1162E+03,AES 2039
     $4.2067E+03,4.4377E+03,4.5287E+03,7.2660E+03,7.3980E+03,7.5340E+03,AES 2040
     $7.6740E+03,7.8175E+03,7.9695E+03,8.3275E+03,8.4865E+03,8.6510E+03,AES 2041
     $8.8205E+03,9.3850E+03,9.5525E+03,9.7225E+03,9.9005E+03,1.1123E+04,AES 2042
     $1.1318E+04,1.1738E+04,1.1953E+04,2.4782E+04,2.5117E+04,2.5477E+04,AES 2043
     $2.5867E+04,3.0292E+04,3.0782E+04,3.1692E+04,3.2207E+04,1.2709E+05,AES 2044
     $1.3024E+05/                                                       AES 2045
C      Z = 92                                                           AES 2046
       DATA(EIP(I),I=4278,4370)/   238.04000,                           AES 2047
     16.1200E+00,1.1450E+01,1.7920E+01,3.1120E+01,4.7330E+01,6.2830E+01,AES 2048
     29.2700E+01,1.0570E+02,1.1910E+02,1.4900E+02,1.6270E+02,1.7840E+02,AES 2049
     32.2180E+02,2.4100E+02,3.3930E+02,3.6340E+02,3.8820E+02,4.1400E+02,AES 2050
     44.4050E+02,4.6800E+02,5.0800E+02,5.3750E+02,5.6800E+02,5.9900E+02,AES 2051
     57.3320E+02,7.6630E+02,8.0100E+02,8.3500E+02,9.4800E+02,9.8600E+02,AES 2052
     61.0910E+03,1.1310E+03,1.3540E+03,1.4040E+03,1.4550E+03,1.5080E+03,AES 2053
```

```
     71.5620E+03,1.6180E+03,1.6750E+03,1.7330E+03,1.8080E+03,1.8690E+03,
     81.9320E+03,1.9970E+03,2.0620E+03,2.1300E+03,2.5130E+03,2.5810E+03,
     92.6510E+03,2.7210E+03,2.7950E+03,2.8690E+03,3.0030E+03,3.0810E+03,
     $3.1600E+03,3.2420E+03,3.5550E+03,3.6370E+03,3.7200E+03,3.8040E+03,
     $4.2090E+03,4.3000E+03,4.5360E+03,4.6290E+03,7.4280E+03,7.5620E+03,
     $7.7010E+03,7.8440E+03,7.9910E+03,8.1460E+03,8.5120E+03,8.6750E+03,
     $8.8430E+03,9.0160E+03,9.5930E+03,9.7640E+03,9.9380E+03,1.0120E+04,
     $1.1370E+04,1.1570E+04,1.2000E+04,1.2220E+04,2.5330E+04,2.5670E+04,
     $2.6340E+04,2.6440E+04,3.0960E+04,3.1460E+04,3.2390E+04,3.2920E+04,
     $1.3040E+05,1.3250E+05/
C
C     ******************************************************************
C     LIBRARY OF ANALYTICAL EOS
C
      COMMON /BIG/ BIGDUM(1)
      DIMENSION TABLE(200), TABPL(200), DTAB(5000)
      EQUIVALENCE (TABLE(1),BIGDUM(101)), (TABPL(1),BIGDUM(301)), (DTAB(
     11),BIGDUM(501))
C
      DATA NUMTAB/5/
C     AIR
      DATA TABLE(1),TABPL(1)/1.,1./
      DATA (DTAB(I),I=1,31)/10HAIR DRY   ,3.,2.,22*0.,7.,.78455,8.,.2107
     15,18.,.0047/
C     GOLD
      DATA TABLE(2),TABPL(2)/2.,32./
      DATA (DTAB(I),I=32,58)/10HGOLD      ,1.,4.,19.3,.02567785,0.,1.75E
     112,3.054,.01551,0.,2.,1.45E10,.1151,12*0.,79.,1./
C     ALUMINUM
      DATA TABLE(3),TABPL(3)/3.,59./
      DATA (DTAB(I),I=59,85)/10HALUMINUM  ,1.,4.,2.7,.02567785,0.,7.63E1
     11,2.06,.0343,-1.,2.,1.2E11,.08,12*0.,13.,1./
C     BERYLLIUM
      DATA TABLE(4),TABPL(4)/4.,86./
      DATA (DTAB(I),I=86,112)/10HBERYLLIUM ,1.,4.,1.845,.02567785,0.,0.,
     11.17,.09995,0.,2.,3.69E11,.134,7.97E5,1.091,10*0.,4.,1./
C     IRON   130KB  PHASE TRANSITION
      DATA TABLE(5),TABPL(5)/5.,113./
      DATA (DTAB(I),I=113,139)/10HIRON 130PT,1.,4.,7.85,.02567785,0.,1.9
     13E12,1.75,0.,0.,2.,7.3E10,.282,5*0.,8.36,8.75,1.12E11,2.30E12,5.E1
     22,2*0.,26.,1./
C
C     SELECT EOS FROM TABLE
      TAB=ISETAB
      DO 10 I=1,NUMTAB
      IF (TAB.NE.TABLE(I)) GO TO 10
      IS=TABPL(I)
      GO TO 20
   10 CONTINUE
      PRINT 50, ISETAB
      STOP
   20 PRINT 60, ISETAB,DTAB(IS)
      DO 30 I=1,24
      IS=IS+1
   30 ZB(I)=DTAB(IS)
```

```
      J1=ZB(1)
      JK=IZ-1
      DO 40 I=1,J1
      JK=JK+1
      ZZS(JK)=DTAB(IS+1)
      COT(JK)=DTAB(IS+2)
   40 IS=IS+2
      RETURN
C
   50 FORMAT (19H1 THERE IS NO TABLE,I6,13H IN DATA LIST)
   60 FORMAT (20H0 LIBRARY EOS NUMBER,I6,3H ( ,A10,15H ) IS REQUESTED,/)
      END
```

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