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

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 report¹ 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 PUFF² and WONDY³, 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 code³).

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

$$P = \rho^2 \frac{\partial F}{\partial \rho}, \quad (1)$$

$$S = - \frac{\partial F}{\partial T}, \quad (2)$$

$$E = F + TS, \quad (3)$$

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

$$\frac{\partial P}{\partial T} = \rho^2 \frac{\partial^2 F}{\partial \rho \partial T}, \quad (5)$$

and

$$\frac{\partial P}{\partial \rho} = 2\rho \frac{\partial F}{\partial \rho} + \rho^2 \frac{\partial^2 F}{\partial \rho^2}, \quad (6)$$

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

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

and various thermodynamic relations, it can be shown that

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

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

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

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

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

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 relatively 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

$$P_c = \rho^2 \frac{dE_c}{d\rho} . \quad (11)$$

Define ρ_{00} as the density of the solid material at zero temperature and pressure and

$$\eta = \rho/\rho_{00} \quad (12)$$

as the compression. It should be noted that ρ_{00} 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 ($\eta \geq 20$), 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 Kirshnits⁴ and Kalitkin⁵ (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 Bakanova⁶ 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 studied⁷ 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

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

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 by⁷

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

and

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

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

$$B_{00} = \left. \frac{dP_c}{d\eta} \right|_{\eta=1} . \quad (16)$$

The Gruneisen coefficient

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

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 expression¹²

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

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

$$T_\Gamma = t - 1 , \quad (19)$$

the expression of current interest is

$$\Gamma_{00} = \frac{1}{2B_{00}} \left. \frac{d^2 P_c}{d\eta^2} \right|_{\eta=1} - \frac{1}{3} T_\Gamma . \quad (20)$$

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

$$E_c = \frac{1}{\rho_{00}} \int_1^\eta P_c \eta^{-2} d\eta$$

$$= \frac{1}{\rho_{00}} \left\{ 3c_{32} \mathcal{E}_3(c_{33} \eta^{-1/3}) + \frac{c_{34}}{\eta} + \frac{3c_{35}}{2\eta^{2/3}} + \frac{3c_{36}}{\eta^{1/3}} - c_{37} \right\} \quad (21)$$

, $\eta > 1$,

where

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

and

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

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, $0.8 \leq \eta \leq 1$, 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

$$P_c = c_4 \eta^{2/3} \left\{ e^{c_5 \nu} - e^{c_6 \nu} \right\} , \quad \eta \leq 1 , \quad (24)$$

where

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

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

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

The lattice separation or zero-temperature sublimation energy is then

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

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

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

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

where

$$\hat{\Gamma} = \Gamma_{oo} + \frac{1}{3} T_{\Gamma} \quad (30)$$

and

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

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

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

for numerical reasons. If condition (32) is not satisfied by the given values, an effective value of T_r is assumed so that C_5 and C_6 are real. Since the high-density expressions are not modified, this change produces a discontinuity in $\frac{d^2 P_c}{d\eta^2}$ at $\eta=1$. Under normal conditions this creates no problems.

Unfortunately, the exact values of ρ_{oo} and B_{oo} are not normally known for materials of interest. The more usual situation is that at some reference point ρ_o , T_o (usually room temperature), the pressure P_o (usually zero or one atmosphere) and bulk modulus B_o are experimentally available. Approximate values of ρ_{oo} and B_{oo} are obtained by expanding P_c in a power series about $\eta=1$ and, by using the low temperature forms of the thermal components found in the next section, projecting values for ρ_{oo} and B_{oo} . One correction is attempted. The Gruneisen coefficient changes only slightly between ρ_o and ρ_{oo} and, since it enters in a second-order term in the expansion, this difference is ignored. This method will only work well for relatively low reference temperatures on the order of room temperature. It would not work, for example, for $T_o \approx 1$ eV. The accuracy of this calculation can be checked by comparing the given and computed values of P_o and B_o . If the accuracy is not sufficient, the input value of B_o should be adjusted, since the calculated value is that actually employed in the routines.

IV. NUCLEAR CONTRIBUTION TO THE EQUATION OF STATE

In this section the nuclear contribution is considered. These terms are intended to describe the kinetic motion of atoms and ions in both solid and gaseous states.

The thermodynamics of simple solids are usually well described by the Debye-Gruneisen equation of state, with appropriate density variations of the Debye temperature and Gruneisen coefficient. The thermal contribution to the free energy is

$$F_D = N_O kT \left\{ 3 \ln(1 - e^{-\theta/T}) - D(\theta/T) \right\}, \quad (33)$$

where θ is the density-dependent Debye temperature, N_O is the number of atoms per unit mass, and

$$D(X) = \frac{3}{X^3} \int_0^X \frac{Y^3 dY}{e^Y - 1}. \quad (34)$$

The corresponding expressions for pressure, energy, and entropy are

$$P_D = 3\Gamma\rho N_O kT D(\theta/T), \quad (35)$$

$$E_D = 3N_O kT D(\theta/T), \quad (36)$$

and

$$S_D = -N_O k \{ 3 \ln(1 - e^{-\theta/T}) - 4D(\theta/T) \}, \quad (37)$$

where Γ is the Gruneisen coefficient and related to θ by

$$\Gamma = \frac{\rho}{\theta} \frac{d\theta}{d\rho}. \quad (38)$$

In the case where $T \gg \theta$, the above expressions may be written

$$F_D = N_O kT \{ 3 \ln(\theta/T) - 1 \}, \quad (39)$$

$$P_D = 3\Gamma\rho N_O kT, \quad (40)$$

$$E_D = 3N_O kT , \quad (41)$$

and

$$S_D = - N_O k \{ 3 \ln(\theta/T) - 4 \} . \quad (42)$$

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

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

The coefficient C_{24} should be $2/3$ to reach the correct limit as $\rho \rightarrow \infty$. 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

$$\theta = \theta_O \left(\frac{\rho}{\rho_O} \right)^{C_{24}} \exp \left\{ \Gamma_O (1 - \rho_O/\rho) - \frac{1}{2} C_{24} \left(3 - 4 \frac{\rho_O}{\rho} + \frac{\rho_O^2}{\rho^2} \right) \right\} . \quad (44)$$

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

$$N_O = \sum_\ell N_\ell \quad (45)$$

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

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

$$P_G = N_O \rho kT , \quad (47)$$

$$E_G = \frac{3}{2} N_O kT , \quad (48)$$

and

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

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 boldly written as

$$F_n = N_O kT \left\{ \frac{3}{2} \ln (\theta/T) - 1 + \frac{3}{2} \ln (1 + \psi) \right\} , \quad (50)$$

where

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

and

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

At low temperatures ($\psi \ll 1$), Eq. (50) reduces to (39) and the thermodynamics to that of a solid. For sufficiently high temperatures ($\psi \gg 1$), 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

$$P_n = \rho N_O kT \left\{ \frac{3\Gamma + \psi}{1 + \psi} \right\} , \quad (53)$$

$$E_n = \frac{3}{2} N_O kT \left\{ \frac{2 + \psi}{1 + \psi} \right\} , \quad (54)$$

and

$$S_n = - N_0 k \left\{ 3 \ln(\theta/T) - 4 + \frac{3}{2} \ln(1 + \psi) + \frac{3}{2} \frac{\psi}{1 + \psi} \right\} . \quad (55)$$

The expressions clearly do not yield a true melting transition. The result is more of a gradual melting which, for hydrodynamic code use, is more acceptable.

For expanded states, Eq. (50) is used with different expressions for Γ and θ . The principle difficulties occur at low temperatures as discussed in Section III. Above the melting point an extension of Γ is required to the two-phase boundary. In general, Eq. (43) or the more complex theoretical models are unsatisfactory in this region since they diverge for slight extensions, while the pressure is surely finite. It has been found that a simple extrapolation of the form

$$\Gamma = C_{16} \rho^2 + C_{17} \rho + 1, \quad \rho < \rho_0 \quad (56)$$

is sufficient where C_{16} and C_{17} are determined so that Γ and $\frac{d\Gamma}{d\rho}$ are continuous at $\rho = \rho_0$. This form has no physical basis and is used only because it works well. To illustrate fully the nature of this expression, further relations are required. When Eq. (38) is integrated, the result is

$$\theta = C_{14} \rho \exp\left\{\frac{1}{2} C_{16} \rho^2 + C_{17} \rho\right\} , \quad (57)$$

where

$$C_{14} = \frac{\theta_0}{\rho_0} \exp(-2\Gamma_0 + 3/2) . \quad (58)$$

The Debye temperature given by (57) clearly has no relation to Debye theory and is purely an extrapolation. However, the value of θ given by (57) decreases rapidly as the density decreases from ρ_0 . Hence, ψ given by (51) increases rapidly with decreasing density, thereby yielding gaseous thermodynamic relations in which Γ is not used. An important point is that the rapid change from solid to vapor equation-of-state relations occurs in a region where the one-phase calculation is not used. It will be eliminated from the final thermodynamic functions by a Maxwellian construction between the solid or liquid and vapor phases as discussed in Section VI. The overall effect of (56) is to provide a reasonable extrapolation of the high-density properties to the mixed-phase boundary, a gas at low densities, and a single form convenient for numerical computation.

With increasing temperature the interpolation problem diminishes. Near the critical point, ψ is generally in the range of 10 to 100. The exact critical point parameters depend only slightly on the form given by (56). Because of the relation given by (38), a change in Γ is reflected by a change in θ and ψ which have opposite effects on the equation of state and tend to cancel. Under the present formulation the critical parameters are principally determined by the expressions used for the zero-temperature isotherm.

The approximation leading from (33) to (39) has some undesirable effects of the equation of state. The entropy calculated from (55) does not vanish at zero temperature. It would be a simple matter to correct this by including the proper terms in (50) and its derivatives. However, this would require the evaluation of the Debye function in the hydrodynamic code. While this presents no difficulty, it is not believed that the accuracy gained is worth the increased computational time required. The only noticeable effect in a hydrodynamic calculation is seen in materials with unusually high Debye temperatures. The calculated entropy at low temperatures can be negative. This has no real effect on the hydrodynamic calculation.

For materials where the Debye temperature is not known but the absolute entropy at the reference point is, θ_0 may be determined by

$$\theta_0 = T_0 \exp \left\{ \frac{4}{3} - \frac{S_0}{3N_0 k} \right\} . \quad (59)$$

If neither of these is known, it is suggested that a value for a similar material be used. Insofar as the hydrodynamic calculation is concerned, the principal effect of θ_0 is the rapidity of the solid-to-gas interpolation.

The derivatives of the thermodynamic functions which are required can be shown to be

$$C_{vn} = \frac{\partial E_n}{\partial T} = \frac{E_n}{T} \left\{ 1 - \frac{\psi}{(1+\psi)(2+\psi)} \right\} , \quad (60)$$

$$\frac{\partial P_n}{\partial T} = \frac{P_n}{T} \left\{ 1 - \left(\frac{\psi}{1+\psi} \right) \frac{(3\Gamma - 1)}{(3\Gamma + \psi)} \right\} , \quad (61)$$

and

$$\begin{aligned} \frac{\partial P_n}{\partial \rho} = \frac{P_n}{\rho} \left\{ 1 + \left(\frac{\psi}{1+\psi} \right) \frac{2(3\Gamma - 1)^2}{3(3\Gamma + \psi)} \right\} \\ + \frac{3\rho N_0 k T}{1+\psi} \frac{d\Gamma}{d\rho} , \end{aligned} \quad (62)$$

where

$$\frac{d\Gamma}{d\rho} = - \frac{\rho_0}{\rho^2} \{ \Gamma_0 - 2C_{24}(1 - \rho_0/\rho) \} , \quad \rho \geq \rho_0 , \quad (63)$$

and

$$\frac{d\Gamma}{d\rho} = 2C_{16}\rho + C_{17} , \quad \rho < \rho_0 . \quad (64)$$

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 Raizer¹⁵ 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.

* 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^{th} ionization potential of element ℓ
- $\bar{m}$ = average atomic mass
- $\bar{Z}_\ell$ = average ionization number of element ℓ
- $\bar{Z}$ = average ionization number
- $\bar{A}$ = average atomic weight
- Z_m = average atomic number

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

$$\sum_\ell C_\ell = 1 \quad , \quad (65)$$

$$\bar{A} = \sum_\ell C_\ell A_\ell \quad , \quad (66)$$

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

$$\bar{m} = \bar{A} / N_{av} = \sum_\ell C_\ell m_\ell \quad , \quad (68)$$

$$Z_m = \sum_\ell C_\ell Z_\ell \quad , \quad (69)$$

$$\bar{Z}_\ell = \sum_i i N_\ell^i \quad , \quad (70)$$

$$\bar{Z} = \sum_\ell C_\ell \bar{Z}_\ell \quad , \quad (71)$$

$$N_e = \bar{Z} N_O \quad , \quad (72)$$

$$N_\ell = C_\ell / \bar{m} = \sum_i N_\ell^i \quad , \quad (73)$$

and

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

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

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

where

$$A = \frac{2(2\pi m_e k)^{3/2}}{h^3} \approx 6 \times 10^{21} (\text{ev})^{-3/2} \text{ cm}^{-3} \quad , \quad (76)$$

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

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

$$P_e = \bar{N}_o \rho kT \quad , \quad (78)$$

$$E_e = \frac{3}{2} \bar{N}_o kT + \sum_{\ell} N_{\ell} Q(\bar{Z}_{\ell}) \quad , \quad (79)$$

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

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

$$\frac{\partial P_e}{\partial T} = N_o \rho k \left\{ \bar{Z} + T \frac{\partial \bar{Z}}{\partial T} \right\} \quad , \quad (82)$$

and

$$\frac{\partial P_e}{\partial \rho} = N_o kT \left\{ \bar{Z} + \rho \frac{\partial \bar{Z}}{\partial \rho} \right\} \quad . \quad (83)$$

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

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

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 that¹⁶

$$\begin{aligned} K(\rho, T) &= \frac{U_\ell^i}{U_\ell^{i-1}} \exp \left\{ - \frac{\mu_e + I_\ell^i}{kT} \right\} \\ &= \frac{U_\ell^i}{U_\ell^{i-1}} \frac{2(2\pi m_e kT)^{3/2}}{\rho N_e h^3} \exp \left(- \frac{I_\ell^i}{kT} \right) \end{aligned} \quad (85)$$

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

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

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

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

$$N_\ell^0 = N_o (1 - \bar{Z}), \quad (88)$$

and

$$\frac{N_{\ell}^1}{N_{\ell}^0} = \frac{\bar{Z}}{1 - \bar{Z}} = \frac{K_1}{\bar{Z}} , \quad (89)$$

where

$$K_1 = \frac{AT^{3/2}}{\rho N_0} \exp(-I_{\ell}^1/T) \quad (90)$$

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

$$\bar{Z} = \frac{1}{2} \{ \sqrt{K_1^2 + 4K_1} - K_1 \} , \quad (91)$$

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

and

$$\frac{\partial \bar{Z}}{\partial \rho} = - \frac{K_1}{\rho} \left\{ \frac{1 - \bar{Z}}{K_1 + 2\bar{Z}} \right\} . \quad (93)$$

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

$$N_e = \bar{Z} N_0 = Z_{\ell} N_{\ell}^{Z_{\ell}} + (Z_{\ell} - 1) N_{\ell}^{Z_{\ell}-1} \quad (94)$$

and

$$N_0 = N_{\ell} = N_{\ell}^{Z_{\ell}} + N_{\ell}^{Z_{\ell}-1} . \quad (95)$$

With the definition

$$K_2 = \frac{AT^{3/2}}{\rho N_0} \exp(-I_{\ell}^{Z_{\ell}}/T) , \quad (96)$$

the result is easily shown to be

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

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

and

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

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

$$\bar{Z} = \frac{AT^{3/2}}{\rho N_0} \exp(-\bar{I}_\ell/T) , \quad (100)$$

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

$$n - 1/2 \leq \bar{Z} < n + 1/2 , \quad (101)$$

then

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

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

$$\frac{\partial \bar{Z}}{\partial T} = \bar{Z} \left\{ \frac{3}{2} + \frac{\bar{I}_\ell}{T} \right\} / \left\{ T + \bar{Z} \Delta \bar{I}_\ell \right\} \quad (103)$$

and

$$\frac{\partial \bar{Z}}{\partial \rho} = - \frac{\bar{Z}T}{\rho \{ T + \bar{Z} \Delta \bar{I}_\ell \}} , \quad (104)$$

where

$$\Delta \bar{I}_\ell = I_\ell^{n+1} - I_\ell^n . \quad (105)$$

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 $\bar{Z}$ is guessed and the values of $\bar{Z}_\ell$ calculated as described below. In general, this set of $\bar{Z}_\ell$ will not yield a value of $\bar{Z}$ by (71) consistent with the assumed value. Again we use a Newton's correction where

$$\Delta \bar{Z} = \frac{\bar{Z} - \sum_\ell C_\ell \bar{Z}_\ell}{\sum_\ell C_\ell \frac{\partial \bar{Z}_\ell}{\partial \bar{Z}} - 1} \quad (106)$$

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

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

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

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

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

and

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

with

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

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

$$\bar{Z}_\ell = Z_\ell - \frac{\bar{Z}}{\bar{Z} + K_{\ell 2}} , \quad (112)$$

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

$$\frac{\partial \bar{Z}_\ell}{\partial T} = \frac{\bar{Z}}{(\bar{Z} + K_{\ell 2})^2} \frac{K_{\ell 2}}{T} \left\{ \frac{\bar{Z}}{2} + \frac{I_\ell^1}{T} \right\} - \frac{K_{\ell 2}}{(\bar{Z} + K_{\ell 2})^2} \frac{\partial \bar{Z}}{\partial T} , \quad (114)$$

and

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

with

$$K_{\ell 2} = \frac{AT^{3/2}}{\rho N_o} \exp \left(- \frac{Z_\ell I_\ell^1}{T} \right) . \quad (116)$$

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

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

$$\frac{\partial \bar{Z}_\ell}{\partial \bar{Z}} = - \frac{T}{\bar{Z} \Delta I_\ell^n} , \quad (118)$$

$$\frac{\partial \bar{Z}_\ell}{\partial T} = \left\{ \ln \left(\frac{AT^{3/2}}{\bar{Z}^3 N_0} \right) + \frac{3}{2} - \frac{T}{\bar{Z}} \frac{\partial \bar{Z}}{\partial T} \right\} / \Delta I_\ell^n , \quad (119)$$

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

where n is an integer,

$$n - 1/2 \leq \bar{Z}_\ell < n + 1/2 , \quad (121)$$

and

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

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

$$\frac{\partial \bar{Z}_\ell}{\partial T} = \alpha_\ell + \frac{\partial \bar{Z}_\ell}{\partial \bar{Z}} \frac{\partial \bar{Z}}{\partial T} \quad (123)$$

and

$$\frac{\partial \bar{Z}_\ell}{\partial \rho} = \beta_\ell + \frac{\partial \bar{Z}_\ell}{\partial \bar{Z}} \frac{\partial \bar{Z}}{\partial \rho} , \quad (124)$$

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

$$\frac{\partial \bar{Z}}{\partial T} = \frac{\sum C_\ell \alpha_\ell}{1 - \sum C_\ell \frac{\partial \bar{Z}_\ell}{\partial \bar{Z}}} \quad (125)$$

and

$$\frac{\partial \bar{Z}}{\partial \rho} = \frac{\sum C_\ell \beta_\ell}{1 - \sum C_\ell \frac{\partial \bar{Z}_\ell}{\partial \bar{Z}}} , \quad (126)$$

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 $0.8 \rho_0$ ($= \rho_{\min}$) 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

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

A two-variable Newton's method is employed. With the assumption of a density and temperature, corrections are computed by

$$\Delta \rho = \frac{\frac{\partial P}{\partial \rho} \frac{\partial^3 P}{\partial T \partial \rho^2} - \frac{\partial^2 P}{\partial \rho^2} \frac{\partial^2 P}{\partial \rho \partial T}}{\frac{\partial^2 P}{\partial T \partial \rho} \frac{\partial^3 P}{\partial \rho^3} - \frac{\partial^2 P}{\partial \rho^2} \frac{\partial^3 P}{\partial T \partial \rho^2}} \quad (128)$$

and

$$\Delta T = \frac{\left(\frac{\partial^2 P}{\partial \rho^2}\right)^2 - \frac{\partial P}{\partial \rho} \frac{\partial^3 P}{\partial \rho^3}}{\frac{\partial^2 P}{\partial T \partial \rho} \frac{\partial^3 P}{\partial \rho^3} - \frac{\partial^2 P}{\partial \rho^2} \frac{\partial^3 P}{\partial T \partial \rho^2}} \quad (129)$$

until the corrections are negligible. Only the quantities $\frac{\partial P}{\partial \rho}$ and $\frac{\partial P}{\partial T}$ are calculated from analytic expressions. The higher order derivatives required in (128) and (129) are computed numerically by using a grid of nine points.

Location of Two-Phase Boundary Values

At a given temperature it is now desired to determine the densities of the two phases. Let ρ_v be the density of the vapor and ρ_ℓ be the density of the liquid or solid, depending on whether the temperature is above or below melt. It is assumed that the two phases are of the same temperature, pressure, and Gibbs potential. Denoting P_ℓ , P_v , G_ℓ , and G_v as the pressure of the liquid, the pressure of the vapor, the Gibbs potential of the liquid, and Gibbs potential of the vapor, respectively, the quantities

$$\mathcal{P} = P_\ell - P_v \quad (130)$$

and

$$\mathcal{G} = G_\ell - G_v \quad (131)$$

are defined to aid in the search for ρ_ℓ and ρ_v . Given the proper densities, both $\mathcal{P}$ and $\mathcal{G}$ vanish. Again, a two-variable Newton's iteration is employed. After noting the relation

$$\frac{\partial G}{\partial \rho} = \frac{1}{\rho} \frac{\partial P}{\partial \rho}, \quad (132)$$

it is easily shown that the corrections are

$$\Delta \rho_l = \frac{\rho_l}{\frac{\partial P_l}{\partial \rho}} \left\{ \frac{\mathcal{P} - \rho_v \mathcal{G}}{\rho_v - \rho_l} \right\} \quad (133)$$

and

$$\Delta \rho_v = \frac{\rho_v}{\frac{\partial P_v}{\partial \rho}} \left\{ \frac{\mathcal{P} - \rho_l \mathcal{G}}{\rho_v - \rho_l} \right\} . \quad (134)$$

At a set of temperatures determined by the critical temperature and the melting temperature, the values of ρ_l and ρ_v are determined as above. For subsequent evaluation of two-phase thermodynamic properties, the code interpolates in the stored set of values to determine the liquid or solid and vapor phase densities.

Determination of Two-Phase Thermodynamic Properties

We now develop the relations that determine the thermodynamic properties at some temperature T and density ρ within the two-phase regions. The first step in the calculation is to determine the values of ρ_l and ρ_v as discussed above and evaluate the thermodynamic functions at these two densities from the one-phase surface. We must, of course, be sure that

$$\rho_v < \rho < \rho_l . \quad (135)$$

If this condition is not satisfied, the two-phase calculation does not apply.

Let l denote quantities corresponding to the liquid or solid and v denote those for the vapor. The mass fractions of vapor and liquid are

$$M_v = \frac{\rho_v}{\rho} \left\{ \frac{\rho_l - \rho}{\rho_l - \rho_v} \right\} \quad (136)$$

and

$$M_l = 1 - M_v = \frac{\rho_l}{\rho} \left\{ \frac{\rho - \rho_v}{\rho_l - \rho_v} \right\} . \quad (137)$$

The mixed-phase thermodynamic functions are

$$E = M_l E_l + M_v E_v , \quad (138)$$

$$S = M_l S_l + M_v S_v , \quad (139)$$

and

$$P = \left\{ \frac{\rho_\ell - \rho}{\rho_\ell - \rho_v} \right\} P_v + \left\{ \frac{\rho - \rho_v}{\rho_\ell - \rho_v} \right\} P_\ell . \quad (140)$$

At first glance, Eq. (140) appears odd, since P_v and P_ℓ should be equal. However, because of numerical noise and interpolation, they are seldom exactly the same. The form given by (140) allows for this and insures continuity during passage from the one- to the two-phase region.

The required derivatives are given by

$$\frac{\partial P}{\partial \rho} = 0 , \quad (141)$$

$$\frac{\partial P}{\partial T} = \left\{ \frac{\rho_\ell - \rho_v}{\rho_\ell - \rho_v} \right\} \left\{ S_v - S_\ell \right\} , \quad (142)$$

and

$$C_v = \frac{\partial E}{\partial T} = (E_\ell - E_v) \frac{dM_\ell}{dT} + M_\ell \frac{dE_\ell}{dT} + M_v \frac{dE_v}{dT} . \quad (143)$$

The total derivatives in (143) are determined along the two-phase boundaries. With some effort it can be shown that

$$\frac{dE_i}{dT} = C_{vi} + \frac{1}{2} \left\{ P_i - T \frac{\partial P_i}{\partial T} \right\} \frac{d\rho_i}{dT} , \quad (144)$$

where i represents either ℓ and v and $\frac{d\rho_i}{dT}$ is determined from the boundary interpolation, and

$$\frac{dM_\ell}{dT} = \frac{1}{\rho(\rho_v - \rho_\ell)} \left\{ \rho_\ell \left[\frac{\rho_\ell - \rho}{\rho_\ell - \rho_v} \right] \frac{d\rho_v}{dT} + \rho_v \left[\frac{\rho - \rho_v}{\rho_\ell - \rho_v} \right] \frac{d\rho_\ell}{dT} \right\} . \quad (145)$$

This completes the evaluation of the two-phase thermodynamics.

Alternate Method of Treatment of the Two-Phase Region

For some problems the detailed calculation given above is not required. An alternate method of treatment similar to that employed in the more advanced versions of PUFF and WONDY is provided. In short, this method ignores the existence of phase mixtures and violates a multitude of thermodynamic inequalities. All thermodynamic functions are calculated from the one-phase surface, except that tensions are suppressed above the point of melt. This, of course, destroys the thermodynamic consistence of the equation-of-state information and in some regions yields imaginary sound speeds. This latter fallacy results in an unstable hydrodynamic calculation. However, in spite of its shortcomings, this treatment is sufficient for some problems. One of the more obvious cases is problems in which the temperatures remain below melt. For a more complex situation consider a high-pressure liquid adjacent to a solid. The liquid is just above melt. The liquid will undergo a rapid expansion and, as soon as the liquid adjacent to the solid interface enters the two-phase region (begins boiling, in this case), the pressure will drop to a very low value. In effect, this decouples the liquid and solid. If only the response of the solid is of interest, the exact treatment of the liquid is irrelevant so long as the decoupling feature is retained and no numerical disaster occurs in the liquid-vapor mixture.

Since this method uses the one-phase energy with zero pressure, lines of constant energy and hydrodynamic code-computed adiabats (by integration of the 1st law) coincide. If sufficiently large expansions occur under these conditions, negative temperatures will result. In CHART D this will cause a termination. However, it is usually unnecessary to perform calculations for a period sufficiently long for this disaster to occur.

VII. HUGONIOT RELATIONS

In many instances calculations involve pressures far in excess of experimental data. It is also possible to completely define the equation of state by the inputs in Appendix A and not include any experimental Hugoniot data. For these reasons, it was felt that a routine should be included to calculate the Hugoniot. The entire calculation requires only fractions of a second.

If ρ_i , T_i , P_i , and E_i are the initial conditions and ρ_s , T_s , P_s , and E_s are the postshock conditions, it is well known that the Rankin-Hugoniot relations yield

$$E_s - E_i = \frac{1}{2}(P_s + P_i) \left\{ \frac{\rho_s - \rho_i}{\rho_i \rho_s} \right\} \quad (146)$$

At a fixed set of temperatures, the values of ρ_s are computed by an iterative procedure. The temperature set is built into the code and ranges from room temperature to 100 eV. This set may easily be changed if so desired.

The shock and material velocities are computed from the relations

$$U_s = \left\{ \frac{P_s - P_i}{\rho_i (1 - \rho_i/\rho_s)} \right\}^{1/2} \quad (147)$$

and

$$U_m = U_s (1 - \rho_i/\rho_s) \quad (148)$$

VIII. RADIATION PROPERTIES

Since these equation-of-state routines are to operate in a radiation diffusion-hydrodynamics code, they must also supply a value of the Rosseland mean opacity. Define λ_R as the Rosseland mean free path and κ_R as the Rosseland mean absorption coefficient. These two quantities are related by

$$\lambda_R = 1/(\rho \kappa_R) \quad , \quad (149)$$

where ρ is the density.

An analytic formulation of the Rosseland mean which has the wide range of validity required for the present calculation was developed by the Russians in conjunction with the ionization calculation given earlier. The end result of their elegant calculation is¹⁵

$$\kappa_R = \frac{10^{11} \rho \bar{Z} \bar{Z}^2}{\bar{A}^2 T^{7/2}} + \frac{0.4 Z_m}{\bar{A}} \quad , \quad (150)$$

where

$$\bar{Z}^2 = \sum_{\ell} c_{\ell} \bar{Z}_{\ell}^2 \quad . \quad (151)$$

At high temperatures, Eq. (150) gives answers close to the most detailed calculations available. At low temperatures, Eq. (150) is, of course, not valid; however, in this case radiation diffusion is usually not important. More important at low temperatures is thermal conduction. In the author's earlier report¹ a method of including thermal conduction in the radiation diffusion equations is given. The heat flux is

$$F_H = - H \nabla T \quad , \quad (152)$$

where H is a characteristic function of the material which may describe many different physical phenomena. The actual energy transport mechanisms in gas, liquids, solids, and plasma are of varying importance. However, in all cases, the dependence on density is slight and the appropriate relations may be approximately represented over limited ranges of temperature by the expression

$$H = H_0 T^{C_{41}}, \quad (153)$$

where H_0 and C_{41} are constants. In most problems conduction is important only in a limited region; hence, Eq. (153) is adequate. However, the values of H_0 and C_{41} might require modification for different areas.

The effective Rosseland mean absorption coefficient is¹

$$\kappa_{\text{eff}} = \frac{\kappa_H \kappa_R}{\kappa_H + \kappa_R}, \quad (154)$$

where

$$\kappa_H = \frac{16\sigma T^3}{3\rho H} = \frac{C_{22} T^{3-C_{41}}}{\rho}, \quad (155)$$

with

$$C_{22} = \frac{16\sigma}{3H_0}. \quad (156)$$

For reasonable input values, κ_{eff} approaches κ_H at low temperatures and κ_R at high temperatures. If H_0 is not supplied in the input parameters, thermal conduction is not allowed.

The thermodynamic properties of the radiation field are not included in the current coding. In the CHART D code, the radiation pressure, energy, and entropy are included after the material functions are calculated. At sufficiently elevated temperatures these terms are dominant. In the diffusion approximation the radiation quantities are

$$E_R = \frac{4 \sigma T^4}{c\rho}, \quad (157)$$

$$P_R = \frac{4 \sigma T^4}{3c}, \quad (158)$$

and

$$S_R = \frac{16 \sigma T^3}{3c\rho}, \quad (159)$$

where, in keeping with the material properties, E_R is a specific energy (ergs/gm) and not the usual radiation energy density (ergs/cc), σ is the Stefan-Boltzmann constant, and c is the velocity of light.

IX. PHASE TRANSITIONS INDEPENDENT OF TEMPERATURE

As discussed in Section III, many substances undergo phase transitions upon compression which result in a more closely packed structure and decreased compressibility. In this section, a method is given whereby some such transitions may be treated in an approximate manner. Both first- and second-order transitions are considered. However, the discussion is restricted to cases that do not depend on the temperature. In many instances, especially those that occur at high pressures, this seems sufficient. This restriction allows all changes to be made in the cold components. The thermal components will not be altered. While this procedure is surely not completely correct, it does allow at least a partial treatment.

In Fig. 1, three types of cold compression curves and the associated Hugoniot are shown. Curve A is for a simple material showing no apparent phase changes. This type of data is treated by the method given in Section III. Curves B and C represent second- and first-order changes, respectively. The second-order transition is clearly a special case of the first-order transition. Thus all relations developed below will be for the more complex case.

The notation is as shown in Fig. 1-C. The term P_{tr} is the pressure at which the first odd behavior is noted in the Hugoniot. The term P_{ctr} is the cold pressure and ρ_1 is the density at this point. The lower density phase (1) exists at this density and below. The higher density phase (2) exists for $\rho \geq \rho_2$, where $\rho_2 \geq \rho_1$. If $\rho_2 = \rho_1$, the transition is of the second order; if $\rho_2 > \rho_1$, it is of the first.

Denote

$$\eta_1 = \rho_1 / \rho_{oo} \quad (160)$$

and

$$\eta_2 = \rho_2 / \rho_{oo} \quad (161)$$

A three-part description of P_c is required. In the region $\eta \leq \eta_1$, Eq. (13) is employed with a slight modification. At $\eta = \eta_1$, we require that $P_c = P_{ctr}$. As (13) has no free parameters, this is accomplished by ignoring condition (20). An effective value of T_r is calculated so that the above requirement is satisfied. New values of C_{34} , C_{35} , C_{36} , and C_{37} are computed.

In the region $\eta_1 < \eta \leq \eta_2$ the value of $P_c = P_{ctr}$ is constant. The energy is given by

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

$$\begin{aligned}
E_c(\eta) &= E_c(\eta_1) + \frac{P_{ctr}}{\rho_{oo}} \int_{\eta_1}^{\eta} \frac{d\eta}{\eta^2} \\
&= E_c(\eta_1) + \frac{P_{ctr}}{\rho_{oo}} \left\{ \frac{\eta - \eta_1}{\eta \eta_1} \right\}, \quad \eta_1 < \eta \leq \eta_2,
\end{aligned}
\tag{162}$$

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,

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

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

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

where

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

$\mathcal{E}_3$ 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 $D_1 < \rho_{00}$, 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_r used in Section III is employed to calculate D_3 . D_4 is related to $\frac{dP_c}{d\eta}|_{\eta_2}$.

If

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

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

If

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

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

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

it is clear that (17) may be written as

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

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

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

At the point of reference the above quantities are

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

and

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

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

$$\Gamma_o = \frac{3\alpha_o B_o}{\rho_o C_v} = \frac{3\alpha_o B_o}{\rho_o C_p - 9\alpha_o^2 T_o B_o} . \quad (173)$$

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

$$U_s = S_o + S_1 U_m \quad (174)$$

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

$$P = P_o + \rho_o U_s U_m \quad (175)$$

and

$$\frac{\rho}{\rho_o} = \frac{U_s}{U_s - U_m} . \quad (176)$$

Combining these relations it may be shown that

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

and

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

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

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

may be used to show that

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

and hence

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

In the same manner the second derivatives yield

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

with the approximation

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

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 Hugoniot.
(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 sub-routines 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.

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APPENDIX A

EMPLOYMENT OF ANALYTIC EQUATION-OF-STATE ROUTINES

APPENDIX A

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_0).
- Variable 4. Reference temperature (T_0).
- Variable 5. Reference pressure (P_0); used only when variables 23 and 24 are zero.
- Variable 6. Reference bulk modulus (B_0); used only when variables 23 and 24 are zero.
- Variable 7. Reference Gruneisen coefficient (Γ_0).
- Variable 8. Reference Debye temperature (θ_0). If zero or negative, code assumes a value of 0.025.
- Variable 9. Parameter T_r [cf. Eq. (20)];
- $T_r = -1$, Slater theory;
 - $T_r = 0$, Dugdale and MacDonald theory;
 - $T_r = 1$, 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_0 [cf. Eq. (174)]. See note with variable 14.
- Variable 14. Constant in Hugoniot data S_1 [cf. Eq. (174)]. If both S_0 and S_1 are greater than 0, the input value of variables 6 and 9 above are ignored (see Section X). If either S_0 or S_1 is zero, both are ignored.
- Variable 15. Thermal conductivity coefficient (H_0) (see Section VIII). If zero, thermal conduction is not included. Note that the units of $H = H_0 T^{C_{41}}$ 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 $0.8 \rho_0$ (see Sections III and VI). If zero or negative, code assumes a value of $0.8 \rho_0$.
Variable 18. Parameter D_1	}	See Section IX.

Normally, all zero except

for phase transitions. |
Variable 19. Parameter D_2		
Variable 20. Parameter D_3		
Variable 21. Parameter D_4		
Variable 22. Parameter D_5		
- Variable 23. Zero pressure - zero temperature density (ρ_{00}). If zero, code will calculate from the reference point conditions, normally zero.
- Variable 24. Zero pressure - zero temperature bulk modulus (B_{00}). 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_0 variable 5, card 2 above.
21. B_0 variable 6, card 2 above.
22. Constant in Eq. (156).
23. $\rho_{\min}$ variable 17, card 2 above.
24. Constant in Eq. (43).
25. θ_0 variable 8, card 2 above.
26. Z_m [Eq. (69)].
27. N_0 [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
BQ= 7.619824E+11	CS= 5.420491E+05

Figure B-1

Figure B-2

Figure B-3

Figure B-4

Figure B-5

Figure B-6

Figure B-7

APPENDIX C

FORTRAN LISTING

	SUBROUTINE ANEOS (T,RHO,P,E,S,CV,DPDT,DPDR,FKROS,CS,KPA,MAT)	AES	1
C	ANALYTICAL EOS CALCULATION MAIN ROUTINE	AES	2
	COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),AES	AES	3
	1 RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,AES	AES	4
	2 EIP(4370),LOGSV(21),LOCKP(21),LOCKPL(21)	AES	5
	T32=T*SQRT(T)	AES	6
	LOC=LOGSV(MAT)	AES	7
	NMATS=ACK(LOC+30)	AES	8
	IF (NMATS.GE.3) GO TO 30	AES	9
	CALL ANEOS1 (T,RHO,MAT,P,E,S,CV,DPDT,DPDR,LOC)	AES	10
	IF (P.GE.0.) GO TO 20	AES	11
	IF (T.GE.ACK(LOC+18)) GO TO 10	AES	12
	IF (RHO.GE.ACK(LOC+23)) GO TO 20	AES	13
10	P=DPDT=DPDR=0.	AES	14
	KPA=3	AES	15
	GO TO 60	AES	16
20	KPA=1	AES	17
	GO TO 60	AES	18
30	IF (RHO.GE.ACK(LOC+11)) GO TO 50	AES	19
	IF (T.GE.TCT(MAT)) GO TO 50	AES	20
	IF (T.GT.ACK(LOC+18)) GO TO 40	AES	21
	IF (RHO.GE.ACK(LOC+23)) GO TO 50	AES	22
40	CALL ANTWOPH (T,RHO,MAT,P,E,S,CV,DPDT,DPDR,LOC,KPA)	AES	23
	IF (KPA.EQ.2) GO TO 60	AES	24
50	CALL ANEOS1 (T,RHO,MAT,P,E,S,CV,DPDT,DPDR,LOC)	AES	25
	KPA=1	AES	26
60	IF (NMATS-3*(NMATS/3)) 80,70,80	AES	27
70	FKROS=1.E5	AES	28
	GO TO 130	AES	29
80	IF (T.GT.0.07) GO TO 90	AES	30
	FKROS=.4*ACK(LOC+26)/ACK(LOC+29)	AES	31
	ZBAR=0.	AES	32
	GO TO 130	AES	33
90	NMATS=ACK(LOC+28)	AES	34
	FN=ACK(LOC+27)	AES	35
	IIZ=ACK(LOC+31)	AES	36
	IF (NMATS.GT.1) GO TO 100	AES	37
	Z=ZZS(IIZ)	AES	38
	CALL ANION1 (T,RHO,Z,FN,PE,EE,SE,CVE,DPTE,DPRE,ZBAR,T32)	AES	39
	FKROS=(1.E11*RHO*ZBAR**3/(ACK(LOC+29)*T32*T**2)+.4*Z)/ACK(LOC+29)	AES	40
	GO TO 120	AES	41
100	Z=ACK(LOC+26)	AES	42
	CALL ANION2 (T,RHO,ZN,NMATS,IIZ,T32,ZBAR,PE,EE,SE,DPTE,DPRE,CVE)	AES	43
	Y=0.	AES	44
	DO 110 I=1,NMATS	AES	45
110	Y=Y+COT(IIZ+I-1)*ZB(I)**2	AES	46
	FKROS=(1.E11*RHO*ZBAR*Y/(ACK(LOC+29)*T32*T**2)+.4*Z)/ACK(LOC+29)	AES	47
120	P=P+PE	AES	48
	E=E+EE	AES	49
	S=S+SE	AES	50
	CV=CV+CVE	AES	51
	DPDT=DPDT+DPTE	AES	52
	DPDR=DPDR+DPRE	AES	53
130	CS=DPDR+(T*DPDT**2)/(CV*RHO**2)	AES	54
	IF (CS.LT.1.E-20) GO TO 140	AES	55

```

      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.-4*ACK(LOC+41))/RHO
      FKRC=FKROS*Y/(Y+FKROS)
      RETURN
      END

```

```

AES 56
AES 57
AES 58
AES 59
AES 60
AES 61
AES 62
AES 63

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	SUBROUTINE ANEOS1 (T,RHO,MAT,P,E,S,CV,DPDT,DPDR,L)	AES	64
C	AN ANALYTICAL EOS CALCULATION FOR NUCLEAR AND GOLD COMPONENTS	AES	65
	COMMON /ANES/ ACK(820),ZZS(103),COT(100),FNI(100),RCT(21),TCT(21),AES	AES	66
	1 RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,AES	AES	67
	2 EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)	AES	68
	FT=BOLTS*ACK(L+27)	AES	69
	IF (ACK(L+30).NE.2.) GO TO 10	AES	70
	DPDR=FT*T	AES	71
	P=DPDR*RHO	AES	72
	E=1.5*FT*T	AES	73
	GO TO 50	AES	74
10	IF (RHO.GT.1.E-10) GO TO 20	AES	75
	DPDR=FT*T	AES	76
	P=RHO*DPDR	AES	77
	E=ACK(L+10)+1.5*FT*T	AES	78
	GO TO 50	AES	79
20	RSQ=RHO*RHO	AES	80
	RHOO=ACK(L+11)	AES	81
	X1=PHO**.3333333333	AES	82
	RHOOO=ACK(L+19)	AES	83
	X2=RHO/RHOOO	AES	84
	X3=X2**.3333333333	AES	85
	X4=X2/X3	AES	86
	X6=1./X3	AES	87
	IF (X2.GT.1.) GO TO 60	AES	88
	X5=1.-X6	AES	89
	X7=EXP(ACK(L+5)*X5)	AES	90
	X8=EXP(ACK(L+6)*X5)	AES	91
	P=ACK(L+4)*(X7-X8)*X4	AES	92
	DPDR=P/(1.5*RHO)+ACK(L+4)*(ACK(L+5)*X7-ACK(L+6)*X8)/(3.*X4*RHOOO)	AES	93
	E=3.*ACK(L+4)*((X7-1.)/ACK(L+5)-(X8-1.)/ACK(L+6))/RHOOO	AES	94
	IF (RHO.GE.RHOO) GO TO 99	AES	95
	THETA=RHO*ACK(L+16)	AES	96
	GM=PHO*(ACK(L+17)+THETA)+1.	AES	97
	GP=ACK(L+17)+2.*THETA	AES	98
	THETA=ACK(L+14)*RHO*EXP(RHO*(ACK(L+17)+.5*THETA))	AES	99
30	PPP=ACK(L+13)*T*(X1/THETA)**2	AES	100
	IF (PPP.GT.1.E5) GO TO 40	AES	101
	X3=1./(1.+PPP)	AES	102
	X4=2.+PPP	AES	103
	X5=3.*GM+PPP	AES	104
	EN=1.5*FT*T*X3*X4	AES	105
	PN=RHO*FT*T*X3*X5	AES	106
	CV=EN*(1.-PPP*X3/X4)/T	AES	107
	X6=1.-3.*GM	AES	108
	DPDT=PN*(1.+PPP*X6*X3/X5)/T	AES	109
	DPDR=DPDR+PN*(1.+PPP*X3*X6**2/(1.5*X5))/RHO+3.*RHO*FT*X3*GP*T	AES	110
	S=FT*(4.-3.*ALOG(THETA/T)+1.5*(ALOG(X3)-PPP*X3))	AES	111
	GO TO 110	AES	112
40	DPDR=DPDR+FT*T	AES	113
	P=P+RHO*FT*T	AES	114
	E=E+1.5*FT*T	AES	115
50	CV=1.5*FT	AES	116
	DPDT=RHO*FT	AES	117
	S=FT*(1.5*ALOG(T/ACK(L+13))-ALOG(RHO)+2.5)	AES	118

GO TO 120	AES 119
60 X8=ACK(L+33)*X6	AES 120
X5=EXP(-X8)	AES 121
X7=X5*ACK(L+32)	AES 122
IF (X2.GT.ACK(L+1)) GO TO 70	AES 123
P=X2*X4*X7-(ACK(L+34)+ACK(L+35)*X3+ACK(L+36)*X4)	AES 124
DPDP=(X7*X3*(5.*X3+ACK(L+33))-X6*(ACK(L+35)*X6+2.*ACK(L+36)))/(3.*	AES 125
1RH000)	AES 126
CALL EPINT3 (X8,X5,GM)	AES 127
E=(3.*ACK(L+32)*X4*GM+(ACK(L+34)+1.5*ACK(L+35)*X3+3.*ACK(L+36)*X4)	AES 128
1/X2-ACK(L+37))/RH000	AES 129
GO TO 90	AES 130
70 IF (X2.GT.ACK(L+2)) GO TO 80	AES 131
P=ACK(L+7)	AES 132
DPDR=0.	AES 133
E=ACK(L+8)+P*(X2-ACK(L+1))/(RH000*X2*ACK(L+1))	AES 134
GO TO 90	AES 135
80 P=X2*X4*X7-(ACK(L+38)+ACK(L+39)*X3+ACK(L+40)*X4)	AES 136
DPDR=(X7*X3*(5.*X3+ACK(L+33))-X6*(ACK(L+39)*X6+2.*ACK(L+40)))/(3.*	AES 137
1RH000)	AES 138
CALL EPINT3 (X8,X5,GM)	AES 139
E=ACK(L+9)+(3.*ACK(L+32)*X4*GM+(ACK(L+38)+1.5*ACK(L+39)*X3+3.*ACK(L+40)*X4)/X2)/RH000	AES 140
1L+40)*X4)/X2)/RH000	AES 141
90 X3=RH00/RH0	AES 142
X4=1.-X3	AES 143
X5=ACK(L+24)	AES 144
X6=ACK(L+15)	AES 145
IF (X5.GT.0.) GO TO 100	AES 146
GM=X3*X6	AES 147
GP=-GM/RH0	AES 148
THETA=ACK(L+25)*EXP(X4*X6)	AES 149
GO TO 30	AES 150
100 GM=X3*X6+X5*X4**2	AES 151
GP=-X3*(X6-2.*X5*X4)/RH0	AES 152
THETA=ACK(L+25)*EXP(X4*X6-.5*X5*(3.-X3*(4.-X3)))*(RH0/RH00)**X5	AES 153
GO TO 30	AES 154
110 E=E+EN	AES 155
P=P+PN	AES 156
120 RETURN	AES 157
END	AES 158

	SUBROUTINE ANEOS2 (IGK,NUM,ITAPE,IZETL)	AES 159
C	SET UP FOR ANALYTICAL EOS DATA	AES 160
C	DIMENSIONS ARE SET FOR 20 EQUATIONS OF STATE	AES 161
C	100 ELEMENTS (AN ELEMENT IS COUNTED ONCE IN EACH EOS)	AES 162
C	1000 TWO-PHASE BOUNDARY POINTS	AES 163
	DIMENSION IZETL(1)	AES 164
	COMMON /ANES/ ACK(820),ZZS(100),DOT(100),FNI(100),RCT(21),TCT(21),	AES 165
	1 RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,	AES 166
	2 EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)	AES 167
C		AES 168
	GO TO (10,450,460), IGK	AES 169
10	PRINT 470	AES 170
	IT=0	AES 171
	IZ=1	AES 172
	IKPN=1	AES 173
	DO 430 IQ=1,NUM	AES 174
	IF (IZETL(IQ).GT.0) GO TO 430	AES 175
	READ 510, ISE,ISETAB,IZI,(DZB(I),I=1,5),RHUG,THUG	AES 176
	PRINT 520, ISE,ISETAB,IZI,(DZB(I),I=1,5),RHUG,THUG	AES 177
	IF (ISE.GE.0) GO TO 30	AES 178
	IF (ISE.LT.-20) GO TO 30	AES 179
	DO 20 JJ=1,NUM	AES 180
	MAT=IZETL(JJ)	AES 181
	IF (MAT.EQ.ISE) GO TO 40	AES 182
20	CONTINUE	AES 183
30	PRINT 530, ISE	AES 184
	STOP 1000	AES 185
40	MAT=-MAT	AES 186
	LOCSV(MAT)=IT	AES 187
	LOCKP(MAT)=IKPN	AES 188
	IF (ISETAB.EQ.0) READ 540, (ZB(I),I=1,24)	AES 189
	IF (ISETAB.NE.0) CALL ANDATA (IT,IZ,ISETAB)	AES 190
	DO 50 I=1,40	AES 191
50	DZB(I)=0.	AES 192
	DZB(28)=ZB(1)	AES 193
	DZB(30)=ZB(2)	AES 194
	DZB(11)=ZB(3)	AES 195
	DZB(12)=ZB(4)	AES 196
	DZB(20)=ZB(5)	AES 197
	DZB(21)=ZB(6)	AES 198
	DZB(15)=ZB(7)	AES 199
	DZB(25)=ZB(8)	AES 200
	TGAM=ZB(9)	AES 201
	DZB(24)=ZB(10)/3.	AES 202
	DZB(10)=ZB(11)	AES 203
	DZB(18)=ZB(12)	AES 204
	DZB(23)=ZB(17)	AES 205
	DZB(19)=ZB(23)	AES 206
	DZB(3)=ZB(24)	AES 207
	DZB(1)=ZB(18)	AES 208
	DZB(2)=ZB(19)	AES 209
	DZB(7)=ZB(20)	AES 210
	DZB(39)=ZB(21)	AES 211
	DZB(40)=ZB(22)	AES 212
	IF (ISETAB.EQ.0) GO TO 60	AES 213

IF (DZB(30).EQ.2.) GO TO 60	AES 214
IF (IZI.LT.0) GO TO 60	AES 215
IF (IZI.GT.4) GO TO 60	AES 216
DZB(30)=IZI	AES 217
60 DZB(31)=IZ	AES 218
IF (DZB(30).GE.0.) GO TO 80	AES 219
70 PRINT 480, DZB(30), (ZB(I), I=1,24)	AES 220
STOP	AES 221
80 IF (DZB(30).GT.4.) GO TO 70	AES 222
IF (DZB(23).LE.0..AND.DZB(30).NE.2.) DZB(23)=0.8*DZB(11)	AES 223
IF (DZB(25).LE.0..AND.DZB(30).NE.2.) DZB(25)=0.025	AES 224
ACK(IT+41)=ZB(16)	AES 225
IF (ZB(15).LE.0.) GO TO 90	AES 226
DZB(22)=5.48E12/ZB(15)	AES 227
GO TO 100	AES 228
90 DZB(22)=0.	AES 229
100 DO 110 I=1,12	AES 230
J1=I+12	AES 231
110 PRINT 550, I, ZB(I), J1, ZB(J1)	AES 232
PRINT 560	AES 233
J1=DZB(28)	AES 234
S=0.	AES 235
IZI=IZ+J1-1	AES 236
IF (ISETAG.EQ.0) READ 650, (ZZS(I), COT(I), I=IZ, IZI)	AES 237
DO 120 I=IZ, IZI	AES 238
120 S=S+COT(I)	AES 239
DZB(26)=DZB(29)=0.	AES 240
S1=0.	AES 241
DO 140 I=IZ, IZI	AES 242
COT(I)=COT(I)/S	AES 243
DZB(26)=DZB(26)+ZZS(I)*COT(I)	AES 244
IKK=ZZS(I)	AES 245
IKJ=IKK+(IKK*(IKK+1))/2	AES 246
IF (EIP(IKJ).NE.0.) GO TO 130	AES 247
IF (DZB(30).LT.1.) GO TO 130	AES 248
PRINT 580, IKK	AES 249
STOP 1017	AES 250
130 DZB(29)=DZB(29)+COT(I)*EIP(IKJ-IKK)	AES 251
140 S1=S1+COT(I)*EIP(IKJ-IKK)*1.66026E-24	AES 252
DZB(27)=0.	AES 253
DO 150 I=IZ, IZI	AES 254
FNI(I)=COT(I)/S1	AES 255
150 DZB(27)=DZB(27)+FNI(I)	AES 256
IF (DZB(30).EQ.2.) GO TO 160	AES 257
IF (DZB(19).GT.0.) GO TO 160	AES 258
IF (DZB(3).GT.0.) GO TO 160	AES 259
IF (ZB(13).LE.0.) GO TO 160	AES 260
IF (ZB(14).LE.0.) GO TO 160	AES 261
S1=3.*DZB(27)*BOLTS*DZB(12)*DZB(15)**2	AES 262
DZB(21)=DZB(11)*(ZB(13)**2-S1)	AES 263
TGAM=-3.*(DZB(15)+1.-2.*ZB(14)+S1*DZB(11)*(DZB(15)-4.*ZB(14)))/(2.*	AES 264
10ZB(21)))	AES 265
160 S1=0.	AES 266
DO 170 I=IZ, IZI	AES 267
IKK=ZZS(I)	AES 268

	IKK=(IKK*(IKK+1))/2	AES	269
	S=EIP(IKK)*1.66026E-24	AES	270
170	S1=S1+ALOG(FNI(I)/(DZB(27)*(DZB(27)*S)**1.5))*FNI(I)/DZB(27)	AES	271
	DZB(13)=4.36050E-42*DZB(27)**(5./3.)*EXP(2.*S1/3.)	AES	272
	IKK=0	AES	273
	IF (DZB(30).EQ.2) GO TO 320	AES	274
	DZB(14)=DZB(25)*EXP(1.5-2.*DZB(15))/DZB(11)	AES	275
	DZB(16)=(1.-2.*DZB(15))/DZB(11)**2	AES	276
	DZB(17)=(3.*DZB(15)-2.)/DZB(11)	AES	277
	IF (DZB(19).LE.0.) GO TO 200	AES	278
	IF (DZB(3).LE.0.) GO TO 200	AES	279
	GAM=DZB(15)+TGAM/3.	AES	280
180	S1=DZB(3)/(DZB(19)*DZB(10)*GAM**2)	AES	281
	IF (S1.LT.1.) GO TO 190	AES	282
	S2=GAM*SQRT(1.00001*S1)	AES	283
	S9=TGAM+3.*(S2-GAM)	AES	284
	PRINT 590, TGAM, S9	AES	285
	GAM=S2	AES	286
	GO TO 180	AES	287
190	S2=SQRT(1.-S1)	AES	288
	DZB(5)=3.*GAM*(1.+S2)	AES	289
	DZB(6)=3.*GAM*(1.-S2)	AES	290
	DZB(4)=3.*DZB(3)/(6.*S2*GAM)	AES	291
	DZB(21)=-7.1	AES	292
	GO TO 310	AES	293
200	S=DZB(13)*DZB(12)*(DZB(11)**(1./3.)/DZB(25))**2	AES	294
	SPS=S	AES	295
	I=0	AES	296
	S1=DZB(20)-DZB(11)*((3.*DZB(15)+S)/(1.+S))*DZB(27)*DZB(12)*BOLTS	AES	297
	IKK=IKK+1	AES	298
	IF (IKK.EQ.2) GO TO 220	AES	299
	IF (DZB(15).EQ.1.) GO TO 210	AES	300
	S=1.+((2.*DZB(15)-1.))**2-2.)*S1/DZB(21)	AES	301
	DZB(3)=DZB(21)*(SQRT(S**2+4.*DZB(15)*(DZB(15)-1.)*(1.-2.*S1/DZB(21))**2)-S)*.5/(DZB(15)-1.)	AES	302
	GO TO 230	AES	303
210	DZB(3)=((DZB(21)-2.*S1)**2)/(DZB(21)-S1)	AES	304
	GO TO 230	AES	305
220	CALL ANEOS (DZB(12),DZB(11),S,S2,S3,S4,S5,S6,S7,S8,I,MAT)	AES	306
	DZB(3)=DZB(3)*DZB(21)/(DZB(11)*S6)	AES	307
230	GAM=DZB(15)+TGAM/3.	AES	308
240	S2=DZB(3)/(DZB(11)*DZB(10)*GAM**2)	AES	309
	IF (S2.LT.1.) GO TO 260	AES	310
	S2=GAM*SQRT(1.00001*S2)	AES	311
	S9=TGAM+3.*(S2-GAM)	AES	312
	IF (IKK.GE.2) PRINT 590, TGAM, S9	AES	313
	GAM=S2	AES	314
	I=I+1	AES	315
	IF (I.GT.20) STOP 20	AES	316
	IF (IKK.GE.2) GO TO 240	AES	317
	S1=DZB(20)-DZB(11)*((3.*DZB(15)+SPS)/(1.+SPS))*DZB(27)*DZB(12)*BOLTS	AES	318
1TS		AES	319
	IF (GAM.EQ.1.) GO TO 250	AES	320
	S=1.+((2.*GAM-1.))**2-2.)*S1/DZB(21)	AES	321
	DZB(3)=DZB(21)*(SQRT(S**2+4.*GAM*(GAM-1.)*(1.-2.*S1/DZB(21))**2)-S)*.5/(DZB(15)-1.)	AES	322
		AES	323

1)*.5/(GAM-1.)	AES	324
GO TO 240	AES	325
250 DZB(3)=(DZB(21)-2.*S1)**2)/(DZB(21)-S1)	AES	326
GO TO 240	AES	327
260 S3=1.	AES	328
S4=.9	AES	329
270 S5=.5*(S3+S4)	AES	330
S6=SQRT(1.-S2*S5)	AES	331
DZB(5)=3.*GAM*(1.+S6)	AES	332
DZB(6)=3.*GAM*(1.-S6)	AES	333
S6=6.*GAM*S6	AES	334
DZB(4)=S5**(-1./3.)	AES	335
IF (S3-S4.LE.1.E-9) GO TO 300	AES	336
S6=1.-3.*DZB(3)*(EXP(DZB(5)*(1.-DZB(4)))-EXP(DZB(6)*(1.-DZB(4))))/	AES	337
1(DZB(4)**2*S1*S6)	AES	338
IF (S6) 280,300,290	AES	339
280 S4=S5	AES	340
GO TO 270	AES	341
290 S3=S5	AES	342
GO TO 270	AES	343
300 DZB(19)=DZB(11)/S5	AES	344
DZB(4)=S1/(S5**(.2./3.)*(EXP(DZB(5)*(1.-DZB(4)))-EXP(DZB(6)*(1.-DZB(4))))/	AES	345
1(4))))	AES	346
310 S=3.1415926536	AES	347
DZB(32)=(3.*6.6252E-27**2/(20.*9.1084E-28*S))*(S/3.)*(1./3.)*(DZB(19)*DZB(26)*DZB(27))**	AES	348
(5./3.)	AES	349
DZB(33)=(S*9.1084E-28/.9)*(4.80238E-10/6.6252E-27)**2*(18.*DZB(26)*DZB(27))	AES	350
1**((1./3.)/5.+11./(12.*S**2*DZB(26))**((1./3.)/(2.*DZB(19)*DZB(27))))	AES	351
2**((1./3.))	AES	352
S2=DZB(33)	AES	353
S=DZB(32)*EXP(-S2)	AES	354
S9=DZB(15)	AES	355
DZB(15)=S9+TGAM/3.	AES	356
DZB(34)=S*(6.+3.*DZB(33)+.5*DZB(33)**2)-9.*DZB(3)*DZB(15)	AES	357
DZB(35)=3.*DZB(3)*(6.*DZB(15)+1.)-S*(15.+7.*DZB(33)+DZB(33)**2)	AES	358
DZB(36)=S*(10.+4.*DZB(33)+.5*DZB(33)**2)-3.*DZB(3)*(3.*DZB(15)+1.)	AES	359
DZB(15)=S9	AES	360
S1=EXP(-S2)	AES	361
CALL EPINT3 (S2,S1,S)	AES	362
DZB(37)=3.*DZB(32)*S+DZB(34)+1.5*DZB(35)+3.*DZB(36)	AES	363
320 DO 330 I=1,40	AES	364
330 ACK(IT+I)=DZB(I)	AES	365
DO 340 I=1,92	AES	366
S=I	AES	367
340 SAVER(I)=ALOG(S+0.5)	AES	368
IF (IKK-1) 350,200,350	AES	369
350 IF (DZB(21).NE.-7.1) GO TO 360	AES	370
CALL ANEOS (DZB(12),DZB(11),ACK(IT+20),S,S1,S2,DZB(1),DZB(2),DZB(3),DZB(4),I,MAT)	AES	371
ACK(IT+3)=DZB(11)*DZB(2)	AES	372
360 CALL ANPHTR (DZB,MAT,IGAM)	AES	373
DO 370 I=1,40	AES	374
370 ACK(IT+I)=DZB(I)	AES	375
DO 380 I=1,20	AES	376
I1=I+20	AES	377
	AES	378

380	PRINT 600, I,ACK(IT+I),I1,ACK(IT+I1)	AES	379
	I1=41	AES	380
	PRINT 570, I1,ACK(IT+I1)	AES	381
	I1=ACK(IT+31)	AES	382
	I2=ACK(IT+28)	AES	383
	DO 390 I=1,I2	AES	384
	PRINT 610, I,ZZS(I1),I,COT(I1),I,FNI(I1)	AES	385
390	I1=I1+1	AES	386
	IF (ACK(IT+12).LE.0.) GO TO 400	AES	387
	IF (ACK(IT+11).LE.0.) GO TO 400	AES	388
	CALL ANEOS (ACK(IT+12),ACK(IT+11),S1,S2,S3,S4,S5,S6,DZB(1),DZB(2),	AES	389
	1I,MAT)	AES	390
	DZB(3)=ACK(IT+11)*S6	AES	391
	PRINT 620, ACK(IT+12),ACK(IT+11),S1,S2,S3,S4,S5,S6,DZB(3),DZB(2)	AES	392
400	CALL ANPHASE (MAT,IT,IKPN)	AES	393
	LOCKPL(MAT)=IKPN-1	AES	394
	PRINT 630, MAT,LOCKP(MAT),MAT,LOCKPL(MAT)	AES	395
	IF (ACK(IT+30).EQ.2.) GO TO 420	AES	396
	PRINT 490	AES	397
	S3=ACK(IT+11)	AES	398
	S2=S3/25.	AES	399
	IF (ACK(IT+1).LT.1.E50) S2=(ACK(IT+2)*ACK(IT+19)-S3)/25.	AES	400
	DO 410 I=1,50	AES	401
	CALL ANEOS1 (1.E-6,S3,MAT,S4,S5,S6,S7,S8,GAM,IT)	AES	402
	S6=S3/ACK(IT+19)	AES	403
	PRINT 500, S3,S4,GAM,S5,S6	AES	404
410	S3=S3+S2	AES	405
420	IT=IT+41	AES	406
	IZ=IZI+1	AES	407
	IF (THUG.LT.0.) THUG=DZB(12)	AES	408
	IF (RHUG.LT.0.) RHUG=DZB(11)	AES	409
	CALL ANHUG (MAT,RHUG,THUG)	AES	410
430	CONTINUE	AES	411
	IF (IZ.GT.100) GO TO 440	AES	412
	IF (IT.GT.820) GO TO 440	AES	413
	IF (IKPN.GT.1000) GO TO 440	AES	414
	RETURN	AES	415
440	PRINT 640, IZ,IT,IKPN	AES	416
	STOP 1016	AES	417
C		AES	418
C	WRITE RESTART DATA	AES	419
450	WRITE (ITAPE) (ACK(I),I=1,4254),(LOCSV(I),I=1,63)	AES	420
	RETURN	AES	421
C		AES	422
C	READ RESTART DATA	AES	423
460	READ (ITAPE) (ACK(I),I=1,4254),(LOCSV(I),I=1,63)	AES	424
	RETURN	AES	425
C		AES	426
470	FORMAT (33H1 ANALYTIC EQUATION OF STATE DATA,/,76H ROUTINES CODE	AES	427
	10 BY S.L.THOMPSON, 5231, SANDIA LABORATORY, ALBUQUERQUE, N.M.)	AES	428
480	FORMAT (18H0 THERE IS NO TYPE,212.5,4H EOS,/, (8E13.6))	AES	429
490	FORMAT (27H1 ZERO-TEMPERATURE ISOTHERM,/,8X,3HRHO,10X,1HP,9X,4HDP	AES	430
	10R,10X,1HE,10X,3HETA)	AES	431
500	FORMAT (2X,5E12.4)	AES	432
510	FORMAT (I3,I5,I2,5A10,2E10.3)	AES	433

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520 FORMAT (34H1 EOS DATA FOR ANALYTIC EOS NUMBER,I6,5X,14HLIBRARY NUMAES 434
1BER,I5,5X,4HTYPE,I3,/,2X,5A10,/,7H RHUG=,E12.4,9X,5HTHUG=,E12.4AES 435
2,/) AES 436
530 FORMAT (7H1 ISE =,I6) AES 437
540 FORMAT (8E10.3) AES 438
550 FORMAT (5H ZB(,I2,2H)=,E16.9,6H Z3(,I2,2H)=,E16.9) AES 439
560 FORMAT (1X) AES 440
570 FORMAT (27X,2HC(,I2,2H)=,E16.9,/) AES 441
580 FORMAT (34H1 THE IONIZATION POTENTIALS FOR Z=,I4,17H ARE NOT IN TAAES 442
1BLE) AES 443
590 FORMAT (110H0 WARNING - - - THE INPUT PARAMETERS YIELD NONPHYSICALAES 444
1 CONSTANTS FOR THE LOW-DENSITY ZERO-TEMPERATURE ISOTHERM,/,69H THAES 445
2E FORM HAS BEEN CHANGED FOR REALISTIC VALUES TGAM EFF FROM,AES 446
3E12.5,4H TO ,E12.5,/) AES 447
600 FORMAT (4H C(,I2,2H)=,E16.9,5H C(,I2,2H)=,E16.9) AES 448
610 FORMAT (4H Z(,I2,2H)=,F4.0,7H COT(,I2,2H)=,E12.5,7H FNI(,I2,2AES 449
1H)=,E12.5) AES 450
620 FORMAT (28H0 REFERENCE POINT CONDITIONS,/,4H T=,E14.6,7X,4HRHO=,EAES 451
114.6,/,4H P=,E14.6,7X,2HE=,E14.6,/,4H S=,E14.6,7X,3HCV=,E14.6,/,AES 452
27H OPDT=,E14.6,4X,5HDPDR=,E14.6,/,5H B0=,E14.6,6X,3HCS=,E14.6) AES 453
630 FORMAT (8H0 LOCKP(,I2,2H)=,I4,11H LOCKPL(,I2,2H)=,I4) AES 454
640 FORMAT (56H1 THERE ARE TOO MANY LAYERS WITH TOO MANY ELEMENTS IZAES 455
1=,I5,5H IT=,I5,7H IKPN=,I6) AES 456
650 FORMAT (5(F5.0,E10.3)) AES 457
END AES 458

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	SUBROUTINE ANION1 (T,RHO,Z,FN,P,E,S,CV,DPDT,DPDR,ZBAR,TTT)	AES	459
C	A SINGLE ELEMENT ANALYTICAL IONIZATION CALCULATION	AES	460
C	AFTER THE METHOD OF ZELDOVICH AND RAIZER.	AES	461
	COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),AES	462	
1	RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,AES	463	
2	EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)	AES	464
	T32=6.E21*TTT/(RHO*FN)	AES	465
	IZ=Z	AES	466
	I1=(IZ*(IZ+1))/2+1	AES	467
	FLT=ALOG(T32)	AES	468
	EIU=EIP(I1)	AES	469
	EIL=EIU/T	AES	470
	FK1=T32*EXP(-EIL)	AES	471
	IF (FK1.GT.0.5) GO TO 20	AES	472
	K=0	AES	473
	ZBAR=.5*(SQRT(FK1*(FK1+4.))-FK1)	AES	474
	IF (ZBAR.GT.1.E-6) GO TO 10	AES	475
	ZBAR=P=E=S=CV=DPDT=DPDR=0.	AES	476
	GO TO 130	AES	477
10	DZBT=FK1*(1.-ZBAR)/(2.*ZBAR+FK1)	AES	478
	DZBR=-DZBT/RHO	AES	479
	DZBT=DZBT*(1.5+EIL)/T	AES	480
	GO TO 100	AES	481
20	I2=I1+IZ-1	AES	482
	EIU=EIP(I2)	AES	483
	EIL=EIU/T	AES	484
	FK2=T32*EXP(-EIL)	AES	485
	IF (FK2.LT.Z-0.5) GO TO 30	AES	486
	K=IZ-1	AES	487
	FK1=FK2-Z+1.	AES	488
	ZBAR=.5*(SQRT(FK1**2+4.*Z*FK2)-FK1)	AES	489
	DZBT=FK2*(Z-ZBAR)/(2.*ZBAR+FK1)	AES	490
	DZBR=-DZBT/RHO	AES	491
	DZBT=DZBT*(1.5+EIL)/T	AES	492
	GO TO 100	AES	493
30	DO 40 I=1,IZ	AES	494
	K=I-1	AES	495
	ZBAR=I	AES	496
	ZBAR=ZBAR+0.5	AES	497
	EIU=EIP(I1+I)	AES	498
	FI=EIU/T+SAVER(I)-FLT	AES	499
	IF (FI.GE.0.) GO TO 50	AES	500
40	CONTINUE	AES	501
	STOP 4040	AES	502
50	EIL=EIP(I1+K)	AES	503
	DLL=(EIU-EIL)/T	AES	504
	FIBAR=EIU	AES	505
	ZBARU=ZBAR	AES	506
	ZBARL=ZBAR-1.	AES	507
	K=0	AES	508
60	FIP=1./ZBAR+DLL	AES	509
	DZBAR=-FI/FIP	AES	510
	ZZBAR=ZBAR	AES	511
	ZBAR=ZBAR+DZBAR	AES	512
	IF (ABS(DZBAR).LE.1.E-6*ZZBAR) GO TO 90	AES	513

70 K=K+1	AES 514
IF (K.GT.100) STOP 4041	AES 515
IF (ZBAR.GT.0.) GO TO 80	AES 516
ZBAR=ZBAR-.5*DZBAR	AES 517
GO TO 70	AES 518
80 FIBAR=EIL*(ZBARU-ZBAR)+EIU*(ZBAR-ZBARL)	AES 519
FI=FIBAR/T+ALOG(ZBAR)-FLT	AES 520
GO TO 60	AES 521
90 DZBT=ZBAR/(T+ZBAR*(EIU-EIL))	AES 522
DZBR=-T*DZBT/RHO	AES 523
DZBT=DZBT*(1.5+FIBAR/T)	AES 524
K=ZBAR	AES 525
100 ZBARL=FN*BOLTS	AES 526
P=ZBAR*ZBARL*RHO*T	AES 527
DPDT=RHO*ZBARL*(ZBAR+T*DZBT)	AES 528
DPDR=ZBARL*T*(ZBAR+RHO*DZBR)	AES 529
E=0.	AES 530
IF (K.EQ.0) GO TO 120	AES 531
DO 110 I=1,K	AES 532
110 E=E+EIP(I1+I-1)	AES 533
120 EIL=K	AES 534
EIU=EIP(I1+K)	AES 535
E=ZBARL*(1.5*ZBAR*T+E+(ZBAR-EIL)*EIU)	AES 536
CV=ZBARL*(1.5*(ZBAR+T*DZBT)+EIU*DZBT)	AES 537
S=ZBAR*ZBARL*(FLT+2.5-ALOG(ZBAR))	AES 538
130 RETURN	AES 539
END	AES 540

	SUBROUTINE ANION2 (T,RHO,FN,ZBARM,NMATS,IIZ,TTT,ZBAR,P,E,S,DPT,DPR	AES	541
	1,CV)	AES	542
C	A MULTIPLE ELEMENT ANALYTICAL IONIZATION CALCULATION	AES	543
C	AFTER THE METHOD OF ZELDOVICH AND RAIZER.	AES	544
	COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),	AES	545
1	RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,	AES	546
2	EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)	AES	547
	DATA ZRAT/.000045/	AES	548
	IT=0	AES	549
	ISK=IIZ-1	AES	550
	XX=6.E21*TTT/(RHO*FN)	AES	551
	ZBAR=ZRAT*XX	AES	552
	IF (ZBAR.LT.1.E-6) GO TO 30	AES	553
	IF (ZBAR.GT.ZBARM) ZBAR=.99*ZBARM	AES	554
10	IT=IT+1	AES	555
	IF (IT.GT.200) STOP 200	AES	556
	FLXX=T*ALOG(XX/ZBAR)	AES	557
	ZC1=ZC2=ZC3=ZC4=ZC5=ZC6=0.	AES	558
	DO 20 I=1,NMATS	AES	559
	CALL ANION3 (T,RHO,XX,FLXX,IIZ,ZBAR,I,I1,S,P,E)	AES	560
	C=COT(ISK+I)	AES	561
	ZC1=ZC1+C*ZB(I)	AES	562
	ZC2=ZC2+C*P	AES	563
	ZC3=ZC3+C*S	AES	564
	ZC4=ZC4+C*E	AES	565
	KK=ZB(I)	AES	566
	C=FNI(ISK+I)*EIP(I1+KK)	AES	567
	ZC5=ZC5+C*S	AES	568
20	ZC6=ZC6+C*P	AES	569
	DEL=(ZBAR-ZC1)/(ZC2-1.)	AES	570
	YY=ZBAR+DEL	AES	571
	IF (YY.GT.1.E-6) GO TO 70	AES	572
	IF (ZBAR.LE.1.E-6) GO TO 40	AES	573
	IF (YY.LT.0.) GO TO 60	AES	574
30	ZBAR=1.E-6	AES	575
	GO TO 10	AES	576
40	ZBAR=E=P=S=CV=DPR=DPT=ZRAT=0.	AES	577
	DO 50 I=1,NMATS	AES	578
50	ZB(I)=0.	AES	579
	RETURN	AES	580
60	IF (YY.GE.0.) GO TO 70	AES	581
	YY=YY-.5*DEL	AES	582
	GO TO 60	AES	583
70	IF (YY.LE.ZBARM) GO TO 80	AES	584
	YY=.7*ZBARM+.3*ZBAR	AES	585
80	IF (ABS(YY-ZBAR).LE.1.E-5*(YY+ZBAR)) GO TO 90	AES	586
	ZBAR=YY	AES	587
	GO TO 10	AES	588
90	E=ZC3/(1.-ZC2)	AES	589
	S=ZC4/(1.-ZC2)	AES	590
	ZC1=FN*BOLTS	AES	591
	P=ZC1*ZBAR*RHO*T	AES	592
	DPT=ZC1*(ZBAR+T*E)	AES	593
	CV=1.5*DPT+(ZC5+E*ZC6)*BOLTS	AES	594
	DPT=RHO*DPT	AES	595

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=ZXS(IZ)	AES 601
I1=(I1*(I1+1))/2	AES 602
KK=ZP(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

C	SUBROUTINE ANION3 (T,RHO,XX,FLXX,IIZ,ZBAR,JKI,I1,AI,BI,DI)	AES	615
	A PART OF THE MULTIPLE ELEMENT ANALYTICAL IONIZATION CALCULATION	AES	616
	COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),AES	AES	617
1	RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZR(40),BOLTS,AES	AES	618
2	EIP(4370),LOGSV(21),LOCKP(21),LOCKPL(21)	AES	619
	IZ=Z=ZZS(IIZ+JKI-1)	AES	620
	I1=(IZ*(IZ+1))/2+1	AES	621
	FK=XX*EXP(-EIP(I1)/T)	AES	622
	ZBARI=FK+ZBAR	AES	623
	IF (ZBARI.GT.0.) GO TO 10	AES	624
	ZBARI=BI=AI=DI=0.	AES	625
	GO TO 70	AES	626
10	ZBARI=FK/(FK+ZBAR)	AES	627
	IF (ZBARI.GT.0.5) GO TO 30	AES	628
	IF (ZBARI.LT.1.E-10) GO TO 20	AES	629
	BI=-ZBARI**2/FK	AES	630
	AI=-ZBAR*BI*(1.5+EIP(I1)/T)/T	AES	631
	DI=ZBAR*BI/RHO	AES	632
	GO TO 70	AES	633
20	ZBARI=AI=BI=DI=0.	AES	634
	GO TO 70	AES	635
30	I2=I1+IZ-1	AES	636
	FK=XX*EXP(-EIP(I2)/T)	AES	637
	ZBARI=Z-ZBAR/(ZBAR+FK)	AES	638
	IF (ZBARI.LT.Z-0.5) GO TO 40	AES	639
	BI=-FK/(FK+ZBAR)**2	AES	640
	AI=-ZBAR*BI*(1.5+EIP(I2)/T)/T	AES	641
	DI=ZBAR*BI/RHO	AES	642
	GO TO 70	AES	643
40	DO 50 I=1,IZ	AES	644
	N=I	AES	645
	ZBARI=I	AES	646
	ZBARI=ZBARI+0.5	AES	647
	EIU=EIP(I1+I)	AES	648
	FK=FLXX-EIU	AES	649
	IF (FK) 60,60,50	AES	650
50	CONTINUE	AES	651
	STOP 3030	AES	652
60	EIL=EIP(I1+N-1)	AES	653
	DL=EIU-EIL	AES	654
	ZBARI=N	AES	655
	ZBARI=(EIU*(ZBARI-.5)-EIL*(ZBARI+.5)+FLXX)/DL	AES	656
	BI=-T/(DL*ZBAR)	AES	657
	AI=(FLXX/T+1.5)/DL	AES	658
	DI=-T/(RHO*DL)	AES	659
70	ZB(JKI)=ZBARI	AES	660
	RETURN	AES	661
	END	AES	662

	SUBROUTINE EPINT3 (ARG,EXPARG,ANS)	AES 663
C	DETERMINES THIRD EXPONENTIAL INTEGRAL	AES 664
C	EXPARG=EXP(-ARG)	AES 665
C	EXPIN=FIRST EXPONENTIAL INTEGRAL	AES 666
	DIMENSION CE(5)	AES 667
	DATA CE0,CE,AE1,AE2,AE3,AE4,BE1,BE2,BE3,BE4/-.57721566,.99999193,-	AES 668
	1.24991055,.05519968,-.00976004,.00107857,8.5733287,18.059017,8.634	AES 669
	27609,.26777373,9.5733223,25.632956,21.099653,3.9584969/	AES 670
	IF (ARG.GT.1.) GO TO 20	AES 671
	EXPIN=CE0-ALOG(ARG)	AES 672
	X1=1.	AES 673
	DO 10 I=1,5	AES 674
	X1=ARG*X1	AES 675
10	EXPIN=EXPIN+X1*CE(I)	AES 676
	GO TO 40	AES 677
20	IF (ARG.LT.100.) GO TO 30	AES 678
	EXPIN=0.	AES 679
	GO TO 40	AES 680
30	EXPIN=EXPARG*(((ARG+AE1)*ARG+AE2)*ARG+AE3)*ARG+AE4)/(ARG*(((ARG+AE1)*ARG+AE2)*ARG+AE3)*ARG+AE4))	AES 681
	1+BE1)*ARG+BE2)*ARG+BE3)*ARG+BE4))	AES 682
40	ANS=.5*(EXPARG-ARG*(EXPARG-ARG*EXPIN))	AES 683
	RETURN	AES 684
	END	AES 685

	SUBROUTINE ANTWOPH (T,R,MAT,P,E,S,CV,DPDT,DPDR,LOC,KPA)	AES	686
C	EVALUATES THERMODYNAMIC FUNCTIONS IN THE TWO-PHASE REGION	AES	687
	COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),	AES	688
1	RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,	AES	689
2	EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)	AES	690
	K1=LOCKP(MAT)	AES	691
	K2=LOCKPL(MAT)	AES	692
	DO 10 I=K1,K2	AES	693
	KJ=I+1	AES	694
	IF (T.GE.TTWO(KJ)) GO TO 20	AES	695
10	CONTINUE	AES	696
	STOP 1543	AES	697
20	KK=KJ-1	AES	698
	TL=TTWO(KJ)	AES	699
	TU=TTWO(KK)	AES	700
	IF (KK.GT.K1) GO TO 30	AES	701
	X1=((TU-T)/(TU-TL))**.3333333333	AES	702
	R1=RSOL(KK)+(RSOL(KJ)-RSOL(KK))*X1	AES	703
	IF (R.GE.R1) GO TO 40	AES	704
	R2=RVAP(KK)-(RVAP(KK)-RVAP(KJ))*X1	AES	705
	IF (R.LE.R2) GO TO 40	AES	706
	R1P=(RSOL(KK)-RSOL(KJ))*X1/(3.*(TU-T))	AES	707
	R2P=(RVAP(KK)-RVAP(KJ))*X1/(3.*(TU-T))	AES	708
	GO TO 50	AES	709
30	DT=TU-TL	AES	710
	P1=((T-TL)*RSOL(KK)+(TU-T)*RSOL(KJ))/DT	AES	711
	IF (R.GE.R1) GO TO 40	AES	712
	R2=((T-TL)*RVAP(KK)+(TU-T)*RVAP(KJ))/DT	AES	713
	IF (R.GT.R2) GO TO 50	AES	714
40	KPA=1	AES	715
	RETURN	AES	716
50	KPA=2	AES	717
	CALL ANEOS1 (T,R1,MAT,P1,E1,S1,CV1,DPDT1,DPDR1,LOC)	AES	718
	CALL ANEOS1 (T,R2,MAT,P2,E2,S2,CV2,DPDT2,DPDR2,LOC)	AES	719
	X3=R1-R2	AES	720
	X1=(R1-R)/X3	AES	721
	X2=(R-R2)/X3	AES	722
	FM1=R1*X2/R	AES	723
	FM2=R2*X1/R	AES	724
	E=FM1*E1+FM2*E2	AES	725
	S=FM1*S1+FM2*S2	AES	726
	IF (P1.LT.1.E8) GO TO 60	AES	727
	P=X1*P2+X2*P1	AES	728
	GO TO 70	AES	729
60	P=P2	AES	730
70	DPDR=0.	AES	731
	DPDT=(S2-S1)*(R1*R2/X3)	AES	732
	IF (KK.EQ.K1) GO TO 80	AES	733
	X4=(RVAP(KK)-RVAP(KJ))/DT	AES	734
	X5=(RSOL(KK)-RSOL(KJ))/DT	AES	735
	GO TO 90	AES	736
80	X4=R2P	AES	737
	X5=R1P	AES	738
90	CONTINUE	AES	739
	X3=-(R1*X1*X4+R2*X2*X5)/(R*X3)	AES	740

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

AES 741
AES 742
AES 743
AES 744
AES 745

C	SUBROUTINE ANPHASE (MAT,IT,IKPN)	AES	746
	SET UP FOR TWO-PHASE CALCULATION	AES	747
	COMMON /ANES/ ACK(820),ZZS(100),COT(100),FNI(100),RCT(21),TCT(21),	AES	748
1	RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),OZB(40),BOLTS,	AES	749
2	EIF(4370),LOCSV(21),LOCKP(21),LOCKPL(21)	AES	750
	IF (ACK(IT+30).LE.2.) RETURN	AES	751
	NTY=0	AES	752
	KLY=0	AES	753
10	KLY=KLY+1	AES	754
	GO TO (20,30,20,30), KLY	AES	755
20	RCT(MAT)=.3*ACK(IT+19)	AES	756
	TCT(MAT)=2.	AES	757
	GO TO 40	AES	758
30	RCT(MAT)=.15*ACK(IT+19)	AES	759
	TCT(MAT)=.5	AES	760
40	S3=.001	AES	761
50	R1=S3*RCT(MAT)	AES	762
	T1=S3*TCT(MAT)	AES	763
	KK=-2	AES	764
	DO 80 I=1,9	AES	765
	IF (3*((I-1)/3).NE.I-1) GO TO 60	AES	766
	KK=KK+1	AES	767
	KN=-2	AES	768
60	KN=KN+1	AES	769
	T2=KK	AES	770
	T2=TCT(MAT)*(1.+5*S3*T2)	AES	771
	R2=KN	AES	772
	R2=RCT(MAT)*(1.+5*S3*R2)	AES	773
	CALL ANEOS1 (T2,R2,MAT,P1,E1,S1,D1,D2,RSOL(IKPN+I),IT)	AES	774
	IF (KLY.LE.2) GO TO 70	AES	775
	PRINT 510, T2,R2,P1,E1,S1,RSOL(IKPN+I),I,KK,KN	AES	776
70	IF (I.NE.5) GO TO 80	AES	777
	RSOL(IKPN+10)=P1	AES	778
	RSOL(IKPN+11)=E1	AES	779
	RSOL(IKPN+12)=S1	AES	780
80	CONTINUE	AES	781
	D1=RSOL(IKPN+5)	AES	782
	D2=(RSOL(IKPN+6)-RSOL(IKPN+4))/R1	AES	783
	D3=(RSOL(IKPN+8)-RSOL(IKPN+2))/T1	AES	784
	D4=4.*(RSOL(IKPN+6)-2.*RSOL(IKPN+5)+RSOL(IKPN+4))/(R1**2)	AES	785
	D5=(RSOL(IKPN+9)-RSOL(IKPN+7)-RSOL(IKPN+3)+RSOL(IKPN+1))/(R1*T1)	AES	786
	DR2=D3*D4-D2*D5	AES	787
	DR1=(D2*D2-D1*D4)/DR2	AES	788
	DR2=(D1*D5-D2*D3)/DR2	AES	789
	IF (KLY.LE.2) GO TO 90	AES	790
	PRINT 520, RCT(MAT),DR2,TCT(MAT),DR1,D1,D2,D3,D4,D5,NTY,(RSOL(IKPN	AES	791
	1+I),I=1,9),S3	AES	792
90	IF (ABS(DR1).GT.1.E-6*TCT(MAT)) GO TO 100	AES	793
	IF (ABS(DR2).LE.1.E-6*RCT(MAT)) GO TO 200	AES	794
100	IF (ABS(DR1).LE..1*TCT(MAT)) GO TO 110	AES	795
	DR1=.1*TCT(MAT)*DR1/ABS(DR1)	AES	796
110	IF (ABS(DR2).LE..1*RCT(MAT)) GO TO 120	AES	797
	DR2=.1*RCT(MAT)*DR2/ABS(DR2)	AES	798
120	RCT(MAT)=RCT(MAT)+DR2	AES	799
	TCT(MAT)=TCT(MAT)+DR1	AES	800

IF (S3.EQ.0.0001) GO TO 130	AES 801
IF (ABS(DR1).GT.1.E-3*TCT(MAT)) GO TO 130	AES 802
IF (ABS(DR2).GT.1.E-3*RCT(MAT)) GO TO 130	AES 803
S3=.0001	AES 804
130 NTY=NTY+1	AES 805
IF (KLY.GT.2) GO TO 150	AES 806
IF (NTY-100) 50,10,140	AES 807
140 IF (NTY-200) 50,170,170	AES 808
150 IF (NTY-300) 50,10,160	AES 809
160 IF (NTY-400) 50,180,180	AES 810
170 PRINT 530	AES 811
GO TO 10	AES 812
180 PRINT 540, MAT	AES 813
190 ACK(IT+30)=ACK(IT+30)-3.	AES 814
RETURN	AES 815
200 KN=IKPN+10	AES 816
KK=KN+2	AES 817
PRINT 550, MAT, RCT(MAT), TCT(MAT), (RSOL(I), I=KN, KK), NTY	AES 818
IF (TCT(MAT).GT.ACK(IT+18)) GO TO 210	AES 819
PRINT 560, ACK(IT+18)	AES 820
GO TO 190	AES 821
210 KK=60	AES 822
KN=20	AES 823
IF (ACK(IT+18).GT.0.15) KN=30	AES 824
IF (ACK(IT+18).GT.0.25) KN=40	AES 825
KLY=0	AES 826
RSOL(IKPN)=RVAP(IKPN)=RCT(MAT)	AES 827
TTWO(IKPN)=TCT(MAT)	AES 828
PRINT 570	AES 829
IK=IKPN+1	AES 830
D5=KK	AES 831
D5=(TCT(MAT)-ACK(IT+18))/D5	AES 832
D6=KN	AES 833
D6=ACK(IT+18)/D6	AES 834
DO 460 JJJ=1,2	AES 835
D4=D5	AES 836
JJJJ=KK+10	AES 837
T=TCT(MAT)	AES 838
IF (JJJ.EQ.1) GO TO 220	AES 839
D4=D6	AES 840
JJJJ=KN	AES 841
T=ACK(IT+18)	AES 842
220 DO 460 I=1,JJJJ	AES 843
IF (I.EQ.KK-9) D4=.5*D4	AES 844
T=T-D4	AES 845
IF (T.GT.0.95*TCT(MAT)) GO TO 460	AES 846
NQPS=0	AES 847
230 IF (I.EQ.KK+10) T=ACK(IT+18)	AES 848
IF (RVAP(IK-1).LT.1.E-100) GO TO 470	AES 849
IF (T.LT.0.015) GO TO 470	AES 850
NTY=0	AES 851
R10=R20=RCT(MAT)	AES 852
R2=ACK(IT+25)**3*EXP(3.*ACK(IT+15)-1.-ACK(IT+10)/(ACK(IT+27)*BOLTS	AES 853
1*T))/(ACK(IT+13)*T)**1.5	AES 854
IF (R2.LE.0..AND.NQPS.NE.0) GO TO 470	AES 855

IF (R2.LE.0) R2=1.E-100	AES 856
IF (NQPS.NE.0) PRINT 580, R2	AES 857
IF (R2.GT..001*ACK(IT+19)) R2=.001*ACK(IT+19)	AES 858
R1=ACK(IT+19)	AES 859
240 I1=I2=0	AES 860
250 CALL ANEOS1 (T,R2,MAT,P2,E2,S2,D1,D2,DP2,IT)	AES 861
IF (DP2.GT.0.) GO TO 270	AES 862
R20=R2	AES 863
R2=.99*R2	AES 864
IF (I2.GT.30) R2=.5*R2	AES 865
I2=I2+1	AES 866
IF (I2-900) 250,250,260	AES 867
260 PRINT 490, R2,I2,R1,I1,T,NTY	AES 868
GO TO 400	AES 869
270 G2=E2-T*S2+P2/R2	AES 870
280 CALL ANEOS1 (T,R1,MAT,P1,E1,S1,D1,D2,DP1,IT)	AES 871
IF (DP1.GT.0.) GO TO 290	AES 872
R10=R1	AES 873
R1=1.005*R1	AES 874
I1=I1+1	AES 875
IF (I1-900) 280,280,260	AES 876
290 G1=E1-T*S1+P1/R1	AES 877
SP=P1-P2	AES 878
SG=G1-G2	AES 879
DR1=R1*(SP-R2*SG)/(DP1*(R2-R1))	AES 880
DR2=R2*(SP-R1*SG)/(DP2*(R2-R1))	AES 881
IF (NQPS.EQ.0) GO TO 300	AES 882
PRINT 580, T,R1,DR1,R2,DR2,SP,SG,P1,E1,S1,G1,P2,E2,S2,G2,NTY,I1,I2	AES 883
1,DP1,DP2	AES 884
300 IF (ABS(DR1).GT.1.E-6*R1) GO TO 310	AES 885
IF (ABS(DR2).LE.1.E-6*R2) GO TO 440	AES 886
310 IKI=NTY-100*((NTY-1)/100)	AES 887
IF (IKI.GT.40) DR1=0.5*DR1	AES 888
IF (IKI.GT.50) DR1=.05*DR1	AES 889
IF (NTY.LT.80) GO TO 320	AES 890
IF (ABS(SP).GT.1.E-2*(ABS(P1)+ABS(P2)+1.E4)) GO TO 320	AES 891
IF (ABS(SG).LE.1.E-2*(ABS(G1)+ABS(G2))) GO TO 440	AES 892
320 D1=R1+DR1	AES 893
IF (D1.GT.R10) GO TO 340	AES 894
330 DR1=.5*DR1	AES 895
GO TO 320	AES 896
340 IF (D1-ACK(IT+19)) 350,350,330	AES 897
350 D2=R2+DR2	AES 898
IF (D2.GT.0.) GO TO 370	AES 899
360 DR2=DR2*.5	AES 900
GO TO 350	AES 901
370 IF (D2.GE.R20) GO TO 360	AES 902
NTY=NTY+1	AES 903
P1=D1	AES 904
R2=D2	AES 905
IF (NTY-100) 240,240,380	AES 906
380 IF (NQPS.EQ.0) GO TO 410	AES 907
IF (NTY-200) 240,240,390	AES 908
390 KLY=KLY+1	AES 909
IF (IK.EQ.IKPN+1) GO TO 430	AES 910

IF (KLY.GT.2) GO TO 480	AES 911
400 PRINT 500, T	AES 912
GO TO 460	AES 913
410 NOPS=1	AES 914
IF (IK.EQ.IKPN+1) GO TO 420	AES 915
IF (KLY-1) 390,390,230	AES 916
420 IF (KLY-30) 390,230,230	AES 917
430 IF (KLY-32) 460,400,400	AES 918
440 RSOL(IK)=R1	AES 919
RVAP(IK)=R2	AES 920
TTWO(IK)=T	AES 921
IK=IK+1	AES 922
KLY=0	AES 923
IF (T.EQ.ACK(IT+18).AND.R1.LT.ACK(IT+23)) PRINT 590, ACK(IT+23),R1	AES 924
IF (T.EQ.ACK(IT+18)) GO TO 450	AES 925
IF (5*(I/5).NE.I) GO TO 460	AES 926
450 PRINT 600, T,R1,P1,F1,S1,G1,NTY,R2,P2,E2,S2,G2	AES 927
460 CONTINUE	AES 928
470 RSOL(IK)=ACK(IT+19)	AES 929
RVAP(IK)=0.	AES 930
TTWO(IK)=0.	AES 931
IKPN=IK+1	AES 932
RETURN	AES 933
480 PRINT 610, T	AES 934
GO TO 190	AES 935
C	AES 936
490 FORMAT (21H0 MAXWELL I1,I2 ERROR,3(E13.5,I5))	AES 937
500 FORMAT (45H0 TWO-PHASE ITERATION WILL NOT CONVERGE AT T=,E13.5,23H	AES 938
1. WILL LEAVE POINT OUT.)	AES 939
510 FORMAT (17H CRITICAL ERROR 1,6E13.6,3I5)	AES 940
520 FORMAT (17H CRITICAL ERROR 2,9E11.4,I5,/, (10X,3E15.8))	AES 941
530 FORMAT (21H CRITICAL POINT ERROR)	AES 942
540 FORMAT (68H0 THE CRITICAL POINT ITERATION WILL NOT CONVERGE FOR MA	AES 943
1TERIAL NUMBER,I5,26H. WILL CHANGE FORM OF EOS.)	AES 944
550 FORMAT (36H1 TWO-PHASE CALCULATION FOR MATERIAL,I5,/,16H CRITICAL	AES 945
1 POINT,/,6H RHO=,E15.7,9X,2HT=,E15.7,/,4H P=,E15.7,11X,2HE=,E15.5	AES 946
27,/,4H S=,E15.7,11X,4HNTY=,I5,/,)	AES 947
560 FORMAT (26H0 THE MELTING TEMPERATURE(,E15.7,64H) IS GREATER THAN CA	AES 948
1RITICAL TEMPERATURE. WILL CHANGE FORM OF EOS.)	AES 949
570 FORMAT (22H0 TWO-PHASE BOUNDARIES,/,7X,1HT,9X,6HRHOLIQ,8X,4HPLIQ,9	AES 950
1X,4HELIQ,9X,4HSLIQ,9X,4HGLIQ,/,17X,6HRHOVAP,8X,4HPVAP,9X,4HEVAP,9X	AES 951
2,4HSVAP,9X,4HGVAP)	AES 952
580 FORMAT (15H0 MAXWELL ERROR,7E13.5,/,8E12.4,3I4)	AES 953
590 FORMAT (40H0 WARNING - - THE MINIMUM SOLID DENSITY(,E12.5,43H) IS	AES 954
1GREATER THAN THE TRIPLE POINT DENSITY(,E12.5,2H).,/,68H IMPROPER	AES 955
2SOLID BEHAVIOR WILL RESULT. TO CORRECT USE SMALLER VALUE.,/)	AES 956
600 FORMAT (/,6E13.5,/,I13,5E13.5)	AES 957
610 FORMAT (45H0 TWO-PHASE ITERATION WILL NOT CONVERGE AT T=,E13.5,26H	AES 958
1. WILL CHANGE FORM OF EOS.)	AES 959
END	AES 960

	SUBROUTINE ANHUG (M,R0,T0)	AES	961
C	CALCULATES HUGONIOT OF ANALYTICAL EOS	AES	962
	DIMENSION TS(48), CD(8)	AES	963
	COMMON /BIG/ B(1)	AES	964
	EQUIVALENCE (P0,B(1)), (E0,B(2)), (S0,B(3)), (D1,B(4)), (D2,B(5)),	AES	965
	1 (D3,B(6)), (D4,B(7)), (V0,B(8)), (T,B(9)), (R,B(10)), (P,B(11)),	AES	966
	2 (E,B(12)), (S,B(13)), (CV,B(14)), (PT,B(15)), (PR,B(16)), (F,B(17))	AES	967
	3), (DF,B(18)), (DR,B(19)), (V,B(20)), (U,B(21)), (TS(1),B(22))	AES	968
	EQUIVALENCE (CD(1),B(75))	AES	969
	DATA (TS(I),I=1,48)/.026,.0265,.0275,.0285,.03,.035,.04,.05,.06,.0	AES	970
	18,.1,.12,.14,.16,.18,.2,.25,.3,.4,.5,.6,.7,.85,1.,1.3,1.5,1.7,2.,2	AES	971
	2.5,3.,4.,5.,6.,7.,8.5,10.,13.,15.,17.,20.,25.,30.,40.,50.,60.,70.,	AES	972
	385.,100./	AES	973
	IF (R0.LE.0.) RETURN	AES	974
	IF (T0.LE.0.) RETURN	AES	975
	PRINT 40	AES	976
	CALL ANEOS (1.E-6,R0,CD(1),CD(2),CD(3),CD(4),CD(5),CD(6),CD(7),CD(8)	AES	977
	18),KP,M)	AES	978
	CALL ANEOS (T0,R0,P0,E0,S0,D1,D2,D3,D4,V0,KP,M)	AES	979
	D1=0.	AES	980
	D2=1.	AES	981
	PRINT 60	AES	982
	PRINT 50, R0,T0,P0,CD(1),E0,S0,V0,D1,D2	AES	983
	N=51	AES	984
	DO 30 I=1,48	AES	985
	T=TS(I)	AES	986
	IF (T.LE.T0) GO TO 30	AES	987
	IF (N.GT.50) R=R0	AES	988
	N=0	AES	989
	10 CALL ANEOS (T,R,P,E,S,CV,PT,PR,D1,D2,KP,M)	AES	990
	F=E-E0+.5*(P0+P)*(R0-R)/(R*R0)	AES	991
	DF=(P-T*PT)/R**2+.5*PR*(R0-R)/(R0*R)-.5*(P0+P)/R**2	AES	992
	IF (DF.EQ.0.) GO TO 30	AES	993
	DR=-F/DF	AES	994
	IF (ABS(DR).LE.1.E-8*R) GO TO 20	AES	995
	D1=1.	AES	996
	IF (DR.LT.0.) D1=-1.	AES	997
	IF (ABS(DR).GT..5*R) DR=.5*R*D1	AES	998
	R=R+DR	AES	999
	N=N+1	AES	1000
	IF (N=50) 10,10,30	AES	1001
	20 V=SQRT((P-P0)/(R0*(1.-R0/R)))	AES	1002
	U=V*(1.-R0/R)	AES	1003
	D1=P/R0	AES	1004
	CALL ANEOS (1.E-6,R,CD(1),CD(2),CD(3),CD(4),CD(5),CD(6),CD(7),CD(8)	AES	1005
	1),KP,M)	AES	1006
	PRINT 50, R,T,P,CD(1),E,S,V,U,D1,N	AES	1007
	30 CONTINUE	AES	1008
	RETURN	AES	1009
C		AES	1010
	40 FORMAT (10H1 HUGONIOT)	AES	1011
	50 FORMAT (9E12.4,I3)	AES	1012
	60 FORMAT (9H0 RHO,10X,1HT,11X,1HP,10X,2HPC,11X,1HE,11X,1HS,11X,1	AES	1013
	1HV,11X,1HU,7X,8HRHO/RH00)	AES	1014
	END	AES	1015

	SUBROUTINE ANPHTR (C,MAT,TGAM)	AES 1016
C	MODIFIES THE ZERO-TEMPERATURE ISOTHERM OF THE ANALYTICAL EOS	AES 1017
C	FOR A TEMPERATURE INDEPENDENT PHASE TRANSITION	AES 1018
	DIMENSION C(1)	AES 1019
	IF (C(30).EQ.2.) RETURN	AES 1020
	IF (C(1).GT.C(19)) GO TO 20	AES 1021
10	C(1)=1.E100	AES 1022
	C(2)=C(7)=C(8)=C(9)=C(38)=C(39)=C(40)=0.	AES 1023
	RETURN	AES 1024
20	S3=C(15)+TGAM/3.	AES 1025
	S1=S3-2.5	AES 1026
	S2=S3+2.5	AES 1027
	S4=EXP(-C(33))*C(32)	AES 1028
	S5=(15.+7.*C(33)+C(33)**2)*S4	AES 1029
	S6=(10.+4.*C(33)+.5*C(33)**2)*S4	AES 1030
	S4=(6.+3.*C(33)+.5*C(33)**2)*S4	AES 1031
	ETA1=C(1)/C(19)	AES 1032
	S7=ETA1**3.3333333333	AES 1033
	S8=C(32)*ETA1*S7**2*EXP(-C(33)/S7)	AES 1034
30	C34=S4-9.*S3*C(3)	AES 1035
	C35=3.*C(3)*(6.*S3+1.)-S5	AES 1036
	C36=S6-3.*C(3)*(3.*S3+1.)	AES 1037
	PTR=S8-(C34+C35*S7+C36*S7**2)	AES 1038
	IF (C(7).EQ.0.) GO TO 70	AES 1039
	IF (ABS(PTR-C(7))).LE.1.E-4*(PTR+C(7))) GO TO 70	AES 1040
	IF (S2-S1.LT.1.E-7) GO TO 70	AES 1041
	IF (PTR-C(7)) 50,70,40	AES 1042
40	S2=S3	AES 1043
	GO TO 60	AES 1044
50	S1=S3	AES 1045
60	S3=.5*(S1+S2)	AES 1046
	GO TO 30	AES 1047
70	IF (C(2).LT.C(1)) C(2)=C(1)	AES 1048
	ETA2=C(2)/C(19)	AES 1049
	C37=C(37)-C(34)+C34-1.5*(C(35)-C35)-3.*(C(36)-C36)	AES 1050
	S1=C(33)/S7	AES 1051
	S2=EXP(-S1)	AES 1052
	CALL EPINT3 (S1,S2,S4)	AES 1053
	C8=(3.*C(32)*S4*S7**2+C34/ETA1+1.5*C35*S7/ETA1+3.*C36/S7-C37)/C(19)	AES 1054
1)		AES 1055
	DP1=C(32)*S7*(5.*S7+C(33))*EXP(-C(33)/S7)/3.-(C35/S7+2.*C36)/(3.*S	AES 1056
17)		AES 1057
	DP2=C(32)*((10.+6.*C(33)/S7)/S7+C(33)**2/ETA1)*EXP(-C(33)/S7)/9.+2	AES 1058
	1.*(C35/S7+C36)/(9.*ETA1*S7)	AES 1059
	IF (C(39)) 80,90,100	AES 1060
80	DP3=-DP1*C(39)	AES 1061
	GO TO 110	AES 1062
90	DP3=DP1*ETA2/ETA1	AES 1063
	GO TO 110	AES 1064
100	DP3=C(39)	AES 1065
110	IF (C(40)) 120,130,140	AES 1066
120	DP4=-DP2*C(40)	AES 1067
	GO TO 150	AES 1068
130	DP4=DP2*(ETA2/ETA1)**2	AES 1069
	GO TO 150	AES 1070

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140 OP4=C(40) AES 1071
150 S1=ETA2** .3333333333 AES 1072
    S2=EXP(-C(33)/S1) AES 1073
    S4=C(32)*S1*(5.*S1+C(33))*S2-3.*DP3 AES 1074
    S5=9.*ETA2*DP4-C(32)*(10.*S1**2+5.*C(33)*S1+C(33)**2)*S2 AES 1075
    C39=S1*S1*(S5-S4) AES 1076
    C40=S1*(S4-.5*S5) AES 1077
    C38=C(32)*S1**2*ETA2*S2-PTR-(C39+C40*S1)*S1 AES 1078
    EN2=C8+PTR*(ETA2-ETA1)/(C(19)*ETA1*ETA2) AES 1079
    S4=C(33)/S1 AES 1080
    CALL EPINT3 (S4,S2,S5) AES 1081
    C9=EN2-(3.*C(32)*S5*S1**2+C38/ETA2+(1.5*C39/S1+3.*C40)/S1)/C(19) AES 1082
    S4=3.*(S3-C(15)) AES 1083
    PRINT 180, PTR,C(7),DP1,DP3,DP2,DP4,C8,EN2,S4,TGAM AES 1084
    IF (C(7).GT.0.) GO TO 160 AES 1085
    IF (ETA2.GT.ETA1) GO TO 170 AES 1086
    IF (C(39).NE.0.) GO TO 170 AES 1087
    IF (C(40).NE.0.) GO TO 170 AES 1088
    PRINT 190 AES 1089
    GO TO 10 AES 1090
160 IF (ABS(PTR-C(7)).LE.1.E-3*(PTR+C(7))) GO TO 170 AES 1091
    PRINT 200 AES 1092
170 PRINT 210 AES 1093
    C(1)=ETA1 AES 1094
    C(2)=ETA2 AES 1095
    C(7)=PTR AES 1096
    C(8)=C8 AES 1097
    C(9)=C9 AES 1098
    C(34)=C34 AES 1099
    C(35)=C35 AES 1100
    C(36)=C36 AES 1101
    C(37)=C37 AES 1102
    C(38)=C38 AES 1103
    C(39)=C39 AES 1104
    C(40)=C40 AES 1105
    RETURN AES 1106
C AES 1107
180 FORMAT (//,74H ZERO-TEMPERATURE ISOTHERM HAS BEEN MODIFIED FOR A AES 1108
1SOLID PHASE TRANSITION,//,12H PCTR(CAL)=,E13.6,10X,12HPCTR(INPUT) AES 1109
2=,E13.6,/,15H DPOETA(ETA1)=,E13.6,7X,13HDPOETA(ETA2)=,E13.6,/,17HAES 1110
3 D2PDETA2(ETA1)=,E13.6,5X,15HD2PDETA2(ETA2)=,E13.6,/,11H EC(ETA1)AES 1111
4)=,E13.6,11X,9HEC(ETA2)=,E13.6,/,11H TGAMSTAR=,E13.6,11X,5HTGAM=,AES 1112
5E13.6) AES 1113
190 FORMAT (64H0 ALL DEFAULT OPTIONS WERE USED. NO TRANSITION WILL BEAES 1114
1 INCLUDED,/,1H1) AES 1115
200 FORMAT (54H0 SOMETHING APPEARS TO BE WRONG CHECK CAREFULLY)AES 1116
210 FORMAT (1H1) AES 1117
    END AES 1118

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SUBROUTINE ANDATA (IT,IZ,ISETAB)
C DATA STATEMENTS FOR ANALYTICAL IONIZATIONAL 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),AES
1 RSOL(1000),RVAP(1000),TTWO(1000),SAVER(92),ZB(92),DZB(40),BOLTS,AES
2 EIP(4370),LOCSV(21),LOCKP(21),LOCKPL(21)
DATA BOLTS/1.60207E-12/
Z = 1
C DATA(EIP(I),I= 1, 2)/ 1.00801,
11.3595E+01/
Z = 2
C DATA(EIP(I),I= 3, 5)/ 4.00280,
12.4581E+01,5.4403E+01/
Z = 3
C DATA(EIP(I),I= 6, 9)/ 6.93300,
15.3900E+00,7.5619E+01,1.2242E+02/
Z = 4
C DATA(EIP(I),I= 10, 14)/ 9.11300,
19.3200E+00,1.8206E+01,1.5385E+02,2.1766E+02/
Z = 5
C DATA(EIP(I),I= 15, 20)/ 10.81200,
18.2960E+00,2.5149E+01,3.7920E+01,2.5930E+02,3.4013E+02/
Z = 6
C 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/
Z = 7
C 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/
Z = 8
C 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/
Z = 9
C 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/
Z = 10
C 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/
Z = 11
C 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/
Z = 12
C 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/
Z = 13
C 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+02,3.9450E+02,4.4190E+02,2.0855E+03,AES
AES 1119
AES 1120
AES 1121
AES 1122
AES 1123
AES 1124
AES 1125
AES 1126
AES 1127
AES 1128
AES 1129
AES 1130
AES 1131
AES 1132
AES 1133
AES 1134
AES 1135
AES 1136
AES 1137
AES 1138
AES 1139
AES 1140
AES 1141
AES 1142
AES 1143
AES 1144
AES 1145
AES 1146
AES 1147
AES 1148
AES 1149
AES 1150
AES 1151
AES 1152
AES 1153
AES 1154
AES 1155
AES 1156
AES 1157
AES 1158
AES 1159
AES 1160
AES 1161
AES 1162
AES 1163
AES 1164
AES 1165
AES 1166
AES 1167
AES 1168
AES 1169
AES 1170
AES 1171
AES 1172
AES 1173

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C 32.2990E+03/ AES 1174
 Z = 14 AES 1175
 DATA(EIP(I),I= 105, 119)/ 28.19000, AES 1176
 18.1490E+00,1.6340E+01,3.3460E+01,4.5130E+01,1.6673E+02,2.0511E+02,AES 1177
 22.4641E+02,3.0307E+02,3.5096E+02,4.0130E+02,4.7600E+02,5.2320E+02,AES 1178
 32.4360E+03,2.6660E+03/ AES 1179
 C Z = 15 AES 1180
 DATA(EIP(I),I= 120, 135)/ 30.97500, AES 1181
 11.0484E+01,1.9720E+01,3.0156E+01,5.1354E+01,6.5007E+01,2.2041E+02,AES 1182
 22.6331E+02,3.0926E+02,3.7160E+02,4.2430E+02,4.7940E+02,5.6030E+02,AES 1183
 36.1140E+02,2.8150E+03,3.0610E+03/ AES 1184
 C Z = 16 AES 1185
 DATA(EIP(I),I= 136, 152)/ 32.16600, AES 1186
 11.0357E+01,2.3400E+01,3.5000E+01,4.7290E+01,7.2500E+01,8.8029E+01,AES 1187
 22.8099E+02,3.2880E+02,3.7895E+02,4.4700E+02,5.0580E+02,5.6600E+02,AES 1188
 36.5100E+02,7.0600E+02,3.2200E+03,3.4820E+03/ AES 1189
 C Z = 17 AES 1190
 DATA(EIP(I),I= 153, 170)/ 35.45400, AES 1191
 11.3010E+01,2.3800E+01,3.9900E+01,5.3500E+01,6.7800E+01,9.6700E+01,AES 1192
 21.1427E+02,3.4830E+02,4.0070E+02,4.5530E+02,5.3090E+02,5.9300E+02,AES 1193
 36.6300E+02,7.4900E+02,8.0700E+02,3.6540E+03,3.9310E+03/ AES 1194
 C Z = 18 AES 1195
 DATA(EIP(I),I= 171, 189)/ 39.94900, AES 1196
 11.5755E+01,2.7620E+01,4.0900E+01,5.9790E+01,7.5000E+01,9.1300E+01,AES 1197
 21.2400E+02,1.4346E+02,4.2260E+02,4.7940E+02,5.3890E+02,6.2100E+02,AES 1198
 36.8700E+02,7.5500E+02,8.5400E+02,9.1600E+02,4.1150E+03,4.4070E+03/ AES 1199
 C Z = 19 AES 1200
 DATA(EIP(I),I= 190, 209)/ 39.10300, AES 1201
 14.3390E+00,3.1810E+01,4.6000E+01,6.0900E+01,8.2600E+01,9.9700E+01,AES 1202
 21.1800E+02,1.5500E+02,1.7594E+02,5.0380E+02,5.6400E+02,6.2900E+02,AES 1203
 37.1700E+02,7.8800E+02,8.7000E+02,9.6600E+02,1.0310E+03,4.6030E+03,AES 1204
 44.9100E+03/ AES 1205
 C Z = 20 AES 1206
 DATA(EIP(I),I= 210, 230)/ 40.08000, AES 1207
 16.1110E+00,1.1868E+01,5.1210E+01,6.7000E+01,8.4390E+01,1.0900E+02,AES 1208
 21.2800E+02,1.4330E+02,1.8800E+02,2.1130E+02,5.9180E+02,6.5500E+02,AES 1209
 37.2700E+02,8.2000E+02,8.9600E+02,9.9000E+02,1.0840E+03,1.1530E+03,AES 1210
 45.1190E+03,5.4710E+03/ AES 1211
 C Z = 21 AES 1212
 DATA(EIP(I),I= 231, 252)/ 44.35800, AES 1213
 16.5400E+00,1.2800E+01,2.4750E+01,7.3900E+01,9.2000E+01,1.1100E+02,AES 1214
 21.3900E+02,1.5900E+02,1.8000E+02,2.2600E+02,2.5000E+02,6.8700E+02,AES 1215
 37.5800E+02,8.3000E+02,9.3000E+02,1.0100E+03,1.1150E+03,1.2100E+03,AES 1216
 41.2820E+03,5.4833E+03,6.0354E+03/ AES 1217
 C Z = 22 AES 1218
 DATA(EIP(I),I= 253, 275)/ 47.90000, AES 1219
 16.8200E+00,1.3570E+01,2.7470E+01,4.3240E+01,9.9800E+01,1.2000E+02,AES 1220
 21.4100E+02,1.7200E+02,1.9300E+02,2.1700E+02,2.6600E+02,2.9100E+02,AES 1221
 37.8800E+02,8.6400E+02,9.4100E+02,1.0460E+03,1.1320E+03,1.2450E+03,AES 1222
 41.3410E+03,1.4178E+03,6.0493E+03,6.6277E+03/ AES 1223
 C Z = 23 AES 1224
 DATA(EIP(I),I= 276, 299)/ 50.94400, AES 1225
 16.7400E+00,1.4650E+01,2.9400E+01,4.8000E+01,6.5000E+01,1.2900E+02,AES 1226
 21.5100E+02,1.7400E+02,2.0600E+02,2.3050E+02,2.5800E+02,3.0900E+02,AES 1227
 33.3600E+02,8.9700E+02,9.7600E+02,1.0570E+03,1.1700E+03,1.2600E+03,AES 1228

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+01,5.0000E+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)/ 54.34100, AES 1237
 17.4330E+00,1.5636E+01,3.3690E+01,5.3000E+01,7.6000E+01,1.0000E+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+02,2.3590E+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+02,2.3000E+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+02,4.4000E+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)/ 65.37000, 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

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 = 32AES 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+02,5.5329E+02,6.0345E+02,6.5704E+02,AES 1290
 47.0845E+02,7.5370E+02,8.4387E+02,8.9333E+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 = 33AES 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 = 34AES 1302
 DATA(EIP(I),I= 595, 629)/ 78.96000,AES 1303
 19.7500E+00,2.1500E+01,3.2000E+01,4.3100E+01,6.8000E+01,8.2000E+01,AES 1304
 21.5500E+02,1.8700E+02,2.2300E+02,2.6100E+02,2.9560E+02,3.4631E+02,AES 1305
 33.8480E+02,4.2499E+02,4.6294E+02,5.4849E+02,6.4099E+02,6.8966E+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+04,1.6185E+04/AES 1309
 C Z = 35AES 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+02,5.1541E+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 = 36AES 1318
 DATA(EIP(I),I= 666, 702)/ 33.80000,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 = 37AES 1326
 DATA(EIP(I),I= 703, 740)/ 35.48000,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 = 38AES 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+02,7.7311E+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+02,9.0055E+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+03,5.6099E+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+01,4.6000E+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+02,3.8774E+02,9.4910E+02,1.0138E+03,1.0739E+03,AES 1395
 51.1334E+03,1.3537E+03,1.4049E+03,1.4589E+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/
 Z = 45 AES 1399
 DATA(EIP(I),I=1035,1080)/ 102.91000, AES 1400
 17.4600E+00,1.8070E+01,3.1050E+01,4.6000E+01,6.7000E+01,8.5000E+01,AES 1401
 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+03,1.3379E+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/
 Z = 46 AES 1409
 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
 86.3034E+03,7.0220E+03,2.8988E+04,3.0127E+04/
 Z = 47 AES 1419
 DATA(EIP(I),I=1128,1175)/ 107.37400, 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+02,3.8059E+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/
 Z = 48 AES 1429
 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+03,1.9686E+03,1.9461E+03,2.0084E+03,2.1711E+03,2.2584E+03,AES 1437
 72.4299E+03,2.5196E+03,5.8194E+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
 Z = 49 AES 1440
 DATA(EIP(I),I=1225,1274)/ 114.92000, AES 1441
 15.7850E+00,1.8860E+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,AES 1449
93.4099E+04/AES 1450
C Z = 50AES 1451
DATA(EIP(I),I=1275,1325)/ 118.70000,AES 1452
17.3420E+00,1.4628E+01,3.0490E+01,4.0729E+01,7.2300E+01,1.0300E+02,AES 1453
21.2600E+02,1.5000E+02,1.7600E+02,2.1300E+02,2.2452E+02,2.4074E+02,AES 1454
32.6068E+02,2.8240E+02,3.3870E+02,4.0734E+02,4.3456E+02,4.6233E+02,AES 1455
45.0334E+02,5.3726E+02,5.6730E+02,6.5458E+02,1.1480E+03,1.2053E+03,AES 1456
51.2617E+03,1.3249E+03,1.3880E+03,1.4558E+03,1.5363E+03,1.6083E+03,AES 1457
61.6807E+03,1.9818E+03,2.0033E+03,2.0867E+03,2.1683E+03,2.2542E+03,AES 1458
72.4083E+03,2.5008E+03,2.6825E+03,2.7777E+03,2.8964E+03,3.0723E+03,AES 1459
86.7561E+03,6.9602E+03,7.4721E+03,7.7210E+03,8.1113E+03,8.3576E+03,AES 1460
93.4406E+04,3.5511E+04/AES 1461
C Z = 51AES 1462
DATA(EIP(I),I=1326,1377)/ 121.76000,AES 1463
18.6390E+00,1.6500E+01,2.5300E+01,4.4100E+01,5.6000E+01,1.0800E+02,AES 1464
21.3200E+02,1.5700E+02,1.8400E+02,2.1100E+02,2.3060E+02,2.4674E+02,AES 1465
32.6615E+02,2.8863E+02,3.1275E+02,3.6238E+02,4.4391E+02,4.7317E+02,AES 1466
45.0317E+02,5.4766E+02,5.8289E+02,6.1117E+02,7.0439E+02,1.2367E+03,AES 1467
51.2949E+03,1.3522E+03,1.4172E+03,1.4820E+03,1.5508E+03,1.6339E+03,AES 1468
61.7080E+03,1.7825E+03,2.0971E+03,2.1195E+03,2.2002E+03,2.2840E+03,AES 1469
72.3716E+03,2.5315E+03,2.6266E+03,2.8133E+03,2.9112E+03,3.0951E+03,AES 1470
86.8746E+03,7.0619E+03,7.2684E+03,7.7992E+03,8.0510E+03,8.4553E+03,AES 1471
98.7085E+03,3.5829E+04,3.6950E+04/AES 1472
C Z = 52AES 1473
DATA(EIP(I),I=1378,1430)/ 127.61000,AES 1474
19.0100E+00,1.8600E+01,3.1000E+01,3.8000E+01,6.0000E+01,7.2000E+01,AES 1475
21.3700E+02,1.6400E+02,1.9200E+02,2.2000E+02,2.2810E+02,2.4990E+02,AES 1476
32.7066E+02,2.9327E+02,3.1829E+02,3.4480E+02,3.8775E+02,4.8217E+02,AES 1477
45.1348E+02,5.4571E+02,5.9367E+02,6.3123E+02,6.5675E+02,7.5589E+02,AES 1478
51.3285E+03,1.3876E+03,1.4458E+03,1.5124E+03,1.5790E+03,1.6489E+03,AES 1479
61.7346E+03,1.8106E+03,1.8873E+03,2.2154E+03,2.2336E+03,2.3168E+03,AES 1480
72.4026E+03,2.4920E+03,2.6576E+03,2.7554E+03,2.9472E+03,3.0478E+03,AES 1481
87.0006E+03,7.1836E+03,7.3745E+03,7.5835E+03,8.1330E+03,8.3879E+03,AES 1482
98.8061E+03,9.0662E+03,9.7279E+04,3.8416E+04/AES 1483
C Z = 53AES 1484
DATA(EIP(I),I=1431,1484)/ 126.90900,AES 1485
11.0454E+01,1.9090E+01,3.2000E+01,4.2000E+01,6.6000E+01,8.1000E+01,AES 1486
29.9000E+01,1.7000E+02,2.0000E+02,2.2900E+02,2.3500E+02,2.4690E+02,AES 1487
32.7090E+02,2.9628E+02,3.2208E+02,3.4964E+02,3.7855E+02,4.1483E+02,AES 1488
45.2214E+02,5.5549E+02,5.8996E+02,6.4139E+02,6.7927E+02,7.0403E+02,AES 1489
58.0910E+02,1.4232E+03,1.4833E+03,1.5424E+03,1.6107E+03,1.6790E+03,AES 1490
61.7499E+03,1.8383E+03,1.9163E+03,1.9951E+03,2.3367E+03,2.3508E+03,AES 1491
72.4364E+03,2.5243E+03,2.6155E+03,2.7868E+03,2.8872E+03,3.0841E+03,AES 1492
83.1874E+03,7.3129E+03,7.4994E+03,7.6938E+03,7.9053E+03,8.4736E+03,AES 1493
98.7315E+03,9.1636E+03,9.4307E+03,3.8756E+04,3.9909E+04/AES 1494
C Z = 54AES 1495
DATA(EIP(I),I=1485,1539)/ 131.30000,AES 1496
11.2129E+01,2.1210E+01,3.2120E+01,3.8300E+01,5.1500E+01,6.4200E+01,AES 1497
29.1400E+01,1.0660E+02,1.7520E+02,1.9620E+02,2.1860E+02,2.4230E+02,AES 1498
32.6740E+02,2.9360E+02,3.2360E+02,3.5260E+02,3.8270E+02,4.1400E+02,AES 1499
44.4360E+02,5.6380E+02,5.9920E+02,6.3590E+02,6.9080E+02,7.3000E+02,AES 1500
57.5300E+02,8.6400E+02,1.5210E+03,1.5820E+03,1.6420E+03,1.7120E+03,AES 1501
61.7820E+03,1.8540E+03,1.9450E+03,2.0250E+03,2.1060E+03,2.4610E+03,AES 1502
72.4710E+03,2.5590E+03,2.6490E+03,2.7420E+03,2.9190E+03,3.0220E+03,AES 1503

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83.2240E+03,3.3300E+03,7.6320E+03,7.8220E+03,8.0200E+03,8.2340E+03,AES 1504
 98.8210E+03,9.0820E+03,9.5280E+03,9.8020E+03,4.0260E+04,4.1430E+04/AES 1505
 C Z = 55 AES 1506
 DATA(EIP(I),I=1540,1595)/ 132.91300,
 AES 1507
 13.8930E+00,2.5100E+01,3.5000E+01,4.6000E+01,6.2000E+01,7.4000E+01,AES 1508
 21.0100E+02,1.2000E+02,1.4400E+02,2.0500E+02,2.2490E+02,2.4863E+02,AES 1509
 32.7364E+02,3.0709E+02,3.2763E+02,3.5963E+02,3.8998E+02,4.2147E+02,AES 1510
 44.5411E+02,4.9318E+02,6.1037E+02,6.4710E+02,6.8506E+02,7.4517E+02,AES 1511
 57.8576E+02,8.1586E+02,9.2476E+02,1.6178E+03,1.6808E+03,1.7431E+03,AES 1512
 61.8150E+03,1.8870E+03,1.9613E+03,2.0574E+03,2.1396E+03,2.2230E+03,AES 1513
 72.5628E+03,2.5982E+03,2.6884E+03,2.7807E+03,2.8760E+03,3.0692E+03,AES 1514
 83.1747E+03,3.3826E+03,3.4910E+03,7.9631E+03,8.1571E+03,8.3599E+03,AES 1515
 98.5790E+03,9.2258E+03,9.4932E+03,9.9508E+03,1.0231E+04,4.1958E+04,AES 1516
 \$4.3151E+04/
 AES 1517
 C Z = 56 AES 1518
 DATA(EIP(I),I=1596,1652)/ 137.35300,
 AES 1519
 15.2100E+00,1.0001E+01,3.6000E+01,4.9000E+01,6.2000E+01,8.0000E+01,AES 1520
 29.3000E+01,1.2000E+02,1.4300E+02,1.5700E+02,2.3120E+02,2.5529E+02,AES 1521
 32.8035E+02,3.0668E+02,3.3447E+02,3.6335E+02,3.9735E+02,4.2905E+02,AES 1522
 44.6194E+02,4.9591E+02,5.4445E+02,6.5863E+02,6.9669E+02,7.3592E+02,AES 1523
 58.0123E+02,8.4321E+02,8.8041E+02,9.8721E+02,1.7177E+03,1.7827E+03,AES 1524
 61.8472E+03,1.9210E+03,1.9951E+03,2.0717E+03,2.1728E+03,2.2572E+03,AES 1525
 72.3430E+03,2.6675E+03,2.7285E+03,2.8209E+03,2.9154E+03,3.0130E+03,AES 1526
 83.2225E+03,3.3305E+03,3.5442E+03,3.6550E+03,8.3009E+03,8.4990E+03,AES 1527
 98.7065E+03,8.9308E+03,9.6374E+03,9.9111E+03,1.0380E+04,1.0667E+04,AES 1528
 \$4.3682E+04,4.4898E+04/
 AES 1529
 C Z = 57 AES 1530
 DATA(EIP(I),I=1653,1710)/ 138.92000,
 AES 1531
 15.6100E+00,1.1430E+01,1.9170E+01,5.2000E+01,6.6000E+01,8.0000E+01,AES 1532
 21.0000E+02,1.1400E+02,1.4400E+02,1.6500E+02,2.0400E+02,2.5910E+02,AES 1533
 32.8739E+02,3.1378E+02,3.4142E+02,3.7056E+02,4.0078E+02,4.3678E+02,AES 1534
 44.6983E+02,5.0411E+02,5.3942E+02,5.9743E+02,7.0860E+02,7.4799E+02,AES 1535
 57.8848E+02,8.5900E+02,9.0237E+02,9.4667E+02,1.0514E+03,1.8206E+03,AES 1536
 61.8876E+03,1.9544E+03,2.0301E+03,2.1062E+03,2.1851E+03,2.2913E+03,AES 1537
 72.3779E+03,2.4661E+03,2.7753E+03,2.8618E+03,2.9564E+03,3.0532E+03,AES 1538
 83.1531E+03,3.3788E+03,3.4893E+03,3.7089E+03,3.8221E+03,8.6456E+03,AES 1539
 98.8478E+03,9.0600E+03,9.2895E+03,1.0056E+04,1.0336E+04,1.0817E+04,AES 1540
 \$1.1110E+04,4.5434E+04,4.6674E+04/
 AES 1541
 C Z = 58 AES 1542
 DATA(EIP(I),I=1711,1769)/ 140.13300,
 AES 1543
 16.9000E+00,1.2300E+01,2.0000E+01,3.5000E+01,7.0000E+01,8.5000E+01,AES 1544
 21.0000E+02,1.2200E+02,1.3700E+02,1.6500E+02,1.8900E+02,2.2523E+02,AES 1545
 32.8870E+02,3.2118E+02,3.4890E+02,3.7786E+02,4.0834E+02,4.3990E+02,AES 1546
 44.7790E+02,5.1230E+02,5.4798E+02,5.8462E+02,6.5210E+02,7.6026E+02,AES 1547
 58.0098E+02,8.4274E+02,9.1846E+02,9.6322E+02,1.0146E+03,1.1172E+03,AES 1548
 61.9265E+03,1.9955E+03,2.0645E+03,2.1421E+03,2.2203E+03,2.3015E+03,AES 1549
 72.4127E+03,2.5015E+03,2.5921E+03,2.8862E+03,2.9981E+03,3.0949E+03,AES 1550
 83.1939E+03,3.2961E+03,3.5381E+03,3.6511E+03,3.8765E+03,3.9921E+03,AES 1551
 98.9971E+03,9.2033E+03,9.4203E+03,9.6549E+03,1.0481E+04,1.0767E+04,AES 1552
 \$1.1260E+04,1.1560E+04,4.7213E+04,4.8476E+04/
 AES 1553
 C Z = 59 AES 1554
 DATA(EIP(I),I=1770,1829)/ 140.91300,
 AES 1555
 15.8000E+00,1.6786E+01,2.3848E+01,3.3130E+01,4.9317E+01,8.9000E+01,AES 1556
 21.0600E+02,1.2200E+02,1.4600E+02,1.6200E+02,1.9700E+02,2.1132E+02,AES 1557
 32.4816E+02,3.2000E+02,3.5667E+02,3.8572E+02,4.1600E+02,4.4782E+02,AES 1558

44.8072E+02,5.2072E+02,5.5647E+02,5.9355E+02,6.3152E+02,7.0847E+02,AES 1559
 58.1362E+02,8.5567E+02,8.9870E+02,9.7962E+02,1.0258E+03,1.0843E+03,AES 1560
 61.1848E+03,2.0355E+03,2.1065E+03,2.1777E+03,2.2572E+03,2.3375E+03,AES 1561
 72.4210E+03,2.5372E+03,2.6282E+03,2.7212E+03,3.0000E+03,3.1375E+03,AES 1562
 83.2365E+03,3.3377E+03,3.4422E+03,3.7005E+03,3.8160E+03,4.0472E+03,AES 1563
 94.1652E+03,9.3553E+03,9.5656E+03,9.7873E+03,1.0027E+04,1.0913E+04,AES 1564
 \$1.1206E+04,1.1710E+04,1.2017E+04,4.9020E+04,5.0305E+04/AES 1565
 Z = 60 AES 1566
 DATA(EIP(I),I=1830,1890)/ 144.25000, AES 1567
 16.3000E+00,1.6051E+01,2.8371E+01,3.7096E+01,4.7959E+01,6.5334E+01,AES 1568
 21.1000E+02,1.2800E+02,1.4700E+02,1.7100E+02,1.8357E+02,2.1904E+02,AES 1569
 32.3533E+02,2.7278E+02,3.5644E+02,3.9387E+02,4.2425E+02,4.5584E+02,AES 1570
 44.8901E+02,5.2325E+02,5.6525E+02,6.0235E+02,6.4082E+02,6.8013E+02,AES 1571
 57.6655E+02,8.6869E+02,9.1207E+02,9.5636E+02,1.0425E+03,1.0900E+03,AES 1572
 61.1556E+03,1.2540E+03,2.1474E+03,2.2204E+03,2.2939E+03,2.3753E+03,AES 1573
 72.4576E+03,2.5434E+03,2.6647E+03,2.7579E+03,2.8533E+03,3.1424E+03,AES 1574
 83.2798E+03,3.3810E+03,3.4845E+03,3.5913E+03,3.8658E+03,3.9838E+03,AES 1575
 94.2209E+03,4.3413E+03,9.7204E+03,9.9347E+03,1.0161E+04,1.0406E+04,AES 1576
 \$1.1352E+04,1.1651E+04,1.2167E+04,1.2480E+04,5.0853E+04,5.2162E+04/AES 1577
 Z = 61 AES 1578
 DATA(EIP(I),I=1891,1952)/ 147.00000, AES 1579
 16.0000E+00,1.8016E+01,2.8001E+01,4.1656E+01,5.2043E+01,6.4487E+01,AES 1580
 28.3050E+01,1.3500E+02,1.5400E+02,1.7300E+02,1.9224E+02,2.0684E+02,AES 1581
 32.4277E+02,2.6105E+02,2.9911E+02,3.9457E+02,4.3276E+02,4.6447E+02,AES 1582
 44.9737E+02,5.3189E+02,5.6747E+02,6.1147E+02,6.4992E+02,6.8978E+02,AES 1583
 57.3043E+02,8.2632E+02,9.2545E+02,9.7016E+02,1.0157E+03,1.1070E+03,AES 1584
 61.1560E+03,1.2287E+03,1.3250E+03,2.2624E+03,2.3374E+03,2.4131E+03,AES 1585
 72.4964E+03,2.5808E+03,2.6689E+03,2.7952E+03,2.8906E+03,2.9884E+03,AES 1586
 83.2879E+03,3.4252E+03,3.5286E+03,3.6343E+03,3.7434E+03,4.0342E+03,AES 1587
 94.1547E+03,4.3976E+03,4.5204E+03,1.0092E+04,1.0311E+04,1.0542E+04,AES 1588
 \$1.0792E+04,1.1798E+04,1.2103E+04,1.2630E+04,1.2950E+04,5.2714E+04,AES 1589
 \$5.4046E+04/AES 1590
 Z = 62 AES 1591
 DATA(EIP(I),I=1953,2015)/ 150.36000, AES 1592
 15.6000E+00,1.1300E+01,3.1432E+01,4.1651E+01,5.6640E+01,6.8690E+01,AES 1593
 28.2715E+01,1.0247E+02,1.6100E+02,1.8100E+02,1.9434E+02,2.1518E+02,AES 1594
 32.3181E+02,2.6821E+02,2.8847E+02,3.2714E+02,4.3441E+02,4.7335E+02,AES 1595
 45.0639E+02,5.4061E+02,5.7647E+02,6.1339E+02,6.5939E+02,6.9919E+02,AES 1596
 57.4045E+02,7.8243E+02,8.8779E+02,9.8391E+02,1.0299E+03,1.0768E+03,AES 1597
 61.1733E+03,1.2236E+03,1.3034E+03,1.3976E+03,2.3804E+03,2.4574E+03,AES 1598
 72.5354E+03,2.6206E+03,2.7070E+03,2.7974E+03,2.9288E+03,3.0264E+03,AES 1599
 83.1266E+03,3.4364E+03,3.5736E+03,3.6792E+03,3.7872E+03,3.8986E+03,AES 1600
 94.2056E+03,4.3286E+03,4.5774E+03,4.7026E+03,1.0471E+04,1.0693E+04,AES 1601
 \$1.0929E+04,1.1185E+04,1.2250E+04,1.2562E+04,1.3101E+04,1.3427E+04,AES 1602
 \$5.4602E+04,5.5956E+04/AES 1603
 Z = 63 AES 1604
 DATA(EIP(I),I=2016,2079)/ 151.96000, AES 1605
 15.6700E+00,1.1200E+01,2.9377E+01,4.6547E+01,5.7000E+01,7.3323E+01,AES 1606
 28.7036E+01,1.0264E+02,1.2358E+02,1.8700E+02,2.0165E+02,2.1738E+02,AES 1607
 32.3982E+02,2.5848E+02,2.9535E+02,3.1758E+02,3.5686E+02,4.7595E+02,AES 1608
 45.1564E+02,5.5001E+02,5.8555E+02,6.2275E+02,6.6101E+02,7.0901E+02,AES 1609
 57.5016E+02,7.9282E+02,8.3613E+02,9.5096E+02,1.0441E+03,1.0914E+03,AES 1610
 61.1395E+03,1.2413E+03,1.2930E+03,1.3799E+03,1.4720E+03,2.5014E+03,AES 1611
 72.5804E+03,2.6607E+03,2.7478E+03,2.8362E+03,2.9289E+03,3.0654E+03,AES 1612
 83.1652E+03,3.2678E+03,3.5879E+03,3.7250E+03,3.8328E+03,3.9431E+03,AES 1613

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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 = 64AES 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+02,2.8685E+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 = 65AES 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 = 66AES 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 = 67AES 1656
DATA(EIP(I),I=2278,2345)/ 164.93700,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+03,4.5367E+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)/ 167.27100,
16.0000E+00,2.0623E+01,3.5849E+01,5.0678E+01,7.0645E+01,8.2949E+01,AES 1669
21.1525E+02,1.3607E+02,1.4665E+02,1.5924E+02,1.8223E+02,2.0426E+02,AES 1670
32.2777E+02,2.5464E+02,3.0560E+02,3.3041E+02,3.5808E+02,3.8850E+02,AES 1671
44.1732E+02,4.5652E+02,4.8864E+02,5.3098E+02,7.0912E+02,7.5259E+02,AES 1672
57.9361E+02,8.3572E+02,8.7965E+02,9.2461E+02,9.8261E+02,1.0305E+03,AES 1673
61.0801E+03,1.1301E+03,1.2923E+03,1.3704E+03,1.4244E+03,1.4788E+03,AES 1674
71.6066E+03,1.6652E+03,1.7876E+03,1.8692E+03,3.1518E+03,3.2408E+03,AES 1675
83.3323E+03,3.4289E+03,3.5276E+03,3.6318E+03,3.7935E+03,3.9043E+03,AES 1676
94.0189E+03,4.3925E+03,4.5274E+03,4.6462E+03,4.7677E+03,4.8929E+03,AES 1677
$5.2974E+03,5.4354E+03,5.7193E+03,5.8589E+03,1.2886E+04,1.3132E+04,AES 1678
$1.3397E+04,1.3683E+04,1.5107E+04,1.5457E+04,1.6065E+04,1.6431E+04,AES 1679
$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,AES 1680
21.0341E+02,1.3932E+02,1.6068E+02,1.7100E+02,1.8478E+02,2.0911E+02,AES 1681
32.3280E+02,2.5789E+02,2.8595E+02,3.3442E+02,3.6126E+02,3.9132E+02,AES 1682
44.2334E+02,4.5418E+02,4.9385E+02,5.2795E+02,5.7090E+02,7.6085E+02,AES 1683
58.0507E+02,8.4742E+02,8.9085E+02,9.3612E+02,9.8242E+02,1.0424E+03,AES 1684
61.0917E+03,1.1427E+03,1.1940E+03,1.3657E+03,1.4407E+03,1.4961E+03,AES 1685
71.5517E+03,1.6847E+03,1.7448E+03,1.8743E+03,1.9538E+03,3.2910E+03,AES 1686
83.3820E+03,3.4757E+03,3.5742E+03,3.6750E+03,3.7815E+03,3.9482E+03,AES 1687
94.0612E+03,4.1782E+03,4.5627E+03,4.6970E+03,4.8180E+03,4.9417E+03,AES 1688
$5.0692E+03,5.4900E+03,5.6305E+03,5.9202E+03,6.0622E+03,1.3312E+04,AES 1689
$1.3563E+04,1.3832E+04,1.4123E+04,1.5607E+04,1.5963E+04,1.6583E+04,AES 1690
$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,AES 1691
21.0941E+02,1.2495E+02,1.6448E+02,1.8637E+02,1.9563E+02,2.1203E+02,AES 1692
32.3769E+02,2.6304E+02,2.8971E+02,3.1897E+02,3.6494E+02,3.9381E+02,AES 1693
44.2626E+02,4.5987E+02,4.9275E+02,5.3288E+02,5.6897E+02,6.1252E+02,AES 1694
58.1428E+02,8.5926E+02,9.0294E+02,9.4768E+02,9.9430E+02,1.0419E+03,AES 1695
61.1039E+03,1.1545E+03,1.2070E+03,1.2596E+03,1.4407E+03,1.5128E+03,AES 1696
71.5695E+03,1.6264E+03,1.7646E+03,1.8260E+03,1.9626E+03,2.0400E+03,AES 1697
83.4331E+03,3.5261E+03,3.6221E+03,3.7225E+03,3.8253E+03,3.9341E+03,AES 1698
94.1059E+03,4.2211E+03,4.3405E+03,4.7359E+03,4.8695E+03,4.9927E+03,AES 1699
$5.1187E+03,5.2485E+03,5.6855E+03,5.8285E+03,6.1241E+03,6.2685E+03,AES 1700
$1.3745E+04,1.4000E+04,1.4274E+04,1.4570E+04,1.6114E+04,1.6476E+04,AES 1701
$1.7108E+04,1.7487E+04,7.0684E+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,AES 1702
21.0444E+02,1.3943E+02,1.4758E+02,1.9073E+02,2.1314E+02,2.2197E+02,AES 1703
32.4097E+02,2.6797E+02,2.9498E+02,3.2324E+02,3.5367E+02,3.9715E+02,AES 1704
44.2806E+02,4.6289E+02,4.9810E+02,5.3301E+02,5.7361E+02,6.1167E+02,AES 1705
56.5584E+02,8.6941E+02,9.1515E+02,9.6016E+02,1.0062E+03,1.0542E+03,AES 1706
61.1032E+03,1.1672E+03,1.2191E+03,1.2729E+03,1.3269E+03,1.5175E+03,AES 1707
71.5865E+03,1.6445E+03,1.7028E+03,1.8461E+03,1.9090E+03,2.0527E+03,AES 1708
82.1280E+03,3.5783E+03,3.6733E+03,3.7716E+03,3.8739E+03,3.9787E+03,AES 1709
94.0898E+03,4.2667E+03,4.3841E+03,4.5059E+03,4.9121E+03,5.0451E+03,AES 1710
$5.1705E+03,5.2988E+03,5.4309E+03,5.8841E+03,6.0296E+03,6.3311E+03,AES 1711

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16.4779E+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+02,5.3804E+02,5.7497E+02,6.1604E+02,AES 1731
56.5608E+02,7.0086E+02,9.2624E+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+03,4.5503E+03,4.6742E+03,5.0914E+03,AES 1736
$5.2237E+03,5.3513E+03,5.4818E+03,5.6162E+03,5.857E+03,6.2377E+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)/ 180.05500,AES 1741
17.8800E+00,1.6200E+01,2.2000E+01,3.3000E+01,4.5000E+01,9.3531E+01,AES 1742
21.1005E+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+03,1.2887E+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+03,1.5385E+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+02,1.6803E+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+03,1.7530E+03,1.8180E+03,1.8800E+03,1.9420E+03,AES 1763
82.1010E+03,2.1680E+03,2.3330E+03,2.4123E+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+03,5.5900E+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+04,8.1009E+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+01,1.4188E+02,1.5874E+02,1.7753E+02,1.9719E+02,2.2869E+02,AES 1773
32.5169E+02,3.1019E+02,3.3594E+02,3.9743E+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+03,1.6288E+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,AES 1779
94.3369E+03,4.4414E+03,4.5491E+03,4.6597E+03,4.7769E+03,4.9593E+03,AES 1780
$5.0828E+03,5.2113E+03,5.6116E+03,5.7787E+03,5.9106E+03,6.0457E+03,AES 1781
$6.1848E+03,6.6422E+03,6.7948E+03,7.1104E+03,7.2643E+03,1.5930E+04,AES 1782
$1.6228E+04,1.6547E+04,1.6886E+04,1.8807E+04,1.9217E+04,1.9882E+04,AES 1783
$2.0308E+04,8.1834E+04,8.3485E+04/AES 1784
C   Z = 76AES 1785
DATA(EIP(I),I=2926,3002)/ 190.20000,AES 1786
18.7000E+00,1.7000E+01,2.5000E+01,4.0000E+01,5.4000E+01,6.8000E+01,AES 1787
28.3000E+01,9.9000E+01,1.6895E+02,1.8737E+02,2.0705E+02,2.2747E+02,AES 1788
32.5847E+02,2.8247E+02,3.4547E+02,3.7297E+02,4.6755E+02,4.9755E+02,AES 1789
45.2930E+02,5.6205E+02,5.9605E+02,6.3105E+02,6.6780E+02,7.0555E+02,AES 1790
57.4755E+02,7.8830E+02,8.3005E+02,8.7305E+02,9.1780E+02,9.6430E+02,AES 1791
61.2246E+03,1.2731E+03,1.3226E+03,1.3733E+03,1.4261E+03,1.4796E+03,AES 1792
71.5463E+03,1.6031E+03,1.6616E+03,1.7203E+03,1.9426E+03,2.0033E+03,AES 1793
82.0661E+03,2.1291E+03,2.2651E+03,2.3326E+03,2.4963E+03,2.5658E+03,AES 1794
94.4436E+03,4.5439E+03,4.6479E+03,4.7551E+03,4.8654E+03,4.9819E+03,AES 1795
$5.1546E+03,5.2776E+03,5.4056E+03,5.7671E+03,5.9704E+03,6.1021E+03,AES 1796
$6.2374E+03,6.3766E+03,6.7894E+03,6.9416E+03,7.2539E+03,7.4076E+03,AES 1797
$1.6322E+04,1.6647E+04,1.6991E+04,1.7354E+04,1.9412E+04,1.9844E+04,AES 1798
$2.0495E+04,2.0943E+04,8.4318E+04,8.5989E+04/AES 1799
C   Z = 77AES 1800
DATA(EIP(I),I=3003,3080)/ 192.20000,AES 1801
19.0000E+00,1.7000E+01,2.7000E+01,3.9000E+01,5.7000E+01,7.2000E+01,AES 1802
28.8000E+01,1.0400E+02,1.2100E+02,1.9791E+02,2.1709E+02,2.3766E+02,AES 1803
32.5884E+02,2.8934E+02,3.1434E+02,3.8184E+02,4.1109E+02,5.4938E+02,AES 1804
45.7988E+02,6.1200E+02,6.4513E+02,6.7963E+02,7.1513E+02,7.5225E+02,AES 1805
57.9038E+02,8.3238E+02,8.7350E+02,9.1563E+02,9.5913E+02,1.0043E+03,AES 1806
61.0510E+03,1.3169E+03,1.3656E+03,1.4154E+03,1.4665E+03,1.5196E+03,AES 1807
71.5734E+03,1.6385E+03,1.6956E+03,1.7544E+03,1.8135E+03,2.0374E+03,AES 1808
82.0985E+03,2.1616E+03,2.2251E+03,2.3496E+03,2.4174E+03,2.5805E+03,AES 1809
92.6503E+03,4.6540E+03,4.7538E+03,4.8573E+03,4.9642E+03,5.0741E+03,AES 1810
$5.1898E+03,5.3530E+03,5.4755E+03,5.6030E+03,5.9257E+03,6.1651E+03,AES 1811
$6.2967E+03,6.4321E+03,6.5715E+03,6.9396E+03,7.0915E+03,7.4003E+03,AES 1812
$7.5540E+03,1.6720E+04,1.7073E+04,1.7442E+04,1.7828E+04,2.0024E+04,AES 1813
$2.0478E+04,2.1116E+04,2.1585E+04,8.6829E+04,8.8520E+04/AES 1814
C   Z = 78AES 1815
DATA(EIP(I),I=3081,3159)/ 195.10000,AES 1816
19.0000E+00,1.8560E+01,2.8000E+01,4.1000E+01,5.5000E+01,7.5000E+01,AES 1817
29.2000E+01,1.0900E+02,1.2700E+02,1.4600E+02,2.2795E+02,2.4790E+02,AES 1818
32.6935E+02,2.9130E+02,3.2130E+02,3.4730E+02,4.1930E+02,4.5030E+02,AES 1819
46.3290E+02,6.6390E+02,6.9640E+02,7.2990E+02,7.6490E+02,8.0090E+02,AES 1820
58.3840E+02,8.7690E+02,9.1890E+02,9.6040E+02,1.0029E+03,1.0469E+03,AES 1821
61.0924E+03,1.1394E+03,1.4109E+03,1.4599E+03,1.5099E+03,1.5614E+03,AES 1822
71.6149E+03,1.6689E+03,1.7324E+03,1.7899E+03,1.8489E+03,1.9084E+03,AES 1823
82.1339E+03,2.1954E+03,2.2589E+03,2.3229E+03,2.4359E+03,2.5039E+03,AES 1824
92.6664E+03,2.7364E+03,4.8673E+03,4.9668E+03,5.0698E+03,5.1763E+03,AES 1825
$5.2858E+03,5.4008E+03,5.5543E+03,5.6763E+03,5.8033E+03,6.0873E+03,AES 1826
$6.3628E+03,6.4943E+03,6.6298E+03,6.7693E+03,7.0328E+03,7.2443E+03,AES 1827
$7.5498E+03,7.7033E+03,1.7126E+04,1.7506E+04,1.7900E+04,1.8309E+04,AES 1828
$2.0643E+04,2.1119E+04,2.1743E+04,2.2233E+04,8.9367E+04,9.1077E+04/AES 1829
C   Z = 79AES 1830
DATA(EIP(I),I=3160,3239)/ 196.97700,AES 1831
19.2200E+00,2.0500E+01,3.0000E+01,4.4000E+01,5.8000E+01,7.3000E+01,AES 1832
29.6000E+01,1.1400E+02,1.3300E+02,1.5300E+02,1.8587E+02,2.5908E+02,AES 1833

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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,
 11.0430E+01,1.8751E+01,3.4200E+01,4.6000E+01,6.1000E+01,7.7000E+01,AES 1847
 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+02,9.7030E+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+03,1.8551E+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+04,2.2+21E+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,
 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)/ 297.20000,
 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+03,2.7990E+03,2.8670E+03,3.0270E+03,3.0980E+03,AES 1888

\$5.7510E+03,5.8490E+03,5.9500E+03,6.0550E+03,6.1630E+03,6.2750E+03,AES 1889
 \$6.3900E+03,6.5100E+03,6.6350E+03,6.7640E+03,7.1840E+03,7.3150E+03,AES 1890
 \$7.4510E+03,7.5910E+03,7.7360E+03,7.8860E+03,8.1780E+03,8.3310E+03,AES 1891
 \$1.8815E+04,1.9305E+04,1.9800E+04,2.0300E+04,2.3186E+04,2.3750E+04,AES 1892
 \$2.4320E+04,2.4895E+04,9.9793E+04,1.0158E+05/
 AES 1893

C Z = 83 AES 1894

DATA(EIP(I),I=3486,3569)/ 208.98300,
 AES 1895
 17.2870E+00,1.6680E+01,2.5560E+01,4.5300E+01,5.6000E+01,8.8300E+01,AES 1896
 21.0700E+02,1.2700E+02,1.4800E+02,1.6900E+02,2.0356E+02,2.3283E+02,AES 1897
 32.6524E+02,3.0127E+02,3.4084E+02,3.9303E+02,4.2211E+02,4.4813E+02,AES 1898
 44.7407E+02,5.1209E+02,5.4289E+02,6.2559E+02,6.7219E+02,1.0171E+03,AES 1899
 51.0519E+03,1.0877E+03,1.1247E+03,1.1636E+03,1.2034E+03,1.2444E+03,AES 1900
 61.2863E+03,1.3321E+03,1.3771E+03,1.4231E+03,1.4711E+03,1.5199E+03,AES 1901
 71.5701E+03,1.8732E+03,1.9251E+03,1.9781E+03,2.0328E+03,2.0888E+03,AES 1902
 82.1468E+03,2.2127E+03,2.2736E+03,2.3356E+03,2.3987E+03,2.6392E+03,AES 1903
 92.7642E+03,2.7709E+03,2.8387E+03,2.9454E+03,3.0171E+03,3.1853E+03,AES 1904
 \$3.2586E+03,5.9099E+03,6.0119E+03,6.1160E+03,6.2259E+03,6.3379E+03,AES 1905
 \$6.4546E+03,6.5989E+03,6.7233E+03,6.8528E+03,6.9864E+03,7.4229E+03,AES 1906
 \$7.5581E+03,7.6978E+03,7.8421E+03,8.1184E+03,8.2734E+03,8.5802E+03,AES 1907
 \$8.7403E+03,1.9469E+04,1.9939E+04,2.0416E+04,2.0901E+04,2.3968E+04,AES 1908
 \$2.4521E+04,2.5131E+04,2.5697E+04,1.0270E+05,1.0479E+05/
 AES 1909

C Z = 84 AES 1910

DATA(EIP(I),I=3570,3654)/ 210.00000,
 AES 1911
 18.4300E+00,1.9000E+01,2.7000E+01,3.8000E+01,6.1000E+01,7.3000E+01,AES 1912
 21.1200E+02,1.3200E+02,1.5400E+02,1.7600E+02,2.0181E+02,2.3520E+02,AES 1913
 32.6575E+02,2.9757E+02,3.3262E+02,3.7077E+02,4.3815E+02,4.6330E+02,AES 1914
 44.9035E+02,5.1722E+02,5.6527E+02,5.9687E+02,6.7227E+02,7.2747E+02,AES 1915
 51.0518E+03,1.0886E+03,1.1261E+03,1.1651E+03,1.2058E+03,1.2476E+03,AES 1916
 61.2906E+03,1.3343E+03,1.3838E+03,1.4308E+03,1.4788E+03,1.5288E+03,AES 1917
 71.5796E+03,1.6318E+03,1.9441E+03,1.9378E+03,2.0528E+03,2.1093E+03,AES 1918
 82.1683E+03,2.2273E+03,2.3021E+03,2.3648E+03,2.4288E+03,2.4941E+03,AES 1919
 92.7431E+03,2.8101E+03,2.8786E+03,2.9481E+03,3.0946E+03,3.1688E+03,AES 1920
 \$3.3453E+03,3.4208E+03,6.0719E+03,6.1779E+03,6.2869E+03,6.3999E+03,AES 1921
 \$6.5159E+03,6.6371E+03,6.8109E+03,6.9396E+03,7.0736E+03,7.2119E+03,AES 1922
 \$7.6649E+03,7.8041E+03,7.9476E+03,8.0961E+03,8.5039E+03,8.6639E+03,AES 1923
 \$8.9854E+03,9.1526E+03,2.0130E+04,2.0580E+04,2.1039E+04,2.1509E+04,AES 1924
 \$2.4756E+04,2.5299E+04,2.5949E+04,2.6505E+04,1.0563E+05,1.0802E+05/AES 1925

C Z = 85 AES 1926

DATA(EIP(I),I=3655,3740)/ 211.00000,
 AES 1927
 19.3000E+00,2.0000E+01,2.9000E+01,4.1000E+01,5.1000E+01,7.8000E+01,AES 1928
 29.1000E+01,1.3800E+02,1.6000E+02,1.8300E+02,2.0998E+02,2.3570E+02,AES 1929
 32.6793E+02,2.9976E+02,3.3099E+02,3.6507E+02,4.0179E+02,4.7936E+02,AES 1930
 45.0558E+02,5.3366E+02,5.6147E+02,6.1954E+02,6.5194E+02,7.2004E+02,AES 1931
 57.8384E+02,1.0883E+03,1.1269E+03,1.1661E+03,1.2071E+03,1.2498E+03,AES 1932
 61.2934E+03,1.3384E+03,1.3840E+03,1.4373E+03,1.4863E+03,1.5363E+03,AES 1933
 71.5883E+03,1.6409E+03,1.6953E+03,2.0166E+03,2.0723E+03,2.1293E+03,AES 1934
 82.1875E+03,2.2485E+03,2.3095E+03,2.3931E+03,2.4578E+03,2.5238E+03,AES 1935
 92.5911E+03,2.8486E+03,2.9176E+03,2.9879E+03,3.0591E+03,3.2454E+03,AES 1936
 \$3.3223E+03,3.5070E+03,3.5848E+03,6.2368E+03,6.3468E+03,6.4598E+03,AES 1937
 \$6.5768E+03,6.6968E+03,6.8227E+03,7.0258E+03,7.1590E+03,7.2975E+03,AES 1938
 \$7.4403E+03,7.9098E+03,8.0532E+03,8.2005E+03,8.3532E+03,8.8923E+03,AES 1939
 \$9.0573E+03,9.3936E+03,9.5680E+03,2.0798E+04,2.1228E+04,2.1669E+04,AES 1940
 \$2.2124E+04,2.5552E+04,2.6034E+04,2.6774E+04,2.7321E+04,1.0859E+05,AES 1941
 \$1.1128E+05/
 AES 1942

C Z = 86 AES 1943

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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+03,1.1663E+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+03,2.6399E+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
29.4000E+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+03,6.3148E+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
$8.3765E+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+04,2.9908E+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+03,3.657E+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=4095,4145)/ 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
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 \$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+02,4.6900E+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

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71.5620E+03,1.6180E+03,1.6750E+03,1.7330E+03,1.8080E+03,1.8690E+03,AES 2054
81.9320E+03,1.9970E+03,2.0620E+03,2.1300E+03,2.5130E+03,2.5810E+03,AES 2055
92.6510E+03,2.7210E+03,2.7950E+03,2.8690E+03,3.0030E+03,3.0810E+03,AES 2056
$3.1600E+03,3.2420E+03,3.5550E+03,3.6370E+03,3.7200E+03,3.8040E+03,AES 2057
$4.2090E+03,4.3000E+03,4.5360E+03,4.6290E+03,7.4280E+03,7.5620E+03,AES 2058
$7.7010E+03,7.8440E+03,7.9910E+03,8.1460E+03,8.5120E+03,8.6750E+03,AES 2059
$8.8430E+03,9.0160E+03,9.5930E+03,9.7640E+03,9.9380E+03,1.0120E+04,AES 2060
$1.1370E+04,1.1570E+04,1.2000E+04,1.2220E+04,2.5330E+04,2.5670E+04,AES 2061
$2.6040E+04,2.6440E+04,3.0960E+04,3.1460E+04,3.2390E+04,3.2920E+04,AES 2062
$1.3040E+05,1.3250E+05/ AES 2063
C AES 2064
C ***** AES 2065
C LIBRARY OF ANALYTICAL EOS AES 2066
C AES 2067
COMMON /BIG/ BIGDUM(1) AES 2068
DIMENSION TABLE(200), TABPL(200), DTAB(5000) AES 2069
EQUIVALENCE (TABLE(1),BIGDUM(101)), (TABPL(1),BIGDUM(301)), (DTAB(AES 2070
11),BIGDUM(501)) AES 2071
C AES 2072
DATA NUMTAB/5/ AES 2073
C AIR AES 2074
DATA TABLE(1),TABPL(1)/1.,1./ AES 2075
DATA (DTAB(I),I=1,31)/10HAIR DRY ,3.,2.,22*0.,7.,.78455,8.,.2107AES 2076
15,18.,.0047/ AES 2077
C GOLD AES 2078
DATA TABLE(2),TABPL(2)/2.,32./ AES 2079
DATA (DTAB(I),I=32,58)/10HGOLD ,1.,4.,19.3,.02567785,0.,1.75EAES 2080
112,3.054,.01551,0.,2.,1.45E10,.1151,12*0.,79.,1./ AES 2081
C ALUMINUM AES 2082
DATA TABLE(3),TABPL(3)/3.,59./ AES 2083
DATA (DTAB(I),I=59,85)/10HALUMINUM ,1.,4.,2.7,.02567785,0.,.7.63E1AES 2084
11,2.06,.0343,-1.,2.,1.2E11,.08,12*0.,13.,1./ AES 2085
C BERYLLIUM AES 2086
DATA TABLE(4),TABPL(4)/4.,86./ AES 2087
DATA (DTAB(I),I=86,112)/10HBERYLLIUM ,1.,4.,1.845,.02567785,0.,0.,AES 2088
11.17,.09995,0.,2.,3.69E11,.134,7.97E5,1.091,10*0.,4.,1./ AES 2089
C IRON 130KB PHASE TRANSITION AES 2090
DATA TABLE(5),TABPL(5)/5.,113./ AES 2091
DATA (DTAB(I),I=113,139)/10HIRON 130PT,1.,4.,7.85,.02567785,0.,1.9AES 2092
13E12,1.75,0.,0.,2.,7.3E10,.282,5*0.,8.36,8.75,1.12E11,2.30E12,5.E1AES 2093
22,2*0.,26.,1./ AES 2094
C AES 2095
C SELECT EOS FROM TABLE AES 2096
TAB=ISETAB AES 2097
DO 10 I=1,NUMTAB AES 2098
IF (TAB.NE.TABLE(I)) GO TO 10 AES 2099
IS=TABPL(I) AES 2100
GO TO 20 AES 2101
10 CONTINUE AES 2102
PRINT 50, ISETAB AES 2103
STOP AES 2104
20 PRINT 60, ISETAB,DTAB(IS) AES 2105
DO 30 I=1,24 AES 2106
IS=IS+1 AES 2107
30 ZB(I)=DTAB(IS) AES 2108

```

J1=ZB(1)	AES 2109
JK=I2-1	AES 2110
DO 40 I=1,J1	AES 2111
JK=JK+1	AES 2112
ZZS(JK)=DTAB(IS+1)	AES 2113
COT(JK)=DTAB(IS+2)	AES 2114
40 IS=IS+2	AES 2115
RETURN	AES 2116
C	AES 2117
50 FORMAT (19H1 THERE IS NO TABLE,I6,13H IN DATA LIST)	AES 2118
60 FORMAT (20H0 LIBRARY EOS NUMBER,I6,3H (,A10,15H) IS REQUESTED,/)	AES 2119
END	AES 2120

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