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A Thermodynamic Surface for the Critical Region of Ethylene

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A Thermodynamic Surface for the Critical Region of Ethylene

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A Thermodynamic Surface for the Critical Region of Ethylene[1]

by

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Tables are presented of thermodynamic properties of ethylene in the range 279-300 K in temperature, 5.75 - 10.5 mol/dm^3 in density, which range includes the critical point. The tables presented here are based on the critical-point scaling laws and incorporate the critical anomalies as presently known from renormalization-group theory. The tables complement the formulation of the equation of state of fluid ethylene by McCarty and Jacobsen (NBS Tech. Note 1045, 1981) which does not claim accuracy near the critical point. The predictions of the present formulation are compared with four sets of recent PVT data, and with speed-of-sound and enthalpy data. Tables are presented of pressure, energy, enthalpy, entropy, specific heats and speed of sound as function of temperature along finely-spaced isochores. The computer program required for table generation is included. Even if the surface were perfect, the reliability of densities calculated at experimental pressures and temperatures of limited accuracy declines rapidly as the critical point is approached. Contour plots in P-T space are presented of regions to be avoided in custody transfer for given uncertainties in pressure , temperature and sample composition.

Key words: critical region; custody transfer; density; enthalpy; ethylene; equation of state; impurity; scaling laws, specific heat; speed of sound; supercritical extraction; thermodynamic properties.

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1. Introduction

A formulation is presented of the thermodynamic behavior of ethylene in a region around the critical point extending from 5.75 to 10.5 mol/dm^3 in density and from 279 to 300 K in temperature. A correct formulation of this near-critical region is more urgent for ethylene than for most other fluids, because in the climatic conditions of the United States the fluid transported in pipes can assume states located in this region. The present formulation will also be useful as a characterization of ethylene as a supercritical solvent. It is well recognized that most engineering equations of state are deficient in representing near-critical states [1-4]. Our formulation of the thermodynamic behavior of ethylene derives from a thermodynamic potential which obeys the critical-point scaling laws; it contains a first correction to scaling and also a revision to scaling designed to accommodate the lack of symmetry of the gas-liquid phase transition. The adjustable parameters in the potential were obtained by a fit to the PVT data of Hastings et al. [5] and to the speed-of-sound data of Gammon [6]. The advantage of our formulation is that the critical anomalies that are common to all fluids are properly incorporated. For instance, the flatness of the critical isotherm, which is hard to describe by analytic equations of state, is built into our potential. Its strength is particularly striking when it comes to presenting the specific heat at constant volume, C_V, and the speed of sound, C_S. The weak divergence of C_V cannot be described by analytic free energy surfaces. This divergence, however, causes the speed of sound to approach the value zero at the critical point, a feature properly incorporated in our potential. The excellent speed-of-sound data of Gammon therefore form a crucial test for the adequacy of our thermodynamic surface. We stress that, by the use of so-called parametric variables, we have closed-form expressions for all thermodynamic properties.

We will describe how our potential is constructed, and proceed to compare it with experimental PVT data from four sources; with vapor pressures and coexisting densities from two sources and with recent enthalpy data. Comparisons are also made with the predictions of the global equation of state of ethylene recently published by McCarty and Jacobsen [7]. From these comparisons it will be evident that our potential will serve as a useful and necessary supplement in a region where the global equation is deficient. In appendices, we present the equations defining our potential and a comparison of all data points mentioned above with the predictions of our surface. A table of the thermodynamic properties pressure, energy, entropy, enthalpy, specific heats C_p and C_V and speed of sound C_S, is presented along finely-spaced isochores with temperature as an entry. Tables of saturation properties are also given. The computer programs for generation of these tables are included. They contain an inversion routine which permits transformation from pressure to density as an independent variable.

For the convenience of the user concerned with custody transfer, we conclude the main body of the paper with a discussion of the uncertainties introduced in the density calculated from our surface due to limited precision in the measurement of pressure and temperature, and due to the presence of impurity. Contour plots indicating regions in P-T space to be avoided if a certain precision in density is desired, are included in this paper.

Our work has been part of a joint industry-U.S. Government project to determine the thermodynamic properties of ethylene.

2. Fundamental Equation

At a critical point, thermodynamic behavior is anomalous. The critical point is characterized by the facts that the compressibility $K_T = -(1/V)(\partial V/\partial P)_T$ and the specific heat C_P diverge and the coexisting densities ρ_ℓ, ρ_v become equal. We write, asymptotically near the critical point,

$$K_T^* = \Gamma |\Delta T^*|^{-\gamma} ,$$
$$\Delta\rho^* = B|\Delta T^*|^{\beta} . \qquad (1)$$

Here asterisks denote reduced properties, while $\Delta T^* \equiv (T-T_c)/T_c$ and $\Delta\rho^* \equiv (\rho_\ell - \rho_v)/2\rho_c$. For classical equations of state of the type of van der Waals' equation, the critical exponent γ equals 1, β equals 1/2. In real fluids, γ equals about 1.24 and β is of the order 1/3. The critical-point scaling laws are constructed so that they yield the correct critical exponents; although one can define as many critical exponents as one sees fit, only two of them are independent. Their values are given by theory and they are the same for all fluids [3,4].

Our fundamental equation incorporates the scaling laws. The thermodynamic potential used in our work is that introduced by Ley-Koo and Green [8]. It is the dependent variable $\tilde{P} = P^*/T^*$ as a function of $\tilde{\mu} = \mu^*/T^*$ and $\tilde{T} = -1/T^*$. Here P is the pressure, μ is the chemical potential and T the absolute temperature. Asterisks denote reduced properties: $P^* = P/P_c$, $T^* = T/T_c$ and $\mu^* = \mu\rho_c/P_c$, where P_c is the critical pressure, T_c the critical temperature and ρ_c the critical density. In terms of this potential, we have

$$(\partial\tilde{P}/\partial\tilde{T})_{\tilde{\mu}} = \tilde{U} ,$$
$$(\partial\tilde{P}/\partial\tilde{\mu})_{\tilde{T}} = \tilde{\rho} , \qquad (2)$$

where $\tilde{U}$ is the reduced energy density $\tilde{U} = U^*/V^*$ and $\tilde{\rho}$ the reduced mass density, while the other thermodynamic functions: Helmholtz free energy density $\tilde{A} = A^*/V^*$, enthalpy density $\tilde{H} = H^*/V^*$ and entropy density $\tilde{S} = S^*/V^*$ follow from

$$\tilde{A} = \tilde{\rho}\,\tilde{\mu} - \tilde{P} ,$$
$$\tilde{H} = \tilde{P} - \tilde{U}\,\tilde{T} ,$$
$$\tilde{S} = \tilde{H} - \tilde{\rho}\,\tilde{\mu} . \qquad (3)$$

Since all variables are intensive, the coexistent phases collapse onto a single curve, which, in the $\tilde{\mu},\tilde{T}$ plane, can be parametrized by the analytic relation

$$\tilde{\mu}_o(\tilde{T}) = \tilde{\mu}_c + \Sigma\, \tilde{\mu}_j(\Delta\tilde{T})^j ,$$

where $\Delta\tilde{T} = (T-T_c)/T$. In scaling, the physical variables $\tilde{\mu}$, $\tilde{T}$ are transformed to a new

coordinate system, one axis of which is the curve $\tilde{\mu}_o(\tilde{T})$, while the other intersects the first at the critical point. The two scaling variables are linear combinations of $\tilde{\mu}-\tilde{\mu}_o$ and $\Delta\tilde{T}$:

$$u_\mu = \tilde{\mu}(\tilde{T}) - \tilde{\mu}_o(\tilde{T}) = \Delta\tilde{\mu}/a,$$
$$u_t = \Delta\tilde{T} + c\,\Delta\tilde{\mu}, \qquad (4)$$

where a is a constant related to the scale of $\tilde{\mu}$. The term $c\Delta\tilde{\mu}$ breaks the liquid-vapor symmetry.

The potential $\tilde{P}$ is decomposed into two parts, one part, $\tilde{P}_{reg}$, that is regular in the scaling variables and one, $\Delta\tilde{P}$, that contains the critical anomalies with correct power-law dependence. We have assumed for $\tilde{P}_{reg}$:

$$\tilde{P}_{reg} = \tilde{P}_o(\tilde{T}) + \Delta\tilde{\mu} + \tilde{P}_{11}\,\Delta\tilde{\mu}\,\Delta\tilde{T},$$
$$\tilde{P}_o(\tilde{T}) = 1 + \sum_{j=1} \tilde{P}_j\,(\Delta\tilde{T})^j. \qquad (5)$$

$\Delta\tilde{P}$, in scaled form, is given by

$$\Delta\tilde{P} = ak_o|u_t|^{\beta(\delta+1)}\,g_o\left(\frac{u_\mu}{|u_t|^{\beta\delta}}\right) + ak_1|u_t|^{\beta(\delta+1)+\Delta_1}\,g_1\left(\frac{u_\mu}{|u_t|^{\beta\delta}}\right). \qquad (6)$$

The first term represents asymptotic scaling, the second a correction to scaling. The critical exponents β and δ are those characterizing the shape of the coexistence curve and the shape of the critical isotherm, respectively. The leading term contains one more adjustable constant k_o, while the function g_o is universal, i.e., the same for all fluids. The correction term contains a new independent critical exponent Δ_1, also given by theory, and a new free constant k_1. The function g_1 is the same for all fluids.

All thermodynamic functions can be given in algebraically closed form by the device of transformation to parametric variables [9]

$$\Delta\tilde{\mu} = au_\mu = r^{\beta\delta}\,a\,\theta\,(1-\theta^2),$$
$$u_t = r\,(1-b^2\theta^2). \qquad (7)$$

The variable r measures "distance from the critical point", while θ is measured along a contour of constant r and reaches the values ± 1 on the phase boundary; b^2 is a constant predicted to be universal. The critical anomalies are all imbedded in the r-dependence while the dependence of the thermodynamic functions on θ is always in the form of simple polynomials or their ratios. All relevant equations are given in Appendix A. Note that the functions are listed separately for the one- and two-phase regions.

The constants defining our potential were obtained as follows. The critical exponent values β,δ,Δ_1 are those predicted by theory [10]. The critical parameters, the four

parameters in the scaling function: a, k_0, k_1, c and the three "background" parameters $\tilde{P}_1$, $\tilde{P}_2$, and $\tilde{P}_{11}$ were determined by a fit to the PVT data of Hastings et al. [5]* while we imposed the condition that the slope of the vapor pressure curve at the critical point be that of the vapor pressure data of Levelt Sengers and Hastings [11], that the critical point lie on the vapor pressure curve and that the diameter of the coexistence curve be that measured by Douslin and Harrison [12]. This implies that the values of T_c and P_c are constrained to be on the vapor pressure curve and cannot be fitted independently. The constant b^2, which is expected to be universal, was set equal to that found for steam [4], consistent with the theoretical value to within the latter's uncertainty. This value of b^2 (Table I) is, however, different from that used in [5]. As a consequence, all adjustable parameters except the critical constants ρ_c, P_c and T_c, differ from those reported in [5]. Two background parameters $\tilde{\mu}_2$,$\tilde{\mu}_3$ were determined by a fit to the speed-of-sound data of Gammon [6]. The other two, $\tilde{\mu}_c$ and $\tilde{\mu}_1$, are related to the zeros for energy, entropy and enthalpy. They were fixed by equating the energy and enthalpy at 288.15 K and 7 mol/dm^3 to those derived from their PVT data [12] by Harrison and Douslin [13]. The parameters characterizing our potential are listed in Table I. The range of validity of the potential is indicated in Fig. 1.

3. The Equation of State

We compare the predictions of our potential for the equation of state of ethylene with experiment. The experimental data are those of Hastings et al. [5] for a 99.993% pure sample, to which the potential was fitted, those of Douslin and Harrison [12], Trappeniers et al. [14] and Thomas and Zander [15,16]. Older data have been adequately reviewed in the IUPAC formulation of Angus et al. [17], and in the reviews of Date et al. [18] and Vashchenko et al. [19].

The potential represents the data of Hastings et al. with a reduced chi-square of 3.6 if the uncertainties are estimated as 5 x 10^{-5} MPa in pressure, 3 x 10^{-3} mol/dm^3 in density and 5 x 10^{-4} K in temperature. It is to be kept in mind that our data were fitted to about twice these close tolerances even though the deviation plots of Fig. 2 show occasionally large density deviations. The percentage differences in density, $100(\rho_{exp.}-\rho_{calc.})/\rho_{exp.}$, between the data, $\rho_{exp.}$, and our surface, $\rho_{calc.}$, assuming the pressures to be the same, and, alternatively, the percentage differences in pressure $100(P_{exp.}-P_{calc.})/P_{exp.}$, assuming the densities to be the same, are shown for the various isotherms in Figs. 2 and 3. At 298.15 K the surface represents our own data to well within 0.1% in density. The agreement between the data sets of [5], [12] and [14] is almost within the 0.1% tolerance originally set as a goal for the U.S. Government - Industry joint project on properties of ethylene.

*The bulk of the experimental PVT data were taken near, but not necessarily exactly at, the temperature values of 30°C, 25°C, 20°C, 16°C, 12.5°C and 10°C. In Ref. [5], the temperatures were reported at these round values, and small adjustments in the experimental pressures had been made accordingly. The fit presented here, however, is to the data as measured (except for the four near-critical isochores that had been reported earlier [11]); these unadjusted data are listed in Table B1.

The data set of Thomas and Zander [15,16] shows more scatter than the other three sets, without, however, showing systematic departures from our formulation. The pressure deviations are similarly small at this temperature, with a tendency to grow in the highly compressed fluid, as is to be anticipated (Fig. 3). When the critical point is approached, the density departures between the data sets, and their departures from the surface, increase dramatically, while the pressure deviations remain more or less the same. At the temperatures from 0.7-3.7 K above the critical temperature, the density departures reach values larger than 0.5% and on isotherms spanning the critical the largest departure is 15%. The pressure deviations, however, remain as well-behaved as at 298.15 K if not better, the departures being of the order of 0.02% in the range around critical (Fig. 3). This is a good illustration of the difference between "density" and "field" variables in the vicinity of a critical point. ("Density" variables are different in coexisting phases while "field" variables are the same.) Due to the strong divergences of the compressibility and expansion coefficients, small systematic differences in temperature and pressure scales between the various laboratories are amplified when the densities are compared. Furthermore, the effect of impurity is largest at the critical point, and small differences in sample composition can lead to large variations in density.

A study of the plots in Fig. 2 will convince the reader that most of the region covered in this report should be avoided if an accuracy of 0.1% in density is desired in custody transfer. Even if our surface were perfect, the finite precision of industrial pressure and temperature measurement will result in large errors if the density is calculated from the equation of state.

Appendix B. Table BI, contains the deviations of the PVT data sets [5], [12], [14], [15] and [16] from the present formulation.

4. Critical Parameters

The critical temperature and density of ethylene were measured by Moldover [20] by the method of visual observation of the meniscus disappearance. His results are given in Table II. The pressure given in his paper was a result of early vapor pressure measurements in the apparatus of Hastings et al. Later, but prior to publications [11], [5], a small temperature calibration error was found in that work. The critical pressure reported by Moldover should therefore be disregarded.

The critical parameters reported by Douslin and Harrison [12] and those determined by us are also listed in Table II. These parameters are results of an analysis of PVT data. As a general rule, such analyses give set of P_c, T_c values that are consistent with the vapor pressure curve but do not determine the value of T_c sharply. A more accurate value of T_c can be obtained by analyzing coexistence - curve data [12]. Coexistence curve data resulting from PVT data, however, rapidly decline in accuracy as the critical point is approached. This is true for both the data of Douslin and Harrison, and those of Hastings et al. It is therefore gratifying to see how well the critical temperatures and densities obtained by PVT data analysis agree with the direct observation by Moldover.

5. Coexistence Properties

Vapor pressures from 279.15 to the critical temperature are compared in Fig. 4. The quantity ΔP equals $P_{exp.}-P_{calc.}$. Data sources are those of Hastings and Levelt Sengers [11] and those of Douslin and Harrison [12]. These two data sets were shown to agree within combined error of 10^{-4} MPa at temperatures below 240 K [11]; the departures are systematic at higher temperatures, and reach a maximum of 7 x 10^{-4} MPa at the critical point. A satisfactory explanation for the difference has not been given. It is larger than expected on the basis of the agreement of pressure scales (1 in 20,000) and temperature scales (1 mK) and not quite of the form expected for a difference in purity [5]. Nevertheless, the agreement between the data sets [11] and [12], better than 2 parts in 10^4, is an order better than that between these sets and the older data (cf. [12], p. 311). Table BII in Appendix B contains the deviations of vapor pressure data sets [11] and [12] from our formulation.

Coexisting densities of Refs. [5] and [12] are compared with our formulation in Fig. 5 and in Table BIII. The quantity $\Delta\rho$ equals $\rho_{exp.}-\rho_{calc.}$. The agreement between the two data sets and the formulation, to ± 0.02 mol/dm^3, is satisfactory in this region close to the top of the coexistence dome.

6. Speed of sound

As we mentioned before, we determined the parameters $\tilde{\mu}_2,\tilde{\mu}_3$ in our potential from a fit to Gammon's speed-of-sound data [6], accepting his density and temperature values as independent variables. It should be stressed that the anomalous contribution to the speed of sound that drives it to zero at the critical point has been completely predicted from the part of the potential that was determined by the PVT data alone. A substantial loss of accuracy is to be expected when second derivatives are calculated from the potential. We therefore consider the result of our procedure, a prediction of the speed of sound that is generally well within 1% from experiment, as very satisfactory. A global view of the speed of sound within the range of our correlation is shown in Fig. 6. Fig. 7 shows the percentage departures of the speed of sound, $100(C_{exp.}-C_{calc.})/C_{exp.}$, from our surface. It should be mentioned that we had to omit a few of Gammon's data points because our surface predicted them to be inside the two-phase region. Also, we omitted the data points on the critical isotherm within $\pm$ 10% from the critical density, these points being heavily affected by dispersion.

The prediction of the speed of sound is about an order of magnitude less accurate than the precision of the data as estimated from Gammon's assessment of uncertainties in density, temperature and speed of sound. Permitting more than two of the model parameters to be freely adjustable did not improve the precision of the fit by more than a factor of 2.

Table BIV in Appendix B contains a listing of the departures of the experimental data from the present formulation.

7. Enthalpy

Fan [21] recently obtained for ethylene values of the enthalpy and specific heat at constant pressure in a range around the critical point. The data were obtained in a carefully designed flow calorimeter with considerable precision. The calorimeter measures enthalpy changes along selected paths, isothermal or isobaric. The independent variables are pressure and temperature. A number of isobaric enthalpy differences were obtained in the range of our formulation. We have calculated with our equation the densities corresponding to Fan's temperatures and pressures, and then predicted the enthalpy differences at isobaric conditions for the observed inlet and outlet temperatures. Experiment and prediction are compared in Table BV. The agreement is not good. The differences are of the order of 0.5 J/g or 14 J/mol, whereas our predicted enthalpies agree with those calculated by Harrison and Douslin on the level

of a few J/mol (cf. Section 8). Of course, a small offset in temperature or pressure scales between the calorimetric experiment and the PVT experiments will have severe consequences for the density derived from the measured pressures and temperatures; this, in turn, may affect the predicted enthalpy differences. We have varied the pressures reported by Fan by amounts of the order of 0.1%, and the temperatures by a few 0.01 K. Neither variation improved the agreement of prediction and experiment significantly. We must, therefore, reluctantly conclude that the experimental enthalpy differences are not completely consistent with the PVT data. The value of the latent heat reported by Fan, 102.8 J/g at 4.8212 MPa, however, agrees closely with our value of 102.8 J/g and differs from that of Harrison and Douslin, 103.3 J/g by an amount corresponding to 25 mK in temperature.

8. Other Formulations

A recent comprehensive correlation of the properties of ethylene, in the form of an equation of state based on the same data sets considered in this paper, is that of McCarty and Jacobsen [7]. It was preceded by several other correlations, such as the IUPAC formulation by Angus et al. [17], which formulation is based on a part-graphical, part-analytic representation of the PVT properties of ethylene obtained prior to 1972; and the correlation obtained by graphical means by Harrison and Douslin [13] of their own data. The dashed curves in Figs. 2 and 3 indicate the density and pressure departures of the McCarty-Jacobsen formulation from our own; here $\Delta\rho(\%) = 100\ (\rho_{MJ} - \rho_{calc.})/\rho_{MJ}$, and analogously for $\Delta P(\%)$. Since the Helmholtz function of McCarty and Jacobsen is analytic, it has difficulty representing the flatness of near-critical isotherms, as was recognized by the authors. At 298.15 K the departures, though systematic, are limited to a maximum of 0.3% in density, but as the temperature approaches the critical the departures become more severe. At temperatures within 1 K from critical, where our formulation agrees with all data to well within 0.1% in pressure, the McCarty-Jacobsen formulation departs by several tenths of a percent in pressure in a systematic fashion. These differences are magnified when derived properties are considered. An example is shown in Fig. 8 for the enthalpy of ethylene, where the departures of the McCarty-Jacobsen enthalpy from that predicted by our surface are shown along the 283.15 K, 288.15 K, and 298.15 K isotherms. Towards completion of this work, a new classical thermodynamic surface was constructed by Jacobsen and Jahangiri. For comparison with our equation, we refer to that work [22]. This new classical surface is considerably more accurate than that of [7].

The graphical method of Harrison and Douslin, if applied with care to excellent data, should be expected to give better results that can be obtained with a fit to an empirical thermodynamic surface that is seldom quite true to the data. A possible exception is the near-critical regime: the anomalous curvature of isochores may be missed by graphical techniques and by the analytic surface alike, but is correctly incorporated in our potential. The intercomparison in Fig. 8, however, shows that the enthalpies calculated by Harrison and Douslin do not depart from our surface by more than a few J/mol anywhere, while the departures of the analytical McCarty-Jacobsen surface peak at more than 20 J/mol at near-critical temperatures and densities.

The departures from our surface of the derived properties according to the IUPAC formulation show strong systematic trends. This formulation was based on older data and was never claimed to possess high quality in the critical region.

First and second derivatives according to the McCarty-Jacobsen formulation are compared with our own in Figs. 9,10; here $\Delta H = H_{MJ} - H_{calc.}$ and similarly for U,S, where calc. refers to our surface. The first derivatives U, H and S have somewhat different density dependence in the two formulations. Moreover, appreciable departures build up around the critical density and near the critical temperature. The departures of C_p, C_v and the speed of sound are substantial; here $\Delta C_v(\%) = 100\ (C_{v,MJ} - C_{v,calc.})/C_{v,calc.}$,

and analogously for ΔC_p, ΔC_s, where calc. refers to our surface. They are about 1% at 298.15 K, 5 - 10% at 288.15 K and 20 - 40% at 283.15 K (0.8 K above critical). An analytic representation cannot describe the divergence of C_V and the accompanying decline to zero of the (thermodynamic) speed of sound while the divergence of C_P is not strong enough; so these large departures are not surprising. The authors themselves did not claim accuracy in the critical region. Since we have represented the speed-of-sound data to about 1% in accuracy, we are confident that our model represents thermodynamic behavior, such as a weakly diverging C_V, accurately.

A formulation of the thermodynamic properties of ethylene in the critical region was recently published by Nehzat et al. [23]. The formulation is a nonanalytic equation of state that incorporates some features of scaled equations, such as a near-cubic coexistence curve and a critical isotherm of degree near 5. The curvatures of the isochores, and the specific heat C_V, however, do not exhibit the predicted weak divergence in the one-phase region. The equation has a higher-order anomaly at the critical isochore; it is not integrable in closed form so that the thermodynamic functions H, G and S must be calculated by numerical integration. The equation of state contains 16 adjustable parameters and claims validity in a density range of 4.5 to 11 mol/dm^3 and 280.15 to 284.15 K. Additional constants in the thermodynamic functions were obtained by "matching" at each isotherm with the entropy and Gibbs function of Harrison and Douslin along the isochore at 4.5 mol/dm^3. For comparison, our equation of state contains 10 constants (4 more for determining the thermodynamic functions), while it is valid from 5.8 to 10.5 mol/dm^3 and from 279-300 K. The equation of state of Nehzat et al. fits the PVT data of Douslin in the 4 K strip to close tolerance.

As far as derived properties are concerned, we compare their tabular values of C_V in the one- and two-phase region with our surface in Figs. 11 and 12. In the two-phase region the two formulations agree as to the values of C_V as demonstrated in Fig. 12. In the one-phase region, however, the C_V values implied by the equation of Nehzat et al. differ appreciably from the behavior predicted from our surface as illustrated in Fig. 11. In fact, along isotherms close to the critical temperature the C_V of Nehzat et al. has an anomalous jump at the critical density. We do not believe that the C_V predictions of [23] correspond with physical reality. In the absence of experimental C_V data for ethylene, we can only argue that there is substantial evidence for many fluids that C_V diverges; furthermore, in the case of steam, where C_V data <u>are</u> available, our scaled equation represents the data at the various isochores closely [4].

The only experimental data related to C_V for ethylene are those of Gammon for the speed of sound [6]. Nehzat et al. predict this quantity on the coexistence curve. In Fig. 13, we compare their and our predictions for the speed of sound of liquid ethylene with the data of Gammon [6]. This comparison confirms that the second derivatives are not accurately represented by the equation of Nehzat et al. [23].

9. The Effect of Pressure and Temperature Errors on Density

In custody transfer, the density of ethylene will be calculated from its measured pressure and temperature. Since these quantities are measured with limited accuracy, an error in density will result that is given by

$$\frac{\delta\rho}{\rho} = (PK_T)\,\frac{\delta P}{P}\,, \tag{8}$$

or

$$\frac{\delta\rho}{\rho} = -\alpha_P\,\delta T = -K_T\left(\frac{\partial P}{\partial T}\right)_V \delta T. \tag{9}$$

In view of the strong divergence of the compressibility K_T and the expansion coefficient α_P, the density error resulting from inaccuracy in the measurement of P or T is a maximum at the critical point. We show the region in P-T space that should be avoided if an accuracy of 0.1% in density is desired and the pressure is measured with an accuracy of 0.1, 0.05 and 0.02%, respectively, (Fig. 14); or the temperature is measured to 0.02, 0.01 or 0.005 K, respectively, (Fig. 15).

10. The Effect of Impurity on Density

The pressure formulation of the equation of state of ethylene is based on the PVT data obtained for 99.993% pure ethylene, with ethane as the prime impurity. The formulation permits the calculation of the density of an ethylene sample from its pressure and temperature. If impurities are present in the sample of interest, the predicted density will differ from the actual one. It is of interest to know what effect a given impurity has on density, and how the effect varies with the temperature and pressure.

Under simplifying assumptions, this question can be answered. We will assume that the impure fluid is in corresponding states with the pure host, and that the impure system displays pseudo-critical constants that are shifted from those of the pure host by amounts linear in concentration:

$$T_{xc} = T_c\,(1 + ax),$$
$$P_{xc} = P_c\,(1 + bx),$$
$$V_{xc} = V_c\,(1 + (a-b)x)\ . \qquad (10)$$

Both assumptions are reasonable and readily justifiable in dilute mixtures not close to the critical line; the only difficulty with the model is the actual assignment of the values of a and b, parameters characteristic of the host-impurity interaction. They can be determined from the critical parameters of the pure components in the case that the critical points are connected by a continuous critical line. For the sake of developing our estimate of the density error introduced by impurity, we will consider these parameters a,b as known.

An equation for the impurity-induced density error was derived by one of us [5]. It was obtained by applying the law of corresponding states to the pure host and the dilute mixture at the same pressure and temperature. The following result was obtained for the change in density:

$$\frac{\delta\rho}{\rho} = x[(a-b) + bPK_T - aT\alpha_P]$$
$$= x[(a-b) + bPK_T - a(PK_T)\,(\frac{T}{P}\frac{\partial P}{\partial T})]\ , \qquad (11)$$

where K_T is the compressibility, α_p the expansion coefficient of the pure host at T, P. It is clear that Eq. (11) permits calculation of the impurity-induced error in density at any point in P-T space once the constants a, b are known. The relation (11) should not be applied too close to the critical point since the coefficient of the term in x diverges. More seriously, an expansion in x has as little justification as one in ρ, which is known to be invalid at the critical point.

A scrutiny of Eq. (11) immediately reveals that impurity-induced density errors will be largest near the critical point. This is a consequence of the fact that both K_T and α_P diverge strongly at this point. The precise nature of this density error will, of course, depend on the values of a and b. Since these values form the least-known part of our model, we will consider only a few extreme cases.

(1) a = - 0.5, b = 0: a highly volatile impurity that depresses the critical
the critical temperature of the mixture strongly without affecting the critical pressure.

(2) $a = +0.5$, $b = 0$: a highly nonvolatile impurity that increases the critical temperature of the mixture strongly without affecting the critical pressure.

The cases (1) and (2) have opposite effects on the density. The impurity-induced density error is given by

$$\frac{\delta\rho}{\rho} = \pm 0.5 \times [1 - (P\ K_T)\ (\frac{T}{P}\frac{\partial P}{\partial T})] \qquad (5)$$

where the + sign refers to case 1, the sign to case 2. In Fig. 16, we show the region in P-T space that should be avoided in custody transfer if an accuracy in density of 0.1% is desired and if various amounts of an impurity very different in volatility from ethylene are present.

11. Tables of Thermodynamic Properties

In Appendix C we present the thermodynamic properties of ethylene in the critical region. It was not possible to organize this table along isobars, as in [6]. The extremely rapid variation of the "density"-like properties ρ, U, H, S with P and T would preclude interpolation in such a table. We have therefore tabulated the properties along isochores, or at constant density, using temperature as the second entry (Table CI). In addition, we present tables of saturation properties first with temperature, then with pressure as an entry (Tables CII, CIII).

The computer program required for the generation of thermodynamic properties of ethylene is listed in Appendix D. Appendix E contains units and conversion factors.

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12. References

[1] Sengers, J.V. and Levelt Sengers, J.M.H., "The critical region", Chem. and Eng. News 46, 104, 1968.

[2] Levelt Sengers, J.M.H., "Scaling predictions for thermodynamic anomalies near the gas-liquid critical point", Ind. Eng. Fund. 9, 470, 1970.

[3] Levelt Sengers, J.M.H., Morrison, G. and Chang, R.F., "Critical behavior in fluids and fluid mixtures", Fluid Phase Equilibria 14, 19, 1983.

[4] Levelt Sengers, J.M.H., Kamgar-Parsi, B. and Sengers, J.V., "Thermodynamic properties of steam in the critical region", J. Phys. Chem. Ref. Data, 12, 1, 1983.

[5] Hastings, J.R., Levelt Sengers, J.M.H. and Balfour, F.W., "The critical-region equation of state of ethylene and the effect of small impurities", J. Chem. Thermodynamics 12, 1009, 1980.

[6] Gammon, B.E., "Velocity of sound in ethylene", presented at the Advisory Committee Meeting of the Joint Industry-Government Ethylene Project, Boulder, Colorado (Dec. 6, 1978).

[7] McCarty, R.D. and Jacobsen, R.T., "An equation of state for fluid ethylene", NBS Tech. Note 1045, (Nat'l Bur. Stand., Washington, DC, 1981).

[8] Ley-Koo, M. and Green, M.S., "Consequences of the renormalization group for the thermodynamics of fluids near the critical point", Phys. Rev. A 23, 2650, 1981.

[9] Schofield, P., "Parametric representation of the equation of state near a critical point", Phys. Rev. Letters 22, 606, 1969.

[10] Le Guillou, J.C. and Zinn-Justin, J., "Critical exponents from field theory", Phys. Rev. B 21, 3976, 1980.

[11] Hastings, J.R., and Levelt Sengers, J.M.H., "Vapor pressure, critical pressure, and critical isochore of ethylene", in Proceedings 7th Symposium on Thermophysical Properties, Cezairliyan, A., ed., (American Society of Mechanical Engineers, New York, 1977) p. 794.

[12] Douslin, D.R., and Harrison, R.H., "Pressure, volume, temperature relations of ethylene", J. Chem. Thermodynamics 8, 301 (1976).

[13] Harrison, R.H. and Douslin, D.R., "Derived thermodynamic properties of ethylene", J. Chem. Eng. Data 22, 24 1977.

[14] Trappeniers, N.J., Wassenaar, J., and Wolkers, G.J., "Isotherms and thermodynamic properties of ethylene at temperatures between 0 and 150 C and at densities up to 500 amagat", Physica 82A, 305 (1976).

[15] Thomas, W., Zander, M., Quietzsch, G., and Hartmann, H., "Dichte des Aethylens fuer Temperaturen von -30 C bis 80 C bei Drucken bis zu 100 bar," Herausgeber Hoechst AG, Frankfurt/M-Hoechst (1976).

[16] Thomas, W., and Zander, M., "Pressure-density-temperature measurements of ethylene", Int. J. Thermophysics 1, 383 (1980).

[17] Angus, S., Armstrong, B., de Reuck, K.M., Featherstone, W., and Gibson, M.R., International Thermodynamic Tables of the Fluid State, Ethylene, 1972, International Union of Pure and Applied Chemistry, Division of Physical Chemistry, Commission on Thermophysic and Thermochemistry, Thermodynamic Tables Project, Butterworths, London (1974).

[18] Date, K., Watanabe, J., and Uematsu, M., "Evaluation of P-V-T properties data, the most probable values of the compressibility factor of gaseous ethane and ethene", Review of Phys. Chem. Japan 43, 92 (1973).

[19] Vashchenko, D.M., Voinov Yu, F., Voityuk, B.V., Dregulyas, E.K., Kolomiets, Ya., A., Labinov, S.D., Morozov, A.A., Neduzhii, I.A., (Principal Author), Provotar, V.P., A. Yu. Soldatenko, Storozhenko, E.I., and Khmara, Yu. I., Thermodynamic and transport properties of ethylene and propylene (translated from the Russian as published by the State Committee of Standards of the Soviet Ministry, U.S.S.R., State Officer of Standards and Reference Data, Series: Monograph No. 8, 1979), Office of Standard Reference Data, National Bureau of Standards U.S. Department of Commerce, Washington, D.C.

[20] Moldover, M.R., "Visual observation of the critical temperature and density: CO_2 and C_2H_4", J. Chem. Phys. 61, 1766 (1979).

[21] Fan, Yu-Chun, "Accurate Calorimetric Determination in the Critical Region of Ethylene", Ph.D. Thesis, Dept. of Chem. Engineering, University of Michigan, Ann Arbor, Michigan, 1982.

[22] Jacobsen, R.T. and Jahangiri, M., to be published.

[23] Nehzat, M.S., Hall, K.R. and Eubank, P.T., "Thermophysical Properties of Ethylene in the Critical Region", J. Chem. Eng. Data 28, 205 (1983).

[24] Waxman, M. and Davis, H.A., Adv. in Chem. Series 182, K.C. Chao and R.L. Robinson, Jr., editors, ACS Washington, p. 285 (1979).

Table I. Parameters in the Thermodynamic Potential for Ethylene

Critical Exponents	$\beta = 0.325$
	$\delta = 4.82$
	$\Delta_1 = 0.50$
Critical Parameters	$T_c = 282.3452$ K
	$\rho_c = 7.634$ mol/dm^3
	$P_c = 5.0403$ MPa (derived)
Parameters in Scaling Function	$a_0 = 19.3214$
	$k_0 = 1.12289$
	$k_1 = 0.54617$
	$c = -0.007811$
	$b^2 = 1.3757$
Pressure background parameters	$\tilde{P}_1 = 5.3350$
	$\tilde{P}_2 = -18.1475$
	$\tilde{P}_{11} = -0.166687$ (derived)
Caloric background parameters	$\tilde{\mu}_0 = -36.4889$
	$\tilde{\mu}_1 = -27.3955$
	$\tilde{\mu}_2 = -12.2091$
	$\tilde{\mu}_3 = -11.8802$

Table II. Critical Parameters of Ethylene

Author	Data Source	T_c,K	P_c, MPa	ρ_c,mol/dm^3
Moldover [20]	visual observation of meniscus disappearance	282.344±0.004		7.650±0.021
Douslin [12]	PVT [12]	282.35	5.0420	7.635±0.006
This work	PVT [5]	282.3452	5.0403	7.634

APPENDIX A: Revised and Extended Scaling Equations for the Thermodynamic Properties of Fluids.

A.1 Reduced thermodynamic quantities

$$\tilde{T} = -\frac{T_c}{T} \quad , \quad \tilde{\mu} = \frac{\mu}{T} \cdot \frac{\rho_c T_c}{P_c} \quad , \quad \tilde{P} = \frac{P}{T} \cdot \frac{T_c}{P_c} \quad ,$$

$$\tilde{\rho} = \frac{\rho}{\rho_c} \quad , \quad \tilde{U} = \frac{U}{V} \cdot \frac{1}{P_c} \quad , \quad \tilde{S} = \frac{S}{V} \cdot \frac{T_c}{P_c} \quad , \tag{A.1}$$

$$\tilde{A} = \frac{A}{VT} \cdot \frac{T_c}{P_c} \quad , \quad \tilde{H} = \frac{H}{VT} \cdot \frac{T_c}{P_c} \quad , \quad \tilde{\chi}_T = \left(\frac{\partial \tilde{\rho}}{\partial \tilde{\mu}}\right)_T \quad ,$$

$$\tilde{C}_v = \frac{C_v}{V} \frac{T_c}{P_c} \quad , \quad \tilde{C}_P = \frac{C_p}{V} \cdot \frac{T_c}{P_c}$$

(T is temperature, μ is chemical potential, P is pressure, ρ is density, U is energy, S is entropy, A is Helmholtz free energy, H is enthalpy, V is volume, C_V is heat capacity at constant V, C_p is heat capacity at constant P).

A.2 Thermodynamic relations

$$d\tilde{P} = \tilde{U}d\tilde{T} + \tilde{\rho}d\tilde{\mu}$$

$$d\tilde{A} = -\tilde{U}d\tilde{T} + \tilde{\mu}d\tilde{\rho} \tag{A.2}$$

$$d\tilde{H} = -\tilde{T}d\tilde{U} + \tilde{\rho}d\tilde{\mu}$$

$$d\tilde{S} = -\tilde{T}d\tilde{U} - \tilde{\mu}d\tilde{\rho}$$

with

$$\tilde{A} = \tilde{\rho}\tilde{\mu} - \tilde{P}$$

$$\tilde{H} = \tilde{P} - \tilde{T}\tilde{U} \qquad \text{(A.3)}$$

$$\tilde{S} = \tilde{H} - \tilde{\rho}\tilde{\mu} = -\tilde{T}\tilde{U} - \tilde{A}$$

A.3 Fundamental equations

$$\Delta\tilde{T} = \tilde{T} + 1 \qquad \text{(A.4a)}$$

$$\Delta\tilde{\mu} = \tilde{\mu} - \tilde{\mu}_o(\tilde{T}) \qquad \text{(A.4b)}$$

$$\tilde{P} = \tilde{P}_o(\tilde{T}) + \Delta\tilde{\mu} + \tilde{P}_{11}\Delta\tilde{\mu}\Delta\tilde{T} + \Delta\tilde{P} \qquad \text{(A.5)}$$

with

$$\tilde{\mu}_o(\tilde{T}) = \tilde{\mu}_c + \sum_{j=1}^{3} \tilde{\mu}_j (\Delta\tilde{T})^j \qquad \text{(A.6a)}$$

$$\tilde{P}_o(\tilde{T}) = 1 + \sum_{j=1}^{2} \tilde{P}_j (\Delta\tilde{T})^j \qquad \text{(A.6b)}$$

A.4 Derived thermodynamic quantities

$$\tilde{\rho} = 1 + \tilde{P}_{11}\Delta\tilde{T} + \left(\frac{\partial\Delta\tilde{P}}{\partial\Delta\tilde{\mu}}\right)_{\Delta\tilde{T}} \qquad \text{(A.7)}$$

$$\tilde{U} = \frac{d\tilde{P}_o}{d\tilde{T}} - \rho\frac{d\tilde{\mu}_o}{d\tilde{T}} + \tilde{P}_{11}\Delta\tilde{\mu} + \left(\frac{\partial\Delta\tilde{P}}{\partial\Delta\tilde{T}}\right)_{\Delta\tilde{\mu}} \qquad \text{(A.8)}$$

$$\tilde{\chi}_T = \left(\frac{\partial^2\Delta\tilde{P}}{\partial\Delta\tilde{\mu}^2}\right)_{\Delta\tilde{T}} \qquad \text{(A.9)}$$

$$\left(\frac{\partial\tilde{P}}{\partial\tilde{T}}\right)_{\tilde{\rho}} = \frac{d\tilde{P}_o}{d\tilde{T}} + \tilde{P}_{11}\left[\Delta\tilde{\mu} - \frac{\tilde{\rho}}{\tilde{\chi}_T}\right] + \left(\frac{\partial\Delta\tilde{P}}{\partial\Delta\tilde{T}}\right)_{\Delta\tilde{\mu}} - \frac{\tilde{\rho}}{\tilde{\chi}_T}\frac{\partial^2\Delta\tilde{P}}{\partial\Delta\tilde{\mu}\partial\Delta\tilde{T}} \tag{A.10}$$

$$\frac{\tilde{C}_v}{\tilde{T}^2} = \frac{d^2\tilde{P}_o}{d\tilde{T}^2} - \tilde{\rho}\frac{d^2\tilde{\mu}_o}{d\tilde{T}^2} - \frac{\tilde{P}_{11}^2}{\tilde{\chi}_T} +$$

$$+ \left(\frac{\partial^2\Delta\tilde{P}}{\partial\Delta\tilde{T}^2}\right)_{\Delta\tilde{\mu}} - \frac{2\tilde{P}_{11}}{\tilde{\chi}_T}\frac{\partial^2\Delta\tilde{P}}{\partial\Delta\tilde{\mu}\partial\Delta\tilde{T}} - \frac{1}{\tilde{\chi}_T}\left(\frac{\partial^2\Delta\tilde{P}}{\partial\Delta\tilde{\mu}\partial\Delta\tilde{T}}\right)^2 \tag{A.11}$$

$$\tilde{C}_p = \tilde{C}_v + \frac{\tilde{\chi}_T}{\tilde{\rho}^2}\left[\tilde{P} - \tilde{T}\left(\frac{\partial\tilde{P}}{\partial\tilde{T}}\right)_{\tilde{\rho}}\right]^2 \tag{A.12}$$

A.5 Critical exponents

$$\alpha_o = \alpha \quad , \qquad \alpha_1 = \alpha - \Delta_1$$

$$\beta_o = \beta \quad , \qquad \beta_1 = \beta + \Delta_1 \tag{A.13}$$

$$\gamma_o = \gamma \quad , \qquad \gamma_1 = \gamma - \Delta_1$$

with

$$2 - \alpha = \beta(\delta+1) \quad , \qquad \gamma = \beta(\delta-1) \tag{A.14}$$

A.6 Parametric equations for singular terms

$$\Delta\tilde{\mu} = r^{\beta\delta}a\theta(1-\theta^2) \tag{A.15}$$

$$\Delta\tilde{T} = r(1-b^2\theta^2) - c\Delta\tilde{\mu} \tag{A.16}$$

$$\Delta\tilde{P} = \sum_{i=0}^{1} r^{2-\alpha_i} a k_i p_i(\theta) \tag{A.17}$$

$$\left(\frac{\partial \Delta\tilde{P}}{\partial \Delta\tilde{\mu}}\right)_{\Delta\tilde{T}} = \sum_{i=0}^{1} \left[r^{\beta_i} k_i \theta + c r^{1-\alpha_i} a k_i s_i(\theta) \right] \tag{A.18}$$

$$\left(\frac{\partial \Delta\tilde{P}}{\partial \Delta\tilde{T}}\right)_{\Delta\tilde{\mu}} = \sum_{i=0}^{1} r^{1-\alpha_i} a k_i s_i(\theta) \tag{A.19}$$

$$\left(\frac{\partial^2 \Delta\tilde{P}}{\partial \Delta\tilde{\mu}^2}\right)_{\Delta\tilde{T}} = \sum_{i=0}^{1} \left[r^{-\gamma_i} \frac{k_i}{a} u_i(\theta) + 2c r^{\beta_i - 1} k_i v_i(\theta) + c^2 r^{-\alpha_i} a k_i w_i(\theta) \right] \tag{A.20}$$

$$\frac{\partial^2 \Delta\tilde{P}}{\partial \Delta\tilde{\mu} \partial \Delta\tilde{T}} = \sum_{i=0}^{1} \left[r^{\beta_i - 1} k_i v_i(\theta) + c r^{-\alpha_i} a k_i w_i(\theta) \right] \tag{A.21}$$

$$\left(\frac{\partial^2 \Delta\tilde{P}}{\partial \Delta\tilde{T}^2}\right)_{\Delta\tilde{\mu}} = \sum_{i=0}^{1} r^{-\alpha_i} a k_i w_i(\theta) \tag{A.22}$$

A.7 Auxiliary functions

$$p_i(\theta) = p_{oi} + p_{2i}\theta^2 + p_{4i}\theta^4 \tag{A.23}$$

$$s_i(\theta) = s_{oi} + s_{2i}\theta^2 \quad , \quad s_i'(\theta) = 2 s_{2i}\theta \tag{A.24}$$

$$q(\theta) = 1 + \{b^2(2\beta\delta - 1) - 3\}\theta^2 - b^2(2\beta\delta - 3)\theta^4 \tag{A.25}$$

$$u_i(\theta) = [1 - b^2(1 - 2\beta_i)\theta^2]/q(\theta) \tag{A.26}$$

$$v_i(\theta) = [\beta_i(1 - 3\theta^2)\theta - \beta\delta(1 - \theta^2)\theta]/q(\theta) \tag{A.27}$$

$$w_i(\theta) = [(1-\alpha_i)(1-3\theta^-)s_i(\theta) - \beta\delta(1-\theta^-)\theta s_i'(\theta)]/q(\theta) \qquad (A.28)$$

with

$$p_{oi} = + \frac{\beta\delta - 3\beta_i - b^2\alpha_i\gamma_i}{2b^4(2-\alpha_i)(1-\alpha_i)\alpha_i}$$

$$p_{2i} = - \frac{\beta\delta - 3\beta_i - b^2\alpha_i(2\beta\delta-1)}{2b^2(1-\alpha_i)\alpha_i} \qquad (A.29)$$

$$p_{4i} = + \frac{2\beta\delta - 3}{2\alpha_i}$$

$$s_{oi} = (2-\alpha_i)p_{oi}$$

$$s_{2i} = - \frac{\beta\delta - 3\beta_i}{2b^2\alpha_i} \qquad (A.30)$$

A.8 Two-phase properties

Variables:

$$\theta = \pm 1$$

$$\Delta\tilde{\mu} = 0$$

$$\Delta\tilde{T} = r(1 - b^2) \qquad (A.31)$$

Vapor pressure:

$$\tilde{P}_{vap} = \tilde{P}_o(T) + \sum_{i=0}^{1} r^{2-\alpha_i} \; ak_i p_i(1) \qquad (A.32)$$

Coexisting Densities:

$$\frac{\tilde{\rho}_L+\tilde{\rho}_v}{2} = 1 + \tilde{P}_{11}\,\Delta\tilde{T} + \sum_{i=0}^{1} c\, r^{1-\alpha_i} a k_i s_i(1)$$

$$\frac{\tilde{\rho}_L-\tilde{\rho}_v}{2} = \sum_{i=0}^{1} r^{\beta_i} k_i \qquad \text{(A.33)}$$

Helmholtz free energy:

$$\tilde{A} = \tilde{\rho}\,\tilde{\mu}_o(\tilde{T}) - \tilde{P}_o(T) - \sum_{i=0}^{1} r^{2-\alpha_i} a k_i p_i(1) \qquad \text{(A.34)}$$

Energy:

$$\tilde{U} = \frac{d\tilde{P}_o}{d\tilde{T}} - \rho\frac{d\tilde{\mu}_o(T)}{d\tilde{T}} + \frac{1}{1-b^2} \sum_{i=0}^{1} (2-\alpha_i) r^{1-\alpha_i} a k_i p_i(1) \qquad \text{(A.35)}$$

Entropy:

$$\tilde{S} = -\tilde{\rho}\,\tilde{\mu}_o(\tilde{T}) + \tilde{P}_o(\tilde{T}) - \tilde{T}\left[\frac{d\tilde{P}_o}{d\tilde{T}} - \tilde{\rho}\,\frac{d\tilde{\mu}_o}{d\tilde{T}}\right]$$

$$+ \sum_{i=0}^{1} r^{2-\alpha_i} a k_i p_i(1) - \frac{\tilde{T}}{1-b^2} \sum_{i=0}^{1} (2-\alpha_i) r^{1-\alpha_i} a k_i p_i(1) \qquad \text{(A.36)}$$

Specific Heat C_v:

$$\frac{\tilde{C}_v}{\tilde{T}^2} = \frac{d^2\tilde{P}_o}{d\tilde{T}^2} - \tilde{\rho}\,\frac{d^2\tilde{\mu}_o}{d\tilde{T}^2} + \left(\frac{1}{1-b^2}\right)^2 \sum_{i=0}^{1} (2-\alpha_i)(1-\alpha_i) r^{-\alpha_1} a k_i p_i(1) \qquad \text{(A.37)}$$

Appendix B. Comparison with Experiment

In Table B I, the experimental PVT data are compared with the formulation (a) as pressure differences under the assumption that the temperatures and densities are exact and (b) as density differences under the assumption that the temperatures and pressures are exact. In Table B II, saturation pressures from two sources are compared with the formulation and in Table B III the saturation densities. In Table B IV, the speed-of-sound data [6] are compared with the theoretical predictions, and in Table B V the enthalpy data. The legend for the various data sources is as follows

A	Hastings et al. [5] 99.993% pure sample.
B	Hastings et al. [5] 99.999% pure sample.
1	Douslin and Harrison [12].
2	Trappeniers et al. [14].
3	Thomas and Zander [15,16].
GAM	Gammon [6].

TABLE BI. Comparison of the experimental PVT data with the formulation.

EXP.ID	TEMPERATURE	PRESSURE				DENSITY			
	K	MPA				MOL/DM3			
		EXP	CALC	DIFF	%DIFF	EXP	CALC	DIFF	%DIFF
A	298.1386	8.32147	8.32105	.00042	.005	10.542	10.543	-.000	-.00
A	298.1386	8.32149	8.32105	.00044	.005	10.542	10.543	-.000	-.00
A	293.1388	7.32940	7.32704	.00236	.032	10.545	10.548	-.003	-.03
A	289.1390	6.54643	6.54307	.00336	.051	10.547	10.552	-.006	-.05
A	283.6392	5.49244	5.48964	.00280	.051	10.550	10.557	-.008	-.07
A	283.6392	5.49234	5.48964	.00270	.049	10.550	10.557	-.007	-.07
A	282.3333	5.24755	5.24556	.00199	.038	10.550	10.557	-.006	-.06
A	281.1393	5.02650	5.02529	.00121	.024	10.551	10.555	-.005	-.04
A	280.6394	4.93481	4.93404	.00077	.016	10.551	10.554	-.003	-.03
A	280.3394	4.88010	4.87961	.00049	.010	10.551	10.553	-.002	-.02
A	280.0394	4.82562	4.82543	.00019	.004	10.551	10.552	-.001	-.01
A	279.7394	4.77146	4.77154	-.00008	-.002	10.551	10.551	.000	.00
A	298.1386	7.89536	7.90041	-.00505	-.064	10.024	10.017	.007	.07
A	298.1386	7.89545	7.90041	-.00496	-.063	10.024	10.017	.007	.07
A	285.6391	5.68452	5.68402	.00050	.009	10.030	10.032	-.002	-.02
A	283.6392	5.34404	5.34389	.00015	.003	10.031	10.032	-.001	-.01
A	282.3333	5.12547	5.12580	-.00033	-.006	10.031	10.029	.002	.02
A	281.1393	4.92924	4.93023	-.00099	-.020	10.032	10.024	.009	.08
A	280.8393	4.88062	4.88185	-.00123	-.025	10.032	10.020	.012	.12
A	280.7393	4.86455	4.86581	-.00126	-.026	10.032	10.020	.013	.13
A	298.1386	7.46041	7.46406	-.00365	-.049	9.285	9.278	.007	.08
A	298.1386	7.46049	7.46406	-.00357	-.048	9.285	9.278	.007	.08
A	293.1388	6.67996	6.68064	-.00068	-.010	9.288	9.286	.002	.02
A	289.1390	6.06498	6.06419	.00079	.013	9.289	9.293	-.003	-.04
A	285.6391	5.53737	5.53628	.00109	.020	9.291	9.299	-.008	-.09
A	283.6392	5.24276	5.24217	.00059	.011	9.292	9.299	-.007	-.08
A	282.3333	5.05492	5.05501	-.00009	-.002	9.292	9.290	.002	.02
A	281.8393	4.98547	4.98586	-.00039	-.008	9.293	9.279	.013	.14
A	281.7893	4.97849	4.97894	-.00045	-.009	9.293	9.277	.016	.17
A	298.1386	7.29300	7.29536	-.00236	-.032	8.911	8.905	.006	.06
A	298.1386	7.29308	7.29536	-.00228	-.031	8.911	8.905	.006	.06
A	293.1388	6.56382	6.56372	.00010	.001	8.913	8.913	-.000	-.00
A	289.1390	5.98874	5.98747	.00127	.021	8.914	8.921	-.007	-.08
A	285.6391	5.49490	5.49353	.00137	.025	8.916	8.930	-.014	-.16
A	283.6392	5.21907	5.21834	.00073	.014	8.917	8.932	-.015	-.17
A	282.3333	5.04370	5.04370	-.00000	-.000	8.917	8.917	.000	.00
A	282.1893	5.02483	5.02489	-.00006	-.001	8.917	8.913	.004	.05
A	282.0893	5.01180	5.01191	-.00011	-.002	8.917	8.907	.010	.11
A	282.0993	5.01308	5.01321	-.00013	-.003	8.917	8.906	.011	.12
A	282.0893	5.01180	5.01191	-.00011	-.002	8.917	8.907	.010	.11
A	282.0943	5.01245	5.01256	-.00011	-.002	8.917	8.908	.010	.11
A	282.0893	5.01182	5.01191	-.00009	-.002	8.917	8.909	.008	.09
A	282.0949	5.01251	5.01264	-.00013	-.003	8.917	8.906	.011	.13
A	282.0946	5.01245	5.01260	-.00015	-.003	8.917	8.904	.013	.15
A	282.0942	5.01246	5.01255	-.00009	-.002	8.917	8.910	.008	.08
A	282.0936	5.01233	5.01247	-.00014	-.003	8.917	8.905	.012	.14
A	282.0891	5.01176	5.01189	-.00013	-.003	8.917	8.906	.011	.13
A	282.0877	5.01156	5.01171	-.00015	-.003	8.917	8.904	.013	.15
A	298.1386	7.23223	7.23416	-.00193	-.027	8.758	8.753	.005	.06
A	298.1386	7.23231	7.23416	-.00185	-.026	8.758	8.753	.005	.05
A	283.6392	5.21245	5.21172	.00073	.014	8.764	8.782	-.018	-.21
A	282.2193	5.02695	5.02703	-.00008	-.002	8.764	8.755	.009	.10
A	282.3333	5.04151	5.04152	-.00001	-.000	8.764	8.764	.000	.01
A	282.1893	5.02316	5.02323	-.00007	-.001	8.764	8.755	.009	.11
A	282.1893	5.02316	5.02323	-.00007	-.001	8.764	8.755	.009	.11
A	282.3960	5.04961	5.04952	.00009	.002	8.764	8.771	-.007	-.08
A	282.1708	5.02097	5.02090	.00007	.001	8.764	8.774	-.010	-.11
A	282.1915	5.02346	5.02351	-.00005	-.001	8.764	8.758	.006	.07
A	282.1909	5.02335	5.02343	-.00008	-.002	8.764	8.753	.011	.12

EXP.ID	TEMPERATURE	PRESSURE				DENSITY			
	K	MPA				MOL/DM3			
		EXP	CALC	DIFF	%DIFF	EXP	CALC	DIFF	%DIFF
A	282.1911	5.02344	5.02346	-.00002	-.000	8.764	8.762	.002	.03
A	282.1916	5.02346	5.02352	-.00006	-.001	8.764	8.756	.008	.09
A	303.1500	7.47281	7.47406	-.00125	-.017	7.672	7.669	.003	.04
A	298.1500	6.88256	6.88293	-.00037	-.005	7.674	7.673	.001	.02
A	298.1500	6.88257	6.88293	-.00036	-.005	7.674	7.673	.001	.02
A	293.1500	6.29461	6.29429	.00032	.005	7.676	7.678	-.002	-.02
A	289.1500	5.82681	5.82615	.00066	.011	7.677	7.684	-.006	-.08
A	285.6500	5.42011	5.41960	.00051	.010	7.678	7.690	-.012	-.15
A	285.6500	5.42003	5.41960	.00043	.008	7.678	7.689	-.010	-.13
A	284.6500	5.30458	5.30419	.00039	.007	7.679	7.693	-.014	-.18
A	284.6500	5.30469	5.30419	.00050	.009	7.679	7.697	-.018	-.23
A	283.6500	5.18952	5.18925	.00027	.005	7.679	7.699	-.019	-.25
A	283.1500	5.13217	5.13200	.00017	.003	7.679	7.702	-.022	-.29
A	283.1500	5.13210	5.13200	.00010	.002	7.679	7.693	-.013	-.18
A	282.6500	5.07503	5.07494	.00009	.002	7.680	7.719	-.039	-.51
A	282.6500	5.07495	5.07494	.00001	.000	7.680	7.685	-.005	-.07
A	282.6500	5.07496	5.07494	.00002	.000	7.680	7.689	-.010	-.13
A	282.5000	5.05789	5.05787	.00002	.000	7.680	7.698	-.019	-.24
A	303.1500	7.45336	7.45446	-.00110	-.015	7.622	7.619	.003	.04
A	298.1500	6.86844	6.86873	-.00029	-.004	7.624	7.623	.001	.01
A	298.1500	6.86837	6.86873	-.00036	-.005	7.624	7.622	.001	.02
A	293.1500	6.28553	6.28525	.00028	.005	7.625	7.627	-.002	-.02
A	289.1500	5.82149	5.82094	.00055	.009	7.627	7.632	-.005	-.07
A	285.6500	5.41783	5.41742	.00041	.008	7.628	7.638	-.010	-.13
A	284.6500	5.30310	5.30279	.00031	.006	7.628	7.640	-.011	-.15
A	283.6500	5.18875	5.18855	.00020	.004	7.629	7.643	-.015	-.19
A	283.1500	5.13169	5.13161	.00008	.002	7.629	7.640	-.011	-.14
A	282.6500	5.07481	5.07482	-.00001	-.000	7.629	7.625	.004	.05
A	303.1500	7.43832	7.43939	-.00107	-.014	7.583	7.580	.003	.04
A	298.1500	6.85749	6.85782	-.00033	-.005	7.585	7.583	.001	.02
A	298.1500	6.85754	6.85782	-.00028	-.004	7.585	7.584	.001	.01
A	293.1500	6.27857	6.27828	.00029	.005	7.586	7.588	-.002	-.02
A	289.1500	5.81749	5.81693	.00056	.010	7.588	7.593	-.005	-.07
A	285.6500	5.41617	5.41574	.00043	.008	7.589	7.599	-.010	-.13
A	284.6500	5.30198	5.30171	.00027	.005	7.589	7.599	-.010	-.13
A	283.6500	5.18817	5.18801	.00016	.003	7.590	7.601	-.012	-.15
A	283.1500	5.13139	5.13131	.00008	.002	7.590	7.600	-.011	-.14
A	282.6500	5.07473	5.07473	.00000	.000	7.590	7.590	-.000	-.00
A	303.1500	7.40673	7.40746	-.00073	-.010	7.499	7.497	.002	.03
A	298.1500	6.83445	6.83468	-.00023	-.003	7.501	7.500	.001	.01
A	293.1500	6.26383	6.26354	.00029	.005	7.503	7.505	-.002	-.02
A	289.1500	5.80890	5.80844	.00046	.008	7.504	7.509	-.005	-.06
A	285.6500	5.41252	5.41219	.00033	.006	7.506	7.513	-.008	-.10
A	284.6500	5.29966	5.29941	.00025	.005	7.506	7.515	-.009	-.12
A	283.6500	5.18698	5.18686	.00012	.002	7.506	7.515	-.009	-.12
A	283.1500	5.13070	5.13067	.00003	.001	7.506	7.510	-.004	-.05
A	282.6500	5.07449	5.07453	-.00004	-.001	7.507	7.488	.019	.25
A	298.1386	6.58431	6.58356	.00075	.011	6.580	6.582	-.003	-.04
A	298.1386	6.58443	6.58356	.00087	.013	6.580	6.583	-.003	-.05
A	293.1388	6.10011	6.09990	.00021	.003	6.581	6.582	-.001	-.02
A	289.1390	5.71065	5.71078	-.00013	-.002	6.583	6.581	.001	.02
A	285.6391	5.36725	5.36758	-.00033	-.006	6.584	6.578	.006	.09
A	285.6392	5.16689	5.16722	-.00033	-.006	6.584	6.572	.012	.19
A	282.3333	5.03721	5.03751	-.00030	-.006	6.585	6.543	.041	.63
A	282.2193	5.02516	5.02580	-.00064	-.013	6.585	6.478	.106	1.61

Table BI. (Continued)

EXP.ID	TEMPERATURE K	PRESSURE MPA				DENSITY MOL/DM3			
		EXP	CALC	DIFF	%DIFF	EXP	CALC	DIFF	%DIFF
A	282.1893	5.02186	5.02270	-.00084	-.017	6.585	6.443	.142	2.16
A	282.0893	5.01081	5.01150	-.00069	-.014	6.585	6.322	.263	3.99
A	298.1386	6.38668	6.38502	.00166	.026	5.899	5.904	-.005	-.09
A	298.1386	6.38663	6.38502	.00161	.025	5.899	5.904	-.005	-.09
A	282.3333	5.02445	5.02465	-.00020	-.004	5.903	5.898	.005	.09
A	282.0393	4.99780	4.99800	-.00020	-.004	5.903	5.897	.006	.11
A	281.6893	4.96445	4.96603	-.00158	-.032	5.904	5.842	.062	1.04
B	298.1386	8.39404	8.39185	.00219	.026	10.617	10.619	-.002	-.02
B	298.1386	8.39409	8.39185	.00224	.027	10.617	10.620	-.002	-.02
B	280.0394	4.84374	4.84224	.00150	.031	10.626	10.633	-.006	-.06
B	279.5394	4.75176	4.75086	.00090	.019	10.627	10.631	-.004	-.04
B	298.1386	7.22930	7.23118	-.00188	-.026	8.750	8.745	.005	.06
B	298.1386	7.22931	7.23118	-.00187	-.026	8.750	8.745	.005	.06
B	282.3693	5.04648	5.04602	.00046	.009	8.757	8.794	-.037	-.42
B	282.3333	5.04177	5.04143	.00034	.007	8.757	8.786	-.030	-.34
B	282.2143	5.02663	5.02633	.00030	.006	8.757	8.791	-.034	-.39
B	282.1893	5.02345	5.02317	.00028	.006	8.757	8.791	-.034	-.39
B	282.1893	5.02348	5.02317	.00031	.006	8.757	8.794	-.038	-.43
B	282.1893	5.02345	5.02317	.00028	.006	8.757	8.791	-.034	-.39
B	303.1500	7.44551	7.44692	-.00141	-.019	7.602	7.599	.004	.05
B	298.1500	6.86299	6.86327	-.00028	-.004	7.604	7.603	.001	.01
B	298.1500	6.86292	6.86327	-.00035	-.005	7.604	7.603	.001	.02
B	293.1500	6.28229	6.28176	.00053	.008	7.606	7.609	-.003	-.04
B	289.1500	5.81975	5.81893	.00082	.014	7.607	7.615	-.008	-.10
B	285.6500	5.41734	5.41658	.00076	.014	7.609	7.626	-.018	-.23
B	284.6500	5.30307	5.30225	.00082	.016	7.609	7.639	-.030	-.39
B	283.6500	5.18886	5.18828	.00058	.011	7.609	7.651	-.042	-.55
B	283.1500	5.13189	5.13146	.00043	.008	7.609	7.666	-.056	-.74
B	298.1386	6.56543	6.56455	.00088	.013	6.511	6.514	-.003	-.05
B	298.1386	6.56551	6.56455	.00096	.015	6.511	6.515	-.003	-.05
B	293.1388	6.08762	6.08714	.00048	.008	6.513	6.515	-.003	-.04
B	289.1390	5.70295	5.70280	.00015	.003	6.514	6.515	-.001	-.02
B	285.6391	5.36362	5.36356	.00006	.001	6.515	6.516	-.001	-.02
B	283.6392	5.16741	5.16734	.00007	.001	6.516	6.518	-.002	-.04
B	282.3333	5.03714	5.03699	.00015	.003	6.516	6.534	-.018	-.28
B	282.2393	5.02761	5.02745	.00016	.003	6.516	6.540	-.024	-.37
B	282.1893	5.02242	5.02236	.00006	.001	6.516	6.526	-.010	-.16
B	298.1386	6.38518	6.38351	.00167	.026	5.894	5.900	-.005	-.09
B	298.1386	6.38512	6.38351	.00161	.025	5.894	5.899	-.005	-.09
B	293.1388	5.96215	5.96127	.00088	.015	5.896	5.899	-.004	-.07
B	289.1390	5.62038	5.61984	.00054	.010	5.897	5.900	-.004	-.06
B	285.6391	5.31734	5.31702	.00032	.006	5.898	5.901	-.003	-.06
B	283.6392	5.14149	5.14121	.00028	.006	5.898	5.903	-.005	-.08
B	282.3333	5.02474	5.02447	.00027	.005	5.898	5.906	-.007	-.13
B	282.2393	5.01624	5.01598	.00026	.005	5.899	5.906	-.008	-.13
B	282.1393	5.00720	5.00692	.00028	.006	5.899	5.907	-.008	-.14
B	281.9393	4.98901	4.98876	.00025	.005	5.899	5.907	-.009	-.15
B	281.8393	4.97992	4.97964	.00028	.006	5.899	5.909	-.011	-.18
B	281.7393	4.97071	4.97049	.00022	.004	5.899	5.907	-.009	-.15
B	281.6893	4.96579	4.96591	-.00012	-.002	5.899	5.894	.005	.09
B	281.6393	4.96035	4.96132	-.00097	-.020	5.899	5.858	.040	.68

TABLE BI. (Continued)

EXP.ID	TEMPERATURE K	PRESSURE MPA				DENSITY MOL/DM3			
		EXP	CALC	DIFF	%DIFF	EXP	CALC	DIFF	%DIFF
1	282.3500	5.04197	5.04084	.00113	.022	7.635	8.563	-.928	-12.15
1	282.3600	5.04288	5.04197	.00091	.018	7.635	8.499	-.864	-11.32
1	282.3700	5.04403	5.04311	.00092	.018	7.635	8.483	-.848	-11.11
1	282.3800	5.04518	5.04424	.00094	.019	7.635	8.467	-.832	-10.90
1	282.3900	5.04626	5.04537	.00089	.018	7.635	8.433	-.798	-10.46
1	282.4000	5.04744	5.04650	.00094	.019	7.635	8.425	-.790	-10.34
1	282.4100	5.04858	5.04763	.00095	.019	7.635	8.406	-.771	-10.10
1	282.4200	5.04978	5.04876	.00102	.020	7.635	8.403	-.768	-10.06
1	282.4300	5.05083	5.04990	.00093	.018	7.635	8.360	-.725	-9.50
1	282.4500	5.05324	5.05216	.00108	.021	7.635	8.359	-.724	-9.49
1	282.5500	5.06452	5.06349	.00103	.020	7.635	8.159	-.524	-6.87
1	282.6500	5.07586	5.07483	.00103	.020	7.635	8.019	-.384	-5.02
1	282.7500	5.08723	5.08618	.00105	.021	7.635	7.930	-.295	-3.86
1	282.8500	5.09858	5.09754	.00104	.020	7.635	7.865	-.230	-3.01
1	282.9500	5.10994	5.10890	.00104	.020	7.635	7.821	-.186	-2.44
1	283.0500	5.12136	5.12028	.00108	.021	7.635	7.798	-.163	-2.13
1	283.1500	5.13277	5.13165	.00112	.022	7.635	7.778	-.143	-1.87
1	283.3500	5.15567	5.15443	.00124	.024	7.635	7.757	-.122	-1.59
1	284.1500	5.24722	5.24574	.00148	.028	7.635	7.706	-.071	-.93
1	285.1500	5.36197	5.36030	.00167	.031	7.635	7.682	-.047	-.62
1	286.1500	5.47701	5.47522	.00179	.033	7.635	7.670	-.035	-.46
1	287.1500	5.59247	5.59047	.00200	.036	7.635	7.664	-.029	-.39
1	288.1500	5.70808	5.70600	.00208	.036	7.635	7.659	-.024	-.32
1	293.1500	6.28886	6.28697	.00189	.030	7.635	7.646	-.011	-.14
1	298.1500	6.87365	6.87194	.00171	.025	7.635	7.641	-.006	-.08
1	303.1500	7.46149	7.45959	.00190	.025	7.635	7.640	-.005	-.06
1	303.1500	6.84890	6.84568	.00322	.047	6.000	6.008	-.008	-.14
1	303.1500	7.03963	7.03704	.00259	.037	6.500	6.507	-.007	-.11
1	303.1500	7.22319	7.22142	.00177	.025	7.000	7.005	-.005	-.07
1	303.1500	7.40872	7.40769	.00103	.014	7.500	7.503	-.003	-.04
1	303.1500	7.60625	7.60600	.00025	.003	8.000	8.001	-.001	-.01
1	303.1500	7.82674	7.82818	-.00144	-.018	8.500	8.497	.003	.04
1	303.1500	8.08490	8.08845	-.00355	-.044	9.000	8.994	.006	.07
1	303.1500	8.39804	8.40388	-.00584	-.069	9.500	9.492	.008	.09
1	303.1500	8.79026	8.79482	-.00456	-.052	10.000	9.995	.005	.05
1	303.1500	9.28873	9.28491	.00382	.041	10.500	10.503	-.003	-.03
1	298.1500	6.42028	6.41712	.00316	.049	6.000	6.010	-.010	-.17
1	298.1500	6.56526	6.56251	.00275	.042	6.500	6.510	-.010	-.15
1	298.1500	6.70124	6.69887	.00237	.035	7.000	7.009	-.009	-.13
1	298.1500	6.83652	6.83436	.00216	.032	7.500	7.508	-.008	-.10
1	298.1500	6.98029	6.97806	.00223	.032	8.000	8.007	-.007	-.09
1	298.1500	7.14174	7.14057	.00117	.016	8.500	8.503	-.003	-.04
1	298.1500	7.33468	7.33480	-.00012	-.002	9.000	9.000	.000	.00
1	298.1500	7.57508	7.57669	-.00161	-.021	9.500	9.497	.003	.03
1	298.1500	7.88281	7.88568	-.00287	-.036	10.000	9.996	.004	.04
1	298.1500	8.29048	8.28482	.00566	.068	10.500	10.506	-.006	-.06
1	293.1500	5.98672	5.98523	.00149	.025	6.000	6.007	-.007	-.12
1	293.1500	6.08774	6.08581	.00193	.032	6.500	6.510	-.010	-.16
1	293.1500	6.17782	6.17598	.00184	.030	7.000	7.011	-.011	-.15
1	293.1500	6.26526	6.26302	.00224	.036	7.500	7.513	-.013	-.17
1	293.1500	6.35743	6.35471	.00272	.043	8.000	8.014	-.014	-.17
1	293.1500	6.46250	6.46012	.00238	.037	8.500	8.510	-.010	-.12
1	293.1500	6.59227	6.59055	.00172	.026	9.000	9.006	-.006	-.06
1	293.1500	6.76196	6.76051	.00145	.021	9.500	9.504	-.004	-.04
1	293.1500	6.99048	6.98849	.00199	.028	10.000	10.004	-.004	-.04
1	293.1500	7.30284	7.29694	.00590	.081	10.500	10.508	-.008	-.08

Table BI. (Continued)

EXP.ID	TEMPERATURE	PRESSURE				DENSITY			
	K	MPA				MOL/DM3			
		EXP	CALC	DIFF	%DIFF	EXP	CALC	DIFF	%DIFF
1	288.1500	5.54964	5.54851	.00113	.020	6.000	6.009	-.009	-.15
1	288.1500	5.60692	5.60585	.00107	.019	6.500	6.511	-.011	-.16
1	288.1500	5.65366	5.65247	.00119	.021	7.000	7.014	-.014	-.20
1	288.1500	5.69652	5.69461	.00191	.033	7.500	7.523	-.023	-.30
1	288.1500	5.74088	5.73834	.00254	.044	8.000	8.027	-.027	-.34
1	288.1500	5.79342	5.79053	.00289	.050	8.500	8.524	-.024	-.28
1	288.1500	5.86313	5.86034	.00279	.048	9.000	9.017	-.017	-.19
1	288.1500	5.96313	5.96052	.00261	.044	9.500	9.511	-.011	-.11
1	288.1500	6.11098	6.10843	.00255	.042	10.000	10.007	-.007	-.07
1	288.1500	6.33296	6.32614	.00682	.108	10.500	10.513	-.013	-.12
1	288.1500	5.67503	5.67373	.00130	.023	7.250	7.266	-.016	-.21
1	288.1500	5.63106	5.63009	.00097	.017	6.750	6.760	-.010	-.15
1	284.1500	5.57352	5.56745	.00607	.109	10.500	10.516	-.016	-.16
1	284.1500	5.42568	5.42329	.00239	.044	10.000	10.011	-.011	-.11
1	284.1500	5.34153	5.33931	.00222	.042	9.500	9.518	-.018	-.19
1	284.1500	5.29548	5.29321	.00227	.043	9.000	9.033	-.033	-.37
1	284.1500	5.27042	5.26832	.00210	.040	8.500	8.555	-.055	-.65
1	284.1500	5.25551	5.25371	.00180	.034	8.000	8.074	-.074	-.92
1	284.1500	5.24964	5.24814	.00150	.029	7.750	7.820	-.070	-.90
1	284.1500	5.24427	5.24298	.00129	.025	7.500	7.563	-.063	-.84
1	284.1500	5.23885	5.23777	.00108	.021	7.250	7.301	-.051	-.70
1	284.1500	5.23306	5.23207	.00099	.019	7.000	7.041	-.041	-.59
1	284.1500	5.22627	5.22539	.00088	.017	6.750	6.780	-.030	-.45
1	284.1500	5.21797	5.21715	.00082	.016	6.500	6.522	-.022	-.34
1	284.1500	5.19400	5.19304	.00096	.018	6.000	6.016	-.016	-.26
1	284.1500	5.15364	5.15266	.00098	.019	5.500	5.510	-.010	-.17
1	283.1500	5.10345	5.10259	.00086	.017	6.000	6.020	-.020	-.33
1	283.1500	5.11928	5.11850	.00078	.015	6.500	6.537	-.037	-.57
1	283.1500	5.12707	5.12620	.00087	.017	7.000	7.083	-.083	-1.19
1	283.1500	5.13169	5.13062	.00107	.021	7.500	7.640	-.140	-1.86
1	283.1500	5.13594	5.13469	.00125	.024	8.000	8.125	-.125	-1.56
1	283.1500	5.14271	5.14122	.00149	.029	8.500	8.576	-.076	-.90
1	283.1500	5.15732	5.15556	.00176	.034	9.000	9.040	-.040	-.44
1	283.1500	5.18994	5.18820	.00174	.033	9.500	9.518	-.018	-.19
1	283.1500	5.25792	5.25591	.00201	.038	10.000	10.011	-.011	-.11
1	283.1500	5.38690	5.38124	.00566	.105	10.500	10.517	-.017	-.16
1	283.1500	5.13368	5.13255	.00113	.022	7.750	7.888	-.138	-1.78
1	283.1500	5.12950	5.12861	.00089	.017	7.250	7.357	-.107	-1.47
1	283.1500	5.12379	5.12301	.00078	.015	6.750	6.804	-.054	-.80
1	283.3500	5.18470	5.18289	.00181	.035	9.000	9.037	-.037	-.41
1	283.3500	5.16820	5.16646	.00174	.034	8.500	8.575	-.075	-.88
1	283.3500	5.15981	5.15838	.00143	.028	8.000	8.112	-.112	-1.40
1	283.3500	5.15692	5.15560	.00132	.026	7.750	7.874	-.124	-1.59
1	283.3500	5.15419	5.15308	.00111	.022	7.500	7.611	-.111	-1.48
1	283.3500	5.15144	5.15047	.00097	.019	7.250	7.340	-.090	-1.25
1	283.3500	5.14829	5.14743	.00086	.017	7.000	7.065	-.065	-.93
1	283.3500	5.14440	5.14356	.00084	.016	6.750	6.798	-.048	-.71
1	283.3500	5.13908	5.13832	.00076	.015	6.500	6.532	-.032	-.49
1	283.3500	5.12159	5.12076	.00083	.016	6.000	6.018	-.018	-.29
1	283.3500	5.08842	5.08745	.00097	.019	5.500	5.511	-.011	-.20
1	282.5500	5.06449	5.06351	.00098	.019	7.650	8.150	-.500	-6.53
1	282.5500	5.06446	5.06344	.00102	.020	7.600	8.140	-.540	-7.10
1	282.6500	5.08928	5.08779	.00149	.029	9.000	9.047	-.047	-.52
1	282.6500	5.07993	5.07866	.00127	.025	8.500	8.615	-.115	-1.35
1	282.6500	5.07695	5.07580	.00115	.023	8.000	8.270	-.270	-3.37
1	282.6500	5.07616	5.07511	.00105	.021	7.750	8.101	-.351	-4.53

Table BI. (Continued)

EXP.ID	TEMPERATURE K	PRESSURE MPA				DENSITY MOL/DM3			
		EXP	CALC	DIFF	%DIFF	EXP	CALC	DIFF	%DIFF
1	282.6500	5.07590	5.07487	.00103	.020	7.650	8.030	-.380	-4.97
1	282.6500	5.07575	5.07475	.00100	.020	7.600	7.985	-.385	-5.07
1	282.6500	5.07556	5.07452	.00104	.021	7.500	7.923	-.423	-5.63
1	282.6500	5.07481	5.07386	.00095	.019	7.250	7.625	-.375	-5.17
1	282.6500	5.07383	5.07292	.00091	.018	7.000	7.240	-.240	-3.43
1	282.6500	5.07221	5.07136	.00085	.017	6.750	6.870	-.120	-1.77
1	282.6500	5.06950	5.06869	.00081	.016	6.500	6.563	-.063	-.96
1	282.6500	5.05791	5.05694	.00097	.019	6.000	6.028	-.028	-.46
1	282.8500	5.10045	5.09928	.00117	.023	8.000	8.183	-.183	-2.28
1	282.8500	5.09920	5.09804	.00116	.023	7.750	7.985	-.235	-3.03
1	282.8500	5.09867	5.09760	.00107	.021	7.650	7.883	-.233	-3.05
1	282.8500	5.09845	5.09739	.00106	.021	7.600	7.838	-.238	-3.13
1	282.8500	5.09804	5.09696	.00108	.021	7.500	7.749	-.249	-3.32
1	282.8500	5.09675	5.09579	.00096	.019	7.250	7.453	-.203	-2.80
1	282.8500	5.09507	5.09428	.00079	.016	7.000	7.121	-.121	-1.73
1	282.1500	5.20165	5.19681	.00484	.093	10.500	10.517	-.017	-.16
1	282.1500	5.09211	5.09070	.00141	.028	10.000	10.009	-.009	-.09
1	282.1500	5.04078	5.03976	.00102	.020	9.500	9.516	-.016	-.17
1	282.1500	5.02694	5.02591	.00103	.021	9.200	9.231	-.031	-.34
1	282.1500	5.02425	5.02313	.00112	.022	9.100	9.144	-.044	-.48
1	282.1500	5.02198	5.02105	.00093	.018	9.000	9.048	-.048	-.54
1	282.1500	5.01959	5.01856	.00103	.021	8.802	8.902	-.100	-1.14
1	282.1500	5.01843	5.01757	.00086	.017	6.400			
1	282.1500	5.01741	5.01655	.00086	.017	6.300	6.382	-.082	-1.30
1	282.1500	5.01606	5.01514	.00092	.018	6.200	6.262	-.062	-1.00
1	282.1500	5.01181	5.01091	.00090	.018	6.000	6.035	-.035	-.59
1	282.1500	5.00892	5.00794	.00098	.020	5.900	5.931	-.031	-.52
1	282.1500	5.00530	5.00431	.00099	.020	5.800	5.825	-.025	-.44
1	282.1500	4.98973	4.98863	.00110	.022	5.500	5.517	-.017	-.31
1	282.2500	5.03540	5.03429	.00111	.022	9.000	9.051	-.051	-.56
1	282.2500	5.03228	5.03127	.00101	.020	8.800	8.882	-.082	-.93
1	282.2500	5.03142	5.03039	.00103	.020	8.700	8.814	-.114	-1.31
1	282.2500	5.03089	5.02982	.00107	.021	8.600	8.761	-.161	-1.88
1	282.2500	5.03035	5.02956	.00079	.016	6.750			
1	282.2500	5.02995	5.02904	.00091	.018	6.600			
1	282.2500	5.02939	5.02843	.00096	.019	6.500	6.687	-.187	-2.88
1	282.2500	5.02842	5.02755	.00087	.017	6.400	6.499	-.099	-1.55
1	282.2500	5.02118	5.02016	.00102	.020	6.000	6.037	-.037	-.62
1	282.2500	4.99803	4.99692	.00111	.022	5.500	5.517	-.017	-.30
1	282.3500	5.23803	5.23354	.00449	.086	10.500	10.515	-.015	-.14
1	282.3500	5.12506	5.12355	.00151	.030	10.000	10.010	-.010	-.10
1	282.3500	5.07067	5.06918	.00149	.029	9.500	9.521	-.021	-.22
1	282.3500	5.04902	5.04759	.00143	.028	9.000	9.058	-.058	-.64
1	282.3500	5.04295	5.04166	.00129	.026	8.500	8.697	-.197	-2.32
1	282.3500	5.04200	5.04087	.00113	.023	8.000	8.568	-.568	-7.10
1	282.3500	5.04200	5.04084	.00116	.023	7.750	8.568	-.818	-10.55
1	282.3500	5.04194	5.04084	.00110	.022	7.500	8.557	-1.057	-14.10
1	282.3500	5.04186	5.04082	.00104	.021	7.250	8.542	-1.292	-17.82
1	282.3500	5.04178	5.04067	.00111	.022	7.000	8.526	-1.526	-21.80
1	282.3500	5.03966	5.03854	.00112	.022	6.500	6.657	-.157	-2.42
1	282.3500	5.03051	5.02938	.00113	.022	6.000	6.039	-.039	-.64
1	282.3500	5.00613	5.00520	.00093	.019	5.500	5.513	-.013	-.25
1	282.4000	5.04746	5.04650	.00096	.019	7.650	8.430	-.780	-10.19
1	282.4000	5.04741	5.04649	.00092	.018	7.600	8.417	-.817	-10.75
1	282.4500	5.05343	5.05245	.00098	.019	8.000	8.405	-.405	-5.07
1	282.4500	5.05322	5.05224	.00098	.019	7.750	8.354	-.604	-7.80

Table BI. (Continued)

EXP.ID	TEMPERATURE	PRESSURE				DENSITY			
	K	MPA				MOL/DM3			
		EXP	CALC	DIFF	%DIFF	EXP	CALC	DIFF	%DIFF
1	282.4500	5.05309	5.05217	.00092	.018	7.650	8.317	-.667	-8.72
1	282.4500	5.05309	5.05214	.00095	.019	7.600	8.317	-.717	-9.44
1	282.4500	5.05303	5.05208	.00095	.019	7.500	8.299	-.799	-10.65
1	282.4500	5.05283	5.05187	.00096	.019	7.250	8.225	-.975	-13.45
1	282.4500	5.05235	5.05146	.00089	.018	7.000	7.901	-.901	-12.87
1	281.1500	5.01853	5.01448	.00405	.081	10.500	10.516	-.016	-.16
1	281.1500	4.92924	4.92831	.00093	.019	10.000	10.008	-.008	-.08
1	281.1500	4.91885	4.91817	.00068	.014	9.899	9.906	-.007	-.07
1	281.1500	4.91325	4.91263	.00062	.013	9.833	9.841	-.008	-.08
1	281.1500	4.91168	4.91113	.00055	.011	9.813	9.821	-.007	-.07
1	281.1500	4.91022	4.90969	.00053	.011	9.794	9.801	-.007	-.08
1	281.1500	4.90938	4.90876	.00062	.013	9.780	9.789	-.009	-.09
1	281.1500	4.90885	4.90831	.00054	.011	9.774	9.782	-.008	-.08
1	281.1500	4.90837	4.90788	.00049	.010	9.767	9.775	-.007	-.07
1	281.6500	4.97260	4.97177	.00083	.017	9.592	9.606	-.014	-.15
1	281.6500	4.96918	4.96838	.00080	.016	9.530	9.546	-.016	-.16
1	281.6500	4.96762	4.96693	.00069	.014	9.500	9.515	-.015	-.15
1	281.6500	4.96606	4.96529	.00077	.016	9.463	9.481	-.018	-.19
1	281.6500	4.96472	4.96406	.00066	.013	9.432	9.449	-.017	-.18
1	281.6500	4.96393	4.96317	.00076	.015	9.408	9.429	-.021	-.22
1	281.6500	4.96300	4.96233	.00067	.013	5.900			
1	281.6500	4.96067	4.95970	.00097	.020	5.800	5.834	-.034	-.58
1	281.6500	4.95740	4.95631	.00109	.022	5.700	5.730	-.030	-.52
1	280.1500	4.83757	4.83472	.00285	.059	10.500	10.514	-.014	-.13
1	280.1500	4.81814	4.81631	.00183	.038	10.400	10.411	-.011	-.10
1	280.1500	4.81214	4.81065	.00149	.031	10.366	10.375	-.009	-.09
1	280.1500	4.80596	4.80505	.00091	.019	10.329	10.335	-.006	-.06
1	280.1500	4.80263	4.80183	.00080	.017	10.307	10.313	-.006	-.05
2	283.6500	5.14322	5.14253	.00069	.013	5.904	5.916	-.012	-.20
2	285.6500	5.31888	5.31860	.00028	.005	5.904	5.907	-.003	-.05
2	289.1500	5.62216	5.62196	.00020	.004	5.904	5.906	-.001	-.02
2	293.1500	5.96416	5.96417	-.00001	-.000	5.904	5.904	.000	.00
2	298.1500	6.38814	6.38761	.00053	.008	5.904	5.906	-.002	-.03
2	283.6500	5.16045	5.15960	.00085	.017	6.254	6.276	-.022	-.35
2	285.6500	5.34820	5.34745	.00075	.014	6.254	6.264	-.010	-.17
2	289.1500	5.67198	5.67157	.00041	.007	6.254	6.257	-.003	-.05
2	293.1500	6.03833	6.03806	.00027	.004	6.254	6.255	-.001	-.02
2	298.1500	6.49362	6.49257	.00105	.016	6.254	6.258	-.004	-.06
2	283.6500	5.16362	5.16340	.00022	.004	6.357	6.363	-.006	-.10
2	285.6500	5.35447	5.35460	-.00013	-.002	6.357	6.355	.002	.03
2	289.1500	5.68487	5.68477	.00010	.002	6.357	6.358	-.001	-.01
2	293.1500	6.05796	6.05841	-.00045	-.007	6.357	6.355	.002	.04
2	298.1500	6.52247	6.52218	.00029	.005	6.357	6.358	-.001	-.02
2	283.6500	5.17651	5.17571	.00080	.015	6.815	6.855	-.040	-.58
2	285.6500	5.38111	5.38112	-.00001	-.000	6.815	6.815	.000	.00
2	289.1500	5.73825	5.73774	.00051	.009	6.815	6.820	-.005	-.07
2	293.1500	6.14315	6.14340	-.00025	-.004	6.815	6.814	.001	.02
2	298.1500	6.64913	6.64900	.00013	.002	6.815	6.816	-.000	-.01
2	283.6500	5.17738	5.17668	.00070	.013	6.863	6.899	-.036	-.52
2	285.6500	5.38421	5.38352	.00069	.013	6.863	6.877	-.014	-.20
2	289.1500	5.74278	5.74291	-.00013	-.002	6.863	6.862	.001	.02
2	293.1500	6.15210	6.15195	.00015	.002	6.863	6.864	-.001	-.01
2	298.1500	6.66181	6.66204	-.00023	-.003	6.863	6.862	.001	.01
2	283.6500	5.18517	5.18372	.00145	.028	7.284	7.385	-.101	-1.39
2	285.6500	5.40368	5.40273	.00095	.018	7.284	7.306	-.022	-.30

Table BI. (Continued)

EXP.ID	TEMPERATURE	PRESSURE				DENSITY			
	K	MPA				MOL/DM3			
		EXP	CALC	DIFF	%DIFF	EXP	CALC	DIFF	%DIFF
2	289.1500	5.78719	5.78619	.00100	.017	7.284	7.294	-.010	-.14
2	293.1500	6.22585	6.22530	.00055	.009	7.284	7.287	-.003	-.04
2	298.1500	6.77549	6.77535	.00014	.002	7.284	7.284	-.000	-.01
2	283.6500	5.18330	5.18655	-.00325	-.063	7.484	7.255	.229	3.06
2	285.6500	5.41285	5.41128	.00157	.029	7.484	7.521	-.037	-.49
2	289.1500	5.80755	5.80640	.00115	.020	7.484	7.496	-.011	-.15
2	293.1500	6.26115	6.26025	.00090	.014	7.484	7.489	-.005	-.07
2	298.1500	6.82979	6.83002	-.00023	-.003	7.484	7.483	.001	.01
2	283.6500	5.19154	5.18979	.00175	.034	7.718	7.839	-.121	-1.57
2	285.6500	5.42238	5.42132	.00106	.020	7.718	7.742	-.024	-.31
2	289.1500	5.83135	5.83039	.00096	.016	7.718	7.727	-.009	-.12
2	293.1500	6.30224	6.30193	.00031	.005	7.718	7.720	-.002	-.02
2	298.1500	6.89369	6.89543	-.00174	-.025	7.718	7.712	.006	.08
2	283.6500	5.19785	5.19576	.00209	.040	8.102	8.214	-.112	-1.38
2	285.6500	5.44163	5.43920	.00243	.045	8.102	8.149	-.047	-.58
2	289.1500	5.87440	5.87253	.00187	.032	8.102	8.118	-.016	-.20
2	293.1500	6.37711	6.37473	.00238	.037	8.102	8.114	-.012	-.15
2	298.1500	7.00764	7.00923	-.00159	-.023	8.102	8.097	.005	.06
2	283.6500	5.21258	5.21123	.00135	.026	8.713	8.749	-.036	-.42
2	285.6500	5.47945	5.47747	.00198	.036	8.713	8.738	-.025	-.28
2	289.1500	5.95566	5.95499	.00067	.011	8.713	8.717	-.004	-.05
2	293.1500	6.51140	6.51178	-.00038	-.006	8.713	8.711	.001	.02
2	298.1500	7.21383	7.21847	-.00464	-.064	8.713	8.701	.012	.14
2	283.6500	5.21950	5.21655	.00295	.056	8.846	8.910	-.064	-.73
2	285.6500	5.49165	5.48863	.00302	.055	8.846	8.879	-.033	-.38
2	289.1500	5.97733	5.97699	.00034	.006	8.846	8.848	-.002	-.02
2	293.1500	6.54496	6.54687	-.00191	-.029	8.846	8.839	.007	.08
2	298.1500	7.26451	7.27067	-.00616	-.085	8.846	8.831	.015	.17
2	283.6500	5.24750	5.24662	.00088	.017	9.326	9.336	-.010	-.11
2	285.6500	5.54389	5.54281	.00108	.020	9.326	9.334	-.008	-.08
2	289.1500	6.07423	6.07457	-.00034	-.006	9.326	9.325	.001	.02
2	293.1500	6.69265	6.69588	-.00323	-.048	9.326	9.317	.009	.10
2	298.1500	7.47712	7.48608	-.00896	-.120	9.326	9.308	.018	.19
2	283.6500	5.28952	5.28946	.00006	.001	9.708	9.709	-.000	-.00
2	285.6500	5.61008	5.60834	.00174	.031	9.708	9.717	-.008	-.09
2	289.1500	6.17898	6.17981	-.00083	-.014	9.708	9.705	.003	.03
2	293.1500	6.84089	6.84716	-.00627	-.092	9.708	9.694	.014	.15
2	298.1500	7.68440	7.69590	-.01150	-.150	9.708	9.689	.019	.20
2	283.6500	5.50719	5.50544	.00175	.032	10.587	10.591	-.005	-.04
2	285.6500	5.89065	5.88784	.00281	.048	10.587	10.593	-.006	-.06
2	289.1500	6.56807	6.56873	-.00066	-.010	10.587	10.586	.001	.01
2	293.1500	7.35645	7.36051	-.00406	-.055	10.587	10.581	.005	.05
2	298.1500	8.35838	8.36512	-.00674	-.081	10.587	10.580	.007	.07
3	283.1700	5.10770	5.10700	.00070	.014	6.060	6.077	-.017	-.28
3	287.3700	5.48740	5.48663	.00077	.014	6.060	6.067	-.007	-.11
3	293.3400	6.01530	6.01477	.00053	.009	6.060	6.062	-.002	-.04
3	298.1900	6.43890	6.43758	.00132	.021	6.056	6.060	-.004	-.07
3	285.5400	5.42540	5.42385	.00155	.029	8.063	8.095	-.032	-.40
3	291.9000	6.21100	6.21050	.00050	.008	8.063	8.066	-.003	-.04
3	292.7500	6.31690	6.31689	.00001	.000	8.063	8.063	-.000	-.00
3	293.1500	7.20000	7.20233	-.00233	-.032	10.362	10.358	.004	.03
3	293.6900	7.30330	7.30549	-.00219	-.030	10.362	10.359	.003	.03
3	298.1400	7.99060	8.02350	-.03290	-.412	10.190	10.147	.043	.42
3	298.1400	6.99690	6.99876	-.00186	-.027	8.072	8.066	.006	.07
3	298.1400	6.69610	6.69971	-.00361	-.054	7.007	6.994	.013	.19

Table BII. Comparison of experimental saturation pressures with the present formulation.

EXP ID.	TEMPERATURE K	PRESSURE MPA				DENSITY MOL/DM3
		EXP	CALC	DIFF	%DIFF	
1	279.1500	4.69367	4.69366	.00001	.0002	
1	280.1500	4.79973	4.79939	.00034	.007	
1	281.1500	4.90813	4.90753	.00006	.012	
1	281.6500	4.96331	4.96256	.00075	.015	
1	282.1500	5.01915	5.01831	.00084	.017	
1	282.2000	5.02481	5.02393	.00088	.018	
1	282.2500	5.03046	5.02956	.00090	.018	
1	282.3000	5.03612	5.03519	.00093	.018	
A	279.4394	4.72372	4.72402	-.00030	-.006	10.552
A	280.6394	4.85179	4.85200	-.00021	-.004	10.032
A	280.5894	4.84640	4.84660	-.00020	-.004	10.032
A	280.5844	4.84596	4.84606	-.00010	-.002	10.032
A	281.7393	4.97264	4.97246	.00018	.004	9.293
A	281.6893	4.96707	4.96692	.00015	.003	9.293
A	281.7393	4.97271	4.97246	.00025	.005	9.293
A	282.0693	5.00948	5.00933	.00015	.003	8.917
A	282.0733	5.00997	5.00985	.00012	.002	8.917
A	282.0493	5.00729	5.00702	.00027	.005	8.917
A	282.1632	5.02002	5.01994	.00008	.002	8.764
A	282.1380	5.01718	5.01696	.00022	.004	8.764
A	281.1500	4.90746	4.90753	-.00007	-.001	7.680
A	282.0500	5.00720	5.00710	.00010	.002	7.680
A	281.7500	4.97377	4.97365	.00012	.002	7.680
A	281.4500	4.94055	4.94047	.00008	.002	7.680
A	281.7500	4.97373	4.97365	.00008	.002	7.680
A	282.3440	5.04018	5.04016	.00002	.000	7.680
A	282.3440	5.04019	5.04016	.00003	.001	7.680
A	282.3440	5.04024	5.04016	.00008	.002	7.680
A	281.7500	4.97366	4.97365	.00001	.000	7.629
A	282.3440	5.04007	5.04016	-.00009	-.002	7.629
A	281.7500	4.97366	4.97365	.00001	.000	7.590
A	281.7500	4.97365	4.97365	-.00000	-.000	7.590
A	282.3440	5.04016	5.04016	.00000	.000	7.590
A	282.3440	5.04011	5.04016	-.00005	-.001	7.507
A	280.6394	4.85177	4.85200	-.00023	-.005	6.585
A	281.6893	4.96654	4.96692	-.00038	-.008	6.585
A	281.6893	4.96655	4.96692	-.00037	-.007	6.585
A	281.1393	4.90608	4.90636	-.00028	-.006	6.585
A	281.4393	4.93896	4.93929	-.00033	-.007	6.585
A	281.4393	4.93780	4.93929	-.00149	-.030	5.904
A	281.4393	4.93779	4.93929	-.00150	-.030	5.904
A	280.6394	4.85132	4.85200	-.00068	-.014	5.904
A	279.4394	4.72339	4.72402	-.00063	-.013	5.904
B	282.1393	5.01753	5.01711	.00042	.008	8.757
B	282.0893	5.01192	5.01150	.00042	.008	8.757
B	282.0393	5.00628	5.00590	.00038	.008	8.757
B	281.1500	4.90747	4.90753	-.00006	-.001	7.610
B	281.4500	4.94046	4.94047	-.00001	-.000	7.610
B	281.7500	4.97369	4.97365	.00004	.001	7.610
B	282.0500	5.00718	5.00710	.00008	.002	7.610
B	282.0500	5.00724	5.00710	.00014	.003	7.610
B	282.1500	5.01841	5.01831	.00010	.002	7.610
B	282.2500	5.02967	5.02956	.00011	.002	7.610
B	282.3440	5.04045	5.04016	.00029	.006	7.610
B	282.3440	5.04044	5.04016	.00028	.005	7.610
B	281.7500	4.97377	4.97365	.00012	.002	7.610
B	281.7500	4.97369	4.97365	.00004	.001	7.610
B	281.6893	4.96693	4.96692	.00001	.000	6.516
B	281.4393	4.93935	4.93929	.00006	.001	6.516
B	282.1893	5.02242	5.02236	.00006	.001	6.516
B	282.1393	5.01690	5.01711	-.00021	-.004	6.516
B	282.0893	5.01135	5.01150	-.00015	-.003	6.516
B	282.0393	5.00573	5.00590	-.00017	-.003	6.516
B	281.7393	4.97239	4.97246	-.00007	-.001	6.516
B	281.4393	4.93925	4.93929	-.00004	-.001	6.516
B	281.4393	4.93873	4.93929	-.00056	-.011	5.899
B	281.1393	4.90599	4.90636	-.00037	-.007	5.899

*

Table BIII. Comparison of experimental coexisting densities with the present formulation.

EXP ID.	TEMPERATURE K	DENSITY MOL/DM3 EXP	CALC	DIFF	%DIFF
1	279.150	10.674	10.692	-.018	-.17
1	279.150	4.724	4.711	.013	.28
1	280.150	10.290	10.290	.000	.00
1	280.150	5.071	5.073	-.002	-.05
1	281.150	9.767	9.762	.005	.05
1	281.150	5.546	5.559	-.013	-.24
1	281.650	9.387	9.390	-.003	-.04
1	281.650	5.911	5.910	.001	.02
1	282.150	8.780	8.770	.010	.12
1	282.150	6.489	6.509	-.020	-.30
A	279.523	10.552	10.551	.001	.01
A	280.697	10.032	10.024	.008	.08
A	281.781	9.293	9.267	.026	.28
A	282.084	8.917	8.887	.030	.34
A	282.165	8.764	8.739	.025	.29
A	281.630	5.904	5.893	.011	.18
B	281.660	5.899	5.919	-.020	-.34
B	282.165	8.757	8.739	.018	.20
B	279.317	10.627	10.630	-.003	-.03

Table BIV. Comparison of the experimental speed of sound data with the present formulation.

EXP.ID	DENSITY	TEMPERATURE	SOUND VELOCITY			
	MOL/DM3	K	M/S			
			EXP	CALC	DIFF	%DIFF
GAM	5.500	298.15	241.910	241.055	.855	.35
GAM	5.549	293.15	232.932	232.661	.271	.12
GAM	5.580	288.15	222.628	222.961	-.333	-.15
GAM	5.603	284.15	212.166	212.958	-.792	-.37
GAM	5.613	282.35	205.512	206.612	-1.100	-.54
GAM	5.616	281.65	201.862	203.264	-1.402	-.69
GAM	6.000	298.15	241.573	240.766	.807	.33
GAM	6.057	293.15	231.574	231.315	.259	.11
GAM	6.099	288.15	219.513	219.808	-.295	-.13
GAM	6.125	284.15	205.844	206.628	-.784	-.38
GAM	6.136	282.35	194.091	195.808	-1.717	-.88
GAM	6.500	298.15	242.772	242.006	.766	.32
GAM	6.570	293.15	231.740	231.462	.278	.12
GAM	6.619	288.15	217.774	217.942	-.168	-.08
GAM	6.648	284.15	200.183	200.702	-.519	-.26
GAM	6.660	282.35	174.989	179.834	-4.845	-2.77
GAM	7.000	298.15	245.751	245.075	.676	.28
GAM	7.082	293.15	233.763	233.505	.258	.11
GAM	7.139	288.15	217.894	217.962	-.068	-.03
GAM	7.171	284.15	196.298	196.498	-.200	-.10
GAM	7.500	298.15	250.886	250.338	.548	.22
GAM	7.594	293.15	238.059	237.944	.115	.05
GAM	7.659	288.15	220.575	220.651	-.076	-.03
GAM	7.695	284.15	196.030	195.816	.214	.11
GAM	8.000	298.15	258.502	258.204	.298	.12
GAM	8.104	293.15	245.187	245.313	-.126	-.05
GAM	8.179	288.15	226.697	226.881	-.184	-.08
GAM	8.219	284.15	200.896	200.342	.554	.28
GAM	8.500	298.15	269.043	269.075	-.032	-.01
GAM	8.611	293.15	255.621	256.097	-.476	-.19
GAM	8.698	288.15	236.918	237.450	-.532	-.22
GAM	8.742	284.15	211.682	211.236	.446	.21
GAM	8.757	282.35	185.537	182.228	3.309	1.78
GAM	9.000	298.15	282.854	283.285	-.431	-.15
GAM	9.111	293.15	269.788	270.527	-.739	-.27
GAM	9.214	288.15	251.935	252.829	-.894	-.35
GAM	9.263	284.15	228.793	228.735	.058	.03
GAM	9.281	282.35	210.086	208.576	1.510	.72
GAM	9.500	298.15	300.682	301.021	-.339	-.11
GAM	9.603	293.15	287.875	288.593	-.718	-.25
GAM	9.725	288.15	271.836	272.975	-1.139	-.42
GAM	9.783	284.15	251.845	252.209	-.364	-.14
GAM	9.802	282.35	238.193	237.495	.698	.29
GAM	9.809	281.65	231.047	229.618	1.429	.62
GAM	9.814	281.15	224.901	222.440	2.461	1.09
GAM	10.000	298.15	322.343	322.283	.060	.02
GAM	10.088	293.15	309.818	310.092	-.274	-.09
GAM	10.227	288.15	296.382	297.219	-.837	-.28
GAM	10.298	284.15	279.924	280.329	-.405	-.14
GAM	10.321	282.35	269.661	269.404	.257	.10
GAM	10.328	281.65	264.938	264.150	.788	.30
GAM	10.334	281.15	261.152	260.014	1.138	.44
GAM	10.344	280.15	252.477	249.908	2.569	1.02

Table BV. Comparison of the isobaric enthalpy differences [21] with the present formulation.

T_{in} (°C)	T_{out} (°C)	Inlet Pressure (MPA)	H(exp) (J/g)	H(eqn) (J/g)	ΔH(exp) (J/g)	ΔH(eqn) (J/g)	Diff (J/g)	% Diff
6.934	9.372	5.1755	25.367	25.591				
					6.449	6.423	.026	0.4
6.928	9.709	5.1749	31.816	32.014				
					9.741	9.433	.308	3.2
6.931	10.041	5.1749	41.557	41.447				
					8.156	7.490	.666	8.2
6.934	10.192	5.1748	49.713	48.937				
					8.879	8.519	.360	4.0
6.933	10.290	5.1748	58.592	57.456				
					9.599	9.659	-.060	-0.63
6.934	10.356	5.1748	68.191	67.115				
					13.951	13.504	.447	3.2
6.936	10.431	5.1747	82.142	80.619				
					7.461	8.141	-.680	-9.1
6.931	10.492	5.1749	89.603	88.760				
					3.846	4.612	-.766	-19.9
6.932	10.537	5.1749	93.449	93.372				
					7.951	8.147	-.196	-2.5
6.932	10.648	5.1749	101.400	101.519				
					8.268	8.448	-.180	-2.8
6.931	10.823	5.1747	109.668	109.967				
					8.590	8.290	.300	3.55
6.930	11.080	5.1747	118.258	118.257				

APPENDIX C

Tables of Thermodynamic Properties

Table CI. The thermodynamic properties of ethylene in the critical region as a function of temperature along isochores

5.75 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	22225.4	23048.1	167.139	169.9		
280.000	4.78338	.0000	.1066	22311.0	23142.9	167.445	172.8		
280.500	4.83695	.0000	.1078	22398.3	23239.5	167.757	176.6		
281.000	4.89114	.0000	.1090	22488.0	23338.6	168.076	182.2		
281.500	4.94477	.0306	.0891	22573.8	23433.7	168.381	62.6	2267.7	198.9
282.000	4.98903	.0409	.0880	22604.3	23472.0	168.490	59.7	1677.1	202.2
282.500	5.03284	.0504	.0873	22633.7	23508.9	168.594	57.8	1349.1	204.8
283.000	5.07632	.0596	.0867	22662.2	23545.0	168.694	56.3	1135.7	207.0
283.500	5.11954	.0686	.0862	22690.0	23580.3	168.793	55.1	984.3	208.9
284.000	5.16253	.0774	.0858	22717.3	23615.1	168.889	54.1	870.6	210.7
284.500	5.20533	.0862	.0854	22744.2	23649.4	168.983	53.3	781.9	212.3
285.000	5.24797	.0949	.0851	22770.6	23683.3	169.076	52.6	710.6	213.8
285.500	5.29046	.1036	.0848	22796.8	23716.8	169.168	52.0	652.0	215.2
286.000	5.33281	.1122	.0846	22822.6	23750.1	169.258	51.4	602.9	216.6
286.500	5.37505	.1209	.0844	22848.2	23783.0	169.348	50.9	561.1	217.9
287.000	5.41717	.1295	.0841	22873.5	23815.7	169.436	50.5	525.2	219.1
287.500	5.45920	.1381	.0840	22898.7	23848.1	169.524	50.1	493.9	220.3
288.000	5.50113	.1467	.0838	22923.6	23880.4	169.610	49.7	466.4	221.5
288.500	5.54297	.1553	.0836	22948.4	23912.4	169.696	49.4	442.1	222.6
289.000	5.58474	.1639	.0834	22973.0	23944.3	169.782	49.1	420.4	223.7
289.500	5.62642	.1726	.0833	22997.5	23976.0	169.866	48.8	400.9	224.8
290.000	5.66804	.1812	.0832	23021.9	24007.6	169.950	48.6	383.3	225.8
291.000	5.75107	.1985	.0829	23070.2	24070.4	170.117	48.1	352.9	227.8
292.000	5.83385	.2158	.0827	23118.1	24132.6	170.281	47.7	327.4	229.8
293.000	5.91641	.2331	.0825	23165.6	24194.5	170.443	47.3	305.8	231.7
294.000	5.99877	.2505	.0823	23212.8	24256.0	170.604	47.0	287.2	233.5
295.000	6.08094	.2680	.0821	23259.6	24317.2	170.763	46.8	271.1	235.3
296.000	6.16294	.2855	.0819	23306.3	24378.1	170.921	46.5	256.9	237.1
297.000	6.24476	.3030	.0818	23352.7	24438.7	171.078	46.3	244.4	238.8
298.000	6.32644	.3206	.0816	23398.9	24499.1	171.233	46.1	233.3	240.5
299.000	6.40797	.3382	.0815	23444.9	24559.3	171.387	45.9	223.3	242.1
300.000	6.48936	.3559	.0813	23490.7	24619.3	171.540	45.8	214.4	243.8

Table CI. (Continued)

6.00 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	22046.3	22834.7	166.376	165.2		
280.000	4.78338	.0000	.1066	22129.5	22926.7	166.673	167.9		
280.500	4.83695	.0000	.1078	22214.4	23020.5	166.976	171.6		
281.000	4.89114	.0000	.1090	22301.4	23116.6	167.286	177.0		
281.500	4.94598	.0000	.1103	22391.9	23216.2	167.608	185.7		
282.000	4.99700	.0237	.0929	22455.7	23288.5	167.834	64.1	2916.6	196.1
282.500	5.04318	.0331	.0919	22486.9	23327.4	167.945	60.8	2062.1	200.0
283.000	5.08893	.0420	.0911	22516.7	23364.8	168.050	58.7	1613.3	202.9
283.500	5.13436	.0507	.0906	22545.6	23401.3	168.152	57.0	1331.5	205.4
284.000	5.17953	.0593	.0901	22573.8	23437.1	168.252	55.8	1136.6	207.5
284.500	5.22450	.0678	.0897	22601.4	23472.2	168.349	54.7	993.3	209.5
285.000	5.26929	.0763	.0894	22628.5	23506.8	168.444	53.8	883.3	211.2
285.500	5.31392	.0848	.0891	22655.3	23540.9	168.538	53.1	796.0	212.9
286.000	5.35842	.0933	.0889	22681.7	23574.7	168.630	52.4	725.1	214.4
286.500	5.40280	.1018	.0886	22707.7	23608.2	168.721	51.8	666.2	215.9
287.000	5.44706	.1103	.0884	22733.5	23641.4	168.811	51.3	616.7	217.3
287.500	5.49123	.1188	.0882	22759.1	23674.3	168.900	50.9	574.3	218.7
288.000	5.53531	.1273	.0881	22784.4	23706.9	168.988	50.4	537.7	219.9
288.500	5.57930	.1359	.0879	22809.5	23739.4	169.075	50.1	505.8	221.2
289.000	5.62321	.1444	.0877	22834.5	23771.7	169.162	49.7	477.7	222.4
289.500	5.66705	.1530	.0876	22859.2	23803.7	169.247	49.4	452.7	223.6
290.000	5.71082	.1616	.0875	22883.9	23835.7	169.332	49.1	430.4	224.7
291.000	5.79817	.1789	.0872	22932.7	23899.1	169.500	48.6	392.4	226.9
292.000	5.88529	.1963	.0870	22981.1	23962.0	169.666	48.1	361.0	229.1
293.000	5.97220	.2138	.0868	23029.0	24024.4	169.830	47.8	334.7	231.1
294.000	6.05893	.2313	.0866	23076.6	24086.4	169.992	47.4	312.4	233.1
295.000	6.14548	.2489	.0865	23123.9	24148.1	170.153	47.1	293.3	235.0
296.000	6.23188	.2666	.0863	23170.9	24209.5	170.312	46.9	276.6	236.9
297.000	6.31812	.2844	.0862	23217.6	24270.6	170.470	46.6	262.0	238.7
298.000	6.40422	.3022	.0860	23264.1	24331.5	170.626	46.4	249.1	240.5
299.000	6.49019	.3201	.0859	23310.4	24392.1	170.781	46.2	237.7	242.3
300.000	6.57603	.3381	.0858	23356.5	24452.5	170.935	46.0	227.4	244.0

Table CI. (Continued)

6.25 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	21881.5	22638.3	165.673	160.8		
280.000	4.78338	.0000	.1066	21962.5	22727.8	165.963	163.5		
280.500	4.83695	.0000	.1078	22045.1	22819.0	166.258	167.0		
281.000	4.89114	.0000	.1090	22129.8	22912.4	166.559	172.2		
281.500	4.94598	.0000	.1103	22217.8	23009.1	166.872	180.6		
282.000	5.00126	.0111	.0979	22309.7	23110.0	167.199	70.7	6299.8	187.8
282.500	5.04976	.0203	.0963	22343.3	23151.3	167.317	64.5	3375.0	194.5
283.000	5.09768	.0287	.0954	22374.7	23190.3	167.428	61.2	2359.0	198.6
283.500	5.14523	.0370	.0948	22404.7	23227.9	167.534	59.0	1823.4	201.8
284.000	5.19251	.0452	.0943	22433.8	23264.6	167.637	57.4	1489.3	204.4
284.500	5.23957	.0534	.0939	22462.1	23300.5	167.737	56.1	1260.2	206.7
285.000	5.28645	.0616	.0936	22489.9	23335.7	167.834	55.0	1093.2	208.8
285.500	5.33317	.0698	.0933	22517.2	23370.5	167.930	54.1	965.8	210.7
286.000	5.37977	.0781	.0931	22544.0	23404.8	168.024	53.3	865.6	212.5
286.500	5.42624	.0864	.0928	22570.5	23438.7	168.116	52.7	784.6	214.2
287.000	5.47262	.0947	.0927	22596.7	23472.3	168.208	52.1	717.8	215.8
287.500	5.51890	.1031	.0925	22622.6	23505.6	168.298	51.5	661.9	217.3
288.000	5.56509	.1116	.0923	22648.3	23538.7	168.387	51.1	614.3	218.7
288.500	5.61121	.1200	.0922	22673.7	23571.5	168.475	50.6	573.3	220.1
289.000	5.65726	.1285	.0920	22698.9	23604.1	168.563	50.3	537.7	221.4
289.500	5.70324	.1371	.0919	22724.0	23636.5	168.649	49.9	506.5	222.7
290.000	5.74916	.1457	.0918	22748.8	23668.7	168.735	49.6	478.9	223.9
291.000	5.84083	.1630	.0916	22798.1	23732.7	168.905	49.0	432.3	226.4
292.000	5.93230	.1804	.0914	22846.9	23796.1	169.072	48.5	394.6	228.6
293.000	6.02359	.1979	.0912	22895.2	23859.0	169.237	48.1	363.3	230.9
294.000	6.11472	.2156	.0911	22943.1	23921.5	169.400	47.7	337.1	233.0
295.000	6.20570	.2334	.0909	22990.7	23983.6	169.562	47.4	314.8	235.0
296.000	6.29654	.2513	.0908	23038.0	24045.4	169.722	47.1	295.6	237.0
297.000	6.38725	.2693	.0907	23084.9	24106.9	169.880	46.9	278.9	239.0
298.000	6.47785	.2874	.0905	23131.7	24168.2	170.038	46.6	264.2	240.9
299.000	6.56833	.3056	.0904	23178.3	24229.2	170.193	46.4	251.2	242.8
300.000	6.65871	.3239	.0903	23224.6	24290.0	170.348	46.3	239.7	244.6

Table CI. (Continued)

6.50 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	21729.3	22457.1	165.025	156.8		
280.000	4.78338	.0000	.1066	21808.3	22544.2	165.307	159.4		
280.500	4.83695	.0000	.1078	21888.8	22633.0	165.594	162.8		
281.000	4.89114	.0000	.1090	21971.4	22723.9	165.889	167.7		
281.500	4.94598	.0000	.1103	22057.1	22818.0	166.193	175.8		
282.000	5.00150	.0000	.1118	22148.7	22918.2	166.519	194.0		
282.500	5.05365	.0114	.1005	22203.3	22980.8	166.712	68.8	5967.6	188.1
283.000	5.10360	.0192	.0994	22236.4	23021.5	166.829	63.9	3508.8	194.0
283.500	5.15315	.0269	.0988	22267.5	23060.3	166.939	60.9	2493.6	198.1
284.000	5.20242	.0346	.0983	22297.5	23097.8	167.044	58.9	1934.0	201.4
284.500	5.25147	.0424	.0979	22326.5	23134.4	167.146	57.3	1578.9	204.2
285.000	5.30036	.0503	.0976	22354.8	23170.3	167.246	56.0	1333.6	206.6
285.500	5.34912	.0583	.0974	22382.6	23205.5	167.343	55.0	1154.2	208.8
286.000	5.39775	.0663	.0972	22409.8	23240.3	167.439	54.1	1017.4	210.8
286.500	5.44628	.0745	.0970	22436.7	23274.6	167.532	53.4	909.7	212.7
287.000	5.49472	.0827	.0968	22463.2	23308.5	167.625	52.7	822.8	214.5
287.500	5.54308	.0909	.0967	22489.4	23342.2	167.716	52.1	751.2	216.2
288.000	5.59137	.0993	.0965	22515.3	23375.5	167.806	51.6	691.3	217.8
288.500	5.63960	.1077	.0964	22541.0	23408.6	167.895	51.1	640.5	219.3
289.000	5.68777	.1161	.0963	22566.4	23441.5	167.983	50.7	596.8	220.8
289.500	5.73588	.1246	.0962	22591.7	23474.1	168.071	50.3	558.9	222.2
290.000	5.78395	.1332	.0961	22616.7	23506.6	168.157	50.0	525.7	223.5
291.000	5.87994	.1505	.0959	22666.4	23571.0	168.328	49.3	470.3	226.1
292.000	5.97578	.1680	.0958	22715.4	23634.8	168.496	48.8	426.1	228.6
293.000	6.07147	.1857	.0956	22764.0	23698.1	168.662	48.4	389.9	231.0
294.000	6.16704	.2035	.0955	22812.2	23761.0	168.827	48.0	359.8	233.3
295.000	6.26249	.2215	.0954	22860.0	23823.5	168.989	47.6	334.5	235.5
296.000	6.35783	.2397	.0953	22907.5	23885.6	169.150	47.3	312.8	237.6
297.000	6.45308	.2580	.0952	22954.7	23947.5	169.309	47.1	294.1	239.7
298.000	6.54824	.2764	.0951	23001.6	24009.0	169.467	46.8	277.7	241.7
299.000	6.64332	.2949	.0950	23048.3	24070.4	169.623	46.6	263.3	243.7
300.000	6.73831	.3135	.0950	23094.9	24131.5	169.778	46.4	250.6	245.6

Table CI. (Continued)

6.75 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	21588.5	22289.3	164.424	153.1		
280.000	4.78338	.0000	.1066	21665.6	22374.2	164.700	155.6		
280.500	4.83695	.0000	.1078	21744.2	22460.8	164.980	158.9		
281.000	4.89114	.0000	.1090	21824.7	22549.3	165.267	163.6		
281.500	4.94598	.0000	.1103	21908.3	22641.0	165.565	171.4		
282.000	5.00150	.0000	.1118	21997.6	22738.6	165.882	188.9		
282.500	5.05576	.0060	.1042	22067.4	22816.4	166.129	73.8	11381.1	180.9
283.000	5.10756	.0129	.1031	22102.1	22858.8	166.252	66.4	5185.4	189.5
283.500	5.15895	.0200	.1025	22134.3	22898.6	166.365	62.6	3337.5	194.7
284.000	5.21009	.0272	.1021	22165.0	22936.9	166.473	60.1	2447.9	198.7
284.500	5.26105	.0346	.1018	22194.6	22974.0	166.578	58.3	1926.5	201.9
285.000	5.31187	.0422	.1015	22223.4	23010.3	166.679	56.9	1585.0	204.7
285.500	5.36258	.0499	.1013	22251.5	23045.9	166.777	55.7	1344.8	207.3
286.000	5.41320	.0577	.1012	22279.1	23081.0	166.874	54.7	1167.0	209.5
286.500	5.46374	.0657	.1010	22306.2	23115.7	166.969	53.9	1030.3	211.7
287.000	5.51421	.0738	.1009	22333.0	23149.9	167.062	53.1	922.1	213.6
287.500	5.56463	.0820	.1008	22359.4	23183.8	167.154	52.5	834.5	215.5
288.000	5.61499	.0902	.1007	22385.5	23217.3	167.244	51.9	762.1	217.2
288.500	5.66531	.0986	.1006	22411.3	23250.6	167.334	51.4	701.5	218.9
289.000	5.71559	.1070	.1005	22436.9	23283.7	167.423	51.0	649.9	220.5
289.500	5.76583	.1155	.1005	22462.3	23316.5	167.511	50.6	605.5	222.0
290.000	5.81604	.1241	.1004	22487.5	23349.1	167.598	50.2	566.9	223.5
291.000	5.91637	.1415	.1003	22537.4	23413.9	167.769	49.6	503.4	226.4
292.000	6.01660	.1592	.1002	22586.7	23478.0	167.938	49.0	453.1	229.0
293.000	6.11673	.1770	.1001	22635.4	23541.6	168.105	48.5	412.5	231.6
294.000	6.21679	.1951	.1000	22683.8	23604.8	168.270	48.1	379.0	234.0
295.000	6.31677	.2134	.1000	22731.7	23667.5	168.432	47.8	350.9	236.4
296.000	6.41669	.2318	.0999	22779.3	23730.0	168.594	47.5	327.1	238.6
297.000	6.51655	.2504	.0998	22826.7	23792.1	168.753	47.2	306.6	240.8
298.000	6.61636	.2692	.0998	22873.7	23853.9	168.911	46.9	288.8	243.0
299.000	6.71611	.2881	.0997	22920.6	23915.5	169.068	46.7	273.2	245.1
300.000	6.81582	.3072	.0997	22967.2	23976.9	169.224	46.5	259.5	247.1

Table CI. (Continued)

7.00 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	21457.7	22133.4	163.867	149.7		
280.000	4.78338	.0000	.1066	21533.1	22216.4	164.136	152.0		
280.500	4.83695	.0000	.1078	21609.8	22300.8	164.410	155.2		
281.000	4.89114	.0000	.1090	21688.5	22387.2	164.691	159.8		
281.500	4.94598	.0000	.1103	21770.1	22476.7	164.981	167.3		
282.000	5.00150	.0000	.1118	21857.3	22571.8	165.290	184.2		
282.500	5.05684	.0030	.1074	21935.9	22658.3	165.569	79.2	22577.5	173.4
283.000	5.11026	.0090	.1064	21972.3	22702.3	165.697	68.5	7334.6	185.3
283.500	5.16334	.0155	.1059	22005.3	22742.9	165.814	63.9	4259.9	191.7
284.000	5.21623	.0223	.1057	22036.5	22781.7	165.924	61.1	2962.5	196.4
284.500	5.26900	.0294	.1054	22066.5	22819.2	166.029	59.0	2255.0	200.1
285.000	5.32168	.0367	.1053	22095.6	22855.8	166.132	57.4	1812.9	203.3
285.500	5.37430	.0443	.1052	22124.0	22891.7	166.231	56.1	1512.1	206.2
286.000	5.42686	.0520	.1051	22151.7	22927.0	166.328	55.1	1294.9	208.7
286.500	5.47937	.0598	.1050	22179.1	22961.8	166.424	54.2	1131.3	211.1
287.000	5.53186	.0679	.1049	22205.9	22996.2	166.517	53.4	1003.8	213.2
287.500	5.58431	.0760	.1049	22232.5	23030.2	166.610	52.7	901.9	215.3
288.000	5.63674	.0843	.1048	22258.7	23063.9	166.701	52.1	818.7	217.2
288.500	5.68915	.0926	.1048	22284.6	23097.4	166.791	51.6	749.6	219.0
289.000	5.74154	.1011	.1048	22310.3	23130.5	166.880	51.1	691.3	220.7
289.500	5.79392	.1097	.1047	22335.8	23163.5	166.968	50.7	641.6	222.4
290.000	5.84629	.1184	.1047	22361.1	23196.2	167.055	50.3	598.6	224.0
291.000	5.95098	.1359	.1047	22411.0	23261.2	167.227	49.7	528.4	227.0
292.000	6.05565	.1538	.1046	22460.4	23325.5	167.397	49.1	473.4	229.9
293.000	6.16028	.1720	.1046	22509.3	23389.3	167.564	48.6	429.2	232.6
294.000	6.26490	.1904	.1046	22557.7	23452.7	167.729	48.2	393.0	235.2
295.000	6.36949	.2090	.1046	22605.7	23515.6	167.892	47.8	362.9	237.7
296.000	6.47407	.2279	.1046	22653.4	23578.3	168.053	47.5	337.4	240.1
297.000	6.57864	.2469	.1046	22700.8	23640.6	168.213	47.2	315.6	242.5
298.000	6.68319	.2661	.1045	22747.9	23702.6	168.371	47.0	296.8	244.7
299.000	6.78773	.2855	.1045	22794.8	23764.5	168.528	46.8	280.3	246.9
300.000	6.89225	.3050	.1045	22841.5	23826.1	168.684	46.6	265.8	249.1

Table CI. (Continued)

7.25 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	21335.9	21988.3	163.348	146.5		
280.000	4.78338	.0000	.1066	21409.7	22069.4	163.611	148.7		
280.500	4.83695	.0000	.1078	21484.8	22151.9	163.879	151.8		
281.000	4.89114	.0000	.1090	21561.7	22236.3	164.154	156.3		
281.500	4.94598	.0000	.1103	21641.5	22323.7	164.437	163.5		
282.000	5.00150	.0000	.1118	21726.6	22416.5	164.739	179.8		
282.500	5.05738	.0016	.1101	21809.4	22507.0	165.033	83.9	41809.0	166.5
283.000	5.11221	.0069	.1094	21847.0	22552.2	165.166	69.9	9471.3	181.9
283.500	5.16685	.0129	.1092	21880.5	22593.2	165.284	64.7	5043.1	189.5
284.000	5.22141	.0195	.1091	21912.0	22632.2	165.395	61.5	3363.4	194.8
284.500	5.27593	.0264	.1090	21942.2	22669.9	165.501	59.3	2496.6	199.0
285.000	5.33043	.0336	.1090	21971.4	22706.7	165.604	57.6	1973.5	202.6
285.500	5.38492	.0411	.1090	21999.9	22742.7	165.704	56.3	1626.1	205.7
286.000	5.43940	.0488	.1090	22027.8	22778.0	165.801	55.2	1379.7	208.5
286.500	5.49388	.0567	.1090	22055.1	22812.9	165.897	54.3	1196.6	211.0
287.000	5.54837	.0647	.1090	22082.1	22847.3	165.991	53.5	1055.6	213.4
287.500	5.60287	.0729	.1090	22108.6	22881.4	166.083	52.8	944.0	215.6
288.000	5.65737	.0813	.1090	22134.9	22915.2	166.174	52.2	853.5	217.7
288.500	5.71189	.0898	.1090	22160.8	22948.6	166.264	51.6	778.7	219.6
289.000	5.76641	.0984	.1091	22186.5	22981.9	166.353	51.2	716.1	221.5
289.500	5.82095	.1071	.1091	22212.0	23014.9	166.441	50.7	662.9	223.3
290.000	5.87550	.1159	.1091	22237.2	23047.6	166.529	50.3	617.2	225.0
291.000	5.98463	.1338	.1092	22287.2	23112.7	166.701	49.7	542.7	228.3
292.000	6.09381	.1521	.1092	22336.6	23177.1	166.870	49.1	484.8	231.4
293.000	6.20303	.1706	.1092	22385.4	23241.0	167.037	48.6	438.5	234.2
294.000	6.31230	.1895	.1093	22433.8	23304.5	167.202	48.2	400.8	237.0
295.000	6.42161	.2086	.1093	22481.8	23367.6	167.365	47.8	369.4	239.7
296.000	6.53096	.2279	.1094	22529.5	23430.3	167.526	47.5	343.0	242.2
297.000	6.64035	.2475	.1094	22576.9	23492.8	167.686	47.2	320.5	244.7
298.000	6.74977	.2673	.1094	22624.0	23555.0	167.844	47.0	301.1	247.1
299.000	6.85923	.2872	.1095	22670.8	23616.9	168.001	46.8	284.1	249.4
300.000	6.96871	.3073	.1095	22717.5	23678.7	168.157	46.6	269.2	251.6

Table CI. (Continued)

7.50 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	21222.2	21852.9	162.863	143.5		
280.000	4.78338	.0000	.1066	21294.5	21932.3	163.122	145.7		
280.500	4.83695	.0000	.1078	21368.0	22012.9	163.384	148.7		
281.000	4.89114	.0000	.1090	21443.4	22095.5	163.652	153.0		
281.500	4.94598	.0000	.1103	21521.4	22180.9	163.930	160.0		
282.000	5.00150	.0000	.1118	21604.6	22271.5	164.225	175.7		
282.500	5.05769	.0011	.1122	21688.3	22362.6	164.522	86.2	60195.4	161.9
283.000	5.11379	.0060	.1122	21726.4	22408.2	164.656	70.3	10666.2	179.9
283.500	5.16992	.0119	.1123	21760.0	22449.3	164.775	64.7	5408.3	188.2
284.000	5.22611	.0184	.1124	21791.5	22488.3	164.886	61.5	3528.7	194.1
284.500	5.28236	.0254	.1126	21821.6	22525.9	164.992	59.2	2586.8	198.7
285.000	5.33867	.0326	.1127	21850.8	22562.6	165.094	57.5	2028.4	202.6
285.500	5.39503	.0402	.1128	21879.2	22598.5	165.194	56.2	1661.9	205.9
286.000	5.45145	.0480	.1129	21907.0	22633.8	165.291	55.1	1404.4	209.0
286.500	5.50792	.0560	.1130	21934.3	22668.7	165.387	54.1	1214.3	211.7
287.000	5.56444	.0643	.1131	21961.1	22703.0	165.480	53.3	1068.7	214.3
287.500	5.62101	.0727	.1132	21987.6	22737.1	165.572	52.6	953.8	216.6
288.000	5.67762	.0812	.1133	22013.8	22770.8	165.663	52.0	861.0	218.9
288.500	5.73428	.0899	.1134	22039.7	22804.2	165.753	51.5	784.7	221.0
289.000	5.79098	.0987	.1134	22065.3	22837.4	165.842	51.0	720.8	223.0
289.500	5.84772	.1077	.1135	22090.7	22870.4	165.930	50.6	666.7	224.9
290.000	5.90450	.1167	.1136	22115.9	22903.2	166.017	50.2	620.2	226.7
291.000	6.01817	.1351	.1137	22165.8	22968.2	166.188	49.5	544.8	230.2
292.000	6.13198	.1540	.1139	22215.0	23032.6	166.357	49.0	486.2	233.4
293.000	6.24592	.1731	.1140	22263.7	23096.5	166.524	48.5	439.6	236.5
294.000	6.35998	.1925	.1141	22312.0	23160.0	166.689	48.1	401.5	239.4
295.000	6.47414	.2123	.1142	22359.9	23223.2	166.851	47.7	370.0	242.2
296.000	6.58839	.2322	.1143	22407.5	23286.0	167.012	47.4	343.5	244.9
297.000	6.70275	.2524	.1144	22454.8	23348.5	167.172	47.2	320.9	247.5
298.000	6.81719	.2729	.1145	22501.8	23410.8	167.330	46.9	301.4	250.0
299.000	6.93170	.2935	.1146	22548.6	23472.8	167.486	46.7	284.4	252.4
300.000	7.04630	.3143	.1146	22595.2	23534.7	167.642	46.5	269.5	254.8

Table CI. (Continued)

7.75 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	21115.9	21726.3	162.410	140.7		
280.000	4.78338	.0000	.1066	21186.7	21803.9	162.663	142.8		
280.500	4.83695	.0000	.1078	21258.8	21882.9	162.921	145.7		
281.000	4.89114	.0000	.1090	21332.6	21963.7	163.183	149.9		
281.500	4.94598	.0000	.1103	21409.1	22047.3	163.455	156.7		
282.000	5.00150	.0000	.1118	21490.6	22135.9	163.744	171.9		
282.500	5.05794	.0011	.1142	21572.5	22225.1	164.035	85.0	57363.7	160.5
283.000	5.11528	.0062	.1150	21610.1	22270.1	164.168	69.5	10192.5	179.4
283.500	5.17291	.0123	.1155	21643.3	22310.8	164.285	64.1	5189.0	188.3
284.000	5.23075	.0190	.1159	21674.6	22349.5	164.395	60.9	3396.6	194.4
284.500	5.28876	.0262	.1162	21704.4	22386.9	164.500	58.7	2496.5	199.3
285.000	5.34692	.0338	.1164	21733.4	22423.3	164.602	57.1	1961.9	203.5
285.500	5.40521	.0416	.1167	21761.6	22459.0	164.701	55.7	1610.6	207.1
286.000	5.46361	.0497	.1169	21789.1	22494.1	164.797	54.7	1363.3	210.3
286.500	5.52213	.0581	.1171	21816.2	22528.8	164.892	53.8	1180.6	213.2
287.000	5.58074	.0666	.1173	21842.9	22563.0	164.985	53.0	1040.4	215.9
287.500	5.63944	.0753	.1175	21869.2	22596.9	165.077	52.3	929.7	218.4
288.000	5.69823	.0842	.1177	21895.3	22630.5	165.167	51.7	840.2	220.8
288.500	5.75710	.0932	.1178	21921.0	22663.8	165.256	51.2	766.5	223.0
289.000	5.81605	.1024	.1180	21946.5	22696.9	165.344	50.7	704.8	225.1
289.500	5.87506	.1117	.1181	21971.7	22729.8	165.432	50.3	652.4	227.1
290.000	5.93415	.1211	.1182	21996.8	22762.5	165.518	50.0	607.5	229.1
291.000	6.05251	.1402	.1185	22046.4	22827.4	165.689	49.3	534.4	232.7
292.000	6.17111	.1598	.1187	22095.5	22891.7	165.857	48.8	477.6	236.2
293.000	6.28992	.1796	.1189	22144.0	22955.6	166.023	48.3	432.3	239.4
294.000	6.40892	.1998	.1191	22192.1	23019.0	166.187	47.9	395.3	242.5
295.000	6.52811	.2203	.1193	22239.8	23082.2	166.349	47.6	364.7	245.4
296.000	6.64746	.2411	.1194	22287.2	23145.0	166.510	47.3	338.8	248.2
297.000	6.76696	.2621	.1196	22334.4	23207.5	166.669	47.0	316.8	250.9
298.000	6.88661	.2833	.1197	22381.3	23269.9	166.826	46.8	297.7	253.5
299.000	7.00638	.3047	.1198	22427.9	23332.0	166.983	46.6	281.2	256.1
300.000	7.12628	.3264	.1200	22474.4	23393.9	167.138	46.4	266.6	258.6

Table CI. (Continued)

8.00 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	21016.2	21607.5	161.985	138.0		
280.000	4.78338	.0000	.1066	21085.7	21683.6	162.234	140.1		
280.500	4.83695	.0000	.1078	21156.4	21761.1	162.486	142.9		
281.000	4.89114	.0000	.1090	21228.8	21840.2	162.744	147.0		
281.500	4.94598	.0000	.1103	21303.8	21922.0	163.010	153.5		
282.000	5.00150	.0000	.1118	21383.6	22008.8	163.294	168.3		
282.500	5.05827	.0017	.1165	21461.5	22093.8	163.570	80.8	36291.8	162.8
283.000	5.11696	.0075	.1180	21497.8	22137.4	163.698	67.7	8299.2	180.8
283.500	5.17619	.0142	.1188	21530.3	22177.3	163.813	62.8	4470.0	189.7
284.000	5.23578	.0215	.1195	21561.0	22215.4	163.921	59.9	3008.7	196.1
284.500	5.29564	.0292	.1200	21590.4	22252.3	164.024	57.9	2250.3	201.2
285.000	5.35575	.0372	.1204	21618.9	22288.4	164.124	56.3	1790.3	205.5
285.500	5.41605	.0456	.1208	21646.7	22323.7	164.222	55.1	1483.3	209.2
286.000	5.47654	.0542	.1211	21674.0	22358.5	164.317	54.0	1264.7	212.6
286.500	5.53719	.0630	.1215	21700.8	22392.9	164.411	53.2	1101.7	215.6
287.000	5.59799	.0720	.1217	21727.2	22426.9	164.503	52.5	975.7	218.5
287.500	5.65893	.0812	.1220	21753.3	22460.6	164.594	51.8	875.6	221.1
288.000	5.71999	.0905	.1222	21779.0	22494.0	164.683	51.3	794.3	223.6
288.500	5.78118	.1000	.1225	21804.5	22527.2	164.772	50.8	726.9	225.9
289.000	5.84247	.1096	.1227	21829.8	22560.1	164.859	50.3	670.4	228.1
289.500	5.90386	.1194	.1229	21854.9	22592.9	164.946	49.9	622.2	230.2
290.000	5.96536	.1293	.1231	21879.8	22625.4	165.032	49.6	580.6	232.3
291.000	6.08862	.1493	.1234	21929.0	22690.1	165.202	49.0	512.9	236.1
292.000	6.21221	.1698	.1237	21977.7	22754.3	165.369	48.5	459.9	239.7
293.000	6.33610	.1906	.1240	22026.0	22818.0	165.534	48.0	417.5	243.1
294.000	6.46027	.2118	.1243	22073.8	22881.3	165.697	47.7	382.8	246.3
295.000	6.58470	.2332	.1245	22121.3	22944.4	165.858	47.3	353.9	249.3
296.000	6.70935	.2549	.1248	22168.5	23007.2	166.018	47.1	329.5	252.2
297.000	6.83422	.2768	.1250	22215.4	23069.7	166.176	46.8	308.6	255.1
298.000	6.95928	.2990	.1252	22262.1	23132.0	166.333	46.6	290.5	257.8
299.000	7.08453	.3214	.1253	22308.6	23194.2	166.489	46.4	274.8	260.4
300.000	7.20995	.3439	.1255	22354.9	23256.2	166.643	46.2	260.9	263.0

Table CI. (Continued)

8.25 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	20922.6	21495.9	161.586	135.6		
280.000	4.78338	.0000	.1066	20990.8	21570.6	161.830	137.6		
280.500	4.83695	.0000	.1078	21060.3	21646.6	162.078	140.3		
281.000	4.89114	.0000	.1090	21131.3	21724.2	162.331	144.2		
281.500	4.94598	.0000	.1103	21204.9	21804.4	162.592	150.6		
282.000	5.00150	.0000	.1118	21283.1	21889.4	162.870	164.9		
282.500	5.05886	.0033	.1195	21354.4	21967.6	163.123	74.7	18061.6	168.5
283.000	5.11915	.0104	.1214	21388.9	22009.4	163.245	65.1	5965.2	184.2
283.500	5.18018	.0181	.1226	21420.4	22048.3	163.356	61.0	3523.6	192.8
284.000	5.24168	.0262	.1234	21450.2	22085.6	163.461	58.5	2484.6	199.2
284.500	5.30357	.0347	.1241	21479.0	22121.8	163.562	56.7	1913.1	204.3
285.000	5.36577	.0435	.1247	21506.9	22157.3	163.660	55.3	1553.3	208.7
285.500	5.42825	.0525	.1252	21534.3	22192.3	163.756	54.1	1306.7	212.5
286.000	5.49096	.0618	.1257	21561.1	22226.7	163.850	53.2	1127.5	216.0
286.500	5.55389	.0712	.1261	21587.5	22260.7	163.942	52.4	991.8	219.1
287.000	5.61702	.0809	.1264	21613.6	22294.4	164.033	51.8	885.5	222.0
287.500	5.68033	.0907	.1268	21639.3	22327.8	164.123	51.2	800.1	224.8
288.000	5.74380	.1006	.1271	21664.8	22361.0	164.211	50.7	730.0	227.3
288.500	5.80743	.1107	.1274	21690.0	22393.9	164.299	50.2	671.6	229.7
289.000	5.87120	.1210	.1277	21715.0	22426.7	164.385	49.8	622.1	232.0
289.500	5.93511	.1313	.1279	21739.8	22459.2	164.471	49.5	579.7	234.2
290.000	5.99914	.1418	.1282	21764.5	22491.6	164.556	49.1	543.0	236.3
291.000	6.12756	.1630	.1286	21813.3	22556.0	164.724	48.6	482.6	240.3
292.000	6.25641	.1846	.1290	21861.6	22620.0	164.890	48.1	435.1	244.0
293.000	6.38564	.2066	.1294	21909.5	22683.5	165.054	47.7	396.8	247.5
294.000	6.51523	.2288	.1298	21957.0	22746.7	165.216	47.3	365.2	250.9
295.000	6.64515	.2514	.1301	22004.2	22809.6	165.376	47.0	338.8	254.0
296.000	6.77536	.2742	.1304	22051.1	22872.3	165.535	46.8	316.3	257.1
297.000	6.90585	.2972	.1306	22097.7	22934.8	165.692	46.6	297.1	260.0
298.000	7.03659	.3204	.1309	22144.2	22997.1	165.848	46.4	280.3	262.8
299.000	7.16756	.3439	.1311	22190.4	23059.2	166.003	46.2	265.7	265.6
300.000	7.29876	.3676	.1313	22236.5	23121.2	166.157	46.0	252.8	268.2

Table CI. (Continued)

8.50 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	20834.4	21391.0	161.210	133.2		
280.000	4.78338	.0000	.1066	20901.5	21464.3	161.450	135.2		
280.500	4.83695	.0000	.1078	20969.7	21538.8	161.694	137.8		
281.000	4.89114	.0000	.1090	21039.6	21615.0	161.942	141.6		
281.500	4.94598	.0000	.1103	21111.8	21693.7	162.199	147.9		
282.000	5.00150	.0000	.1118	21188.6	21777.0	162.472	161.8		
282.500	5.06009	.0070	.1234	21250.3	21845.6	162.690	68.5	8563.9	176.7
283.000	5.12236	.0157	.1255	21282.7	21885.3	162.805	62.1	3983.0	189.6
283.500	5.18545	.0247	.1268	21312.9	21922.9	162.912	58.9	2615.3	197.6
284.000	5.24913	.0339	.1278	21341.8	21959.3	163.013	56.8	1950.4	203.8
284.500	5.31325	.0434	.1287	21369.8	21994.9	163.112	55.3	1556.7	208.8
285.000	5.37776	.0531	.1294	21397.1	22029.8	163.208	54.0	1296.5	213.2
285.500	5.44261	.0631	.1300	21423.9	22064.2	163.302	53.1	1111.8	217.0
286.000	5.50774	.0732	.1305	21450.2	22098.2	163.394	52.2	974.0	220.5
286.500	5.57314	.0835	.1310	21476.1	22131.8	163.484	51.6	867.4	223.7
287.000	5.63877	.0939	.1315	21501.8	22165.1	163.574	51.0	782.4	226.7
287.500	5.70462	.1045	.1319	21527.1	22198.2	163.662	50.4	713.2	229.5
288.000	5.77068	.1152	.1323	21552.2	22231.1	163.749	50.0	655.7	232.1
288.500	5.83692	.1260	.1327	21577.1	22263.8	163.836	49.6	607.2	234.6
289.000	5.90334	.1370	.1330	21601.8	22296.3	163.921	49.2	565.7	236.9
289.500	5.96992	.1480	.1333	21626.3	22328.6	164.006	48.9	529.9	239.2
290.000	6.03665	.1592	.1336	21650.6	22360.8	164.090	48.6	498.7	241.4
291.000	6.17054	.1818	.1342	21699.0	22424.9	164.256	48.1	446.8	245.5
292.000	6.30496	.2048	.1347	21746.8	22488.6	164.420	47.6	405.5	249.3
293.000	6.43985	.2281	.1351	21794.2	22551.9	164.582	47.3	371.9	252.9
294.000	6.57516	.2516	.1355	21841.3	22614.9	164.743	47.0	344.0	256.3
295.000	6.71087	.2754	.1359	21888.2	22677.7	164.902	46.7	320.4	259.6
296.000	6.84693	.2995	.1362	21934.7	22740.3	165.060	46.5	300.3	262.7
297.000	6.98333	.3238	.1366	21981.1	22802.7	165.216	46.3	283.0	265.7
298.000	7.12004	.3483	.1369	22027.3	22864.9	165.371	46.1	267.9	268.6
299.000	7.25703	.3730	.1371	22073.3	22927.0	165.525	45.9	254.6	271.5
300.000	7.39429	.3979	.1374	22119.1	22989.0	165.678	45.8	242.8	274.2

Table CI. (Continued)

8.75 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	20751.3	21292.0	160.856	131.0		
280.000	4.78338	.0000	.1066	20817.3	21364.0	161.092	133.0		
280.500	4.83695	.0000	.1078	20884.4	21437.2	161.331	135.5		
281.000	4.89114	.0000	.1090	20953.0	21512.0	161.576	139.2		
281.500	4.94598	.0000	.1103	21024.0	21589.3	161.828	145.3		
282.000	5.00150	.0000	.1118	21099.4	21671.0	162.096	158.8		
282.500	5.06266	.0142	.1282	21147.9	21726.5	162.268	63.1	4324.0	186.5
283.000	5.12732	.0247	.1303	21178.3	21764.3	162.375	59.0	2598.0	196.9
283.500	5.19284	.0351	.1317	21207.2	21800.7	162.477	56.6	1884.2	204.1
284.000	5.25898	.0457	.1328	21235.1	21836.1	162.576	55.0	1487.1	209.9
284.500	5.32563	.0564	.1337	21262.3	21870.9	162.671	53.7	1232.5	214.8
285.000	5.39271	.0672	.1345	21288.8	21905.2	162.764	52.7	1055.0	219.1
285.500	5.46016	.0782	.1353	21315.0	21939.0	162.856	51.9	924.0	222.9
286.000	5.52795	.0893	.1359	21340.7	21972.5	162.946	51.2	823.2	226.4
286.500	5.59603	.1006	.1365	21366.2	22005.7	163.035	50.6	743.2	229.6
287.000	5.66439	.1120	.1370	21391.3	22038.7	163.123	50.1	678.2	232.6
287.500	5.73300	.1235	.1375	21416.2	22071.4	163.209	49.6	624.3	235.4
288.000	5.80184	.1351	.1379	21440.9	22104.0	163.295	49.2	578.9	238.0
288.500	5.87090	.1468	.1383	21465.4	22136.4	163.380	48.8	540.1	240.5
289.000	5.94016	.1586	.1387	21489.8	22168.6	163.465	48.5	506.6	242.9
289.500	6.00960	.1704	.1391	21513.9	22200.8	163.548	48.2	477.3	245.2
290.000	6.07922	.1824	.1394	21538.0	22232.8	163.631	48.0	451.6	247.4
291.000	6.21896	.2066	.1401	21585.7	22296.5	163.795	47.5	408.3	251.6
292.000	6.35931	.2311	.1406	21633.0	22359.8	163.958	47.1	373.5	255.5
293.000	6.50020	.2559	.1411	21680.0	22422.9	164.118	46.8	344.7	259.2
294.000	6.64158	.2809	.1416	21726.7	22485.7	164.277	46.5	320.7	262.7
295.000	6.78342	.3062	.1421	21773.1	22548.3	164.435	46.3	300.2	266.0
296.000	6.92568	.3317	.1425	21819.3	22610.8	164.591	46.1	282.6	269.2
297.000	7.06832	.3574	.1428	21865.3	22673.1	164.747	45.9	267.4	272.3
298.000	7.21132	.3832	.1432	21911.2	22735.3	164.901	45.8	253.9	275.3
299.000	7.35466	.4093	.1435	21956.9	22797.4	165.054	45.6	242.1	278.2
300.000	7.49830	.4355	.1438	22002.4	22859.4	165.206	45.5	231.5	281.0

Table CI. (Continued)

9.00 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	20672.9	21198.5	160.522	129.0		
280.000	4.78338	.0000	.1066	20737.8	21269.3	160.754	130.8		
280.500	4.83695	.0000	.1078	20803.8	21341.2	160.989	133.3		
281.000	4.89114	.0000	.1090	20871.3	21414.8	161.230	136.9		
281.500	4.94598	.0000	.1103	20941.1	21490.7	161.478	142.8		
282.000	5.00150	.0000	.1118	21015.2	21570.9	161.741	155.9		
282.500	5.06764	.0267	.1340	21046.5	21609.6	161.852	58.7	2408.0	197.4
283.000	5.13514	.0388	.1359	21075.1	21645.7	161.953	56.1	1717.0	205.9
283.500	5.20346	.0508	.1373	21102.7	21680.9	162.051	54.4	1352.4	212.3
284.000	5.27242	.0628	.1385	21129.6	21715.4	162.145	53.1	1123.2	217.6
284.500	5.34190	.0748	.1394	21155.9	21749.4	162.238	52.1	964.7	222.3
285.000	5.41185	.0869	.1403	21181.7	21783.0	162.328	51.3	848.0	226.4
285.500	5.48219	.0991	.1411	21207.2	21816.3	162.418	50.6	758.3	230.1
286.000	5.55290	.1114	.1417	21232.3	21849.3	162.506	50.0	687.1	233.5
286.500	5.62393	.1237	.1424	21257.2	21882.1	162.593	49.5	629.1	236.7
287.000	5.69526	.1361	.1429	21281.9	21914.7	162.679	49.1	581.0	239.6
287.500	5.76687	.1486	.1435	21306.3	21947.1	162.764	48.7	540.3	242.4
288.000	5.83873	.1612	.1440	21330.6	21979.3	162.848	48.4	505.5	245.1
288.500	5.91083	.1739	.1444	21354.7	22011.5	162.932	48.1	475.3	247.6
289.000	5.98315	.1866	.1449	21378.7	22043.5	163.015	47.8	449.0	250.0
289.500	6.05569	.1994	.1453	21402.5	22075.3	163.097	47.5	425.7	252.3
290.000	6.12842	.2123	.1456	21426.2	22107.1	163.179	47.3	405.0	254.5
291.000	6.27442	.2383	.1464	21473.3	22170.5	163.341	46.9	369.9	258.7
292.000	6.42112	.2645	.1470	21520.1	22233.6	163.502	46.6	341.1	262.7
293.000	6.56841	.2910	.1476	21566.6	22296.4	163.660	46.3	317.1	266.4
294.000	6.71624	.3176	.1481	21612.7	22359.0	163.818	46.1	296.8	270.0
295.000	6.86459	.3445	.1486	21658.7	22421.5	163.974	45.9	279.3	273.4
296.000	7.01341	.3715	.1490	21704.5	22483.8	164.129	45.7	264.2	276.7
297.000	7.16267	.3987	.1495	21750.2	22546.0	164.283	45.6	251.0	279.8
298.000	7.31232	.4261	.1498	21795.7	22608.1	164.436	45.4	239.3	282.8
299.000	7.46235	.4537	.1502	21841.0	22670.2	164.588	45.3	228.9	285.8
300.000	7.61273	.4814	.1505	21886.3	22732.2	164.739	45.2	219.6	288.6

Table CI. (Continued)

9.25 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	20598.6	21110.0	160.205	127.0		
280.000	4.78338	.0000	.1066	20662.6	21179.7	160.434	128.8		
280.500	4.83695	.0000	.1078	20727.6	21250.5	160.666	131.3		
281.000	4.89114	.0000	.1090	20794.0	21322.8	160.902	134.8		
281.500	4.94598	.0000	.1103	20862.7	21397.4	161.147	140.5		
282.000	5.00679	.0315	.1383	20917.2	21458.4	161.340	57.8	2058.9	200.0
282.500	5.07656	.0460	.1406	20945.3	21494.1	161.440	55.1	1475.0	209.4
283.000	5.14731	.0598	.1423	20972.4	21528.9	161.536	53.5	1174.0	216.3
283.500	5.21883	.0733	.1437	20998.9	21563.1	161.629	52.2	984.9	222.0
284.000	5.29096	.0868	.1448	21024.7	21596.7	161.720	51.3	853.5	226.9
284.500	5.36362	.1002	.1458	21050.2	21630.0	161.810	50.5	756.2	231.2
285.000	5.43675	.1136	.1467	21075.3	21663.0	161.898	49.9	680.9	235.1
285.500	5.51029	.1270	.1475	21100.1	21695.8	161.985	49.3	620.7	238.7
286.000	5.58421	.1405	.1482	21124.6	21728.3	162.071	48.9	571.4	242.0
286.500	5.65848	.1540	.1488	21149.0	21760.7	162.156	48.5	530.2	245.0
287.000	5.73306	.1676	.1495	21173.1	21792.9	162.240	48.1	495.3	248.0
287.500	5.80793	.1812	.1500	21197.1	21825.0	162.323	47.8	465.2	250.7
288.000	5.88307	.1948	.1505	21220.9	21856.9	162.406	47.5	439.1	253.3
288.500	5.95846	.2085	.1510	21244.6	21888.8	162.488	47.3	416.1	255.8
289.000	6.03410	.2223	.1515	21268.2	21920.5	162.570	47.0	395.8	258.2
289.500	6.10996	.2361	.1519	21291.6	21952.2	162.651	46.8	377.6	260.5
290.000	6.18603	.2500	.1523	21315.0	21983.8	162.732	46.6	361.3	262.7
291.000	6.33876	.2779	.1531	21361.5	22046.7	162.892	46.3	333.3	267.0
292.000	6.49223	.3059	.1538	21407.6	22109.5	163.050	46.0	309.9	270.9
293.000	6.64635	.3342	.1544	21453.6	22172.1	163.207	45.8	290.2	274.7
294.000	6.80108	.3626	.1550	21499.3	22234.5	163.363	45.6	273.3	278.3
295.000	6.95636	.3912	.1555	21544.8	22296.8	163.517	45.5	258.7	281.7
296.000	7.11215	.4199	.1560	21590.2	22359.1	163.671	45.3	245.9	285.0
297.000	7.26841	.4488	.1565	21635.4	22421.2	163.824	45.2	234.6	288.2
298.000	7.42512	.4778	.1569	21680.6	22483.3	163.975	45.1	224.6	291.3
299.000	7.58223	.5069	.1573	21725.6	22545.3	164.126	45.0	215.6	294.2
300.000	7.73984	.5363	.1577	21770.6	22607.4	164.277	44.9	207.5	297.1

Table CI. (Continued)

9.50 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	20528.3	21026.2	159.905	125.2		
280.000	4.78338	.0000	.1066	20591.3	21094.8	160.131	126.9		
280.500	4.83695	.0000	.1078	20655.3	21164.5	160.359	129.3		
281.000	4.89114	.0000	.1090	20720.8	21235.6	160.592	132.7		
281.500	4.94598	.0000	.1103	20788.4	21309.0	160.833	138.3		
282.000	5.01779	.0581	.1461	20817.4	21345.6	160.936	53.8	1203.0	215.2
282.500	5.09135	.0739	.1480	20843.9	21379.8	161.029	52.2	980.5	222.3
283.000	5.16574	.0892	.1495	20869.7	21413.5	161.121	51.1	837.2	228.1
283.500	5.24083	.1042	.1508	20895.1	21446.7	161.210	50.3	735.6	233.1
284.000	5.31650	.1191	.1519	20920.0	21479.7	161.298	49.6	659.2	237.5
284.500	5.39269	.1339	.1529	20944.7	21512.3	161.385	49.0	599.2	241.5
285.000	5.46934	.1486	.1537	20969.1	21544.8	161.471	48.5	550.6	245.2
285.500	5.54640	.1633	.1545	20993.2	21577.1	161.555	48.1	510.5	248.5
286.000	5.62384	.1781	.1552	21017.2	21609.2	161.639	47.7	476.7	251.7
286.500	5.70163	.1928	.1559	21041.0	21641.2	161.722	47.4	447.7	254.7
287.000	5.77975	.2075	.1565	21064.6	21673.0	161.805	47.1	422.6	257.5
287.500	5.85816	.2223	.1571	21088.1	21704.8	161.887	46.9	400.7	260.2
288.000	5.93686	.2371	.1577	21111.5	21736.4	161.968	46.7	381.3	262.8
288.500	6.01582	.2519	.1582	21134.8	21768.0	162.049	46.5	364.0	265.2
289.000	6.09503	.2667	.1587	21158.0	21799.6	162.129	46.3	348.5	267.6
289.500	6.17447	.2816	.1591	21181.1	21831.0	162.209	46.1	334.5	269.9
290.000	6.25414	.2965	.1595	21204.1	21862.4	162.288	46.0	321.8	272.0
291.000	6.41409	.3264	.1604	21249.9	21925.1	162.446	45.7	299.7	276.2
292.000	6.57482	.3564	.1611	21295.5	21987.6	162.602	45.5	281.0	280.2
293.000	6.73624	.3866	.1618	21340.9	22050.0	162.757	45.3	265.0	283.9
294.000	6.89830	.4169	.1624	21386.1	22112.2	162.912	45.1	251.1	287.5
295.000	7.06095	.4473	.1629	21431.2	22174.4	163.065	45.0	239.0	291.0
296.000	7.22415	.4778	.1635	21476.1	22236.6	163.217	44.9	228.3	294.3
297.000	7.38785	.5084	.1639	21521.0	22298.6	163.368	44.8	218.8	297.5
298.000	7.55202	.5392	.1644	21565.7	22360.7	163.518	44.7	210.2	300.6
299.000	7.71663	.5700	.1648	21610.4	22422.7	163.668	44.7	202.6	303.6
300.000	7.88166	.6010	.1652	21655.1	22484.7	163.817	44.6	195.6	306.5

Table CI. (Continued)

9.75 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	20461.6	20946.7	159.621	123.4		
280.000	4.78338	.0000	.1066	20523.7	21014.3	159.843	125.1		
280.500	4.83695	.0000	.1078	20586.8	21082.9	160.068	127.4		
281.000	4.89114	.0000	.1090	20651.3	21152.9	160.298	130.8		
281.500	4.95987	.0770	.1526	20690.9	21199.6	160.439	52.1	947.9	223.5
282.000	5.03667	.0948	.1545	20716.6	21233.2	160.530	50.8	798.2	230.4
282.500	5.11434	.1119	.1561	20741.8	21266.3	160.619	49.9	697.2	236.1
283.000	5.19274	.1286	.1574	20766.5	21299.1	160.707	49.2	623.1	241.0
283.500	5.27176	.1450	.1586	20790.9	21331.6	160.793	48.6	566.0	245.4
284.000	5.35132	.1613	.1596	20815.1	21363.9	160.878	48.1	520.2	249.4
284.500	5.43138	.1774	.1606	20839.0	21396.1	160.962	47.6	482.6	253.1
285.000	5.51188	.1935	.1614	20862.7	21428.1	161.046	47.3	451.1	256.5
285.500	5.59278	.2095	.1622	20886.3	21459.9	161.128	47.0	424.1	259.7
286.000	5.67406	.2254	.1629	20909.7	21491.7	161.210	46.7	400.9	262.7
286.500	5.75569	.2414	.1636	20933.0	21523.3	161.291	46.4	380.5	265.6
287.000	5.83764	.2573	.1642	20956.1	21554.9	161.372	46.2	362.6	268.3
287.500	5.91989	.2733	.1648	20979.2	21586.4	161.452	46.0	346.6	270.9
288.000	6.00243	.2892	.1653	21002.1	21617.8	161.532	45.8	332.2	273.4
288.500	6.08523	.3051	.1659	21025.0	21649.1	161.612	45.7	319.3	275.7
289.000	6.16829	.3211	.1664	21047.8	21680.5	161.691	45.5	307.6	278.1
289.500	6.25159	.3370	.1668	21070.6	21711.7	161.769	45.4	296.9	280.3
290.000	6.33511	.3530	.1673	21093.2	21743.0	161.847	45.3	287.1	282.4
291.000	6.50281	.3850	.1681	21138.4	21805.4	162.003	45.1	269.7	286.6
292.000	6.67129	.4171	.1689	21183.4	21867.6	162.157	44.9	254.9	290.5
293.000	6.84050	.4492	.1695	21228.3	21929.8	162.311	44.8	242.0	294.2
294.000	7.01037	.4815	.1702	21273.0	21992.0	162.463	44.7	230.7	297.8
295.000	7.18086	.5138	.1708	21317.6	22054.1	162.614	44.6	220.7	301.2
296.000	7.35192	.5462	.1713	21362.1	22116.2	162.765	44.5	211.8	304.5
297.000	7.52351	.5786	.1718	21406.6	22178.2	162.915	44.4	203.9	307.7
298.000	7.69559	.6112	.1723	21451.0	22240.2	163.064	44.4	196.7	310.8
299.000	7.86811	.6438	.1728	21495.3	22302.3	163.213	44.3	190.1	313.8
300.000	8.04109	.6765	.1732	21539.6	22364.3	163.361	44.3	184.2	316.7

Table CI. (Continued)

10.00 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	20398.2	20871.2	159.351	121.7		
280.000	4.78338	.0000	.1066	20459.4	20937.8	159.570	123.4		
280.500	4.83695	.0000	.1078	20521.7	21005.4	159.792	125.7		
281.000	4.90425	.1047	.1601	20565.3	21055.7	159.947	50.2	738.0	234.1
281.500	4.98477	.1243	.1619	20590.2	21088.7	160.036	49.3	643.5	240.5
282.000	5.06615	.1431	.1635	20614.6	21121.2	160.123	48.5	575.6	245.9
282.500	5.14825	.1614	.1649	20638.7	21153.6	160.208	47.9	523.8	250.7
283.000	5.23098	.1793	.1660	20662.6	21185.7	160.292	47.4	482.5	255.0
283.500	5.31427	.1971	.1671	20686.2	21217.6	160.376	47.0	448.7	258.9
284.000	5.39806	.2146	.1681	20709.6	21249.4	160.458	46.7	420.4	262.5
284.500	5.48232	.2321	.1689	20732.9	21281.1	160.540	46.4	396.3	265.9
285.000	5.56699	.2494	.1698	20756.0	21312.7	160.621	46.1	375.4	269.0
285.500	5.65206	.2667	.1705	20779.0	21344.2	160.702	45.9	357.1	272.0
286.000	5.73748	.2839	.1712	20801.9	21375.6	160.782	45.7	340.9	274.9
286.500	5.82325	.3011	.1719	20824.7	21407.0	160.862	45.5	326.6	277.6
287.000	5.90933	.3182	.1725	20847.4	21438.3	160.941	45.3	313.6	280.2
287.500	5.99572	.3353	.1731	20870.0	21469.6	161.019	45.2	302.0	282.6
288.000	6.08238	.3524	.1736	20892.5	21500.8	161.098	45.0	291.4	285.0
288.500	6.16931	.3695	.1741	20915.0	21532.0	161.176	44.9	281.7	287.4
289.000	6.25650	.3865	.1746	20937.5	21563.1	161.254	44.8	272.8	289.6
289.500	6.34393	.4036	.1751	20959.9	21594.2	161.331	44.7	264.6	291.8
290.000	6.43158	.4207	.1755	20982.2	21625.4	161.408	44.6	257.1	293.9
291.000	6.60754	.4548	.1764	21026.8	21687.5	161.561	44.5	243.5	297.9
292.000	6.78430	.4890	.1771	21071.2	21749.6	161.714	44.4	231.8	301.7
293.000	6.96180	.5231	.1778	21115.5	21811.7	161.865	44.3	221.4	305.4
294.000	7.13998	.5574	.1785	21159.7	21873.7	162.016	44.2	212.3	308.9
295.000	7.31879	.5916	.1791	21203.9	21935.8	162.166	44.1	204.1	312.3
296.000	7.49819	.6259	.1797	21248.0	21997.8	162.315	44.1	196.7	315.6
297.000	7.67812	.6603	.1802	21292.1	22059.9	162.464	44.0	190.1	318.7
298.000	7.85857	.6947	.1807	21336.1	22121.9	162.612	44.0	184.1	321.8
299.000	8.03950	.7291	.1812	21380.1	22184.0	162.759	44.0	178.6	324.8
300.000	8.22087	.7636	.1816	21424.0	22246.1	162.906	44.0	173.5	327.8

Table CI. (Continued)

10.25 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	20337.9	20799.4	159.094	120.1		
280.000	4.78338	.0000	.1066	20398.3	20865.0	159.310	121.8		
280.500	4.85286	.1428	.1685	20440.1	20913.6	159.459	48.4	579.1	246.7
281.000	4.93755	.1639	.1702	20464.2	20945.9	159.545	47.7	520.6	252.5
281.500	5.02305	.1842	.1717	20487.9	20977.9	159.629	47.2	476.1	257.5
282.000	5.10926	.2041	.1730	20511.3	21009.8	159.712	46.7	440.6	262.0
282.500	5.19608	.2235	.1742	20534.6	21041.5	159.795	46.3	411.5	266.1
283.000	5.28346	.2427	.1753	20557.7	21073.1	159.876	46.0	387.0	269.8
283.500	5.37134	.2616	.1762	20580.6	21104.6	159.957	45.7	366.0	273.3
284.000	5.45968	.2804	.1771	20603.4	21136.0	160.038	45.5	347.8	276.6
284.500	5.54845	.2991	.1779	20626.0	21167.4	160.117	45.2	331.9	279.7
285.000	5.63761	.3177	.1787	20648.6	21198.6	160.197	45.1	317.8	282.6
285.500	5.72715	.3362	.1794	20671.1	21229.8	160.275	44.9	305.1	285.4
286.000	5.81703	.3546	.1801	20693.5	21261.0	160.354	44.7	293.7	288.1
286.500	5.90723	.3729	.1807	20715.8	21292.2	160.432	44.6	283.4	290.6
287.000	5.99775	.3912	.1813	20738.1	21323.3	160.509	44.5	274.1	293.1
287.500	6.08855	.4095	.1819	20760.3	21354.3	160.587	44.4	265.5	295.5
288.000	6.17964	.4278	.1824	20782.5	21385.4	160.664	44.3	257.6	297.8
288.500	6.27098	.4460	.1829	20804.6	21416.4	160.741	44.2	250.3	300.0
289.000	6.36257	.4642	.1834	20826.7	21447.5	160.817	44.1	243.5	302.1
289.500	6.45441	.4823	.1839	20848.8	21478.5	160.893	44.1	237.3	304.2
290.000	6.54646	.5005	.1843	20870.8	21509.5	160.969	44.0	231.4	306.3
291.000	6.73123	.5368	.1852	20914.8	21571.5	161.121	43.9	220.9	310.2
292.000	6.91679	.5730	.1859	20958.7	21633.5	161.271	43.8	211.5	313.9
293.000	7.10309	.6093	.1867	21002.5	21695.5	161.421	43.8	203.3	317.5
294.000	7.29008	.6455	.1873	21046.2	21757.5	161.570	43.7	195.8	321.0
295.000	7.47770	.6818	.1879	21089.9	21819.5	161.719	43.7	189.2	324.3
296.000	7.66592	.7180	.1885	21133.6	21881.5	161.867	43.7	183.1	327.5
297.000	7.85469	.7543	.1890	21177.3	21943.6	162.014	43.7	177.6	330.7
298.000	8.04397	.7906	.1895	21221.0	22005.7	162.161	43.7	172.5	333.7
299.000	8.23374	.8269	.1900	21264.6	22067.9	162.307	43.7	167.9	336.7
300.000	8.42397	.8633	.1904	21308.3	22130.1	162.453	43.7	163.6	339.6

Table CI. (Continued)

10.50 MOL/DM3 ISOCHORE

TEMPERATURE	PRESSURE	ISOTHERM DERIV.	ISOCHORE DERIV.	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	SOUND VELOCITY
K	MPA	MPA.DM3/MOL	MPA/K	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.500	4.73040	.0000	.1054	20280.5	20731.0	158.849	118.6		
280.000	4.80802	.1928	.1778	20314.9	20772.8	158.972	46.8	463.1	260.9
280.500	4.89731	.2151	.1794	20338.2	20804.6	159.055	46.2	426.7	266.0
281.000	4.98734	.2368	.1808	20361.2	20836.2	159.137	45.8	397.5	270.6
281.500	5.07803	.2580	.1820	20384.0	20867.6	159.218	45.5	373.3	274.7
282.000	5.16932	.2788	.1831	20406.7	20899.0	159.299	45.2	352.8	278.6
282.500	5.26114	.2993	.1841	20429.2	20930.3	159.379	44.9	335.2	282.1
283.000	5.35345	.3196	.1851	20451.6	20961.5	159.458	44.7	319.8	285.5
283.500	5.44622	.3398	.1860	20473.9	20992.6	159.537	44.5	306.3	288.6
284.000	5.53941	.3597	.1868	20496.2	21023.7	159.615	44.4	294.2	291.6
284.500	5.63300	.3796	.1875	20518.3	21054.8	159.693	44.2	283.3	294.4
285.000	5.72695	.3993	.1883	20540.4	21085.8	159.771	44.1	273.5	297.1
285.500	5.82125	.4190	.1889	20562.4	21116.8	159.848	44.0	264.6	299.7
286.000	5.91588	.4386	.1896	20584.4	21147.8	159.925	43.9	256.5	302.2
286.500	6.01083	.4581	.1902	20606.3	21178.8	160.001	43.8	249.0	304.6
287.000	6.10606	.4775	.1908	20628.2	21209.7	160.078	43.7	242.1	307.0
287.500	6.20158	.4969	.1913	20650.0	21240.7	160.154	43.7	235.7	309.2
288.000	6.29736	.5163	.1918	20671.9	21271.6	160.229	43.6	229.8	311.4
288.500	6.39340	.5356	.1923	20693.7	21302.6	160.305	43.6	224.3	313.5
289.000	6.48967	.5549	.1928	20715.4	21333.5	160.380	43.5	219.1	315.6
289.500	6.58619	.5742	.1932	20737.2	21364.4	160.456	43.5	214.3	317.6
290.000	6.68292	.5934	.1937	20758.9	21395.4	160.531	43.4	209.7	319.6
291.000	6.87702	.6318	.1945	20802.3	21457.3	160.680	43.4	201.4	323.4
292.000	7.07191	.6702	.1953	20845.7	21519.2	160.829	43.3	194.0	327.0
293.000	7.26754	.7085	.1960	20889.0	21581.1	160.977	43.3	187.4	330.5
294.000	7.46384	.7468	.1966	20932.3	21643.2	161.124	43.3	181.4	333.9
295.000	7.66078	.7850	.1972	20975.6	21705.2	161.271	43.3	175.9	337.2
296.000	7.85830	.8233	.1978	21018.9	21767.3	161.418	43.3	170.9	340.3
297.000	8.05638	.8615	.1983	21062.2	21829.5	161.564	43.3	166.3	343.4
298.000	8.25498	.8997	.1988	21105.5	21891.7	161.710	43.3	162.1	346.4
299.000	8.45407	.9379	.1993	21148.9	21954.0	161.855	43.3	158.2	349.4
300.000	8.65362	.9762	.1998	21192.2	22016.4	162.000	43.4	154.6	352.2

Table CIIa. Saturation properties of ethylene as a function of temperature

COEXISTING PHASE PROPERTIES, LIQUID

TEMPERATURE	PRESSURE	DENSITY	LATENT HEAT	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	VELOCITY OF SOUND
K	MPA	MOL/DM3	J/MOL	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.700	4.75152	10.481	3216.9	20308.5	20761.9	158.952	47.3	502.2	255.9
279.800	4.76211	10.440	3168.9	20329.8	20785.9	159.035	47.6	519.9	253.6
279.900	4.77273	10.398	3120.0	20351.4	20810.4	159.119	47.8	539.1	251.3
280.000	4.78338	10.356	3069.9	20373.4	20835.3	159.204	48.1	560.0	249.0
280.100	4.79404	10.312	3018.8	20395.8	20860.7	159.291	48.4	583.0	246.6
280.200	4.80473	10.267	2966.4	20418.7	20886.7	159.380	48.8	608.2	244.2
280.300	4.81545	10.221	2912.7	20442.1	20913.2	159.471	49.1	636.0	241.7
280.400	4.82619	10.174	2857.5	20465.9	20940.3	159.564	49.5	666.9	239.2
280.500	4.83695	10.125	2800.8	20490.4	20968.1	159.659	49.8	701.5	236.7
280.600	4.84774	10.074	2742.4	20515.5	20996.7	159.757	50.3	740.2	234.1
280.700	4.85855	10.022	2682.1	20541.2	21026.0	159.858	50.7	784.1	231.4
280.800	4.86939	9.969	2619.7	20567.7	21056.2	159.961	51.1	834.1	228.7
280.900	4.88026	9.913	2555.0	20595.1	21087.4	160.069	51.6	891.6	225.9
281.000	4.89114	9.854	2487.8	20623.3	21119.7	160.180	52.2	958.3	223.0
281.100	4.90206	9.793	2417.7	20652.7	21153.2	160.295	52.8	1036.8	220.0
281.200	4.91300	9.730	2344.3	20683.2	21188.1	160.415	53.4	1130.3	216.9
281.300	4.92397	9.662	2267.1	20715.1	21224.7	160.541	54.1	1243.3	213.7
281.400	4.93496	9.591	2185.5	20748.6	21263.1	160.674	54.9	1382.8	210.3
281.500	4.94598	9.515	2098.6	20784.0	21303.8	160.814	55.8	1558.7	206.8
281.600	4.95703	9.434	2005.5	20821.7	21347.1	160.964	56.8	1787.1	203.0
281.700	4.96810	9.345	1904.7	20862.2	21393.8	161.125	58.0	2094.6	199.0
281.800	4.97921	9.248	1794.0	20906.3	21444.8	161.302	59.5	2528.8	194.7
281.900	4.99034	9.138	1670.2	20955.3	21501.4	161.499	61.3	3183.9	189.9
282.000	5.00150	9.012	1528.0	21011.1	21566.1	161.724	63.6	4273.4	184.4
282.100	5.01270	8.861	1357.2	21077.6	21643.3	161.993	66.8	6396.2	178.0
282.200	5.02393	8.662	1134.4	21163.6	21743.6	162.344	72.2	12021.7	169.5
282.300	5.03519	8.330	766.1	21305.2	21909.6	162.928	85.6	50818.0	154.5
282.345	5.04030	7.634	0.0	21610.1	22270.3	164.203			0.0

Table CIIb. Saturation properties of ethylene as a function of temperature

COEXISTING PHASE PROPERTIES, VAPOR

TEMPERATURE	PRESSURE	DENSITY	LATENT HEAT	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	VELOCITY OF SOUND
K	MPA	MOL/DM3	J/MOL	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
281.400	4.93496	5.720	2185.4	22585.8	23448.5	168.440	62.7	2253.7	199.0
281.500	4.94598	5.792	2098.6	22548.4	23402.4	168.269	63.6	2545.1	197.7
281.600	4.95703	5.869	2005.5	22508.0	23352.7	168.086	64.7	2921.0	196.2
281.700	4.96810	5.953	1904.7	22464.0	23298.5	167.887	65.9	3423.2	194.5
281.800	4.97921	6.046	1794.0	22415.2	23238.8	167.668	67.4	4125.8	192.4
281.900	4.99034	6.151	1670.2	22360.3	23171.6	167.424	69.2	5173.2	190.0
282.000	5.00150	6.273	1528.0	22296.7	23094.0	167.142	71.5	6887.8	186.9
282.100	5.01270	6.420	1357.2	22219.7	23000.5	166.804	74.7	10155.8	182.7
282.200	5.02393	6.614	1134.4	22118.4	22878.0	166.364	80.0	18527.2	176.2
282.300	5.03519	6.940	766.1	21950.2	22675.7	165.641	93.0	72255.4	162.1
282.345	5.04030	7.634	0.0	21610.2	22270.4	164.203			0.0

Table CIIIa. Saturation properties of ethylene as a funtion of pressure

COEXISTING PHASE PROPERTIES, LIQUID

TEMPERATURE	PRESSURE	DENSITY	LATENT HEAT	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	VELOCITY OF SOUND
K	MPA	MOL/DM3	J/MOL	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
279.686	4.75000	10.487	3223.7	20305.5	20758.4	158.941	47.3	499.8	256.2
279.780	4.76000	10.448	3178.6	20325.5	20781.1	159.018	47.5	516.2	254.0
279.874	4.77000	10.409	3132.7	20345.8	20804.0	159.097	47.8	534.0	251.9
279.968	4.78000	10.369	3085.9	20366.4	20827.4	159.177	48.0	553.2	249.7
280.062	4.79000	10.329	3038.3	20387.3	20851.0	159.258	48.3	574.0	247.5
280.156	4.80000	10.287	2989.7	20408.5	20875.1	159.340	48.6	596.7	245.3
280.249	4.81000	10.245	2940.2	20430.1	20899.6	159.424	48.9	621.5	243.0
280.342	4.82000	10.201	2889.5	20452.1	20924.6	159.510	49.3	648.7	240.7
280.435	4.83000	10.156	2837.6	20474.5	20950.1	159.597	49.6	678.7	238.3
280.528	4.84000	10.111	2784.5	20497.4	20976.1	159.687	50.0	712.0	236.0
280.621	4.85000	10.064	2729.9	20520.8	21002.7	159.778	50.3	748.9	233.5
280.713	4.86000	10.015	2673.9	20544.7	21030.0	159.871	50.7	790.4	231.0
280.806	4.87000	9.965	2616.1	20569.2	21057.9	159.967	51.2	837.1	228.5
280.898	4.88000	9.914	2556.6	20594.4	21086.6	160.066	51.6	890.1	225.9
280.989	4.89000	9.861	2495.0	20620.3	21116.2	160.168	52.1	950.8	223.3
281.081	4.90000	9.805	2431.1	20647.0	21146.8	160.273	52.6	1021.0	220.5
281.173	4.91000	9.747	2364.7	20674.7	21178.4	160.382	53.2	1102.9	217.7
281.264	4.92000	9.687	2295.4	20703.4	21211.3	160.495	53.9	1199.9	214.8
281.355	4.93000	9.624	2222.8	20733.3	21245.5	160.613	54.5	1316.1	211.8
281.446	4.94000	9.557	2146.4	20764.5	21281.4	160.737	55.3	1458.0	208.7
281.536	4.95000	9.486	2065.5	20797.4	21319.2	160.867	56.2	1634.7	205.4
281.627	4.96000	9.411	1979.3	20832.2	21359.3	161.006	57.1	1860.5	202.0
281.717	4.97000	9.329	1886.5	20869.5	21402.2	161.155	58.3	2158.1	198.3
281.807	4.98000	9.240	1785.6	20909.7	21448.6	161.315	59.6	2566.6	194.3
281.897	4.99000	9.142	1674.2	20953.7	21499.6	161.492	61.2	3159.1	190.0
281.987	5.00000	9.031	1548.5	21003.1	21556.8	161.691	63.2	4087.2	185.2
282.076	5.01000	8.900	1401.8	21060.3	21623.2	161.923	65.9	5722.8	179.7
282.165	5.02000	8.739	1220.9	21130.2	21704.7	162.208	69.9	9256.3	172.8
282.254	5.03000	8.514	969.4	21227.0	21817.8	162.604	77.3	21237.6	163.0
282.343	5.04000	7.909	301.1	21486.9	22124.2	163.686	127.5	1.8003+6	128.3
282.345	5.04030	7.634	0.0	21610.1	22270.3	164.203			0.0

Table CIIIb. Saturation properties of ethylene as a function of pressure

COEXISTING PHASE PROPERTIES, VAPOR

TEMPERATURE	PRESSURE	DENSITY	LATENT HEAT	INTERNAL ENERGY	ENTHALPY	ENTROPY	CV	CP	VELOCITY OF SOUND
K	MPA	MOL/DM3	J/MOL	J/MOL	J/MOL	J/MOL.K	J/MOL.K		M/S
281.446	4.94000	5.752	2146.4	22569.0	23427.8	168.363	63.1	2378.5	198.4
281.536	4.95000	5.819	2065.5	22534.1	23384.7	168.204	64.0	2670.5	197.2
281.627	4.96000	5.891	1979.3	22496.6	23338.6	168.034	65.0	3041.2	195.8
281.717	4.97000	5.968	1886.5	22456.0	23288.7	167.851	66.1	3526.4	194.2
281.807	4.98000	6.053	1785.6	22411.6	23234.2	167.652	67.5	4186.7	192.3
281.897	4.99000	6.148	1674.2	22362.1	23173.8	167.431	69.1	5133.8	190.1
281.987	5.00000	6.255	1548.5	22305.9	23105.2	167.183	71.1	6596.8	187.3
282.076	5.01000	6.381	1401.8	22239.9	23025.0	166.892	73.8	9127.7	183.8
282.165	5.02000	6.538	1220.9	22157.8	22925.6	166.535	77.8	14453.0	178.9
282.254	5.03000	6.759	969.4	22043.1	22787.2	166.039	84.9	31738.1	170.5
282.343	5.04000	7.360	301.1	21740.5	22425.3	164.752	133.1	2.1474+6	132.4
282.345	5.04030	7.634	0.0	21610.2	22270.4	164.203			0.0

APPENDIX D

Listing of Computer Program for Table Generation

```
C
C MAIN PROGRAM TO GENERATE ISOCHORE TABLES AS IN REPORT
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL ANAMES,QNAMES
C
      COMMON /COEFS/ A(20),Q(20),JAA(20),ANAMES(20),QNAMES(20)
      COMMON /CRITS/ TC,XMLWGT,RHOC,PC,PCON,UCON,SCON,DPCON
      COMMON /THERM/ IPHASE,DPDD,DPDT,U,H,ENTROP,CP,CV,CS,COMP
C
      DATA TMIN,TMAX,DMIN,DMAX/279.4D0,303.15D0,5.7D0,10.6D0/
      DATA XMLWGT/28.0541D0/
C
      CALL CONGEN
C
      TC=Q(4)+A(8)
      RHOC=Q(5)+A(3)
      PC=Q(6)+Q(3)
      PCON=PC/TC
      UCON=1.D3*PC
      SCON=UCON/TC
      DPCON=PCON/RHOC/RHOC
C
    1 WRITE(6,101)
  101 FORMAT(' <ENTER DENSITY (MOL/DM3)> ')
      READ(5,100,END=999) DENS
  100 FORMAT( )
C
      IF(DENS.LE.DMAX.AND.DENS.GE.DMIN) GO TO 11
      WRITE(6,102)
  102 FORMAT(' <**THE DENSITY INPUT IS OUTSIDE RANGE OF ',
     1'EQUATION''S VALIDITY**>')
      GO TO 1
C
   11 IDFIND=0
C
      WRITE(6,130)
  130 FORMAT(' ENTER START TEMP., STOP TEMP., & INCREMENT')
      READ(5,100) T1,T2,TINC
      IF(T1.LT.TMIN) T1=TMIN
      IF(T2.GT.TMAX) T2=TMAX
C
      WRITE(6,110) DENS
  110 FORMAT('1',5(/),T20,F5.2,' MOL/DM3 ISOCHORE',/)
      WRITE(6,111)
  111 FORMAT(' ',T2,'TEMPERATURE',T15,'PRESSURE',T25,'ISOTHERM',
     1T35,'ISOCHORE',T45,'INTERNAL',T55,'ENTHALPY',T65,'ENTROPY',
     2T76,'CV',T86,'CP',T94,'SOUND')
      WRITE(6,113)
  113 FORMAT(' ',T26,'DERIV.',T36,'DERIV.',T46,'ENERGY',T93,
     1'VELOCITY')
      WRITE(6,112)
  112 FORMAT(' ',/,T6,' K ',T16,' MPA ',T23,' MPA.DM3/MOL ',T35,
     1' MPA/K ',T45,' J/MOL ',T55,' J/MOL ',T64,' J/MOL.K ',T78,
     2' J/MOL.K ',T93,'  M/S ',/)
C
      XNUM=(T2-T1)/TINC
      INUM=IFIX(XNUM)
C
      DO 200 I=1,INUM
      TEMK=T1+TINC*(I-1)
C
      CALL THERMO(IDFIND,TEMK,DENS,PRESS,R,THETA)
C
      IF(IPHASE.GT.1.) GO TO 12
      WRITE(6,120) TEMK,PRESS,DPDD,DPDT,U,H,ENTROP,CV,CP,CS
  120 FORMAT(' ',T4,F7.3,T13,F9.5,T26,F6.4,T35,F6.4,T43,F9.1,
     1   T53,F9.1,T64,F8.3,T75,F5.1,T83,F7.1,T94,F5.1)
      GO TO 13
   12 WRITE(6,120) TEMK,PRESS,DPDD,DPDT,U,H,ENTROP,CV
   13 CONTINUE
C
  400 CONTINUE
  200 CONTINUE
      WRITE(6,121)
  121 FORMAT('1',19(/))
      GO TO 1
C
  999 STOP
      END
*
```

```
C
C THIS PROGRAM CALCULATES THE COEXISTENCE PROPERTIES
C INDEPENDENT VARIABLE IS TEMPERATURE
C
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL TITLE
      REAL ANAMES,QNAMES
      COMMON/COEFS/A(20),Q(20),JAA(20),ANAMES(20),QNAMES(20)
      COMMON/SATUR/IVAP,HEAT,RHOL,RHOG
      COMMON/THERM/IPHASE,DPDD,DPDT,U,H,S,CP,CV,CS,COMP
      COMMON/CRITS/TC,XMLWGT,RHOC,PC,PCON,UCON,SCON,DPCON
      DATA DMIN,DMAX/5.5D0,10.5D0/
      DATA XMLWGT,TMIN/28.0541D0,279.7D0/
C
      CALL CONGEN
      Q(3)=A(8)*Q(7)
      TC=Q(4)+A(8)
      RHOC=Q(5)+A(3)
      PC=Q(6)+Q(3)
      PCON=PC/TC
      UCON=1.D3*PC
      SCON=UCON/TC
      DPCON=PCON/RHOC/RHOC
C
      WRITE(6,333)
  333 FORMAT(' <ENTER SELECTION PARAMETER....1=LIQ,-1=VAP>'
      READ(5,1) IVAP
      IF(IVAP.EQ.-1) TITLE='VAPOR '
      IF(IVAP.EQ.1) TITLE='LIQUID'
      IF(IVAP.EQ.-1) TMIN=281.4
  201 FORMAT(1H1////,4X,'COEXISTING PHASE PROPERTIES, ',A6//4X,'TEMPERAT
     1URE',2X,'PRESSURE   DENSITY   LATENT  INTERNAL  ENTHALPY',3X,
     2 'ENTROPY     CV      CP     VELOCITY'/39X,'HEAT    ENERGY',38X,
     3'  OF SOUND'//8X,' K          MPA       MOL/DM3   J/MOL     J/MOL ',
     4   3X,' J/MOL      J/MOL.K      J/MOL.K         M/S '/)
      IFIN=0
C
      WRITE(6,334)
  334 FORMAT(' <ENTER START TEMP.,STOP TEMP., & INCREMENT>')
      READ(5,1) T1,T2,TINC
      IF(T1.LT.TMIN) T1=TMIN
      WRITE(6,201) TITLE
      T=T1-TINC
  100 T=T+TINC
      IF(T.GT.T2) IFIN=1
      IF(T.GE.TC) IFIN=2
      IF(T.GE.TC) T=TC-1.D-14
      D=RHOC
      CALL THERMO(0,T,D,P,R,THETA)
      IF(IFIN.EQ.2) HEAT=0.D0
      IF(IFIN.EQ.2) WRITE(6,202) T,PC,RHOC,HEAT,U,H,S,HEAT
  202 FORMAT(1X/F13.3,F11.5,F10.3,F10.1,F9.1,F10.1,F11.3,17X,F9.1////)
      IF(T.LT.TC .AND. CP.LT.99999.99) WRITE(6,203)
     1   T,P,D,HEAT,U,H,S,CV,CP,CS
  203 FORMAT(F13.3,F11.5,F10.3,F10.1,F9.1,F10.1,F11.3,F8.1,F9.1,F9.1)
      IICP=0
      IF(T.LT.TC .AND. CP.GT.99999.99.AND.IFIN.NE.2) IICP=1
      IF(IICP.EQ.1) ICP=DLOG10(CP)
      IF(IICP.EQ.1) CP=CP/10.D0**ICP
      IF(IICP.EQ.1) WRITE(6,204) T,P,D,HEAT,U,H,S,CV,CP,ICP,CS
  204 FORMAT(F13.3,F11.5,F10.3,F10.1,F9.1,F10.1,F10.3,F8.1,F9.4,'+',I1
     1       ,F8.1)
      IF(IFIN.EQ.0) GO TO 100
C
      WRITE(6,210)
  210 FORMAT(' ',20(/))
      STOP
C
  1   FORMAT( )
      END
*
```

```
      SUBROUTINE THERMO(IDFIND,T,D,P,R1,TH1)
C
C  1. NOT ON THE SATURATION CURVE (ISAT=0) :
C  GIVEN THE TEMPERATURE T(K) AND DENSITY D(KG/M3), THIS ROUTINE
C  CALCULATES PRESSURE P(MPA) AND ITS DERIVATIVES W.R.T D AT
C  CONSTANT T DPDD(MPA/(MOL/DM3)) AND W.R.T T AT CONSTANT D
C  DPDT(MPA/K), ENERGY U AND ENTHALPY H(J/MOL), ENTROPY AND
C  SPECIFIC HEATS CP AND CV(J/MOL.K), VELOCITY OF SOUND CS(M/S),
C  AND COMPRESSIBILITY COMP(1/MPA).
C  IF THE ENTRY POINT IS IN THE 2-PHASE REGION (IPHASE=2) IT
C  RETURNS CP=COMP=CS=0.
C  IF IDFIND=1 IT CALCULATES ONLY P AND DPDD.
C  2. ON THE SATURATION CURVE (ISAT.NE.0) :
C  GIVEN THE TEMPERATURE T, IT CALCULATES THE DENSITY D, LATENT HEAT
C  AND ALL THE ABOVE PROPERTIES ON THE VAPOR SIDE (ISAT=-1), OR THE
C  LIQUID SIDE (ISAT=1).
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      COMMON/THERM/IPHASE,DPDD,DPDT,U,H,ENTROP,CP,CV,CS,COMP
      COMMON/SATUR/ISAT,HEAT,DLIQ,DVAP
      COMMON/COEFS/A(20),Q(20)
      COMMON/CRITS/TC,XMLWGT,RHOC,PC,PCON,UCON,SCON,DPCON
      DIMENSION S(2),XK(2),SD(2)
      EQUIVALENCE (PW1,A(5)),(PW2,A(4)),(PW3,A(2)),
     1   (AMC,A(13)),(AM1,A(14)),(AM2,A(15)),(AM3,A(16)),
     2   (P00,Q(11)),(P20,Q(12)),(P40,Q(13)),
     3   (P01,Q(18)),(P21,Q(19)),(P41,Q(20)),
     4   (AA,A(10)),(XK0,A(7)),(XK1,A(12)),(PW11,Q(9)),
     5   (ALPHA,Q(10)),(ALHI,Q(15)),(BESQ,A(9))
      DATA XMLWGT/28.0541D0/
C
      XK(1)=XK0
      XK(2)=XK1
      TEE=(T-TC)/TC
      TW=-TC/T
      DTW=1.D0+TW
      IF(ISAT.NE.0) GO TO 10
      RHO=D/RHOC
      CALL CONVER(RHO,TEE,AMU,TH1,R1,RHO1,S,RHODI,ERR)
      GO TO 12
 10   TH1=1.D0
      IF(ISAT.EQ.-1) TH1=-0.99999999999999999D0
      IF(ISAT.EQ. 1) TH1= 0.99999999999999999D0
      R1=DTW/(1.D0-BESQ)
      CALL SS(R1,TH1,S,SD)
      RHO=TH1*(XK0*R1**A(6)+XK1*R1**Q(16))+A(1)*(S(1)+S(2))
      RHO=1.D0+PW11*DTW+RHO
      D=RHO*RHOC
      AMU=0.D0
 12   TT1=TH1*TH1
      TT2=TT1*TT1
      PW0=1.D0+DTW*(PW1+DTW*(PW2+DTW*PW3))
      PWMU=AMU*RHODI
      P0TH=P00+P20*TT1+P40*TT2
      P1TH=P01+P21*TT1+P41*TT2
      DPW0=XK0*P0TH*R1**(2.-ALPHA)
      DPW1=XK1*P1TH*R1**(2.-ALHI)
      DPW=AA*(DPW0+DPW1)
      PW=PW0+PWMU+DPW
      IF(IDFIND.EQ.1) GO TO 11
      DP0DT=PW1+DTW*(2.D0*PW2+3.D0*PW3*DTW)
      DM0DT=AM1+DTW*(2.D0*AM2+3.D0*AM3*DTW)
      UW=DP0DT-RHO*DM0DT+PW11*AMU+S(1)+S(2)
      HW=PW-TW*UW
      AMW=AMU+AMC+DTW*(AM1+DTW*(AM2+DTW*AM3))
      SW=HW-RHO*AMW
C
```

```
      D2PODT=2.D0*PW2+6.D0*PW3*DTW
      D2MODT=2.D0*AM2+6.D0*AM3*DTW
 11   IF(DABS(TH1).GE.1.D0) GO TO 13
      IPHASE=1
      CALL AUX(R1,TH1,D2PDT2,D2PDMT,D2PDM2,AA,XK,SD,CVCOEX)
      DPDD=DPCON*D*T/D2PDM2
      IF(IDFIND.EQ.1) GO TO 15
      DPDTCD=DPODT+PW11*(AMU-RHO/D2PDM2)+S(1)+S(2)-D2PDMT*RHO/D2PDM2
      DPWDTW=PW-TW*DPDTCD
      CVITW2=D2PODT-RHO*D2MODT+D2PDT2-(PW11+D2PDMT)**2/D2PDM2
      CVW=CVITW2*TW*TW
      CPW=CVW+D2PDM2*DPWDTW*DPWDTW/(RHO*RHO)
      COMP=1.D0/(D*DPDD)
      CS=1.D3*DSQRT(CPW/CVW*DPDD)/DSQRT(XMLWGT)
      IF(ISAT.EQ.0) GO TO 14
      RHO1=1.D0+PW11*DTW+A(1)*(S(1)+S(2))
      RHO2=XK0*R1**A(6)+XK1*R1**Q(16)
      DLIQ=RHOC*(RHO1+RHO2)
      DVAP=RHOC*(RHO1-RHO2)
      DPDT2=PW-TW*(UW+RHO*DMODT)
      HEAT=1.D3*T*(PCON*DPDT2)*(1.D0/DVAP-1.D0/DLIQ)
      GO TO 14
 13   IPHASE=2
      DPDD=0.
      IF(IDFIND.EQ.1) GO TO 15
      DPDTCD=UW+RHO*DMODT
      DPWDTW=PW-TW*DPDTCD
      CVI0=(2.-ALPHA)*(1.-ALPHA)*R1**(-ALPHA)*XK0*P0TH
      CVI1=(2.-ALHI )*(1.-ALHI )*R1**(-ALHI )*XK1*P1TH
      CVITW2=D2PODT-RHO*D2MODT+AA*(1./(1.-BESQ))**2*(CVI0+CVI1)
      CVW=CVITW2*TW*TW
      CPW=0.
      COMP=0.
      CS=0.
C
 14   DPDT=PCON*DPWDTW
      SCOND=SCON/D
      U=UW*UCON/D
      H=HW*SCOND*T
      ENTROP=SW*SCOND
      CV=CVW*SCOND
      CP=CPW*SCOND
 15   P=PW*PCON*T
      RETURN
      END
*
```

```
      SUBROUTINE CONVER(RHO,TEE,AMU,TH1,R1,RHO1S,S1,RHODI,ERROR1)
C  THIS ROUTINE TRANSFORMS TEMPERATURE AND DENSITY TO THE
C  PARAMETRIC VARIABLES R AND THETA ACCORDING TO THE REVISED
C  AND EXTENDED SCALING EQUATIONS.
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /COEFS/ A(20),Q(20)
      DIMENSION S1(2),SD(2)
      EQUIVALENCE(BETA,A(6)),(DELTA,A(11)),(XK1,A(12)),(CC,A(1))
     1 ,(ALHI,Q(15)),(ALPHA,Q(10)),(BESQ,A(9)),(P11,Q(9))
     2 ,(DELI,Q(14)),(P1W,Q(18)),(P2W,Q(19)),(P4W,Q(20))
     3,(AA,A(10)),(XK0,A(7)),(S00,A(17)),(S20,A(18)),(BETAI,Q(16))
      TSTAR = TEE+1.D0
       DTSTIN = 1.D0 -  (1.D0/TSTAR)
      R1=DTSTIN
      IF(DTSTIN.LT.0.) R1=DTSTIN/(1.-BESQ)
      TH1=0.
      IF(DTSTIN.LT.0.) TH1=1.
      CALL SS(R1,TH1,S1,SD)
      RHODI = 1.D0 + P11*DTSTIN
      RHODIT = RHODI + CC*S1(1) + CC*S1(2)
      DRHO = RHO - RHODIT
      AMU = 0.D0
      IF(DTSTIN.GT.0.D0) GO TO 1
      RHO1CO = XK0*R1**BETA + XK1*R1**BETAI
      TWOFAZ = RHO1CO
      IF (DABS(DRHO).GT.TWOFAZ) GO TO 1
      RHO1S = DSIGN(RHO1CO,DRHO) + CC*S1(1)
      TH1 = DSIGN(1.D0,DRHO)
      ERROR1 = 1.D0
      GO TO 999
  1   CONTINUE
      IF(DRHO.NE.0.D0) GO TO 2
      TH1 = 0.D0
      R1 = DTSTIN
      RHO1S = CC*S1(1)
   2  CONTINUE
C RULE FOR FIRST PASS
       Y1 = DTSTIN
        DEN1 = RHO - RHODIT
      CALL RTHETA(R1,TH1,DEN1,Y1)
      TT=TH1*TH1
       AMU = AA* R1**(BETA*DELTA)*TH1*(1.D0-TT)
      Y1 = DTSTIN + CC*AMU
      CALL SS(R1,TH1,S1,SD)
        RHOWEG =  XK1*(R1**BETAI)*TH1 + CC*S1(2)
      RHO1S = DEN1 + CC*S1(1) + RHOWEG
      ERROR1 = RHO - RHODI - RHO1S
      IF( DABS(ERROR1).LT.1.D-5 ) GO TO 999
C RULE FOR SECOND PASS
      DEN12 = RHO - RHODI    - CC*S1(1) + RHOWEG
        IF (DEN12.EQ.DEN1) DEN12 = DEN1 - 1.D-06
      CALL RTHETA(R1,TH1,DEN12,Y1)
      TT = TH1*TH1
       AMU = AA* R1**(BETA*DELTA)*TH1*(1.D0-TT)
      Y1 = DTSTIN + CC*AMU
      CALL SS(R1,TH1,S1,SD)
        RHOWEG =  XK1*R1**BETAI*TH1 + CC*S1(2)
      RHO1S2 = DEN12 + CC*S1(1) + RHOWEG
      ERROR2 = RHO - RHODI - RHO1S2
      IF( DABS(ERROR2).GT.1.D-5 ) GO TO 998
      ERROR1 = ERROR2
      RHO1S = RHO1S2
      GO TO 999
```

```
 998  CONTINUE
C RULE FOR NTH PASS
       DEN2 = DEN12
      DO 44 ISIG = 1,10
      SLOPE = (ERROR2-ERROR1)/(DEN2 -DEN1)
        HOLD = DEN2
      DEN2 = DEN1 - (ERROR1/SLOPE)
      CALL RTHETA(R1,TH1,DEN2,Y1)
      TT = TH1*TH1
       AMU = AA* R1**(BETA*DELTA)*TH1*(1.D0-TT)
       Y1 = DTSTIN + CC*AMU
      CALL SS(R1,TH1,S1,SD)
        RHOWEG =  XK1*R1**BETAI*TH1 + CC*S1(2)
      RHO1S = DEN2 + CC*S1(1) + RHOWEG
       ERROR1 = ERROR2
      ERROR2 = RHO - RHODI - RHO1S
      IF( DABS(ERROR2).LT.1.D-6 ) GO TO 999
       DEN1 = HOLD
  44  CONTINUE
      IF(DABS(ERROR2).GT.1.D-6) WRITE (6,66) ERROR2,RHO,DTSTIN,DEN2,CC
  66  FORMAT(1X,'CONVER DOES NOT CONVERGE ',5E12.6)
  999 CONTINUE
      RETURN
      END
EOF AT LINE 87
*
```

```
      BLOCKDATA
      DOUBLE PRECISION A,Q
      COMMON /COEFS/A(20),Q(20),JAA(20),ANAMES(20),QNAMES(20)
C  THIS SUBROUTINE SUPPLIES THE PARAMETERS USED IN THE EQUATION
C  OF STATE.
      DATA A/-.007811D0,0.D0,0.D0,-18.1475D0,5.3350D0,.325D0,1.12289
     1D0,0.D0,1.3757D0,19.3214D0,4.82D0,.54617D0,-36.48891D0,-27.395534D0
     2,-12.2091D0,-11.8802D0,4*0.D0/
      DATA Q/-.008369D0,-.001218D0,0.D0,282.3452D0,7.634D0,5.0403D0
     1,.113090D0,-.777D0,12*0.D0/
      DATA ANAMES/6HC      ,6HCOT3  ,6HDELROC,6HCOT2  ,6HDPDT  ,6HBETA
     1,6HK0     ,6HDELTC ,6HB*B    ,6HA      ,6HDELTA ,6HK1     ,6HMUC
     2,6HMU1    ,6HMU2   ,6HMU3    ,6HS00    ,6HS20   ,6HS01    ,6HS21    /
      DATA QNAMES/2*6H       ,6HDELPC ,6HTC     ,6HRHOC  ,6HPC
     1,6HDPCDTC,6HSLOPDI,6HP11    ,6HALPHA ,6HP00    ,6HP20    ,6HP40
     2,6HDELTAI,6HALPHAI,6HBETA I,6HGAMMAI,6HP01    ,6HP21    ,6HP41    /
      END
EOF AT LINE 17
*
```

```
      SUBROUTINE CONGEN
C THIS SUBROUTINE CALCULATES ALL QUANTITIES NOT DEPENDENT ON R OR THETA
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      COMMON /COEFS/ A(20),Q(20)
      DATA DELPP,DELPM,DELPPH,DELPMH/1.D-6,-1.D-6,1.000001D0,.999999D0/
      EQUIVALENCE (DELI,Q(14)),(DRHOC,A(3)),(BETA,A(6)),(DELTA,A(11))
     1,(COTEE2,A(4)),(DPDT,A(5)),(BESQ,A(9))
     2,(CC,A(1)),(AA,A(10)),(TCK,Q(4)),(RHOC,Q(5)),(PC,Q(6)),(XK0,A(7))
     3,(ALHI,Q(15)),(BETI,Q(16)),(GAMI,Q(17)),(P01,Q(18)),(P21,Q(19))
     4,(ALPHA,Q(10)),(P00,Q(11)),(P20,Q(12)),(P40,Q(13)),(P41,Q(20))
     5,(S00,A(17)),(S20,A(18)),(S01,A(19)),(S21,A(20))
       ALPHA = 2.D0 - A(6)*(A(11) + 1.D0    )
        GAMMA = BETA*(DELTA - 1.D0)
       DELI =  0.50D0
        ALHI = ALPHA - DELI
        BETI = BETA + DELI
         GAMI = GAMMA - DELI
       ERR = 2.D0*BETA*DELTA - 1.D0
       P00 = (BETA*(DELTA-3.D0)-BESQ*ALPHA*GAMMA)/(2.D0*
     1 BESQ*BESQ*(2.D0-ALPHA)*(1.D0-ALPHA)*ALPHA)
      P20=-(BETA*(DELTA-3.)-BESQ*ALPHA*ERR)/(2.*BESQ*(1.-ALPHA)*(ALPHA))
      P40=(ERR-2.)/2./ALPHA
      S00 = (2.-ALPHA)*P00
      S20 = -BETA*(DELTA-3.)/2./BESQ/ALPHA
      DA=Q(1)
      DB=Q(2)
       RA = DA/(1.D0 - BESQ)
       RB = DB/(1.D0 - BESQ)
      SW0 = S00+S20
      DR0=SW0*(RA**(1.-ALPHA)-RB**(1.-ALPHA))
       P01 = (BETA*(DELTA-3.D0)-3.D0*DELI-A(9)*ALHI*GAMI)
     1 /(2.D0*A(9)*A(9)*(2.D0-ALHI)*(1.D0-ALHI)*ALHI)
       P21 = -((BETA*(DELTA-3.D0)-3.D0*DELI-A(9)*ALHI*ERR)/
     1  (2.D0*A(9)*(1.D0-ALHI)*ALHI))
      P41 = (.5*ERR - 1.)/ALHI
      S01 = (2.-ALHI)*P01
      S21 = -(BETA*DELTA-3.*BETI)/2./BESQ/ALHI
        PTW = P01 + P21 + P41
      SW1 = S01+S21
      DR1=SW1*(RA**(1.-ALHI)-RB**(1.-ALHI))
      GO TO 10
C
      ENTRY  Q9GEN
 10   IF(XK0.LE.0.D0) XK0=0.0001D0
CC      Q(6)=A(13)
CC      Q(8)=A(14)
      D1=CC*AA*XK0*DR0
      D2=CC*AA*A(12)*DR1
      Q(9) = (Q(8)*(1./(1.-DB)-1./(1.-DA))+D1+D2)/(DB-DA)
      Q(7)=(A(5)+1.D0)*Q(6)/Q(4)
      Q(3)=A(8)*Q(7)
      RETURN
      END
EOF AT LINE 53
*
```

```
      SUBROUTINE AUX(R1,TH1,D2PDT2,D2PDMT,D2PDM2,AA,XK,SD,CVCOEX)
C  THIS ROUTINE CALCULATES SECOND DERIVATIVES OF THE SCALED
C  EQUATION OF STATE
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /COEFS/ A(20),Q(20)
       DIMENSION XK(2),S(2), SD(2),W(2),Y(2),Z(2),COEX(2)
      EQUIVALENCE (CC,A(1)),(BETA,A(6)),(BESQ,A(9)),(DELTA,A(11))
     1,(ALPHA,Q(10)),(S00,A(17)),(S20,A(18)),(S01,A(19)),(S21,A(20))
        DELI = 0.D0
       S(1)=S00+S20*TH1*TH1
       S(2)=S01+S21*TH1*TH1
       SD(1) = 2.*TH1*S20
       SD(2) = 2.*TH1*S21
        WW = 0.D0
        YY = 0.D0
        ZZ = 0.D0
         GAMMA = BETA*(DELTA - 1.D0)
       TT1 = TH1*TH1
        TER = 2.D0*BETA*DELTA - 1.D0
       G = (1.+(BESQ*TER-3.)*TT1 - BESQ*(TER-2.)*TT1*TT1)
        CVCOEX = 0.D0
         DO 30 I = 1,2
         ALHI = ALPHA - DELI
         BETI = BETA + DELI
         GAMI = GAMMA - DELI
        W(I)=(1.-ALHI)*(1.-3.*TT1)*S(I)-BETA*DELTA*(1.-TT1)*TH1*SD(I)
        W(I) = (W(I) *(R1**(-ALHI)))/G
        W(I) = W(I)*XK(I)
        WW = WW + W(I)
       Y(I) = BETI*(1.D0-3.D0*TT1)*TH1 - BETA*DELTA*(1.D0-TT1)*TH1
        Y(I) = (Y(I) *(R1**(BETI - 1.D0)))*XK(I)/G
        YY = YY + Y(I)
         Z(I) = 1.D0 - BESQ*(1.D0 - (2.D0*BETI))*TT1
        Z(I) = (Z(I) *(R1**(-GAMI)))*XK(I)/G
        ZZ = ZZ + Z(I)
        A1 = (BETA*(DELTA-3.D0)-3.D0*DELI-BESQ*ALHI*GAMI)
     1 /(2.D0*BESQ*BESQ*(2.D0-ALHI)*(1.D0-ALHI)*ALHI)
        A2 = 1+((BETA*(DELTA-3.D0)-3.D0*DELI-BESQ*ALHI*TER)/
     1   (2.D0*BESQ*(1.D0-ALHI)*ALHI))
        A2 = - A2
        A4 = 1.D0+((TER-2.D0)/(2.D0*ALHI))
        F1 = A1 + A2 + A4
        COEX(I) = ((2.D0 - ALHI)*(1.D0 - ALHI)*(R1**(-ALHI))*F1*XK(I))
        CVCOEX = CVCOEX + COEX(I)
        DELI = 0.5D0
30       CONTINUE
        D2PDT2 = AA*WW
        D2PDMT = YY + AA*CC*WW
        D2PDM2 = ZZ/AA + 2.D0*CC*YY + (CC**2)*AA*WW
       RETURN
       END
EOF AT LINE 51
*
```

```
      SUBROUTINE DFIND(T,P,D,DGUESS,DMIN,DMAX)
C
C  GIVEN THE TEMPERATURE T(K), PRESSURE P(MPA), AND AN INITIAL
C  GUESS DENSITY DGUESS(KG/M3), THIS ROUTINE FINDS THE
C  CORRESPONDING DENSITY D(KG/M3) IN THE RANGE (DMIN,DMAX).
C  IF T IS BELOW THE CRITICAL ISOTHERM, DGUESS MUST BE SET
C  EQUAL TO THE CRITICAL DENSITY, OTHERWISE IT MAY YIELD
C  ERRONEOUS RESULTS. IF THE ENTRY POINT IS IN THE 2-PHASE
C  REGION CRITICAL DENSITY IS RETURNED FOR D.
C
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/THERM/IPHASE,DPDD
C
      D=DGUESS
      DO 10 I=1,20
      CALL THERMO(1,T,D,PP,R,THETA)
      PDIF=PP-P
      IF(IPHASE.EQ.2) GO TO 18
      DELD=-PDIF/DPDD
      D=D+DELD
      IF(D.LT.DMIN) D=DMIN
      IF(D.GT.DMAX) D=DMAX
      IF(DABS(DELD/D).LT.1.D-6) GO TO 19
      GO TO 10
 18   IF(DABS(PDIF).LE.0.D0) GO TO 19
      IF(PDIF.LT.0.D0) D=DMAX
      IF(PDIF.GT.0.D0) D=DMIN
 10   CONTINUE
      WRITE(6,21) T,P,PP,D
 21   FORMAT(5X,'DFIND DOES NOT CONVERGE :',4F12.4)
 19   RETURN
      END
EOF AT LINE 32
*



      SUBROUTINE TFIND(P,T)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      COMMON/THERM/IPHASE,DPDD,DPDT,U,H,ENTROP,CP,CV,CS,COMP
      COMMON/SATUR/IVAP,HEAT,RHOL,RHOG
      COMMON/COEFS/A(20),Q(20)
      COMMON/CRITS/TC,XMLWGT,RHOC,PC,PCON,UCON,SCON,DPCON
C
      T=TC-1.D0
      D=RHOC
      ISAVE=IVAP
      IVAP=2
      DO 10 I=1,20
      CALL THERMO(0,T,D,PP,R1,TH1)
      DT=(PP-P)/DPDT
      T=T-DT
      IF(T.GT.TC) GO TO 12
      IF(DABS(DT/T).LT.1.D-8) GO TO 20
      GO TO 10
 12   T=TC-0.001D0
 10   CONTINUE
      WRITE(6,11) P,PP,T
 11   FORMAT(1X/1X'TFIND DOES NOT CONVERGE :',3F12.6/)
 20   IVAP=ISAVE
      RETURN
      END
```

```
C  MAIN PROGRAM TO GENERATE TABLES IN DIFFERENT UNITS
      IMPLICIT REAL*8(A-H,O-Z)
      REAL ANAMES,QNAMES
C
      COMMON /COEFS/ A(20),Q(20),JAA(20),ANAMES(20),QNAMES(20)
      COMMON /UNITS/ IT,ID,IP,IH,NT,ND,NP,NH,FT,FD,FP,FH
      COMMON /CRITS/ TC,XMLWGT,RHOC,PC,PCON,UCON,SCON,DPCON
      COMMON /THERM/ IPHASE,DPDD,DPDT,U,H,ENTROP,CP,CV,CS,COMP
C
      DATA TMIN,TMAX,DMIN,DMAX/279.4D0,303.15D0,5.7D0,10.6D0/
      DATA XMLWGT/28.0541D0/
C
      CALL CONGEN
C
      TC=Q(4)+A(8)
      RHOC=Q(5)+A(3)
      PC=Q(6)+Q(3)
      PCON=PC/TC
      UCON=1.D3*PC
      SCON=UCON/TC
      DPCON=PCON/RHOC/RHOC
C
      CALL UNIT
C
    1 WRITE(6,101)
  101 FORMAT(' <ENTER DENSITY (MOL/DM3)> ')
      READ(5,100,END=999) DENSIN
  100 FORMAT( )
      DENS=DENSIN*FD
C
      IF(DENS.LE.DMAX.AND.DENS.GE.DMIN) GO TO 11
      WRITE(6,102)
  102 FORMAT(' <**THE DENSITY INPUT IS OUTSIDE RANGE OF ',
     1'EQUATION''S VALIDITY**>')
      GO TO 1
C
   11 IDFIND=0
C
      WRITE(6,130)
  130 FORMAT(' ENTER START TEMP., STOP TEMP., & INCREMENT')
      READ(5,100) TT1,TT2,TTINC
      T1=TTT(TT1)
      T2=TTT(TT2)
      IF(T1.LT.TMIN) T1=TMIN
      IF(T2.GT.TMAX) T2=TMAX
      TT1=TTI(T1)
      TT2=TTI(T2)
C
      WRITE(6,110) DENSIN
  110 FORMAT('1',5(/),T20,F5.2,'  ISOCHORE',/)
      WRITE(6,111)
  111 FORMAT(' ',T2,'TEMPERATURE',T15,'PRESSURE',T25,'ISOTHERM',
     1T35,'ISOCHORE',T45,'INTERNAL',T55,'ENTHALPY',T65,'ENTROPY',
     2T76,'CV',T86,'CP',T94,'SOUND')
      WRITE(6,113)
*
```

```
  113 FORMAT(' ',T26,'DERIV.',T36,'DERIV.',T46,'ENERGY',T93,
     1'VELOCITY..M/S')
C
      XNUM=(TT2-TT1)/TTINC
      INUM=IFIX(XNUM)
C
      DO 200 I=1,INUM
      TEMK=TT1+TTINC*(I-1)
C
      TEMKK=TTT(TEMK)
      CALL THERMO(IDFIND,TEMKK,DENS,PRESS,R,THETA)
      DPDD=DPDD*FP/FD
      DPDT=DPDT*FP*FT
      PRESS=PRESS*FP
      U=U*FH
      H=H*FH
      ENTROP=ENTROP*FH*FT
      CV=CV*FH*FT
      CP=CP*FH*FT
C
      IF(IPHASE.GT.1.) GO TO 12
      WRITE(6,120) TEMK,PRESS,DPDD,DPDT,U,H,ENTROP,CV,CP,CS
  120 FORMAT(' ',T4,F7.3,T13,F9.5,T26,F6.4,T35,F6.4,T43,F9.1,
     1   T53,F9.1,T64,F8.3,T75,F5.1,T83,F7.1,T94,F5.1)
      GO TO 13
   12 WRITE(6,120) TEMK,PRESS,DPDD,DPDT,U,H,ENTROP,CV
   13 CONTINUE
C
  400 CONTINUE
  200 CONTINUE
      WRITE(6,121)
  121 FORMAT('1',19(/))
      GO TO 1
C
  999 STOP
      END
*
```

```
      FUNCTION TTT(T)
C FUNCTION TO CONVERT INPUT TEMPERATURES IN EXTERNAL UNITS TO DEG K
      DOUBLE PRECISION T,TTT,FT,FD,FP,FH
      COMMON /UNITS/ IT,ID,IP,IH,NT,ND,NP,NH,FT,FD,FP,FH
      GO TO (1,2,3,4),IT
   1  TTT=T
      FT=1.D0
      RETURN
   2  TTT=T+273.15D0
      FT=1.D0
      RETURN
   3  TTT=T/1.8D0
      FT=.55555555555556D0
      RETURN
   4  TTT=(T+459.67D0)/1.8D0
      FT=.55555555555556D0
      RETURN
      END
*
```

```
      FUNCTION TTI(T)
C FUNCTION TO CONVERT INTERNAL TEMPERATURES IN DEG K TO EXTERNAL UNIT
      DOUBLE PRECISION T,TTI,FT,FD,FP,FH
      COMMON /UNITS/ IT,ID,IP,IH,NT,ND,NP,NH,FT,FD,FP,FH
      GO TO (5,6,7,8),IT
   5  TTI=T*1.D0
      RETURN
   6  TTI=T-273.15D0
      TTI=TTI*1.D0
      RETURN
   7  TTI=T*1.8D0
      RETURN
   8  TTI=T*1.8D0-459.67D0
      RETURN
      END
*
```

```
      SUBROUTINE UNIT
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      COMMON /UNITS/ IT,ID,IP,IH,NT,ND,NP,NH,FT,FD,FP,FH
      DIMENSION FFD(4),FFP(4),FFH(6),NNT(4),NNP(4)
      DIMENSION NND(4),NNH(6)
      DATA FFD/0.03564541D0,35.64541D0,1.D0,.570953D0/
      DATA FFP/1.D0,10.D0,9.869232667D0,145.037738D0/
      DATA FFH/2*.03564541D0,1.D0,8.51379D-3,.238845 9D0,.01532476D0/
      DATA NNT/1HK,1HC,1HR,1HF/
      DATA NND/6HKG/M3 ,6HG/CM3 ,6HMOL/L ,6HLB/FT3/
      DATA NNP/3HMPA,3HBAR,3HATM,3HPSI/
      DATA NNH/6HKJ/KG ,6H J/G  ,6HJ/MOL ,6HCAL/G ,6HCAL/M ,6HBTU/LB/
      DATA A1,A2,A3,A4,A5,A6,A7,A8/6HTEMPER,6HATURE ,6HDENSIT,
     16HY     ,6HPRESSU,6HRE    ,6HENERGY,6H      /
      WRITE(6,11) A1,A2
      WRITE(6,12)
      READ(5,10) IT
      NT=NNT(IT)
      WRITE(6,11) A3,A4
      WRITE(6,13)
      READ(5,10) ID
      ND=NND(ID)
      FD=FFD(ID)
      WRITE(6,11) A5,A6
      WRITE(6,14)
      READ(5,10) IP
      NP=NNP(IP)
      FP=FFP(IP)
      WRITE(6,11) A7,A8
      WRITE(6,15)
      READ(5,10) IH
      NH=NNH(IH)
      FH=FFH(IH)
      RETURN
   10 FORMAT()
   11 FORMAT(' ENTER UNITS CHOSEN FOR ',2A6)
   12 FORMAT(' CHOOSE FROM 1=DEG K, 2=DEG C, 3=DEG R, 4=DEG F')
   13 FORMAT(' CHOOSE FROM 1=KG/M3, 2=G/CM3, 3=MOL/L, 4=LB/FT3')
   14 FORMAT(' CHOOSE FROM 1=MPA, 2=BAR, 3=ATM, 4=PSIA')
   15 FORMAT(' CHOOSE FROM 1=KJ/KG, 2=J/G, 3=J/MOL, 4=CALORIES/G, 5=CALI
     1RIES/MOL, 6=BTU/LB')
      END
*
```

Appendix E. Units and Conversion Factors

Units used in the Tables

Pressure - MPa
Temperature - K
Density - mol/dm^3
Energy, Enthalpy - J/mol
Entropy - J/(mol·K)
Specific heat - J/(mol·K)
Speed of sound - m/s

Molecular weight of ethylene M = 28.0541
Gas constant* R = 8.31434 J/mol

Reduction Factors

Pressure

MPa to	Multiply table value by
Pa	10^6
bar	10
atmosphere	9.869233
psi, lbf/in^2	145.037738

Density

mol/dm^3 to	Multiply table value by
kg/m^3	28.0541
lbm/ft^3	1.7513585

Energy, Enthalpy

J/mol to	Multiply table value by
kJ/kg	0.0356454
BTU/lbm	0.01532476

Entropy, Specific heats

J/(mol·K) to	Multiply table value by
kJ/(kg.K)	0.0356454
BTU/(lbm·R)	0.00851375

Temperature

K to	Transform table value by
°C	(T,°C) = (T,K) - 273.15
°F	(T,°F) = $\frac{9}{5}$ [(T,K) - 273.15] + 32
R	(T,R) = $\frac{9}{5}$ (T,K)

Speed of sound

m/s to	Multiply table value by
ft/s	3.28083

*The actual value of the gas constant is not required for the programs in this Tech. Note. The value given here is that used in reducing the original Burnett PVT data [5,24] and in NBS Tech. Note 1045 [7].

FIGURES

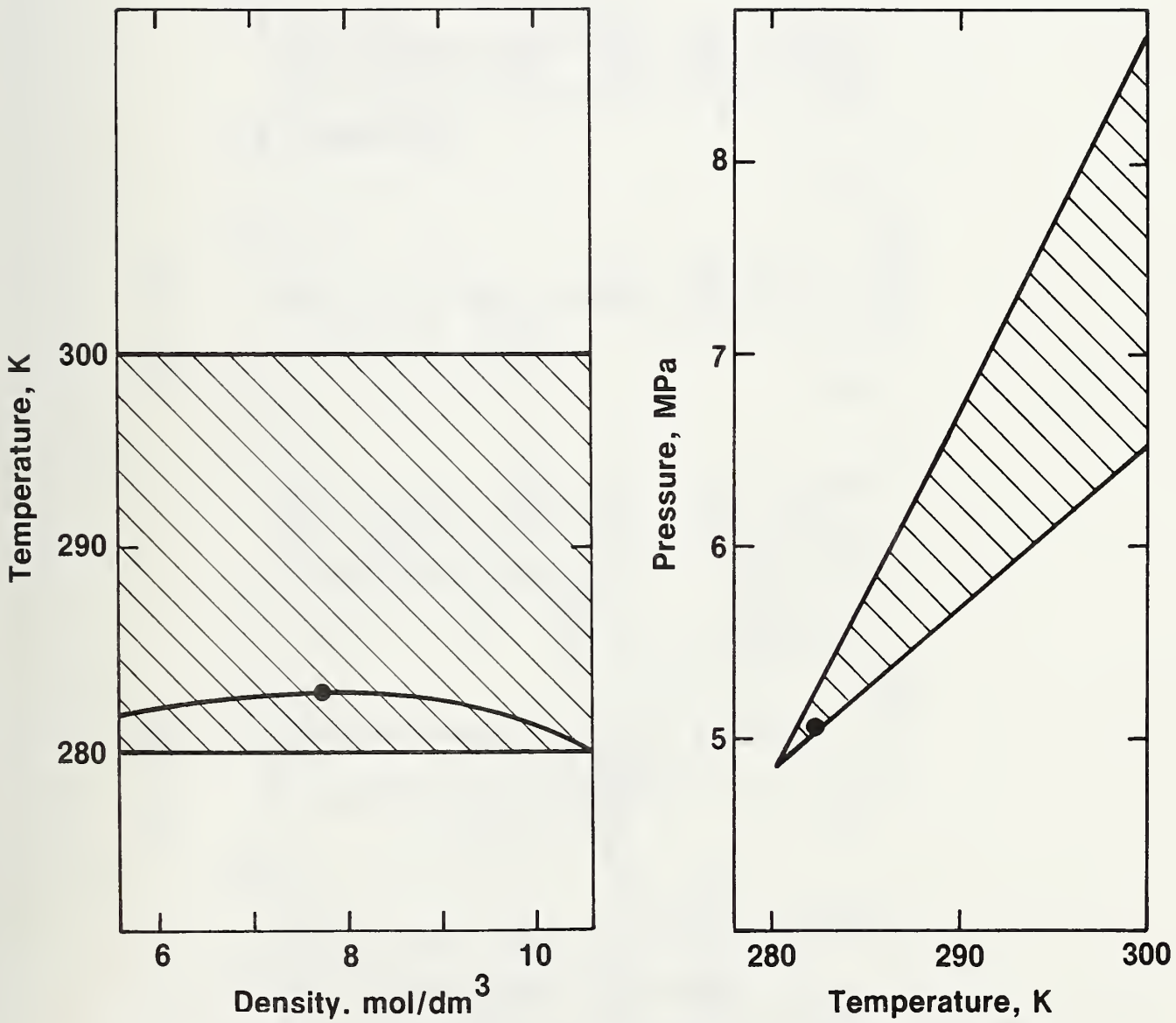

Fig. 1 Range of validity of the present formulation. Left: in temperature - density space. Right: in pressure - temperature space.

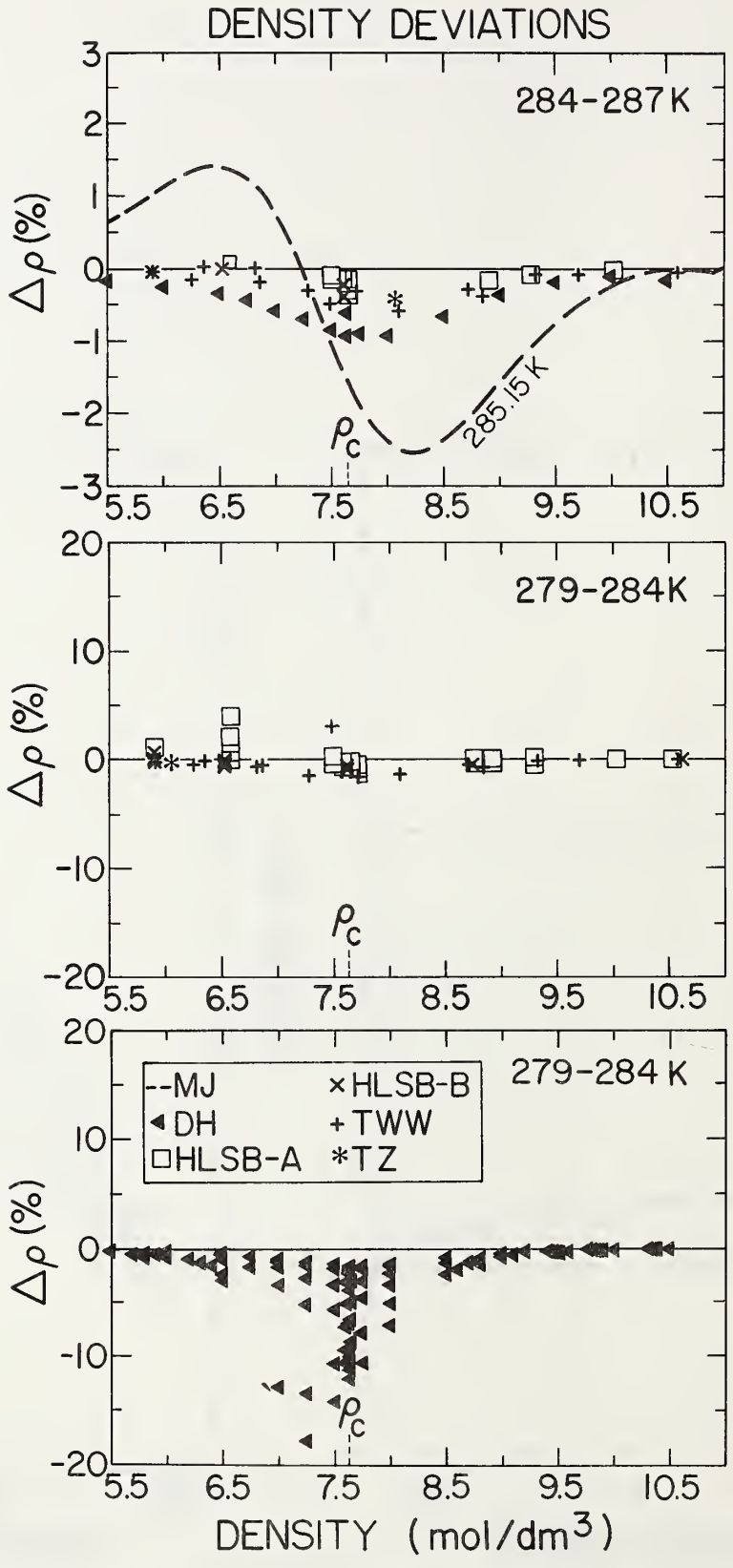

Fig. 2a Departures of the experimental densities of Douslin and Harrison (◄), Hastings et al. (□, sample A and X, sample B), Trappeniers et al. (+) and Thomas and Zander (*) from our formulation (baseline) if compared at the same temperature and pressure. The dashed curve represents the departures of the McCarty-Jacobsen formulation from our own.

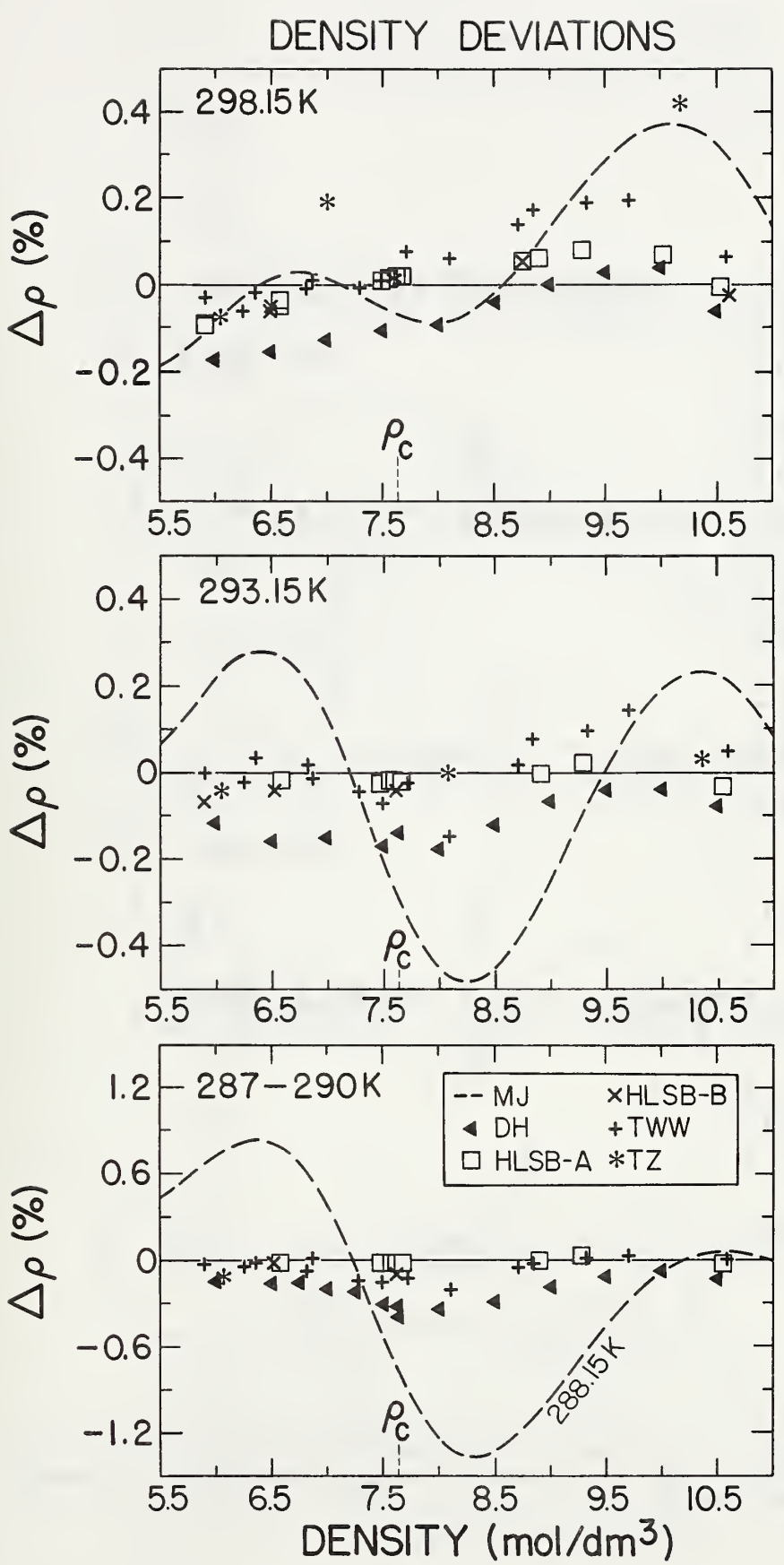

Fig. 2b As in Fig. 2a.

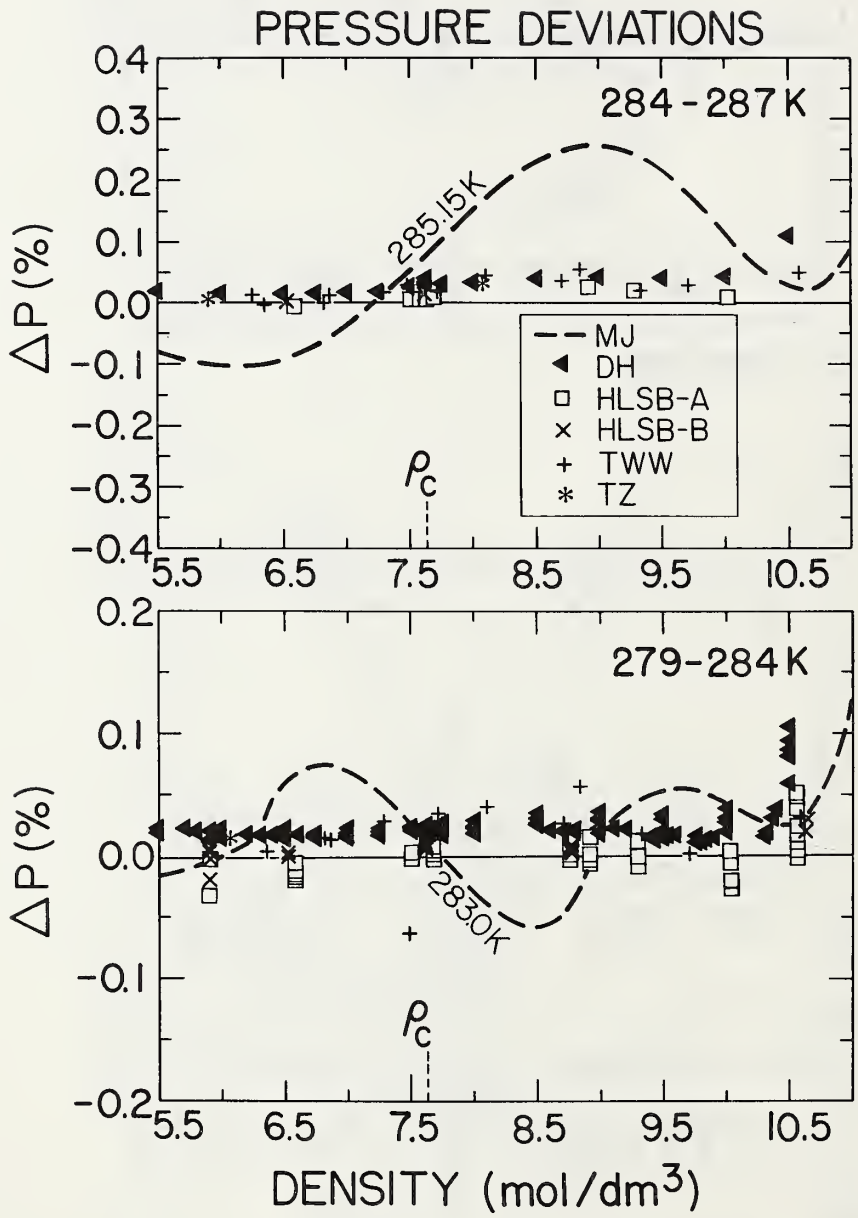

Fig. 3a Departures of the experimental pressures of Douslin and Harrison (◀), Hastings et al. (□, sample A and X, sample B), Trappeniers et al. (+) and Thomas and Zander (*) from our formulation (base line) if compared at the same temperature and density. The dashed curve represents the departures of the McCarty-Jacobsen formulation from our own.

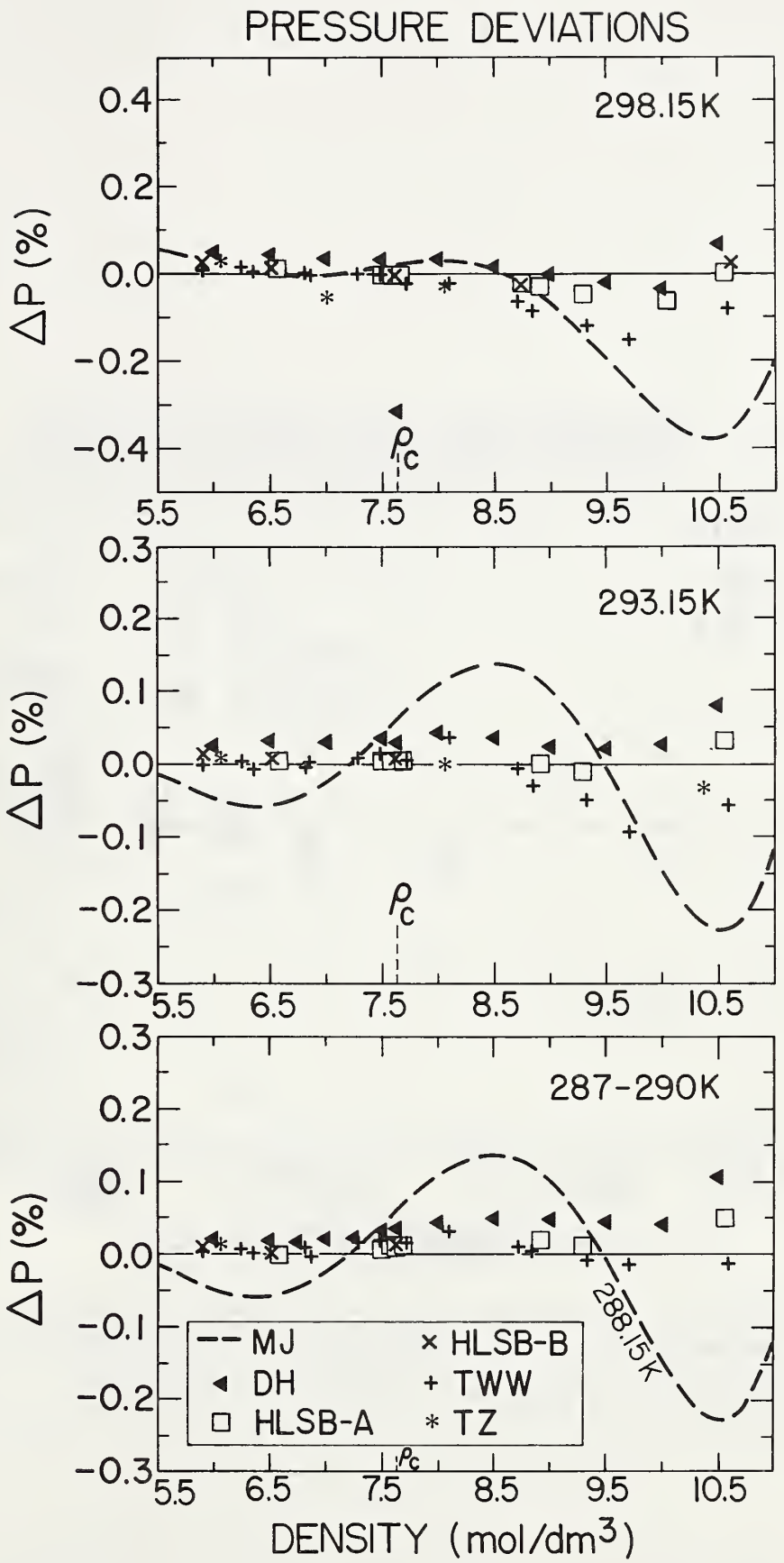

Fig. 3b As in Fig. 3a.

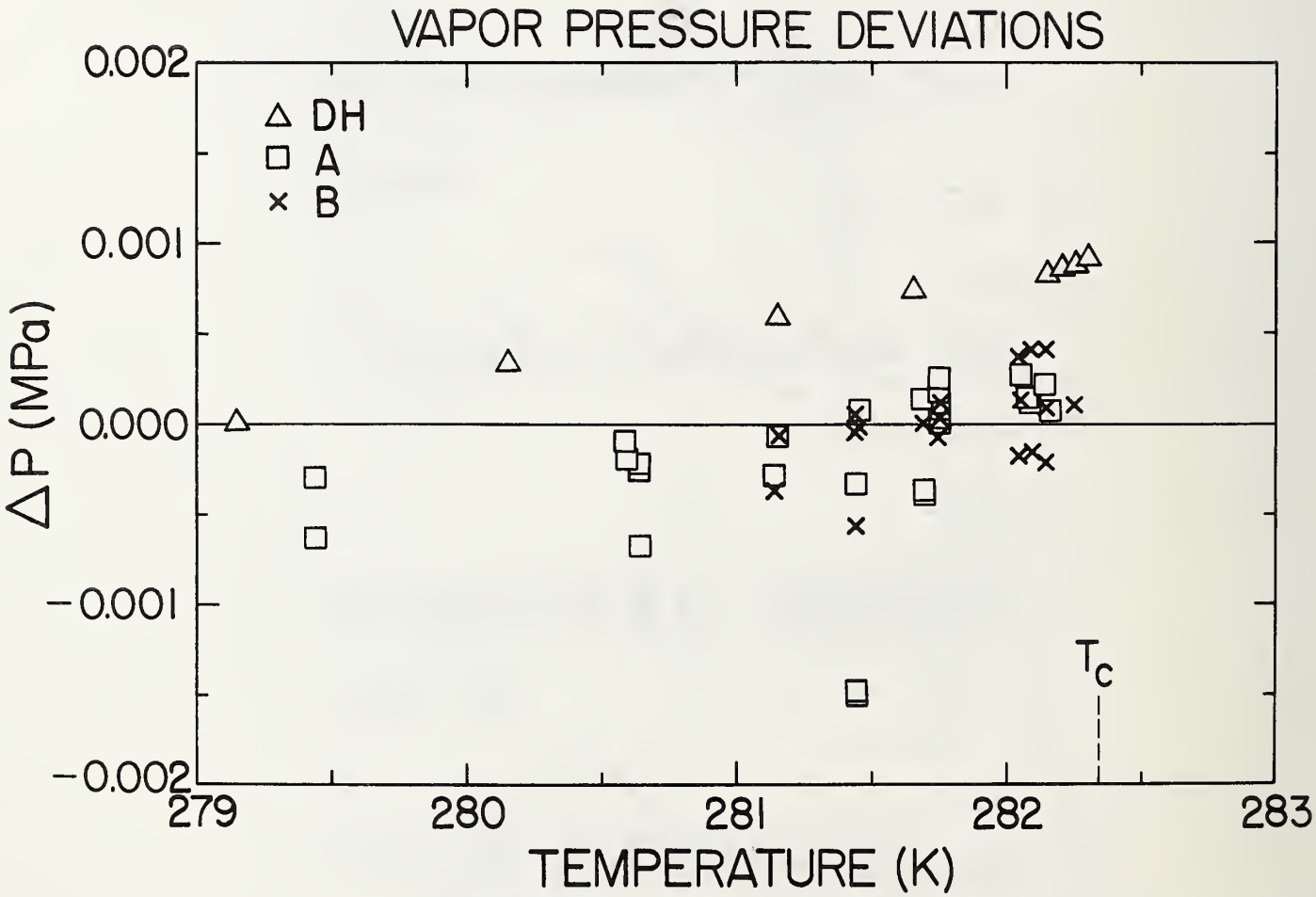

Fig. 4 Departures of the experimental vapor pressures of Douslin and Harrison (△) and Hastings et al. (□, sample A and X, sample B) from the present formulation.

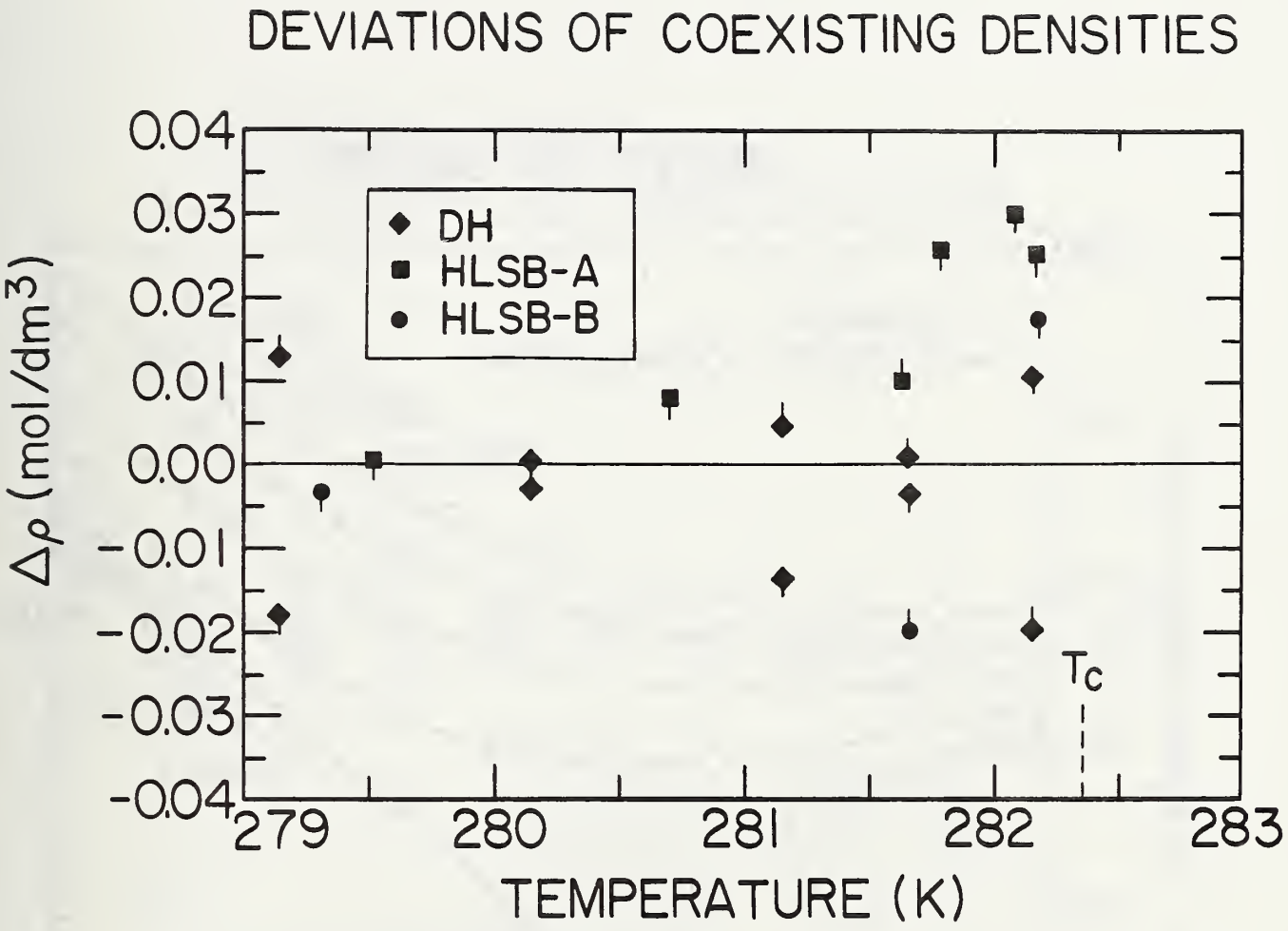

Fig. 5 Departures of experimental coexisting densities of Douslin and Harrison (◆) and Hastings et al. (■, sample A and ●, sample B) from the present formulation. Upward-pointing line segments denote vapor densities; downward-pointing ones denote liquid densities.

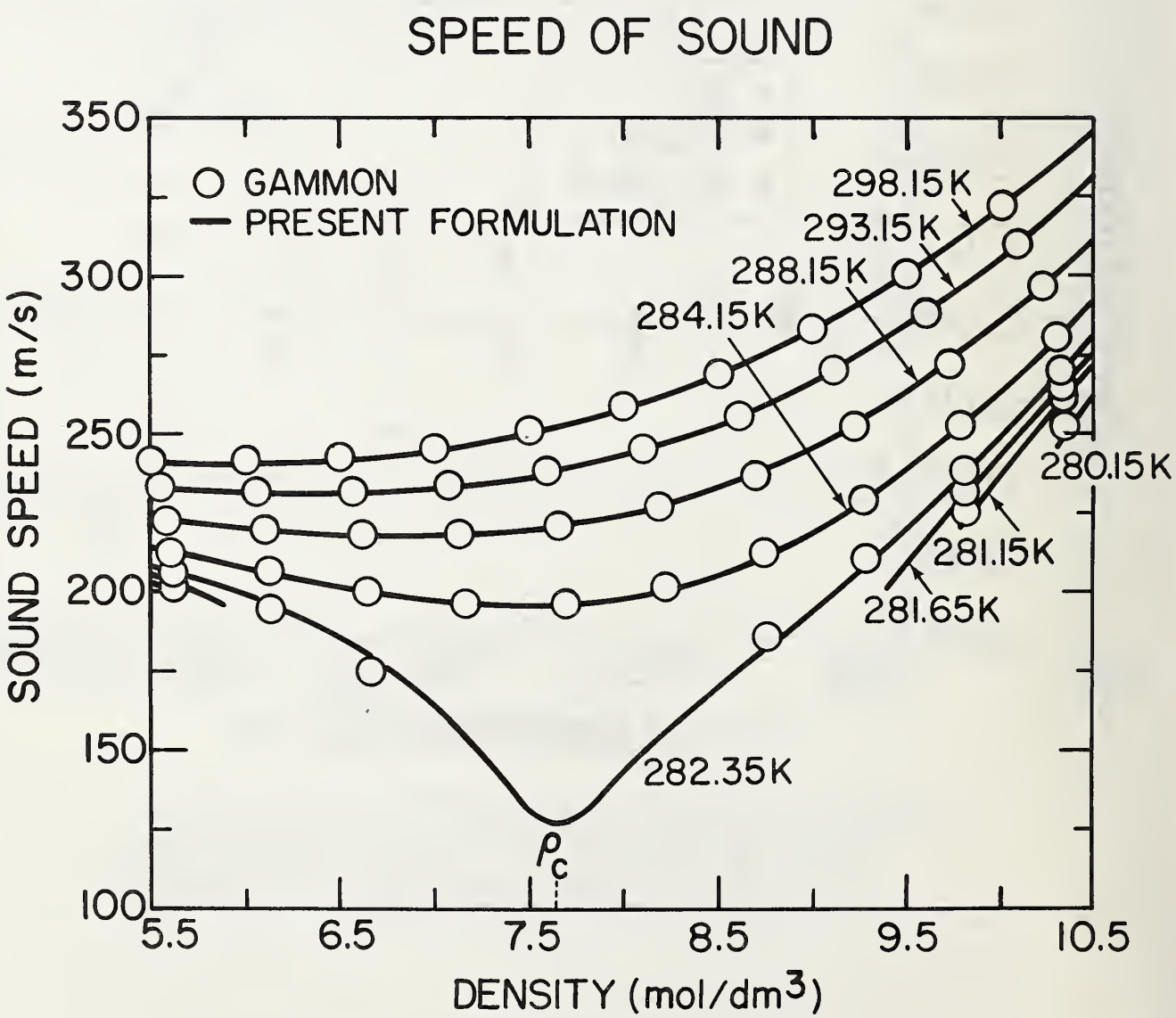

Fig. 6 The speed of sound as measured by Gammon compared with the present formulation.

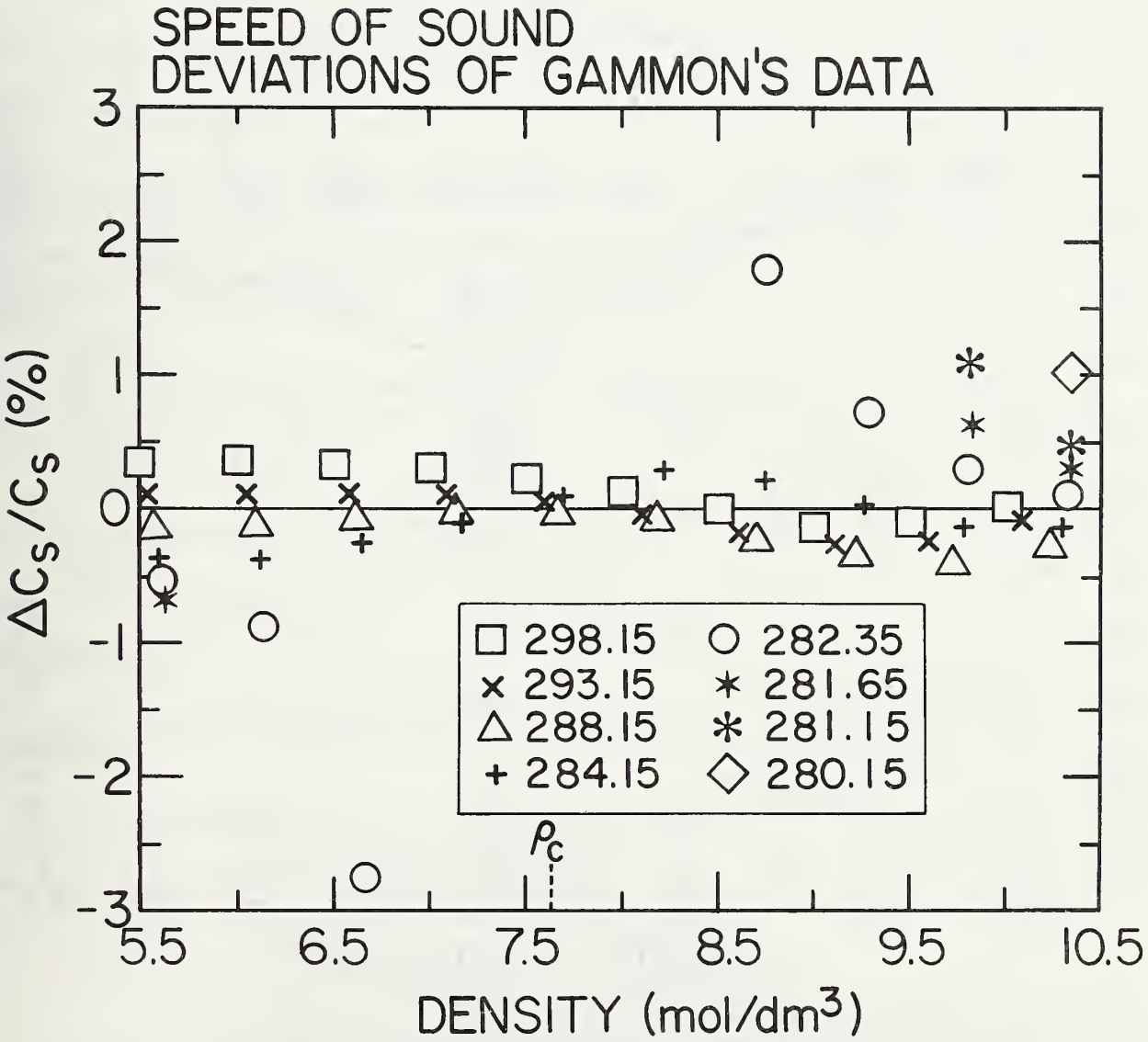

Fig. 7 Departures of Gammon's speed of sound data, in %, from the present formulation.

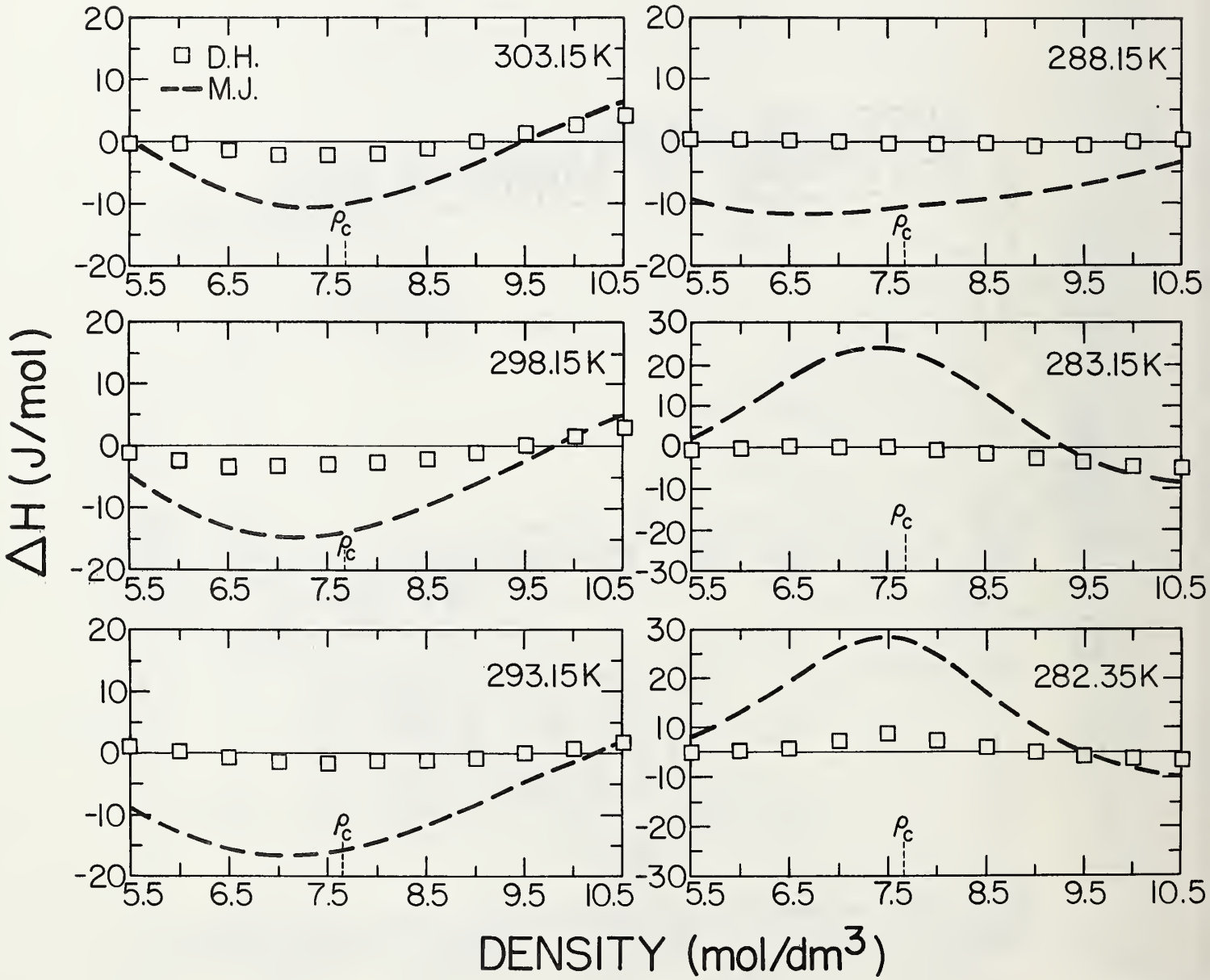

Fig. 8 Comparison of the enthalpies of ethylene according to different formulations. The base line is the present formulation, which was anchored to the Douslin and Harrison data at 7 mol/dm^3, 288.15 K. The squares are from the Douslin-Harrison calculation and the dashed curves from the McCarty-Jacobsen formulation.

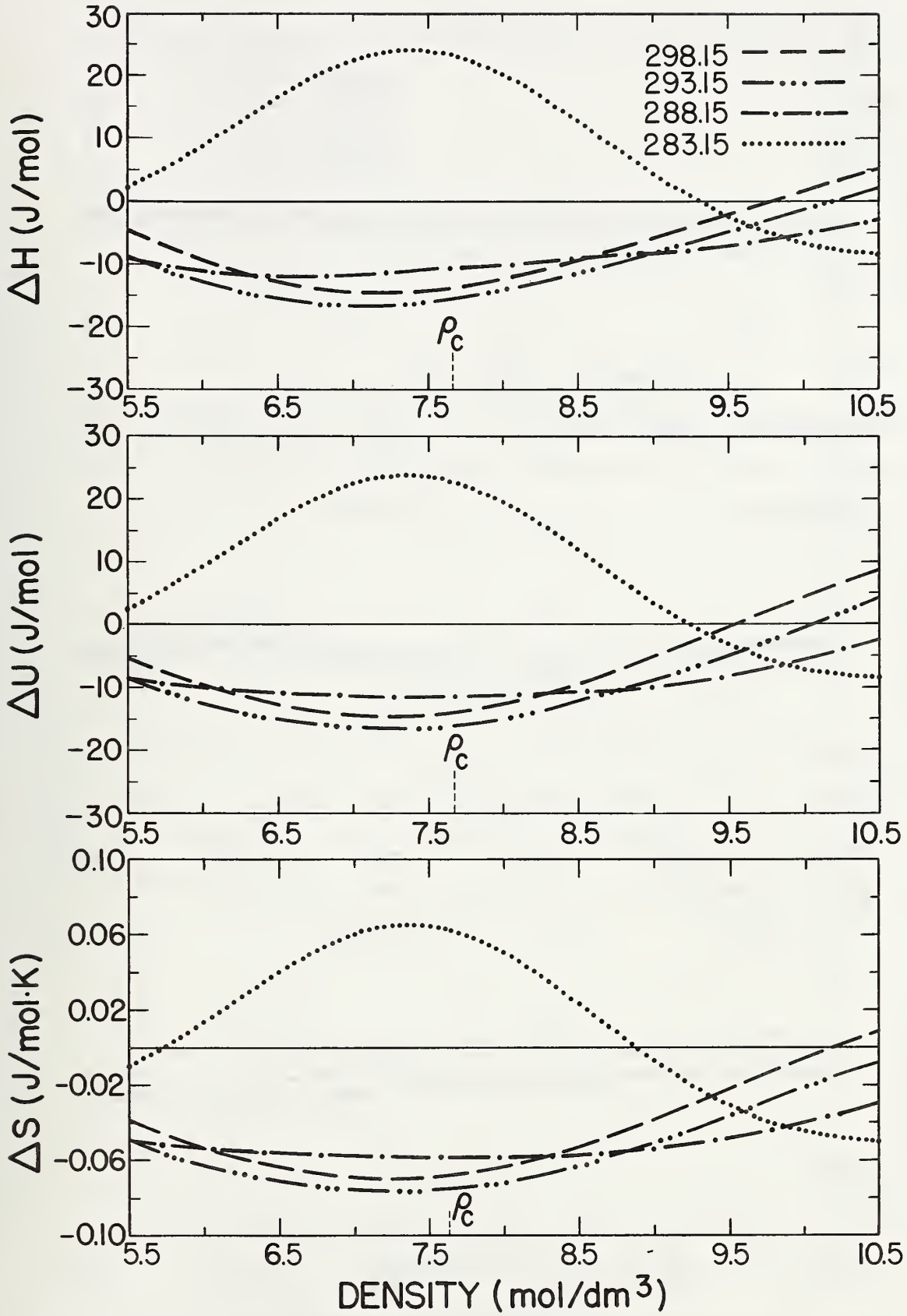

Fig. 9 The difference between the prediction of the McCarty and Jacobsen surface for several first-derivative thermodynamic properties and the present formulation.

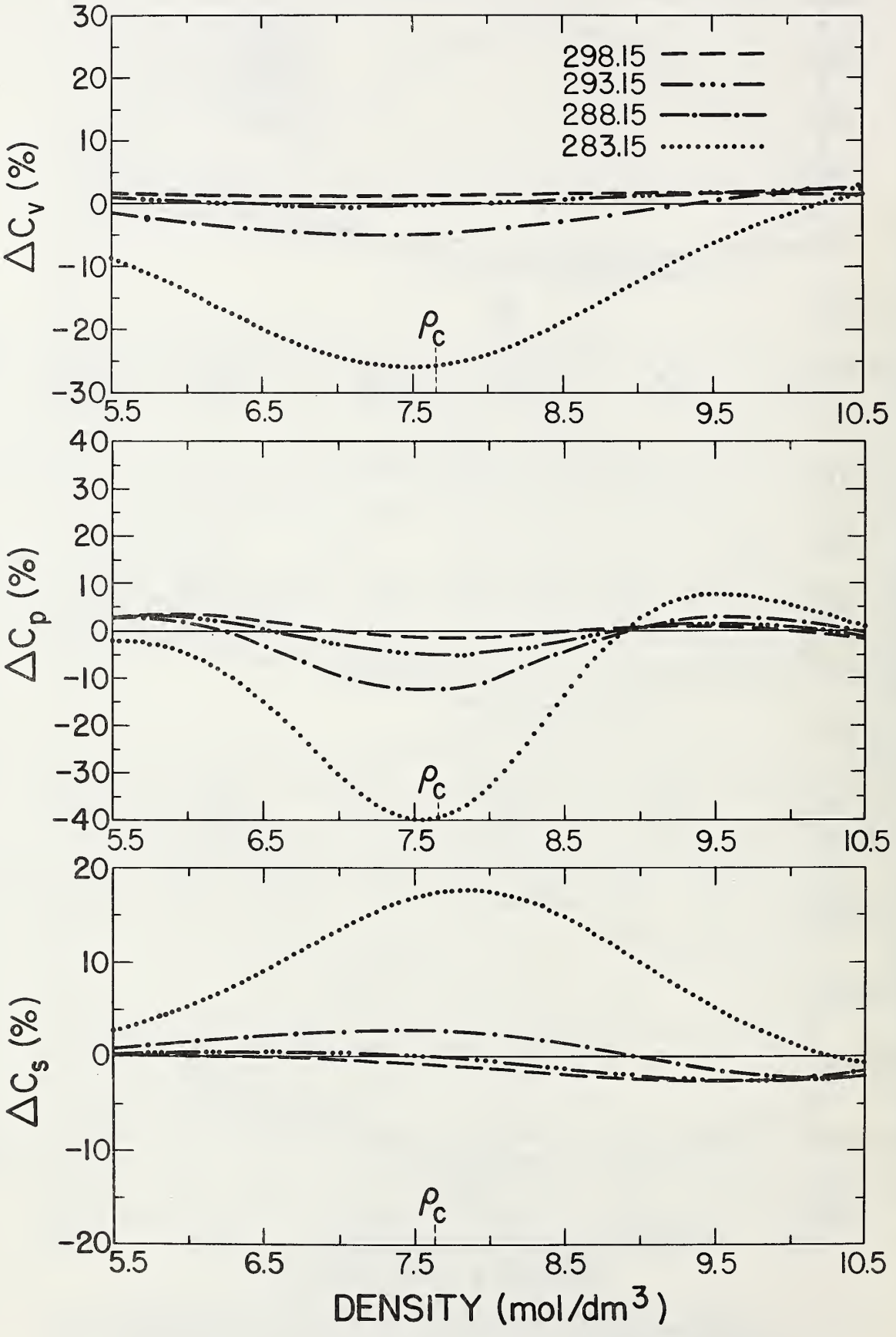

Fig. 10 Percentage differences between the McCarty-Jacobsen and the present formulation for second-derivative values.

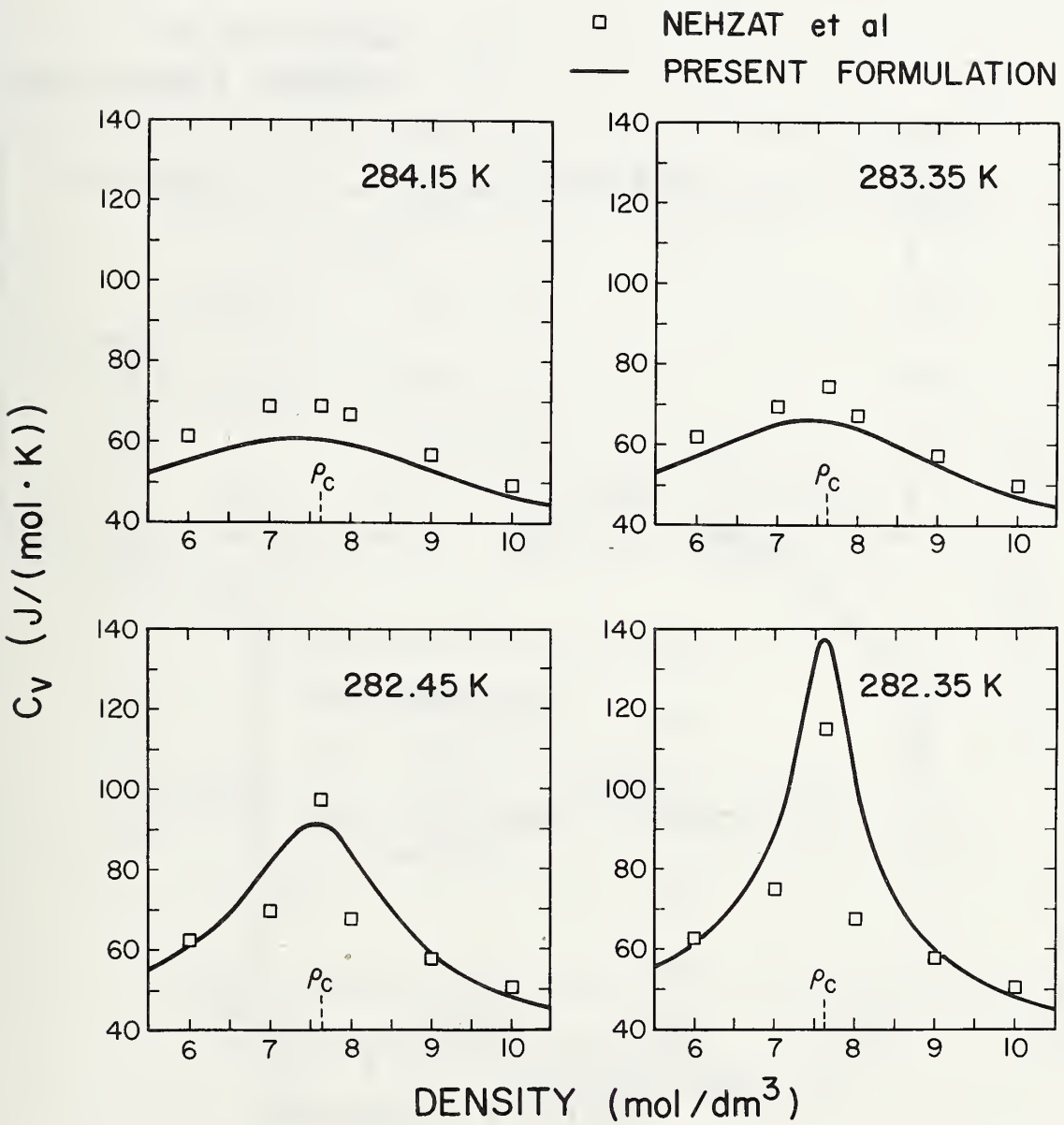

Fig. 11 Comparison of the specific heat C_v predicted by Nehzat et al. [23] with our formulation in the one-phase region above the critical temperature.

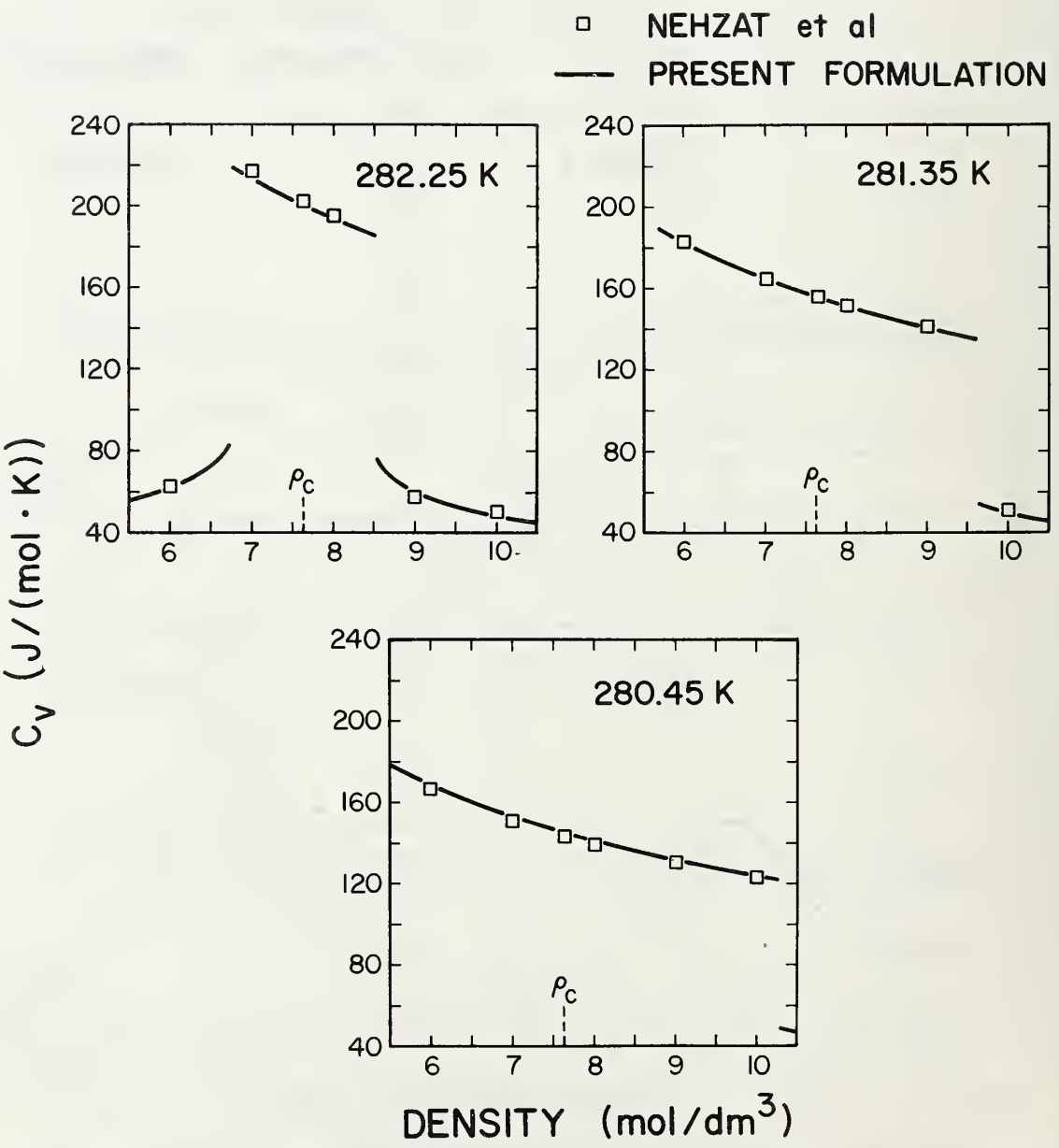

Fig. 12 Comparison of the specific heat C_v predicted by Nehzat et al. [23] with our formulation in the two-phase region below the critical temperature.

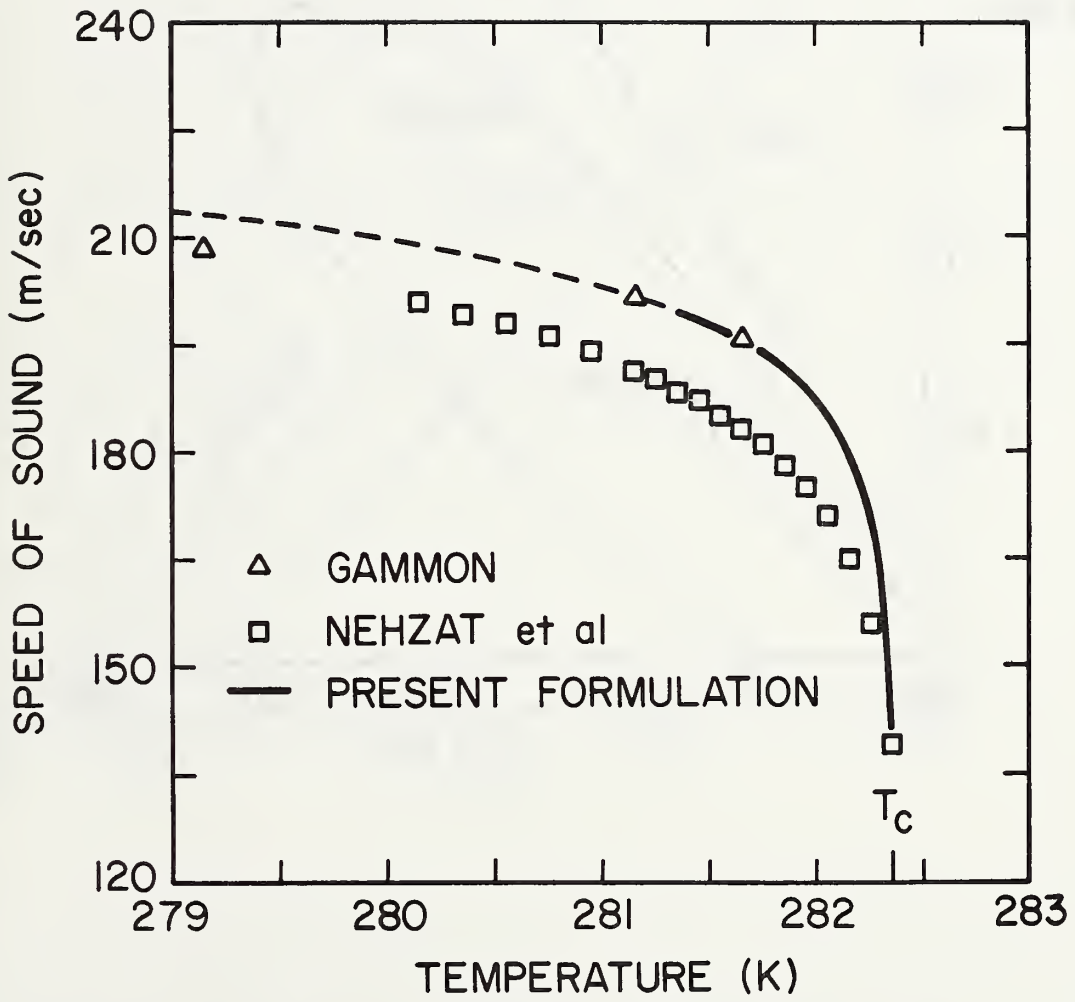

Fig. 13 Comparison of the formulation of Nehzat et al. [23] and of our formulation with the experimental speed of sound data of Gammon for the saturated vapor below the critical temperature. The dashed part of the curve indicates our formulation when extrapolated outside its range of validity.

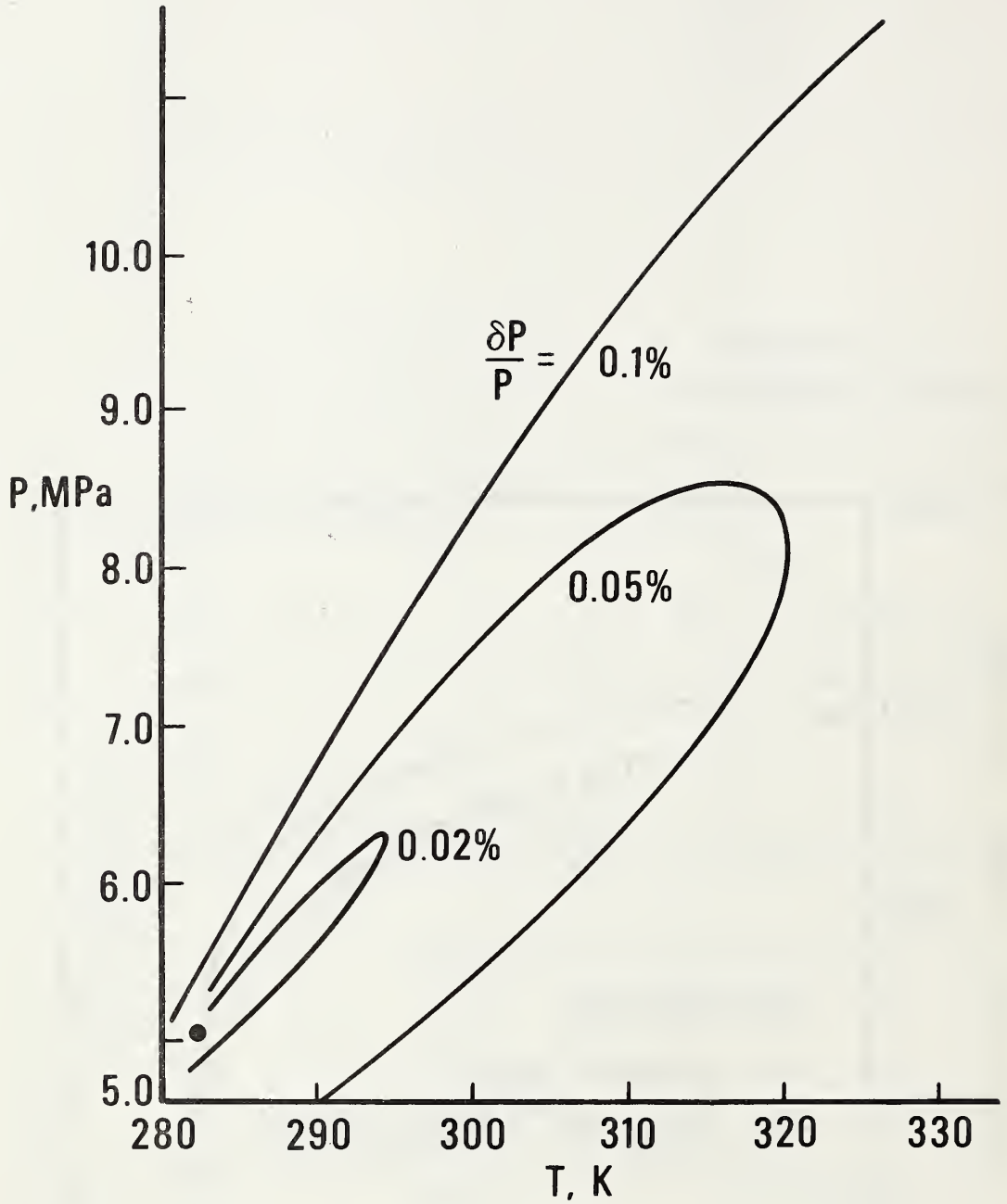

Fig. 14 The regions of P-T space that should be avoided in custody transfer if the pressure is measured to, respectively, 0.1%, 0.05% or 0.02% and an accuracy of 0.1% is desired in density.

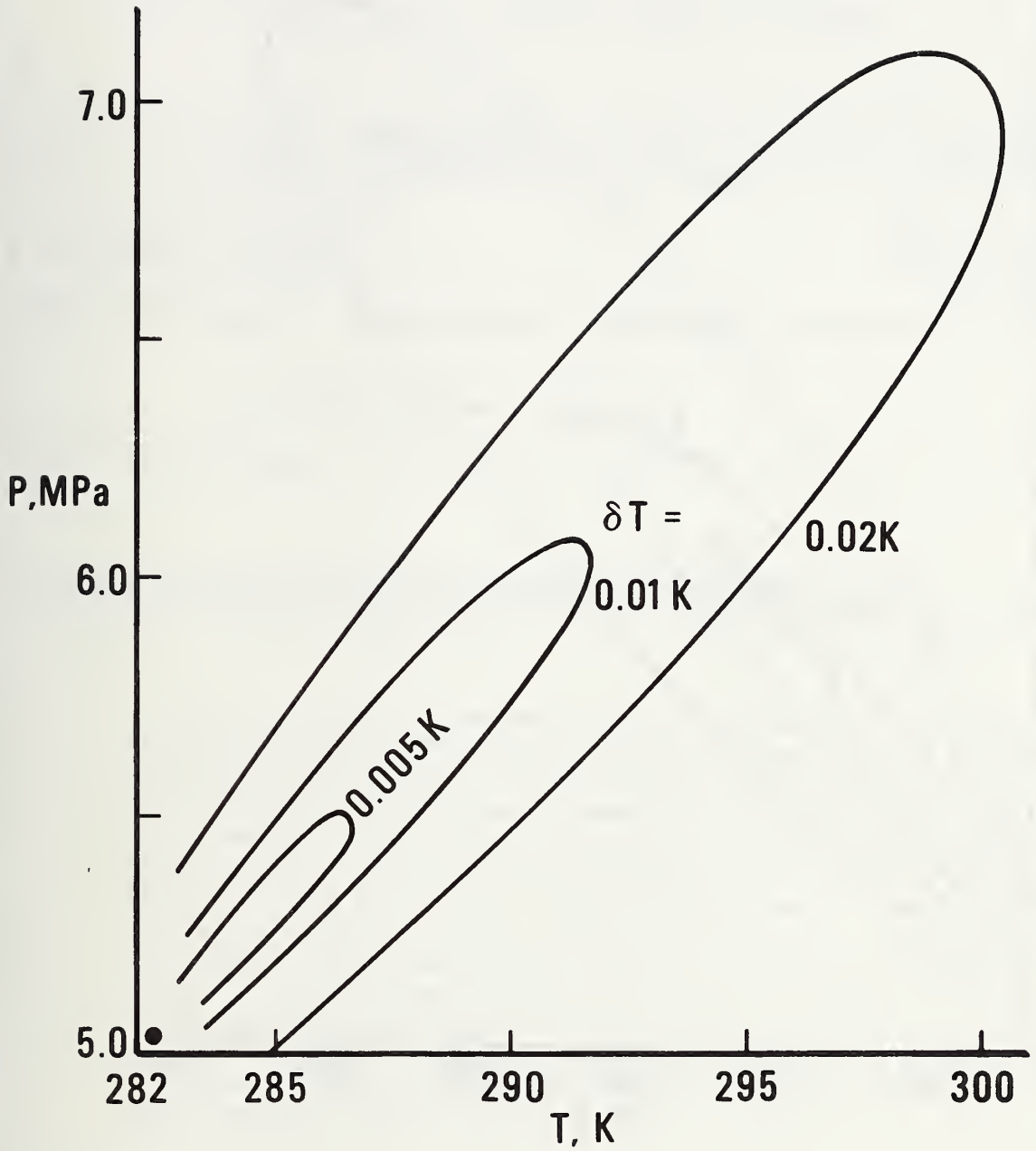

Fig. 15 The regions of P-T space that should be avoided in custody transfer if the temperature is measured to, respectively, 0.02 K, 0.01 K and 0.005 K and an accuracy of 0.1% is desired in density.

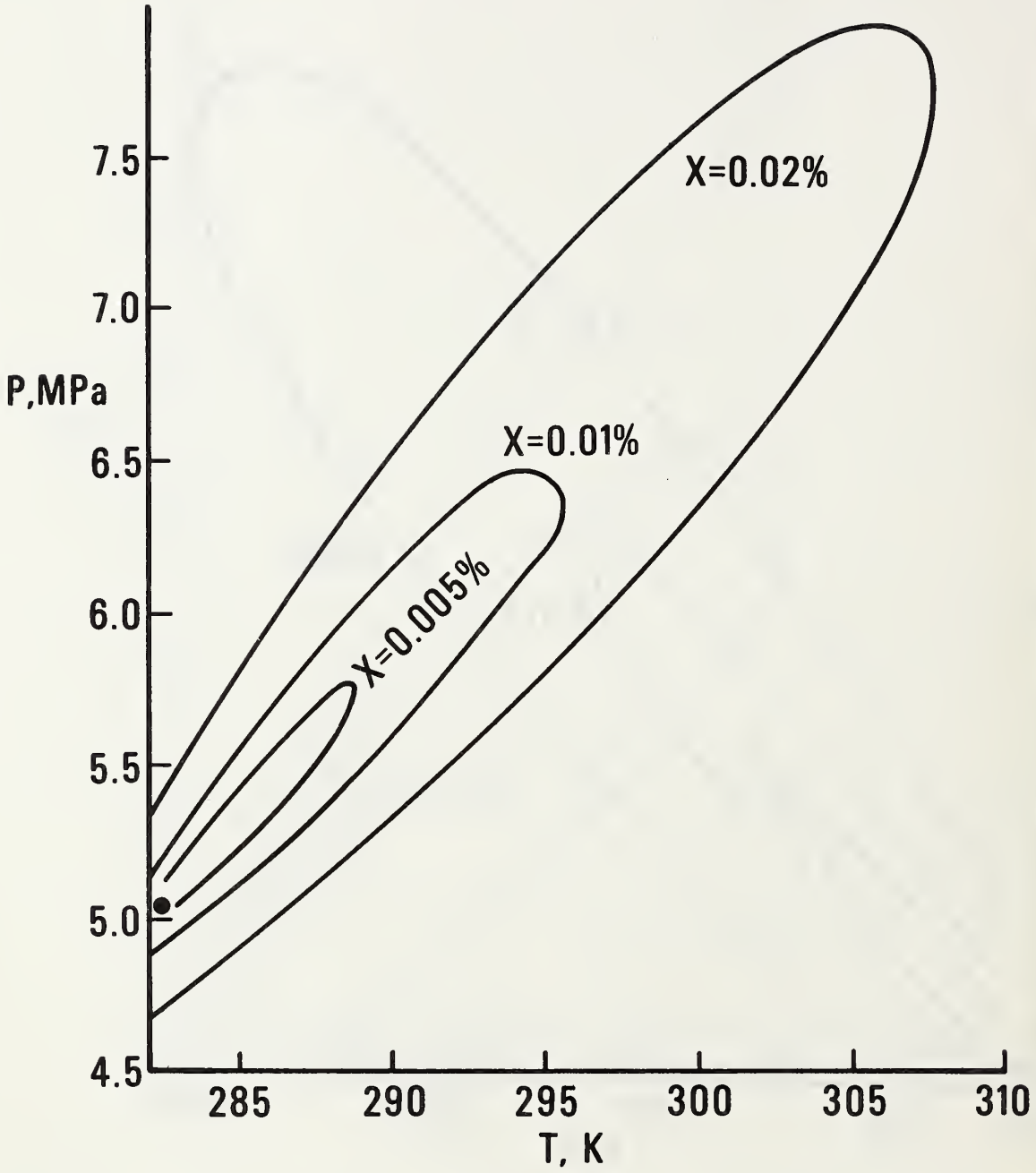

Fig. 16 The regions of P-T space that should be avoided in custody transfer if respectively 0.005%, 0.01% or 0.02% (in mole fraction) of an impurity very different in volatility from ethylene is present and an accuracy of 0.1% is desired in density.

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See footnote on page 1.

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

Tables are presented of thermodynamic properties of ethylene in the range 279-300 K in temperature, 5.75 - 10.5 mol/dm^3 in density, which range includes the critical point. The tables presented here are based on the critical-point scaling laws and incorporate the critical anomalies as presently known from renormalization-group theory. The tables complement the formulation of the equation of state of fluid ethylene by McCarty and Jacobsen (NBS Tech. Note 1045, 1981) which does not claim accuracy near the critical point. The predictions of the present formulation are compared with four sets of recent PVT data, and with speed-of-sound and enthalpy data. Tables are presented of pressure, energy, enthalpy, entropy, specific heats and speed of sound as function of temperature along finely-spaced isochores. The computer program required for table generation is included. Even if the surface were perfect, the reliability of densities calculated at experimental pressures and temperatures of limited accuracy declines rapidly as the critical point is approached. Contour plots in P-T space are presented of regions to be avoided in custody transfer for given uncertainties in pressure , temperature and sample composition.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

critical region; custody transfer; density; enthalpy; ethylene; equation of state; impurity; scaling laws; specific heat; speed of sound; supercritical extraction; thermodynamic properties

13. AVAILABILITY

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Erratum

Equation (A. 28), top p. 18, should read:

$$w_i(\Theta) = [(1 - \alpha_i)(1 - 3\theta^2)\, s_i(\theta) - \beta\delta (1 - \theta^2)\, \theta\, s_i'(\theta)] / q(\theta).$$

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Special Publications—Include proceedings of conferences sponsored by NBS, NBS annual reports, and other special publications appropriate to this grouping such as wall charts, pocket cards, and bibliographies.

Applied Mathematics Series—Mathematical tables, manuals, and studies of special interest to physicists, engineers, chemists, biologists, mathematicians, computer programmers, and others engaged in scientific and technical work.

National Standard Reference Data Series—Provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Developed under a worldwide program coordinated by NBS under the authority of the National Standard Data Act (Public Law 90-396).

NOTE: The principal publication outlet for the foregoing data is the Journal of Physical and Chemical Reference Data (JPCRD) published quarterly for NBS by the American Chemical Society (ACS) and the American Institute of Physics (AIP). Subscriptions, reprints, and supplements available from ACS, 1155 Sixteenth St., NW, Washington, DC 20056.

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