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Fugacity coefficients of gases in binary mixtures

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FUGACITY COEFFICIENTS OF GASES
IN BINARY MIXTURES

BY

DAVID A. OLSON

A THESIS

PRESENTED IN PARTIAL FULFILLMENT OF

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ABSTRACT

A proposed method of Joffe for determining fugacity coefficients of gases in binary mixtures is presented. The method is evaluated by calculating 320 pairs of fugacity coefficients and comparing the results with experimental data and with values calculated by the method of Pitzer.

Joffe derived the expression for fugacity coefficients by employing the technique of Gamson and Watson. The expression is based on the three-parameter corresponding states principle as previously presented by Pitzer and a proposed definition of the pseudocritical properties.

The method of Pitzer and the proposed method of Joffe both require the same data.

This study is based on the experimental data for five binary mixtures: methane - carbon dioxide, methane - ethane, n-butane - carbon dioxide, methane - n-pentane, and methane - n-butane.

The proposed method has been found to produce an overall average deviation of 10.5 % for 640 data points as compared to 11.2 % found for the same data points by the method of Pitzer.

APPROVAL OF THESIS

FOR

DEPARTMENT OF CHEMICAL ENGINEERING
NEWARK COLLEGE OF ENGINEERING

BY

FACULTY COMMITTEE

APPROVED: ______________________________

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It is with great regard that the author wishes to thank Professor Joseph Joffe for his work which formed the basis for this thesis.

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INTRODUCTION

In the hydrocarbon processing industry there is a definite need for an accurate method or methods of predicting fugacity values. Fugacity is important, since it determines both chemical-reaction equilibrium and phase equilibrium.(24)

The object of this thesis was to evaluate the methods of predicting gas phase fugacity coefficients in binary mixtures. Consequently the subsequent discussion has been limited to gases.

A Definitions

In a multiphase system, equilibrium is reached when material has distributed itself in such a way that the free energy of the system is a minimum at constant temperature and pressure. Each phase, in effect, has material leaving or escaping to another phase until a balance is reached.

Fugacity and equilibrium are analogous to temperature and heat. Just as temperature is a measure of the tendency or potential of thermal energy to distribute itself, fugacity is a measure of the distribution of a material within a system. An example of this distributive effect is vapor pressure which involves a redistribution of molecules escaping into a more stable state. Vapor pressure has therefore been used as a qualitative measure of fugacity.

Fugacities and free energy (F) are related. The relationship, for one mole of material, was defined by G.N. Lewis(22) in 1901 as:

$$(dF)_T = RT(d \ln f)_T \qquad (1)$$

where f is the fugacity. This definition of fugacity also holds for real gases as well as liquids and solids.(24) On integration this becomes:

$$F = RT \ln f + C \qquad (2)$$

where C is the constant of integration and is a function of temperature only.

Since free energy is equal to the chemical potential (μ), the equation:

$$(d\mu)_T = RT\ (d \ln f)_T \qquad (3)$$

is used by some authors.

Lewis and Randall(24) have defined the fugacity of an ideal mixture as one in which the fugacity of each component is proportional to the mole fraction (x) of that component at every pressure and at every temperature. Therefore:

$$f_i = f_i^o x_i \qquad (4)$$

for the i^{th} component, where f_i^o, the pure component fugacity, is a constant at the given pressure and temperature of the mixture. This equation has become known as the Lewis and Randall rule.

When dealing with equilibrium in a gaseous system, involving a pure material, the deviation from perfect-gas behavior can be significant at high pressure. The free-energy difference (ΔF) between the gas in the hypothetical one-atmosphere perfect-gas standard state and the real gas at an absolute equilibrium pressure (p), corresponding to a fugacity (f), is:

$$\Delta F = RT(\ln \frac{f}{p} + \ln p) \qquad (5)$$

where the fugacity coefficient $(\frac{f}{p})$ is a measure of the deviation from perfect-gas behavior.(24)

The general prediction of nonideality in gaseous solutions has been hampered by the absence of adequate theory. However attempts are being made(24) and will be outlined subsequently.

The theory of corresponding states has been one approach. This principle was proposed by van der Waals.(46) It states that all gases may be said to behave alike when their P-V-T relations are expressed in ratios of the critical state values:

$$T_r = \frac{T}{T_c}$$
$$P_r = \frac{P}{P_c} \qquad (6)$$
$$V_r = \frac{V}{V_c}$$

The above equations are the ratios of the actual variables to the values of the critical temperature (T_c), pressure (P_c) and volume (V_c), respectively.(46) The more familiar statement of corresponding states is the two-parameter equation:

$$z = f(P_r, T_r) \qquad (7)$$

where z, the compressibility factor, is defined by:

$$z = \frac{PV}{RT} \qquad (8)$$

Equation 7 is not exact, but is useful as an approximation. To improve the accuracy,(25,27) another parameter has been introduced. This is the critical compressibility factor (z_c), given in terms of the other critical constants:

$$z_c = \frac{P_c V_c}{R\,T_c} \qquad (9)$$

The theorem of corresponding states therefore becomes(14)

$$z = f(P_r, T_r, z_c) \qquad (10)$$

The use of an equation of state is another method for determining the fugacity. The equation of state is, in general, an equation of the form:

$$\theta(P, V, T) = 0 \qquad (11)$$

based on a unit molal mass. The equation of state is usually more useful, however, in the form:(5)

$$V = \theta(P, T) \qquad (12)$$

B Previous Methods of Determining Fugacity Coefficients

The thermodynamic properties of a pure gas may be represented by an equation of state which gives the volume as a function of pressure and temperature.(24) However, the volumetric behavior of an actual gas at high pressures is very complex.

1. Residual molal volume. A more satisfactory definition of the fugacity of a pure component system has been suggested by Tunell.(45) This is:

$$\ln f = \ln P - \frac{1}{RT}\int_{0}^{P} \alpha\, dP \qquad (13)$$

where $\alpha = \frac{RT}{P} - V$, V is the molal volume and P is the total pressure of the system. This equation is essentially the same as used by Lewis and Randall and all subsequent workers.(5) If sufficiently extensive P-V-T data for the system in question is available then the above integral may be evaluated by graphical means.(5)

The results of Sage and Lacey(37) for pure compounds, which are used in this thesis, were determined using a procedure based on this method. However, the extensive amount of data needed, precludes the general utilization of the residual molal volume method for mixtures.

Since adequate theory for mixtures is not available, approximate methods which give sufficiently accurate results must be used.

2. Lewis and Randall. An early method was to evaluate the i^{th} pure component fugacity at the desired temperature and pressure and apply it to the mixture using the Lewis and Randall rule:

$$f_i = f_i^o x_i \qquad (4)$$

As previously stated, this rule is only valid for real gases which behave in an ideal manner.

Attempts at improving the accuracy, particularly at high pressures, have produced several correlations of an empirical nature.(12,13,19,28,29,36,48)

<u>3. Gamson and Watson.</u> Generalized correlations, based on experimental data, have been applied to mixtures.(44) Kay's pseudocritical concept and the work of Gamson and Watson,(11) which combines Kay's rule with the corresponding states principle, are examples.

The resulting equation of Gamson and Watson for determining fugacity coefficients involved the evaluation of an integral using a special generalized chart.

Gamson(9) improved his correlation by incorporating Joffe's relationship(15) for the pseudocritical properties.

<u>4. Joffe.</u> A method has been presented by Joffe(16) for the evaluation of the component fugacities. The method, in conjunction with the corresponding states theory and generalized charts and the pseudocritical method of Kay, is in principle similiar to the method of Gamson and Watson. However, it is believed applicable over a different range of conditions. It has an advantage over the method of Gamson and Watson, since it does not require the evaluation of an integral.

<u>5. Benedict, Webb, Rubin and Friend.</u> An empirical equation

of state has been developed by Benedict et al.(1) The equation was used to calculate the fugacities of binary systems involving twelve light hydrocarbons. The calculations resulted in 144 charts of K-values for pressure from 1000-3600 psia. By introducing molal average boiling point these charts have been applied to calculations in multicomponent systems.

DePriester(4) has replotted the first 144 charts into 24 charts which have a two-parameter form. The result was that the accuracy was improved in some ranges and easier pressure interpolation was facilitated.

6. Edmister and Ruby. An empirical generalized correlation for liquid and vapor phase fugacity coefficients of hydrocarbons has been presented by Edmister and Ruby.(8) This correlation is based on the work of Benedict et al., and presents a function of reduced pressure, reduced temperature and boiling point ratio. The effect of molecule size has been taken into account by the use of the boiling point ratio. The correlation is applicable to paraffin and olefin hydrocarbon systems. It can be extended to other hydrocarbon systems using a composition parameter to correct for differences in molecular character.(8)

7. Redlich, Kister and Turnquist. The calculation of fugacity coefficients of vapor mixtures can also be made by using an equation presented by Redlich et al.(34,35) This equation of state is:

$$P = \frac{RT}{(V-b)} - \frac{a}{V(V+b)T^{1/2}} \quad (14)$$

where:

$$a = \frac{0.4278R^2T_c^{2.5}}{P_c} \quad (15)$$

$$b = \frac{0.0867RT_c}{P_c} \quad (16)$$

8. Pitzer, Lippman, Curl, Huggins and Peterson. The principle of corresponding states was previously presented containing the critical compressibility factor (z_c) as the third parameter.

Pitzer et al., however, have introduced the slope of the reduced vapor pressure curve as the basis for the third parameter, as it is a most sensitive property.(33) An additional advantage is that the vapor pressure is more accurately measured than the terms determining the critical compressibility factor.

This parameter, based on vapor pressure, is called the acentric factor (w) since it measures the deviation from simple spherical molecules of the intermolecular potential function. The acentric factor is defined as:

$$w = -\log \frac{P_s}{P_c} - 1.000 \quad (17)$$

where P_s is the vapor pressure at a reduced temperature (T_r) of 0.700 and $\frac{P_s}{P_c}$ is the reduced vapor pressure ratio at a point well removed from the critical point. This definition was chosen so that the simple fluids (Ar, Kr, and Xe), which have spherical molecules, would have an acentric factor equal to zero. This definition therefore takes into account the various types of molecular dipole moment and molecular shapes which would cause deviations from simple fluid properties.(24)

According to Pitzer, therefore, the form of the corresponding states correlation is:

$$z = f(P_r, T_r, w) \qquad (18)$$

For simplicity this function is assumed to be linear in the acentric factor.

Pitzer further defined the compressibility factor, fugacity coefficient, enthalpy departure, and entropy departure, respectively as:

$$z = (z)^o + w(z)^1 \qquad (19)$$

$$\log \frac{f}{P} = (\log \frac{f}{P})^o + w(\log \frac{f}{P})^1 \qquad (20)$$

$$\frac{H^o-H}{RT_c} = (\frac{H^o-H}{RT_c})^o + w(\frac{H^o-H}{RT_c})^1 \qquad (21)$$

$$\frac{S^o-S}{R} = (\frac{S^o-S}{R})^o + w(\frac{S^o-S}{R})^1 + R \ln P \qquad (22)$$

where the bracketted quantities above are tabulated values. The tables, as a function of T_r and P_r, have been given by Pitzer et al.,(33) for normal fluids.

Most fluids except H_2, He, highly polar molecules and associated fluids may be considered normal.

Pitzer and Hultgren have applied their version of the corresponding states principle to binary gaseous mixtures in an effort to improve the prediction of the mixture's thermodynamic properties. They have also presented a technique for determining the pseudocritical constants (T_c,P_c,w) of these mixtures.(32) The resulting constants (T_{cm},P_{cm},w_m) for twelve binary mixtures were shown to produce a maximum deviation of 1% or less from the theoretical curves.

It should be noted that w, as well as T_c and P_c, can be calculated by an extension of Kay's rule (i.e. they can be linear functions of mole fraction). However, to handle cases where Kay's rule is not followed sufficiently accurately, Pitzer has added a quadratic term. The pseudocritical constants of a solution of mole fraction x_1 and x_2 are given therefore as:

$$T_{cx} = x_1 T_{c1} + x_2 T_{c2} + 2x_1 x_2 (2T_{cM} - T_{c1} - T_{c2}) \tag{23}$$

$$P_{cx} = x_1 P_{c1} + x_2 T_{c2} + 2x_1 x_2 (2P_{cM} - P_{c1} - P_{c2}) \tag{24}$$

$$w_x = x_1 w_1 + x_2 w_2 + 2x_1 x_2 (2w_M - w_1 - w_2) \tag{25}$$

where the subscript c stands for critical or pseudocritical values and the subscripts 1 and 2 are for pure component 1 and 2, respectively. The M subscript is for the equilmolal mixture and x for any mixture.

Pitzer and Hultgren have derived equations for the fugacity coefficients of a binary mixture as follows:

$$\log \frac{f_1}{x_1 P} = \left[\log \frac{f}{P} \right]_x + x_2 Y \tag{26}$$

$$\log \frac{f_2}{x_2 P} = \left[\log \frac{f}{P}\right]_x - x_1 Y \qquad (27)$$

where Y is given as an explicit analytical expression.(32)

The method of Pitzer can be extended, reasonably well, to other multicomponent mixtures as well as to other thermodynamic functions.(24)

Mazzei(26) has used Equations 23,24,25,26,27 as the basis for his thesis and the results will be compared to the present work subsequently.

9. Gamson, Leland, and Chappelear. A recent procedure that can be used to determine fugacity coefficients, based on the corresponding states principle and the composition-dependent pseudocritical properties, is the method of Gamson et al. The liquid and vapor mixture properties can be either evaluated from generalized tables of thermodynamic properties or the experimentally determined properties of closely related pure materials. The pseudocritical property expression which is derived is applicable to liquids approximated by simple spherical molecules. However, the derivation is said to be extendable to more complex molecules.(10)

The Leland and Mueller(20) modifications of Joffe's definitions are used for the pseudocritical pressure and temperature, while Kay's rule is used to determine the pseudocritical compressibility factor. For binary gaseous mixtures the equations for determining the fugacity coefficients are:

$$\ln\left(\frac{f}{xP} \right)_1 = \ln\left(\frac{f}{P} \right)_x + \mathbb{U}_{1G} \qquad (28)$$

$$\ln\left(\frac{f}{xP} \right)_2 = \ln\left(\frac{f}{P} \right)_x + \mathbb{U}_{2G} \qquad (29)$$

where $\mathbb{U}_{1G}$ and $\mathbb{U}_{2G}$ are correction terms given in an explicit form.

Klee(21) has used Equations 28,29 and generalized charts as the basis for his thesis. He concluded that the method of Pitzer et al., as tested by Mazzei, generally gave better results for the binary gaseous mixtures considered.

PROPOSED METHOD

This thesis is based on a method, derived by Joffe,(17) for calculating the fugacity coefficients of binary mixtures of gases. The method makes use of Pitzer's form of the principle of corresponding states as given by Equation 18:

$$z = f(P_r, T_r, w) \tag{18}$$

The derivation makes use of the work of Gamson and Watson,(11) Joffe,(15,16) and Pitzer and Hultgren.(32)

The partial molal fugacity coefficient is defined by:(5)

$$\log \frac{f_1}{x_1 P} = \log \frac{f_m}{P} + x_2 \frac{\partial \log \frac{f_m}{P}}{\partial x_1} \tag{30}$$

The partial derivative need only be given as an explicit expression in order to use this exact equation.

Proceeding, therefore, using the usual techniques of partial differentiation, one obtains:

$$\frac{\partial \log \frac{f_m}{P}}{\partial x_1} = \frac{\partial \log \frac{f_m}{P}}{\partial T_r} \cdot \frac{d T_r}{d x_1} + \frac{\partial \log \frac{f_m}{P}}{\partial P_r} \cdot \frac{d P_r}{d x_1}$$

$$+ \frac{\partial \log \frac{f_m}{P}}{\partial w_m} \cdot \frac{d w_m}{d x_1} \tag{31}$$

We also have the relations:(5)

$$\frac{\partial \log \frac{f_m}{P}}{\partial T_r} = \frac{T_{cm}(H^* - H)}{2.303RT^2} \tag{32}$$

$$\frac{\partial \log \frac{f_m}{P}}{\partial P_r} = \frac{z - 1}{2.303RT} \tag{33}$$

and from Pitzer et al., we have:

$$\frac{\partial \log \frac{f_m}{P}}{\partial w_m} = (\log \frac{f_m}{P})^{(1)} \tag{34}$$

also from Joffe:

$$\frac{\partial T_r}{\partial x_1} = - \frac{T}{T_{cm}^2} \cdot \frac{\partial T_{cm}}{\partial x_1} \tag{35}$$

$$\frac{\partial P_r}{\partial x_1} = - \frac{P}{P_{cm}^2} \cdot \frac{\partial P_{cm}}{\partial x_1} \tag{36}$$

Now suppose that the pseudocritical constants are of the form of the van der Waals equation of state. It can be shown that the usual constants (a and b) are given as:

$$a = \frac{27 R^2}{64} \cdot \frac{T_{cm}^2}{P_{cm}} \tag{37}$$

$$b = \frac{R}{8} \cdot \frac{T_{cm}}{P_{cm}} \tag{38}$$

The constants for a binary gaseous mixture (m), consisting of mole fractions x_1 and x_2, would be given as:

$$a_m = a_1x_1^2 + a_2x_2^2 + 2a_{12}x_1x_2 \tag{39}$$

$$b_m = b_1x_1^2 + b_2x_2^2 + 2b_{12}x_1x_2 \tag{40}$$

Hence, by substituting Equation 37 into 39:

$$\frac{T_{cm}^2}{P_{cm}} = \frac{T_{c1}^2}{P_{c1}} x_1^2 + \frac{T_{c2}^2}{P_{c2}} x_2^2 + \frac{2T_{c12}^2}{P_{c12}} x_1 x_2 \qquad (41)$$

or

$$\frac{T_{cm}^2}{P_{cm}} = \alpha x_1^2 + \beta x_2^2 + 2 \gamma x_1 x_2 \qquad (42)$$

Similiarly, using Equations 38 and 40:

$$\frac{T_{cm}}{P_{cm}} = \frac{T_{c1}}{P_{c1}} x_1^2 + \frac{T_{c2}}{P_{c2}} x_2^2 + \frac{2T_{c12}}{P_{c12}} x_1 x_2 \qquad (43)$$

or

$$\frac{T_{cm}}{P_{cm}} = A x_1^2 + B x_2^2 + 2 C x_1 x_2 \qquad (44)$$

Let us now divide Equation 42 by 44 and we have:

$$T_{cm} = \frac{\alpha x_1^2 + \beta x_2^2 + 2 \gamma x_1 x_2}{A x_1^2 + B x_2^2 + 2 C x_1 x_2} \qquad (45)$$

Dividing Equation 45 by 44:

$$P_{cm} = \frac{\alpha x_1^2 + \beta x_2^2 + 2 \gamma x_1 x_2}{\left[A x_1^2 + B x_2^2 + 2 C x_1 x_2\right]^2} \qquad (46)$$

We can also consider the acentric factor (w) in the same form as Equation 39:

$$w_m = w_1 x_1^2 + w_2 x_2^2 + 2 w_{12} x_1 x_2 \qquad (47)$$

Equations 45,46,47 now give an explicit definition of the pseudocritical properties. To complete the definition of Equation 31, it can be shown that the derivatives of 45,46, and 47 are:

$$\frac{d\,T_{cm}}{d\,x_1} = \frac{2P_{cm}}{T_{cm}}\left[\alpha x_1 - \beta x_2 + \gamma(x_2 - x_1)\right] -$$

$$2P_{cm}\left[Ax_1 - Bx_2 + C(x_2 - x_1)\right] \qquad (48)$$

$$\frac{d\,P_{cm}}{d\,x_1} = \frac{2P_{cm}^2}{T_{cm}^2}\left[\alpha x_1 - \beta x_2 + \gamma(x_2 - x_1)\right] -$$

$$\frac{4P_{cm}^2}{T_{cm}}\left[Ax_1 - Bx_2 + C(x_2 - x_1)\right] \qquad (49)$$

$$\frac{d\,w_m}{d\,x_1} = 2\left[w_1x_1 - w_2x_2 + w_{12}(x_2 - x_1)\right] \qquad (50)$$

All terms needed in Equation 31 have therefore, been defined. Combining with 30, the desired expression becomes:

$$\log\frac{f_1}{x_1P} = \log\frac{f_m}{P} + x_2Y \qquad (51)$$

$$\log\frac{f_2}{x_2P} = \log\frac{f_m}{P} - x_1Y \qquad (52)$$

$$Y = \left[\frac{-2P_{cm}}{2.303T}\frac{H^* - H}{RT_{cm}}\left[\frac{E}{T_{cm}} - F\right] - \frac{2P_{cm}(z-1)}{2.303\ T_{cm}}\right.\Bigg[$$

$$\left.\frac{E}{T_{cm}} - 2F\right] + (\log\frac{f_m}{P})^{(1)}.\ 2G\Bigg] \qquad (53)$$

$$E = \alpha x_1 - \beta x_2 + \gamma(x_2 - x_1) \qquad (54)$$

$$F = Ax_1 - Bx_2 + C(x_2 - x_1) \qquad (55)$$

$$G = w_1x_1 - w_2x_2 + w_{12}(x_2 - x_1) \qquad (56)$$

where the subscript c stands for pseudocritical for a mixture m of mole fraction x_1 and x_2.

The method used in this thesis is based on applying Equations 51 through 56. All the experimental data used by Klee were also used in the present study.

The tables of Pitzer et al., were used to determine z,

$\frac{H^* - H}{RT_{cm}}$, $\log \frac{f_m}{P}$, and $(\log \frac{f_m}{P})^{(1)}$.

The constants γ, C, and w_{12} were evaluated using the data of Pitzer and Hultgren for equimolal solutions.

Sample Calculation

System A: Component 1 is methane

Component 2 is carbon dioxide

Conditions: $T = 310.94\ ^{o}K$

$P = 400.00$ atm.

Point number 61

$x_1 = .406$

$x_2 = .594$

Data for Pure Components:

	CH_4	CO_2
$T_c\ ^{o}K$	190.66	304.16
P_c atm.	45.80	72.80
w	0.013	0.225

Data for equimolal mixture:

$T_{cM} = 242.\ ^{o}K$

$P_{cM} = 57.6$ atm.

$w_M = 0.15$

Step (1) Calculating the constant γ

For $x_1 = .5 = x_2$, Equation 41 reduces to:

$$\frac{T_{cM}^2}{P_{cM}} = \frac{T_{c1}^2}{P_{c1}} \cdot \frac{1}{4} + \frac{T_{c2}^2}{P_{c2}} \cdot \frac{1}{4} + \frac{T_{c12}^2}{P_{c12}} \cdot \frac{1}{2}$$

$$\frac{(242.)^2}{57.6} = \frac{(190.66)^2}{45.8}\frac{1}{4} + \frac{(304.16)^2}{72.80}\frac{1}{4} + \frac{T_{c12}^2}{P_{c12}}\frac{1}{2}$$

$$\frac{T_{c12}^2}{P_{c12}} = \gamma = 1001.2312$$

Step (2) Calculating the constant C

For $x_1 = .5 = x_2$, Equation 43 reduces to:

$$\frac{T_{cM}}{P_{cM}} = \frac{T_{c1}}{P_{c1}} \cdot \frac{1}{4} + \frac{T_{c2}}{P_{c2}} \cdot \frac{1}{4} + \frac{T_{c12}}{P_{c12}} \cdot \frac{1}{2}$$

$$\frac{242.}{57.6} = \frac{190.66}{45.8}\,\frac{1}{4} + \frac{304.16}{72.80}\,\frac{1}{4} + \frac{T_{c12}}{P_{c12}}\,\frac{1}{2}$$

$$\frac{T_{c12}}{P_{c12}} = C = 4.2323$$

Step (3) Calculating the constant w_{12}

For $x_1 = .5 = x_2$, Equation 47 reduces to:

$$w_M = w_1\,\frac{1}{4} + w_2\,\frac{1}{4} + w_{12}\,\frac{1}{2}$$

$$0.15 = 0.013\,\frac{1}{4} + 0.225\,\frac{1}{4} + w_{12}\,\frac{1}{2}$$

$$w_{12} = 0.1810$$

Step (4) Pseudocritical temperature of mixture by Equation 45

$$T_{cm} = \frac{\frac{(190.66)^2}{45.80}(.406)^2 + \frac{(304.16)^2}{72.80}(.594)^2 + 2\gamma(.406)(.594)}{\frac{190.66}{45.80}(.406)^2 + \frac{304.16}{72.80}(.594)^2 + 2C(.406)(.594)}$$

$$T_{cm} = 252.7849\ ^{o}K$$

Step (5) Pseudocritical pressure of mixture by Equation 46

$$P_{cm} = \frac{\frac{(190.66)^2}{45.80}(.406)^2 + \frac{(304.16)^2}{72.80}(.594)^2 + 2\gamma(.406)(.594)}{\left[\frac{190.66}{45.80}(.406)^2 + \frac{304.16}{72.80}(.594)^2 + 2C(.406)(.594)\right]^2}$$

$$P_{cm} = 60.1623 \text{ atm.}$$

Step (6) Calculation of acentric factor (w) of mixture by Equation 47

$$w = (.013)(.406)^2 + (.225)(.594)^2 + 2(.181)(.406)(.594)$$

$$w = .1688$$

Step (7) Calculation of reduced temperature and pressure

$$T_r = \frac{T}{T_{cm}} = \frac{310.94}{252.7849} = 1.2301$$

$$P_r = \frac{P}{P_{cm}} = \frac{400.00}{60.1623} = 6.6487$$

Step (8) Determination of compressibility factor (z)

Using linear interpolation in the tables of Pitzer et al.

$$(z)^{(0)} = .8742$$

$$(z)^{(1)} = -.0759$$

By Equation 19:

$$z = (z)^{(0)} + w(z)^{(1)}$$

$$z = .8742 + (.1688)(-.0759) = .8614$$

Step (9) Determination of fugacity coefficient of the mixture

Using linear interpolation in the tables of Pitzer et al.

$$(\log \frac{f}{P})^{(0)} = -.3454$$

$$(\log \frac{f}{P})^{(1)} = 0.0915$$

By Equation 20:

$$\log \frac{f_m}{P} = -.3454 + (.1688)(.0915) = -.3299$$

Step (10) Determination of enthalpy departure

Using linear interpolation in the tables of Pitzer et al.

$$\left[\frac{H^o - H}{RT_c}\right]^{(0)} = 2.9810$$

$$\left[\frac{H^o - H}{RT_c}\right]^{(1)} = 2.0834$$

By Equation 21:

$$\left[\frac{H^* - H}{RT_c}\right] = 2.9810 + (.1688)(2.0834) = 3.3327$$

Step (11) Calculation of constant E from Equation 54

$$E = \frac{(190.66)^2}{45.80}(.406) - \frac{(304.16)^2}{72.80}(.594)$$

$$+ (1001.2312)(.594 - .406)$$

$$E = -244.3759$$

Step (12) Calculation of constant F from Equation 55

$$F = \frac{190.66}{45.80}(.406) - \frac{304.16}{72.80}(.594)$$

$$+ (4.2323)(.594 - .406)$$

$$F = 0.004062$$

Step (13) Calculation of constant G from Equation 56

$$G = (.013)(.406) - (.225)(.594) + (.181)(.594 - .406)$$

$$G = -.09434$$

Step (14) Calculation of constant Y from Equation 53

$$Y = \left[\frac{(-2)(60.1623)}{2.303(310.94)}(3.3327)\left[\frac{-244.3759}{252.7849} - .004062\right] - \right.$$

$$\left.\frac{2(60.1623)(.8614 - 1.)}{2.303(252.7849)}\left[\frac{-244.3759}{252.7849} - 2(.004062)\right]\right]$$

$$+ (.0915)(2)(-.09434)\Big] = .4984$$

$$Y = .4984$$

Step (15) Calculation of fugacity coefficient of Component 1 by Equation 51

$$\log \frac{f_1}{x_1 P} = -.3299 + (.594)(.4984)$$

$$\frac{f_1}{x_1 P} = .9254$$

Experimental $\frac{f_1}{x_1 P} = .970$

Difference = 4.64 %

Step (16) Calculation of fugacity coefficient of Component 2 by Equation 52

$$\log \frac{f_2}{x_2 P} = -.3299 - (.406)(.4984)$$

$$\frac{f_2}{x_2 P} = .2940$$

Experimental $\frac{f_2}{x_2 P} = .279$

Difference = -5.37 %

PROCEDURE

General

The fugacity coefficients of six binary gaseous systems, consisting of five binary mixtures, were calculated using a correlation proposed by Joffe.(17)

The systems which were used in the evaluation were:

A.	Methane - Carbon dioxide	(superheated)
B.	Methane - Ethane	(superheated)
C.	n-Butane - Carbon dioxide	(saturated)
D.	Methane - n-Pentane	(saturated)
E.	Methane - n-Butane	(saturated)
F.	Methane - n-Butane	(superheated)

The experimental data for systems B through F were determined by Sage et al.(37,38,39,40,41) The experimental fugacity coefficients were found by them by the residual molal volume method discussed previously.

The experimental data for system A was given by Capik(3) and Sievering.(42) These investigators determined the fugacity coefficients of this system by the method of H. C. Van Ness,(47) using the Redlich and Kwong equation of state.

Both methods are essentially the same. The P-V-T behavior of the mixture was experimentally determined, then using Equation 13, or an equation derived from Equation 14, the fugacity values were calculated. The fugacity coefficient was then calculated as defined in Equation 5.

Statistical Definitions

In the present investigation the fugacity coefficient of each component was calculated at each experimental datum point. The per cent deviation of each experimental value from the calculated value was then determined by the formula:

$$\% \text{ Dev.} = \left[\frac{\text{Exper.} - \text{Calc.}}{\text{Exper.}}\right] \times 100.$$

The absolute average deviation of the system for component 1 or 2 was found by the equation:

$$\text{a.d.} = \frac{\sum |\% \text{ Dev.}|}{\text{No. of points}}$$

The mean deviation of the system for component 1 or 2 was calculated from the equation:

$$\% \text{ mean deviation} = \frac{\sum \% \text{ Dev.}}{\text{No. of points}}$$

It should be noted that a positive mean deviation value indicates that the correlation gives values less than the experimental values. Conversely, a negative mean deviation would indicate higher calculated values than the experimental data. The mean deviation therefore shows the bias of the correlation.

DISCUSSION OF RESULTS

In general, for the system under study, when a component is present in low mole fraction the deviation of that component increases as the pressure increases. For these conditions the amount of deviation decreases for increasing temperature. This is to be expected since the molecular interaction increases at higher pressures and decreasing temperature.

Table 1 gives the average per cent deviation and per cent mean of the fugacity coefficients of each component in each of the six systems studied.

From Table 1 it can be seen that the value for the larger molecule of the pair in each system has the larger error. Also it can be seen that the correlation gives higher results, in general, than the experimental values, as shown by the negative mean values.

Methane - Carbon Dioxide (superheated)

The experimental pressure range for this system is 100-500 atm. The temperature range is 310.94-415.94 ^{o}K. The mole fraction of methane is .204-.847.

The average deviation of methane is 4.79%, while it is 4.07% for carbon dioxide. The per cent mean for the former component is 1.39, and -1.19 for the latter.

Relatively large deviations resulted at the lowest

TABLE 1

COMPARISON OF RESULTS WITH EXPERIMENTAL DATA AND PITZER'S METHOD

SYSTEM	NO. Points	THIS WORK				PITZER'S METHOD	
		Component 1		Component 2		Comp. 1	Comp. 2
		a.d.%	mean%	a.d.%	mean%	a.d.%	a.d.%
A. $CH_4 - CO_2$ (superheated)	34	4.79	1.39	4.07	-1.19	4.49	3.94
B. $CH_4 - C_2H_6$ (superheated)	69	3.95	-3.23	6.21	0.10	4.22	6.86
C. $C_4H_{10} - CO_2$ (saturated)	41	4.35	-1.61	2.53	0.02	5.15	2.46
D. $CH_4 - nC_5H_{12}$ (saturated)	40	2.64	-0.96	9.41	4.89	3.24	6.40
E. $CH_4 - nC_4H_{10}$ (saturated)	33	6.19	-5.75	30.88	-30.33	8.98	31.7
F. $CH_4 - nC_4H_{10}$ (superheated)	102	1.49	-1.34	34.58	-34.54	2.17	37.4

Notes: 1) Average deviation for Pitzer's method is based on the same points.

2) Component 1 is the first molecule stated in each system's title.

temperature and mole fraction for both components.

Methane - Ethane (superheated)

This system consists of 69 data points, with a methane mole fraction range of .319-.893. The temperature range is 294.27-394.27 ^{o}K and the pressure range is 102.07-238.16 atm.

Of the calculated fugacity coefficients for methane, 93% are larger than the experimental values. The maximum deviation for this component is 7.93%, while the average deviation is 3.95%.

The deviations of the ethane fugacity coefficients are evenly distributed, as shown by its 0.10% mean. The per cent deviation of this component is relatively large at 10-12% for the higher pressure values and smallest mole fraction while the average deviation is 6.21%. Temperature change seems to have little effect on the ethane values.

At .556 mole fraction methane, an interesting feature of the system is that the ethane and methane deviations are about the same in magnitude, but the ethane coefficient is less than the experimental value while the methane value is greater than the experimental coefficient.

Butane - Carbon Dioxide (saturated)

The temperature range for this system of 41 data points is 310.94-415.94 ^{o}K. The range of the butane mole fraction is .050-.981 and the pressure range is 11.91-80.56 atm.

The calculated butane coefficients are generally larger than the experimental values as seen by a mean of -1.61%. The average deviation of this component is 4.35. The greatest deviation of this component occurs at its lowest mole fraction. Larger mole fraction also results in significant deviation for butane.

The average deviation of the calculated fugacity coefficients for the carbon dioxide component is less, at 2.53%, than the butane values. The calculated carbon dioxide deviations are equally distributed as seen from the mean of .02%. Generally, the largest deviations occur at low mole fraction. The effect of temperature is not easily seen since only large mole fraction values are present at the lowest temperature, while the highest temperature value has the lowest mole fraction values.

For those points where the mole fractions are about equal, the correlation produces coefficients which are generally slightly larger than the experimental values for both components.

Methane - n-Pentane (saturated)

For the 40 data points of this system the pressure range is 13.61-167.05 atm. The methane mole fraction range is .058-.946 and the range of the temperature is 310.94-444.27 ^{o}K.

The average per cent deviation of the methane coefficients is 2.64. The coefficients for this component are less than the experimental values at low pressure, but the calculated values become greater than the experimental coefficients as the pressure increases. The deviations at low mole fraction of methane are large, the calculated values being greater than the experimental values, as seen from the data at the highest temperature value. Generally, however, the correlation gives nearly evenly distributed results as seen from the per cent mean of -.96.

The average deviation for pentane is 9.41%. As may be expected, the greatest deviations occur at very low mole fractions and high pressures for pentane. At low pressure and mole fraction the pentane coefficients are greater than the experimental values. However, for increasing pressure, the calculated coefficients become less than the experimental coefficients. The mean deviation of 4.89% shows that the correlation calculates pentane values which are less than the experimental coefficients.

Methane - n-Butane (saturated)

The methane mole fraction range for this system of 34 data points is .111-.920. The temperature range is 294.27-394.27 °K. The range of the pressure is 10.2-127.65 atm.

The deviation of the methane coefficients in this system is greater at 6.19%, than in any other system. The correlation gives values for this component which generally are larger than the experimental coefficients, as seen from the mean of

-5.75%. The larger errors occur at low mole fraction of methane and low pressure. This may not be a pressure effect, since there are only a few data points at low pressure and low methane mole fraction.

The calculated butane fugacity coefficients are greater than the experimental values and are in large error, as seen from the -30.33% mean. The average per cent deviation is 30.88. The fact that the mole fraction of butane is low in most of the cases can account for some of this error. Increasing pressure also produces large deviations even when the temperature is high and the butane mole fraction is large.

Methane - n-Butane (superheated)

The methane mole fraction range is .287-.970. The pressure range is 20.43-204.14 atm. The temperature range is 294.27-394.27 °K.

Again, as shown in the previous system, the methane values are the most accurate at high mole fraction, while at low mole fraction the butane coefficients are in large error. Increasing pressure, at constant temperature and mole fraction, tends to increase the error of the methane coefficients. At constant pressure and mole fraction, the error of the methane coefficient is slightly increased for increasing temperature.

Comparison With Previous Work

The work of Mazzei(26) used all data, consisting of 1050 points, available in the literature for the five mixtures for the evaluation of the method of Pitzer et al. Mazzei concluded that although the method of Redlich et al., gave slightly more accurate results in two systems, the method of Pitzer et al., was preferred over the previous methods, since it produced consistently good results for the mixtures investigated.

Klee(21) has investigated the method of Gamson et al., using generalized charts. Klee in his evaluation chose in an arbitrary but representative manner 318 points as used by Mazzei. The points were selected from those areas of composition and/or P-V-T conditions where the largest deviations from ideal behavior might be encountered. In so doing, the method was given a significant test of its accuracy. The resulting values were compared only to the same points as given by Mazzei. Klee concluded that, overall, the method of Pitzer et al., as tested by Mazzei gave more accurate results.

Any other method of predicting fugacity coefficients of binary gaseous mixtures must be compared to the method of Pitzer et al., to determine its relative merits.

Pitzer and Hultgren state that Kay's rule plus an additional term will suffice to produce adequate values of pseudocritical temperature, pressure and acentric factor for binary gaseous mixtures of normal fluids. These definitions are Equations 23,24,25 respectively. For systems which deviate from normal fluid behavior, this statement becomes less valid as evidenced by their own evaluation.(32)

The present work states, however, that the pseudocritical temperature, pressure and acentric factor are based on second degree equations in mole fraction with cross-products. These definitions (Equations 45,46,47) give a somewhat more accurate estimate of the pseudocritical properties of binary mixtures. This conclusion is supported be the results of Table 1.

Specifically the fugacity coefficients of systems B,C,E and F are more accurately determined by the method tested in the present work than by the method of Pitzer et al. For system A, Pitzer's method gives slightly better results. In system D, Pitzer's method gives a better estimate of the fugacity coefficient of the second component, pentane by 3%, than this work. However, for system F, where both methods give large deviation for the butane coefficient, this method gives a 2.8% better estimate than Pitzer's correlation.

The statement therefore can be made that the method investigated in this work produces slightly better estimates of the fugacity coefficients in the saturated or superheated region for the six systems studied than Pitzer's method.

CONCLUSIONS

This work has presented an evaluation of a method proposed by Joffe which will predict, in general, more accurate fugacity coefficients of binary gaseous mixtures than the method of Gamson et al., or the previously published more accurate method of Pitzer et al. The proposed method can be used over a wide range of conditions.

The method of Pitzer et al., and the method studied in the present work both require experimental mixture data (P_{cM}, T_{cM}, w_M).

The fugacity coefficients for simple molecules as calculated by the present method are quite usable in engineering work. However, as the complexity of the molecule increases, significant error will be introduced. The error is also significant for molecules in concentrations of low mole fraction. High pressure also tends to increase the error, the calculated fugacity coefficients being greater than the experimental data values. However it can be noticed that in a system such as methane - n-butane, the predicted values for the simple molecule are very accurate. This fact may be useful, Also in such a system, the information that the more complex molecule yields significantly higher values of calculated fugacity coefficient than the actual coefficient may be useful. Some of the error in the methane - n-butane system may be attributed to the low mole fraction of n-butane.

It should be remembered that several previous methods were based on the two-parameter corresponding states principle. The introduction of a third parameter has significantly increased the accuracy of this theory. The acentric factor as the third parameter is preferred over the critical compressibility factor for reasons previously stated. The introduction of a fourth parameter such as molecular weight could increase the accuracy of this principle.

The use of tables for the determination of pertinent thermodynamic quantities is desirable.

Another point to consider is the complexity of the procedure needed to determine the fugacity coefficients. The answer to this should be quite obvious in that all three of the latest methods required evaluation by digital computers, which are readily available and whose programming has become relatively easy.

The method proposed in this work is readily extended to multicomponent systems.

RECOMMENDATIONS

The evaluation of the method of Joffe in this work should be considered only the start of a more complete study. As more data for other binary mixtures becomes available in the literature it would be worthwhile to evaluate this method further.

Another area that should be considered is the fact that a majority of the calculated coefficients were larger than the experimental data. The question is why?

The general procedure based on the pseudocritical properties that was used by Gamson et al., Pitzer et al., and Joffe seems quite promising as the direction to use in deriving other methods of predicting thermodynamic quantities for mixtures.

APPENDIX I

Computer Program

Computer Program Description

The binary system and the number of experimental data points for which the calculations were carried out were:

A	Methane - Carbon dioxide	(superheated)	34 points
B	Methane - Ethane	(superheated)	69 points
C	Butane - Carbon dioxide	(saturated)	41 points
D	Methane - Pentane	(saturated)	40 points
E	Methane - Butane	(saturated)	34 points
F	Methane - Butane	(superheated)	102 points
			320

The pure component critical values, the pseudocritical values and acentric factors used in this work were given by Pitzer and Hultgren. They were the same values as used by Mazzei in his evaluation of the method of Pitzer et al. The 320 points used in this work were the 318 used by Klee and 2 additional points of Mazzei.

The fugacity coefficients in the present study were calculated with an I.B.M. 1620 digital computer. The instructions describing the calculations were programmed in Fortran language. This language is widely used for digital computers, since it is independent of the machine used.

The calculations were divided into two parts. The first part dealt with fugacity coefficients outside the two-phase and critical region of the tables of Pitzer et al. The ranges of reduced variables in this part were P_r = 2.0 to 9.0 for T_r = .8 to 1.15, and P_r = .2 to 9.0 T_r = 1.15 to 2.5. The values used were as given by Pitzer et al. The second part dealt with the values inside the two-phase and critical region. For the second part the table range was P_r = .2 to 2.0 for T_r = .8 to 1.15. Since in this section of the tables linear interpolation would have a significant error, Pitzer et al., have supplied supplementary tables. From the tables, data were generated in this work by third order interpolation, with the result that the second part supplied values for P_r = .2 to 2.0 in steps of .2 and values for T_r = .8, .85 to 1.11 in steps of .01; 1.13 and 1.15. The tables were keypunched on cards in "free form" format, as allowed by the Fortran compiler used.

Titles were entered using a slightly non-standard format.

The sequence of input data was as follows:

1) Heading title number 1
2) Heading title number 2
3) Heading title number 3
4) Pertinent tables of Pitzer et al.
5) System title
6) Critical values of pure components 1 and 2
7) Pseudocritical values for the system
8) System conditions as per Klee and Mazzei
    a) point number

b) temperature

c) pressure

d) mole fraction of component 1

e) experimental fugacity coefficient of:

  1) component 1

  2) component 2

The calculations were performed and the final output data were punched on cards as follows:

1) System conditions as per Klee and Mazzei:

  a) point number

  b) temperature

  c) pressure

  d) mole fraction of component 1

2) Calculated fugacity coefficient of component 1

3) Experimental fugacity coefficient of component 1

4) Per cent difference between 2 and 3 above

5) Calculated fugacity coefficient of component 2

6) Experimental fugacity coefficient of component 2

7) Per cent difference between 5 and 6 above

The above values were rounded off before being punched.

Intermediate results:

1) Point number

2) Pseudocritical

  a) temperature

  b) pressure

3) Acentric factor (w) of mixture

4) Interpolated values of:

   a) $(z)^{(0)}$

   b) $(z)^{(1)}$

   c) $(\log \frac{f}{p})^{(0)}$

   d) $(\log \frac{f}{p})^{(1)}$

   e) $(\frac{H^{o} - H}{RT_{c}})^{(0)}$

   f) $(\frac{H^{o} - H}{RT_{c}})^{(1)}$

   g) Y

The intermediate values were not rounded off, but were truncated before being punched.

The program used computer console sense switches to allow only final answers or intermediate values, or both to be punched.

Upon punching the output values for the system, the program subsequentially returned to step 5 of the input section to repeat the process for the next system.

The additional data:

1) The absolute average of the per cent deviation for:

   a) component 1

   b) component 2

2) The average of 1a and 1b above, (i.e. the overall

average for the system)

3) The mean of the per cent deviations for:

   a) component 1

   b) component 2

was calculated by another program.

```
      DIMENSION Z0(19,26),Z1(19,21),FP0(19,26),FP1(19,21),DH0(19,26)
      DIMENSION DH1(19,21)
C
C     SW3 ON FOR CALCULATIONS OUTSIDE OF TWO-PHASE AND CRITICAL REGION
C     SW2 OFF FOR FINAL ANS.
C     SW1 ON FOR GETTING INTERMEDIATE RESULTS
C     READ HEADING NO. 1 AND 2
      READ 4
      READ 5
C     TRC = MAX. TR VALUE USED
C
C     INITIALIZE VALUES FOR CALCULATIONS INSIDE TWO-PHASE AND CRITICAL REGIO
      TRC=1.15
      NDEX=1
C     LIMITS FOR ROWS AND COLUMNS
      NTR=30
      NPR=10
      NPR1=10
C
      IF(SENSE SWITCH 3) 1,2
C
C     REDEFINE VALUES FOR CALCULATIONS OUTSIDE TWO-PHASE AND CRITICAL REGION
    1 TRC=2.5
      NDEX=2
C     LIMITS FOR ROWS AND COLUMNS
      NTR=19
      NPR=26
      NPR1=21
C     READ HEADING NO. 3
    2 READ 6
    3 FORMAT(/)
    4 FORMAT(80X)
    5 FORMAT(80X)
    6 FORMAT(80X)
      DIMENSION TRR(30)
      TRR(1)=.8
      TRR(2)=.85
      IF(SENSE SWITCH 3) 36,39
   36 DO 37 I=3,11
   37 TRR(I)=TRR(I-1) + .05
      DO 38 I=12,18
   38 TRR(I)=TRR(I-1) + .1
      TRR(19)=2.5
C     READ IN AND STORE PITZERS TABLES WHICH WILL BE USED FOR CALCULATIONS
C           OUTSIDE TWO-PHASE AND CRITICAL REGION
      DO 10 I=1,NTR
      DO 10 J=1,NPR
   10 READ,Z0(I,J)
      DO 15 I=1,NTR
      DO 15 J=1,NPR1
   15 READ,Z1(I,J)
```

```
      DO 20 I=1,NTR
      DO 20 J=1,NPR
   20 READ,FP0(I,J)
      DO 25 I=1,NTR
      DO 25 J=1,NPR1
   25 READ,FP1(I,J)
      DO 30 I=1,NTR
      DO 30 J=1,NPR
   30 READ,DH0(I,J)
      DO 35 I=1,NTR
      DO 35 J=1,NPR1
   35 READ,DH1(I,J)
      GO TO 51
   39 DO 40 I=3,28
   40 TRR(I)=TRR(I-1) + .01
      TRR(29)=1.13
      TRR(30)=1.15
C  READ IN AND STORE PITZERS TABLES WHICH WILL BE USED FOR CALCULATIONS
C        INSIDE TWO-PHASE AND CRITICAL REGION
      DO 41 J=1,NPR
      DO 41 I=1,NTR
   41 READ,Z0(I,J)
      DO 42 J=1,NPR1
      DO 42 I=1,NTR
   42 READ,Z1(I,J)
      DO 43 J=1,NPR
      DO 43 I=1,NTR
   43 READ,FP0(I,J)
      DO 44 J=1,NPR1
      DO 44 I=1,NTR
   44 READ,FP1(I,J)
      DO 45 J=1,NPR
      DO 45 I=1,NTR
   45 READ,DH0(I,J)
      DO 46 J=1,NPR1
      DO 46 I=1,NTR
   46 READ,DH1(I,J)
   50 FORMAT(80X)
C
C  PROGRAM IS SET UP FOR 6 MIXTURES
   51 DO 905 MIX=1,6
      SUMP1=0.0
      SUMP2=0.0
      DSUM=0.0
      PUNCH 55,MIX
   55 FORMAT(/31X5HTABLE I4//25X 21HFUGACITY COEFFICIENTS / )
C  READ TITLE OF SYSTEM
      READ 50
```

```
      PUNCH 50
      PUNCH 3
      PUNCH 4
      PUNCH 5
      PUNCH 6
C  READ CRITICAL VALUES
      READ.TC1.PC1.W1.TC2.PC2.W2
      READ.TCM.PCM.wCM
C  CALCULATION OF CONSTANTS IN CORRALATION
      X1=.5
      X2=.5
      A=TC1/PC1
      B=TC2/PC2
      D=TCM/PCM
      ALPH=TC1*A
      BETA=TC2*B
      SIGM=TCM*D
      GAM=(SIGM-ALPH*X1*x1-BETA*X2*X2)/(2.*X1*X2)
      C=(D-A*x1*X1-B*X2*X2)/(2.*X1*X2)
      W12=(WCM-w1*X1*X1-w2*X2*x2)/(2.*X1*X2)
C
C  START OF MAIN PROGRAM
C
C  NI IS NUMBER OF DATA POINTS PER MIXTURE
      READ.NI
      DNI=NI
      DO 900 IND=1.NI
      READ.N.TM.PM.X1.F1.F2
      X2=1.-X1
      TOP=ALPH*X1*X1+BETA*X2*X2+2.*GAM*X1*X2
      BOT=A*X1*X1+B*X2*X2+2.*C*X1*X2
      TCM=TOP/BOT
      PCM=TCM/BOT
      TR=TM/TCM
      PR=PM/PCM
      W=W1*X1*X1+W2*X2*X2+2.*W12*X1*X2
C  CHECK TO SEE IF TR AND PR ARE IN RANGE OF TABLES
      IF(TR-.8) 1000.110.100
  100 IF(TR-TRC) 110.110.1000
  110 IF(PR-.2) 1000.112.112
  112 GO TO(114.116).NDEX
  114 IF(PR-2.0) 135.1000.1000
  116 IF(PR-9.0) 120.1000.1000
  120 IF(PR-2.0) 125.1000.135
  125 IF(TR-1.15) 1000.1000.135
C  ANY CASE WHICH RESULTS IN A TR OR PR EXACTLY EQUAL TO TRR(I) OR PRR
C        IS OMITTED. AND SINCE THIS IS HIGHLY UNLIKELY. IT IS NOT A
C        RESTRICTION OF ANY IMPORTANCE.
```

```
  135 DO 140 I=1,NTR
      IF(TR-TRR(I)) 145,1000,140
  140 CONTINUE
  145 I1R=I-1
      I2R=I
      PRR=0.0
C  CHECK FOR PR BETWEEN 0.2 AND 3.0
      DO 150 J=1,15
      K=J
      PRR=PRR + .2
      IF(PR-PRR) 160,1000,150
  150 CONTINUE
      MM=-1
      GO TO 205
  160 P1=PRR-.2
      P2=PRR
      MM=1
      GO TO 239
C  PR IS ABOVE 3.0 IF CONTROL IS TRANSFERED TO 205
  205 FACT=.2
      II=1
      JJ=5
      KK=K
  206 DO 210 J=1,JJ
      K=K+1
      PRR=PRR+FACT
      IF(PR-PRR) 235,1000,210
  210 CONTINUE
      GO TO  (220,225,235),II
  220 FACT=.5
      II=2
      JJ=2
      GO TO 206
  225 FACT=1.0
      II=3
      JJ=4
      GO TO 206
  235 P1=PRR-FACT
      P2=PRR
  239 K=K-1
      ST1=TRR(I2R)-TRR(I1R)
      ST2=TRR(I2R)-TR
      SP03=P2-P1
      SP04=PR-P1
C  INTERPOLATE FOR Z(0)
  240 T1=Z0(I2R,K)-Z0(I1R,K)
      T2=ST1
      TT1=Z0(I2R,K)-ST2*T1/T2
```

```
      T1=   (ZO(I2R,K+1)-ZO(I1R,K+1))
      TT2=ZO(I2R,K+1)-ST2*T1/T2
      T1=TT2-TT1
      T2=SP03
      ZZO=TT1+SP04*T1/T2
C  INTERPOLATE FOR LOG(F/P)(0)
  245 T1=FPO(I2R,K)-FPO(I1R,K)
      T2=ST1
      TT1=FPO(I2R,K)-ST2*T1/T2
      T1=   (FPO(I2R,K+1)-FPO(I1R,K+1))
      TT2=FPO(I2R,K+1)-ST2*T1/T2
      T1=TT2-TT1
      T2=SP03
      FPOO=TT1+SP04*T1/T2
C  INTERPOLATE FOR ((H*-H)/RTC)(0)
  250 T1=DHO(I2R,K)-DHO(I1R,K)
      T2=ST1
      TT1=DHO(I2R,K)-ST2*T1/T2
      T1=   (DHO(I2R,K+1)-DHO(I1R,K+1))
      TT2=DHO(I2R,K+1)-ST2*T1/T2
      T1=TT2-TT1
      T2=SP03
      DHOO=TT1+SP04*T1/T2
      IF(MM) 305,340,340
  305 PRR=3.0
      K=KK
      JJ=6
  306 DO 310 J=1,JJ
      K=K+1
      PRR=PRR+1.
      IF(PR-PRR) 335,1000,310
  310 CONTINUE
  335 P1=PRR-1.
      P2=PRR
      K=K-1
  340 SP13=P2-P1
      SP14=PR-P1
C  INTERPOLATE FOR Z(1)
  345 T1=Z1(I2R,K)-Z1(I1R,K)
      T2=ST1
      TT1=Z1(I2R,K)-ST2*T1/T2
      T1=   (Z1(I2R,K+1)-Z1(I1R,K+1))
      TT2=Z1(I2R,K+1)-ST2*T1/T2
      T1=TT2-TT1
      T2=SP13
      ZZ1=TT1+SP14*T1/T2
C  INTERPOLATE FOR LOG(F/P)(1)
  350 T1=FP1(I2R,K)-FP1(I1R,K)
```

```
      T2=ST1
      TT1=FP1(I2R,K)-ST2*T1/T2
      T1=    (FP1(I2R,K+1)-FP1(I1R,K+1))
      TT2=FP1(I2R,K+1)-ST2*T1/T2
      T1=TT2-TT1
      T2=SP13
      FP11=TT1+SP14*T1/T2
C   INTERPOLATE FOR ((H*-H)/RTC)(1)
  360 T1=DH1(I2R,K)-DH1(I1R,K)
      T2=ST1
      TT1=DH1(I2R,K)-ST2*T1/T2
      T1=    (DH1(I2R,K+1)-DH1(I1R,K+1))
      TT2=DH1(I2R,K+1)-ST2*T1/T2
      T1=TT2-TT1
      T2=SP13
      DH11=TT1+SP14*T1/T2
  800 PT1=A*X1-B*X2+C*(X2-X1)
      PT2=W1*X1-W2*X2+W12*(X2-X1)
      PT3=ALPH*X1-BETA*X2+GAM*(X2-X1)
      Z=ZZ0+W*ZZ1
      DHRT=DH00+W*DH11
      FP=FP00+W*FP11
      PT4=(-2.*PCM/(2.303*TM))
      PT5=(PT3/TCM)-PT1
      PT6=(PT3/TCM)-2.*PT1
      PT7=(-2.*PCM/(2.303*TCM))
      Y=PT4*DHRT*PT5 + PT7*(Z-1.)*PT6 + FP11*2.*PT2
      CF1=EXP(2.303*(FP+X2*Y))
      CF2=EXP(2.303*(FP-X1*Y))
      PCD1=(F1-CF1)/F1*100.
      PCD2=(F2-CF2)/F2*100.
      SUMP1=SUMP1 + ABS(PCD1)
      SUMP2=SUMP2 + ABS(PCD2)
      DSUM=DSUM+ABS(PCD1)+ABS(PCD2)
      CF1=CF1 + .0005
      CF2=CF2 + .0005
      PCD1=PCD1 + .005
      PCD2=PCD2 + .005
  840 IF(SENSE SWITCH 2) 855,850
  850 PUNCH 915,N,TM,PM,X1,CF1,F1,PCD1,CF2,F2,PCD2
      IF(SENSE SWITCH 1) 855,900
  855 PUNCH 920,N,TCM,PCM,W,ZZ0,ZZ1,FP00,FP11,DH00,DH11,Y,1
  900 CONTINUE
      DEV=DSUM/(2.*DNI) + .005
      AVP1=SUMP1/DNI + .005
      AVP2=SUMP2/DNI +.005
      PUNCH 930, AVP1,AVP2
      NI=DNI
```

```
      PUNCH 925,DEV,NI
  905 CONTINUE
      STOP
  915 FORMAT(I5,2F8.2,3F7.3,F7.2,2F7.3,F7.2)
  920 FORMAT(I5,2F8.2F7.3, 7F7.4,I3)
  925 FORMAT(/8X19HAVERAGE DEVIATION =F7.2,5H  FORI4,12H DATA POINTS)
  930 FORMAT( 43X 6H------ 15X 6H------ /42X F7.2, 14X F7.2 )
 1000 CF1=0.0
      CF2=0.0
      PCD1=0.0
      PCD2=0.0
      ZZ0=0.0
      ZZ1=0.0
      FP00=0.0
      FP11=0.0
      DH00=0.0
      DH11=0.0
      Y=0.0
      DNI=DNI-1.
      GO TO 900
      END
```

FOR CALCULATIONS INSIDE THE TWO-PHASE AND CRITICAL REGION, USE THE FOLLOWING TWO CARDS INSTEAD OF THEIR CORRESPONDINGLY NUMBERED COUNTER-PARTS.

```
      DIMENSION Z0(30,10),Z1(30,10),FP0(30,10),FP1(30,10),DH0(30,10)      001
      DIMENSION DH1(30,10)                                                002
```

APPENDIX II

Nomenclature For Computer Program

CF1	Calculated fugacity coefficient of component 1
CF2	Calculated fugacity coefficient of component 2
DHO	Enthalpy departure in Pitzer's tables
DH1	Enthalpy departure in Pitzer's tables
F1	Experimental fugacity coefficient of component 1
F2	Experimental fugacity coefficient of component 2
FPO	Fugacity coefficient in Pitzer's tables
FP1	Fugacity coefficient in Pitzer's tables
N	Data point number
PC1	Critical pressure of component 1
PC2	Critical pressure of component 2
PCM	Critical pressure of mixture
PM	Experimental pressure
PR	Reduced pressure of mixture
PRR	Reduced pressure table index
TC1	Critical temperature of component 1
TC2	Critical temperature of component 2
TCM	Critical temperature of mixture
TM	Experimental temperature
TR	Reduced temperature of mixture
TRR	Reduced temperature table index
W	Acentric factor of mixture
W1	Acentric factor of component 1
WCM	Acentric factor for mixture
X1	Mole fraction of component 1
Z	Compressibility factor of mixture

APPENDIX III

Component Critical Properties

TABLE 1

The Acentric Factor and Critical Data(30)

Substance	w	T_c °K	P_c atm.
CH_4	0.013	190.66	45.80
C_2H_6	0.105	305.75	48.86
nC_4H_{10}	0.201	425.17	37.47
nC_5H_{12}	0.252	470.60	33.63
CO_2	0.225	304.16	72.80

TABLE 2

Pseudo-Critical Constants of Equimolal Mixtures(32)

System	w_M	T_{cM} °K	P_{cM} atm.
CH_4 - CO_2	0.15	242.	57.6
CH_4 - C_2H_6	0.05	254.	48.5
nC_4H_{10} - CO_2	0.20	352.	46.1
CH_4 - nC_5H_{12}	0.13	356.	39.5
CH_4 - nC_4H_{10}	0.17	324.	42.2

APPENDIX IV

Calculated Results

TABLE 1

FUGACITY COEFFICIENTS

SYSTEM A COMP 1 IS METHANE COMP 2 IS CO2

				FUGACITY COEFF. 1			FUGACITY COEFF. 2		
POINT	TEMP. K	PRESS. ATM	X1	CALC	EXP	PCT DEV	CALC	EXP	PCT DEV
1	344.27	100.00	.204	1.014	1.003	-1.09	.725	.721	-.54
5	344.27	200.00	.204	1.113	1.096	-1.54	.526	.520	-1.14
6	344.47	200.00	.406	.960	.945	-1.58	.556	.560	.71
8	344.27	200.00	.847	.866	.863	-.34	.653	.638	-2.34
9	344.27	300.00	.204	1.150	1.102	-4.35	.433	.431	-.45
11	344.27	300.00	.605	.893	.880	-1.47	.505	.503	-.39
13	344.27	400.00	.204	1.175	1.117	-5.18	.392	.392	.00
14	344.27	400.00	.406	.993	.964	-3.00	.420	.424	.94
15	344.27	400.00	.605	.906	.894	-1.33	.463	.459	-.86
17	344.27	500.00	.204	1.227	1.158	-5.95	.375	.373	-.53
18	344.27	500.00	.406	1.040	1.002	-3.78	.399	.406	1.72
25	415.94	100.00	.204	1.020	1.016	-.38	.865	.853	-1.40
29	415.94	200.00	.204	1.081	1.063	-1.68	.755	.737	-2.43
31	415.94	200.00	.605	.985	.963	-2.27	.804	.783	-2.67
32	415.94	200.00	.847	.961	.954	-.72	.849	.802	-5.85
33	415.94	300.00	.204	1.140	1.114	-2.32	.681	.663	-2.70
35	415.94	300.00	.847	.967	.959	-.82	.816	.748	-9.08
36	415.94	400.00	.204	1.204	1.175	-2.46	.640	.620	-3.22
37	415.94	400.00	.406	1.090	1.035	-5.30	.668	.655	-1.97
39	415.94	400.00	.847	.987	.977	-1.01	.793	.723	-9.67
40	415.94	500.00	.204	1.277	1.239	-3.06	.621	.601	-3.32
48	310.94	100.00	.204	1.065	1.230	13.36	.590	.575	-2.76
51	310.94	100.00	.847	.874	.869	-.57	.707	.733	3.55
52	310.94	200.00	.204	1.186	1.421	16.54	.365	.351	-3.98
53	310.94	200.00	.406	.938	1.018	7.86	.410	.392	-4.58
55	310.94	200.00	.847	.794	.781	-1.65	.522	.586	10.92
56	310.94	300.00	.204	1.147	1.408	18.54	.293	.281	-4.26
57	310.94	300.00	.406	.920	.945	2.65	.327	.311	-5.13
59	310.94	300.00	.847	.762	.743	-2.55	.435	.502	13.35
60	310.94	400.00	.204	1.144	1.417	19.27	.263	.252	-4.36
61	310.94	400.00	.406	.925	.970	4.64	.294	.279	-5.37
63	310.94	400.00	.847	.763	.738	-3.38	.394	.478	17.57
64	310.94	500.00	.204	1.188	1.468	19.07	.250	.238	-5.03
65	310.94	500.00	.406	.965	.996	3.11	.278	.263	-5.69
						------			------
						4.79			4.07

AVERAGE DEVIATION = 4.43 FOR 34 DATA POINTS

```
MEAN          =               1.39          -1.19
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TABLE 2

FUGACITY COEFFICIENTS

SYSTEM B COMP 1 IS METHANE COMP 2 IS ETHANE

				FUGACITY COEFF. 1			FUGACITY COEFF. 2		
POINT	TEMP. K	PRESS. ATM	X1	CALC	EXP	PCT DEV	CALC	EXP	PCT DEV
79	294.27	136.09	.556	.870	.838	-3.81	.317	.340	6.76
82	294.27	187.12	.556	.801	.773	-3.61	.257	.275	6.55
85	294.27	238.16	.556	.756	.720	-4.99	.229	.245	6.53
95	294.27	170.11	.738	.784	.739	-6.08	.300	.322	6.83
98	294.27	221.15	.738	.745	.695	-7.18	.252	.274	8.03
107	294.27	136.09	.893	.801	.791	-1.25	.391	.372	-5.10
110	294.27	187.12	.893	.753	.741	-1.61	.303	.285	-6.31
113	294.27	238.16	.893	.723	.708	-2.11	.257	.239	-7.52
119	310.94	102.07	.319	1.042	1.049	.67	.440	.451	2.44
121	310.94	136.09	.319	.991	1.060	6.51	.359	.361	.55
124	310.94	187.12	.319	.905	.983	7.93	.301	.298	-1.00
127	310.94	238.16	.319	.848	.918	7.63	.272	.271	-.36
135	310.94	136.09	.556	.893	.861	-3.71	.397	.340	-16.75
138	310.94	187.12	.556	.845	.828	-2.04	.323	.275	-17.44
141	310.94	238.16	.556	.808	.770	-4.93	.286	.245	-16.72
149	310.94	136.09	.738	.851	.817	-4.15	.431	.452	4.65
152	310.94	187.12	.738	.811	.773	-4.91	.346	.365	5.21
155	310.94	238.16	.738	.785	.739	-6.21	.299	.321	6.85
164	310.94	153.10	.893	.824	.812	-1.47	.429	.404	-6.18
167	310.94	204.14	.893	.790	.775	-1.93	.354	.328	-7.92
169	310.94	238.16	.893	.774	.758	-2.10	.323	.296	-9.11
181	327.60	204.14	.319	.925	.941	1.70	.354	.358	1.12
193	327.60	170.11	.556	.886	.850	-4.23	.411	.430	4.42
196	327.60	221.15	.556	.857	.814	-5.27	.357	.379	5.80
206	327.60	153.10	.738	.868	.832	-4.32	.465	.488	4.71
209	327.60	204.14	.738	.840	.798	-5.25	.393	.414	5.07
211	327.60	238.16	.738	.827	.780	-6.02	.362	.384	5.73
223	327.60	204.14	.893	.829	.815	-1.71	.418	.386	-8.28
225	327.60	238.16	.893	.815	.800	-1.87	.387	.351	-10.25
236	344.27	187.12	.319	.963	.950	-1.36	.433	.439	1.37
239	344.27	238.16	.319	.930	.903	-2.98	.392	.401	2.24
248	344.27	187.12	.556	.904	.878	-2.95	.454	.529	14.18
251	344.27	204.14	.556	.899	.848	-6.00	.435	.460	5.43
253	344.27	238.16	.556	.888	.830	-6.98	.406	.434	6.45
261	344.27	136.09	.738	.906	.867	-4.49	.560	.584	4.11
264	344.27	187.12	.738	.879	.837	-5.01	.477	.498	4.22
267	344.27	238.16	.738	.862	.814	-5.89	.425	.445	4.49
279	344.27	204.14	.893	.862	.847	-1.76	.480	.435	-10.33
281	344.27	238.16	.893	.852	.836	-1.90	.448	.399	-12.27

```
295  360.94  238.16   .319    .956    .936  -2.13    .450    .461   2.39
306  360.94  187.12   .556    .926    .876  -5.70    .512    .545   6.06
309  360.94  238.16   .536    .917    .854  -7.37    .462    .498   7.23
320  360.94  187.12   .738    .904    .861  -4.98    .537    .559   3.94
323  360.94  238.16   .738    .892    .842  -5.93    .485    .507   4.34
332  360.94  153.10   .893    .909    .896  -1.44    .611    .563  -8.52
335  360.94  204.14   .893    .893    .877  -1.81    .536    .489  -9.60
337  360.94  238.16   .893    .885    .869  -1.83    .506    .453 -11.69
346  377.60  153.10   .319    .994    .977  -1.73    .596    .606   1.65
349  377.60  204.14   .319    .985    .966  -1.96    .532    .544   2.21
351  377.60  238.16   .319    .979    .955  -2.50    .505    .518   2.51
361  377.60  170.11   .556    .947    .897  -5.56    .591    .627   5.74
364  377.60  221.15   .556    .940    .880  -6.81    .535    .573   6.63
371  377.60  102.07   .738    .952    .919  -3.58    .728    .752   3.19
374  377.60  153.10   .738    .933    .894  -4.35    .636    .661   3.78
378  377.60  204.14   .738    .924    .876  -5.47    .570    .597   4.52
380  377.60  238.16   .738    .919    .869  -5.74    .540    .566   4.59
392  377.60  204.14   .893    .918    .898  -2.22    .590    .535 -10.27
394  377.60  238.16   .893    .913    .892  -2.34    .561    .501 -11.97
403  394.27  153.10   .319   1.000    .981  -1.93    .646    .655   1.37
406  394.27  204.14   .319    .997    .979  -1.83    .585    .596   1.85
408  394.27  238.16   .319    .995    .975  -2.04    .557    .571   2.45
417  394.27  153.10   .556    .965    .915  -5.45    .663    .700   5.29
420  394.27  204.14   .556    .960    .901  -6.54    .603    .643   6.22
422  394.27  238.16   .556    .957    .895  -6.92    .574    .616   6.82
429  394.27  119.08   .738    .960    .921  -4.22    .733    .755   2.91
432  394.27  170.11   .738    .949    .902  -5.20    .660    .684   3.51
435  394.27  221.15   .738    .945    .890  -6.17    .604    .633   4.58
447  394.27  187.12   .893    .940    .921  -2.05    .663    .599 -10.67
450  394.27  238.16   .893    .935    .914  -2.29    .616    .548 -12.40
                                                ------                  ------
                                                  3.95                    6.21

     AVERAGE DEVIATION =     5.08   FOR   69 DATA POINTS

     MEAN              =                       -3.23                     .10
```

TABLE 3

FUGACITY COEFFICIENTS

SYSTEM C COMP 1 IS BUTANE   COMP 2 IS CO2

				FUGACITY COEFF. 1			FUGACITY COEFF. 2		
POINT	TEMP. K	PRESS. ATM	X1	CALC	EXP	PCT DEV	CALC	EXP	PCT DEV
452	310.94	13.61	.286	.770	.759	-1.44	.960	.966	.62
453	310.94	17.01	.235	.731	.717	-1.94	.944	.946	.21
454	310.94	20.41	.202	.694	.673	-3.11	.928	.927	-.10
455	310.94	23.82	.178	.659	.634	-3.93	.912	.909	-.32
456	310.94	27.22	.160	.621	.597	-4.01	.897	.893	-.44
457	310.94	30.62	.145	.586	.564	-3.89	.881	.878	-.33
458	310.94	34.02	.133	.554	.532	-4.13	.866	.865	-.11
460	310.94	47.63	.100	.428	.415	-3.12	.807	.802	-.61
461	310.94	54.44	.090	.361	.351	-2.84	.780	.772	-1.03
462	310.94	61.24	.075	.306	.313	2.24	.751	.740	-1.48
463	310.94	68.05	.056	.267	.300	11.00	.721	.710	-1.54
464	310.94	71.45	.051	.234	.271	13.65	.703	.699	-.56
465	310.94	74.51	.060	.191	.191	.00	.689	.701	1.71
466	310.94	71.92	.050	.231	.271	14.76	.700	.698	-.28
467	310.94	74.37	.054	.200	.215	6.98	.688	.696	1.15
469	344.27	11.91	.723	.781	.800	2.38	1.072	1.011	-6.02
472	344.27	20.41	.464	.712	.698	-2.00	.998	1.001	.30
474	344.27	27.22	.365	.657	.644	-2.01	.963	.963	.00
476	344.27	34.02	.306	.607	.594	-2.18	.936	.937	.11
478	344.27	47.63	.246	.502	.488	-2.86	.892	.889	-.33
480	344.27	61.24	.220	.402	.387	-3.87	.856	.856	.00
481	344.27	68.05	.216	.355	.336	-5.64	.850	.847	-.34
482	344.27	74.85	.222	.296	.281	-5.33	.845	.850	.59
484	344.27	80.56	.287	.206	.191	-7.84	.903	.923	2.17
485	344.27	69.41	.216	.344	.326	-5.51	.848	.847	-.11
487	377.60	20.41	.850	.694	.730	4.93	1.498	1.142	-31.16
489	377.60	27.22	.687	.668	.668	.00	1.111	1.089	-2.01
491	377.60	34.02	.589	.620	.614	-.97	1.068	1.056	-1.13
492	377.60	40.83	.520	.572	.569	-.52	1.036	1.021	-1.46
493	377.60	47.63	.476	.525	.522	-.56	1.010	1.009	-.09
495	377.60	61.24	.432	.436	.425	-2.58	1.006	1.005	-.09
496	377.60	68.05	.432	.384	.371	-3.49	1.019	1.030	1.07
497	377.60	71.45	.448	.348	.336	-3.56	1.059	1.070	1.03
499	415.94	30.62	.981	.697	.684	-1.89	1.439	1.464	1.71
500	415.94	34.02	.923	.667	.646	-3.24	1.491	1.460	-2.11
501	415.94	37.42	.876	.647	.614	-5.36	1.382	1.443	4.23
503	415.94	44.23	.809	.590	.557	-5.91	1.370	1.435	4.53
504	415.94	47.63	.790	.564	.528	-6.81	1.386	1.470	5.71
505	415.94	51.03	.795	.528	.490	-7.75	1.495	1.639	8.79
506	415.94	51.59	.812	.514	.476	-7.97	1.606	1.810	11.27

```
507  415.94   49.26   .788   .550   .519  -5.96  1.417  1.525   7.08
                                          ------                ------
                                            4.35                  2.53

     AVERAGE DEVIATION =   3.44  FOR  41 DATA POINTS

     MEAN              =                  -1.61                  .02
```

TABLE 4

FUGACITY COEFFICIENTS

SYSTEM D COMP 1 IS METHANE COMP 2 IS PENTANE

				FUGACITY COEFF. 1			FUGACITY COEFF. 2		
POINT	TEMP. K	PRESS. ATM	X1	CALC	EXP	PCT DEV	CALC	EXP	PCT DEV
508	310.94	13.61	.894	.982	.990	.81	.796	.741	-7.41
509	310.94	20.41	.920	.969	.979	1.02	.717	.675	-6.21
510	310.94	27.22	.932	.960	.965	.52	.639	.620	-3.05
511	310.94	40.83	.943	.942	.944	.21	.507	.509	.39
512	310.94	54.44	.946	.925	.926	.11	.396	.412	3.88
514	310.94	85.06	.946	.892	.890	-.21	.215	.258	16.67
515	310.94	102.21	.941	.877	.873	-.45	.150	.196	23.47
516	310.94	119.08	.933	.863	.880	1.93	.107	.152	29.61
517	310.94	136.09	.920	.854	.841	-1.54	.074	.114	35.09
518	310.94	153.10	.897	.853	.831	-2.64	.051	.082	37.80
519	310.94	167.05	.822	.894	.879	-1.70	.029	.046	36.96
522	344.27	20.41	.819	.987	.998	1.10	.745	.711	-4.77
523	344.27	27.22	.849	.979	.990	1.11	.682	.645	-5.73
524	344.27	40.83	.879	.965	.979	1.43	.572	.550	-3.99
526	344.27	68.05	.894	.948	.957	.94	.385	.388	.77
527	344.27	85.06	.893	.942	.943	.11	.292	.310	5.81
528	344.27	102.21	.887	.937	.939	.21	.219	.231	5.19
530	344.27	136.09	.856	.940	.931	-.96	.123	.148	16.89
531	344.27	153.10	.814	.967	.959	-.82	.087	.105	17.14
532	344.27	159.09	.766	1.008	1.012	.40	.068	.081	16.05
534	377.60	20.41	.614	1.025	1.038	1.25	.732	.706	-3.67
535	377.60	27.22	.685	1.013	1.030	1.65	.684	.649	-5.38
536	377.60	40.83	.757	1.001	1.018	1.67	.594	.564	-5.31
537	377.60	54.44	.788	.992	1.009	1.68	.510	.493	-3.44
538	377.60	68.05	.798	.992	1.012	1.98	.431	.421	-2.37
539	377.60	85.06	.801	.998	1.019	2.06	.343	.347	1.15
541	377.60	119.08	.758	1.042	1.047	.48	.196	.216	9.26
542	377.60	136.09	.742	1.058	1.054	-.37	.158	.184	14.13
543	377.60	141.60	.675	1.144	1.154	.87	.123	.142	13.38
544	415.94	13.61	.058	1.260	1.038	-21.38	.787	.785	-.24
546	415.94	27.22	.429	1.108	1.131	2.03	.677	.650	-4.14
547	415.94	40.83	.602	1.053	1.038	-1.44	.622	.624	.32
548	415.94	54.44	.614	1.072	1.120	4.29	.526	.483	-8.89
550	415.94	85.06	.642	1.110	1.143	2.89	.368	.340	-8.23
552	415.94	109.55	.510	1.400	1.439	2.71	.211	.199	-6.02
553	444.27	27.22	.094	1.524	1.469	-3.73	.664	.657	-1.06
554	444.27	40.83	.279	1.368	1.241	-10.22	.565	.547	-3.28
555	444.27	54.44	.356	1.352	1.257	-7.55	.477	.458	-4.14
556	444.27	68.05	.337	1.626	1.504	-8.10	.367	.374	1.87
557	444.27	69.75	.295	1.915	1.725	-11.00	.338	.328	-3.04

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                                    2.64                9.41
AVERAGE DEVIATION =  6.02  FOR  40 DATA POINTS
MEAN              =                 -.96                4.89
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TABLE 5

FUGACITY COEFFICIENTS

SYSTEM E COMP 1 IS METHANE COMP 2 IS BUTANE (SATURATED)

				FUGACITY COEFF. 1			FUGACITY COEFF. 2		
POINT	TEMP. K	PRESS. ATM	X1	CALC	EXP	PCT DEV	CALC	EXP	PCT DEV
558	294.27	10.21	.752	.994	1.004	1.00	.823	.708	-16.23
559	294.27	13.61	.809	.983	.990	.71	.797	.673	-18.41
561	294.27	34.02	.898	.945	.954	.94	.602	.441	-36.50
563	294.27	40.83	.907	.933	.944	1.17	.542	.392	-38.26
565	294.27	68.05	.920	.891	.895	.45	.346	.256	-35.15
568	294.27	95.26	.909	.862	.852	-1.16	.202	.169	-19.52
579	310.94	20.41	.783	.982	.991	.91	.740	.581	-27.36
582	310.94	40.83	.862	.951	.963	1.25	.573	.389	-47.29
584	310.94	68.05	.881	.919	.924	.54	.387	.262	-47.70
587	310.94	95.26	.865	.904	.899	-.55	.237	.174	-36.20
591	310.94	119.08	.835	.907	.880	-3.06	.148	.124	-19.34
598	327.60	20.41	.678	1.001	.995	-.59	.738	.624	-18.26
599	327.60	27.22	.739	.988	.988	.00	.686	.545	-25.86
602	327.60	54.44	.819	.959	.962	.31	.500	.336	-48.80
605	327.60	85.06	.827	.944	.934	-1.06	.322	.215	-49.76
607	327.60	102.21	.815	.944	.925	-2.04	.245	.172	-42.43
609	327.60	115.68	.786	.964	.929	-3.76	.186	.135	-37.77
612	327.60	125.89	.729	1.032	.900	-14.66	.131	.100	-30.99
613	327.60	127.65	.622	1.213	1.135	-6.86	.088	.071	-23.93
614	344.27	10.21	.172	1.392	1.004	-38.64	.762	.809	5.81
620	344.27	54.44	.745	.991	.982	-.91	.517	.361	-43.20
622	344.27	81.67	.759	.991	.977	-1.42	.360	.237	-51.89
624	344.27	95.26	.753	.997	.974	-2.35	.297	.195	-52.30
628	344.27	119.08	.683	1.088	1.027	-5.93	.178	.119	-49.57
630	344.27	123.16	.616	1.215	1.127	-7.80	.137	.095	-44.20
631	360.94	13.61	.111	1.345	1.010	-33.16	.763	.780	2.18
637	360.94	68.05	.672	1.036	1.007	-2.87	.443	.319	-38.86
640	360.94	95.26	.610	1.161	1.121	-3.56	.266	.182	-46.14
644	360.94	115.54	.550	1.324	1.212	-9.23	.177	.128	-38.27
657	377.60	103.43	.472	1.456	1.331	-9.38	.228	.193	-18.12
658	394.27	27.22	.142	1.327	1.038	-27.83	.688	.697	1.29
659	394.27	34.02	.265	1.246	1.071	-16.33	.643	.621	-3.53
664	394.27	81.67	.410	1.452	1.390	-4.45	.342	.287	-19.15
666	394.27	86.01	.360	1.680	1.593	-5.45	.295	.255	-15.68
						------			------
						6.19			30.88

AVERAGE DEVIATION = 18.53 FOR 34 DATA POINTS

MEAN	=	-5.75	-30.33

TABLE 6

FUGACITY COEFFICIENTS

SYSTEM F COMP 1 IS METHANE COMP 2 IS BUTANE (SUPERHEATED)

POINT	TEMP. K	PRESS. ATM	X1	FUGACITY COEFF. 1 CALC	FUGACITY COEFF. 1 EXP	FUGACITY COEFF. 1 PCT DEV	FUGACITY COEFF. 2 CALC	FUGACITY COEFF. 2 EXP	FUGACITY COEFF. 2 PCT DEV
670	294.27	27.22	.894	.956	.964	.83	.673	.497	-35.40
675	294.27	40.83	.912	.932	.934	.21	.546	.395	-38.22
678	294.27	85.06	.912	.873	.865	-.91	.246	.208	-18.26
682	294.27	204.14	.912	.752	.739	-1.75	.061	.062	1.61
686	294.27	34.02	.970	.940	.941	.11	.641	.519	-23.50
689	294.27	68.05	.970	.886	.887	.11	.393	.295	-33.21
691	294.27	102.07	.970	.840	.838	-.23	.231	.180	-28.32
693	294.27	170.11	.970	.765	.765	.00	.106	.083	-27.70
694	294.27	204.14	.970	.740	.739	-.13	.081	.063	-28.56
697	310.94	27.22	.845	.968	.980	1.22	.698	.505	-38.21
704	310.94	68.05	.894	.915	.920	.54	.401	.278	-44.23
707	310.94	136.09	.894	.856	.841	-1.77	.157	.130	-20.76
709	310.94	204.14	.894	.807	.786	-2.66	.090	.080	-12.49
713	310.94	34.02	.912	.952	.953	.10	.666	.526	-26.61
715	310.94	54.44	.912	.926	.926	.00	.505	.380	-32.88
716	310.94	68.05	.912	.912	.909	-.32	.417	.312	-33.64
719	310.94	136.09	.912	.849	.834	-1.79	.169	.142	-19.00
721	310.94	204.14	.912	.801	.782	-2.42	.097	.084	-15.47
726	310.94	40.83	.970	.942	.942	.00	.629	.488	-28.88
728	310.94	68.05	.970	.907	.907	.00	.459	.323	-42.10
729	310.94	85.06	.970	.887	.886	-.10	.367	.255	-43.91
732	310.94	170.11	.970	.808	.805	-.36	.158	.103	-53.39
733	310.94	204.14	.970	.787	.784	-.37	.124	.081	-53.08
737	327.60	34.02	.845	.965	.971	.62	.679	.516	-31.58
740	327.60	68.05	.845	.942	.944	.21	.431	.311	-38.58
743	327.60	136.09	.845	.906	.885	-2.36	.183	.152	-20.38
745	327.60	204.14	.845	.866	.840	-3.09	.113	.098	-15.30
750	327.60	40.83	.894	.955	.958	.31	.646	.493	-31.02
753	327.60	85.06	.894	.919	.915	-.43	.376	.282	-33.32
757	327.60	204.14	.894	.845	.825	-2.41	.133	.115	-15.64
761	327.60	34.02	.912	.963	.962	-.09	.701	.566	-23.84
764	327.60	68.05	.912	.930	.926	-.42	.483	.355	-36.05
769	327.60	204.14	.912	.840	.821	-2.30	.143	.115	-24.34
775	327.60	54.44	.970	.938	.939	.11	.590	.418	-41.14
778	327.60	102.07	.970	.894	.892	-.21	.369	.235	-57.01
781	327.60	204.14	.970	.827	.823	-.48	.175	.104	-68.26
786	344.27	40.83	.845	.967	.968	.10	.670	.499	-34.26
788	344.27	68.05	.845	.952	.948	-.41	.497	.351	-41.59
791	344.27	136.09	.845	.926	.907	-2.08	.245	.185	-32.42
793	344.27	204.14	.845	.897	.875	-2.50	.158	.120	-31.66

798	344.27	40.83	.894	.965	.964	-.09	.684	.515	-32.81
801	344.27	85.06	.894	.935	.928	-.74	.440	.315	-39.67
804	344.27	170.11	.894	.890	.873	-1.94	.222	.169	-31.35
805	344.27	204.14	.894	.877	.858	-2.20	.183	.142	-28.86
809	344.27	34.02	.912	.969	.969	.00	.732	.580	-26.20
812	344.27	68.05	.912	.942	.939	-.31	.538	.387	-39.01
815	344.27	136.09	.912	.902	.888	-1.57	.292	.218	-33.93
817	344.27	204.14	.912	.871	.853	-2.10	.193	.147	-31.28
822	344.27	40.83	.970	.963	.962	-.09	.708	.532	-33.07
825	344.27	85.06	.970	.927	.925	-.21	.498	.322	-54.65
828	344.27	170.11	.970	.876	.871	-.56	.280	.163	-71.77
833	360.94	34.02	.845	.980	.976	-.40	.748	.592	-26.34
836	360.94	68.05	.845	.964	.955	-.93	.556	.400	-38.99
839	360.94	136.09	.845	.944	.923	-2.27	.309	.230	-34.34
841	360.94	204.14	.845	.923	.902	-2.32	.211	.158	-33.53
846	360.94	40.83	.894	.972	.970	-.20	.718	.554	-29.59
849	360.94	85.06	.894	.947	.941	-.63	.500	.359	-39.27
851	360.94	136.09	.894	.927	.913	-1.52	.344	.253	-35.96
853	360.94	204.14	.894	.905	.886	-2.13	.239	.180	-32.77
860	360.94	68.05	.912	.954	.950	-.41	.588	.422	-39.33
863	360.94	136.09	.912	.922	.908	-1.53	.358	.258	-38.75
865	360.94	204.14	.912	.899	.881	-2.03	.250	.184	-35.86
869	360.94	34.02	.970	.976	.974	-.20	.779	.609	-27.90
873	360.94	85.06	.970	.943	.939	-.42	.553	.355	-55.76
877	360.94	204.14	.970	.895	.885	-1.12	.288	.168	-71.42
886	377.60	102.07	.845	.964	.948	-1.68	.462	.346	-33.52
889	377.60	204.14	.845	.944	.925	-2.04	.265	.198	-33.83
895	377.60	54.44	.894	.972	.986	1.42	.689	.515	-33.78
899	377.60	136.09	.894	.943	.929	-1.50	.409	.300	-36.32
901	377.60	204.14	.894	.928	.910	-1.97	.297	.224	-32.58
907	377.60	54.44	.912	.971	.967	-.40	.697	.514	-35.59
913	377.60	204.14	.912	.925	.905	-2.20	.309	.223	-38.56
921	377.60	85.06	.970	.956	.950	-.62	.607	.394	-54.05
925	377.60	204.14	.970	.917	.909	-.87	.358	.206	-73.78
932	394.27	68.05	.845	.979	.969	-1.02	.646	.493	-31.02
937	394.27	204.14	.845	.961	.936	-2.66	.323	.244	-32.37
943	394.27	54.44	.894	.980	.973	-.71	.726	.551	-31.75
946	394.27	102.07	.894	.967	.954	-1.35	.553	.399	-38.59
949	394.27	204.14	.894	.950	.930	-2.14	.354	.267	-32.57
955	394.27	54.44	.912	.981	.973	-.81	.733	.547	-33.99
959	394.27	136.09	.912	.956	.941	-1.58	.488	.344	-41.85
961	394.27	204.14	.912	.949	.926	-2.47	.366	.265	-38.10
966	394.27	40.83	.970	.982	.980	-.19	.810	.611	-32.56
970	394.27	102.07	.970	.959	.955	-.41	.619	.388	-59.53
973	394.27	204.14	.970	.938	.930	-.85	.429	.246	-74.38
978	310.94	20.43	.784	.982	.991	.91	.740	.583	-26.92
986	327.60	34.02	.784	.978	.980	.20	.645	.488	-32.16
990	344.27	25.80	.608	1.020	1.002	-1.79	.692	.593	-16.68

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 997  344.27   34.02   .707    .999    .990    -.90    .655    .517 -26.68
1005  344.27   85.06   .784    .974    .964   -1.03    .360    .246 -46.33
1008  344.27  170.11   .784    .946    .936   -1.06    .160    .114 -40.34
1016  360.94   34.02   .608   1.031   1.006   -2.48    .658    .550 -19.63
1023  360.94   68.05   .707   1.012    .990   -2.21    .467    .333 -40.23
1028  360.94  204.14   .707   1.011    .967   -4.54    .155    .107 -44.85
1040  360.94  204.14   .784    .957    .928   -3.12    .181    .133 -36.08
1041  377.60   25.30   .287   1.176   1.039  -13.18    .693    .656  -5.63
1044  377.60   40.15   .475   1.103   1.068   -3.27    .604    .517 -16.82
1053  377.60  102.07   .608   1.132   1.095   -3.37    .313    .249 -25.69
1055  377.60  204.14   .608   1.119   1.053   -6.26    .171    .142 -20.41
1062  377.60  204.14   .707   1.026    .966   -6.20    .200    .155 -29.02
1069  377.60  204.14   .784    .973    .941   -3.39    .233    .172 -35.46
1071  394.27   27.22   .287   1.146   1.032  -11.04    .719    .668  -7.62
                                          ------                  ------
                                            1.49                   34.58

      AVERAGE DEVIATION =   18.04   FOR 102 DATA POINTS

      MEAN              =                  -1.34                  -34.54
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APPENDIX V

Intermediate Calculated Results

TABLE 1

CRITICAL PROPERTIES AND INTERMEDIATE VALUES

SYSTEM A COMP 1 IS METHANE COMP 2 IS CO2

POINT	T_{cm}	P_{cm}	W	$(Z)^0$	$(Z)^1$	$(\mathrm{LOG}\frac{f}{P})^0$	$(\mathrm{LOG}\frac{f}{P})^1$	$(\frac{H^o-H}{RT_c})^0$	$(\frac{H^o-H}{RT_c})^1$	Y
1	277.32	66.10	.201	.7088	.1469	-.1192	.0456	1.2340	.2774	.1459
5	277.32	66.10	.201	.5910	.1096	-.2318	.0968	2.4474	.8500	.3250
6	252.78	60.16	.168	.6903	.1726	-.1774	.1127	2.0640	.4338	.2369
8	205.35	49.11	.061	.8659	.2356	-.0898	.1414	1.5127	-.0278	.1225
9	277.32	66.10	.201	.6823	.0154	-.2982	.1065	2.8528	1.4953	.4237
11	230.40	54.87	.126	.8475	.1522	-.1663	.1543	2.1977	.5841	.2468
13	277.32	66.10	.201	.8196	-.0406	-.3300	.1043	2.9429	1.8720	.4762
14	252.78	60.16	.168	.8885	.0214	-.2494	.1463	2.6540	1.2616	.3730
15	230.40	54.87	.126	.9524	.1000	-.1796	.1694	2.3614	.9462	.2915
17	277.32	66.10	.201	.9565	-.1011	-.3402	.0948	2.9634	2.1507	.5151
18	252.78	60.16	.168	1.0182	-.0266	-.2548	.1447	2.7143	1.6457	.4162
25	277.32	66.10	.201	.8659	.1412	-.0595	.0556	.7565	.0401	.0716
29	277.32	66.10	.201	.7892	.2097	-.1126	.1105	1.5405	.0930	.1560
31	230.40	54.87	.126	.9075	.2422	-.0577	.1293	1.1848	-.1626	.0884
32	205.35	49.11	.061	.9600	.2624	-.0334	.1316	.9642	-.2914	.0536
33	277.32	66.10	.201	.8065	.1837	-.1497	.1407	2.0189	.3457	.2240
35	205.35	49.11	.061	1.0023	.3554	-.0375	.1911	1.2331	-.2001	.0738
36	277.32	66.10	.201	.8798	.1383	-.1703	.1604	2.2545	.6896	.2746
37	252.78	60.16	.168	.9455	.2117	-.1208	.1894	1.9843	.4794	.2123
39	205.35	49.11	.061	1.0720	.4341	-.0346	.2337	1.4059	.0171	.0951
40	277.32	66.10	.201	.9711	.0986	-.1772	.1699	2.3642	.9957	.3129
48	277.32	66.10	.201	.5264	.1157	-.1824	.0293	1.8711	.6164	.2562
51	205.35	49.11	.061	.8347	.1819	-.0769	.0718	1.0409	.0344	.0919
52	277.32	66.10	.201	.4986	-.0453	-.3415	.0424	3.0910	2.1413	.5116
53	252.78	60.16	.168	.5917	.0773	-.2574	.0952	2.6182	1.1003	.3598
55	205.35	49.11	.061	.7984	.2008	-.1360	.1328	1.8650	.1978	.1819
56	277.32	66.10	.201	.6505	-.0929	-.4180	.0265	3.2682	2.6754	.5930
57	252.78	60.16	.168	.7199	-.0153	-.3203	.1020	2.9286	1.7235	.4490
59	205.35	49.11	.061	.8868	.1439	-.1652	.1639	2.2251	.6671	.2432
60	277.32	66.10	.201	.8148	-.1453	-.4520	.0104	3.2720	2.9914	.6385
61	252.78	60.16	.168	.8741	-.0758	-.3453	.0915	2.9809	2.0833	.4984
63	205.35	49.11	.061	1.0114	.0957	-.1720	.1756	2.3646	1.1056	.2868
64	277.32	66.10	.201	.9704	-.2113	-.4626	-.0086	3.2673	3.2202	.6775
65	252.78	60.16	.168	1.0263	-.1373	-.3509	.0849	3.0047	2.3988	.5408

TABLE 2

CRITICAL PROPERTIES AND INTERMEDIATE VALUES

SYSTEM B COMP 1 IS METHANE COMP 2 IS ETHANE

POINT	T_{cm}	P_{cm}	W	$(Z)^0$	$(Z)^1$	$(\mathrm{LOG}\frac{f}{p})^0$	$(\mathrm{LOG}\frac{f}{p})^1$	$\left(\frac{H^o-H}{RT_c}\right)^0$	$\left(\frac{H^o-H}{RT_c}\right)^1$	Y
79	247.64	48.37	.044	.5368	.0676	-.2587	.0753	2.6366	1.2268	.4387
82	247.64	48.37	.044	.6022	-.0014	-.3195	.0799	2.9344	1.7631	.4942
85	247.64	48.37	.044	.7040	-.0463	-.3558	.0806	3.0536	2.0852	.5191
95	225.89	47.73	.030	.6518	.1358	-.2179	.1115	2.3678	.7010	.4167
98	225.89	47.73	.030	.7127	.0637	-.2548	.1267	2.6457	1.0041	.4709
107	205.71	46.78	.019	.7434	.2062	-.1320	.1086	1.6712	.1903	.3111
110	205.71	46.78	.019	.7510	.1652	-.1682	.1299	2.0885	.3738	.3947
113	205.71	46.78	.019	.8000	.1249	-.1919	.1502	2.3454	.6724	.4496
119	273.64	48.75	.067	.4595	.0598	-.2402	.0445	2.5277	1.1820	.3743
121	273.64	48.75	.067	.4874	-.0157	-.3073	.0517	2.9362	1.8374	.4403
124	273.64	48.75	.067	.5809	-.0516	-.3719	.0433	3.1528	2.3076	.4784
127	273.64	48.75	.067	.6907	-.0894	-.4101	.0369	3.2222	2.6225	.4933
135	247.64	48.37	.044	.6022	.1443	-.2094	.0917	2.2699	.6192	.3513
138	247.64	48.37	.044	.6369	.0649	-.2631	.1096	2.6632	1.1510	.4172
141	247.64	48.37	.044	.7209	.0083	-.2976	.1121	2.8449	1.4871	.4504
149	225.89	47.73	.030	.7048	.2027	-.1505	.1076	1.8064	.2864	.2958
152	225.89	47.73	.030	.7155	.1427	-.1915	.1260	2.2319	.5258	.3702
155	225.89	47.73	.030	.7707	.0940	-.2191	.1451	2.4959	.8164	.4186
164	205.71	46.78	.019	.7904	.2079	-.1165	.1157	1.6092	.1060	.2839
167	205.71	46.78	.019	.8055	.1922	-.1425	.1384	1.9477	.2792	.3484
169	205.71	46.78	.019	.8344	.1719	-.1550	.1521	2.1031	.4668	.3798
181	273.64	48.75	.067	.6342	-.0097	-.3235	.0877	2.9512	1.7830	.4164
193	247.64	48.37	.044	.6649	.1467	-.2055	.1126	2.2798	.6171	.3336
196	247.64	48.37	.044	.7183	.0797	-.2413	.1293	2.5727	.9098	.3798
206	225.89	47.73	.030	.7516	.1988	-.1356	.1141	1.7471	.2017	.2710
209	225.89	47.73	.030	.7718	.1654	-.1662	.1355	2.1039	.4004	.3302
211	225.89	47.73	.030	.8031	.1405	-.1811	.1497	2.2719	.5964	.3592
223	205.71	46.78	.019	.8384	.2143	-.1162	.1465	1.7593	.1460	.2970
225	205.71	46.78	.019	.8614	.2051	-.1264	.1609	1.9014	.3100	.3239
236	273.64	48.75	.067	.6363	.0696	-.2600	.1097	2.6445	1.1174	.3467
239	273.64	48.75	.067	.7183	.0124	-.2946	.1130	2.8327	1.4535	.3749
248	247.64	48.37	.044	.7227	.1520	-.1824	.1263	2.1673	.4614	.2994
251	247.64	48.37	.044	.7368	.1358	-.1923	.1332	2.2737	.5505	.3151
253	247.64	48.37	.044	.7726	.1063	-.2092	.1465	2.4419	.7460	.3403
261	225.89	47.73	.030	.8048	.2082	-.1005	.1025	1.4241	.0579	.2086
264	225.89	47.73	.030	.7995	.2052	-.1296	.1306	1.7974	.1559	.2655
267	225.89	47.73	.030	.8337	.1798	-.1494	.1521	2.0576	.4215	.3075
279	205.71	46.78	.019	.8696	.2364	-.0943	.1472	1.5914	.0320	.2547
281	205.71	46.78	.019	.8891	.2395	-.1023	.1618	1.7276	.1684	.2790
295	273.64	48.75	.067	.7393	.0597	-.2515	.1324	2.6433	1.0074	.3273

306	247.64	48.37	.044	.7627	.1822	-.1532	.1273	1.9652	.2867	.2566
309	249.93	48.42	.046	.7968	.1393	-.1825	.1483	2.2751	.5927	.2979
320	225.89	47.73	.030	.8335	.2188	-.1070	.1374	1.6173	.0475	.2258
323	225.89	47.73	.030	.8589	.2092	-.1236	.1595	1.8735	.2816	.2647
332	205.71	46.78	.019	.8911	.2211	-.0622	.1181	1.1499	-.1290	.1727
335	205.71	46.78	.019	.8975	.2585	-.0756	.1472	1.4569	-.0635	.2218
337	205.71	46.78	.019	.9142	.2732	-.0819	.1623	1.5840	.0448	.2432
346	273.64	48.75	.067	.7031	.1881	-.1613	.1107	1.9261	.3377	.2219
349	273.64	48.75	.067	.7291	.1317	-.1973	.1313	2.2985	.5821	.2670
351	273.64	48.75	.067	.7659	.1009	-.2146	.1439	2.4639	.7747	.2876
361	247.64	48.37	.044	.7962	.2073	-.1198	.1216	1.6614	.1144	.2048
364	247.64	48.37	.044	.8174	.1906	-.1420	.1439	1.9681	.3115	.2449
371	225.89	47.73	.030	.8889	.1697	-.0542	.0769	.8836	-.0507	.1162
374	225.89	47.73	.030	.8624	.2150	-.0770	.1162	1.2632	-.0686	.1666
378	225.89	47.73	.030	.8675	.2355	-.0937	.1455	1.5735	.0178	.2095
380	225.89	47.73	.030	.8847	.2385	-.1021	.1597	1.7177	.1562	.2305
392	205.71	46.78	.019	.9218	.2721	-.0603	.1472	1.3234	-.1395	.1919
394	205.71	46.78	.019	.9364	.2963	-.0653	.1627	1.4469	-.0636	.2116
403	273.64	48.75	.067	.7462	.1993	-.1368	.1128	1.7441	.2076	.1900
406	273.64	48.75	.067	.7635	.1636	-.1682	.1337	2.1084	.3996	.2316
408	273.64	48.75	.067	.7937	.1386	-.1834	.1476	2.2782	.5921	.2516
417	247.64	48.37	.044	.8326	.2113	-.0931	.1148	1.3966	.0008	.1628
420	247.64	48.37	.044	.8355	.2158	-.1140	.1436	1.7203	.1132	.2019
422	247.64	48.37	.044	.8547	.2077	-.1246	.1576	1.8757	.2772	.2216
429	225.89	47.73	.030	.8990	.1847	-.0510	.0847	.9310	-.1028	.1170
432	225.89	47.73	.030	.8874	.2320	-.0679	.1269	1.2510	-.1179	.1574
435	225.89	47.73	.030	.8997	.2611	-.0802	.1526	1.5246	-.0112	.1940
447	205.71	46.78	.019	.9376	.2599	-.0458	.1383	1.1034	-.2215	.1517
450	205.71	46.78	.019	.9559	.3045	-.0517	.1627	1.3009	-.1611	.1813

TABLE 3

CRITICAL PROPERTIES AND INTERMEDIATE VALUES

SYSTEM C COMP 1 IS BUTANE COMP 2 IS CO2

POINT	T_{cm}	P_{cm}	W	$(Z)^0$	$(Z)^1$	$(\mathrm{LOG}\frac{f}{p})^0$	$(\mathrm{LOG}\frac{f}{p})^1$	$(\frac{H^o-H}{RT_c})^0$	$(\frac{H^o-H}{RT_c})^1$	Y
452	325.43	53.13	.207	.8937	-.0297	-.0423	-.0124	.3070	.3264	-.0959
453	320.04	55.45	.210	.8760	-.0270	-.0486	-.0128	.3627	.3704	-.1109
454	316.82	57.14	.211	.8579	-.0241	-.0554	-.0126	.4186	.4133	-.1258
455	314.64	58.48	.213	.8393	-.0225	-.0624	-.0121	.4766	.4571	-.1411
456	313.09	59.56	.214	.8181	-.0221	-.0704	-.0115	.5496	.5142	-.1597
457	311.87	60.50	.215	.7977	-.0209	-.0782	-.0107	.6203	.5674	-.1772
458	310.94	61.29	.215	.7776	-.0191	-.0861	-.0100	.6903	.6194	-.1942
460	308.62	63.64	.217	.6795	-.0240	-.1180	-.0128	1.0219	.8075	-.2752
461	307.99	64.41	.218	.6114	-.0216	-.1349	-.0145	1.2726	.9977	-.3339
462	307.11	65.61	.219	.5448	-.0167	-.1499	-.0151	1.5339	1.2067	-.3896
463	306.12	67.24	.220	.4893	-.0177	-.1631	-.0138	1.7469	1.3972	-.4315
464	305.89	67.68	.221	.4396	-.0292	-.1746	-.0128	1.9518	1.6902	-.4768
465	306.32	66.88	.220	.3626	-.0476	-.1924	-.0139	2.2821	2.1593	-.5578
466	305.84	67.78	.221	.4335	-.0306	-.1760	-.0126	1.9765	1.7256	-.4821
467	306.03	67.41	.221	.3795	-.0433	-.1883	-.0130	2.2039	2.0493	-.5367
469	383.58	41.42	.197	.8387	-.0626	-.0627	-.0327	.4653	.5540	-.1377
472	347.19	47.05	.200	.8284	-.0220	-.0665	-.0117	.5146	.4858	-.1464
474	334.61	50.11	.204	.8062	-.0026	-.0764	-.0033	.6099	.4566	-.1659
476	327.67	52.31	.206	.7789	.0077	-.0863	.0000	.7166	.4328	-.1884
478	321.16	54.92	.209	.7086	.0286	-.1123	.0053	.9983	.4771	-.2497
480	318.55	56.20	.210	.6191	.0619	-.1424	.0132	1.3595	.5853	-.3286
481	318.16	56.40	.211	.5634	.0807	-.1560	.0175	1.5886	.6776	-.3793
482	318.74	56.09	.210	.4837	.0934	-.1782	.0183	1.9113	.8636	-.4552
484	325.54	53.09	.207	.3447	.0060	-.2319	.0148	2.6219	1.7689	-.6426
485	318.16	56.40	.211	.5496	.0833	-.1599	.0177	1.6452	.7084	-.3923
487	402.45	39.42	.197	.7328	-.0981	-.0984	-.0507	1.4025	1.3469	-.3342
489	378.32	42.06	.197	.7263	-.0303	-.1034	-.0132	.8574	.7548	-.2209
491	364.28	44.00	.198	.7088	.0072	-.1101	-.0022	.9585	.6063	-.2363
492	354.71	45.59	.199	.6854	.0268	-.1197	.0057	1.0765	.5268	-.2579
493	348.78	46.73	.200	.6572	.0508	-.1330	.0107	1.2080	.5129	-.2839
495	343.01	47.97	.201	.5723	.0931	-.1581	.0200	1.5835	.5800	-.3624
496	343.01	47.97	.201	.5076	.1082	-.1794	.0209	1.8615	.7045	-.4239
497	345.09	47.50	.201	.4576	.0875	-.1963	.0246	2.1153	.9030	-.4825
499	422.27	37.69	.200	.5787	-.0946	-.1432	-.0360	1.3425	1.2028	-.3143
500	413.46	38.43	.199	.5427	-.0372	-.1453	-.0190	1.5075	1.3378	-.3494
501	406.36	39.06	.198	.5663	-.0047	-.1468	-.0067	1.4630	1.0360	-.3295
503	396.31	40.03	.197	.5341	.0136	-.1611	.0097	1.6655	.9757	-.3657
504	393.48	40.32	.197	.5068	.0436	-.1688	.0120	1.7905	.9978	-.3900
505	394.22	40.24	.197	.4429	.0337	-.1867	.0118	2.0673	1.2556	-.4518
506	396.76	39.98	.197	.4038	-.0052	-.1977	.0090	2.2395	1.5423	-.4946

507	393.18	40.35	.197	.4837	.0497	-.1751	.0126	1.8890	1.0630	-.4110

TABLE 4

CRITICAL PROPERTIES AND INTERMEDIATE VALUES

SYSTEM D COMP 1 IS METHANE COMP 2 IS PENTANE

POINT	T_{cm}	P_{cm}	W	$(Z)^0$	$(Z)^1$	$(\mathrm{LOG}\frac{f}{p})^0$	$(\mathrm{LOG}\frac{f}{p})^1$	$(\frac{H^o-H}{RT_c})^0$	$(\frac{H^o-H}{RT_c})^1$	Y
508	236.53	45.66	.037	.9571	.0204	-.0179	.0100	.1644	.0425	.0913
509	226.24	45.89	.031	.9433	.0343	-.0244	.0122	.2276	.0507	.1308
510	221.31	45.96	.028	.9306	.0484	-.0302	.0196	.3043	.0572	.1766
511	216.68	46.01	.026	.9047	.0743	-.0421	.0343	.4588	.0697	.2691
512	215.40	46.02	.025	.8751	.0986	-.0547	.0439	.6251	.0790	.3687
514	215.40	46.02	.025	.8125	.1780	-.0846	.0680	1.0466	.0851	.6174
515	217.53	46.00	.026	.7752	.2007	-.1042	.0807	1.3102	.1154	.7672
516	220.90	45.97	.028	.7395	.2099	-.1271	.0987	1.5667	.1794	.9049
517	226.24	45.89	.031	.7007	.1965	-.1565	.1074	1.8685	.3149	1.0597
518	235.37	45.69	.036	.6597	.1583	-.1993	.1091	2.2245	.5744	1.2235
519	262.68	44.71	.054	.5895	.0020	-.3177	.0760	2.9266	1.7489	1.4896
522	263.70	44.67	.054	.9319	.0313	-.0284	.0128	.2646	.0699	.1224
523	253.23	45.10	.047	.9204	.0460	-.0340	.0201	.3323	.0766	.1570
524	242.24	45.49	.040	.9005	.0744	-.0441	.0348	.4700	.0781	.2269
526	236.53	45.66	.037	.8502	.1410	-.0665	.0545	.7977	.0731	.3912
527	236.92	45.65	.037	.8161	.1778	-.0831	.0678	1.0410	.0775	.5091
528	239.22	45.58	.039	.7797	.2012	-.1025	.0812	1.3009	.1081	.6307
530	250.71	45.20	.046	.6989	.1940	-.1590	.1075	1.8939	.3276	.8827
531	265.40	44.59	.055	.6439	.1421	-.2154	.1084	2.3447	.6863	1.0462
532	281.17	43.82	.067	.6040	.0502	-.2773	.0960	2.7258	1.3022	1.1718
534	325.92	41.27	.102	.8872	.0138	-.0458	.0017	.3829	.1931	.1459
535	305.83	42.45	.086	.8826	.0365	-.0490	.0114	.4415	.1929	.1708
536	284.02	43.67	.069	.8666	.0694	-.0569	.0296	.5764	.1382	.2266
537	274.06	44.18	.061	.8445	.1048	-.0673	.0412	.7231	.1295	.2892
538	270.77	44.34	.059	.8203	.1501	-.0799	.0561	.9046	.1231	.3613
539	269.77	44.39	.058	.7842	.1858	-.0979	.0757	1.1679	.1204	.4640
541	283.70	43.68	.069	.6713	.1987	-.1646	.0993	1.8982	.3642	.7264
542	288.70	43.42	.072	.6480	.1711	-.1958	.1034	2.1849	.5495	.8250
543	308.73	42.29	.088	.5877	.0686	-.2641	.0926	2.6586	1.1748	.9670
544	458.22	34.17	.237	.7860	-.0818	-.0838	-.0354	.5850	.6714	.2043
546	373.70	38.47	.147	.8068	.0250	-.0785	.0053	.6817	.3010	.2139
547	329.20	41.08	.105	.8281	.0692	-.0718	.0296	.7059	.2271	.2284
548	325.92	41.27	.102	.7748	.1178	-.0930	.0380	.9582	.2369	.3092
550	318.14	41.74	.096	.6936	.1994	-.1331	.0724	1.4988	.2441	.4788
552	353.44	39.64	.127	.5232	.0529	-.2654	.0707	2.6804	1.3239	.8212
553	450.45	34.52	.228	.6145	-.0881	-.1366	-.0326	1.1881	1.0389	.3610
554	409.21	36.54	.183	.6153	.0670	-.1432	.0146	1.3845	.5706	.3835
555	391.27	37.50	.164	.5776	.1223	-.1652	.0285	1.6488	.4749	.4528
556	395.75	37.25	.169	.4533	.0832	-.2238	.0365	2.3551	.9317	.6465
557	405.53	36.73	.179	.3969	.0076	-.2542	.0283	2.6979	1.6019	.7535

TABLE 5

CRITICAL PROPERTIES AND INTERMEDIATE VALUES

SYSTEM E COMP 1 IS METHANE COMP 2 IS BUTANE (SATURATED)

POINT	T_{cm}	P_{cm}	W	$(Z)^0$	$(Z)^1$	$(\mathrm{LOG}\frac{f}{p})^0$	$(\mathrm{LOG}\frac{f}{p})^1$	$\left(\frac{H^o-H}{RT_c}\right)^0$	$\left(\frac{H^o-H}{RT_c}\right)^1$	Y
558	263.88	44.82	.106	.9447	.0035	-.0231	.0000	.1876	.1269	.0820
559	248.73	45.32	.087	.9388	.0116	-.0252	.0033	.2069	.1168	.0909
561	223.33	45.88	.055	.8918	.0525	-.0455	.0212	.4464	.1129	.1956
563	220.62	45.91	.051	.8749	.0659	-.0534	.0278	.5383	.1279	.2361
565	216.65	45.95	.046	.8035	.1421	-.0850	.0498	.9327	.1649	.4109
568	220.01	45.92	.050	.7160	.1976	-.1256	.0760	1.4455	.2087	.6300
579	255.73	45.10	.096	.9135	.0224	-.0355	.0100	.3057	.1517	.1230
582	233.89	45.70	.068	.8728	.0658	-.0541	.0276	.5456	.1312	.2194
584	228.37	45.80	.061	.8050	.1428	-.0846	.0504	.9301	.1609	.3750
587	233.03	45.72	.067	.7124	.1979	-.1272	.0761	1.4604	.2137	.5810
591	241.55	45.52	.078	.6359	.1888	-.1790	.0905	2.0005	.4270	.7859
598	282.56	44.08	.128	.8951	.0137	-.0424	.0018	.3529	.1832	.1325
599	267.24	44.70	.110	.8859	.0328	-.0476	.0102	.4221	.1912	.1581
602	245.99	45.40	.084	.8264	.0998	-.0728	.0399	.7647	.1645	.2824
605	243.78	45.46	.081	.7435	.1855	-.1114	.0679	1.2718	.1893	.4666
607	247.09	45.37	.085	.6900	.2006	-.1401	.0806	1.6043	.2475	.5850
609	254.93	45.13	.095	.6354	.1891	-.1771	.0881	1.9760	.4124	.7132
612	269.80	44.60	.113	.5624	.1019	-.2385	.0831	2.4944	.9666	.8951
613	296.06	43.50	.143	.4808	-.0589	-.3514	.0339	3.1475	2.2801	1.1384
614	392.15	38.95	.204	.7860	-.0567	-.0613	-.0571	.7665	.9414	.2617
620	265.70	44.75	.108	.8055	.1024	-.0802	.0392	.8317	.1989	.2825
622	262.06	44.89	.104	.7260	.1817	-.1166	.0623	1.3033	.2244	.4398
624	263.63	44.83	.106	.6836	.1997	-.1391	.0764	1.5674	.2548	.5251
628	281.33	44.14	.127	.5706	.1266	-.2234	.0847	2.3705	.7916	.7863
630	297.48	43.43	.144	.5076	.0110	-.2887	.0629	2.8294	1.6041	.9482
631	404.03	38.41	.204	.7605	-.0751	-.0792	-.0532	.7610	.9389	.2463
637	284.03	44.02	.130	.7310	.1518	-.1118	.0472	1.1766	.2571	.3686
640	298.89	43.37	.146	.5631	.1647	-.1952	.0698	2.0872	.5530	.6405
644	312.77	42.73	.159	.4961	.0172	-.2812	.0616	2.7959	1.5497	.8741
657	330.17	41.90	.175	.4735	.0242	-.2709	.0504	2.7481	1.4854	.8054
658	398.02	38.68	.205	.6795	-.0561	-.1172	-.0212	.9935	.8725	.2848
659	373.63	39.82	.200	.6926	.0190	-.1160	.0031	1.0387	.5490	.2871
664	343.56	41.25	.184	.4829	.0990	-.2174	.0479	2.3237	.8135	.6279
666	354.11	40.75	.191	.4241	.0142	-.2646	.0353	2.7222	1.6140	.7548

TABLE 6

CRITICAL PROPERTIES AND INTERMEDIATE VALUES

SYSTEM F COMP 1 IS METHANE COMP 2 IS BUTANE (SUPERHEATED)

POINT	T_{cm}	P_{cm}	W	$(Z)^0$	$(Z)^1$	$(\text{LOG}\frac{f}{P})^0$	$(\text{LOG}\frac{f}{P})^1$	$(\frac{H^o-H}{RT_c})^0$	$(\frac{H^o-H}{RT_c})^1$	Y
670	224.52	45.86	.056	.9121	.0413	-.0368	.0196	.3504	.0945	.1522
675	219.10	45.93	.049	.8780	.0668	-.0523	.0287	.5290	.1224	.2323
678	219.10	45.93	.049	.7451	.1840	-.1105	.0668	1.2585	.1898	.5500
682	219.10	45.93	.049	.7207	.0986	-.2259	.1306	2.4828	.7971	1.0894
686	200.75	45.94	.025	.9261	.0631	-.0324	.0270	.3694	.0431	.1665
689	200.75	45.94	.025	.8551	.1394	-.0643	.0540	.7802	.0653	.3530
691	200.75	45.94	.025	.7971	.2003	-.0947	.0803	1.2336	.0822	.5607
693	200.75	45.94	.025	.7643	.1899	-.1454	.1240	1.8850	.2436	.8596
694	200.75	45.94	.025	.7856	.1680	-.1631	.1388	2.1008	.4066	.9607
697	238.74	45.59	.075	.9099	.0409	-.0376	.0198	.3568	.0984	.1421
704	224.52	45.86	.056	.8198	.1425	-.0794	.0526	.8861	.1326	.3583
707	224.52	45.86	.056	.7089	.1986	-.1517	.1084	1.8306	.2864	.7378
709	224.52	45.86	.056	.7438	.1230	-.2016	.1368	2.3535	.6353	.9515
713	219.10	45.93	.049	.9176	.0610	-.0364	.0270	.3821	.0650	.1553
715	219.10	45.93	.049	.8669	.0987	-.0584	.0417	.6455	.0960	.2635
716	219.10	45.93	.049	.8369	.1414	-.0726	.0540	.8348	.0999	.3400
719	219.10	45.93	.049	.7342	.2034	-.1380	.1096	1.7239	.2145	.7013
721	219.10	45.93	.049	.7616	.1426	-.1840	.1388	2.2453	.5257	.9174
726	200.75	45.94	.025	.9281	.0762	-.0321	.0344	.4175	.0176	.1755
728	200.75	45.94	.025	.8836	.1332	-.0524	.0540	.6994	.0204	.2957
729	200.75	45.94	.025	.8595	.1676	-.0649	.0625	.8983	.0155	.3828
732	200.75	45.94	.025	.8086	.2098	-.1171	.1274	1.6661	.0998	.7078
733	200.75	45.94	.025	.8226	.2008	-.1318	.1437	1.8823	.2377	.8022
737	238.74	45.59	.075	.9060	.0580	-.0408	.0252	.4103	.0877	.1527
740	238.74	45.59	.075	.8108	.1438	-.0826	.0518	.9158	.1481	.3398
743	238.74	45.59	.075	.6986	.1952	-.1583	.1072	1.8855	.3246	.6948
745	238.74	45.59	.075	.7381	.1143	-.2097	.1354	2.4001	.6921	.8854
750	224.52	45.86	.056	.9098	.0758	-.0398	.0345	.4510	.0568	.1695
753	224.52	45.86	.056	.8198	.1768	-.0814	.0668	1.0258	.0727	.3877
757	224.52	45.86	.056	.7824	.1641	-.1663	.1390	2.1236	.4258	.8029
761	219.10	45.93	.049	.9314	.0644	-.0300	.0270	.3616	.0293	.1376
764	219.10	45.93	.049	.8665	.1383	-.0591	.0540	.7464	.0435	.2842
769	219.10	45.93	.049	.8008	.1840	-.1500	.1388	2.0104	.3323	.7684
775	200.75	45.94	.025	.9239	.0987	-.0350	.0492	.5145	-.0127	.2014
778	200.75	45.94	.025	.8726	.1778	-.0624	.0800	.9679	-.0294	.3846
781	200.75	45.94	.025	.8550	.2247	-.1065	.1488	1.6979	.1066	.6749
786	238.74	45.59	.075	.9054	.0754	-.0418	.0347	.4606	.0665	.1590
788	238.74	45.59	.075	.8448	.1419	-.0690	.0546	.8149	.0832	.2821
791	238.74	45.59	.075	.7497	.2046	-.1310	.1096	1.6741	.1811	.5767
793	238.74	45.59	.075	.7746	.1539	-.1745	.1395	2.1835	.4765	.7540

798	224.52	45.86	.056	.9251	.0769	-.0333	.0345	.4235	.0230	.1491
801	224.52	45.86	.056	.8533	.1693	-.0673	.0627	.9190	.0233	.3271
804	224.52	45.86	.056	.8012	.2076	-.1218	.1265	1.7063	.1218	.6024
805	224.52	45.86	.056	.8167	.1961	-.1370	.1423	1.9202	.2657	.6792
809	219.10	45.93	.049	.9433	.0650	-.0255	.0270	.3410	.0077	.1219
812	219.10	45.93	.049	.8905	.1310	-.0498	.0540	.6808	.0115	.2431
815	219.10	45.93	.049	.8262	.2086	-.0931	.1081	1.3739	.0110	.4896
817	219.10	45.93	.049	.8315	.2072	-.1245	.1460	1.8308	.2004	.6536
822	200.75	45.94	.025	.9531	.0788	-.0214	.0344	.3603	-.0365	.1333
825	200.75	45.94	.025	.9120	.1525	-.0425	.0625	.7219	-.0659	.2701
828	200.75	45.94	.025	.8775	.2331	-.0756	.1310	1.3384	-.0909	.4957
833	238.74	45.59	.075	.9337	.0652	-.0291	.0273	.3598	.0240	.1169
836	238.74	45.59	.075	.8713	.1380	-.0572	.0546	.7361	.0352	.2389
839	238.74	45.59	.075	.7962	.2099	-.1084	.1092	1.5002	.0762	.4843
841	238.74	45.59	.075	.8089	.1891	-.1446	.1407	1.9767	.3087	.6401
846	224.52	45.86	.056	.9387	.0748	-.0282	.0345	.3979	-.0026	.1315
849	224.52	45.86	.056	.8815	.1619	-.0566	.0627	.8294	-.0137	.2771
851	224.52	45.86	.056	.8431	.2083	-.0846	.1083	1.3048	-.0260	.4311
853	224.52	45.86	.056	.8459	.2176	-.1131	.1490	1.7504	.1428	.5785
860	219.10	45.93	.049	.9106	.1234	-.0415	.0540	.6263	-.0236	.2099
863	219.10	45.93	.049	.8572	.2081	-.0766	.1081	1.2318	-.0578	.4110
865	219.10	45.93	.049	.8610	.2292	-.1024	.1488	1.6661	.0849	.5565
869	200.75	45.94	.025	.9681	.0652	-.0141	.0270	.2797	-.0368	.0980
873	200.75	45.94	.025	.9292	.1525	-.0339	.0625	.6595	-.0991	.2317
877	200.75	45.94	.025	.9126	.2726	-.0670	.1488	1.4106	-.1000	.4920
886	238.74	45.59	.075	.8532	.1852	-.0713	.0800	1.0456	.0013	.3193
889	238.74	45.59	.075	.8363	.2098	-.1216	.1477	1.8159	.1907	.5506
895	224.52	45.86	.056	.9332	.0992	-.0311	.0493	.4861	-.0326	.1493
899	224.52	45.86	.056	.8692	.2083	-.0699	.1083	1.1713	-.0853	.3625
901	224.52	45.86	.056	.8742	.2392	-.0933	.1490	1.5961	.0371	.4945
907	219.10	45.93	.049	.9399	.0992	-.0277	.0492	.4654	-.0468	.1442
913	219.10	45.93	.049	.8886	.2511	-.0832	.1488	1.5218	-.0162	.4764
921	200.75	45.94	.025	.9436	.1525	-.0273	.0625	.5992	-.1607	.1972
925	200.75	45.94	.025	.9350	.2768	-.0536	.1488	1.2547	-.1679	.4084
932	238.74	45.59	.075	.9111	.1240	-.0413	.0546	.6283	-.0257	.1802
937	238.74	45.59	.075	.8631	.2304	-.1017	.1495	1.6660	.0857	.4739
943	224.52	45.86	.056	.9444	.0993	-.0252	.0493	.4530	-.0564	.1305
946	224.52	45.86	.056	.9092	.1712	-.0447	.0800	.8283	-.0936	.2424
949	224.52	45.86	.056	.8992	.2607	-.0762	.1490	1.4747	-.0518	.4288
955	219.10	45.93	.049	.9505	.0992	-.0218	.0492	.4350	-.0691	.1264
959	219.10	45.93	.049	.9081	.2081	-.0505	.1081	.9996	-.1559	.2921
961	219.10	45.93	.049	.9131	.2731	-.0666	.1488	1.4086	-.1016	.4138
966	200.75	45.94	.025	.9751	.0760	-.0111	.0344	.2754	-.0852	.0837
970	200.75	45.94	.025	.9499	.1646	-.0257	.0800	.6278	-.2319	.1901
973	200.75	45.94	.025	.9536	.2777	-.0417	.1453	1.1163	-.2394	.3395
978	255.47	45.11	.096	.9137	.0226	-.0354	.0100	.3053	.1515	.1229
986	255.47	45.11	.096	.8786	.0500	-.0506	.0191	.4865	.1513	.1805
990	299.36	43.35	.146	.8592	.0120	-.0574	.0000	.4853	.2285	.1686

997	275.36	44.38	.120	.8644	.0476	-.0564	.0183	.5312	.2046	.1831
1005	255.47	45.11	.096	.7449	.1864	-.1113	.0690	1.2742	.1851	.4316
1008	255.47	45.11	.096	.6903	.1388	-.2022	.1201	2.2786	.5993	.7708
1016	299.36	43.35	.146	.8409	.0434	-.0648	.0110	.6077	.2336	.1950
1023	275.36	44.38	.120	.7663	.1499	-.0988	.0477	1.0627	.2207	.3358
1028	275.36	44.38	.120	.7141	.0707	-.2491	.1277	2.6149	.9640	.8136
1040	255.47	45.11	.096	.7618	.1361	-.1887	.1404	2.2856	.5641	.7230
1041	369.16	40.03	.198	.7619	-.0036	-.0923	-.0045	.7578	.5755	.2296
1044	329.51	41.93	.174	.7547	.0584	-.0977	.0172	.8939	.3151	.2618
1053	299.36	43.35	.146	.6203	.1862	-.1765	.0782	1.9396	.3901	.5581
1055	299.36	43.35	.146	.7042	.0242	-.2873	.1138	2.8016	1.3733	.8148
1062	275.36	44.38	.120	.7448	.1082	-.2132	.1373	2.4297	.7292	.7094
1069	255.47	45.11	.096	.7949	.1721	-.1593	.1404	2.0834	.3976	.6199
1071	369.16	40.03	.198	.7815	.0149	-.0852	.0009	.7240	.3884	.2022

NOMENCLATURE

F	Free energy
f	Fugacity
H	Enthalpy
P	Pressure
p	Pressure
R	Gas constant
S	Entropy
T	Temperature
μ	Chemical potential
x	Mole fraction
V	Volume
w	Acentric factor
z	Compressibility factor

Subscripts

c	Critical
i	The i^{th} component
M	Equimolal mixture
m	Any mixture
r	Reduced, (i.e. ratio to value for critical state)
x	Any mixture

Superscripts

$0,1$	Functions in acentric-factor theory for fluids

REFERENCES

1. Benedict, M., G.B. Webb, L.C. Rubin, and L. Friend, Chem. Eng. Progr., vol. 47(1951) pp. 419,449,571,609.

2. Bennett, C.O., Chem. Eng. Progr. Symposium Series No. 7, vol. 49(1953) pg. 45.

3. Capik, R.J., Fugacity and Activity Coefficients; Thesis, Newark College of Engineering, Newark, N.J., 1959.

4. DePriester, C.L., Chem. Eng. Progr. Symposium Series No. 7, vol. 49(1953) pg. 1.

5. Dodge, B.F., Chemical Engineering Thermodynamics, McGraw-Hill Book Co., Inc., (1944) pp. 167,98,237,106,99,240.

6. Edmister, W.C., Ind. Eng. Chem., vol. 30(1938) pg. 352.

7. Edmister, W.C., Petro. Refiner, vol. 28, No. 2(Feb. 1938) pg. 137.

8. Edmister, W.C., and C.L. Ruby, Chem. Eng. Progr., vol. 51(1955) pp. 91-F,99-F.

9. Gamson, B.W., Ind. Eng. Chem., vol. 40(1948) pg. 2439.

10. Gamson, B.W., T.W. Leland, Jr. and P.S. Chappelear, A.I.Ch.E. Journal, vol. 8, No. 4(Sept. 1962) pg. 482.

11. Gamson, B.W. and K.M. Watson, Natl. Petro. News, vol. 36(1944) pg. R-623.

12. Hedden, S.T., Chem. Eng. Progr., vol. 44(1948) pp. 37,135.

13. Hedden, S.T., Chem. Eng. Progr. Symposium Series No. 7, vol. 49(1953) pg. 53.

14. Hougen, O.A., K.M. Watson, and R.A. Ragatz, Chemical Process Principles - Part II Thermodynamics, 2nd ed., John Wiley and Sons, Inc., N.Y. (1959) pg. 570.

15. Joffe, J., Ind. Eng. Chem., vol. 39(1947) pg. 897.

16. Joffe, J., Ind. Eng. Chem., vol. 40(1948) pg. 1738.

17. Joffe, J., private communication, (Feb. 1964).

18. Kay., W.B., Ind. Eng. Chem., vol. 28(1936) pg. 1014.

19. Katz, D.L., and G.G. Brown, Ind. Eng. Chem., vol. 25 (1933) pg. 1373.

20. Leland, T.W. Jr., and W.H. Mueller, Ind. Eng. Chem., vol. 51(1959) pg. 597.

21. Klee, H.J., Gas Phase Fugacity Coefficients; Thesis, Newark College of Engineering, Newark, N. J. (1964).

22. Lewis, G.N., Proc. Am. Acad. Arts Science, vol. 37(1949) pg. 49.

23. Lewis, G.N., and M. Randall, Thermodynamics, McGraw-Hill Book Co., Inc. (1923).

24. Lewis, G.N., and M. Randall, Thermodynamics, 2nd ed., revised by K.S. Pitzer and L. Brewer, McGraw-Hill Book Co., Inc. (1961) pp. 633,172,154,225,184-189,295,197, 607,634.

25. Lyderson, A.L., R.A. Greenkorn and O.A. Hougen, Generalized Thermodynamic Properties of Pure Fluids, Univ. Wisconsin Eng. Exp. Sta. Rept. No. 4(1955).

26. Mazzei, L.D., Jr., Fugacity Coefficients of Gases; Thesis, Newark College of Engineering, Newark, N.J. (1961).

27. Meissner, H.P., and R. Seferian, Chem. Eng. Progr., vol. 45(1951) pg. 579.

28 Organick, E.I., Chem. Eng. Progr. Symposium Series No. 6, vol. 49(1953) pg. 81.

29. Organick, E.I., and G.G. Brown, Chem. Eng. Progr. Symposium Series No. 2, vol. 48(1952) pg. 97.

30. Pitzer, K.E., J. Am. Chem. Soc., vol. 77(1955) pg. 3427.

31. Pitzer, K.E., Ind. Eng. Chem., vol. 50(1958) pg. 265.

32. Pitzer, K.E., and G.O. Hultgren, J. Am. Chem. Soc., vol. 80(1958) pg. 4793.

33. Pitzer, K.E., D.Z. Lippman, R.F. Curl, Jr., C.M. Higgins, and D.E. Petersen, J. Am. Chem. Soc., vol. 77(1955) pg. 3433.

34. Redlich, O.O., A.T. Kister, and C.E. Turnquist, Chem. Eng. Progr. Symposium Series No. 2, vol. 48(1952) pg. 42.

35. Redlich, O., and J.S. Kwong, Chem. Reviews, vol. 44 (1949) pg. 233.

36. Rzasa, M.J., E.D. Glass, and J.B. Opfell, *Chem. Eng. Progr. Symposium Series No. 2*, vol. 48(1952) pg. 28.

37. Sage, B.H., and W.N. Lacey, *Ind. Eng. Chem.*, vol. 31 (1939) pg. 1497.

38. Sage, B.H., W.N. Lacey, and R.A. Budenholzer, *Ind. Eng. Chem.*, vol. 32(1940) pg. 1262.

39. Sage, B.H., W.N. Lacey, B.L. Hicks, *Ind. Eng. Chem.*, vol. 32(1940) pg. 1085.

40. Sage, B.H., W.N. Lacey, H.H. Reamer, and R.H. Olds, *Ind. Eng. Chem.*, vol. 34(1942) pg. 1108.

41. Sage, B.H., W.N. Lacey, H.H. Reamer, and R.H. Olds, *Ind. Eng. Chem.*, vol. 41(1949) pg. 475.

42. Sievering, P.J., *Fugacity and Activity Coefficients*; Thesis, Newark College of Engineering, Newark, N.J. (1958).

43. Smith, K.A., and K.M. Watson, *Chem. Eng. Progr.*, vol. 45(1949) pg. 439.

44. Souders, M., C.W. Selheimer, and G.G. Brown, *Ind. Eng. Chem.*, vol. 24(1932) pg. 517.

45. Tunell, G., *J. Phys.*, vol. 35(1931) pg. 2885.

46. Van der Waals, J., *Dissertation*, Leiden, 1873.

47. Van Ness, H.C., *A.I.Ch.E. Journal*, vol. 1(1955) pg. 100.

48. Winn, F.W., *Chem. Eng. Progr. Symposium Series No. 2*, vol. 48(1952) pg. 121.