

feed to a typical coal processing fluidized bed (Skinner, 1970); fine particles in the distribution have a considerable effect on the calculation. Similarly, it is not clear at present exactly how d_p should be specified in applying the correlation for jet penetration depth to a bed with a wide range of particle sizes.

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NOTATION

d_0	= jet nozzle diameter
d_p	= mean particle diameter
D_b	= initial bubble diameter
g	= acceleration due to gravity
G	= volumetric gas flow rate
L	= jet penetration depth measured from nozzle
L_0	= jet penetration depth measured from apex of cone
u_0	= jet nozzle velocity
V_0	= initial bubble volume
y_c	= length of conical section of jet ($y_c/L = 0.55$)
y_0	= distance between apex of cone and jet nozzle

Greek Letters

θ	= jet half-angle
ρ_f	= density of fluid
ρ_p	= density of solids

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A Generalized Thermodynamic Correlation Based on Three-Parameter Corresponding States

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The volumetric and thermodynamic functions correlated by Pitzer and co-workers analytically represented with improved accuracy by a modified BWR equation of state. The representation provides a smooth transition between the original tables of Pitzer et al. and more recent extensions to lower temperatures. It is in a form particularly convenient for computer use.

SCOPE

The 3-parameter corresponding states principle as proposed by Pitzer and co-workers has been widely used to correlate the volumetric and thermodynamic properties needed for process design. The original correlations by Pitzer et al., based on that principle, were limited to reduced temperatures above 0.8. Several extensions to lower temperatures have appeared in the last five years. Most of these correlations are in tabular or graphical form, difficult to implement on the computer. Also, significant discrepancies appear at the interface (near $T_r = 0.8$)

between the original and extended correlations.

The objective of this work was to develop an analytical correlation, based on the 3-parameter corresponding states principle and covering the whole range of T_r and P_r of practical interest in hydrocarbon processing. Another objective was to improve the accuracy and consistency of the published correlations. This has been achieved by means of two equations of state, similar in form to that of Benedict, Webb, and Rubin, for the simple and reference fluids.

CONCLUSIONS AND SIGNIFICANCE

This paper describes a method of analytically representing volumetric and thermodynamic functions based on Pitzer's 3-parameter corresponding states principle. The functions include: densities, enthalpy departures, entropy departures, fugacity coefficients, isobaric and isochoric heat capacity departures, and the second virial coefficients.

Two equations of state, for the simple and reference fluids, accurately represent the volumetric and thermodynamic properties of vapor and liquid as a function of 3-parameters (reduced temperature, reduced pressure, and acentric factor) over the range of $T_r = 0.3$ to 4 and $P_r = 0$ to 10. This analytical form has led to improved representation of these properties near the critical region and at low temperatures. It has also provided a smooth transition between the original correlations of Pitzer et al. and

more recent extensions by others to low temperatures.

The method has been found to be reliable over a wide range of conditions for nonpolar and slightly polar substances and their mixtures. Its accuracy, like that of the original Pitzer correlations, is best in the subcooled and superheated regions. The accuracy is diminished, although to a lesser extent than in the Pitzer correlations, at saturated conditions and near the critical and retrograde regions when applied to widely boiling mixtures. Included in these developments is a new reduced vapor pressure equation and a means of estimating acentric factors from that equation, as well as a set of mixing rules for calculating pseudo critical properties and acentric factors of mixtures.

In a series of papers, Pitzer and co-workers (Pitzer et al., 1955; Pitzer and Curl, 1957; Curl and Pitzer, 1958) demonstrated that the compressibility factor and other derived thermodynamic functions can be adequately represented, at constant reduced temperature and pressure, by a linear function of the acentric factor. In particular, the compressibility factor of a fluid whose acentric factor is ω , is given by the following equation:

$$Z = Z^{(0)} + \omega Z^{(1)} \quad (1)$$

where $Z^{(0)}$ is the compressibility factor of a simple fluid and $Z^{(1)}$ represents the deviation of the compressibility factor of the real fluid from $Z^{(0)}$. $Z^{(0)}$ and $Z^{(1)}$ are assumed functions of the reduced temperature and pressure.

Using this approach, Pitzer and co-workers correlated volumetric and thermodynamic properties in tabular form over the range of reduced temperatures, 0.8-4.0, and reduced pressures, 0-9.0. More recently a number of authors (Chao et al., 1971; Chao and Greenkorn, 1971; Carruth and Kobayashi, 1972; Lu et al., 1973; Hsi and Lu, 1974) have extended the correlations to lower temperatures.

The correlations of Pitzer and co-workers have been used extensively to calculate compressibility factors and enthalpies of nonpolar substances and their mixtures. This approach, however, has proven inadequate when calculations are made:

1. In the critical region;
2. For liquids at low temperatures;
3. At the interface of the original correlations and the corresponding extensions;
4. For widely boiling mixtures, particularly those con-

taining high concentrations of very light and very heavy components. This difficulty is closely related to problems in defining the pseudo critical properties of the mixture.

One of the objectives of this work was to improve the correlations in the above areas. More generally, the objective has been to provide a practical analytical framework for representing the volumetric and thermodynamic functions in terms of the three parameters of the corresponding states principle developed by Pitzer and co-workers.

To facilitate analytical representation, the compressibility factor of any fluid has been expressed in this work in terms of the compressibility factor of a simple fluid $Z^{(0)}$ and the compressibility factor of a reference fluid $Z^{(r)}$, as follows:

$$Z = Z^{(0)} + \frac{\omega}{\omega^{(r)}} (Z^{(r)} - Z^{(0)}) \quad (2)$$

When Z is expressed as in Equation (2), the deviation term $Z^{(1)}$ in Equation (1) is obviously equivalent to $(Z^{(r)} - Z^{(0)})/\omega^{(r)}$. This expression is convenient since, as will be shown later, both $Z^{(r)}$ and $Z^{(0)}$ are given by the same equation with, however, different constants. A similar approach is used to represent analytically other derived thermodynamic functions, such as fugacity and the departures of enthalpy, entropy, and isobaric and isochoric heat capacities from the ideal gas state.

n-Octane has been chosen as the heavy reference fluid since it is the heaviest hydrocarbon for which there are accurate P - V - T and enthalpy data over a wide range of conditions. However, the final values of $Z^{(r)}$ and of the corresponding equation of state constants were readjusted

TABLE 1. CONSTANTS FOR EQUATION (3)

Constant	Simple fluids	Reference fluids	Constant	Simple fluids	Reference fluid
b_1	0.1181193	0.2026579	c_3	0.0	0.016901
b_2	0.265728	0.331511	c_4	0.042724	0.041577
b_3	0.154790	0.027655	$d_1 \times 10^4$	0.155488	0.48736
b_4	0.030323	0.203488	$d_2 \times 10^4$	0.623689	0.0740336
c_1	0.0236744	0.0313385	β	0.65392	1.226
c_2	0.0186984	0.0503618	γ	0.060167	0.03754

to fit better the compressibility factors and the derived thermodynamic properties of other substances, in addition to those of octane.

Briefly, the work consisted of the following:

1. Modification of Benedict et al. equation of state (1940) as represented by Equation (3).
2. Fitting the constants in Equation (3) using experimental data on enthalpy, P - V - T , and the second virial coefficient.
3. Derivation of a new vapor pressure equation and its use to derive an equation for estimating acentric factors.
4. Use of a new set of mixing rules to define critical temperatures and pressures and acentric factors of mixtures.

These steps are described below in further detail.

DESCRIPTION OF WORK

The compressibility factors of both the simple fluid $Z^{(0)}$ and the reference fluid $Z^{(r)}$ have been represented by the following reduced form of a modified BWR equation of state:

$$Z = \left(\frac{P_r V_r}{T_r} \right) = 1 + \frac{B}{V_r} + \frac{C}{V_r^2} + \frac{D}{V_r^5} + \frac{c_4}{T_r^3 V_r^2} \left(\beta + \frac{\gamma}{V_r^2} \right) \exp \left(-\frac{\gamma}{V_r^2} \right) \quad (3)$$

where

$$B = b_1 - b_2/T_r - b_3/T_r^2 - b_4/T_r^3 \quad (4)$$

$$C = c_1 - c_2/T_r + c_3/T_r^3 \quad (5)$$

$$D = d_1 + d_2/T_r \quad (6)$$

In determining the constants in these equations, the following constraints, Equations (7) and (8), were used along with the data shown in Tables 3 and 4.

$$f^V = f^L \quad (\text{at saturated condition}) \quad (7)$$

$$\left(\frac{\partial P_r}{\partial V_r} \right)_{T_r} = \left(\frac{\partial^2 P_r}{\partial V_r^2} \right)_{T_r} = 0 \quad (\text{at critical point}) \quad (8)$$

Additional care was exercised to obtain a smooth function of $[Z^{(r)} - Z^{(0)}]$ around the loci of minimum compressibility factors between $P_r = 1$ and 2.

The data used to determine the constants in the equation of state for the simple fluid were principally of Ar, Kr, and methane. Since the triple points of simple fluids are above $T_r = 0.5$, additional data on light hydrocarbons were used to represent the low temperature region. This was done using Equation (2) along with the corresponding expression for other thermodynamic properties, and Equation (3) with the constants for $Z^{(r)}$ determined from n -octane data. However, as alluded to earlier, these constants were adjusted to obtain the best fit to all the data, as referenced in Tables 3 and 4. The constants are given in Table 1.

TABLE 2. COMPARISON OF REDUCED VAPOR PRESSURE

T_r	$-\text{Log } P_r^{(0)}$				$-\text{Log } P_r^{(1)}$			
	This work	Pitzer et al.	Carruth-Kobayashi	Hsi-Lu	This work	Pitzer et al.	Carruth-Kobayashi	Hsi-Lu
1.00	0.000	0.0	—	—	0.000	0.0	—	—
0.98	0.051	0.050	—	—	0.042	0.042	—	—
0.96	0.103	0.102	—	—	0.086	0.086	—	—
0.94	0.157	0.156	—	—	0.132	0.133	—	—
0.92	0.213	0.212	—	—	0.179	0.180	—	—
0.90	0.270	0.270	—	—	0.229	0.230	—	—
0.88	0.329	0.330	—	—	0.282	0.285	—	—
0.86	0.390	0.391	—	—	0.339	0.345	—	—
0.84	0.454	0.455	—	—	0.400	0.405	—	—
0.82	0.521	0.522	—	—	0.466	0.475	—	—
0.80	0.591	0.592	—	0.591	0.537	0.545	—	0.542
0.78	0.665	0.665	—	0.664	0.615	0.620	—	0.620
0.76	0.742	0.742	—	0.740	0.699	0.705	—	0.709
0.74	0.823	0.823	—	0.823	0.790	0.800	—	0.789
0.72	0.909	0.909	—	0.908	0.890	0.895	—	0.880
0.70	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.68	1.096	1.096	1.096	1.099	1.120	1.120	1.120	1.078
0.66	1.199	1.198	1.198	1.199	1.252	1.25	1.250	1.206
0.64	1.308	1.308	1.308	1.307	1.397	1.39	1.390	1.343
0.62	1.425	1.426	1.424	1.420	1.557	1.54	1.545	1.518
0.60	1.549	1.552	1.544	1.543	1.734	1.70	1.710	1.688
0.58	1.683	1.688	1.680	1.679	1.929	1.88	1.908	1.867
0.56	1.827	1.834	1.818	1.823	2.144	2.08	2.120	2.061
0.54	1.982	—	1.965	1.982	2.383	—	2.370	2.273
0.52	2.150	—	2.130	2.149	2.648	—	2.660	2.526
0.50	2.332	—	2.315	2.333	2.944	—	2.960	2.826
0.48	2.530	—	2.515	—	3.273	—	3.310	—
0.46	2.746	—	2.730	—	3.642	—	3.695	—
0.44	2.983	—	2.970	—	4.056	—	4.100	—
0.42	3.244	—	3.240	—	4.521	—	4.540	—
0.40	3.532	—	3.540	—	5.047	—	5.010	—
0.38	3.852	—	3.870	—	5.644	—	5.560	—
0.36	4.209	—	4.220	—	6.323	—	6.240	—
0.34	4.609	—	4.600	—	7.102	—	7.080	—
0.32	5.062	—	5.005	—	8.000	—	8.300	—
0.30	5.578	—	5.450	—	9.042	—	9.940	—

To calculate Z for the fluid of interest, given a T and P , first calculate the appropriate values of $T_r (= T/T_c)$ and $P_r (= P/P_c)$ using critical properties of the fluid. From the simple fluid constants in Table 1 and Equation (3), solve for V_r . (This is *not* the correct reduced volume for the fluid of interest, but rather, it is defined as $P_c V/RT_c$ with V a simple fluid volume.) When V_r is employed in the first equality of Equation (3), $Z^{(0)}$ is calculated for the simple fluid. The next step is identical to the first except that the reference fluid constants of Table 1 are used, *but with the same T_r and P_r values of the fluid of interest* that were determined in the first step. The result of the second step is $Z^{(r)}$. Finally, with $Z^{(0)}$ from the first step and $Z^{(r)}$ from the second, the compressibility factor Z for the fluid of interest is determined from Equation (2) where $\omega^{(r)} = 0.3978$.

The thermodynamic functions derived from Equation (3) follow:

a. Fugacity coefficient

$$\ln \left(\frac{f}{P} \right) = Z - 1 - \ln(Z) + \frac{B}{V_r} + \frac{C}{2V_r^2} + \frac{D}{5V_r^5} + E \quad (9)$$

where

$$E = \frac{c_4}{2T_r^3 \gamma} \left\{ \beta + 1 - \left(\beta + 1 + \frac{\gamma}{V_r^2} \right) \exp \left(-\frac{\gamma}{V_r^2} \right) \right\} \quad (10)$$

b. Enthalpy departure

$$\frac{H - H^*}{RT_c} = T_r \left\{ Z - 1 - \frac{b_2 + 2b_3/T_r + 3b_4/T_r^2}{T_r V_r} - \frac{c_2 - 3c_3/T_r^2}{2T_r V_r^2} + \frac{d_2}{5T_r V_r^5} + 3E \right\} \quad (11)$$

c. Entropy departure

TABLE 3. COMPARISON OF CALCULATED COMPRESSIBILITY FACTORS WITH LITERATURE DATA

Systems	No. of points	T_r	P_r	Avg. abs. dev., %	References
Subcooled liquid and dense phase					
Methane*	21	0.79-1.44	0.32-10	1.06	Vennix et al. (1970)
1-Butene	16	0.74-1.06	0.34-8.5	1.06	Sage and Lacey (1955)
Neopentane*	18	1.0-1.15	1.05-9.5	1.17	Dawson et al. (1974)
1-Pentene	17	0.76-1.07	0.16-8.9	2.22	Day and Felsing (1951)
<i>n</i> -Octane*	12	0.66-0.96	0.20-8.2	1.87	Felsing and Watson (1942)
<i>n</i> -Octane*	9	0.46-0.70	0.04	1.26	Chappelow et al. (1971)
<i>n</i> -Nonane	13	0.52-0.86	0.6-15	1.09	Sage and Lacey (1955)
<i>n</i> -Decane*	9	0.41-0.72	0.05	0.99	Rossini et al. (1953)
<i>n</i> -Dodecane	9	0.41-0.72	0.06	1.14	Rossini et al. (1953)
<i>n</i> -Heptadecane	15	0.44-0.78	0.0-23	2.82	Doolittle (1964)
Cyclohexane	14	0.56-0.92	0.34-8.5	0.43	Reamer and Sage (1957)
Benzene	17	0.55-0.91	0.28-7.0	3.15	Sage and Lacey (1955)
H ₂ S	12	0.74-0.92	0.16-7.7	1.12	Sage and Lacey (1955)
Ethane- <i>n</i> -pentane	13	0.7-1.28	0.34-8.5	0.86	Reamer et al. (1960)
Propane- <i>n</i> -decane	16	0.53-0.86	0.1-7.0	1.03	Reamer and Sage (1966)
<i>n</i> -Decane- <i>n</i> -tetradecane	10	0.45-0.55	0.06-7.6	2.84	Snyder et al. (1974)
<i>n</i> -Dodecane- <i>n</i> -hexadecane	9	0.43-0.52	0.06-8.7	3.46	Snyder et al. (1974)
Hydrogen- <i>n</i> -hexane	15	0.64-1.56	3.8-21	0.95	Reamer and Sage (1957)
Methane- <i>n</i> -Butane- <i>n</i> -Decane	20	0.53-1.60	0.9-29	1.84	Sage and Lacey (1950)
Superheated-vapor					
Methane*	16	1.09-1.17	1.3-2.0	0.3	Vennix et al. (1970)
Neopentane*	24	0.8-1.15	0.05-0.76	0.44	Dawson et al. (1974)
H ₂ S	20	0.74-1.19	0.01-7.7	0.41	Sage and Lacey (1955)
Saturated liquid					
1-Butene	6	0.78-1.0	0.17-1.0	1.55	Sage and Lacey (1955)
<i>n</i> -Nonane	5	0.63-0.86	0.01-0.3	1.36	Sage and Lacey (1955)
Benzene	7	0.55-0.91	0-0.51	3.15	Sage and Lacey (1955)
H ₂ S	7	0.76-1.0	0.15-1.0	1.96	Sage and Lacey (1955)
Ethane- <i>n</i> -pentane	5	0.7-1.03	0.3-1.57	0.97	Reamer et al. (1960)
Hydrogen- <i>n</i> -hexane	15	0.59-1.56	4.4-21	1.68	Reamer and Sage (1957)
Saturated vapor					
1-Butene	6	0.78-1.0	0.17-1.0	1.51	Sage and Lacey (1955)
H ₂ S	7	0.76-1.0	0.15-1.0	4.12	Sage and Lacey (1955)
Ethane- <i>n</i> -pentane	5	0.7-1.03	0.02-0.75	2.52	Reamer et al. (1960)
Hydrogen- <i>n</i> -hexane	15	2.8-8.7	6.1-31.4	1.33	Reamer and Sage (1957)

* Data used in correlational work.

TABLE 4. COMPARISON OF CALCULATED ENTHALPIES WITH LITERATURE DATA

System	No. of points	T_r	P_r	Avg. abs. dev. J/Kg	References
Methane*	40	0.61-1.49	0.37-3.0	2600	Jones et al. (1963)
Ethane	70	0.4-1.35	0.28-2.83	2300	Starling (1972)
Propane*	42	0.32-1.07	0.81-3.25	2100	Yesavage (1968)
<i>n</i> -Pentane*	66	0.63-1.3	0.41-2.87	3000	Lenoir et al. (1970)
<i>n</i> -Octane*	50	0.52-1.03	0.55-3.88	2600	Lenoir et al. (1970)
<i>n</i> -Hexadecane*	30	0.41-0.85	0.19-6.8	4000	Lenoir and Hipkin (1970)
cis-2-pentene	25	0.95-1.05	0.38-2.64	5600	Lenoir et al. (1971)
Cyclohexane	36	0.76-1.12	0.17-2.37	2800	Lenoir et al. (1971)
Benzene	37	0.83-1.15	0.28-1.97	3300	Lenoir et al. (1971)
Methane-propane 49.4%-50.6%	44	0.4-1.36	0.37-3.0	6100	Yesavage (1968)
Ethane-propane 49.8%-50.2%	28	0.82-1.14	0.38-3.02	1600	Starling (1972)
<i>n</i> -Pentane- <i>n</i> -octane 59.7%-40.3%	13	0.58-1.04	0.46-3.25	2600	Lenoir et al. (1970)
<i>n</i> -pentane-cyclohexane 61.2%-38.8%	19	0.83-1.06	0.38-2.66	2600	Lenoir et al. (1971)
<i>n</i> -pentane- <i>n</i> -hexadecane 58.7%-41.3%	26	0.55-0.98	0.08-4.22	7400	Lenoir and Hipkin (1970)
Benzene- <i>n</i> -hexadecane 58.1%-41.9%	18	0.74-0.87	0.31-4.4	4600	Hayworth et al. (1971)

* Data used in correlational work.

$$\frac{S - S^*}{R} + \ln \left(\frac{P}{P^*} \right) = \ln(Z) - \frac{b_1 + b_3/T_r^2 + 2b_4/T_r^3}{V_r} - \frac{c_1 - 2c_3/T_r^3}{2V_r^2} - \frac{d_1}{5V_r^5} + 2E \quad (12)$$

where $P^* = 1$ atm. for API Research Project 44 S^* data.

d. Isochoric heat capacity departure

$$\frac{C_v - C_v^*}{R} = \frac{2(b_3 + 3b_4/T_r)}{T_r^2 V_r} - \frac{3c_3}{T_r^3 V_r^2} - 6E \quad (13)$$

e. Isobaric heat capacity departure

$$\frac{C_p - C_p^*}{R} = \frac{C_v - C_v^*}{R} - 1 - T_r \left(\frac{\partial P_r}{\partial T_r} \right)_{V_r} \bigg/ \left(\frac{\partial P_r}{\partial V_r} \right)_{T_r} \quad (14)$$

where

$$\left(\frac{\partial P_r}{\partial T_r} \right)_{V_r} = \frac{1}{V_r} \left\{ 1 + \frac{b_1 + b_3/T_r^2 + 2b_4/T_r^3}{V_r} + \frac{c_1 - 2c_3/T_r^3}{2V_r^2} + \frac{d_1}{5V_r^5} - \frac{2c_4}{T_r^3 V_r^2} \left[\left(\beta + \frac{\gamma}{V_r^2} \right) \exp \left(-\frac{\gamma}{V_r^2} \right) \right] \right\} \quad (15)$$

$$\left(\frac{\partial P_r}{\partial V_r} \right)_{T_r} = -\frac{T_r}{V_r^2} \left\{ 1 + \frac{2B}{V_r} + \frac{3C}{V_r^2} + \frac{6D}{V_r^5} + \frac{c_4}{T_r^3 V_r^2} \left[3\beta + \left\{ 5 - 2 \left(\beta + \frac{\gamma}{V_r^2} \right) \right\} \frac{\gamma}{V_r^2} \right] \exp \left(-\frac{\gamma}{V_r^2} \right) \right\} \quad (16)$$

To calculate any of the quantities given in Equations (9) through (16), given a T and P for the fluid of interest, the following procedure, illustrated by the enthalpy departure function, should be followed.

1. As described earlier, determine V_r and $Z^{(0)}$ for the simple fluid at the T_r and P_r appropriate for the fluid of interest. Employ Equation (11) and, with the simple fluid constants in Table 1, calculate $(H - H^*)/RT_c$. Call this $[(H - H^*)/RT_c]^{(0)}$. In this calculation, Z in Equation (11) is $Z^{(0)}$.

2. Repeat step 1, using the same T_r and P_r , but employing the reference fluid constants from Table 1. A new V_r and $Z^{(r)}$ will be obtained. With these, Equation (11) allows the calculation of $[(H - H^*)/RT_c]^{(r)}$. In this calculation, Z in Equation (11) is $Z^{(r)}$.

3. Determine the enthalpy departure function for the fluid of interest from

$$[(H - H^*)/RT_c] = [(H - H^*)/RT_c]^{(0)} + (\omega/\omega^{(r)}) \{ [(H - H^*)/RT_c]^{(r)} - [(H - H^*)/RT_c]^{(0)} \}$$

where $\omega^{(r)} = 0.3978$. The tabulated values generated by this procedure are shown in Tables 5 through 14.

As with any other correlation based on the corresponding states principle, the success of this method depends on the accuracy of the values of the critical temperatures, critical pressures, and acentric factors. For most compounds the critical properties have been fairly well established, but values of the acentric factor have not been satisfactorily determined until recently. Passut and Danner (1973) have reported accurate values for a large number of hydrocarbons. However, some of their reported values (for example, 1-pentene, diolefins, and acetylenes) do not appear to be consistent. This is likely the result of the use of inaccurate data for the vapor pressure or critical properties for these compounds. In addition, Passut and Danner's tabulations do not include a number of compounds encountered in hydrocarbon processing. The above considerations have prompted the development of a new reduced vapor pressure equation and the use of the equation for estimating the acentric factor from the normal boiling point and critical properties of the fluid of interest. The vapor pressure equation is based on that of Riedel (1954) and on the experimental data of Prydz

TABLE 5. VALUES OF $Z^{(0)}$

TR	PR															
	0.010	0.050	0.100	0.200	0.400	0.600	0.800	1.000	1.200	1.500	2.000	3.000	5.000	7.000	10.000	
0.30	0.0029	0.0145	0.0290	0.0579	0.1158	0.1737	0.2315	0.2892	0.3470	0.4335	0.5775	0.8648	1.4366	2.0048	2.8507	
0.35	0.0026	0.0130	0.0261	0.0522	0.1043	0.1564	0.2084	0.2604	0.3123	0.3901	0.5195	0.7775	1.2902	1.7987	2.5539	
0.40	0.0024	0.0119	0.0239	0.0477	0.0953	0.1429	0.1904	0.2379	0.2853	0.3563	0.4744	0.7095	1.1758	1.6373	2.3211	
0.45	0.0022	0.0110	0.0221	0.0442	0.0882	0.1322	0.1762	0.2200	0.2638	0.3294	0.4384	0.6551	1.0841	1.5077	2.1338	
0.50	0.0021	0.0103	0.0207	0.0413	0.0825	0.1236	0.1647	0.2056	0.2465	0.3077	0.4092	0.6110	1.0094	1.4017	1.9801	
0.55	0.0804	0.0098	0.0195	0.0390	0.0778	0.1166	0.1553	0.1939	0.2323	0.2899	0.3853	0.5747	0.9475	1.3137	1.8520	
0.60	0.0849	0.0093	0.0186	0.0371	0.0741	0.1109	0.1476	0.1842	0.2207	0.2753	0.3657	0.5446	0.8959	1.2398	1.7440	
0.65	0.0881	0.0377	0.0178	0.0356	0.0710	0.1063	0.1415	0.1765	0.2113	0.2634	0.3495	0.5197	0.8526	1.1773	1.6519	
0.70	0.0904	0.0504	0.0858	0.0344	0.0687	0.1027	0.1366	0.1703	0.2038	0.2538	0.3364	0.4991	0.8161	1.1241	1.5729	
0.75	0.0922	0.0598	0.09165	0.0336	0.0670	0.1001	0.1330	0.1656	0.1981	0.2464	0.3260	0.4823	0.7854	1.0787	1.5047	
0.80	0.0935	0.0669	0.09319	0.08539	0.0661	0.0985	0.1307	0.1626	0.1942	0.2411	0.3182	0.4690	0.7598	1.0400	1.4456	
0.85	0.0946	0.0725	0.09436	0.0810	0.0661	0.0983	0.1301	0.1614	0.1924	0.2382	0.3132	0.4591	0.7388	1.0071	1.3943	
0.90	0.0954	0.0768	0.09528	0.09015	0.0780	0.1006	0.1321	0.1630	0.1935	0.2383	0.3114	0.4527	0.7220	0.9793	1.3496	
0.93	0.0959	0.0790	0.09573	0.09115	0.08059	0.6635	0.1359	0.1664	0.1963	0.2405	0.3122	0.4507	0.7138	0.9648	1.3257	
0.95	0.0961	0.0803	0.09600	0.09174	0.08206	0.6967	0.1410	0.1705	0.1998	0.2432	0.3138	0.4501	0.7092	0.9561	1.3108	
0.97	0.0963	0.0815	0.09625	0.09227	0.8338	0.7240	0.5580	0.1779	0.2055	0.2474	0.3164	0.4504	0.7052	0.9480	1.2968	
0.98	0.0965	0.0821	0.09637	0.09253	0.8398	0.7360	0.5887	0.1844	0.2097	0.2503	0.3182	0.4508	0.7035	0.9442	1.2901	
0.99	0.0966	0.0826	0.09648	0.09277	0.8455	0.7471	0.6138	0.1959	0.2154	0.2538	0.3204	0.4514	0.7018	0.9406	1.2835	
1.00	0.0967	0.0832	0.09659	0.09300	0.8509	0.7574	0.6353	0.2001	0.2237	0.2583	0.3229	0.4522	0.7004	0.9372	1.2772	
1.01	0.0968	0.0837	0.09669	0.09322	0.8561	0.7671	0.6542	0.2048	0.2370	0.2640	0.3260	0.4533	0.6991	0.9339	1.2710	
1.02	0.0969	0.0842	0.09679	0.09343	0.8610	0.7761	0.6710	0.5146	0.2629	0.2715	0.3297	0.4547	0.6980	0.9307	1.2650	
1.05	0.0971	0.0855	0.09707	0.09401	0.8743	0.8002	0.7130	0.6026	0.4437	0.3131	0.3452	0.4604	0.6956	0.9222	1.2481	
1.10	0.0975	0.0874	0.09747	0.09485	0.8930	0.8323	0.7649	0.6880	0.5984	0.4580	0.3953	0.4770	0.6950	0.9110	1.2232	
1.15	0.0978	0.0891	0.09780	0.09554	0.9081	0.8576	0.8032	0.7443	0.6803	0.5798	0.4760	0.5042	0.6987	0.9033	1.2021	
1.20	0.0981	0.0904	0.09808	0.09611	0.9205	0.8779	0.8330	0.7858	0.7363	0.6605	0.5605	0.5425	0.7069	0.8990	1.1844	
1.30	0.0985	0.0926	0.09852	0.09702	0.9396	0.9083	0.8764	0.8438	0.8111	0.7624	0.6908	0.6344	0.7358	0.8998	1.1580	
1.40	0.0988	0.0942	0.09884	0.09768	0.9534	0.9298	0.9062	0.8827	0.8595	0.8256	0.7753	0.7202	0.7761	0.9112	1.1419	
1.50	0.0991	0.0954	0.09909	0.09818	0.9636	0.9456	0.9278	0.9103	0.8933	0.8689	0.8328	0.7887	0.8200	0.9297	1.1339	
1.60	0.0993	0.0964	0.09928	0.09856	0.9714	0.9575	0.9439	0.9308	0.9180	0.9000	0.8738	0.8410	0.8617	0.9518	1.1320	
1.70	0.0994	0.0971	0.09943	0.09886	0.9775	0.9667	0.9563	0.9463	0.9367	0.9234	0.9043	0.8809	0.8984	0.9745	1.1343	
1.80	0.0995	0.0977	0.09955	0.09910	0.9823	0.9739	0.9659	0.9583	0.9511	0.9413	0.9275	0.9118	0.9297	0.9961	1.1391	
1.90	0.0996	0.0982	0.09964	0.09929	0.9861	0.9796	0.9735	0.9678	0.9624	0.9552	0.9456	0.9359	0.9557	1.0157	1.1452	
2.00	0.0997	0.0986	0.09972	0.09944	0.9892	0.9842	0.9796	0.9754	0.9715	0.9664	0.9599	0.9550	0.9772	1.0328	1.1516	
2.20	0.0998	0.0992	0.09983	0.09967	0.9937	0.9910	0.9886	0.9865	0.9847	0.9826	0.9806	0.9827	1.0094	1.0600	1.1635	
2.40	0.0999	0.0996	0.09991	0.09983	0.9969	0.9957	0.9948	0.9941	0.9936	0.9935	0.9945	1.0011	1.0313	1.0793	1.1728	
2.60	1.0000	0.9998	0.9997	0.9994	0.9991	0.9990	0.9990	0.9993	0.9998	1.0010	1.0040	1.0137	1.0463	1.0926	1.1792	
2.80	1.0000	1.0000	1.0001	1.0002	1.0007	1.0013	1.0021	1.0031	1.0042	1.0063	1.0106	1.0223	1.0565	1.1016	1.1830	
3.00	1.0000	1.0002	1.0004	1.0008	1.0018	1.0030	1.0043	1.0057	1.0074	1.0101	1.0153	1.0284	1.0635	1.1075	1.1848	
3.50	1.0001	1.0004	1.0008	1.0017	1.0035	1.0055	1.0075	1.0097	1.0120	1.0156	1.0221	1.0368	1.0723	1.1138	1.1834	
4.00	1.0001	1.0005	1.0010	1.0021	1.0043	1.0066	1.0090	1.0115	1.0140	1.0179	1.0249	1.0401	1.0747	1.1136	1.1773	

TABLE 6. VALUES OF Z⁽¹⁾

PR

TR	0.010	0.050	0.100	0.200	0.400	0.600	0.800	1.000	1.200	1.500	2.000	3.000	5.000	7.000	10.000
0.30	-0.0008	-0.0040	-0.0081	-0.0161	-0.0323	-0.0484	-0.0645	-0.0806	-0.0966	-0.1207	-0.1608	-0.2407	-0.3996	-0.5572	-0.7915
0.35	-0.0009	-0.0046	-0.0093	-0.0185	-0.0370	-0.0554	-0.0738	-0.0921	-0.1105	-0.1379	-0.1834	-0.2738	-0.4523	-0.6279	-0.8863
0.40	-0.0010	-0.0048	-0.0095	-0.0190	-0.0380	-0.0570	-0.0758	-0.0946	-0.1134	-0.1414	-0.1879	-0.2799	-0.4603	-0.6365	-0.8936
0.45	-0.0009	-0.0047	-0.0094	-0.0187	-0.0374	-0.0560	-0.0745	-0.0929	-0.1113	-0.1387	-0.1840	-0.2734	-0.4475	-0.6162	-0.8606
0.50	-0.0009	-0.0045	-0.0090	-0.0181	-0.0360	-0.0539	-0.0716	-0.0893	-0.1069	-0.1330	-0.1762	-0.2611	-0.4253	-0.5831	-0.8099
0.55	-0.0314	-0.0043	-0.0086	-0.0172	-0.0343	-0.0513	-0.0682	-0.0849	-0.1015	-0.1263	-0.1669	-0.2465	-0.3991	-0.5446	-0.7521
0.60	-0.0205	-0.0041	-0.0082	-0.0164	-0.0326	-0.0487	-0.0646	-0.0803	-0.0960	-0.1192	-0.1572	-0.2312	-0.3718	-0.5047	-0.6928
0.65	-0.0137	-0.0072	-0.0078	-0.0156	-0.0309	-0.0461	-0.0611	-0.0759	-0.0906	-0.1122	-0.1476	-0.2160	-0.3447	-0.4653	-0.6346
0.70	-0.0093	-0.0507	-0.1161	-0.0148	-0.0294	-0.0438	-0.0579	-0.0718	-0.0855	-0.1057	-0.1385	-0.2013	-0.3184	-0.4270	-0.5785
0.75	-0.0064	-0.0339	-0.0744	-0.0143	-0.0282	-0.0417	-0.0550	-0.0681	-0.0808	-0.0996	-0.1298	-0.1872	-0.2929	-0.3901	-0.5250
0.80	-0.0044	-0.0228	-0.0487	-0.0160	-0.0272	-0.0401	-0.0526	-0.0648	-0.0767	-0.0940	-0.1217	-0.1736	-0.2682	-0.3545	-0.4740
0.85	-0.0029	-0.0152	-0.0319	-0.0715	-0.0268	-0.0391	-0.0509	-0.0622	-0.0731	-0.0888	-0.1138	-0.1602	-0.2439	-0.3201	-0.4254
0.90	-0.0019	-0.0099	-0.0205	-0.0442	-0.1118	-0.0396	-0.0503	-0.0604	-0.0701	-0.0840	-0.1059	-0.1463	-0.2195	-0.2862	-0.3788
0.95	-0.0015	-0.0075	-0.0154	-0.0326	-0.0763	-0.1662	-0.0514	-0.0602	-0.0687	-0.0810	-0.1007	-0.1374	-0.2045	-0.2661	-0.3516
0.97	-0.0012	-0.0062	-0.0126	-0.0262	-0.0589	-0.1110	-0.0540	-0.0607	-0.0678	-0.0788	-0.0967	-0.1310	-0.1943	-0.2526	-0.3339
0.98	-0.0010	-0.0050	-0.0101	-0.0208	-0.0450	-0.0770	-0.1647	-0.0623	-0.0669	-0.0759	-0.0921	-0.1240	-0.1837	-0.2391	-0.3163
0.99	-0.0009	-0.0044	-0.0090	-0.0184	-0.0390	-0.0641	-0.1100	-0.0641	-0.0661	-0.0740	-0.0893	-0.1202	-0.1783	-0.2322	-0.3075
1.00	-0.0008	-0.0039	-0.0079	-0.0161	-0.0335	-0.0531	-0.0796	-0.0680	-0.0646	-0.0715	-0.0861	-0.1162	-0.1728	-0.2254	-0.2989
1.01	-0.0007	-0.0034	-0.0069	-0.0140	-0.0285	-0.0435	-0.0588	-0.0879	-0.0609	-0.0678	-0.0824	-0.1118	-0.1672	-0.2185	-0.2902
1.02	-0.0006	-0.0030	-0.0060	-0.0120	-0.0240	-0.0351	-0.0429	-0.0223	-0.0473	-0.0621	-0.0778	-0.1072	-0.1615	-0.2116	-0.2816
1.05	-0.0005	-0.0026	-0.0051	-0.0102	-0.0198	-0.0277	-0.0303	-0.0062	-0.0227	-0.0524	-0.0722	-0.1021	-0.1556	-0.2047	-0.2731
1.10	-0.0003	-0.0015	-0.0029	-0.0054	-0.0092	-0.0097	-0.0032	-0.0220	0.1059	0.0451	-0.0432	-0.0838	-0.1370	-0.1835	-0.2476
1.15	-0.0000	0.0000	0.0001	0.0007	0.0038	0.0106	0.0236	0.0476	0.0897	0.1630	0.0698	-0.0373	-0.1021	-0.1469	-0.2056
1.20	0.0002	0.0011	0.0023	0.0052	0.0127	0.0237	0.0396	0.0625	0.0943	0.1548	0.1667	0.0332	-0.0611	-0.1084	-0.1642
1.30	0.0004	0.0019	0.0039	0.0084	0.0190	0.0326	0.0499	0.0719	0.0991	0.1477	0.1990	0.1095	-0.0141	-0.0678	-0.1231
1.40	0.0006	0.0030	0.0061	0.0125	0.0267	0.0429	0.0612	0.0819	0.1048	0.1420	0.1991	0.2079	0.0875	0.0176	-0.0423
1.50	0.0007	0.0036	0.0072	0.0147	0.0306	0.0477	0.0661	0.0857	0.1063	0.1383	0.1894	0.2397	0.1737	0.1008	0.0350
1.60	0.0008	0.0039	0.0078	0.0158	0.0323	0.0497	0.0677	0.0864	0.1055	0.1345	0.1806	0.2433	0.2309	0.1717	0.1058
1.70	0.0008	0.0040	0.0080	0.0162	0.0330	0.0501	0.0677	0.0855	0.1035	0.1303	0.1729	0.2381	0.2631	0.2255	0.1673
1.80	0.0008	0.0040	0.0081	0.0163	0.0329	0.0497	0.0667	0.0838	0.1008	0.1259	0.1658	0.2305	0.2788	0.2628	0.2179
1.90	0.0008	0.0040	0.0081	0.0162	0.0325	0.0488	0.0652	0.0816	0.0978	0.1216	0.1593	0.2224	0.2846	0.2871	0.2576
2.00	0.0008	0.0040	0.0079	0.0159	0.0318	0.0477	0.0635	0.0792	0.0947	0.1173	0.1532	0.2144	0.2848	0.3017	0.2876
2.20	0.0008	0.0039	0.0078	0.0155	0.0310	0.0464	0.0617	0.0767	0.0916	0.1133	0.1476	0.2069	0.2819	0.3097	0.3096
2.40	0.0007	0.0037	0.0074	0.0147	0.0293	0.0437	0.0579	0.0719	0.0857	0.1057	0.1374	0.1932	0.2720	0.3135	0.3355
2.60	0.0007	0.0035	0.0070	0.0139	0.0276	0.0411	0.0544	0.0675	0.0803	0.0989	0.1285	0.1812	0.2602	0.3089	0.3459
2.80	0.0007	0.0033	0.0066	0.0131	0.0260	0.0387	0.0512	0.0634	0.0754	0.0929	0.1207	0.1706	0.2484	0.3009	0.3475
3.00	0.0006	0.0031	0.0062	0.0124	0.0245	0.0365	0.0483	0.0598	0.0711	0.0876	0.1138	0.1613	0.2372	0.2915	0.3443
3.50	0.0006	0.0029	0.0059	0.0117	0.0232	0.0345	0.0456	0.0565	0.0672	0.0828	0.1076	0.1529	0.2268	0.2817	0.3385
4.00	0.0005	0.0026	0.0052	0.0103	0.0204	0.0303	0.0401	0.0497	0.0591	0.0728	0.0949	0.1356	0.2042	0.2584	0.3194
	0.0005	0.0023	0.0046	0.0091	0.0182	0.0270	0.0357	0.0443	0.0527	0.0651	0.0849	0.1219	0.1857	0.2378	0.2994

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TABLE 8. VALUES OF $\left[\frac{H^\circ - H}{RT_c} \right]^{(1)}$

TR	PR														
	0.010	0.050	0.100	0.200	0.400	0.600	0.800	1.000	1.200	1.500	2.000	3.000	5.000	7.000	10.000
0.30	11.098	11.096	11.095	11.091	11.083	11.076	11.069	11.062	11.055	11.044	11.027	10.992	10.935	10.872	10.781
0.35	10.656	10.655	10.654	10.653	10.650	10.646	10.643	10.640	10.637	10.632	10.624	10.609	10.581	10.554	10.529
0.40	10.121	10.121	10.121	10.120	10.121	10.121	10.121	10.121	10.121	10.121	10.122	10.123	10.128	10.135	10.150
0.45	9.515	9.515	9.516	9.517	9.519	9.521	9.523	9.525	9.527	9.531	9.537	9.549	9.576	9.611	9.663
0.50	8.868	8.869	8.870	8.872	8.876	8.880	8.884	8.888	8.892	8.899	8.909	8.932	8.978	9.030	9.111
0.55	0.080	8.211	8.212	8.215	8.221	8.226	8.232	8.238	8.243	8.252	8.267	8.298	8.360	8.425	8.531
0.60	0.059	7.568	7.570	7.573	7.579	7.585	7.591	7.596	7.603	7.614	7.632	7.669	7.745	7.824	7.950
0.65	0.045	0.247	6.949	6.952	6.959	6.966	6.973	6.980	6.987	6.997	7.017	7.059	7.147	7.239	7.381
0.70	0.034	0.185	0.415	6.360	6.367	6.373	6.381	6.388	6.395	6.407	6.429	6.475	6.574	6.677	6.837
0.75	0.027	0.142	0.306	5.796	5.802	5.809	5.816	5.824	5.832	5.845	5.868	5.918	6.027	6.142	6.318
0.80	0.021	0.110	0.234	0.542	5.266	5.271	5.278	5.285	5.293	5.306	5.330	5.385	5.506	5.632	5.824
0.85	0.017	0.087	0.182	0.401	4.753	4.754	4.758	4.763	4.771	4.784	4.810	4.872	5.008	5.149	5.358
0.90	0.014	0.070	0.144	0.308	0.751	4.254	4.248	4.249	4.255	4.268	4.298	4.371	4.530	4.688	4.916
0.93	0.012	0.061	0.126	0.265	0.612	1.236	3.942	3.934	3.937	3.951	3.987	4.073	4.251	4.422	4.662
0.95	0.011	0.056	0.115	0.241	0.542	0.994	3.737	3.712	3.713	3.730	3.773	3.873	4.068	4.248	4.497
0.97	0.010	0.052	0.105	0.219	0.483	0.837	1.616	3.470	3.467	3.492	3.551	3.670	3.885	4.077	4.336
0.98	0.010	0.050	0.101	0.209	0.457	0.776	1.324	3.332	3.327	3.363	3.434	3.568	3.795	3.992	4.257
0.99	0.009	0.048	0.097	0.200	0.433	0.722	1.154	3.164	3.164	3.223	3.313	3.464	3.705	3.909	4.178
1.00	0.009	0.046	0.093	0.191	0.410	0.675	1.034	2.471	2.952	3.065	3.186	3.358	3.615	3.825	4.100
1.01	0.009	0.044	0.089	0.183	0.389	0.632	0.940	1.375	2.595	2.880	3.051	3.251	3.525	3.742	4.023
1.02	0.008	0.042	0.085	0.175	0.370	0.594	0.863	1.180	1.723	2.650	2.906	3.142	3.435	3.661	3.947
1.05	0.007	0.037	0.075	0.153	0.318	0.498	0.691	0.877	0.878	1.496	2.381	2.800	3.167	3.418	3.722
1.10	0.006	0.030	0.061	0.123	0.251	0.381	0.507	0.617	0.673	0.617	1.261	2.167	2.720	3.023	3.362
1.15	0.005	0.025	0.050	0.099	0.199	0.296	0.385	0.459	0.503	0.487	0.604	1.497	2.275	2.641	3.019
1.20	0.004	0.020	0.040	0.080	0.158	0.232	0.297	0.349	0.381	0.381	0.361	0.934	1.840	2.273	2.692
1.30	0.003	0.013	0.026	0.052	0.100	0.142	0.177	0.203	0.218	0.218	0.178	0.300	1.066	1.592	2.086
1.40	0.002	0.008	0.016	0.032	0.060	0.083	0.100	0.111	0.115	0.108	0.070	0.044	0.504	1.012	1.547
1.50	0.001	0.005	0.009	0.018	0.032	0.042	0.048	0.049	0.046	0.032	-0.008	-0.078	0.142	0.556	1.080
1.60	0.000	0.002	0.004	0.007	0.012	0.013	0.011	0.005	-0.004	-0.023	-0.065	-0.151	-0.082	0.217	0.689
1.70	0.000	0.000	0.000	-0.000	-0.003	-0.009	-0.017	-0.027	-0.040	-0.063	-0.109	-0.202	-0.223	-0.028	0.369
1.80	-0.000	-0.001	-0.003	-0.006	-0.015	-0.025	-0.037	-0.051	-0.067	-0.094	-0.143	-0.241	-0.317	-0.203	0.112
1.90	-0.001	-0.003	-0.005	-0.011	-0.023	-0.037	-0.053	-0.070	-0.088	-0.117	-0.169	-0.271	-0.381	-0.330	-0.092
2.00	-0.001	-0.003	-0.007	-0.015	-0.030	-0.047	-0.065	-0.085	-0.105	-0.136	-0.190	-0.295	-0.428	-0.424	-0.255
2.20	-0.001	-0.005	-0.010	-0.020	-0.040	-0.062	-0.083	-0.106	-0.128	-0.163	-0.221	-0.331	-0.493	-0.551	-0.489
2.40	-0.001	-0.006	-0.012	-0.023	-0.047	-0.071	-0.095	-0.120	-0.144	-0.181	-0.242	-0.356	-0.535	-0.631	-0.645
2.60	-0.001	-0.006	-0.013	-0.026	-0.052	-0.078	-0.104	-0.130	-0.156	-0.194	-0.257	-0.376	-0.567	-0.687	-0.754
2.80	-0.001	-0.007	-0.014	-0.028	-0.055	-0.082	-0.110	-0.137	-0.164	-0.204	-0.269	-0.391	-0.591	-0.729	-0.836
3.00	-0.001	-0.007	-0.014	-0.029	-0.058	-0.086	-0.114	-0.142	-0.170	-0.211	-0.278	-0.403	-0.611	-0.763	-0.899
3.50	-0.002	-0.008	-0.016	-0.031	-0.062	-0.092	-0.122	-0.152	-0.181	-0.224	-0.294	-0.425	-0.650	-0.827	-1.015
4.00	-0.002	-0.008	-0.016	-0.032	-0.064	-0.096	-0.127	-0.158	-0.188	-0.233	-0.306	-0.442	-0.680	-0.874	-1.097

TABLE 9. VALUES OF $\left[\frac{S^* - S}{R} \right]^{(0)}$

TR	PR														
	0.010	0.050	0.100	0.200	0.400	0.600	0.800	1.000	1.200	1.500	2.000	3.000	5.000	7.000	10.000
0.30	11.614	10.008	9.319	8.635	7.961	7.574	7.304	7.099	6.935	6.740	6.497	6.182	5.847	5.683	5.578
0.35	11.185	9.579	8.890	8.205	7.529	7.140	6.869	6.663	6.497	6.299	6.052	5.728	5.376	5.194	5.060
0.40	10.802	9.196	8.506	7.821	7.144	6.755	6.483	6.275	6.109	5.909	5.660	5.330	4.967	4.772	4.619
0.45	10.453	8.847	8.157	7.472	6.794	6.404	6.132	5.924	5.757	5.557	5.306	4.974	4.603	4.401	4.234
0.50	10.137	8.531	7.841	7.156	6.479	6.089	5.816	5.608	5.441	5.240	4.989	4.656	4.282	4.074	3.899
0.55	0.038	8.245	7.555	6.870	6.193	5.803	5.531	5.324	5.157	4.956	4.706	4.373	3.998	3.788	3.607
0.60	0.029	7.983	7.294	6.610	5.933	5.544	5.273	5.066	4.900	4.700	4.451	4.120	3.747	3.537	3.353
0.65	0.023	0.122	7.052	6.368	5.694	5.306	5.036	4.830	4.665	4.467	4.220	3.892	3.523	3.315	3.131
0.70	0.018	0.096	0.206	6.140	5.467	5.082	4.814	4.610	4.446	4.250	4.007	3.684	3.322	3.117	2.935
0.75	0.015	0.078	0.164	5.917	5.248	4.866	4.600	4.399	4.238	4.045	3.807	3.491	3.138	2.939	2.761
0.80	0.013	0.064	0.134	0.294	5.026	4.649	4.388	4.191	4.034	3.846	3.615	3.310	2.970	2.777	2.605
0.85	0.011	0.054	0.111	0.239	4.785	4.418	4.166	3.976	3.825	3.646	3.425	3.135	2.812	2.629	2.463
0.90	0.009	0.046	0.094	0.199	0.463	4.145	3.912	3.738	3.599	3.434	3.231	2.964	2.663	2.491	2.334
0.93	0.008	0.042	0.085	0.179	0.408	0.750	3.723	3.569	3.444	3.295	3.108	2.860	2.577	2.412	2.262
0.95	0.008	0.039	0.080	0.168	0.377	0.671	3.556	3.433	3.326	3.193	3.023	2.790	2.520	2.362	2.215
0.97	0.007	0.037	0.075	0.157	0.350	0.607	1.056	3.259	3.188	3.081	2.932	2.719	2.463	2.312	2.170
0.98	0.007	0.036	0.073	0.153	0.337	0.580	0.971	3.142	3.106	3.019	2.884	2.682	2.436	2.287	2.148
0.99	0.007	0.035	0.071	0.148	0.326	0.555	0.903	2.972	3.010	2.953	2.835	2.646	2.408	2.263	2.126
1.00	0.007	0.034	0.069	0.144	0.315	0.532	0.847	2.178	2.893	2.879	2.784	2.609	2.380	2.239	2.105
1.01	0.007	0.033	0.067	0.139	0.304	0.510	0.799	1.391	2.736	2.798	2.730	2.571	2.352	2.215	2.083
1.02	0.006	0.032	0.065	0.135	0.294	0.491	0.757	1.225	2.495	2.706	2.673	2.533	2.325	2.191	2.062
1.05	0.006	0.030	0.060	0.124	0.267	0.439	0.656	0.965	1.523	2.328	2.483	2.415	2.242	2.121	2.001
1.10	0.005	0.026	0.053	0.108	0.230	0.371	0.537	0.742	1.012	1.557	2.081	2.202	2.104	2.007	1.903
1.15	0.005	0.023	0.047	0.096	0.201	0.319	0.452	0.607	0.790	1.126	1.649	1.968	1.966	1.897	1.810
1.20	0.004	0.021	0.042	0.085	0.177	0.277	0.389	0.512	0.651	0.890	1.308	1.727	1.827	1.789	1.722
1.30	0.003	0.017	0.033	0.068	0.140	0.217	0.298	0.385	0.478	0.628	0.891	1.299	1.554	1.581	1.556
1.40	0.003	0.014	0.027	0.056	0.114	0.174	0.237	0.303	0.372	0.478	0.663	0.990	1.303	1.386	1.402
1.50	0.002	0.011	0.023	0.046	0.094	0.143	0.194	0.246	0.299	0.381	0.520	0.777	1.088	1.208	1.260
1.60	0.002	0.010	0.019	0.039	0.079	0.120	0.162	0.204	0.247	0.312	0.421	0.628	0.913	1.050	1.130
1.70	0.002	0.008	0.017	0.033	0.067	0.102	0.137	0.172	0.208	0.261	0.350	0.519	0.773	0.915	1.013
1.80	0.001	0.007	0.014	0.029	0.058	0.088	0.117	0.147	0.177	0.222	0.296	0.438	0.661	0.799	0.908
1.90	0.001	0.006	0.013	0.025	0.051	0.076	0.102	0.127	0.153	0.191	0.255	0.375	0.570	0.702	0.815
2.00	0.001	0.006	0.011	0.022	0.044	0.067	0.089	0.111	0.134	0.167	0.221	0.325	0.497	0.620	0.733
2.20	0.001	0.004	0.009	0.018	0.035	0.053	0.070	0.087	0.105	0.130	0.172	0.251	0.388	0.492	0.599
2.40	0.001	0.004	0.007	0.014	0.028	0.042	0.056	0.070	0.084	0.104	0.138	0.201	0.311	0.399	0.496
2.60	0.001	0.003	0.006	0.012	0.023	0.035	0.046	0.058	0.069	0.086	0.113	0.164	0.255	0.329	0.416
2.80	0.000	0.002	0.005	0.010	0.020	0.029	0.039	0.048	0.058	0.072	0.094	0.137	0.213	0.277	0.353
3.00	0.000	0.002	0.004	0.008	0.017	0.025	0.033	0.041	0.049	0.061	0.080	0.116	0.181	0.236	0.303
3.50	0.000	0.001	0.003	0.006	0.012	0.017	0.023	0.029	0.034	0.042	0.056	0.081	0.126	0.166	0.216
4.00	0.000	0.001	0.002	0.004	0.009	0.013	0.017	0.021	0.025	0.031	0.041	0.059	0.093	0.123	0.162

TABLE 10. VALUES OF $\left[\frac{S^* - S}{R} \right]^{(1)}$

TR	PR															
	0.010	0.050	0.100	0.200	0.400	0.600	0.800	1.000	1.200	1.500	2.000	3.000	5.000	7.000	10.000	10.000
0.30	16.782	16.774	16.764	16.744	16.705	16.665	16.626	16.586	16.547	16.488	16.390	16.195	15.837	15.468	14.925	14.925
0.35	15.413	15.408	15.401	15.387	15.359	15.333	15.305	15.278	15.251	15.211	15.144	15.011	14.751	14.496	14.153	14.153
0.40	13.990	13.986	13.981	13.972	13.953	13.934	13.915	13.896	13.877	13.849	13.803	13.714	13.541	13.376	13.144	13.144
0.45	12.564	12.561	12.558	12.551	12.537	12.523	12.509	12.496	12.482	12.462	12.430	12.367	12.248	12.145	11.999	11.999
0.50	11.202	11.200	11.197	11.192	11.182	11.172	11.162	11.153	11.143	11.129	11.107	11.063	10.985	10.920	10.836	10.836
0.55	0.115	0.948	0.946	0.942	0.935	0.928	0.921	0.914	0.907	0.897	0.882	0.853	0.806	0.769	0.732	0.732
0.60	0.078	0.828	0.826	0.823	0.817	0.811	0.806	0.799	0.794	0.787	0.779	0.760	0.736	0.723	0.720	0.720
0.65	0.055	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309
0.70	0.040	0.216	0.491	0.6951	0.945	0.941	0.937	0.933	0.930	0.926	0.922	0.919	0.929	0.952	0.952	0.952
0.75	0.029	0.156	0.340	0.6173	0.9167	0.9162	0.9158	0.9155	0.9152	0.9149	0.9147	0.9149	0.9174	0.9213	0.9213	0.9213
0.80	0.022	0.116	0.246	0.578	0.9175	0.9168	0.9162	0.9158	0.9155	0.9152	0.9147	0.9149	0.9174	0.9213	0.9213	0.9213
0.85	0.017	0.088	0.183	0.408	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744
0.90	0.013	0.068	0.140	0.301	0.593	0.593	0.593	0.593	0.593	0.593	0.593	0.593	0.593	0.593	0.593	0.593
0.93	0.011	0.058	0.120	0.254	0.517	0.517	0.517	0.517	0.517	0.517	0.517	0.517	0.517	0.517	0.517	0.517
0.95	0.010	0.053	0.109	0.228	0.456	0.456	0.456	0.456	0.456	0.456	0.456	0.456	0.456	0.456	0.456	0.456
0.97	0.010	0.048	0.099	0.206	0.429	0.429	0.429	0.429	0.429	0.429	0.429	0.429	0.429	0.429	0.429	0.429
0.98	0.009	0.046	0.094	0.196	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405
0.99	0.009	0.044	0.090	0.186	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382
1.00	0.008	0.042	0.086	0.177	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361
1.01	0.008	0.040	0.082	0.169	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342
1.02	0.008	0.039	0.078	0.161	0.322	0.322	0.322	0.322	0.322	0.322	0.322	0.322	0.322	0.322	0.322	0.322
1.05	0.007	0.034	0.069	0.140	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292
1.10	0.005	0.028	0.055	0.112	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259
1.15	0.005	0.023	0.045	0.091	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213
1.20	0.004	0.019	0.037	0.075	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149
1.30	0.003	0.013	0.026	0.052	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
1.40	0.002	0.010	0.019	0.037	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072
1.50	0.001	0.007	0.014	0.027	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053
1.60	0.001	0.005	0.011	0.021	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
1.70	0.001	0.004	0.008	0.016	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031
1.80	0.001	0.003	0.006	0.013	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
1.90	0.001	0.003	0.005	0.010	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
2.00	0.000	0.002	0.004	0.008	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
2.20	0.000	0.001	0.003	0.006	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
2.40	0.000	0.001	0.002	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
2.60	0.000	0.001	0.002	0.003	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
2.80	0.000	0.001	0.001	0.003	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
3.00	0.000	0.001	0.001	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
3.50	0.000	0.000	0.001	0.001	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
4.00	0.000	0.000	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002

TABLE 11. VALUES OF $[\log(f/p)]^{(0)}$

TR	PR														
	0.010	0.050	0.100	0.200	0.400	0.600	0.800	1.000	1.200	1.500	2.000	3.000	5.000	7.000	10.000
0.30	-3.708	-4.402	-4.696	-4.985	-5.261	-5.412	-5.512	-5.584	-5.638	-5.697	-5.759	-5.810	-5.782	-5.679	-5.461
0.35	-2.471	-3.166	-3.461	-3.751	-4.029	-4.183	-4.285	-4.359	-4.416	-4.479	-4.547	-4.611	-4.608	-4.530	-4.352
0.40	-1.566	-2.261	-2.557	-2.848	-3.128	-3.283	-3.387	-3.463	-3.522	-3.588	-3.661	-3.735	-3.752	-3.694	-3.545
0.45	-0.879	-1.575	-1.871	-2.162	-2.444	-2.601	-2.707	-2.785	-2.845	-2.913	-2.990	-3.071	-3.104	-3.063	-2.938
0.50	-0.344	-1.040	-1.336	-1.628	-1.912	-2.070	-2.177	-2.256	-2.317	-2.387	-2.468	-2.555	-2.601	-2.572	-2.468
0.55	-0.008	-0.614	-0.911	-1.204	-1.488	-1.647	-1.755	-1.835	-1.897	-1.969	-2.052	-2.145	-2.201	-2.183	-2.096
0.60	-0.007	-0.269	-0.566	-0.859	-1.144	-1.304	-1.413	-1.494	-1.557	-1.630	-1.715	-1.812	-1.878	-1.869	-1.795
0.65	-0.005	-0.026	-0.283	-0.576	-0.862	-1.023	-1.132	-1.214	-1.278	-1.352	-1.439	-1.539	-1.612	-1.611	-1.549
0.70	-0.004	-0.021	-0.043	-0.341	-0.627	-0.789	-0.899	-0.981	-1.045	-1.120	-1.208	-1.312	-1.391	-1.396	-1.344
0.75	-0.003	-0.017	-0.035	-0.144	-0.430	-0.592	-0.703	-0.785	-0.850	-0.925	-1.015	-1.121	-1.204	-1.215	-1.172
0.80	-0.003	-0.014	-0.029	-0.059	-0.264	-0.426	-0.537	-0.619	-0.685	-0.760	-0.851	-0.958	-1.046	-1.062	-1.026
0.85	-0.002	-0.012	-0.024	-0.049	-0.123	-0.285	-0.396	-0.479	-0.544	-0.620	-0.711	-0.819	-0.911	-0.930	-0.901
0.90	-0.002	-0.010	-0.020	-0.041	-0.086	-0.166	-0.276	-0.359	-0.424	-0.500	-0.591	-0.700	-0.794	-0.817	-0.793
0.93	-0.002	-0.009	-0.018	-0.037	-0.077	-0.122	-0.214	-0.296	-0.361	-0.437	-0.527	-0.637	-0.732	-0.756	-0.735
0.95	-0.002	-0.008	-0.017	-0.035	-0.072	-0.113	-0.176	-0.258	-0.322	-0.398	-0.488	-0.598	-0.693	-0.719	-0.699
0.97	-0.002	-0.008	-0.016	-0.033	-0.067	-0.105	-0.148	-0.223	-0.287	-0.362	-0.452	-0.561	-0.657	-0.683	-0.665
0.98	-0.002	-0.008	-0.016	-0.032	-0.065	-0.101	-0.142	-0.206	-0.270	-0.344	-0.434	-0.543	-0.639	-0.666	-0.649
0.99	-0.001	-0.007	-0.015	-0.031	-0.063	-0.098	-0.137	-0.191	-0.254	-0.328	-0.417	-0.526	-0.622	-0.649	-0.633
1.00	-0.001	-0.007	-0.015	-0.030	-0.061	-0.095	-0.132	-0.176	-0.238	-0.312	-0.401	-0.509	-0.605	-0.633	-0.617
1.01	-0.001	-0.007	-0.014	-0.029	-0.059	-0.091	-0.127	-0.168	-0.224	-0.297	-0.385	-0.493	-0.589	-0.617	-0.602
1.02	-0.001	-0.007	-0.014	-0.028	-0.057	-0.088	-0.122	-0.161	-0.210	-0.282	-0.370	-0.477	-0.573	-0.601	-0.588
1.05	-0.001	-0.006	-0.013	-0.025	-0.052	-0.080	-0.110	-0.143	-0.180	-0.242	-0.327	-0.433	-0.529	-0.557	-0.546
1.10	-0.001	-0.005	-0.011	-0.022	-0.045	-0.069	-0.093	-0.120	-0.148	-0.193	-0.267	-0.368	-0.462	-0.491	-0.482
1.15	-0.001	-0.005	-0.009	-0.019	-0.039	-0.059	-0.080	-0.102	-0.125	-0.160	-0.220	-0.312	-0.403	-0.433	-0.426
1.20	-0.001	-0.004	-0.008	-0.017	-0.034	-0.051	-0.069	-0.088	-0.106	-0.135	-0.184	-0.266	-0.352	-0.382	-0.377
1.30	-0.001	-0.003	-0.006	-0.013	-0.026	-0.039	-0.052	-0.066	-0.080	-0.100	-0.134	-0.195	-0.269	-0.296	-0.293
1.40	-0.001	-0.003	-0.005	-0.010	-0.020	-0.030	-0.040	-0.051	-0.061	-0.076	-0.101	-0.146	-0.205	-0.229	-0.226
1.50	-0.000	-0.002	-0.004	-0.008	-0.016	-0.024	-0.032	-0.039	-0.047	-0.059	-0.077	-0.111	-0.157	-0.176	-0.173
1.60	-0.000	-0.002	-0.003	-0.006	-0.012	-0.019	-0.025	-0.031	-0.037	-0.046	-0.060	-0.085	-0.120	-0.135	-0.129
1.70	-0.000	-0.001	-0.002	-0.005	-0.010	-0.015	-0.020	-0.024	-0.029	-0.036	-0.046	-0.065	-0.092	-0.102	-0.094
1.80	-0.000	-0.001	-0.002	-0.004	-0.008	-0.012	-0.015	-0.019	-0.023	-0.028	-0.036	-0.050	-0.069	-0.075	-0.066
1.90	-0.000	-0.001	-0.002	-0.003	-0.006	-0.009	-0.012	-0.015	-0.018	-0.022	-0.028	-0.038	-0.052	-0.054	-0.043
2.00	-0.000	-0.001	-0.001	-0.002	-0.005	-0.007	-0.009	-0.012	-0.014	-0.017	-0.021	-0.029	-0.037	-0.037	-0.024
2.20	-0.000	-0.000	-0.001	-0.001	-0.003	-0.004	-0.005	-0.007	-0.008	-0.009	-0.012	-0.015	-0.017	-0.012	0.004
2.40	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003	-0.003	-0.004	-0.004	-0.005	-0.006	-0.003	0.005	0.024
2.60	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.001	0.007	0.017	0.037
2.80	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.003	0.005	0.014	0.025	0.046
3.00	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.003	0.003	0.005	0.009	0.018	0.031	0.053
3.50	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.004	0.005	0.006	0.008	0.013	0.025	0.038	0.061
4.00	0.000	0.000	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.010	0.016	0.028	0.041	0.064

TABLE 12. VALUES OF $[\log(f/p)]^{(1)}$

TR	PR															
	0.010	0.050	0.100	0.200	0.400	0.600	0.800	1.000	1.200	1.500	2.000	3.000	5.000	7.000	10.000	
0.30	-8.778	-8.779	-8.781	-8.785	-8.790	-8.797	-8.804	-8.811	-8.818	-8.828	-8.845	-8.880	-8.953	-9.022	-9.126	
0.35	-6.528	-6.530	-6.532	-6.536	-6.544	-6.551	-6.559	-6.567	-6.575	-6.587	-6.606	-6.645	-6.723	-6.800	-6.919	
0.40	-4.912	-4.914	-4.916	-4.919	-4.929	-4.937	-4.945	-4.954	-4.962	-4.974	-4.995	-5.035	-5.115	-5.195	-5.312	
0.45	-3.726	-3.728	-3.730	-3.734	-3.742	-3.750	-3.758	-3.766	-3.774	-3.786	-3.806	-3.845	-3.923	-4.001	-4.114	
0.50	-2.838	-2.839	-2.841	-2.845	-2.853	-2.861	-2.869	-2.877	-2.884	-2.896	-2.915	-2.953	-3.027	-3.101	-3.208	
0.55	-0.013	-2.163	-2.165	-2.169	-2.177	-2.184	-2.192	-2.199	-2.207	-2.218	-2.236	-2.273	-2.342	-2.410	-2.510	
0.60	-0.009	-1.644	-1.646	-1.650	-1.657	-1.664	-1.671	-1.677	-1.684	-1.695	-1.712	-1.747	-1.812	-1.875	-1.967	
0.65	-0.006	-0.031	-1.242	-1.245	-1.252	-1.258	-1.265	-1.271	-1.278	-1.287	-1.304	-1.336	-1.397	-1.456	-1.539	
0.70	-0.004	-0.021	-0.044	-0.047	-0.054	-0.060	-0.066	-0.071	-0.076	-0.081	-0.086	-0.091	-0.096	-1.124	-1.201	
0.75	-0.003	-0.014	-0.030	-0.033	-0.038	-0.042	-0.046	-0.050	-0.054	-0.058	-0.062	-0.066	-0.070	-1.124	-1.201	
0.80	-0.002	-0.010	-0.020	-0.023	-0.027	-0.030	-0.033	-0.036	-0.039	-0.042	-0.045	-0.048	-0.051	-0.054	-0.057	
0.85	-0.001	-0.006	-0.013	-0.016	-0.019	-0.021	-0.023	-0.025	-0.027	-0.029	-0.031	-0.033	-0.035	-0.037	-0.039	
0.90	-0.001	-0.004	-0.009	-0.012	-0.015	-0.017	-0.019	-0.021	-0.023	-0.025	-0.027	-0.029	-0.031	-0.033	-0.035	
0.93	-0.001	-0.003	-0.007	-0.010	-0.013	-0.015	-0.017	-0.019	-0.021	-0.023	-0.025	-0.027	-0.029	-0.031	-0.033	
0.95	-0.001	-0.003	-0.005	-0.008	-0.011	-0.013	-0.015	-0.017	-0.019	-0.021	-0.023	-0.025	-0.027	-0.029	-0.031	
0.97	-0.000	-0.002	-0.004	-0.006	-0.009	-0.011	-0.013	-0.015	-0.017	-0.019	-0.021	-0.023	-0.025	-0.027	-0.029	
0.98	-0.000	-0.002	-0.004	-0.006	-0.008	-0.010	-0.012	-0.014	-0.016	-0.018	-0.020	-0.022	-0.024	-0.026	-0.028	
0.99	-0.000	-0.002	-0.004	-0.006	-0.008	-0.010	-0.012	-0.014	-0.016	-0.018	-0.020	-0.022	-0.024	-0.026	-0.028	
1.00	-0.000	-0.002	-0.004	-0.006	-0.008	-0.010	-0.012	-0.014	-0.016	-0.018	-0.020	-0.022	-0.024	-0.026	-0.028	
1.01	-0.000	-0.001	-0.003	-0.005	-0.007	-0.009	-0.011	-0.013	-0.015	-0.017	-0.019	-0.021	-0.023	-0.025	-0.027	
1.02	-0.000	-0.001	-0.003	-0.005	-0.007	-0.009	-0.011	-0.013	-0.015	-0.017	-0.019	-0.021	-0.023	-0.025	-0.027	
1.05	-0.000	-0.001	-0.002	-0.004	-0.006	-0.008	-0.010	-0.012	-0.014	-0.016	-0.018	-0.020	-0.022	-0.024	-0.026	
1.10	-0.000	-0.001	-0.001	-0.002	-0.004	-0.006	-0.008	-0.010	-0.012	-0.014	-0.016	-0.018	-0.020	-0.022	-0.024	
1.15	-0.000	-0.000	-0.000	-0.000	-0.001	-0.002	-0.004	-0.006	-0.008	-0.010	-0.012	-0.014	-0.016	-0.018	-0.020	
1.20	-0.000	-0.000	-0.001	-0.002	-0.003	-0.005	-0.007	-0.009	-0.011	-0.013	-0.015	-0.017	-0.019	-0.021	-0.023	
1.30	-0.000	-0.001	-0.002	-0.003	-0.004	-0.006	-0.008	-0.010	-0.012	-0.014	-0.016	-0.018	-0.020	-0.022	-0.024	
1.40	-0.000	-0.001	-0.003	-0.005	-0.007	-0.009	-0.011	-0.013	-0.015	-0.017	-0.019	-0.021	-0.023	-0.025	-0.027	
1.50	-0.000	-0.002	-0.003	-0.006	-0.013	-0.020	-0.027	-0.034	-0.041	-0.053	-0.074	-0.112	-0.161	-0.181	-0.191	
1.60	-0.000	-0.002	-0.003	-0.007	-0.014	-0.021	-0.028	-0.036	-0.043	-0.055	-0.074	-0.112	-0.167	-0.197	-0.218	
1.70	-0.000	-0.002	-0.003	-0.007	-0.014	-0.021	-0.029	-0.036	-0.043	-0.055	-0.074	-0.110	-0.167	-0.204	-0.234	
1.80	-0.000	-0.002	-0.004	-0.007	-0.014	-0.021	-0.029	-0.036	-0.043	-0.054	-0.072	-0.107	-0.165	-0.205	-0.242	
1.90	-0.000	-0.002	-0.003	-0.007	-0.014	-0.021	-0.028	-0.035	-0.042	-0.053	-0.070	-0.104	-0.161	-0.203	-0.246	
2.00	-0.000	-0.002	-0.003	-0.007	-0.014	-0.021	-0.028	-0.034	-0.041	-0.052	-0.068	-0.101	-0.157	-0.200	-0.246	
2.20	-0.000	-0.002	-0.003	-0.007	-0.013	-0.020	-0.027	-0.034	-0.040	-0.050	-0.066	-0.097	-0.152	-0.196	-0.244	
2.40	-0.000	-0.002	-0.003	-0.006	-0.013	-0.019	-0.025	-0.032	-0.038	-0.047	-0.062	-0.091	-0.143	-0.186	-0.236	
2.60	-0.000	-0.002	-0.003	-0.006	-0.012	-0.018	-0.024	-0.030	-0.036	-0.044	-0.058	-0.086	-0.134	-0.176	-0.227	
2.80	-0.000	-0.001	-0.003	-0.006	-0.011	-0.017	-0.023	-0.028	-0.034	-0.042	-0.055	-0.080	-0.127	-0.167	-0.217	
3.00	-0.000	-0.001	-0.003	-0.005	-0.011	-0.016	-0.021	-0.027	-0.032	-0.039	-0.052	-0.076	-0.120	-0.158	-0.208	
3.50	-0.000	-0.001	-0.003	-0.005	-0.010	-0.015	-0.020	-0.025	-0.030	-0.037	-0.049	-0.072	-0.114	-0.151	-0.199	
3.50	-0.000	-0.001	-0.002	-0.004	-0.009	-0.013	-0.018	-0.022	-0.026	-0.033	-0.043	-0.063	-0.101	-0.134	-0.179	
4.00	-0.000	-0.001	-0.002	-0.004	-0.008	-0.012	-0.016	-0.020	-0.023	-0.029	-0.038	-0.057	-0.090	-0.121	-0.163	

TABLE 13. VALUES OF $\left[\frac{C_p - C_p^*}{R} \right]^{(0)}$

TR	PR														
	0.010	0.050	0.100	0.200	0.400	0.600	0.800	1.000	1.200	1.500	2.000	3.000	5.000	7.000	10.000
0.30	2.805	2.807	2.809	2.814	2.830	2.842	2.854	2.866	2.878	2.896	2.927	2.989	3.122	3.257	3.466
0.35	2.808	2.810	2.812	2.815	2.823	2.835	2.844	2.853	2.861	2.875	2.897	2.944	3.042	3.145	3.313
0.40	2.925	2.926	2.928	2.933	2.935	2.940	2.945	2.951	2.956	2.965	2.979	3.014	3.085	3.164	3.293
0.45	2.989	2.990	2.990	2.991	2.993	2.995	2.997	2.999	3.002	3.006	3.014	3.032	3.079	3.135	3.232
0.50	3.006	3.005	3.004	3.003	3.001	3.000	2.998	2.997	2.996	2.995	2.995	2.999	3.019	3.054	3.122
0.55	0.118	3.002	3.000	2.997	2.990	2.984	2.978	2.973	2.968	2.961	2.951	2.938	2.934	2.947	2.988
0.60	0.089	3.009	3.006	2.999	2.986	2.974	2.963	2.952	2.942	2.927	2.907	2.874	2.840	2.831	2.847
0.65	0.069	0.387	3.047	3.036	3.014	2.993	2.973	2.955	2.938	2.914	2.878	2.822	2.753	2.720	2.709
0.70	0.054	0.298	0.687	3.138	3.099	3.065	3.033	3.003	2.975	2.937	2.881	2.792	2.681	2.621	2.582
0.75	0.044	0.236	0.526	3.351	3.284	3.225	3.171	3.122	3.076	3.015	2.928	2.795	2.629	2.537	2.469
0.80	0.036	0.191	0.415	1.032	3.647	3.537	3.440	3.354	3.277	3.176	3.038	2.838	2.601	2.473	2.373
0.85	0.030	0.157	0.336	0.794	4.404	4.158	3.957	3.790	3.647	3.470	3.240	2.931	2.599	2.427	2.292
0.90	0.025	0.131	0.277	0.633	1.858	5.679	5.095	4.677	4.359	4.000	3.585	3.096	2.626	2.399	2.227
0.93	0.023	0.118	0.249	0.560	1.538	4.208	6.720	5.766	5.149	4.533	3.902	3.236	2.657	2.392	2.195
0.95	0.021	0.111	0.232	0.518	1.375	3.341	9.316	7.127	6.010	5.050	4.180	3.351	2.684	2.391	2.175
0.97	0.020	0.104	0.217	0.480	1.240	2.778	9.585	10.011	7.451	5.785	4.531	3.486	2.716	2.393	2.159
0.98	0.019	0.101	0.210	0.463	1.181	2.563	7.350	13.270	8.611	6.279	4.743	3.560	2.733	2.395	2.151
0.99	0.019	0.098	0.204	0.447	1.126	2.378	6.038	21.948	10.362	6.897	4.983	3.641	2.752	2.398	2.144
1.00	0.018	0.095	0.197	0.431	1.076	2.218	5.156	*****	13.281	7.686	5.255	3.729	2.773	2.401	2.138
1.01	0.018	0.092	0.191	0.417	1.029	2.076	4.516	22.295	18.967	8.708	5.569	3.821	2.794	2.405	2.131
1.02	0.017	0.089	0.185	0.403	0.986	1.951	4.025	13.184	31.353	10.062	5.923	3.920	2.816	2.408	2.125
1.05	0.016	0.082	0.169	0.365	0.872	1.648	3.047	6.458	20.234	16.457	7.296	4.259	2.891	2.425	2.110
1.10	0.014	0.071	0.147	0.313	0.724	1.297	2.168	3.649	6.510	13.256	9.787	4.927	3.033	2.462	2.093
1.15	0.012	0.063	0.128	0.271	0.612	1.058	1.670	2.553	3.885	6.985	9.094	5.535	3.186	2.508	2.083
1.20	0.011	0.055	0.113	0.237	0.525	0.885	1.345	1.951	2.758	4.430	6.911	5.710	3.326	2.555	2.079
1.30	0.009	0.044	0.089	0.185	0.400	0.651	0.946	1.297	1.711	2.458	3.850	4.793	3.452	2.628	2.077
1.40	0.007	0.036	0.072	0.149	0.315	0.502	0.711	0.946	1.208	1.650	2.462	3.573	3.282	2.626	2.068
1.50	0.006	0.029	0.060	0.122	0.255	0.399	0.557	0.728	0.912	1.211	1.747	2.647	2.917	2.525	2.038
1.60	0.005	0.025	0.050	0.101	0.210	0.326	0.449	0.580	0.719	0.938	1.321	2.016	2.508	2.347	1.978
1.70	0.004	0.021	0.042	0.086	0.176	0.271	0.371	0.475	0.583	0.752	1.043	1.586	2.128	2.130	1.889
1.80	0.004	0.018	0.036	0.073	0.150	0.229	0.311	0.397	0.484	0.619	0.848	1.282	1.805	1.907	1.778
1.90	0.003	0.016	0.031	0.063	0.129	0.196	0.265	0.336	0.409	0.519	0.706	1.060	1.538	1.696	1.656
2.00	0.003	0.014	0.027	0.055	0.112	0.170	0.229	0.289	0.350	0.443	0.598	0.893	1.320	1.505	1.531
2.20	0.002	0.011	0.021	0.043	0.086	0.131	0.175	0.220	0.265	0.334	0.446	0.661	0.998	1.191	1.292
2.40	0.002	0.009	0.017	0.034	0.069	0.104	0.138	0.173	0.208	0.261	0.347	0.510	0.779	0.956	1.086
2.60	0.001	0.007	0.014	0.028	0.056	0.084	0.112	0.140	0.168	0.210	0.278	0.407	0.624	0.780	0.917
2.80	0.001	0.006	0.012	0.023	0.046	0.070	0.093	0.116	0.138	0.172	0.227	0.332	0.512	0.647	0.779
3.00	0.001	0.005	0.010	0.020	0.039	0.058	0.078	0.097	0.116	0.144	0.190	0.277	0.427	0.545	0.668
3.50	0.001	0.003	0.007	0.013	0.027	0.040	0.053	0.066	0.079	0.098	0.128	0.187	0.289	0.374	0.472
4.00	0.000	0.002	0.005	0.010	0.019	0.029	0.038	0.048	0.057	0.071	0.093	0.135	0.209	0.272	0.350

TABLE 14. VALUES OF $\left[\frac{C_p - C_p^*}{R} \right]^{(1)}$

TR	PR														
	0.010	0.050	0.100	0.200	0.400	0.600	0.800	1.000	1.200	1.500	2.000	3.000	5.000	7.000	10.000
0.30	8.462	8.445	8.424	8.381	8.281	8.192	8.102	8.011	7.920	7.785	7.558	7.103	6.270	5.372	4.020
0.35	9.775	9.762	9.746	9.713	9.646	9.568	9.499	9.430	9.360	9.256	9.080	8.728	8.013	7.290	6.285
0.40	11.494	11.484	11.471	11.438	11.394	11.343	11.291	11.240	11.188	11.110	10.980	10.709	10.170	9.625	8.803
0.45	12.651	12.643	12.633	12.613	12.573	12.532	12.492	12.451	12.409	12.347	12.243	12.029	11.592	11.183	10.533
0.50	13.111	13.106	13.099	13.084	13.055	13.025	12.995	12.964	12.933	12.886	12.805	12.639	12.288	11.946	11.419
0.55	0.511	13.035	13.030	13.021	13.002	12.981	12.961	12.939	12.917	12.882	12.823	12.695	12.407	12.103	11.673
0.60	0.345	12.679	12.675	12.668	12.653	12.637	12.620	12.589	12.574	12.550	12.506	12.407	12.165	11.905	11.526
0.65	0.242	1.518	12.148	12.145	12.137	12.128	12.117	12.105	12.092	12.060	12.026	11.943	11.728	11.494	11.141
0.70	0.174	1.026	2.698	11.557	11.564	11.563	11.559	11.553	11.536	11.524	11.495	11.416	11.208	10.985	10.661
0.75	0.129	0.726	1.747	10.967	10.995	11.011	11.019	11.024	11.022	11.013	10.986	10.898	10.677	10.448	10.132
0.80	0.097	0.532	1.212	3.511	10.490	10.536	10.566	10.583	10.590	10.587	10.556	10.446	10.176	9.917	9.591
0.85	0.075	0.399	0.879	2.247	9.999	10.153	10.245	10.297	10.321	10.324	10.278	10.111	9.740	9.433	9.075
0.90	0.058	0.306	0.658	1.563	5.486	9.793	10.180	10.349	10.409	10.401	10.279	9.940	9.389	8.999	8.592
0.93	0.050	0.263	0.560	1.289	3.890	***	10.285	10.769	10.875	10.801	10.523	9.965	9.225	8.766	8.322
0.95	0.046	0.239	0.505	1.142	3.215	9.389	9.993	11.420	11.607	11.387	10.865	10.055	9.136	8.621	8.152
0.97	0.042	0.217	0.456	1.018	2.712	6.588	***	13.001	***	12.498	11.445	10.215	9.061	8.485	7.986
0.98	0.040	0.207	0.434	0.962	2.506	5.711	***	***	***	***	11.856	10.323	9.037	8.420	7.905
0.99	0.038	0.198	0.414	0.911	2.324	5.027	***	***	***	***	12.388	10.457	9.011	8.359	7.826
1.00	0.037	0.189	0.394	0.863	2.162	4.477	10.511	***	***	***	13.081	10.617	8.990	8.293	7.747
1.01	0.035	0.181	0.376	0.819	2.016	4.026	8.437	***	***	***	***	10.805	8.973	8.236	7.670
1.02	0.034	0.173	0.359	0.778	1.884	3.648	7.044	***	***	***	***	11.024	8.960	8.182	7.595
1.05	0.030	0.152	0.313	0.669	1.559	2.812	4.679	7.173	2.277	***	***	11.852	8.939	8.018	7.377
1.10	0.024	0.123	0.252	0.528	1.174	1.968	2.919	3.877	4.002	3.927	***	***	8.933	7.759	7.031
1.15	0.020	0.101	0.205	0.424	0.910	1.460	2.048	2.587	2.844	2.236	7.716	12.812	8.849	7.504	6.702
1.20	0.016	0.083	0.168	0.345	0.722	1.123	1.527	1.881	2.095	1.962	2.965	9.494	8.508	7.206	6.384
1.30	0.012	0.058	0.116	0.235	0.476	0.715	0.938	1.129	1.264	1.327	1.288	3.855	6.758	6.365	5.735
1.40	0.008	0.042	0.083	0.166	0.329	0.484	0.624	0.743	0.833	0.904	0.905	1.652	4.524	5.193	5.035
1.50	0.006	0.030	0.061	0.120	0.235	0.342	0.437	0.517	0.580	0.639	0.666	0.907	2.823	3.944	4.289
1.60	0.005	0.023	0.045	0.089	0.173	0.249	0.317	0.374	0.419	0.466	0.499	0.601	1.755	2.871	3.545
1.70	0.003	0.017	0.034	0.068	0.130	0.187	0.236	0.278	0.312	0.349	0.380	0.439	1.129	2.060	2.867
1.80	0.003	0.013	0.027	0.052	0.100	0.143	0.180	0.212	0.238	0.267	0.296	0.337	0.764	1.483	2.287
1.90	0.002	0.011	0.021	0.041	0.078	0.111	0.140	0.164	0.185	0.209	0.234	0.267	0.545	1.085	1.817
2.00	0.002	0.008	0.017	0.032	0.062	0.088	0.110	0.130	0.146	0.166	0.187	0.217	0.407	0.812	1.446
2.20	0.001	0.005	0.011	0.021	0.040	0.057	0.072	0.085	0.096	0.110	0.126	0.150	0.256	0.492	0.941
2.40	0.001	0.004	0.007	0.014	0.028	0.039	0.049	0.058	0.066	0.076	0.089	0.109	0.180	0.329	0.644
2.60	0.001	0.003	0.005	0.010	0.020	0.028	0.035	0.042	0.048	0.056	0.066	0.084	0.137	0.239	0.466
2.80	0.000	0.002	0.004	0.008	0.014	0.021	0.026	0.031	0.036	0.042	0.051	0.067	0.110	0.187	0.356
3.00	0.000	0.001	0.003	0.006	0.011	0.016	0.020	0.024	0.028	0.033	0.041	0.055	0.092	0.153	0.285
3.50	0.000	0.001	0.002	0.003	0.006	0.009	0.012	0.015	0.017	0.021	0.026	0.038	0.067	0.108	0.190
4.00	0.000	0.001	0.001	0.002	0.004	0.006	0.008	0.010	0.012	0.015	0.019	0.029	0.054	0.085	0.146

and Goodwin (1972), Carruth and Kobayashi (1973), and Wilhoit and Zwolinski (1971) for heavy hydrocarbons. The equation is given below:

$$\ln P_r^s = 5.92714 - 6.09648/T_r - 1.28862 \ln T_r + 0.169347 T_r^6 + \omega(15.2518 - 15.6875/T_r - 13.4721 \ln T_r + 0.43577 T_r^6) \quad (17)$$

This equation satisfies:

1. The definition of acentric factor, $\omega = -\log(P_r^s) - 1$ at $T_r = 0.7$.
2. The Riedel condition $d\alpha/dT_r = 0$ at $T_r = 1.0$.
3. The critical point requirement, $P_r^s = 1.0$ at $T_r = 1.0$.

Equation (17) gives the following relation between Riedel's parameter and the acentric factor:

$$\alpha_c = 5.824 + 4.83\omega \quad (18)$$

As shown in Table 2, Equation (17) is in good agreement with the tabular correlations of others (Carruth and Kobayashi, 1972; Pitzer et al., 1955; Hsi and Lu, 1974).

Applying Equation (17) at the normal boiling point gives the following expression for the acentric factor:

$$\omega = \frac{\ln P_{br}^s - 5.92714 + 6.09648/T_{br} + 1.28862 \ln T_{br} - 0.169347 T_{br}^6}{15.2518 - 15.6875/T_{br} - 13.4721 \ln T_{br} + 0.43577 T_{br}^6} \quad (19)$$

Equation (19) yields results which are in excellent agreement with the values of the acentric factor given by Passut and Danner, with the exception of the hydrocarbons previously mentioned.

As is well known, the values obtained from a corresponding states correlation are sensitive to the calculated pseudo critical properties of the mixtures. This is particularly true for the widely boiling mixtures encountered in petroleum processing, where compositions often range from methane to components boiling over 600°C.

The use of Kay's additive rule to calculate critical pressures of such mixtures often leads to significant errors. To improve overall accuracy, several sets of mixing rules have been studied. The following set of mixing rules have been found to give the best results:

$$V_{ci} = Z_{ci}RT_{ci}/P_{ci} \quad (20)$$

$$Z_{ci} = 0.2905 - 0.085\omega_i \quad (21)$$

$$V_c = \frac{1}{8} \sum_j \sum_k x_j x_k (V_{cj}^{1/3} + V_{ck}^{1/3})^3 \quad (22)$$

$$T_c = \frac{1}{8V_c} \sum_j \sum_k x_j x_k (V_{cj}^{1/3} + V_{ck}^{1/3})^3 \sqrt{T_{cj}T_{ck}} \quad (23)$$

$$\omega = \sum_j x_j \omega_j \quad (24)$$

$$P_c = Z_c RT_c / V_c = (0.2905 - 0.085\omega) RT_c / V_c \quad (25)$$

EVALUATION AND DISCUSSION

Figures 1 through 4 compare the results obtained from the proposed correlations with those of other methods in calculating compressibility factors and enthalpy departures. As can be seen, the proposed analytical method is in good agreement with other tabular correlations for simple fluids. The comparison of this correlation with experimental data for real fluids is also favorable as shown in Table 3 and 4. Similar agreement was also

observed for entropy values and fugacity coefficients. On the other hand, the agreement in the deviation functions as defined by Pitzer and co-workers is only fair. The disagreement, however, is probably due to inaccuracies in the original deviation functions rather than in those of new correlations. As shown in Table 3, this method was successfully applied to T_r and P_r as high as 8.7 and 31, respectively.

Since Pitzer's method, as adopted in this work, is less accurate around the two-phase region, the compressibility factors of saturated vapor and liquid were also evaluated. These are given in Table 3. As expected, the accuracy in this case is slightly poorer than that of subcooled or superheated fluids. In this connection it should be pointed out that the values at saturation conditions were obtained by extrapolating isotherms into the saturation envelopes of the simple and reference fluids. This is in line with the Curl and Pitzer's observation (1958) that fluids with higher acentric factors have lower reduced vapor pressures at the same reduced temperatures.

The second virial coefficients obtained from Equation (4) and the equivalent form of Equation (2) are compared in Figures 5 and 6 with those of other correlations (Pitzer and Curl, 1957; Tsonopoulos, 1974). Again the

values obtained from Equation (4) compare favorably with literature data.

Isobaric heat capacity equation, Equation (14), was also evaluated using the methane and propane data of

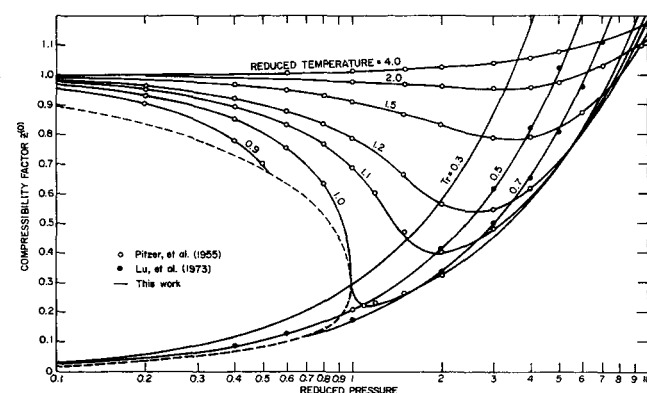


Fig. 1. Comparison of $Z(0)$.

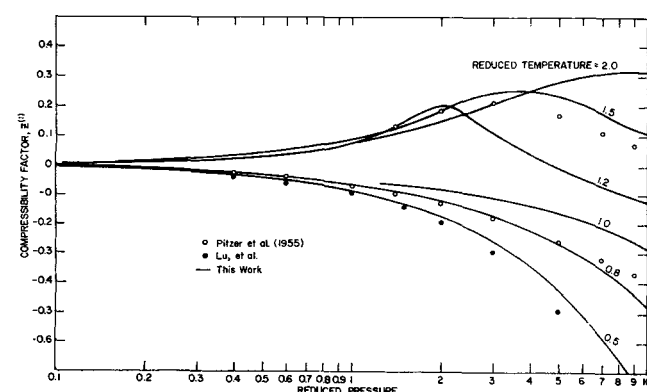


Fig. 2. Comparison of $Z(1)$.

Jones et al. (1963) and of Yesavage et al. (1968). The average absolute deviation was about 2%. It should be noted that the isobaric heat capacity departures are not accurate near the critical region where the heat capacity changes rapidly with temperature and pressure.

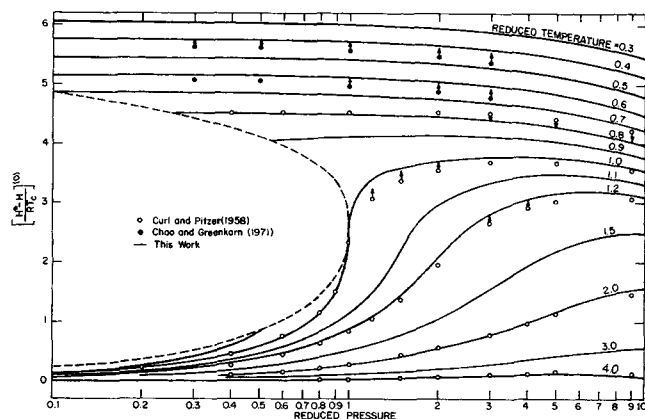


Fig. 3. Comparison of $\left[\frac{H^* - H}{RT_c} \right]^{(0)}$.

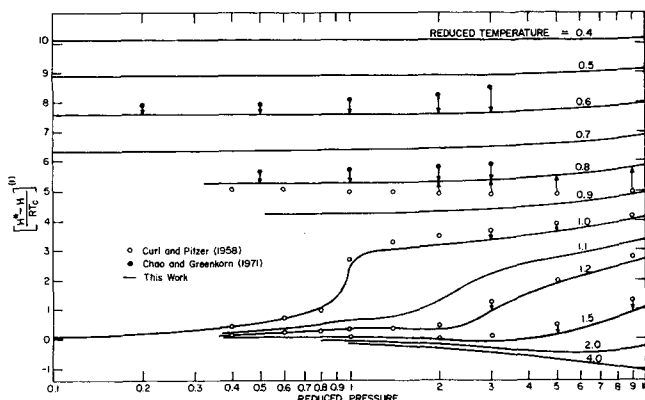


Fig. 4. Comparison of $\left[\frac{H^* - H}{RT_c} \right]^{(1)}$.

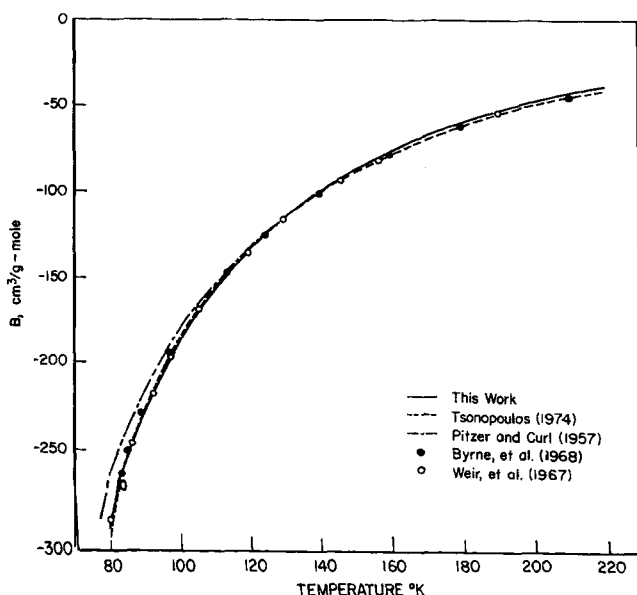


Fig. 5. Second virial coefficients of simple fluids.

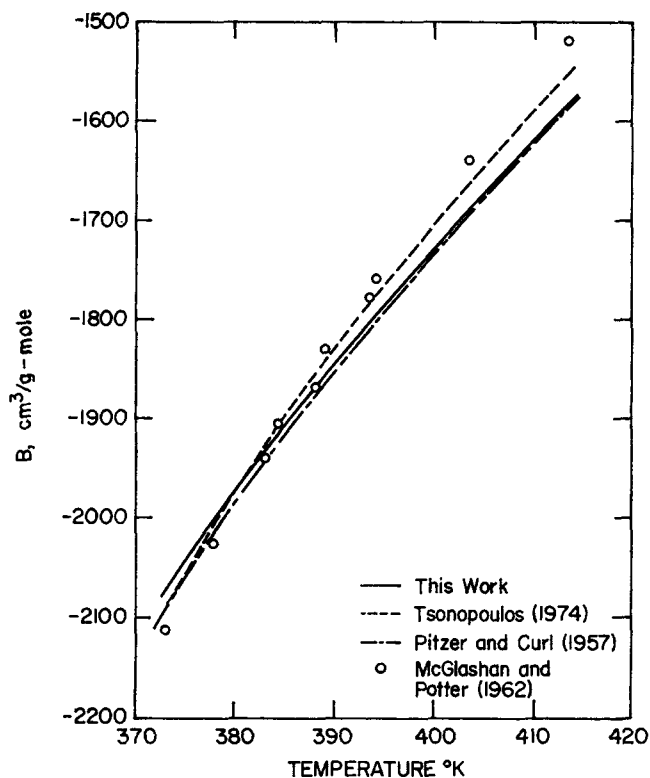


Fig. 6. Second virial coefficient of *n*-octane.

It should be pointed out that the critical properties used throughout this work, except for the critical pressure of 1-pentene ($P_c = 39.9$ atm. from Reid and Sherwood, 1966) were taken from the API Data Book, while the acentric factors were obtained from Equation (19).

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NOTATION

- b_1, b_2, b_3, b_4 = constants as given in Table 1
 c_1, c_2, c_3, c_4 = constants as given in Table 1
 d_1, d_2 = constants as given in Table 1
 B, C, D = coefficients in Equation (3)
 C_p = isobaric heat capacity
 C_v = isochoric heat capacity
 E = defined by Equation (10)
 f = fugacity
 H = enthalpy
 P = pressure
 P^* = reference pressure for ideal gas state entropy
 R = gas constant
 S = entropy
 T = temperature
 V = volume
 $V_r = P_c V / RT_c$
 x = molar composition
 Z = compressibility factor

Greek Letters

- α = Riedel's parameter
 β = constant as given in Table 1
 γ = constant as given in Table 1
 ω = acentric factor

Superscripts

- L = liquid

- s = saturation condition
 V = vapor
 $\bullet$ = ideal gas state
 (0) = simple fluid property
 (1) = deviation function
 (r) = reference fluid

Subscripts

- b = normal boiling point
 c = critical condition
 i, j, k = component identification
 r = reduced property

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