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Thermodynamic properties of perfluoropropane

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THERMODYNAMIC PROPERTIES OF PERFLUOROPROPANE

BY

FRANK FANG

A THESIS

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THE REQUIREMENTS FOR THE DEGREE

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ABSTRACT

The thermodynamic properties of perfluoropropane (octafluoropropane) have been determined by the author for the saturated region from -100°C to the critical temperature, 71°C. Properties in the superheated region were likewise determined by the author for temperatures from -35°C to 300°C and over a pressure range from 1 atmosphere to 40 atmospheres. Enthalpies, entropies, densities, and specific volumes are reported for both vapor and liquid phases where applicable. The datum point used in these calculations is based on a zero value for vapor enthalpy and vapor entropy at -100°C and 0.0183 atmospheres.

Constants used in the Benedict-Webb-Rubin equation of state were calculated. Calculated results using Benedict-Webb-Rubin, Martin and Hou equations of state, and Hirschfelder's generalized equation of state in determination of P-V-T relationships were compared with the experimental data.

Pressure-temperature-volume relations were predicted using the Martin and Hou equation of state. This equation of state was also used to evaluate the isothermal variation of enthalpy and entropy with pressure.

The low pressure heat capacity equation was obtained from experimental data.

The values for temperature, pressure, specific volume, enthalpy and entropy for liquid and vapor in the saturated region and for vapor in the superheated region are reported in the form of tables. The data are also presented in the form of temperature-enthalpy and temperature-entropy diagrams.

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INTRODUCTION

Perfluoropropane is produced by catalytic reaction between fluorine and carbon or by the electrofluorination of various organic compounds.

It is essentially chemically unreactive and thermally stable. Under severe conditions, negligible corrosion or decomposition in contact with metals or glass can be detected.

The most important industrial uses of perfluoropropane are as refrigerant and gaseous dielectric. It is also used as a component of aerosol propellent, as a heat transfer medium, as a low temperature hydraulic fluid and as an acoustical gas.

The growing importance of perfluoropropane as a commercial chemical, its diversified and wide applications and its many unique characteristics have definitely created the need for a thorough knowledge of thermodynamic properties in process evaluations and engineering designs in industry. The purpose of this investigation is to fulfill this requirement.

The following sections cover in detail, sourses of data, derivation of equations and calculation procedures.

SOURCES OF DATA

Critical evaluation of the thermodynamic properties of a compound requires some knowledge of pressure-volume-temperature behavior as well as some measurements of vapor heat capacity over the range of temperature and pressure involved. Limited data for perfluoropropane are available in the literature and were used in the preparation of this thesis. A full tabulation of these data is presented in Table I in the Appendix. As in some cases where there are more than one source of data available, only the most recent ones were chosen in this study. The table below indicates the sources of data:

	Property	Source
1)	Normal Boiling Point	Brown(4)
2)	Normal Freezing Point	Allied Chem.Corp.Pub.(1)
3)	Critical Constants	Brown(4)
4)	Vapor Pressure	Brown(4)
5)	Specific Heat	Masi et al(15)
6)	Liquid Density	Brown(4)
7)	Thermal Conductivity	Matheson Co. Pub.(16)
8)	Vapor Viscosity	Allied Chem.Corp.Pub.(1)

Equation of State

The choice of an equation of state for predicting P-V-T behavior is generally based on two important factors; extent of accuracy desired, and ability to obtain the necessary constants for the specific compound to be used in the equation of state. Hirschfelder's(10) generalized equation of state has been generally used in predicting the thermodynamic properties of refrigerants whenever experimental data are unavailable. However, advantage is taken in this study of the fact that some limited P-V-T data are available and that some data on physical properties have been obtained. A closer look at the situation seems to indicate a more accurate result if either the Martin and Hou(14) or the Benedict-Webb-Rubin(2) equation of state is used.

Generalized equation of state. Based on a modified principle of corresponding states, Hirschfelder and co-workers(10) were able to predict the thermodynamic properties of gases and liquids suitable for general applications usually well within engineering accuracy requirements for design work.

The biggest advantage of this equation of state is that only few input data are required. They are: critical constants; normal boiling point; and for the liquid region only, the density of the saturated liquid at two temperatures.

P-V-T values have been arbitrarily divided into three regions, with different equations applying in each region:

For gas region, where density is less than critical density at all temperature levels,

$$P_{rI}/T_r = -w_1(T_r)\rho_r^{2} - w_2(T_r)\rho_r^{3} + g(\rho_r) \qquad (1)$$

For high density gas region, where reduced temperature is equal to or greater than 1.0, and reduced density is equal to or greater than 1.0, the following equation is used:

$$P_{rII}/T_r = -w_1(T_r)\rho_r^{2} - w_2(T_r)\rho_r^{3} + 1 + \beta\rho_r^{2} + s(\rho_r - 1)^{5}/\rho_r + D(\rho_r, T_r) \qquad (2)$$

For liquid region, where temperature is below the critical, $T_r \leq 1.0$, and density is greater than the critical, $\rho_r \geq 1.0$,

$$P_{rIII} = P_{rII}(\rho_r, T_r) - P_{rIII}\left[\rho_1(T_r), T_r\right] + P(T_r) \qquad (3)$$

Benedict-Webb-Rubin equation. Benedict and co-workers(2) derived an empirical equation to predict the thermodynamic properties of pure substances in both the gaseous and liquid states. The equation is considered to be a modification of the Beattie-Bridgeman equation of state.

This equation was originally proposed for calculating the thermodynamic behavior of hydrocarbons. Since then, it has been used for predicting that of other pure substances.

The B-W-R equation expresses the isothermal variation with density of the work content A of a mole of gaseous or liquid substance. The residual work content may be defined by the equation:

$$\tilde{A} = a - RT \ln d - \lim_{d \to 0} (A - RT \ln d) \tag{4}$$

The corresponding equation of state takes the form of:

$$P = RTd + (B_oRT - A_o - C_o/T^2)d^2 + (bRT - a)d^3 + a\alpha d^6 + \frac{cd^3(1+\gamma d^2)\exp(-\gamma d^2)}{T^2} \tag{5}$$

It can be seen that Equation (5) contains eight characteristic constants which can be determined from experimental data.

The numerical values of these parameters for perfluoropropane were evaluated according to the procedure suggested by Benedict and co-workers. They are listed in Table II in the Appendix.

Martin and Hou equation of state. The Martin and Hou equation is empirical and was derived in the following form:

$$P = f_1/(V-b) + f_2/(V-b)^2 + f_3/(V-b)^3 + f_4/(V-b)^4 + f_5/(V-b)^5 \qquad (6)$$

where f's are functions of temperature and defined as follows:

$$f_1 = A_1 + B_1T + C_1e^{-kT/T_c} \qquad (7)$$

$$f_2 = A_2 + B_2T + C_2e^{-kT/T_c}$$

etc.

The equations for f were found to represent the curvature of isometrics of many different compounds with only one value of k, this value being 5.475. Substituting Eqs. (7) in Eq. (6) gives the generalized equation. By virtue of the hypothesis that the P-V-T behavior of a given compound is a function of the critical properties, the final equation of state becomes:

$$P = \frac{RT}{(V-b)} + \frac{A_2 + B_2 + C_2e^{-(kT/T_c)}}{(V-b)^2} + \frac{A_3 + B_3T + C_3e^{-(kT/T_c)}}{(V-b)^3} + \frac{A_4}{(V-b)^4} + \frac{B_5T}{(V-b)^5} \qquad (8)$$

Nine characteristic constants are necessary in the above equation. Martin and Hou's solution yielded 17 equations, principally derived from gas behavior in the critical region in determining these constants. A plot of Boyle temperature versus critical temperature, and a reduced vapor pressure-temperature plot with M, the slope of the reduced vapor pressure curve at critical point, as the parameter are needed. The two graphs are presented in Figures II and III in the Appendix. The equations required are as follows:

$$Z_c = P_cV_c/RT_c \tag{9}$$

$$T^1 = T_c(-0.6751Z_c + 0.9869) \tag{10}$$

$$\beta = -31.883Z_c^{\,2} + 20.533Z_c \tag{11}$$

$$m = -MP_c/T_c \tag{12}$$

$$b = V_c - \frac{V_c}{15Z_c} \tag{13}$$

$$f_2(T_c) = 9P_c(V_c-b)^2 - 3.8RT_c(V_c-b) \tag{14}$$

$$f_3(T_c) = 5.4RT_c(V_c-b)^2 - 17P_c(V_c-b)^3 \tag{15}$$

$$f_4(T_c) = 12P_c(V_c-b)^4 - 3.4RT(V_c-b)^3 \tag{16}$$

$$f_5(T_c) = 0.8RT_c(V_c-b)^4 - 3P_c(V_c-b)^5 \tag{17}$$

$$C_2 = \frac{f_2(T_c)+bRT^1+\frac{(RT^1)^2}{P_c}(1-Z_c)\ (T_B-T_c)+\ f_2(T_c)+bRT_B\ (T_c-T^1)}{(T_B-T_c)(e^{-k}-e^{-kT^1/Tc})\ -\ (T_c-T^1)(e^{-kT_B/T_c}-e^{-k})} \tag{18}$$

$$B_2 = \frac{-f_2(T_c)\ -\ bRT_B-C_2(e^{-kT_B/T_c}-e^{-k})}{T_B-T_c} \tag{19}$$

$$C_3 = -(V_c-b)C_2 \tag{20}$$

$$A_2 = f_2(T_c)-B_2T_c-C_2e^{-k} \tag{21}$$

$$A_4 = f_4(T_c) \tag{22}$$

$$B_5 = f_5(T_c)/T_c \tag{23}$$

$$B_3 = m(V_c-b)^3-R(V_c-b)^2-B_2(V_c-b)-\frac{B_5}{(V_c-b)^2} \tag{24}$$

$$A_3 = f_3(T_c)-B_3T_c-C_3e^{-k} \tag{25}$$

Brown(4) has evaluated the constants for perfluoropropane, and the numerical values were used in this investigation.

Comparison of various equations of state. Calculated P-V-T results using Hirschfelder's generalized, Benedict-Webb-Rubin and Martin and Hou equations of state were compared with the experimental data. Table IV gives the tabulated results.

All three equations may be used for the prediction of thermodynamic behavior of perfluoropropane for engineering applications. The generalized equation is usually limited in its application to cases when only a few physical properties are available. Although the Benedict-Webb-Rubin equation gives good results, its complexity in evaluating the constants has discouraged many from using the equation. The Martin and Hou equation, on the other hand, not only yields satisfactory results, but also is easily manipulated so as to obtain the necessary constants for the equation. Consequently, the Martin and Hou equation of state was chosen in this study for determining the thermodynamic properties of perfluoropropane.

Heat Capacity Equation

Experimental gas heat capacities at low pressures and over a range of temperatures were obtained by Masi and co-workers(15). Edgell and co-workers(7) studied the Raman and infrared spectrum of perfluoropropane, and found twenty-two of the twenty-seven fundamental frequencies of vibration. Using statistical methods, additional data were calculated(1).

Data were then fitted to several generalized forms of heat capacity equations. The following equation was developed in the present study as the one most consistent with the data:

$$C_p^\circ = 3.0911305+0.1485887T - 0.15309\times10^{-3}T^2+5.7292141\times10^{-8}T^3 \quad (26)$$

Since for temperatures below -30°C where data are not available, extrapolation was necessary in order to cover the temperature range studied. Three equations commonly used for estimation of heat capacity were evaluated for comparison. Dobratz's(17) equation, modification of Meghreblian, Crawford and Parr(17), and Crawford and Parr's(6) expression all yielded values to within 10% when compared with Eq. (26). Since none of the three methods investigated are reliable at temperatures below 250°K, equation (26) was used throughout the entire temperature range of this study.

DERIVATION OF EQUATIONS

To apply the constants determined for the equation of state and the heat capacity equation, it is necessary to derive some fundamental equations for evaluation of enthalpies and entropies over the range of temperature and pressure involved. The basic differential equation expressing the enthalpy is:

$$dH = TdS + Vdp \tag{27}$$

Since pressure is a single-valued continuous function of two independent variables, volume and temperature,

$$P = f\ (V,T) \tag{28}$$

the total differential of pressure can be expressed in terms of its partial derivatives with respect to two independent variables, thus

$$dP = \left(\frac{\partial p}{\partial V}\right)_T dV + \left(\frac{\partial p}{\partial T}\right)_V dT \tag{29}$$

Substituting equation (29) into equation (27),

$$dH = TdS + V\left[\left(\frac{\partial p}{\partial V}\right)_T dV + \left(\frac{\partial p}{\partial T}\right)_V dT\right] \tag{30}$$

Keeping temperature constant, and differentiating with respect to volume,

$$\left(\frac{\partial H}{\partial V}\right)_T = T\left(\frac{\partial S}{\partial V}\right)_T + V\left(\frac{\partial p}{\partial V}\right)_T \tag{31}$$

Using Maxwell relations, (11)

$$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial p}{\partial T}\right)_V \tag{32}$$

Combining equations (31) and (32),

$$\left(\frac{\partial H}{\partial V}\right)_T = T\left(\frac{\partial p}{\partial T}\right)_V + V\left(\frac{\partial p}{\partial V}\right)_T \tag{33}$$

Integrating with respect to volume,

$$\Delta H = \int T\left(\frac{\partial p}{\partial T}\right)_V dV + \int V\left(\frac{\partial p}{\partial V}\right)_T dV \tag{34}$$

For ideal gas, the change in enthalpy is expressed by the following equation:

$$dH = C_p dT \tag{35}$$

Therefore, the value of enthalpy for a real gas can be calculated by the expression:

$$H = H_o + \int C_p dT + \int T\left(\frac{\partial p}{\partial T}\right)_V dV + \int V\left(\frac{\partial p}{\partial V}\right)_T dV \tag{36}$$

where H_o is arbitrary enthalpy value at some initial temperature and pressure. In this particular study, H_o is designated as zero at -100°C and 0.0183 atmospheres. The first integral is enthalpy variation with temperature at constant pressure, and the second and third integrals are enthalpy departures from ideality.

The first integral is obtained by integrating the heat capacity equation (equation 26) to yield:

$$\int C_p dT = A(T - T_o) + {}^B/_2(T^2 - T_o{}^2) + {}^C/_3(T^3 - T_o^3) + {}^D/_4(T^4 - T_o{}^4) \tag{37}$$

To evaluate $T\left(\frac{\partial p}{\partial T}\right)_V$ using equation (8):

$$T\left(\frac{\partial p}{\partial T}\right)_V = \frac{TR}{V-b} + \frac{B_2T-C_2k\frac{T}{T_c}\,e^{-(kT/T_c)}}{(V-b)^2}$$

$$+\frac{B_3T-C_3k\frac{T}{T_c}\,e^{-(kT/T_c)}}{(V-b)^3} + \frac{B_5T}{(V-b)^5} \qquad (38)$$

To evaluate $V\left(\frac{\partial p}{\partial V}\right)_T$ using Equation (8):

$$V\left(\frac{\partial p}{\partial V}\right)_T = -\frac{RTV}{(V-b)^2} - 2V\frac{\left[A_2+B_2T+C_2e^{-(kT/T_c)}\right]}{(V-b)^3}$$

$$-3V\frac{\left[A_3+B_3T+C_3e^{-(kT/T_c)}\right]}{(V-b)^4} - \frac{4A_4V}{(V-b)^4}$$

$$-5V\frac{B_5T}{(V-b)^6} \qquad (39)$$

Substituting Equations (38) and (39) into Equation (34) and integrating, using boundary conditions:

$$V_2 = V;\; V_1 = \infty \quad (p = 0)$$

$$\Delta H = \frac{1}{(V-b)}\left[2A_2+(B_2+bR)T+\left(k\frac{T}{T_c}+2\right)C_2e^{-(kT/T_c)}\right]$$

$$+\frac{1}{(V-b)^2}\left[bA_2+\frac{3}{2}A_3+(B_3+bB_2)T+\left(\frac{3C_3}{2}+\frac{C_3}{2}k\frac{T}{T_c}+bC_2\right)e^{-(kT/T_c)}\right]$$

$$+\frac{1}{(V-b)^3}\left[bA_3+\frac{4}{3}A_4+bB_3T+bC_3e^{-(kT/T_c)}\right]$$

$$+\frac{1}{(V-b)^4}\left[bA_4+B_5T\right]+\frac{1}{(V-b)^5}\left[bB_5T\right] \tag{40}$$

Equations (37) and (40), therefore, are the necessary solutions for determination of enthalpy.

In similar fashion, entropy can be calculated as a function of volume and temperature,

$$S = f(V,T) \tag{41}$$

and the exact equation of the form of Equation (41) is

$$dS = \left(\frac{\partial S}{\partial V}\right)_T dV + \left(\frac{\partial S}{\partial T}\right)_V dT \tag{42}$$

Using the Maxwell relations(11),

$$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial p}{\partial T}\right)_V \tag{43}$$

Combining Equations (42) and (43),

$$dS = \left(\frac{\partial p}{\partial T}\right)_V dV + \left(\frac{\partial S}{\partial T}\right)_V dT \tag{44}$$

Integrating at constant temperature,

$$\Delta S = \int \left(\frac{\partial p}{\partial T}\right)_V dV \tag{45}$$

Accordingly, the value of entropy can be calculated by the following equation:

$$S = S_o + \int C_p dT/T + \int \left(\frac{\partial p}{\partial T}\right)_V dV \tag{46}$$

where S_o is an arbitrary entropy value designated at some base temperature and pressure. In this study, S_o is set at zero at -100°C and 0.0183 atmospheres. The first integral is the entropy variation with temperature at constant pressure, while the second integral is the entropy departure from ideality.

The first integral of Equation (46) can be solved by dividing the heat capacity equation and integrating. This yields:

$$\int C_p dT/T = A \ln\frac{T}{T_o} + B(T-T_o) + \frac{C}{2}(T^2-T_o^2) + \frac{D}{3}(T^3-T_o^3) \quad (47)$$

The second integral of Equation (46) can be evaluated using Equation (8):

$$\int_{V_1}^{V_2} \left(\frac{\partial p}{\partial T}\right)_V dV = \int_{V_1}^{V_2} \left[\frac{R}{V-b} + \frac{B_2 - C_2\frac{k}{T_c}e^{-(kT/T_c)}}{(V-b)^2} + \frac{B_3 - C_3\frac{k}{T_c}e^{-(kT/T_c)}}{(V-b)^3} + \frac{B_5 - C_5\frac{k}{T_c}e^{-(kT/T_c)}}{(V-b)^5}\right] dV \quad (48)$$

B. C.

$$V_2 = V;$$

$$V_1 = \frac{RT}{p_i}$$

Equation (48) yields:

$$\Delta S = R \ln\left(\frac{V-b}{\frac{RT}{p_i} - b}\right) - \left[B_2 - C_2\frac{k}{T_c}e^{-(kT/T_c)}\right]\left(\frac{1}{V-b} - \frac{1}{\frac{RT}{p_i} - b}\right)$$

$$- \frac{1}{2}\left[B_3 - C_3\frac{k}{3T_c}e^{-(kT/T_c)}\right]\left(\frac{1}{(V-b)^2} - \frac{1}{(\frac{RT}{p_i} - b)^2}\right)$$

$$- \frac{B_5}{4}\left[\frac{1}{(V-b)^4} - \frac{1}{(\frac{RT}{p_i} - b)^4}\right] \qquad (49)$$

Both Equations (47) and (49) are the necessary solutions of Equation (46) for evaluation of entropy.

To determine the enthalpy of vaporization the Clausius-Clapeyron equation was used:

$$\Delta H_{lg} = (\frac{dp}{dT})\ T(V_g - V_l) \qquad (50)$$

where dp/dT is the rate of pressure change with respect to temperature.

Differentiating the vapor pressure equation in the form of

$$\log p = A + B/T + CT + D\log T \qquad (51)$$

with respect to temperature there results:

$$dp/dT = 2.303p(\frac{-B}{T^2} + C + \frac{D}{2.303T}) \qquad (52)$$

In similar fashion, entropy of vaporization can be obtained by dividing the enthalpy of vaporization by the absolute temperature.

$$\Delta S_{lg} = (dp/dT)\quad (V_g - V_l) \qquad (53)$$

Enthalpy-entropy relationships can be expressed as:

$$\left(\frac{\partial H}{\partial S}\right)_p = T \tag{54}$$

Integrating at constant pressure to give

$$\Delta H = H_2 - H_1 = \Delta (TS) - \int_{T_1}^{T_2} SdT \tag{55}$$

Equation (55) is used to check the internal consistency of H-S diagram.

CALCULATION PROCEDURE

The following steps were used to calculate the thermodynamic properties of perfluoropropane:

1. An arbitrary datum point was chosen to have a zero value for both saturated vapor enthalpy and vapor entropy of perfluoropropane at -100°C and 0.0183 atmospheres.

2. Specific volume of vapor along the saturation curve and in superheated region was calculated by successive iteration using the Martin and Hou equation of state. (Equation 8)

3. Specific volume of liquid along the saturation curve to the critical temperature was calculated using the liquid density equation of Brown(4).

4. Enthalpy of vaporization along the saturation curve was calculated using the Clausius-Clapeyron equation. (Equation 50)

5. Enthalpy of saturated liquid at -100°C and 0.0183 atmospheres was taken as the negative enthalpy of vaporization at -100°C.

6. Enthalpy of vapor at temperatures above -100°C was obtained by adding the constant pressure variation of

of enthalpy with temperature to the value at -100°C.

7. Correction of enthalpy from ideality for both saturated and superheated vapor was calculated by using enthalpy departure equation. (Equation 40)

8. Enthalpy of saturated liquid was obtained by subtracting the enthalpy of vaporization from the corresponding value of vapor enthalpy.

9. Entropy of vaporization along the saturation curve was obtained by dividing the enthalpy of vaporization by its corresponding absolute temperature.

10. Entropy of saturated liquid at -100°C and 0.0183 atmospheres was taken as the negative entropy of vapor at -100°C.

11. Entropy of vapor above -100°C was obtained by adding the constant pressure variation of entropy with temperature to the value at -100°C. (Equation 47)

12. Correction of entropy from ideality for both saturated and superheated vapor was obtained by using the entropy departure equation. (Equation 48)

13. Entropy of saturated liquid above -100°C was obtained by subtracting the entropy of vaporization from the corresponding vapor entropy.

DISCUSSION

An extensive literature search on perfluoropropane was carried out prior to this particular investigation. Although Simons(18), Haszeldine(9), and Lebeau and co-worker(13) reported some physical data as far back as 1930, the results disagree with each other by ± 5%. A more comprehensive study of the physical properties of perfluoropropane was made by Brown(4) in 1963. The data used in this investigation is mainly taken from the work of Brown.

The vapor pressure equation derived from experimental data is accurate to within 0.5%. While the liquid density equation has an error of only 0.08% covering the temperature range of -50°C to 50°C, greater deviation should be expected since both sides of the range have been exceeded in this work.

The characteristic constants for the Martin and Hou equation of state were calculated by Brown(4), using the critical properties of perfluoropropane suggested by Martin and Hou(14). The numerical values of the parameters for the Benedict-Webb-Rubin equation of state were calculated in this study using the procedure suggested by Benedict and co-workers(2). Numerous steps in the calculation procedure were not clearly defined, and some judgment had to be used. Consequently, variations in values of calculated B-W-R constants are possible.

The predicted P-V-T data using the equations when compared with measured values, give the following results:

Equation of State	Range of % Dev.	Average % Dev.
Generalized	0.33 - 5.70	2.64
B-W-R	0 - 2.16	0.95
M-H	0.022- 0.56	0.22

While the Martin and Hou equation of state was chosen to predict the thermodynamic behavior of perfluoropropane in this study because of its small deviations from the actual data, it is believed that the Benedict-Webb-Rubin equation could have yielded a smaller average deviation than 0.95% if the numerical value of the constants used in the equation was calculated by digital computer using the method suggested by Brough, Schlinger and Sage(3).

The Martin and Hou equation of state was tested against actual measured thermodynamic data for CO_2, H_2O, C_6H_6, N_2, C_3H_6, H_2S and C_3H_8 by its authors. A maximum error of 1.0% was found, and usually much less, for densities up to about 1.5 times the critical density. Since the calculated values for perfluoropropane were extended to a density less than one and half times of its critical density, it is expected that the predicted thermodynamic behavior is accurate within 1.0%.

The heat capacity equation was derived from data for a temperature range from -30°C to 90°C. Extrapolation to lower temperatures would probably introduce some error. Generalized methods for estimating heat capacity using statistical theory are not recommended below 250°K. Heat capacity calculations made at -100°C using various equations yielded results agreeing with each other within 10%. In order to keep the internal consistency, the derived equation (Equation 26) was used throughout the entire temperature range in this paper. Application of the data outside the experimental temperature range should be pursued with caution.

Fundamental thermodynamic relationships are usually employed to check the internal consistency of enthalpy-entropy values. Using the method suggested by Kang and McKetta(12), five values of enthalpy change were calculated and compared by means of Equation (55). Table V in the Appendix indicates that the thermodynamic properties of perfluoropropane evaluated in this work are internally consistent.

This investigation is the basis for the compilation of thermodynamic tables for perfluoropropane. The calculations were made by an IBM 7074 digital computer using a program devised by Eichenbaum(8). Recognizing the fact that some small deviations from actual values exist, it is the author's opinion that the information presented herein is well within engineering accuracy and should therefore find useful application.

APPENDIX

NOMENCLATURE

A	General constant (Heat Capacity Equation)
A	Work content
$\tilde{A}$	Residual work content
A_o	Characteristic constant (Benedict-Webb-Rubin Equation of State)
A_2	Characteristic constant (Martin and Hou Equation of State)
A_3	Characteristic constant (Martin and Hou Equation of State)
A_4	Characteristic constant (Martin and Hou Equation of State)
a	Characteristic constant (Benedict-Webb-Rubin Equation of State)
B	General constant (Heat Capacity Equation)
B_o	Characteristic constant (Benedict-Webb-Rubin Equation of State)
B_2	Characteristic constant (Martin and Hou Equation of State)
B_3	Characteristic constant (Martin and Hou Equation of State)
B_5	Characteristic constant (Martin and Hou Equation of State)
b	Characteristic constant (Martin and Hou Equation of State)

b	Characteristic constant (Benedict-Webb-Rubin Equation of State)
C	General constant (Heat Capacity Equation)
C_o	Characteristic constant (Benedict-Webb-Rubin Equation of State)
C_2	Characteristic constant (Martin and Hou Equation of State)
C_3	Characteristic constant (Martin and Hou Equation of State)
C_p°	Ideal heat capacity at constant pressure
c	Characteristic constant (Benedict-Webb-Rubin Equation of State)
D	General constant (Heat Capacity Equation)
$D(\rho_r,T_r)$	Correction term (Generalized Equation of State)
d	Density
d_L	Liquid density
e	Base of natural logarithm, 2.7183
f	Function
$f_2(T_c)$	Temperature function evaluated at T_c (Martin and Hou Equation of State)
$f_3(T_c)$	Temperature function evaluated at T_c (Martin and Hou Equation of State)
$f_4(T_c)$	Temperature function evaluated at T_c (Martin and Hou Equation of State)

$f_5(T_c)$	Temperature function evaluated at T_c (Martin and Hou Equation of State)
$g(\rho_r)$	Density function (Generalized Equation of State)
H	Enthalpy
H_o	Enthalpy evaluated at base temperature and pressure
ΔH_{lg}	Enthalpy of vaporization
ΔH	Change in enthalpy
J	Conversion factor, 0.0413 liter-atm/g-mole
k	5.475
log	Common logarithm
ln	Natural logarithm
M	Slope of reduced vapor pressure curve at critical point
m	Slope of the critical isometric on P-T diagram
P	Pressure
P_c	Critical pressure
P_r	Reduced pressure
p	Pressure
p_i	Pressure at which gas is assumed to be ideal, 0.0001 psia or $0.6803x10^{-5}$ atm.
R	Gas constant, 0.08205 liter-atm/g-mole °K
S	Entropy
S_o	Entropy evaluated at base temperature and pressure
ΔS_{lg}	Entropy of vaporization
s	Characteristic constant (Generalized Equation of State)

T	Temperature
T^1	Temperature for which slope of isotherm at $P = 0$ on compressibility chart equals slope of line joining critical point and $(Z=1, P_r=0)$
T_B	Boyle temperature
T_c	Critical temperature
T_o	Base temperature
Tr	Reduced temperature
t	Temperature
V	Volume
V	Viscosity
V_c	Critical volume
V_g	Vapor specific volume
V_1	Liquid specific volume
$w_1(T_r)$	Temperature function (Generalized Equation of State)
$w_2(T_r)$	Temperature function (Generalized Equation of State)
Z	Compressibility factor
Z_c	Critical compressibility factor
α	Characteristic constant (Benedict-Webb-Rubin Equation of State)
β	Characteristic constant (Martin and Hou Equation of State)

β	Critical compressibility factor function (Generalized Equation of State)
γ	Characteristic constant (Benedict-Webb-Rubin Equation of State)
ρ	Density
ρ_r	Reduced density

SAMPLE CALCULATIONS

1. Determine the specific volume of saturated liquid and vapor at 0°C and 4.1099 atmospheres.

   a) Liquid density $= 1.4531 - 4.5363\text{x}10^{-3}(0)$

   $- 2.1518\text{x}10^{-5}(0) - 2.1174\text{x}10^{-7}(0)^3 = 1.4531$ g/cc

   $= 7.728$ g-mole/liter

   Liquid volume $= 0.129392$ liters/g-mole

   b) Vapor volume: from Equation (8)

$$P = \frac{0.08205(273.16)}{(V-0.05332833)} - \frac{15.126979+0.014656016(273.16) - (385.33552)e^{-5.475(\frac{273.16}{345.06})}}{(V-0.05332833)^2}$$

$$+ \frac{1.7276043+0.34736373\text{x}10^{-3}(273.16)+104.35258e^{-5.475(\frac{273.16}{345.06})}}{(V-0.05332833)^3}$$

$$- \frac{0.20515732}{(V-0.05332833)^4} + \frac{1.8182426\text{x}10^{-5}(273.16)}{(V-0.05332833)^5}$$

   By successful trials $V = 4.69484$ liters/g-mole

2. Determine enthalpy of saturated liquid and vapor at 0°C and 4.1099 atmospheres.

   a) From definition of H_o

   $H_o = 0$ at -100°C and 0.0183 atmospheres

   b) Vapor volume at -100°C and 0.0183 atmospheres can be calculated using Equation (8) with successive trials

$V = 773.84863$ liters/g-mole

c) Enthalpy departure from ideality at -100°C is calculated from Equation (40)

$$\Delta H = \frac{1}{(773.84863-0.05332833)} \Bigg\{ 2(-15.126979)$$

$$+ \Big[0.014656016+(0.05332833)(0.08205) \Big] (173.16)$$

$$+ \Big[(5.475)\left(\frac{173.16}{345.06}\right)+2 \Big] (-385.33552)\, e^{-(5.475)\left(\frac{173.16}{345.06}\right)} \Bigg\}$$

$$+ \frac{1}{(773.84863-0.05332833)^{2}} \Bigg\{ (0.05332833)(-15.126979)$$

$$+ \frac{3}{2}(1.7276043) + \Big[(0.34736373\times 10^{-3}) + (0.05332833)$$

$$(0.014656016) \Big] (173.16) + \Big[\frac{3}{2}(104.35258)$$

$$+ \left(\frac{104.35258}{2}\right)(5.475)\left(\frac{173.16}{345.06}\right) + (0.05332833)$$

$$(-385.33552) \Big]\, e^{-(5.475)\left(\frac{173.16}{345.06}\right)} \Bigg\}$$

$$+ \frac{1}{(773.84863-0.05332833)^{3}} \Bigg\{ (0.05332833)(1.7276043)$$

$$+ \frac{4}{3}(-0.20515732) + (0.05332833)(0.34736373\times 10^{-3})(173.16)$$

$$+ (0.05332833)(104.35258)\, e^{-(5.475)\left(\frac{173.16}{345.06}\right)} \Bigg\}$$

$$+ \frac{1}{(773.84863-0.05332833)^{4}} \Big[(0.05332833)(-0.20515732)$$

$$+ (1.8182426\times10^{-5})(173.16)\Big]$$

$$+ \frac{1}{(773.84863-0.05332833)^5}\Big[(0.05332833)(1.8182426\times10^{-5})$$

$$(173.16)\Big]$$

$\Delta H = -0.1863$ liter-atm/g-mole

$= -4.51$ cal/g-mole

d) Ideal enthalpy change from -100°C to 0°C can be calculated using Equation (26)

$$\int_{T}^{T_2} C_p dT = 3.0911305T + 0.07429435T^2$$

$$-0.05103\times10^{-3} + 1.432303525\times10^{-8}T^4 \Bigg|_{173.16}^{273.16}$$

$\Delta H = 2916.7342$ cal/g-mole

e) Enthalpy departure from ideality at 0°C can be calculated using Equation (40)

$$\Delta H = \frac{1}{(4.69484-0.05332833)}\Bigg\{2(-15.126979)$$

$$+\Big[0.014656016+(0.05332833)(0.08205)\Big](273.16)$$

$$+\Big[(5.475)(\tfrac{273.16}{345.06})+2\Big](-385.33552)e^{-(5.475)(\frac{273.16}{345.06})}\Bigg\}$$

$$+\frac{1}{(4.69484-0.05332833)^2}\Bigg\{(0.05332833)(-15.126979)$$

$$\frac{3}{2}(1.7276043)+\Big[(0.34736373\times10^{-3})+(0.05332833)$$

$$(0.014656016)\Big](273.16)+\Big[\frac{3}{2}(104.35258)$$

$$+\left(\frac{104.35258}{2}\right)\left(\frac{273.16}{345.06}\right)(5.475)+(0.05332833)$$

$$(-385.33552)\Big]e^{-(5.475)\left(\frac{273.16}{345.06}\right)}\Big\}$$

$$+\frac{1}{(4.69484-0.05332833)^{3}}\Big\{(0.05332833)(1.7276043)$$

$$+\frac{4}{3}(-0.20515732)+(0.05332833)(0.34736373\times10^{-3})$$

$$(273.16)+(0.05332833)(104.35258)e^{-(5.475)\left(\frac{273.16}{345.06}\right)}\Big\}$$

$$+\frac{1}{(4.69484-0.05332833)^{4}}\Big\{(0.05332833)(-0.20515732)$$

$$+(1.8182426\times10^{-5})(273.16)\Big\}$$

$$+\frac{1}{(4.69484-0.05332833)^{5}}\Big[(0.05332833)(1.8182426\times10^{-5})(273.16)\Big]$$

ΔH = -11.977 liter-atm/g-mole

= -289.9142 cal/g-mole

f) Vapor enthalpy at 0°C and 4.1099 atmospheres

H = 2916.7342 + 4.51 - 289.9142

= 2631.33 cal/g-mole

g) Enthalpy of vaporization at 0°C and 4.1099 atm.

ΔH_{lg} = (0.1354)(273.16)(4.69484-0.129392)

= 168.857 liter-atm/g-mole

= 4087.384 cal/g-mole

h) Liquid enthalpy at 0°C and 4.1099 atmospheres

$H = 2631.33 - 4087.384$

$= -1456.054$ cal/g-mole

3. Determine entropy of saturated liquid and vapor at 0°C and 4.1099 atmospheres

a) From definition of S_o

$S_o = 0$ at -100°C and 0.0183 atmospheres

b) Entropy departure from ideality at -100°C is calculated from Equation (49)

$$\Delta S = 0.08205\ln\left(\frac{773.84863-0.05332833}{\frac{(0.08205)(173.16)(14.7)}{(0.0001)} - 0.05332833}\right)$$

$$- \left[(0.014656016)+(385.33552)\left(\frac{5.475}{345.06}\right)e^{-(5.475)\left(\frac{173.16}{345.06}\right)}\right]$$

$$\left[\frac{1}{(773.84863-0.05332833)} - \frac{1}{\frac{(0.08205)(173.16)(14.7)}{(0.0001)} - 0.05332833}\right]$$

$$- \frac{1}{2}\left\{(0.34736373\times10^{-3})-(104.35258)\left(\frac{5.475}{345.06}\right)e^{-(5.475)\left(\frac{173.16}{345.06}\right)}\right\}$$

$$\left\{\frac{1}{(773.84863-0.05332833)^2} - \frac{1}{\left[\frac{(0.08205)(173.16)(14.7)}{0.0001} - 0.05332833\right]^2}\right\}$$

$$- \frac{1}{4}\left\{(1.8182426\times10^{-5})\right\}\left\{\frac{1}{(773.84863-0.05332833)^4}\right.$$

$$\left. - \frac{1}{\left[\frac{(0.08205)(173.16)(14.7)}{0.0001} - 0.05332833\right]^4}\right\}$$

$$\Delta S = -0.648364 \text{ liter-atm/g-mole °K}$$

$$= -15.699 \text{ cal/g-mole °K}$$

c) Ideal entropy change from -100°C to 0°C can be calculated from Equation (47)

$$\Delta S = \int_{T_1}^{T_2} C_p dT/T = 3.0911306 \ln T + 0.1485887\, T - 0.076545\text{x}10^{-3}T^2 + 1.909738033\text{x}10^{-8}T^3 \Bigg|_{173.16}^{273.16}$$

$$= 13.141923 \text{ cal/g-mole °K}$$

d) Entropy departure from ideality at 0°C & 4.1099 atmospheres can be calculated from Equation (49)

$$\Delta S = 0.08205 \ln \left(\frac{4.69484-0.05332833}{\frac{(0.08205)(273.16)(14.7)}{0.0001} - 0.05332833} \right)$$

$$- \left[(0.014656016)+(385.33552)\left(\frac{5.475}{345.06}\right) e^{-(5.475)\left(\frac{273.16}{345.06}\right)} \right]$$

$$\left[\frac{1}{(4.69484-0.05332833)} - \frac{1}{\frac{(0.08205)(273.16)(14.7)}{(0.0001)} -(0.05332833)} \right]$$

$$- \frac{1}{2} \left\{ (0.34736373\text{x}10^{-3})-(104.35258)\left(\frac{5.475}{345.06}\right) e^{-(5.475)\left(\frac{273.16}{345.06}\right)} \right\}$$

$$\left\{ \frac{1}{(4.69484-0.05332833)^2} - \frac{1}{\frac{(0.08205)(273.16)(14.7)}{(0.0001)} -(0.05332833)} \right\}^2$$

$$- \frac{1}{4} \left[1.8182426\text{x}10^{-5} \right] \left\{ \frac{1}{(4.69484-0.05332833)^4} \right.$$

$$\left. - \frac{1}{\left[\frac{(0.08205)(273.16)(14.7)}{(0.0001)} - (0.05332833) \right]^4} \right\}$$

$\Delta S = -1.1254$ liter-atm/g-mole °K

$= -27.2410$ cal/g-mole °K

e) Vapor entropy at 0°C and 4.1099 atmospheres

$S = 15.7 + 13.141923 - 27.241$

$= 1.603$ cal/g-mol °K

f) Entropy of vaporization at 0°C and 4.1099 atmospheres

$\Delta S_{1g} = (0.1354)(4.69484-0.129392)$

$= 0.6181659$

$= 14.963331$ cal/g-mole °K

g) Liquid entropy at 0°C and 4.1099 atmospheres

$S = 1.603 - 14.963331$

$= -13.3603$ cal/g-mole °K

4. Determine enthalpy and entropy of superheated vapor at 100°C and 10 atmospheres.

   a) Specific volume of vapor is calculated from Equation (8) as in Example 1 (b) for saturated vapor.

   b) Enthalpy of superheated vapor is calculated from Equations (26) and (40) same as for enthalpy of saturated vapor shown in Example 2 (a), (b), (c), (d) and (e).

   c) Entropy of superheated vapor is calculated from Equations (47) and (49) same as for saturated vapor shown in Example 3 (a), (b), (c), (d) and (e).

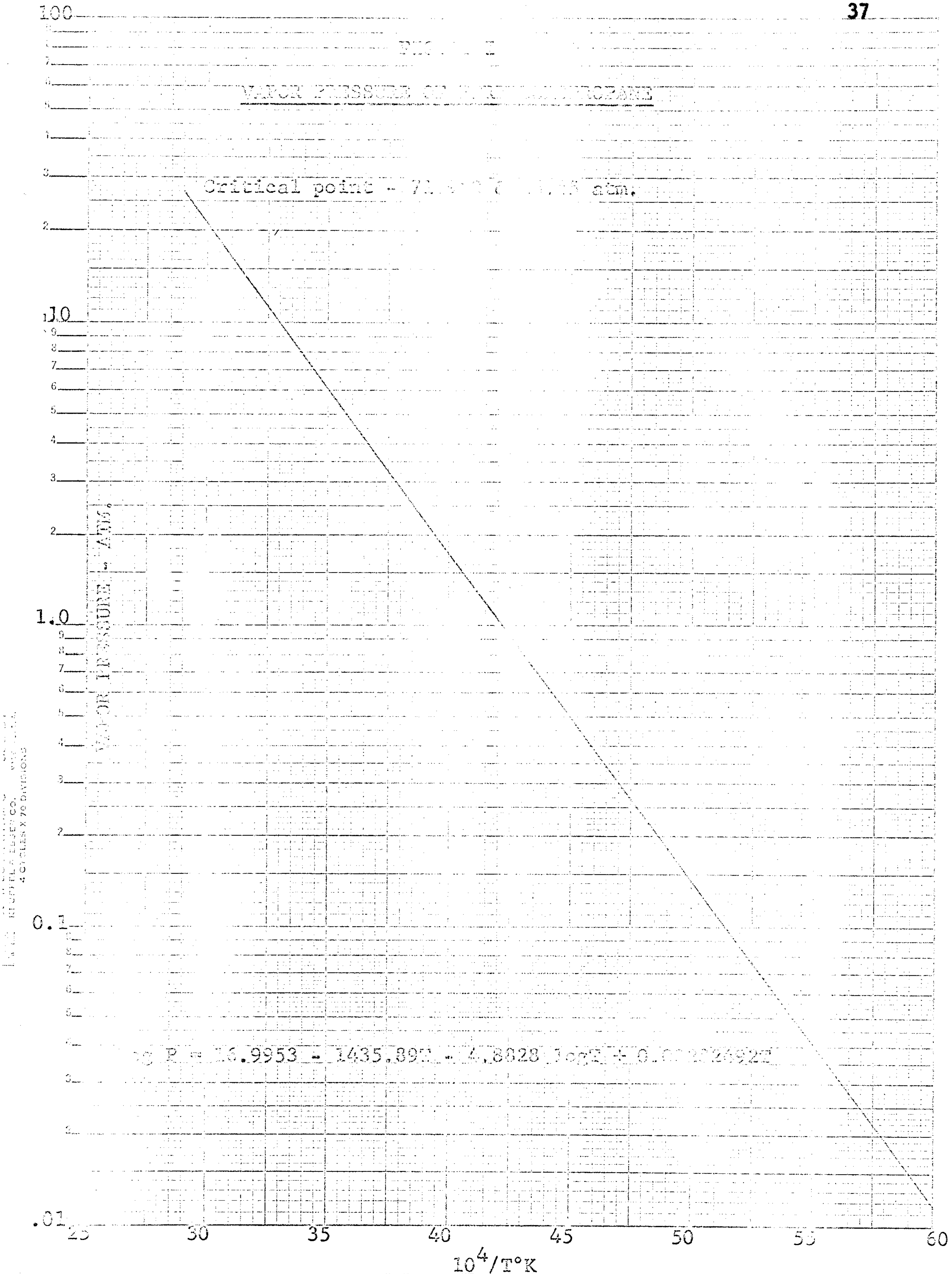
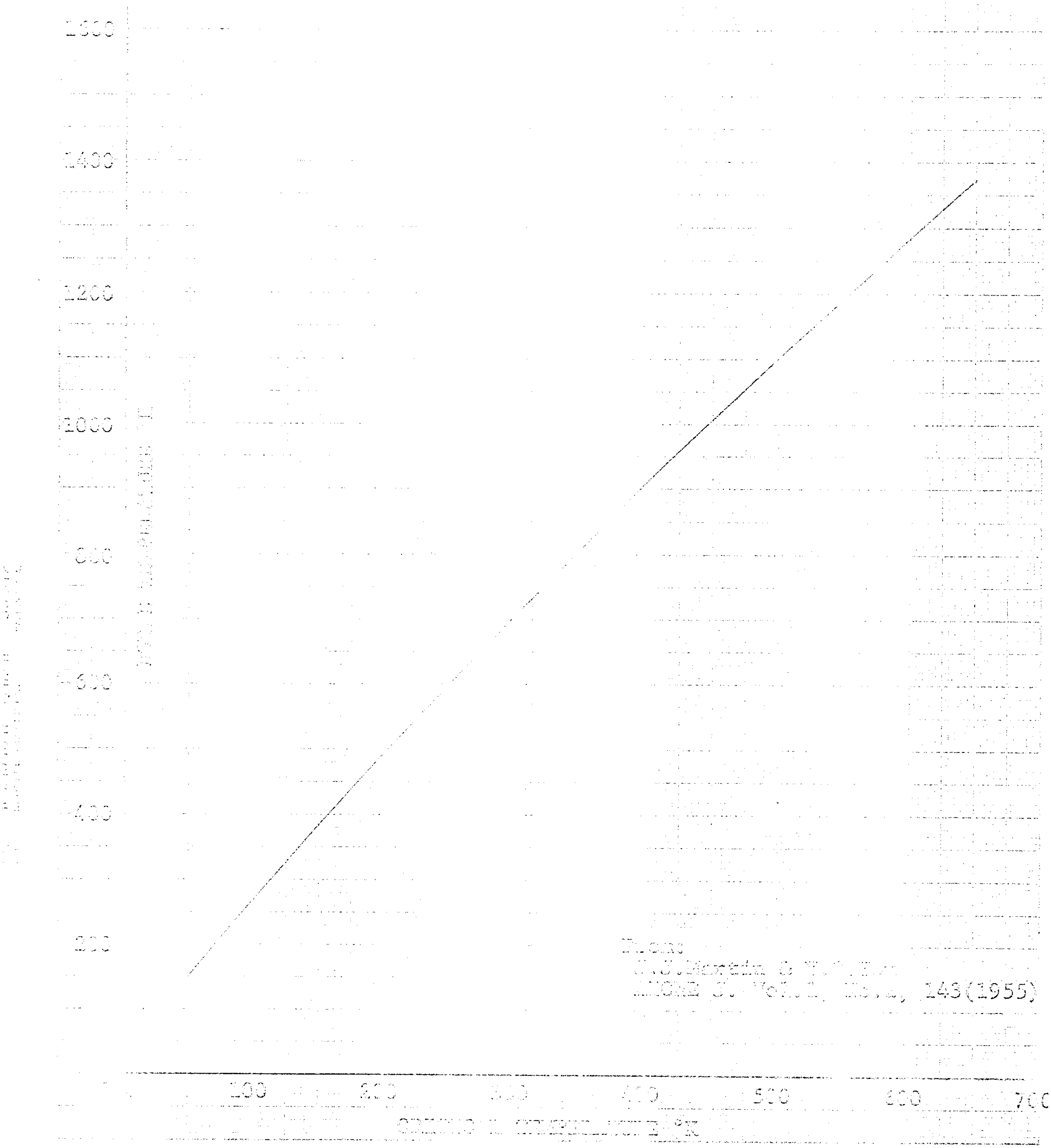


FIG. [illegible] I

VAPOR PRESSURE OF [illegible] PROPANE

[illegible] TEMPERATURE



From:
[illegible]
AIChE J. Vol. 1, No. 2, 143(1955)

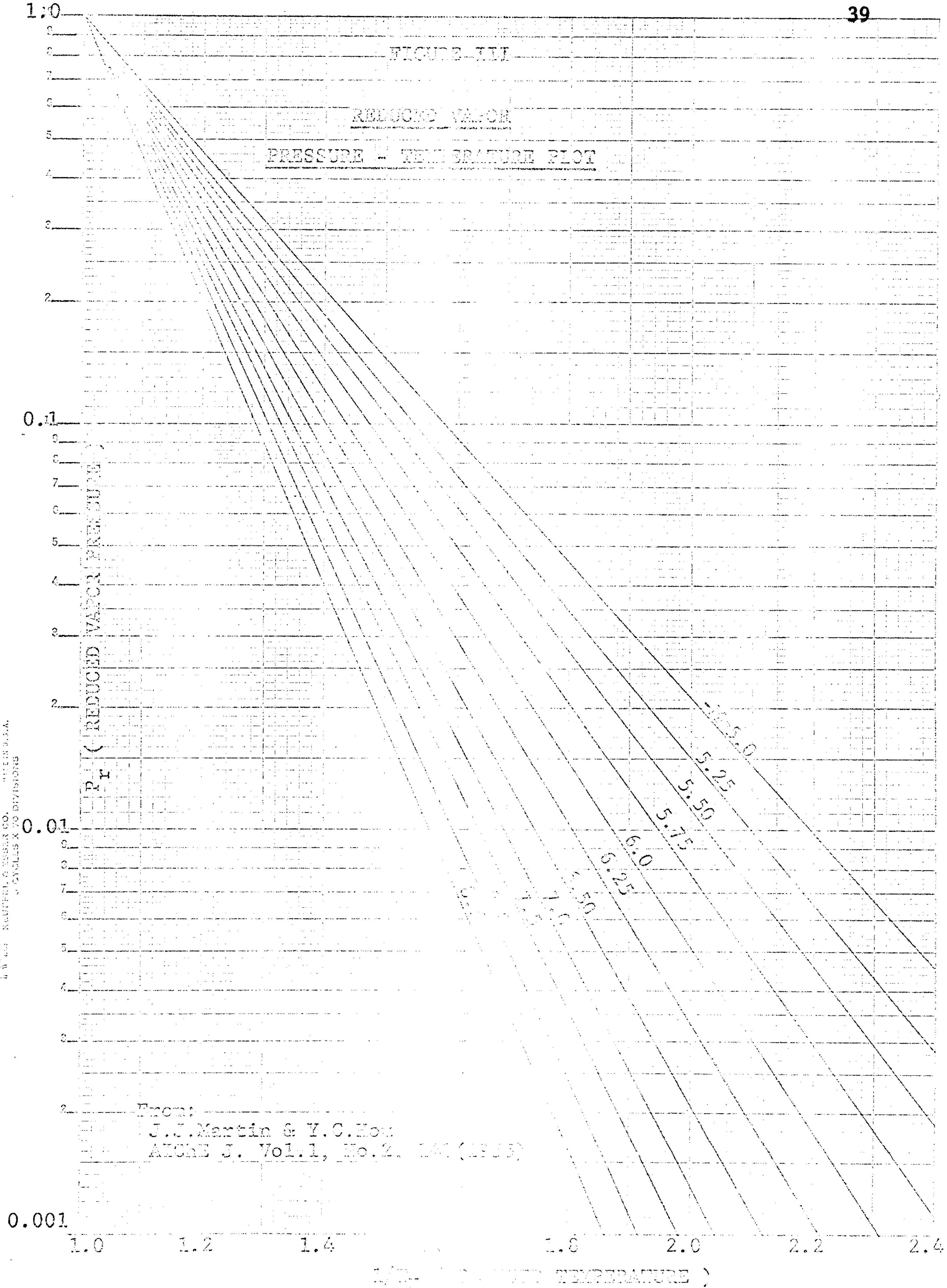


FIGURE III

REDUCED VAPOR PRESSURE - TEMPERATURE PLOT

From:
J.J.Martin & Y.C.Hou
AIChE J. Vol.1, No.2. 142(1955)

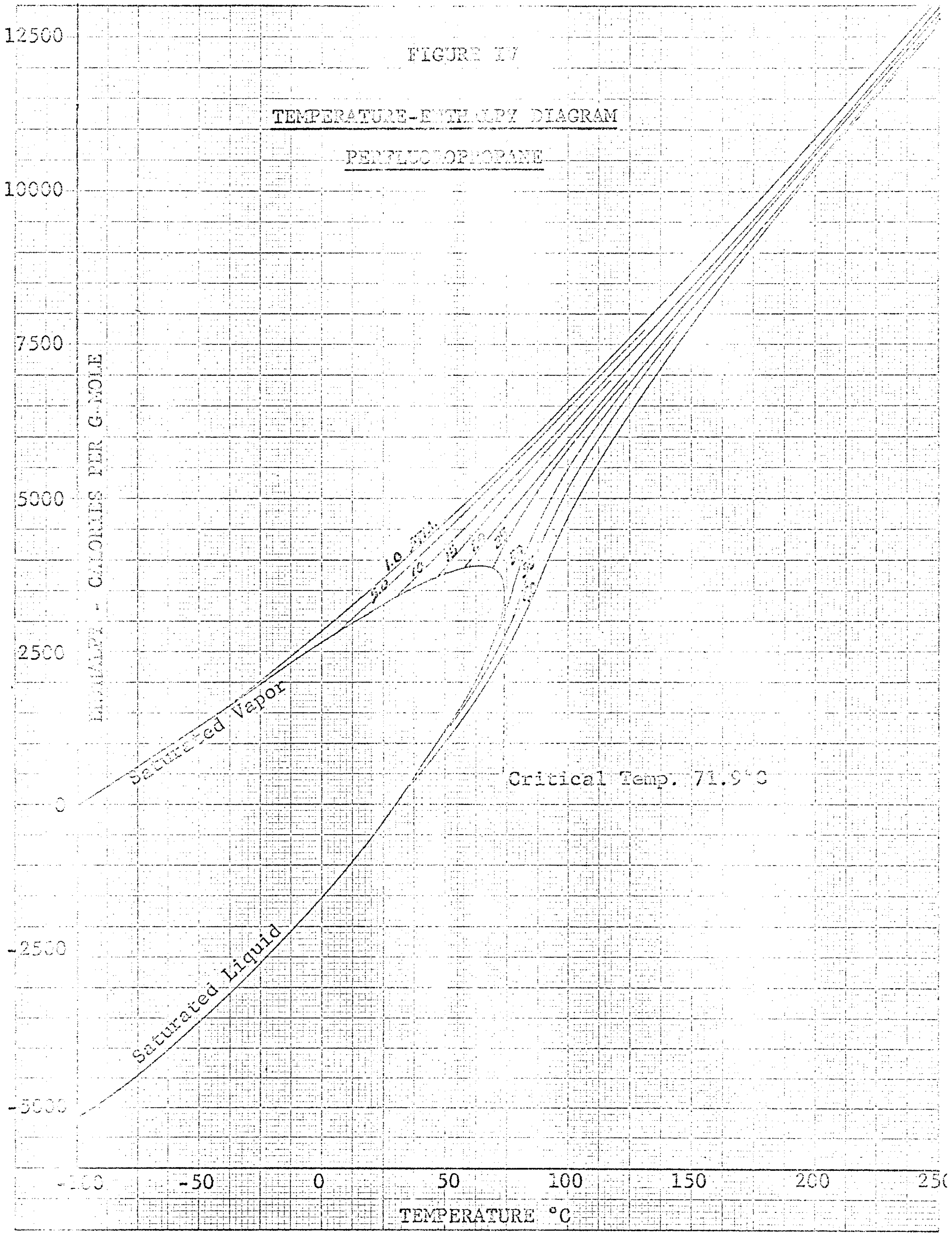


FIGURE IV

TEMPERATURE-ENTHALPY DIAGRAM

PERFLUOROPROPANE

FIGURE V

TEMPERATURE-ENTROPY DIAGRAM

PERFLUOROPROPANE

TABLE I

PHYSICAL PROPERTIES OF PERFLUOROPROPANE

Chemical Formula	C_3F_8
Molecular Weight	188.02
Normal Boiling Point	-36.7°C
Normal Freezing Point	-160°C
Critical Temperature	71.9°C
Critical Pressure	26.45 Atmospheres
Critical Volume	0.299 liter/g-mole
Heat of Vaporization @ b.p.	4690 cal/g-mole
Thermal Conductivity @ 70°F	3.6×10^{-5} cal/sec.cm^2°C/cm

Liquid Density

$$d_L\ (\text{gm/cc}) = 1.4531 - 4.5363\times10^{-3}t - 2.1518\times10^{-5}t^2 - 2.1174\times10^{-7}t^3 \qquad t = {}^\circ\text{C}$$

Vapor Pressure

$$\text{Log } P(\text{atm}) = 16.9953 - 1435.89T - 4.8828 \log T + 0.00282492T \qquad T = {}^\circ\text{K}$$

Heat Capacity

$$C_p{}^\circ(\text{cal/g-mole }{}^\circ\text{K}) = 3.0911305 + 0.1485887T - 0.15390\times10^{-3}T^2 + 5.7292141\times10^{-8}T^3 \qquad T = {}^\circ\text{K}$$

Theoretical Vapor Viscosity

$$V\ (\text{cp}) = 10.32\times10^{-4}\sqrt{T} \qquad T = {}^\circ\text{K}$$

TABLE II

CONSTANTS EVALUATED FOR BENEDICT-WEBB-RUBIN EQUATION OF STATE

$$P = \frac{RT}{V} + (B_oRT - A_o - C_o/T^2)\ /V^2 + (bRT - a)/V^3$$

$$+ a\alpha/V^6 + (c/V^3T^2)(1 + \gamma/V^2)^{-\gamma/V^2}$$

$A_o = 4.0739$

$a = 4.3497$

$B_o = 0.108688$

$b = 0.0765592$

$C_o = 110.3093 \times 10^4$

$c = 39.7196 \times 10^4$

$\alpha = 0.004$

$\gamma = 0.065$

Units: Atm.; liter; g-mole; °K

TABLE III

CONSTANTS FOR MARTIN AND HOU EQUATION OF STATE

$$P = \frac{-RT}{V-b} + \frac{A_2 + B_2T + C_2e^{-kT/T_c}}{(V-b)^2} + \frac{A_3 + B_3T + C_3e^{-kT/T_c}}{(V-b)^3} + \frac{A_4}{(V-b)^4} + \frac{B_5T}{(V-b)^5}$$

$b = 0.05332833$

$A_2 = -15.126979$

$B_2 = 0.014656016$

$C_2 = -385.33552$

$A_3 = 1.7276043$

$B_3 = 0.34736373 \times 10^{-3}$

$C_3 = 104.35258$

$A_4 = -0.20515732$

$B_5 = 1.8182426 \times 10^{-5}$

Units: atm.; liter; g-mole; °K

TABLE IV

COMPARISON OF OBSERVED P-V-T DATA* WITH THOSE CALCULATED FROM EQUATION OF STATE

Volume Liter/Mole	Temp. °C	Pressure - Atmospheres			
		Obsd.	M-H dev.	B-W-R dev.	Generalized dev.
0.30389	74.63	28.03	+0.02	+0.21	+0.23
	84.90	33.94	+0.06	-0.23	+0.63
	94.56	39.55	+0.10	-0.34	+1.17
	103.72	44.76	-0.01	-0.55	+1.29
	114.74	51.27	+0.08	-0.56	+2.30
	125.98	57.88	+0.10	-0.60	+1.04
0.33301	73.12	27.01	-0.07	+0.15	-0.09
	81.51	31.37	-0.05	+0.16	+0.46
	94.74	38.20	-0.04	+0.17	+1.18
	109.49	45.66	-0.15	+0.05	+1.85
	112.65	47.33	-0.10	+0.10	+2.08
	132.44	57.35	-0.22	+0.00	+3.02
0.39177	74.56	27.39	-0.12	+0.57	+0.40
	80.73	30.07	-0.06	+0.66	+0.34
	86.01	32.31	-0.04	+0.70	+0.65
	89.05	33.56	-0.07	+0.68	+0.77
	102.06	39.03	+0.01	+0.78	+1.48
	117.60	45.27	-0.09	+0.67	+2.05
	149.04	57.93	-0.02	+0.66	+3.31

Volume Liter/Mole	Temp. °C	Pressure - Atmospheres			
		Obsd.	M-H dev.	B-W-R dev.	Generalized dev.
0.50104	92.90	31.99	-0.06	+0.33	+0.57
	107.13	36.22	-0.01	+0.28	+1.10
	130.16	42.86	+0.05	+0.49	+1.76
	166.24	53.08	+0.30	+0.11	+2.69
1.00120	59.82	17.78	-0.01	+0.18	+0.30
	82.58	20.65	+0.04	+0.05	-0.11
	102.11	22.97	+0.05	-0.09	+0.11
	120.94	25.20	+0.13	-0.15	-0.28
	135.46	26.88	+0.19	-0.20	+0.46

* Experimental data from Brown(4)

TABLE V

INTERNAL CONSISTENCY CHECK FOR ENTHALPY AND ENTROPY VALUES

Pressure, Atm.	40	30	20	10	1
Temp. 1, °K	373.16	373.16	373.16	373.16	373.16
Temp. 2, °K	473.16	473.16	473.16	473.16	473.16
Entropy 1	5.51063	7.71620	9.53012	11.59477	16.4748
Entropy 2	18.49634	19.34159	20.41063	22.03568	26.8182
T_1S_1	2056.3467	2879.377	3556.2596	4326.704	6212.174
T_2S_2	8751.728	9151.666	9657.4937	10426.402	12689.304
$\Delta(TS)$	6695.381	6272.290	6101.234	6099.700	6477.13
$\int Sdt$*	1262.334	1384.000	1514.000	1700.667	2191.667
ΔH	5433.047	4888.290	4587.234	4399.033	4285.46
H_1(table)	4842.6261	5548.9127	6012.0464	6348.0586	6593.6418
H_2(Eq. 55)	10275.6731	10437.2027	10599.2805	10747.0916	10879.1018
H_2(table)	10267.0790	10433.401	10596.1670	10752.6020	10886.9920
ΔH_2	8.5941	3.8017	3.11349	5.5104	7.8902
% dev.	0.084	0.036	0.029	0.051	0.072

* Graphical method using Simpson's rule(5)

TABLE VI

THERMODYNAMIC PROPERTIES OF SATURATED PERFLUOROPROPANE

Temperature °C	Pressure Atm Absolute	Specific Volume Liter/GMole	
		Liquid	Vapor
-100.00	0.0183	0.098787	773.84863
-95.00	0.0281	0.100471	517.87708
-90.00	0.0421	0.102105	354.80764
-85.00	0.0616	0.103692	248.63003
-80.00	0.0882	0.105233	177.82506
-75.00	0.1239	0.106732	129.49229
-70.00	0.1709	0.108192	95.92254
-65.00	0.2318	0.109620	72.17430
-60.00	0.3095	0.111021	55.09950
-55.00	0.4074	0.112403	42.61537
-50.00	0.5291	0.113773	33.36480
-45.00	0.6787	0.115141	26.41407
-40.00	0.8606	0.116517	21.12422
-35.00	1.0795	0.117911	17.05606
-30.00	1.3404	0.119337	13.89273
-25.00	1.6489	0.120807	11.40579
-20.00	2.0104	0.122336	9.43401
-15.00	2.4311	0.123941	7.85450
-10.00	2.9169	0.125638	6.58065

Temperature °C	Pressure Atm Absolute	Specific Volume Liter/GMole	
		Liquid	Vapor
-5.00	3.4743	0.127448	5.54432
0.00	4.1099	0.129392	4.69484
5.00	4.8303	0.131496	3.99321
10.00	5.6425	0.133787	3.41020
15.00	6.5534	0.136296	2.92239
20.00	7.5701	0.139061	2.51124
25.00	8.6996	0.142123	2.16304
30.00	9.9491	0.145534	1.86583
35.00	11.3259	0.149354	1.61065
40.00	12.8369	0.153653	1.39008
45.00	14.4895	0.158520	1.19790
50.00	16.2906	0.164063	1.02897
55.00	18.2475	0.170419	0.87863
60.00	20.3671	0.177759	0.74257
65.00	22.6564	0.186310	0.61617
70.00	25.1223	0.196367	0.49299

Temperature °C	Enthalpy Cal/GMole		
	Liquid	Latent	Vapor
-100.00	-5189.124	5189.124	0.000
-95.00	-5013.778	5135.780	122.002
-90.00	-4943.775	5189.655	245.880
-85.00	-4835.370	5206.951	371.580
-80.00	-4653.370	5151.939	498.879
-75.00	-4461.469	5089.107	627.638
-70.00	-4284.003	5041.717	757.714
-65.00	-4122.051	5011.004	888.953
-60.00	-3915.672	4936.880	1021.208
-55.00	-3738.703	4893.018	1154.315
-50.00	-3561.524	4849.658	1288.135
-45.00	-3370.601	4793.111	1422.510
-40.00	-3173.482	4730.765	1557.283
-35.00	-2975.221	4667.545	1692.324
-30.00	-2777.280	4604.764	1827.484
-25.00	-2565.711	4528.297	1962.586
-20.00	-2353.360	4450.856	2097.496
-15.00	-2135.117	4367.114	2231.991
-10.00	-1914.534	4280.490	2365.956

Temperature °C	Enthalpy Cal/GMole		
	Liquid	Latent	Vapor
-5.00	-1688.600	4187.745	2499.145
0.00	-1456.054	4087.384	2631.330
5.00	-1216.031	3978.249	2762.218
10.00	-973.354	3864.889	2891.535
15.00	-722.095	3740.989	3018.895
20.00	-465.357	3609.136	3143.780
25.00	-201.277	3466.999	3265.722
30.00	71.334	3312.564	3383.898
35.00	352.660	3144.756	3497.416
40.00	642.357	2962.685	3605.042
45.00	942.593	2762.426	3705.019
50.00	1253.622	2541.202	3794.823
55.00	1578.623	2291.911	3870.534
60.00	1917.972	2007.365	3925.337
65.00	2274.140	1672.400	3946.540
70.00	2644.838	1260.311	3905.149

Temperature °C	Entropy Cal/GMole-C		
	Liquid	Latent	Vapor
-100.00	-29.967223	29.967223	0.00000
-95.00	-28.980680	28.826786	-0.15389
-90.00	-28.600691	28.333998	-0.26669
-85.00	-28.013331	27.672997	-0.34033
-80.00	-27.051001	26.671872	-0.37913
-75.00	-26.069905	25.681808	-0.38810
-70.00	-25.185561	24.816485	-0.36908
-65.00	-24.397934	24.072848	-0.32509
-60.00	-23.418809	23.160442	-0.25837
-55.00	-22.607829	22.428575	-0.17925
-50.00	-21.799233	21.731754	-0.06748
-45.00	-20.954710	21.007676	0.05297
-40.00	-20.102612	20.289778	0.18717
-35.00	-19.264056	19.598357	0.33430
-30.00	-18.444428	18.937177	0.49275
-25.00	-17.586752	18.247490	0.66074
-20.00	-16.743742	17.581198	0.83746
-15.00	-15.895238	16.916306	1.02107
-10.00	-15.054645	16.265730	1.21108

Temperature °C	Entropy Cal/GMole-C		
	Liquid	Latent	Vapor
-5.00	-14.210542	15.616591	1.40605
0.00	-13.358541	14.963331	1.60479
5.00	-12.496124	14.302015	1.80589
10.00	-11.640721	13.649135	2.00841
15.00	-10.771480	12.982333	2.21085
20.00	-9.899904	12.311147	2.41124
25.00	-9.019619	11.627981	2.60836
30.00	-8.127383	10.926783	2.79940
35.00	-7.223102	10.204946	2.98184
40.00	-6.308429	9.460612	3.15218
45.00	-5.377080	8.682506	3.30542
50.00	-4.428917	7.863602	3.43468
55.00	-3.455348	6.984126	3.52878
60.00	-2.456116	6.025229	3.56911
65.00	-1.425076	4.945586	3.54051
70.00	-0.370376	3.672664	3.30229

TABLE VII

THERMODYNAMIC PROPERTIES OF SUPERHEATED PERFLUOROPROPANE

Pressure = 1.000 Atmospheres

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
-35.00	18.49861	1700.7313	0.51425
-30.00	18.97461	1861.3651	1.18171
-25.00	19.44494	2023.5092	1.84177
-20.00	19.90986	2187.1977	2.49482
-15.00	20.36998	2352.4590	3.14126
-10.00	20.82581	2519.3150	3.78141
-5.00	21.27599	2687.7751	4.41539
0.00	21.72481	2857.8627	5.04385
5.00	22.17059	3029.5781	5.66681
10.00	22.61359	3202.9239	6.28449
15.00	23.05407	3377.9002	6.89705
20.00	23.49230	3554.5053	7.50469
25.00	23.92848	3732.7337	8.10752
30.00	24.36282	3912.5797	8.70572
35.00	24.79547	4094.0345	9.29940
40.00	25.22660	4277.0888	9.88866
45.00	25.65635	4461.7317	10.47362

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
50.00	26.08484	4647.9207	11.05438
55.00	26.51218	4835.7335	11.63102
60.00	26.93847	5025.0654	12.20362
65.00	27.36380	5215.9324	12.77227
70.00	27.78825	5408.3191	13.33703
75.00	28.21188	5602.2599	13.89798
80.00	28.63477	5797.5883	14.45516
85.00	29.05699	5994.4380	15.00865
90.00	29.47856	6192.7418	15.55850
95.00	29.89957	6392.4821	16.10476
100.00	30.32003	6593.6418	16.64748
105.00	30.74000	6796.2029	17.18671
110.00	31.15952	7000.1476	17.72248
115.00	31.57860	7205.4577	18.26486
120.00	31.99730	7412.1151	18.78386
125.00	32.41562	7620.1009	19.30954
130.00	32.83361	7829.3977	19.83194
135.00	33.25127	8039.9878	20.35108
140.00	33.66864	8251.8517	20.86700
145.00	34.08573	8464.9718	21.37973

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
150.00	34.50257	8679.3281	21.88931
155.00	34.91916	8894.9058	22.39578
160.00	35.33552	9111.6823	22.89986
165.00	35.75167	9329.6437	23.39946
170.00	36.16762	9548.7692	23.89673
175.00	36.58338	9769.0415	24.39101
180.00	36.99896	9990.4429	24.88230
185.00	37.41437	10212.9570	25.37064
190.00	37.82963	10436.5650	25.85606
195.00	38.24473	10661.2490	26.33857
200.00	38.65969	10886.9920	26.81821
205.00	39.07452	11113.7780	27.29501
210.00	29.48923	11341.5890	27.76897
215.00	39.90380	11570.4070	28.24012
220.00	40.31827	11800.2180	28.70851
225.00	40.73262	12031.0030	29.17412
230.00	41.14687	12262.748	29.63703
235.00	41.56102	12495.4330	30.09718
240.00	41.97507	12729.0460	30.55466
245.00	42.38903	12963.5690	31.00947

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
250.00	42.80291	13198.9880	31.46163
255.00	43.21670	13435.2850	31.91116
260.00	43.63041	13672.4470	32.35809
265.00	44.04405	13910.4570	32.80243
270.00	44.45326	14149.3010	33.24400
275.00	44.87109	14388.9650	33.68342
280.00	45.28038	14629.4320	34.11994
285.00	45.69786	14870.6930	34.55431
290.00	46.10722	15112.7260	34.98584
295.00	46.52439	15355.5250	35.41525
300.00	46.93382	15599.0700	35.84188

Pressure = 2.000 Atmospheres

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
-20.00	9.48759	2098.4546	0.85187
-15.00	9.74689	2269.9149	1.52235
-10.00	10.00227	2442.3660	2.18399
-5.00	10.25305	2615.8818	2.83718
0.00	10.49976	2790.5416	3.48253
5.00	10.74290	2966.4099	4.12055
10.00	10.98287	3143.5382	4.75169
15.00	11.22000	3321.9677	5.37633
20.00	11.45462	3501.7325	5.99483
25.00	11.68698	3682.8578	6.60746
30.00	11.91731	3865.3644	7.21450
35.00	12.14582	4049.2673	7.81618
40.00	12.37158	4234.5704	8.41252
45.00	12.59704	4421.2968	9.00409
50.00	12.82117	4609.4117	9.59087
55.00	13.04405	4799.0070	10.17300
60.00	13.26580	4989.9911	10.75061
65.00	13.48653	5182.3914	11.32383
70.00	13.70631	5376.2028	11.89279

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
75.00	13.92523	5571.4692	12.45758
80.00	14.14336	5768.0324	13.01829
85.00	14.36077	5966.0337	13.57502
90.00	14.57752	6165.4128	14.12786
95.00	14.79366	6366.1584	14.67687
100.00	15.00923	6568.2590	15.22213
105.00	15.22429	6771.7018	15.76371
110.00	15.43887	6976.4736	16.30166
115.00	15.65300	7182.5605	16.84605
120.00	15.86672	7389.9483	17.36693
125.00	16.08007	7598.6217	17.89435
130.00	16.29305	7808.5665	18.41836
135.00	16.50571	8019.7680	18.93901
140.00	16.71806	8232.2095	19.45634
145.00	16.93013	8445.8757	19.97039
150.00	17.14193	8660.7491	20.48120
155.00	17.35348	8876.8168	20.98882
160.00	17.56479	9094.0584	21.49399
165.00	17.77588	9312.4614	21.99459
170.00	17.98677	9532.0071	22.49283

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
175.00	18.19746	9752.6793	22.98800
180.00	18.40797	9974.4619	23.48014
185.00	18.61831	10197.3400	23.96928
190.00	18.82849	10421.2950	24.45545
195.00	19.03851	10646.3110	24.93867
200.00	19.24838	10872.3720	25.41899
205.00	19.45812	11099.4630	25.89642
210.00	19.66773	11327.5660	26.37099
215.00	19.87722	11556.6650	26.84273
220.00	20.08658	11786.7450	27.31166
225.00	20.29584	12017.7900	27.77780
230.00	20.50499	12249.786	28.24128
235.00	20.71403	12482.7110	28.70184
240.00	20.92298	12716.5550	29.15977
245.00	21.13184	12951.3030	29.61501
250.00	21.34060	13186.9380	30.06759
255.00	21.54929	13423.4450	30.51752
260.00	21.75789	13660.8100	30.96483
265.00	21.96641	13899.0170	31.40953
270.00	22.17486	14138.0520	31.85166

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
275.00	22.38323	14377.9000	32.29123
280.00	22.59154	14618.5480	32.72825
285.00	22.79978	14859.9820	33.16275
290.00	23.00796	15102.1860	33.59476
295.00	23.21607	15345.1490	34.02428
300.00	23.42413	15588.8560	34.45136

Pressure = 5.000 Atmospheres

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
10.00	3.95501	2941.2972	2.38712
15.00	4.07725	3133.6810	3.06053
20.00	4.19581	3325.8784	3.72182
25.00	4.31093	3518.1255	4.37209
30.00	4.42307	3710.6334	5.01241
35.00	4.53220	3903.5489	5.64343
40.00	4.63956	4097.0566	6.26638
45.00	4.74490	4291.2404	6.88159
50.00	4.84847	4486.1614	7.48960
55.00	4.95044	4681.9860	8.09086
60.00	5.05099	4878.6858	8.68575
65.00	5.15028	5076.3433	9.27464
70.00	5.24841	5275.0005	9.85782
75.00	5.34552	5474.7424	10.43556
80.00	5.44169	5675.4473	11.00808
85.00	5.53701	5877.2881	11.57561
90.00	5.63155	6080.2327	12.13833
95.00	5.72539	6284.2948	12.69641

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
100.00	5.81859	6489.4852	13.25000
105.00	5.91119	6695.8110	13.79926
110.00	6.00326	6903.2768	14.34428
115.00	6.09426	7111.8743	14.89502
120.00	6.18539	7321.6257	15.42195
125.00	6.27612	7532.5175	15.95499
130.00	6.36645	7744.5469	16.48422
135.00	6.45641	7957.7098	17.00972
140.00	6.54603	8171.9992	17.53156
145.00	6.63533	8387.4088	18.04981
150.00	6.72433	8603.9289	18.56454
155.00	6.81306	8821.5541	19.07583
160.00	6.90154	9040.2705	19.58442
165.00	6.98977	9260.0719	20.08825
170.00	7.07778	9480.9450	20.58950
175.00	7.16558	9702.8788	21.08751
180.00	7.25318	9925.8619	21.58231
185.00	7.34060	10149.8830	22.07396
190.00	7.42784	10374.9290	22.56251
195.00	7.51491	10600.9870	23.04798

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
200.00	7.60183	10828.0440	23.53041
205.00	7.68860	11056.0870	24.00985
210.00	7.77523	11285.1030	24.48632
215.00	7.86174	11515.0760	24.95986
220.00	7.94811	11745.9970	25.43050
225.00	8.03437	11977.8490	25.89828
230.00	8.12051	12210.621	26.36325
235.00	8.20655	12444.2940	26.82534
240.00	8.29248	12678.8590	27.28469
245.00	8.37832	12914.3020	27.74128
250.00	8.46406	13150.6080	28.19515
255.00	8.54972	13387.7630	28.64631
260.00	8.63529	13625.7550	29.09481
265.00	8.72077	13864.5680	29.54064
270.00	8.80618	14104.1910	29.98385
275.00	8.89151	14344.6090	30.42447
280.00	8.97678	14585.8100	30.86249
285.00	9.06197	14827.7800	31.29797
290.00	9.14709	15070.5060	31.73090
295.00	9.23215	15313.9760	32.16132
300.00	9.31715	15558.1750	32.58926

Pressure = 10.000 Atmospheres

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
35.00	1.93488	3600.6749	3.50245
40.00	2.01200	3817.6688	4.20072
45.00	2.08534	4032.1129	4.88015
50.00	2.15516	4244.6346	5.54306
55.00	2.22186	4455.8771	6.19155
60.00	2.28641	4666.2862	6.82795
65.00	2.34886	4876.1772	7.45331
70.00	2.40952	5085.8192	8.06875
75.00	2.46862	5295.4777	8.67519
80.00	2.52636	5505.1769	9.27337
85.00	2.58289	5715.2089	9.86393
90.00	2.63809	5925.6125	10.44719
95.00	2.69264	6136.5470	11.02410
100.00	2.74634	6348.0586	11.59477
105.00	2.79925	6560.2143	12.15956
110.00	2.85147	6773.0709	12.71877
115.00	2.90306	6986.6756	13.28266
120.00	2.95407	7201.0679	13.82148

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
125.00	3.00455	7416.2797	14.36543
130.00	3.05455	7632.3389	14.90471
135.00	3.10411	7849.2682	15.43949
140.00	3.15327	8067.0841	15.96991
145.00	3.20205	8285.8013	16.49611
150.00	3.25049	8505.4200	17.01823
155.00	3.29861	8725.9787	17.53638
160.00	3.34643	8947.4514	18.05137
165.00	3.39398	9169.8547	18.56116
170.00	3.44127	9393.1874	19.06799
175.00	3.48832	9617.4498	19.57122
180.00	3.53515	9842.6405	20.07093
185.00	3.58143	10068.7420	20.56697
190.00	3.62787	10295.7810	21.05984
195.00	3.67414	10523.7370	21.54940
200.00	3.72023	10752.6020	22.03568
205.00	3.76616	10982.3710	22.51876
210.00	3.81193	11213.0340	22.99867
215.00	3.85756	11444.5840	23.47546
220.00	3.90305	11677.0130	23.94919

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
225.00	3.94841	11910.3120	24.41988
230.00	3.99364	12144.481	24.88777
235.00	4.03876	12379.4780	25.35237
240.00	4.08376	12615.3250	25.81423
245.00	4.12866	12852.0020	26.27322
250.00	4.17346	13089.4970	26.72938
255.00	4.21816	13327.7980	27.18273
260.00	4.26277	13566.8960	27.63331
265.00	4.30729	13806.7780	28.08114
270.00	4.35173	14047.4350	28.52628
275.00	4.39609	14288.8530	28.96872
280.00	4.44037	14531.0230	29.40851
285.00	4.48458	14773.9320	29.84567
290.00	4.52871	15017.5680	30.28023
295.00	4.57278	15261.9210	30.71222
300.00	4.61678	15506.9790	31.14166

Pressure = 15.000 Atmospheres

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
50.00	1.19986	3913.8117	3.91195
55.00	1.26755	4159.5700	4.66638
60.00	1.32905	4397.2682	5.38525
65.00	1.38601	4629.5148	6.07727
70.00	1.43935	4857.8672	6.74765
75.00	1.48975	5083.4529	7.40010
80.00	1.53794	5306.9804	8.03775
85.00	1.58420	5529.1193	8.66238
90.00	1.62866	5750.2117	9.27532
95.00	1.67191	5970.6891	9.87833
100.00	1.71394	6190.7606	10.47211
105.00	1.75490	6410.6403	11.05746
110.00	1.79491	6630.5030	11.63507
115.00	1.83410	6850.4915	12.21552
120.00	1.87255	7070.7244	12.76929
125.00	1.91032	7291.2995	13.32680
130.00	1.94733	7512.2709	13.87819
135.00	1.98399	7733.7722	14.42426
140.00	2.02016	7955.8251	14.96501
145.00	2.05588	8178.4789	15.50071

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
150.00	2.09118	8401.7730	16.03155
155.00	2.12611	8625.7454	16.55775
160.00	2.16069	8850.4202	17.08019
165.00	2.19495	9075.8257	17.59688
170.00	2.22891	9301.9784	18.11011
175.00	2.26260	9528.8947	18.61930
180.00	2.29604	9756.5874	19.12456
185.00	2.32923	9985.0676	19.62600
190.00	2.36221	10214.3400	20.12371
195.00	2.39498	10444.4110	20.61780
200.00	2.42756	10675.2840	21.10835
205.00	2.45996	10906.9610	21.59542
210.00	2.49219	11139.4400	22.07910
215.00	2.52427	11372.7200	22.55945
220.00	2.55619	11606.8010	23.03653
225.00	2.58797	11841.6770	23.51040
230.00	2.61936	12077.364	23.98136
235.00	2.65089	12313.7780	24.44855
240.00	2.68231	12551.0120	24.91313
245.00	2.71361	12789.0200	25.37471

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
250.00	2.74481	13027.7930	25.83333
255.00	2.77590	13267.3240	26.28902
260.00	2.80689	13507.6060	26.74184
265.00	2.83779	13748.6290	27.19181
270.00	2.86860	13990.3870	27.63898
275.00	2.89932	14232.8670	28.08338
280.00	2.92996	14476.0630	28.52503
285.00	2.96052	14719.9650	28.96399
290.00	2.99101	14964.5620	29.40026
295.00	3.02143	15209.8460	29.83390
300.00	3.05178	15455.8070	30.26493

Pressure = 20.000 Atmospheres

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
60.00	0.78005	3974.3359	3.73800
65.00	0.85767	4279.1895	4.64625
70.00	0.92052	4554.2381	5.45375
75.00	0.97510	4813.5855	6.20398
80.00	1.02422	5063.0711	6.91564
85.00	1.06941	5306.0426	7.59879
90.00	1.11174	5544.4530	8.25991
95.00	1.15159	5779.4463	9.62437
100.00	1.18967	6012.0464	9.53012
105.00	1.22615	6242.8225	10.14449
110.00	1.26129	6472.2667	10.74729
115.00	1.29515	6700.7117	11.34955
120.00	1.32817	6928.5608	11.92284
125.00	1.36031	7155.9902	12.49770
130.00	1.39168	7383.1950	13.06481
135.00	1.42236	7610.3359	13.62477
140.00	1.45244	7837.5434	14.17806
145.00	1.48197	8064.9281	14.72513

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
150.00	1.51100	8292.5806	15.26633
155.00	1.53944	8520.5451	15.80175
160.00	1.56764	8748.9610	16.33289
165.00	1.59547	8977.8446	16.85758
170.00	1.62295	9207.2393	17.37819
175.00	1.65012	9437.1846	17.89418
180.00	1.67700	9667.7141	18.40574
185.00	1.70362	9898.8571	18.91303
190.00	1.72998	10130.6340	19.41619
195.00	1.75611	10363.0660	19.91535
200.00	1.78204	10596.1670	20.41063
205.00	1.80776	10829.9510	20.90214
210.00	1.83329	11064.4270	21.38998
215.00	1.85865	11299.6020	21.87423
220.00	1.88385	11535.4830	22.35499
225.00	1.90889	11772.0730	22.83232
230.00	1.93379	12009.3800	23.30636
235.00	1.95855	12247.3850	23.77701
240.00	1.98318	12486.1080	24.24450
245.00	2.00770	12725.5400	24.70883

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
250.00	2.03209	12965.6780	25.17006
255.00	2.05638	13206.5180	25.62823
260.00	2.08037	13448.0360	26.08320
265.00	2.10446	13690.2680	26.53543
270.00	2.12846	13933.1910	26.98476
275.00	2.15238	14176.7930	27.43121
280.00	2.17621	14421.0710	27.87484
285.00	2.19996	14666.0170	28.31568
290.00	2.22363	14911.6220	28.75376
295.00	2.24722	15157.8810	29.18913
300.00	2.27075	15404.7850	29.62181

Pressure = 25.000 Atmospheres

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
70.00	0.50771	3942.0801	3.41578
75.00	0.61793	4395.9101	4.72932
80.00	0.68588	4725.0849	5.66840
85.00	0.74004	5016.7936	6.48871
90.00	0.78671	5289.3239	7.24445
95.00	0.82849	5550.0911	7.95763
100.00	0.86678	5802.9832	8.63990
105.00	0.90254	6050.4168	9.29865
110.00	0.93622	6293.7841	9.93804
115.00	0.96814	6534.0867	10.57110
120.00	0.99876	6772.1970	11.17066
125.00	1.02821	7008.6046	11.76821
130.00	1.05665	7243.7455	12.35513
135.00	1.08412	7477.9134	12.93230
140.00	1.11095	7711.4857	13.50112
145.00	1.13710	7944.6196	14.06203
150.00	1.16265	8177.4941	14.61566
155.00	1.18767	8410.2616	15.16252
160.00	1.21221	8643.0418	15.70378
165.00	1.23632	8875.9430	16.23768
170.00	1.26004	9109.0499	16.76670

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
175.00	1.28328	9342.3960	17.29017
180.00	1.30633	9576.1324	17.80886
185.00	1.32908	9810.2653	18.32272
190.00	1.35155	10044.8370	18.83195
195.00	1.37377	10279.8860	19.33675
200.00	1.39575	10515.4460	19.83726
205.00	1.41751	10751.5440	20.33364
210.00	1.43907	10988.2010	20.82602
215.00	1.46044	11225.4380	21.31452
220.00	1.48163	11463.2700	21.79925
225.00	1.50266	11701.7090	22.28032
230.00	1.52353	11940.7810	22.75792
235.00	1.54426	12180.4490	23.23183
240.00	1.56484	12420.7630	23.70244
245.00	1.58530	12661.7140	24.16971
250.00	1.60564	12903.3030	24.63373
255.00	1.62586	13145.5310	25.09455
260.00	1.64597	13388.3990	25.55223
265.00	1.66598	13631.9040	26.00683
270.00	1.68589	13876.0480	26.45840

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
275.00	1.70571	14120.8240	26.90700
280.00	1.72527	14366.2050	27.35245
285.00	1.74492	14612.2400	27.79524
290.00	1.76449	14858.8960	28.23520
295.00	1.78399	15106.1700	28.67236
300.00	1.80341	15354.0520	29.10677

Pressure = 30.000 Atmospheres

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
80.00	0.37769	4013.1199	3.46846
85.00	0.48466	4568.2939	5.03052
90.00	0.54960	4940.3738	6.06249
95.00	0.60002	5257.8952	6.93096
100.00	0.64281	5548.9127	7.71620
105.00	0.68070	5824.1199	8.44886
110.00	0.71517	6088.9460	9.14459
115.00	0.74705	6346.5061	9.82242
120.00	0.77702	6598.8732	10.45850
125.00	0.80536	6847.2910	11.08641
130.00	0.83233	7092.6758	11.69882
135.00	0.85825	7335.8490	12.29833
140.00	0.88321	7577.2757	12.88627
145.00	0.90736	7817.3756	13.46393
150.00	0.93071	8056.4288	14.03213
155.00	0.95353	8294.8165	14.59222
160.00	0.97579	8532.6857	15.14531
165.00	0.99756	8770.2196	15.68985
170.00	1.01887	9007.5643	16.22849

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
175.00	1.03978	9244.8446	16.76094
180.00	1.06032	9482.1654	17.28757
185.00	1.08053	9719.6162	17.80870
190.00	1.10034	9957.2252	18.32437
195.00	1.11998	10195.1530	18.83536
200.00	1.13936	10433.4010	19.34159
205.00	1.15851	10672.1170	19.84327
210.00	1.17744	10911.0370	20.34057
215.00	1.19616	11150.4950	20.83365
220.00	1.21470	11390.4220	21.32266
225.00	1.23305	11630.8410	21.80772
230.00	1.25124	11871.7999	22.28914
235.00	1.26928	12113.2280	22.76649
240.00	1.28717	12355.2270	23.24040
245.00	1.30493	12597.7810	23.71078
250.00	1.32255	12840.8970	24.17774
255.00	1.34006	13084.5820	24.64132
260.00	1.35745	13328.8420	25.10163
265.00	1.37474	13573.6790	25.55872
270.00	1.39192	13819.0970	26.01265

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
275.00	1.40901	14065.0960	26.46349
280.00	1.42600	14311.6770	26.91129
285.00	1.44291	14558.8380	27.35611
290.00	1.45973	14806.5770	27.79798
295.00	1.47633	15054.8660	28.23676
300.00	1.49301	15303.7660	28.67292

Pressure = 35.000 Atmospheres

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
90.00	0.35742	4402.4338	4.43143
95.00	0.42377	4860.1182	5.68337
100.00	0.47502	5228.3209	6.67695
105.00	0.51750	5552.4427	7.53992
110.00	0.55434	5851.2783	8.32500
115.00	0.58738	6134.2549	9.06878
120.00	0.61768	6406.4737	9.75570
125.00	0.64575	6670.8303	10.42384
130.00	0.67218	6929.5411	11.06963
135.00	0.69721	7183.9040	11.69671
140.00	0.72102	7434.8812	12.30782
145.00	0.74392	7683.3504	12.90565
150.00	0.76598	7929.8081	13.49157
155.00	0.78731	8174.7077	14.06694
160.00	0.80793	8418.3468	14.63331
165.00	0.82808	8661.1424	15.18995
170.00	0.84772	8903.2533	15.73941

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
175.00	0.86692	9144.8741	16.28161
180.00	0.88571	9386.1672	16.81706
185.00	0.90414	9627.2691	17.34621
190.00	0.92223	9868.2918	17.86944
195.00	0.94003	10109.3320	18.38709
200.00	0.95746	10350.4220	18.89920
205.00	0.97474	10591.7420	19.40657
210.00	0.99179	10833.2900	19.90914
215.00	1.00862	11075.1160	20.40710
220.00	1.02525	11317.2660	20.90065
225.00	1.04169	11559.7770	21.38993
230.00	1.05796	11802.7260	21.87538
235.00	1.07407	12046.0030	22.35634
240.00	1.09002	12289.7690	22.83371
245.00	1.10584	12533.9980	23.30735
250.00	1.12152	12778.7060	23.77736
255.00	1.13708	13023.9050	24.24383
260.00	1.15251	13269.6090	24.70686
265.00	1.16784	13415.8240	25.16652
270.00	1.18306	13762.5590	25.62289

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
275.00	1.19819	14009.8190	26.07603
280.00	1.21322	14257.6070	26.52603
285.00	1.22815	14505.9270	26.97293
290.00	1.24301	14754.7800	27.41679
295.00	1.25778	15004.1660	27.85768
300.00	1.27235	15254.0520	28.29540

Pressure = 40.000 Atmospheres

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
95.00	0.29748	4374.3131	4.24697
100.00	0.35084	4842.6261	5.51063
105.00	0.39580	5234.7160	6.55457
110.00	0.43449	5580.8606	7.46404
115.00	0.46852	5897.8654	8.29605
120.00	0.49922	6195.8649	9.04899
125.00	0.52727	6480.4107	9.76818
130.00	0.55328	6755.3064	10.45428
135.00	0.57772	7023.1492	11.11463
140.00	0.60081	7285.5218	11.75359
145.00	0.62274	7543.6066	12.37445
150.00	0.64378	7798.4839	12.98040
155.00	0.66401	8050.7612	13.57312
160.00	0.68354	8300.9828	14.15489
165.00	0.70238	8549.5183	14.72456
170.00	0.72076	8796.8686	15.28593
175.00	0.73866	9043.2259	15.83877
180.00	0.75612	9288.8247	16.38378
185.00	0.77320	9533.8605	16.92157
190.00	0.78992	9778.4936	17.45264
195.00	0.80633	10022.8610	17.97744

Temperature °C	Volume Liter/GMole	Enthalpy Cal/GMole	Entropy Cal/GMole-C
200.00	0.82244	10267.0790	18.49634
205.00	0.83829	10511.2470	19.00968
210.00	0.85382	10755.3970	19.51751
215.00	0.86921	10999.7080	20.02059
220.00	0.88439	11244.1850	20.51888
225.00	0.89938	11488.8790	21.01258
230.00	0.91419	11733.8990	21.50221
235.00	0.92883	11979.0930	21.98692
240.00	0.94332	12224.6870	22.46787
245.00	0.95766	12470.6460	22.94487
250.00	0.97187	12716.9930	23.41803
255.00	0.98594	12963.7510	23.88747
260.00	0.99990	13210.9360	24.35329
265.00	1.01374	13458.5620	24.81559
270.00	1.02748	13706.6450	25.27445
275.00	1.04111	13955.1910	25.72996
280.00	1.05465	14204.2110	26.18218
285.00	1.06810	14453.7110	26.63121
290.00	1.08146	14703.6950	27.07709
295.00	1.09474	14954.1680	27.51990
300.00	1.10794	15205.1310	27.95969

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