

THERMODYNAMIC PROPERTIES
OF ISOPENTANE

By

SHING KE CHIAN

Bachelor of Science

Taipei Institute of Technology

Taipei, Taiwan

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Thesis Approved:

Charles L. Nickless

Thesis Adviser

G. N. Maddox

James Mansura

Dean of the Graduate School

438574

PREFACE

The purpose of this study was to compile the thermodynamic properties of isopentane from the modern experimental data and the Benedict-Webb-Rubin equation of state.

Thermodynamic properties of isopentane are presented in the form of tables and Mollier Diagram; i.e., pressure-enthalpy plot.

These properties are presented for the vapor phase over a range of 100° to 570° F. in temperature and 10 to 3000 lb./sq.in.abs. in pressure. The properties of saturated liquid and vapor are also presented.

The datum state is the pure compound at ideal gas state and absolute zero temperature.

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CHAPTER I

INTRODUCTION

During the past 30 years many thermodynamic compilations have been developed for the hydrocarbons. Some of these have been rather widely used. Most of the earlier compilations should be discarded in favor of more recent and accurate thermodynamic data. With the appearance in the literature of precise pressure-volume-temperature measurements for isopentane, it was possible to calculate the thermodynamic properties of this compound very accurately.

The Benedict-Webb-Rubin equation was chosen because of the extensive application it has recently received in petroleum processing and because it covers a more extensive region of measured pressure-volume-temperature data than other equation of state. When the equation of state was used to calculate the pressure at highly nonideal conditions, the accuracy of the computed data was greatly improved by combining with results of graphical calculations made on the residual between the equation of state and the actual P-V-T data. In addition, with the aid of the high speed electronic computer, IBM 650, the complicated Benedict equation could be evaluated to its fullest precision.

The reason of this work to compile the Mollier diagram is that it has been proven a very useful tool for the engineer. From it, changes in enthalpy and volume may be found for isothermal, isobaric or isentropic

paths. Also changes in entropy, pressure and temperature may be readily found.

A comprehensive and consistent set of Mollier diagrams for hydrocarbons would be most valuable to process engineers engaged in design work. Therefore, it has consistent datum points for the enthalpy and entropy, and consistent units for present-day industry calculations. This need for consistency in units and datum is clearly obvious in calculations dealing with hydrocarbon mixtures.

Thermodynamic data are available for many paraffinic, olefinic and aromatic hydrocarbons, including methane (25), ethane (8), ethylene (42), propane (15,38), propylene (14), n-butane (29,32), isobutane (18), 1-butene (40), n-pentane (13), n-hexane (41), n-heptane (39) and benzene (26) etc., but not for isopentane. Consequently, it is the purpose of this work to present the derived properties, calculated from rigorous thermodynamic relationships, for isopentane.

CHAPTER II

REVIEW OF THE LITERATURE

Isopentane is a paraffin hydrocarbon with a molecular weight of 72.146, a freezing point in air of -225.82°F. , and a normal boiling point of 82.13°F. (3,4). Its physical properties have been under investigation for at least 90 years. Critical constants have been reported by Pawlewski (28), Schmidt (34), Altschul (1) and Young (44). The values of the critical constants selected both by Kobe and Lynn (23) and by Rossini et al. (30) are those determined by Young (44): critical temperature, 370°F. ; critical pressure, 483 lb./sq.in.; critical density, 0.202 lb-mole/cu.ft.

The vapor pressure of isopentane was studied by Schumann (35), data up to 71.6°F. ; by Young (44), data from normal boiling point to critical point; by Issac, Li and Canjar (22), data from 257° to 347°F. ; by Rossini et al. (6), data from 20° to 120°F. ; and by Silberberg (37), data from 120° to 347°F.

The vapor pressure measurements of Silberberg's were correlated and smoothed as logarithmic residuals according to the following equation:

$$\log \frac{P_{\text{obs}}}{P_{\text{cal}}} = \log P_{\text{obs}} - 4.37585 + \frac{1314.74}{T} \dots\dots\dots (1)$$

$$P = \text{atm.}$$

$$T = \text{ }^{\circ}\text{K}$$

The resulting correlation is shown in Fig.1

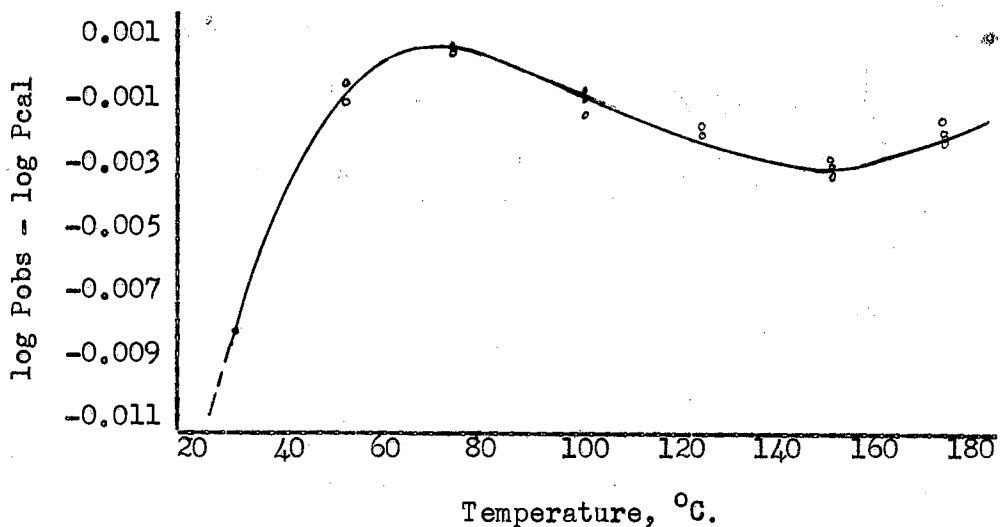


Figure 1 Residual Correlation of Vapor Pressures

The comparison of vapor pressures of isopentane in Table I was made by Silberberg. It is concluded that Young's data are always lower than those of the recent investigations made by Issac et al. (22), and by Silberberg (37).

TABLE I
COMPARISON OF VAPOR PRESSURE DATA

Temp. °C	Vapor pressure, atm			Deviation %	
	Silberberg	Issac	Young	Issac	Young
50	2.025	.....	2.022	.....	-0.15
75	3.983	.....	3.954	.....	-0.71
100	7.106	.....	7.031	.....	-1.05
125	11.787	11.881	11.621	0.80	-1.41
150	18.499	18.474	18.171	0.14	-1.50
175	27.566	27.590	27.171	0.12	-1.40

Several studies have been made of the saturated liquid density-temperature relationship of isopentane, Young (44) reports data from 86°F. to critical point; Issac et al. (22) data from 257° to 347°F.; and API Research Project 44 (4) up to 86°F. International Critical Tables (21) fitted an equation

$$d_{t_o_c}(\text{gm/cm}^3) = d_s + \alpha(t-t_s) + \beta(t-t_s)^2 + \gamma(t-t_s)^3 \dots\dots\dots(2)$$

to Young's data. In which d_t is saturated liquid density at the given temperature $t^\circ\text{C}.$; d_s is standard density at the given temperature $t_s^\circ\text{C}.$; α , β , and γ are constants. Francis (19) fitted two equations

$$D_s(\text{gm/cm}^3) = A - Bt - \frac{C}{E - t} \dots\dots\dots(3)$$

$$(D_s - D_c)^h = G(t_c - t) \dots\dots\dots(4)$$

to the results of Young's, Issac et al., and of API 44. In which A, B, C, E, h, and G are constants; D_s is the density of the saturated liquid; D_c is the critical density; t is the temperature in $^\circ\text{C}.$; t_c is the critical temperature. Equation 3 holds for a temperature range of 0° to $175^\circ\text{C}.$ and the equation 4 holds for temperatures near the critical point. The average deviation of observations in densities from these equations is less than 0.00035 gm/cm^3 or about 0.05%.

Volume of saturated vapor has been measured by three groups of investigators. The earliest work, that of Young (44), covers the temperature range of 86° to 370°F. Other investigation of the saturated vapor volumes was made by Issac et al. (22) at temperature 347°F. The recent work of Silberberg (37), covered the temperature range of 122° to 347°F.

The deviation of smoothed and interpolated values of Young's saturated

vapor volumes from those of Silberberg's work are shown in Table II.

TABLE II
COMPARISON OF SATURATED VAPOR VOLUMES OF YOUNG (44)
WITH THE WORK OF SILBERBERG (37)

Temp. °C	Saturated Vapor Volumes, liters/g-m		Deviation %
	Young	Silberberg	
50	12.077	12.067	0.08
75	6.346	6.324	0.35
100	3.569	3.556	0.37
125	2.089	2.077	0.58
150	1.234	1.222	0.98
175	0.6714	0.6646	1.02

Pressure-volume-temperature relations in the superheated region of isopentane have been reported by Young (43,44), Young and Thomas (45), Issac et al (22), and Silberberg (37). The investigation of Young and Thomas was limited to the vapor phase at pressures below 825 m.m. Hg. Measurements reported by Young were at temperatures from -22° to 536° F. and at pressures from near atmospheric to 1060 lb./sq.in. Issac et al. studied the unsaturated vapor volume of isopentane from 392° to 572° F. and from 400 to 3000 lb./sq.in. An investigation of gaseous isopentane was made by Silberberg (37) at temperature from 122° to 392° F. and at pressures from atmospheric to 882 lb./sq.in.

The smoothed and interpolated molal volumes from Young's data were made by Silberberg to compare with his results at the same pressures. The deviation between the two sets of volumes is consistent in its direction

and increases very rapidly with pressure at both 347° and 392°F. This behavior was suggestive of a systematic deviation in the pressure scales of the two investigators, a possibility which is also supported by the deviation in vapor pressures shown in Table I. In addition, Young's vapor pressures for normal pentane (44) are consistently lower than values reported by Beattie et al. (9), Li and Ganjar (24), and Sage and Lacey (33). In fact, it appears to be generally true that the vapor pressures determined by Young in his studies are consistently lower than those reported in more modern investigations.

Only at 347° and 392°F. is it possible to compare the data of Issac et al. with those of Silberberg's work. This comparison has been made by Silberberg. The magnitude of the deviation is as large as 6.24%. The behavior is not characteristic of a systematic error in pressure. Furthermore, the saturated vapor volume at 347°F. reported by Issac et al. is 0.6296 liters/gm-mole, which differs by 5.27 % from the value 0.6646 liters/gm-mole determined in Silberberg's work. Data reported by Issac et al. were compared with the smoothed data of Young. Young's data were smoothed as isotherms of volume as a function of pressure, and it is believed that smoothing errors are less than 0.2%. The comparison shows Young's molal volumes are almost consistently larger than those reported by Issac et al., the discrepancy becoming as large as 5.0%.

The latent heat of vaporization was calorimetrically determined by Schumann et al (35) as 5,842 cal. per gm-mole at 25°C., which was later selected by API 44 workers. Scott et al. (36) reported 5,901 cal./gm-mole for the latent heat of vaporization of isopentane at 25°C., a value about 1% higher than that found by Schumann et al. Above the boiling point latent heats measured directly were not available. Use of the Clapeyron equation (equation 5) is widely accepted when accurate P-V-T data is

available.

$$\frac{dP}{dT} = \frac{\Delta H_v}{T\Delta V} \dots\dots\dots(5)$$

The entropy of isopentane vapor was computed by Scott et al. (36) at the temperatures at which the heat of vaporization was measured. The entropy of the liquid is from the work of Guthrie and Huffman (20), and the compression term utilizes the vapor pressure equation of API Project 44 (5). For computing the gas imperfection term, which is given by $P(\partial B/\partial T)_p$ in terms of the second virial coefficient, the equation for the second virial coefficient as function of temperature derived in their work was used. The computed values of entropy at 43.47°, 77° and 82.13°F. were 80.37, 82.11 and 82.39 Btu/lb-mole°R, respectively.

There is considerable divergence among different authors on the datum point used. This inconsistent reference states complicates calculations dealing with hydrocarbon mixtures. The reason to choose a consistent datum is thus obvious for any compilation of hydrocarbon thermodynamic properties. As recommended early by Edmister (16), ideal gas state at any temperature would make a good datum, especially at absolutely zero temperature. An advantage of this datum is that Rossini et al. (31) have computed and tabulated enthalpy and entropy values for hydrocarbons above this reference point. Their work is considered as being the most accurate and consistent tabulations of these thermodynamic properties available for hydrocarbons.

Although no attempt has been made to extend the thermodynamic network to the liquid region, several studies of physical properties have been reported in this region. Bridgman (12) investigated the compressibility of liquid isopentane at 0°, 50° and 95°C. at pressures from 500 to 9000 kg/cm³ (484 to 8700 atm.), and fitted an equation as a function of temperature and pressure to his results. Issac et al. (22) reported data for

volumetric behavior of the liquid from 212° to 347°F. at pressures up to 3100 lb/sq.in. Francis (19) studied all existing liquid P-V-T data for isopentane and developed an empirical relation as expressed in the following equation:

$$\log S = K D - F \dots\dots\dots(6)$$

in which $D (=1/V)$ is the density in grams per milliliter; S is the slope of isochor $(dP/dT)_V$ in atmospheres per °C.; K and F are constants, which have been evaluated in the literature. Calculated values from equation 6 are believed to be accurate to 0.2%. The Benedict equations for enthalpy and entropy will also hold in the liquid phase, although the equation of state did not fit the P-V-T data well. Finally, Parks and Huffman (27) measured the heat capacity of isopentane up to 298°K in order to compute the absolute entropy.

CHAPTER III

METHOD OF CALCULATION

A complete set of steps for developing the Mollier Chart by rigorous method was made as suggested by Edmister (16,17).

Vapor Pressure

Vapor pressure data were compiled from the following investigators:

API Research Project 44 (6)

Young (44)

Issac, Li and Canjar (22)

Silberberg (37)

Greatest weight was given to the work of Silberberg, and that of the API 44 Tables.

Below 120°F., vapor pressures were read from API 44 Tables directly with an interval of 10°F. Above 120°F. equation (1) was used. The logarithmic residuals were then read from Figure 1. An attempt was made to compute the vapor pressures up to 360°F. by equation (1). At the critical temperature, vapor pressure, or rather to say critical pressure, was read from API 44 Tables.

The final values of vapor pressures from normal boiling point to critical point with a temperature interval of 10°F. are contained in Table IV.

Volume of Saturated Liquid

Saturated liquid volumes were from a plot which included the following points:

API 44 Tables (4): at 68°, 77° and 90°F.

International Critical Tables (21) equation 2: from 90° to 120°F.

Issac, Li and Canjar (22): at 257°, 302° and 347°F.

Francis (19) equations 3 and 4: computed values from 120° to 365°F.

Kobe and Lynn (23): critical volume

Final values for volume of saturated liquid are reported in Table IV.

P-V-T Relations of the Superheated Region

Two groups of investigated P-V-T data of isopentane were selected in this work. Issac, Li and Canjar (22) reported the volumetric behavior of superheated vapor at five isotherms, 392°, 437°, 482°, 527° and 572°F. and pressures from 450 to 3100 lb./sq.in. Their data was used in the high pressure region. Silberberg (37) investigated the compressibility of gaseous isopentane at eight isotherms, 122°, 167°, 212°, 257°, 302°, 347°, 373.1° and 392°F., and pressures from atmospheric to 882 lb./sq.in. His data was used for the low pressure region.

Pressures were first calculated from the Benedict-Webb-Rubin equation of state (10,11)

$$P = RTd + (BoRT - Ao - \frac{Co}{T^2})d^2 + (bRT - a)d^3 + axd^6 + \frac{cd^3}{T^2}(1 + \tau d^2)e^{-\tau d^2}$$

.....(7)

at temperatures and densities given in all available P-V-T data. The pressure residuals, difference between observed and equation, were then obtained from experimental and calculated data.

Pressure residuals from the Benedict equation were almost all negative

in the high pressure region; i.e., the experimental data of Issac et al. were almost all lower than the calculated values from the equation. These can be seen clearly in Figure 2.

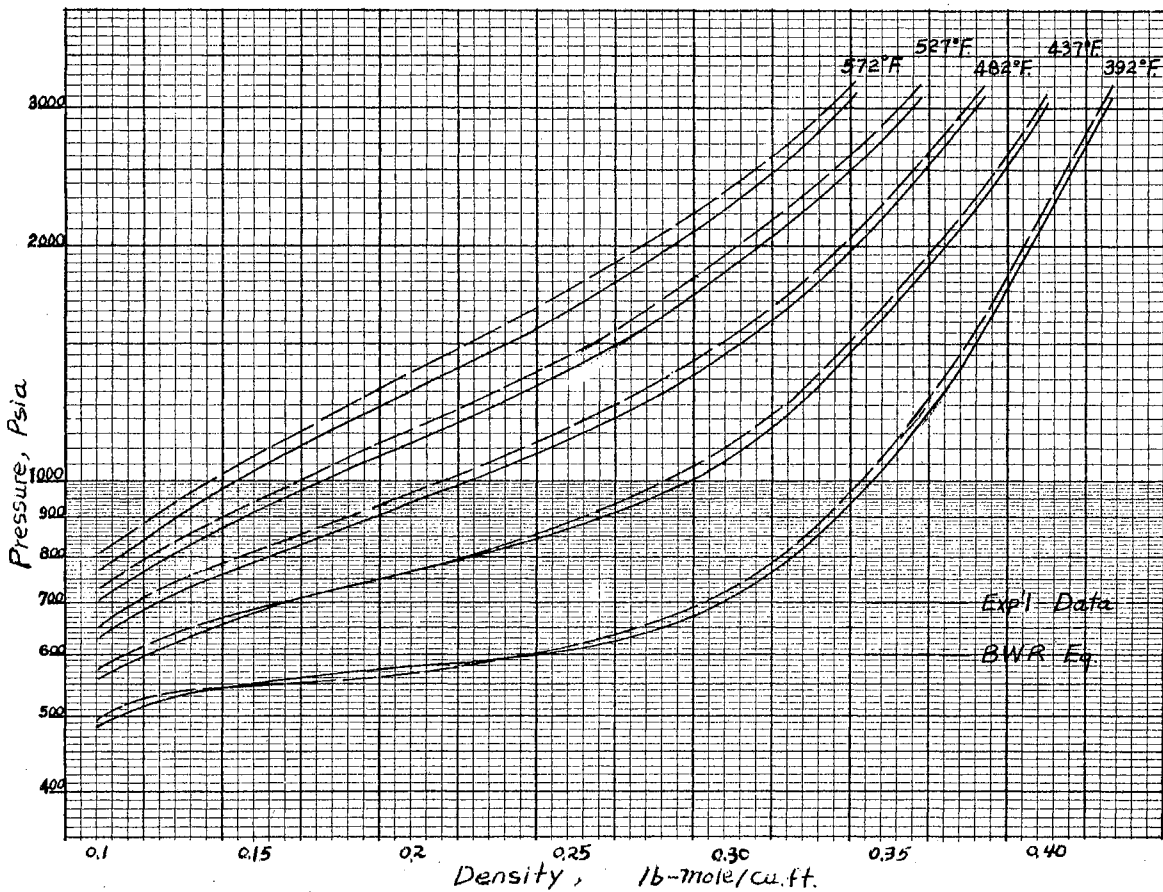


Figure 2 Plot of Experimental Data and Those of Calculated Values

In the low pressure region, pressure residuals from the equation were all positive; i.e., Silberberg data were all higher than those calculated by the equation.

Pressure residuals from Silberberg may be neglected at isotherms of 122° and 167°F. under their own vapor pressures; at isotherms of 212°, 257° and 302°F. under atmospheric pressure; and at isotherms of 373.1° and 392°F. under pressures of 147 lb./sq.in.

This inconsistency in the deviation of residuals between the two sets of experimental data makes difficult the evaluation of specific volume at pressures between 500 and 600 lb./sq.in. The author believes it would be best to take specific volumes below 500 lb./sq.in. from data of Silberberg, and above 550 lb./sq.in. from those of Issac et al.

Pressure residuals were originally plotted against density as lines of constant temperature. By cross plotting, the residuals were expressed as isometrics of temperature. Pressures were recalculated from the Benedict equation for a sufficient number of isotherms. Residual corrections were read from the isometrics plot and added to the corresponding isotherms calculated from the equation.

The corrected volumetric data were then smoothed with the aid of large-scale plots of density as a function of pressure with temperature parameters.

The final specific volumes were read from these plots at temperature and pressure intervals as reported in Table V.

Volume of Saturated Vapor

Volumes of saturated vapor were also read from the same corrected P-V-T plots as used for reading the specific volumes for the temperatures and vapor pressures listed in Table IV.

At atmospheric conditions the saturated vapor volume was calculated by means of the Clapeyron equation from the heat of vaporization, temperature-vapor pressure slopes, and saturated liquid volumes reported by API 44 Tables (4,7).

Greatest weight was given to the work of Silberberg.

Latent Heat of Vaporization

With the exception of two values given in API 44 Tables (7) all the latent heat of vaporization data were calculated by the Clapeyron equation:

$$\frac{dP}{dT} = \frac{\Delta H_v}{T \Delta V}$$

Fortunately, smoothed saturated volumes and vapor pressure-temperature slopes were made by Silberberg (37) at temperatures of 122°, 167°, 212°, 257°, 302° and 347°F. These are shown in Table III. Volumes of saturated liquid were read from the same plot used for tabulating the saturated liquid volume data in Table IV. The latent heat of vaporization was then calculated.

TABLE III

SMOOTHED SATURATED VAPOR VOLUMES AND VAPOR
PRESSURE-TEMPERATURE SLOPES

Temp., °C.	Saturated Vapor Volumes liters/gm-mole	Slope dP/dT atm./°C.
50	12.067	0.059
75	6.324	0.099
100	3.556	0.153
125	2.077	0.223
150	1.222	0.313
175	0.6646	0.421

The API 44 values and the calculated values of heat of vaporization were finally plotted on large-scale plot and extrapolated to zero heat of vaporization at the critical point. The final temperature intervals that were selected are those reported in Table IV.

The entropy change on vaporization is obtained by dividing the latent heat of vaporization; i.e., enthalpy change on vaporization by the absolute temperature. This quantity is also listed in Table IV.

Enthalpy of Saturated and Unsaturated Vapors

The enthalpy of superheated and saturated vapors is given by the equation

$$(H - H^{\circ})_T = (BoRT - 2Ao - \frac{4Co}{T^2})d + (bRT - \frac{3a}{2})d^2 + \frac{6acd^5}{5} + \frac{cd^2}{T^2} \left[\frac{3(1-e^{-\gamma d^2})}{\gamma d^2} - \frac{e^{-\gamma d^2}}{2} + \gamma d^2 e^{-\gamma d^2} \right] \dots\dots\dots(8)$$

The density "d" used in this equation was the root from the Benedict equation of state (equation 7) for the given pressure and temperature, instead of that from the corrected specific volume plots. The reason is that the enthalpy equation is a function of pressure and was originally derived from the equation of state based on fundamental thermodynamic relationships.

H° was obtained from the values tabulated by Edmister (18) at 10°F intervals. The source of data was originally from API Project 44 (31).

The enthalpy at a given temperature and pressure was obtained by subtracting the value of $(H^{\circ} - H)_T$ obtained from equation from the value of H° read from Edmister's tabulations for the given temperature. These data are reported in Table IV and Table V.

Enthalpy of Saturated Liquid

There were no data for the enthalpy of saturated liquid for isopentane. These properties were then determined by subtracting the latent heat of vaporization from the enthalpy of the saturated vapor. The results are reported in Table IV.

Entropy of Saturated and Unsaturated Vapors

The entropy of saturated and unsaturated vapor is given by the equation

$$(S - S^{\circ})_T = -R \ln dRT - (BoR + \frac{2Co}{T^3})d - \frac{bRd^2}{2} + \frac{2cd^2}{T^3} \left[\frac{1 - e^{-\gamma d^2}}{\gamma d^2} - \frac{e^{-\gamma d^2}}{2} \right]$$

.....(9)

For a given temperature and pressure "d" was evaluated from the Benedict equation of state (equation 7), the entropy difference from ideal gas, $S - S^{\circ}$, at the given temperature is then calculated.

Values of S° were also obtained from Edmister (18) tabulation at 10°F intervals. In this way the interpolations yielded values of S° that agreed with the shorter API tabulation.

S was obtained by subtracting the value of $(S^{\circ} - S)_T$ from that of S° read from Edmister's tabulation for the given temperature. The resulting values are listed in Table IV and Table V.

Entropy of Saturated Liquid

The entropy of saturated liquid at normal boiling reported by Parks and Huffmann (27) was the only experimental value available. Above this temperature these properties were determined by subtracting the entropy of vaporization from the entropy for saturated vapor. These results also reported in Table IV.

Thermodynamic values resulting from this work were all converted to engineering units.

All the physical constants and unit equivalents used in this work were taken from API 44 Tables (2).

CHAPTER IV

RESULTS AND DISCUSSION

The final results are presented in the form of a pressure-enthalpy diagram in Figure 3, and as tabulated values in Table IV and Table V.

The results were checked for internal consistency through the fundamental relationship

$$\left(\frac{\partial \ln P}{\partial H}\right)_s = \frac{1}{PV} \dots\dots\dots(10)$$

i.e., on log"P" versus "H" coordinates the slope of the isentropes is equal to reciprocal PV. It can be seen that a negative slope of the isentropes is impossible because the PV product is always positive.

Rearranging the equation 10 and integrating results in equation 11

$$H_2 - H_1 = \frac{144}{778.3} \int_{P_1}^{P_2} PV \, d \ln P \dots\dots\dots(11)$$

The right hand member can then be evaluated by graphical integration and compared with enthalpy differences obtained from the calculated data. Such consistency checks were made on the thermodynamic data presented in this work, and good agreement was obtained in each instance.

Only one check can be made of the thermodynamic data presented in this work with data from an independent source. Scott, McCullough, Williamson and Waddington (36) reported entropy data for the saturated vapor of

isopentane vapor at 43.47° , 77° and 82.13°F . With the data of these investigations, the entropy at normal boiling point is $1.1419 \text{ Btu}/^{\circ}\text{R lb.}$, and from this work the entropy is $1.1372 \text{ Btu}/^{\circ}\text{R lb.}$ This would appear to be an error, but in reality it is not. From the data of Scott et al. the entropy difference for vaporization at this temperature is $0.2715 \text{ Btu}/^{\circ}\text{R lb.}$, and from API Report 44 (7) the entropy difference is $0.2688 \text{ Btu}/^{\circ}\text{R lb.}$ This would indicate that the entropy data of Scott et al. are a little higher. The corrected entropy of saturated vapor at normal boiling point based on API Project 44 will then be $1.1392 \text{ Btu}/^{\circ}\text{R lb.}$, which is only $0.0020 \text{ Btu}/^{\circ}\text{R lb.}$, a value about 0.18% higher than computed in this work.

With this single minor exception, there are no thermal data available to check the accuracy of the thermodynamic data presented here. However, it is believed that smoothing errors in volumetric data are less than 0.15%; reading errors in pressures throughout the whole region are 0.05%; reading errors in densities are 0.12% below density of 0.1 lb-mole/cu.ft., and 0.06% above that. It may be therefore concluded that the reported values of specific volumes in low pressure region are accurate to 0.32%, and that in high pressure region are accurate to 0.26%. The volumes of saturated vapor are accurate to the same value as those reported specific volumes in low pressure region; i.e., 0.32%. The enthalpy and entropy should be of the same order of precision, which can be seen roughly in the previous check; i.e., 0.18% deviation of entropy from the precise experimental data at normal boiling point.

Both smoothing errors and reading errors in saturated liquid volumes are believed to be 0.06%. The over-all errors are therefore 0.12%.

The errors in heat of vaporization are believed to be 0.12%, including 0.02% errors in reading and 0.1% in smoothing.

CHAPTER V

CONCLUSION AND SUMMARY

Canjar, Goldman and March (14) employed the Benedict equation to calculate the thermodynamic properties of propylene with correction determined by a graphical analysis of the residual; i.e., the terms γ_p for pressure correction; $\int_0^d \left[T \left(\frac{\partial \hat{\gamma}_p}{\partial T} \right) - \hat{\gamma}_p \right] \frac{dd}{d^2} + \frac{\hat{\gamma}_p}{d^2}$ for enthalpy correction; and $\int_0^d \left(\frac{\partial \hat{\gamma}_p}{\partial T} \right) d \frac{dd}{d^2}$ for entropy correction. In which γ_p is the pressure residual from the equation. Although the derivation of these correction terms were based on fundamental thermodynamic relationships, this caused a complicated graphical integration.

In this work the thermodynamic properties were computed directly from the related equations with the roots of the density determined from the equation of state (equation 7) for given temperatures and pressures. Corrections were only made on specific volumes. It not only simplified the way of calculation, but also made full advantage of applying the digital computer, since for given pressures and temperatures the roots of the density from the equation of state and the related equations of thermodynamic properties could be determined on the computer at the same time. With the high accuracy of the computed values, it is believed that no error would be presented throughout the calculation work.

Thermodynamic properties of isopentane have been calculated over a

temperature range of 100° to 570°F. , and at pressure up to 3000 lb./sq.in. abs. These properties were determined from vapor pressure, volumetric, ideal gas state enthalpy and entropy, and latent heat of vaporization data through the application of rigorous thermodynamic relationships. The calculated data have been found to be internally consistent. An over-all analysis of the results indicates that the resulting values are accurate to 0.32%.

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APPENDIX A

TABULATIONS AND MOLLIER DIAGRAM FOR THE THER-
MODYNAMIC PROPERTIES OF ISOPENTANE

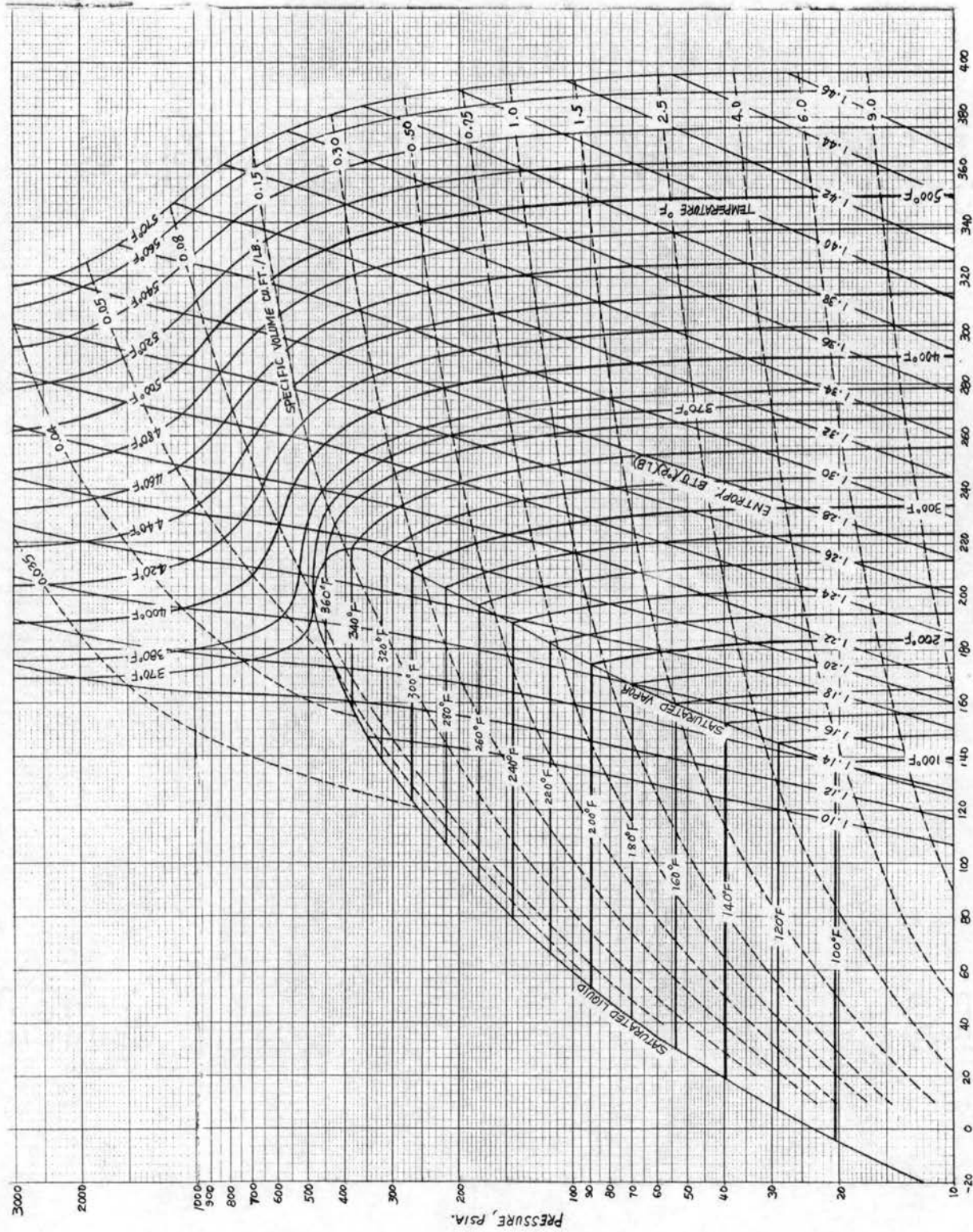


Figure 3
Mollier Chart for Isopentane
Datum: $H^{\circ}=0$ and $S^{\circ}=0$ of OR and Ideal Gas State

TABLE IV PROPERTIES OF SATURATED VAPOR AND LIQUID

Temp. OF	Absolute Pressure Psia	Volume, Cu. ft./lb.		Enthalpy, B.T.U./lb.			Entropy, B.T.U./lb./°R		
		v_f	v_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g
82.13	14.696	0.02619	5.185	-14.2	145.66	131.5	0.8684	0.2688	1.1372
90	16.713	0.02639	4.620	- 9.8	144.2	134.4	0.8766	0.2624	1.1390
100	20.467	0.02664	3.808	- 4.4	142.3	137.9	0.8870	0.2542	1.1412
110	24.350	0.02691	3.239	1.4	140.2	141.6	0.8967	0.2461	1.1428
120	28.784	0.02719	2.772	7.2	138.0	145.2	0.9066	0.2381	1.1447
130	33.819	0.02747	2.382	13.0	135.9	148.9	0.9161	0.2305	1.1466
140	39.548	0.02778	2.044	18.7	133.9	152.6	0.9252	0.2233	1.1485
150	45.922	0.02809	1.777	24.3	132.0	156.3	0.9356	0.2165	1.1521
160	53.069	0.02840	1.540	29.7	130.2	159.9	0.9441	0.2101	1.1542
170	61.009	0.02872	1.375	35.0	128.3	163.3	0.9495	0.2038	1.1533
180	69.833	0.02904	1.210	41.2	126.0	167.2	0.9616	0.1970	1.1586
190	79.521	0.02940	1.066	47.4	123.6	171.0	0.9711	0.1902	1.1613
200	90.219	0.02978	0.9175	53.6	121.1	174.7	0.9802	0.1836	1.1638
210	101.95	0.03018	0.8145	59.9	118.5	178.4	0.9909	0.1769	1.1678

TABLE IV (continued)

$^{\circ}\text{F}$	Psia	v_f	v_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g
220	114.80	0.03060	0.7215	66.2	115.8	182.0	1.0000	0.1704	1.1704
230	128.85	0.03102	0.6410	72.6	112.9	185.5	1.0091	0.1637	1.1728
240	144.15	0.03150	0.5665	79.8	109.6	189.4	1.0196	0.1566	1.1762
250	160.77	0.03200	0.5020	86.4	106.2	192.6	1.0285	0.1496	1.1779
260	178.76	0.03254	0.4438	93.6	102.4	196.0	1.0382	0.1423	1.1805
270	198.22	0.03313	0.3965	100.8	98.53	199.3	1.0477	0.1350	1.1827
280	219.22	0.03378	0.3525	108.2	94.40	202.6	1.0577	0.1276	1.1853
290	241.86	0.03451	0.3115	115.3	90.30	205.6	1.0669	0.1205	1.1874
300	266.15	0.03521	0.2772	122.9	85.90	208.8	1.0768	0.1130	1.1898
310	292.15	0.03622	0.2465	130.6	81.00	211.6	1.0867	0.1052	1.1919
320	319.98	0.03732	0.2183	138.9	75.00	213.9	1.0971	0.0962	1.1933
330	349.72	0.03860	0.1890	147.3	69.30	216.6	1.1069	0.0877	1.1946
340	381.45	0.04020	0.1660	155.0	62.2	217.2	1.1171	0.0778	1.1949
350	415.32	0.04390	0.1406	168.5	49.25	217.5	1.1333	0.0608	1.1941
360	451.47	0.05620	0.1165	187.0	25.80	212.8	1.1560	0.0314	1.1874
370	483.0	0.06485	0.06485	197.0	0	197.0	1.1678	0	1.1678

TABLE V PROPERTIES OF SUPERHEATED VAPOR -ISOPENTANE

VOLUME (ft³/lb.); ENTHALPY (B.T.U./lb.); ENTROPY (B.T.U./lb.°R)

Abs. Pressure, Psia	Property	Temperature, F.								
		100	120	140	160	180	200	220	240	260
0	h	141.2	149.5	158.0	166.8	175.8	185.1	194.6	204.3	214.3
	v	8.11	8.45	8.66	9.00	9.30	9.63	10.04	10.34	10.58
10	h	139.6	148.1	156.7	165.6	174.7	184.0	193.6	203.5	213.5
	s	1.1633	1.1775	1.1912	1.2067	1.2276	1.2347	1.2504	1.2643	1.2781
	v	4.04	4.06	4.24	4.44	4.61	4.78	4.92	5.08	5.23
20	h	138.0	146.6	155.3	164.4	173.6	183.0	192.7	202.6	212.7
	s	1.1419	1.1562	1.1706	1.1864	1.2075	1.2148	1.2301	1.2442	1.2582
	v			2.77	2.88	3.01	3.11	3.23	3.33	3.45
30	h			154.0	163.1	172.4	182.0	191.7	201.7	211.8
	s			1.1579	1.1736	1.1951	1.2023	1.2180	1.2320	1.2462
	v				2.13	2.21	2.29	2.38	2.47	2.55
40	h				161.8	171.2	180.9	190.7	200.7	211.0
	s				1.1642	1.1857	1.1932	1.2090	1.2232	1.2374
	v				1.66	1.73	1.80	1.88	1.94	2.02
50	h				160.4	169.9	179.7	189.7	199.8	210.1
	s				1.1564	1.1780	1.1858	1.2017	1.2161	1.2303
	v						1.16	1.20	1.24	1.30
75	h						176.7	186.9	197.2	207.8
	s						1.1714	1.1876	1.2021	1.2169
	v							0.850	0.895	0.936
100	h							183.9	194.3	205.3
	s							1.1762	1.1914	1.2063

TABLE V (continued)

Abs. Pressure, Psia	Property	Temperature, °F.								
		280	300	320	340	360	370	380	400	420
0	h	224.5	235.0	245.6	256.6	267.6	273.3	279.0	290.6	302.4
10	v	10.83	11.18	11.55	11.85	12.16	12.27	12.38	12.83	13.08
	h	223.8	234.3	245.0	255.9	267.1	272.7	278.5	290.1	301.9
	s	1.2918	1.3059	1.3200	1.3339	1.3478	1.3546	1.3615	1.3757	1.3895
20	v	5.39	5.54	5.68	5.87	6.00	6.08	6.16	6.33	6.48
	h	223.0	233.5	244.3	255.3	266.5	272.2	277.9	289.5	301.4
	s	1.2722	1.2862	1.3001	1.3142	1.3280	1.3350	1.3420	1.3560	1.3699
30	v	3.55	3.65	3.76	3.86	3.97	4.02	4.09	4.20	4.32
	h	222.2	232.8	243.6	254.6	265.9	271.6	277.3	289.0	300.9
	s	1.2603	1.2742	1.2883	1.3023	1.3164	1.3233	1.3304	1.3444	1.3585
40	v	2.63	2.72	2.79	2.87	2.96	2.99	3.04	3.12	3.19
	h	221.4	232.1	242.9	254.0	265.3	271.0	276.8	288.4	300.3
	s	1.2515	1.2657	1.2798	1.2938	1.3164	1.3233	1.3304	1.34444	1.3585
50	v	2.08	2.15	2.22	2.28	2.34	2.38	2.41	2.48	2.54
	h	220.6	231.3	242.2	253.3	264.7	270.4	276.2	287.9	299.8
	s	1.2446	1.2588	1.2731	1.2871	1.3012	1.3083	1.3153	1.3293	1.3433
75	v	1.35	1.39	1.44	1.48	1.53	1.55	1.58	1.62	1.67
	h	218.5	229.4	240.4	251.6	263.1	268.9	274.7	286.5	298.5
	s	1.2314	1.2458	1.2602	1.2744	1.2886	1.2957	1.3028	1.3170	1.3312
100	v	0.976	1.01	1.05	1.08	1.11	1.13	1.16	1.19	1.24
	h	216.3	227.3	238.5	249.9	261.4	267.2	273.1	285.1	297.2
	s	1.2213	1.2359	1.2504	1.2648	1.2789	1.2862	1.2935	1.3079	1.3223

TABLE V (continued)

Abs. Pressure, Psia	Property	Temperature, °F.							
		440	460	480	500	520	540	560	570
0	h	314.4	326.6	339.0	351.6	364.3	377.3	390.5	397.2
	v	13.33	13.72	14.00	14.14	14.59	15.07	15.23	15.40
	s	1.4019	1.4160	1.4284	1.4420	1.4547	1.4689	1.4798	1.4882
10	h	313.9	326.1	338.5	351.1	364.0	376.6	390.1	396.8
	v	6.63	6.76	6.93	7.07	7.22	7.41	7.53	7.62
	s	1.3824	1.3962	1.4088	1.4227	1.4352	1.4492	1.4603	1.4686
20	h	313.4	325.7	338.1	350.7	363.6	376.4	389.8	396.5
	v	4.40	4.49	4.62	4.71	4.81	4.90	5.02	5.08
	s	1.3709	1.3847	1.3975	1.4113	1.4239	1.4384	1.4489	1.4573
30	h	312.9	325.2	337.7	350.3	363.2	376.2	389.4	396.1
	v	3.28	3.38	3.44	3.51	3.59	3.68	3.75	3.78
	s	1.3626	1.3767	1.3891	1.4030	1.4156	1.4296	1.4407	1.4490
40	h	312.5	324.8	337.2	349.9	362.8	375.8	389.1	395.8
	v	2.61	2.67	2.73	2.79	2.86	2.93	2.97	3.01
	s	1.3561	1.3700	1.3826	1.3965	1.4091	1.4232	1.4342	1.4426
50	h	312.0	324.3	336.8	349.5	362.4	375.5	388.7	395.4
	v	1.71	1.75	1.80	1.84	1.88	1.93	1.97	1.99
	s	1.3438	1.3579	1.3706	1.3846	1.3972	1.4113	1.4238	1.4375
75	h	310.7	323.1	335.7	348.4	361.4	374.6	387.8	394.6
	v	1.26	1.31	1.33	1.37	1.40	1.44	1.47	1.48
	s	1.3348	1.3492	1.3618	1.3760	1.3886	1.4027	1.4139	1.4223
100	h	309.4	321.9	334.5	347.4	360.4	373.6	386.9	393.6
	v	1.26	1.31	1.33	1.37	1.40	1.44	1.47	1.48
	s	1.3348	1.3492	1.3618	1.3760	1.3886	1.4027	1.4139	1.4223

TABLE V (continued)

Abs. Pressure, Psia	Property	260	280	300	320	340	360	370	380	400	420
150	v	0.571	0.601	0.633	0.660	0.688	0.714	0.726	0.741	0.766	0.792
	h	199.8	211.3	222.9	234.4	246.1	258.0	263.9	270.0	282.1	294.4
	s	1.1894	1.2050	1.2205	1.2354	1.2502	1.2650	1.2722	1.2796	1.2941	1.3086
200	v		0.405	0.434	0.462	0.486	0.508	0.520	0.533	0.552	0.574
	h		205.4	217.6	229.9	242.0	254.2	260.4	266.6	278.9	291.4
	s		1.1908	1.2071	1.2231	1.2384	1.2536	1.2613	1.2688	1.2835	1.2918
250	v			0.310	0.338	0.363	0.383	0.393	0.403	0.424	0.442
	h			211.2	224.4	237.3	250.1	256.4	262.8	275.5	288.4
	s			1.1942	1.2112	1.2276	1.2437	1.2514	1.2591	1.2745	1.2896
300	v				0.247	0.275	0.297	0.307	0.317	0.337	0.354
	h				217.6	231.6	245.3	252.0	258.5	271.8	284.9
	s				1.1992	1.2169	1.2340	1.2422	1.2502	1.2660	1.2814
350	v					0.206	0.230	0.241	0.250	0.270	0.282
	h					224.3	239.5	246.7	253.7	267.6	281.2
	s					1.2051	1.2239	1.2328	1.2413	1.2579	1.2739
400	v						0.178	0.189	0.201	0.222	0.237
	h						231.9	240.1	248.0	262.9	277.1
	s						1.2125	1.2225	1.2320	1.2498	1.2665
450	v						0.108	0.144	0.158	0.181	0.197
	h						214.8	230.5	240.5	257.1	272.5
	s						1.1899	1.2090	1.2211	1.2410	1.2590
500	v							0.0508	0.1153	0.1459	0.1658
	h							187.6	227.8	250.1	267.1
	s							1.1588	1.2046	1.2311	1.2510

TABLE V (continued)

Abs. Pres- sure, Psia	Prop- erty	Temperature, °F.							
		440	460	480	500	520	540	560	570
150	v	0.815	0.840	0.866	0.889	0.912	0.930	0.956	0.969
	h	306.8	319.4	332.2	345.2	358.2	371.5	385.0	391.8
	s	1.3215	1.3358	1.3488	1.3630	1.3758	1.3898	1.4012	1.4098
200	v	0.592	0.613	0.635	0.651	0.670	0.690	0.704	0.714
	h	304.1	316.8	329.8	342.9	356.1	369.6	383.1	389.9
	s	1.3114	1.3258	1.3390	1.3533	1.3663	1.3806	1.3919	1.4005
250	v	0.462	0.479	0.495	0.508	0.523	0.539	0.554	0.561
	h	301.3	314.1	327.3	340.5	353.9	367.5	381.1	388.0
	s	1.3032	1.3175	1.3307	1.3454	1.3584	1.3729	1.3845	1.3930
300	v	0.369	0.382	0.398	0.413	0.427	0.443	0.456	0.462
	h	298.2	311.3	324.7	338.0	351.7	365.3	379.1	386.1
	s	1.2954	1.3102	1.3237	1.3383	1.3518	1.3662	1.3779	1.3866
350	v	0.301	0.317	0.332	0.346	0.358	0.369	0.381	0.385
	h	294.8	308.3	321.9	335.5	349.2	363.0	377.0	384.0
	s	1.2881	1.3035	1.3172	1.3321	1.3455	1.3602	1.3722	1.3807
400	v	0.251	0.265	0.279	0.292	0.303	0.316	0.328	0.333
	h	291.2	305.0	318.9	332.8	346.7	360.8	374.8	381.9
	s	1.2813	1.2969	1.3110	1.3262	1.3399	1.3549	1.3668	1.3755
450	v	0.214	0.228	0.238	0.250	0.262	0.274	0.284	0.289
	h	287.2	301.6	315.8	330.0	344.2	358.4	372.6	379.8
	s	1.2745	1.2908	1.3057	1.3207	1.3347	1.3498	1.3619	1.3708
500	v	0.1819	0.1958	0.2084	0.2193	0.2299	0.2385	0.2493	0.2541
	h	282.8	298.0	312.5	327.0	341.5	355.9	370.3	377.6
	s	1.2676	1.2849	1.2919	1.3153	1.3296	1.3449	1.3572	1.3661

TABLE V (continued)

Abs. Pres- sure, Psia	Prop- erty	Temperature, °F.									
		370	380	390	400	410	420	430	440	450	460
550	v	0.04461	0.05230	0.09241	0.1066	0.1192	0.1281	0.1363	0.1436	0.1498	0.1561
	h	181.5	197.4	222.9	239.8	251.0	260.4	269.6	278.0	285.8	293.7
	s	1.1486	1.1651	1.1978	1.2178	1.2308	1.2406	1.2510	1.2606	1.2697	1.2783
600	v	0.04265	0.04640	0.05555	0.07700	0.09303	0.1050	0.1146	0.1221	0.1293	0.1356
	h	178.9	190.3	205.7	224.2	240.3	252.4	263.0	272.2	280.9	289.1
	s	1.1450	1.1586	1.1770	1.1917	1.2175	1.2301	1.2420	1.2526	1.2626	1.2718
650	v	0.04140	0.04404	0.04821	0.05644	0.07043	0.08400	0.09455	0.1036	0.1112	0.1180
	h	177.2	187.4	199.1	215.5	228.5	242.8	254.9	265.6	275.3	284.2
	s	1.1426	1.1545	1.1686	1.1877	1.2030	1.2181	1.2321	1.2442	1.2550	1.2651
700	v	0.04047	0.04261	0.04550	0.04973	0.05716	0.06179	0.07831	0.08773	0.09599	0.1027
	h	176.0	185.5	195.8	207.3	220.3	233.9	246.8	258.5	269.0	278.8
	s	1.1407	1.1519	1.1640	1.1777	1.1930	1.2074	1.2217	1.2355	1.2470	1.2580
750	v	0.03972	0.04151	0.04378	0.04676	0.05124	0.05720	0.06526	0.07460	0.08756	0.08960
	h	175.0	184.0	193.4	203.8	215.3	227.5	239.7	251.6	262.9	273.3
	s	1.1389	1.1457	1.1608	1.1732	1.1867	1.1993	1.2134	1.2267	1.2393	1.2510
800	v	0.03912	0.04109	0.04307	0.04496	0.04796	0.05234	0.05799	0.06223	0.07192	0.07875
	h	174.1	182.8	191.8	201.5	211.7	222.9	234.5	246.1	257.2	267.9
	s	1.1377	1.1480	1.1584	1.1700	1.1820	1.1935	1.2068	1.2199	1.2325	1.2443
850	v	0.03867	0.03989	0.04157	0.04359	0.04603	0.04913	0.05237	0.05824	0.06387	0.0700
	h	173.5	181.8	190.6	199.8	209.4	219.6	230.7	241.5	252.1	263.0
	s	1.1362	1.1463	1.1565	1.1675	1.1787	1.1892	1.2018	1.2140	1.2262	1.2383

TABLE V (continued)

Abs. Pres- sure, Psia	Prop- erty	Temperature, °F.										
		470	480	490	500	510	520	530	540	550	560	570
550	v	0.1625	0.1676	0.1726	0.1781	0.1824	0.1883	0.1899	0.1952	0.1980	0.2033	0.2081
	h	301.3	308.8	316.1	323.9	331.2	338.6	345.9	353.5	360.7	367.9	375.1
	s	1.2870	1.2941	1.3018	1.3104	1.3180	1.3250	1.3325	1.3406	1.3478	1.3542	1.3615
600	v	0.1414	0.1475	0.1510	0.1579	0.1633	0.1672	0.1705	0.1766	0.1795	0.1826	0.1873
	h	297.2	305.0	312.8	320.6	328.2	335.6	343.0	350.8	358.0	365.2	372.8
	s	1.2809	1.2882	1.2966	1.3050	1.3133	1.3200	1.3278	1.3364	1.3436	1.3497	1.3575
650	v	0.1240	0.1298	0.1346	0.1400	0.1444	0.1495	0.1527	0.1575	0.1608	0.1653	0.1694
	h	292.9	301.1	309.1	317.1	324.9	332.8	340.1	348.0	355.5	363.0	370.4
	s	1.2741	1.2823	1.2913	1.2998	1.3085	1.3154	1.3232	1.3315	1.3393	1.3482	1.3537
700	v	0.1088	0.1146	0.1197	0.1254	0.1300	0.1340	0.1386	0.1427	0.1467	0.1510	0.1544
	h	288.0	296.6	305.4	313.5	321.5	329.5	330.5	345.2	353.0	360.0	368.1
	s	1.2682	1.2764	1.2858	1.2947	1.3035	1.3107	1.3187	1.3273	1.3353	1.3418	1.3498
750	v	0.09606	0.1019	0.1066	0.1116	0.1169	0.1211	0.1253	0.1295	0.1329	0.1372	0.1416
	h	283.0	292.2	301.2	309.7	317.9	326.0	334.2	342.7	350.0	358.0	365.2
	s	1.2617	1.2706	1.2802	1.2922	1.2985	1.3058	1.3143	1.3228	1.3312	1.3380	1.3460
800	v	0.08504	0.09059	0.09586	0.1008	0.1052	0.1100	0.1140	0.1180	0.1216	0.1249	0.1295
	h	277.9	287.5	296.8	305.8	314.4	322.7	331.1	339.1	347.0	355.2	363.3
	s	1.2554	1.2642	1.2747	1.2845	1.2938	1.3015	1.3101	1.3182	1.3267	1.3340	1.3423
850	v	0.07595	0.08172	0.08652	0.09125	0.09592	0.1003	0.1044	0.1083	0.1121	0.1158	0.1195
	h	273.2	283.0	292.5	301.7	311.0	319.4	328.0	336.2	344.0	352.6	360.7
	s	1.2494	1.2592	1.2693	1.2793	1.2891	1.2968	1.3060	1.3143	1.3230	1.3303	1.3386

TABLE V (continued)

Abs. Pressure, Psia	Property	Temperature, °F.									
		370	380	390	400	410	420	430	440	450	460
900	v	0.03833	0.03934	0.04087	0.04252	0.04457	0.04707	0.05013	0.05398	0.05853	0.06344
	h	173.0	181.0	189.5	198.3	207.6	217.3	227.6	238.0	248.4	258.8
	s	1.1352	1.1444	1.1544	1.1654	1.1762	1.1860	1.1978	1.2096	1.2215	1.2330
950	v	0.03800	0.03885	0.04032	0.04162	0.04345	0.04556	0.04805	0.05096	0.05466	0.05873
	h	172.7	180.5	188.8	197.2	206.3	215.5	225.2	235.1	245.2	255.3
	s	1.1344	1.1438	1.1536	1.1637	1.1742	1.1835	1.1946	1.2060	1.2173	1.2287
1000	v	0.03769	0.03852	0.03981	0.04094	0.04252	0.04438	0.04647	0.04891	0.05187	0.05518
	h	172.3	180.0	188.2	196.4	205.1	214.0	223.2	232.9	242.5	252.4
	s	1.1336	1.1427	1.1525	1.1623	1.1723	1.1814	1.1920	1.2029	1.2139	1.2250
1050	v	0.03731	0.03808	0.03927	0.04035	0.04175	0.04337	0.04521	0.04728	0.04968	0.05252
	h	171.9	179.5	187.5	195.6	204.1	213.6	221.5	230.9	240.2	249.9
	s	1.1325	1.1417	1.1514	1.1610	1.1708	1.1794	1.1895	1.2001	1.2108	1.2217
1100	v	0.03969	0.03774	0.03883	0.03983	0.04113	0.04256	0.04423	0.04605	0.04813	0.05055
	h	171.5	179.0	187.0	195.0	203.2	211.6	220.3	229.5	238.6	247.9
	s	1.1315	1.1409	1.1503	1.1598	1.1694	1.1779	1.1877	1.1980	1.2085	1.2190
1150	v	0.03669	0.03741	0.03842	0.03940	0.04055	0.04188	0.04338	0.04500	0.04791	0.04887
	h	171.2	178.6	186.4	194.4	202.5	210.9	219.2	228.1	237.1	246.2
	s	1.1307	1.1398	1.1492	1.1586	1.1682	1.1767	1.1860	1.1960	1.2064	1.2165
1200	v	0.03644	0.03731	0.03808	0.03904	0.04006	0.04130	0.04265	0.04411		0.04750
	h	171.0	178.3	186.0	194.0	201.9	210.0	218.4	227.0	235.8	244.2
	s	1.1299	1.1390	1.1483	1.1578	1.1671	1.1752	1.1847	1.1945	1.2045	1.2143

TABLE V (continued)

Abs. Pressure, Psia	Property	Temperature, °F.										
		470	480	490	500	510	520	530	540	550	560	570
900	v	0.06862	0.07412	0.07875	0.08335	0.08784	0.09179	0.09626	0.09972	0.1034	0.1074	0.1109
	h	269.0	279.0	288.5	298.1	307.2	316.0	324.8	333.2	341.6	349.8	358.1
	s	1.2442	1.2539	1.2644	1.2746	1.2843	1.2923	1.3016	1.3106	1.3192	1.3265	1.3350
950	v	0.06312	0.06768	0.07234	0.07658	0.08092	0.08478	0.08885	0.09241	0.09599	0.09957	0.1034
	h	265.3	275.2	285.0	294.5	303.8	312.7	321.6	332.7	338.8	347.3	355.8
	s	1.2396	1.2492	1.2592	1.2701	1.2801	1.2882	1.2975	1.3068	1.3155	1.3228	1.3317
1000	v	0.05893	0.06286	0.06719	0.07086	0.07492	0.07882	0.08250	0.08593	0.08954	0.09290	0.09559
	h	262.2	272.0	280.7	291.3	300.5	309.7	318.5	327.5	336.0	344.2	353.2
	s	1.2359	1.2452	1.2539	1.2659	1.2759	1.2842	1.2936	1.3030	1.3120	1.3194	1.3282
1050	v	0.05567	0.05898	0.06258	0.06616	0.06986	0.07365	0.07692	0.07975	0.08370	0.08674	0.08971
	h	259.6	269.6	278.9	288.5	297.5	306.8	315.7	324.2	333.5	342.1	350.6
	s	1.2326	1.2416	1.2519	1.2623	1.2723	1.2806	1.2901	1.2995	1.3086	1.3161	1.3246
1100	v	0.05311	0.05607	0.05916	0.06235	0.06569	0.06889	0.07208	0.07513	0.07853	0.08153	0.08452
	h	257.3	266.3	276.4	285.8	295.0	304.3	313.3	322.2	331.0	339.7	348.3
	s	1.2295	1.2385	1.2487	1.2588	1.2688	1.2770	1.2870	1.2953	1.3054	1.3130	1.3215
1150	v	0.05122	0.05362	0.05637	0.05923	0.06216	0.06507	0.06811	0.07094	0.07412	0.07700	0.07989
	h	255.5	264.2	274.1	283.4	292.7	301.6	310.8	319.7	328.6	337.5	346.1
	s	1.2269	1.2356	1.2458	1.2558	1.2658	1.2738	1.2837	1.2928	1.3023	1.3100	1.3187
1200	v	0.04964	0.05168	0.05414	0.05654	0.05898	0.06133	0.06477	0.06735	0.07029	0.07295	0.07566
	h	254.0	262.8	272.0	281.2	290.5	299.5	308.7	317.5	326.4	335.2	344.0
	s	1.2242	1.2331	1.2431	1.2531	1.2629	1.2710	1.2807	1.2901	1.2994	1.3070	1.3160

TABLE V (continued)

Abs. Pres- sure, Psia	Prop- erty	Temperature, °F.									
		370	380	390	400	410	420	430	440	450	460
1250	v	0.03623	0.03688	0.03775	0.03867	0.03962	0.04077	0.04200	0.04331	0.04477	0.04642
	h	170.7	178.0	185.5	193.4	201.3	209.4	217.5	226.0	234.2	243.4
	s	1.1292	1.1382	1.1474	1.1567	1.1659	1.1740	1.1834	1.1930	1.2028	1.2124
1300	v	0.03603	0.03667	0.03744	0.03829	0.03923	0.04029	0.04139	0.04263	0.04400	0.04514
	h	170.5	177.7	185.2	193.0	200.8	208.8	216.9	225.3	233.6	242.2
	s	1.1286	1.1375	1.1464	1.1557	1.1650	1.1728	1.1822	1.1917	1.2012	1.2133
1350	v	0.03584	0.03648	0.03715	0.03797	0.03887	0.03985	0.04087	0.04203	0.04327	0.04468
	h	170.4	177.5	185.0	192.6	200.3	208.2	216.2	224.5	232.8	241.3
	s	1.1280	1.1368	1.1455	1.1542	1.1640	1.1717	1.1811	1.1904	1.1998	1.2093
1400	v	0.03566	0.03628	0.03690	0.03769	0.03855	0.03946	0.04039	0.04150	0.04265	0.04396
	h	170.2	177.4	184.7	192.3	200.0	207.7	215.7	223.9	232.0	240.5
	s	1.1274	1.1363	1.1448	1.1539	1.1631	1.1707	1.1800	1.1892	1.1986	1.2080
1450	v	0.03547	0.03610	0.03669	0.03746	0.03829	0.03910	0.03994	0.04106	0.04205	0.04331
	h	170.0	177.1	184.5	192.0	199.7	207.3	215.2	223.3	231.4	239.6
	s	1.1268	1.1357	1.1444	1.1533	1.1622	1.1699	1.1785	1.1881	1.1975	1.2066
1500	v	0.03527	0.03591	0.03649	0.03723	0.03806	0.03878	0.03957	0.04060	0.04152	0.04285
	h	169.9	177.0	184.3	191.8	199.5	207.0	214.7	222.8	230.7	239.0
	s	1.1262	1.1351	1.1435	1.1527	1.1617	1.1690	1.1780	1.1870	1.1962	1.2055

TABLE V (continued)

Abs. Pressure, Psia	Property	Temperature, °F.										
		470	480	490	500	510	520	530	540	550	560	570
1250	v	0.04830	0.05015	0.05230	0.05445	0.05699	0.05939	0.06193	0.06441	0.06703	0.06951	0.07212
	h	252.3	261.3	270.2	279.2	288.5	297.6	306.6	315.5	324.3	333.2	341.8
	s	1.2225	1.2310	1.2407	1.2505	1.2604	1.2685	1.2781	1.2874	1.2968	1.3043	1.3132
1300	v	0.04715	0.04887	0.05077	0.05274	0.05487	0.05713	0.06026	0.06283	0.06529	0.06768	0.07036
	h	251.0	259.9	268.7	277.7	286.8	295.8	304.7	313.5	322.5	331.4	340.0
	s	1.2207	1.2290	1.2385	1.2483	1.2580	1.2660	1.2755	1.2844	1.2942	1.3018	1.3107
1350	v	0.04614	0.04775	0.04938	0.05126	0.05303	0.05522	0.05728	0.05974	0.06174	0.06393	0.06626
	h	250.0	258.6	267.5	276.3	285.1	294.1	303.0	311.9	320.7	330.7	338.2
	s	1.2190	1.2270	1.2367	1.2463	1.2558	1.2638	1.2731	1.2826	1.2918	1.3010	1.3084
1400	v	0.04525	0.04675	0.04823	0.04998	0.05153	0.05352	0.05544	0.05780	0.05962	0.06166	0.06376
	h	249.0	257.5	266.3	275.0	283.8	292.5	301.5	310.4	318.5	327.8	336.6
	s	1.2174	1.2254	1.2343	1.2444	1.2538	1.2617	1.2711	1.2805	1.2895	1.2973	1.3063
1450	v	0.04445	0.04588	0.04723	0.04881	0.05018	0.05217	0.05419	0.05600	0.05770	0.05990	0.06199
	h	248.0	256.5	265.1	273.9	282.5	291.2	300.0	308.9	317.6	326.2	335.1
	s	1.2159	1.2239	1.2332	1.2426	1.2520	1.2599	1.2690	1.2785	1.2874	1.2952	1.3042
1500	v	0.04378	0.04512	0.04636	0.04780	0.04805	0.05096	0.05250	0.05436	0.05611	0.05792	0.05959
	h	246.1	255.6	264.1	272.9	281.3	290.0	298.7	307.5	316.3	324.3	333.7
	s	1.2146	1.2225	1.2317	1.2411	1.2503	1.2582	1.2672	1.2765	1.2855	1.2933	1.3022

TABLE V (continued)

Abs. Pres- sure, Psia	Prop- erty	Temperature °F											
		370	380	400	420	440	460	480	500	520	540	560	570
1750	v	0.03452	0.03507	0.03623	0.03756	0.03883	0.04058	0.04101	0.04440	0.04636	0.05031	0.05134	0.05290
	h	169.3	176.3	190.8	206.1	220.7	237.0	252.3	269.7	285.4	302.1	319.3	327.8
	s	1.1232	1.1323	1.1498	1.1655	1.1827	1.2019	1.2168	1.2346	1.2510	1.2683	1.2852	1.2940
2000	v	0.03395	0.03439	0.03545	0.03648	0.03773	0.03902	0.04041	0.04191	0.04372	0.04559	0.04755	0.04870
	h	169.0	175.9	190.3	204.2	219.5	234.8	250.2	265.9	282.2	298.5	315.3	323.7
	s	1.1216	1.1300	1.1472	1.1624	1.1797	1.1968	1.2124	1.2292	1.2455	1.2630	1.2789	1.2875
2250	v	0.03342	0.03386	0.03471	0.03572	0.03677	0.03787	0.03898	0.04041	0.04180	0.04331	0.04486	0.04574
	h	169.0	175.7	190.0	204.1	218.9	233.6	248.8	264.4	280.2	296.2	312.5	320.8
	s	1.1196	1.1279	1.1449	1.1599	1.1769	1.1938	1.2090	1.2260	1.2416	1.2585	1.2741	1.2826
2500	v	0.03292	0.03337	0.03416	0.03506	0.03600	0.03690	0.03805	0.03920	0.04039	0.04165	0.04305	0.04372
	h	169.0	175.7	189.7	203.9	218.3	233.0	248.0	263.3	278.8	294.5	310.5	318.5
	s	1.1171	1.1260	1.1425	1.1577	1.1744	1.1908	1.2062	1.2229	1.2382	1.2544	1.2700	1.2782
2750	v	0.03246	0.03291	0.03372	0.03445	0.03536	0.03617	0.03718	0.03815	0.03927	0.04025	0.04162	0.04223
	h	169.0	175.9	189.6	203.6	218.0	232.5	247.3	262.5	277.8	293.3	309.2	317.1
	s	1.1157	1.1243	1.1410	1.1557	1.1722	1.1885	1.2038	1.2202	1.2355	1.2516	1.2670	1.2750
3000	v	0.03202	0.03246	0.03328	0.03386	0.03474	0.03543	0.03638	0.03732	0.03818	0.03927	0.04024	0.04085
	h	169.0	176.3	189.5	203.6	217.9	232.2	246.9	261.8	277.0	292.5	307.9	316.0
	s	1.1136	1.1223	1.1391	1.1537	1.1701	1.1860	1.2014	1.2177	1.2326	1.2491	1.2638	1.2720

APPENDIX B

VALUES OF CONSTANTS AND DIMEN-
SIONAL EQUIVALENTS

<u>Physical Constants</u>	<u>Value</u>
Molecular Weight of isopentane	72.146 (3)
Ice Point	273.160 ± 0.010°K (2)
Gas Constant, R	0.0820544 $\frac{(\text{liter})(\text{atm})}{(\text{g}\cdot\text{mole})(^\circ\text{K})}$ (2)

Constants of Benedict-Webb-Rubin Equation of State (11)

$$A_0 = 12.7959$$

$$B_0 = 0.160053$$

$$C_0 = 1.74632 \times 10^6$$

$$a = 3.75620$$

$$b = 0.066812$$

$$c = 6.95000 \times 10^5$$

$$\alpha = 1.7000 \times 10^{-3}$$

$$\gamma = 4.63000 \times 10^{-2}$$

Constants of Francis Equations (19)

$$A = 0.6666$$

$$B = 88 \times 10^{-5}$$

$$C = 6$$

$$E = 222$$

$$F = 1.0$$

$$G = 321 \times 10^{-6}$$

$$h = 2.9$$

$$K = 2.94$$

Constants of Equation 2 (21)

$$d_s = 0.63930 \text{ gm/cm}^3$$

$$t_s = 0 \text{ } ^\circ\text{C.}$$

$$\alpha = -0.9714$$

$$\beta = -0.695$$

$$\gamma = -7.08$$

Equivalents (2)

$$1 \text{ pound mass} = 453.5924 \text{ gram mass}$$

$$1 \text{ cubic foot} = 28.31622 \text{ liters}$$

$$1 \text{ Std. atm.} = 760 \text{ Std. m.m. Hg}$$

$$1 \text{ Std. atm.} = 14.69601 \text{ pounds/sq.in.}$$

$$1 \text{ atm-liter} = 0.0960417 \text{ B.T.U.}$$

$$1 \text{ }^\circ\text{K} = 1.8 \text{ }^\circ\text{R}$$

NOMENCLATURE

D	Liquid density (gm/cm^3)
D_c	Critical density (gm/cm^3)
D_s	Density of the saturated liquid (gm/cm^3)
d	Density ($\text{g}\cdot\text{mole}/\text{cm}^3$)
d_s	Standard liquid density (gm/cm^3) at the given temperature $t_s^\circ\text{C}$.
d_t	Saturated liquid density (gm/cm^3) at the given temperature $t^\circ\text{C}$.
e	Base of natural logarithms, 2.7181, dimensionless.
H	Enthalpy ($E + PV$), (B.T.U./lb.)
H°	Ideal gas enthalpy of the pure compound (B.T.U./lb.)
H_v	Enthalpy of vaporization (B.T.U./lb.)
R	Gas constant (liter-atm./g·mole $^{-\circ}\text{K}$)
P	Absolute pressure (atm.) unless specified as Psia.
P_{cal}	Calculated vapor pressure (atm.)
P_{obs}	Observed vapor pressure (atm.)
S	Entropy (B.T.U./lb. $^{-\circ}\text{R}$.)
S	(= dP/dT) slope of isochor (atm./ $^\circ\text{C}$.)
S°	Ideal gas entropy of the pure compound (B.T.U./lb. $^{-\circ}\text{R}$.)
T	Absolute temperature ($^\circ\text{K}$) unless specified as $^\circ\text{C}$.
t	Temperature ($^\circ\text{C}$.)
t_c	Critical temperature ($^\circ\text{C}$.)
t_s	Standard temperature ($^\circ\text{C}$.) for standard density.
V	Specific volume (cu.ft./lb.)
γ_p	Residual pressure, difference between observed and equation.

VITA

Shing Ke Chian

Candidate for the Degree of

Master of Science

Thesis: THERMODYNAMIC PROPERTIES OF ISOPENTANE

Major Field: Chemical Engineering

Biographical:

Personal data: Born in Shanghai, China, May 24, 1935, the son of
Jorng Yuan Chian and Shih Mei Chian.

Education: Attended elementary school in Shanghai, China; graduated
from St. John's Y.M.C.A. Middle School; received the Bachelor of
Science degree from Taipei Institute of Technology in July, 1955;
completed the requirements for the Master of Science degree in
August, 1959; member of Chinese Chemical Engineer Association.

Professional experience: Accepted employment with Taiwan Alkaline Company
in their Research and Development Department during the summer
of 1953 and 1954; entered the Chinese Army in September, 1955;
received an Honorable Discharge with a rank of second lieutenant
in field of Chemical Warfare in August, 1956; employed by Taipei
Institute of Technology as an assistant in Chemical Engineering
Department from September, 1956, to August, 1957.