$\underline{Q}$ = heat, B.t.u.
$\underline{\mathring{Q}}$ = thermal flux, B.t.u./sec.
$\not{q}$ = heat, an infinitesimal, B.t.u.
$\underline{\mathring{q}}$ = net thermal flux, B.t.u./sec.
T = temperature, ° R.
V = specific volume, cu. ft./lb.
θ = time, sec.
∂ = partial differential operator
$\oint$ = line integral

Subscripts

A = calorimeter
B = jacket
b = bubble point
c = conduction
d = dew point
E = electrical
g = gas phase
H = heater
I = current
l = liquid phase
r = radiation
s = agitation
1 = initial condition
2 = final condition

Superscript

$*$ = average

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Thermodynamic Properties of Perfluoro-2- butyltetrahydrofuran

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THE FLUOROCARBONS show great promise for industrial applications where operating conditions are unusually severe, because of their marked chemical inertness and great thermal stability (*1*). In this class are the fluorinated cyclic ethers, which are stable to temperatures in excess of 400° C. and have electrical insulating properties much superior to hydrocarbon oils (*2*). As an aid in their industrial application, data are needed on their physical and thermal properties. This article presents the thermodynamic properties of an important cyclic ether, perfluoro-2-butyltetrahydrofuran. The values were calculated by applying the rigorous thermodynamic equations to the data on the heat capacities and *P-V-T* relations of this compound. The temperature and pressure ranges covered are from the standard bolining point (102.6° C.) to 300° C. and a pressure of 44 atm.

Since the preparation of the manuscript, a chromatographic analysis of the sample that was studied showed that the sample was a mixture of close boiling isomers of indeterminate amounts. While the perfluoro-2-butyltetrahydrofuran [perfluoro-cyclic oxide ($C_8F_{16}O$)] is undoubtedly a major component, it is only one of several. The boiling range of the sample at atmospheric pressure was approximately 0.1° C.

PROPERTIES OF PERFLUORO-2-BUTYL-TETRAHYDROFURAN

Data on the heat capacities of perfluoro-2-butyltetrahydrofuran at 1 atm. as a function of temperature have been determined (*6, 7*) and are summarized by the following equations for the liquid,

$$C = 50.75 + 0.1752\,T \tag{1}$$

and for the vapor,

$$C_p = 72.73 + 0.6745\,T \tag{2}$$

where C and C_p are the heat capacities in calories per gram-mole, ° C., and T is ° K. The over-all accuracy of the data calculated by means of the equations is ±1.1% for the liquid and ±1.3% for the vapor.

The *P-V-T* relations were reported by Throckmorton (*5*). Data were given for the vapor pressure and saturated liquid and vapor specific volumes from 160° C. to the critical point, the specific volume of the liquid from 25° to 110° C., and *P-V-T* relations for the superheated vapor from 160° to 300° C. at pressures from 3.4 to 44 atm. Saturated vapor volumes at 100° and 110° C. and superheated vapor volumes for pressures near 1 atm. were measured by Leverett (*3*). Vapor pressure data between 60° and 100° C. have been reported by the Minnesota Mining and Manufacturing Co. (*4*).

Values of the vapor pressure between 110° and 160° C. are missing. These were estimated by extrapolating the experimental data with the aid of the standard vapor pressure equation, $\log P_{\text{calcd.}} = A/T + B$. The constants, A and B, were calculated using the values of the pressure and temperature at the critical point and the standard boiling point, to give the following equation:

$$\log P_{\text{calcd.}} \text{ (atm.)} = -1812.96/T\ (^\circ\text{ K.}) + 4.82465 \qquad (3)$$

The deviation, r, of the calculated pressure, $P_{\text{calcd.}}$, from the experimental vapor pressure, P, was calculated and plotted as a function of the temperature. A smooth curve was drawn through the points and extended to the atmospheric boiling point. The deviation curve is shown in Figure 1. With the aid of the equation and the curve, the missing data were estimated for temperatures between 100° and 160° C.

The missing saturated liquid volumes in this temperature region were obtained by an extrapolation of the data to the standard boiling point.

CALCULATION OF THE THERMODYNAMIC PROPERTIES

The molal latent heat of vaporization, ΔH_v, was calculated with the aid of the Clapeyron equation together with the vapor pressure equation and the deviation plot, Figure 1. By the Clapeyron equation

$$\Delta H_v = T(V_v - V_l)\ \frac{dP}{dT} \qquad (4)$$

where V_v and V_l are the molal volumes of the saturated vapor and liquid, respectively at temperature T.

Since,

$$P = P_{\text{calcd.}} - r \qquad (5)$$

differentiating with respect to temperature gives,

$$\frac{dP}{dT} = \frac{dP_{\text{calcd.}}}{dT} - \frac{dr}{dT} \qquad (6)$$

The term $\frac{dP_{\text{calcd.}}}{dT}$ was obtained by differentiating Equation 3 to give

$$\frac{dP_{\text{calcd.}}}{dT} = 2.303\ \frac{(1812.96)\ P_{\text{calcd.}}}{T^2} \qquad (7)$$

dr/dt is the slope of the deviation curve at the given temperature. dP/dt, calculated by Equation 6, was substituted in Equation 4 to give ΔH_v. A large plot of the molal latent heat as a function of temperature was prepared and extended to 60° C. to give a consistent set of values of the latent heat from 60° C. to the critical temperature.

These values of the molal latent heat between 60° and 160° C. were used to calculate the corresponding values of the saturated molal vapor volumes by rearranging Equation 4 to give,

$$V_v = V_l + \Delta V = V_l + \Delta H_v$$

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

The saturated liquid at 0° C. was chosen as the reference state for the tables of properties. To calculate the enthalpy and entropy of the saturated liquid from 60° to 102.6° C., it was assumed that the heat capacity of the saturated liquid was equal to the heat capacity of the liquid at 1 atm. The equations were as follows:

$$H_l - H^\circ = H_l = 50.75\ (T - 273.2) + 0.0876\ (T^2 - 273.2^2) \qquad (8)$$

and for the entropy,

$$S_l - S^\circ = S_l = 50.75 \ln\frac{T}{273.2} + 0.1752\ (T - 273.2) \qquad (9)$$

The enthalpy and entropy of the saturated vapor between 60° and 102° C., were obtained by adding the molal latent heat of vaporization and entropy of vaporization to the respective values for the saturated liquid.

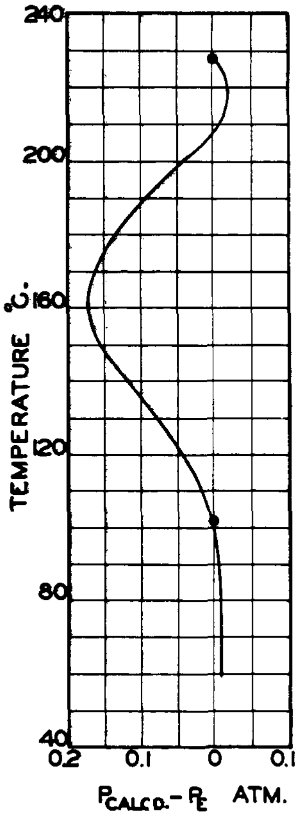

Figure 1. Deviation of observed vapor pressure from standard vapor pressure equation →

In the superheated region, the effect of pressure on the enthalpy and entropy, respectively, is given by the equations

$$\left(\frac{\partial H}{\partial P}\right)_T = V - T\ \left(\frac{\partial V}{\partial T}\right)_P \qquad (10)$$

and

$$\left(\frac{\partial S}{\partial P}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P \qquad (11)$$

Generally, it is desirable to use an equation of state which fits the P-V-T data throughout the region of calculations to calculate the quantity $\left(\frac{\partial V}{\partial T}\right)_P$. However, for perfluoro-2-butyltetrahydrofuran attempts at fitting the data to existing equations proved unsatisfactory, and a graphical method was adopted, in which the residual volume, ($\alpha = RT/P - V$), was used.

The residual volumes were evaluated using the data for pressures above 3 atm., and temperatures above 160° C. The residual volumes were plotted against pressure for a series of constant temperatures and smooth curves drawn and extended to zero pressure. Each isotherm was drawn so as to be consistent with surrounding isotherms. A cross plot of residual volume, α, as a function of temperature at constant pressure was used to smooth the data further and to ensure its consistency. The regularity of the constant pressure curves indicated that the α-values had been satisfactorily extended to zero pressure.

From curves of α *vs.* temperature at constant pressure, slopes were determined visually with a straight-edge at 10° intervals between 160° and 300° C. and for pressure intervals of 1 atm. from 1 to 44 atm. The consistency of the measured slopes was shown to be satisfactory by the regularity of the plots of the term $\left[T\left(\frac{\partial \alpha}{\partial T}\right)_P - \alpha\right]$ *vs.* the pressure.

The pressure correction for the enthalpy in terms of residual volume was obtained by graphically integrating the equation,

$$\int dH = \int_{P=1}^{P} \left[T\left(\frac{\partial \alpha}{\partial T}\right)_P - \alpha\right] dP \qquad (12)$$

In the temperature region immediately above the critical point where $\left(\frac{\partial \alpha}{\partial T}\right)_P$ changes rapidly, values of $\left[T\left(\frac{\partial \alpha}{\partial T}\right)_P - \alpha\right]$ were determined for each 0.2-atm. change in pressure.

Likewise, the pressure correction for the entropy in terms of the residual volume was evaluated by graphical integration of the equation,

$$\int dS = \int_{P=1}^{P} \left[\frac{R}{P} - \left(\frac{\partial \alpha}{\partial T}\right)_P\right] dP \qquad (13)$$

From the α-*vs.* pressure plots, the activity coefficient,

Table I. Saturated Properties of Perfluoro-2-butyltetrahydrofuran with Temperature as Independent Variable

(Reference point, saturated liquid at 1 atm. and 0° C.)

Temp., ° C.	$p.$, Atm.	V_l, L./Mole	V_v, L./Mole	H_l, Cal./Mole	ΔH_v, Cal./Mole	H_v, Cal./Mole	S_l, Cal./Mole, ° K.	ΔS_v, Cal./Mole, ° K.	S_v, Cal./Mole, ° K.
60	0.2307	0.24851	123.55	6,232	9,029	15,261	20.59	27.35	47.94
70	0.3428	0.25245	86.34	7,332	8,824	16,156	23.85	25.94	49.79
80	0.4910	0.25691	61.54	8,449	8,449	17,061	27.06	24.59	51.65
90	0.6824	0.26164	44.66	9,585	8,400	17,985	30.23	23.32	53.55
100	0.9269	0.26653	32.91	10,740	8,179	18,920	33.36	21.92	55.28
102.6	1.000	0.26779	28.26	11,040	8,123	19,160	34.16	21.62	55.78
110	1.257	0.2722	22.99	11,860	7,941	19,800	36.28	20.73	57.01
120	1.679	0.2794	17.44	12,970	7,696	20,670	39.16	19.57	58.73
130	2.207	0.2875	13.24	14,090	7,433	21,520	42.00	18.44	60.44
140	2.853	0.2964	10.42	15,240	7,138	22,380	44.88	17.28	62.16
150	3.623	0.3051	8.238	16,440	6,796	23,240	47.81	16.06	63.87
160	4.528	0.31570	6.5659	17,810	6,405	24,210	50.95	14.79	65.74
170	5.579	0.32904	5.2218	19,010	5,924	24,930	53.90	13.37	67.27
180	6.799	0.34411	4.0958	20,390	5,428	25,820	56.93	11.98	68.91
190	8.225	0.35911	3.2390	21,790	4,917	26,710	59.75	10.62	70.37
200	9.887	0.37996	2.5065	23,150	4,351	27,500	62.59	9.196	71.79
210	11.803	0.41125	1.9213	24,640	3,654	28,290	65.58	7.563	73.14
220	14.053	0.46064	1.4090	26,280	2,753	29,030	68.79	5.582	74.37
223	14.795	0.49351	1.1994	26,800	2,321	29,120	69.76	4.678	74.44
225	15.318	0.52251	1.0732	27,350	1,736	29,090	70.79	3.485	74.28
227.06	15.861	0.70738	0.70738	28,490	0	28,490	73.09	0	73.09

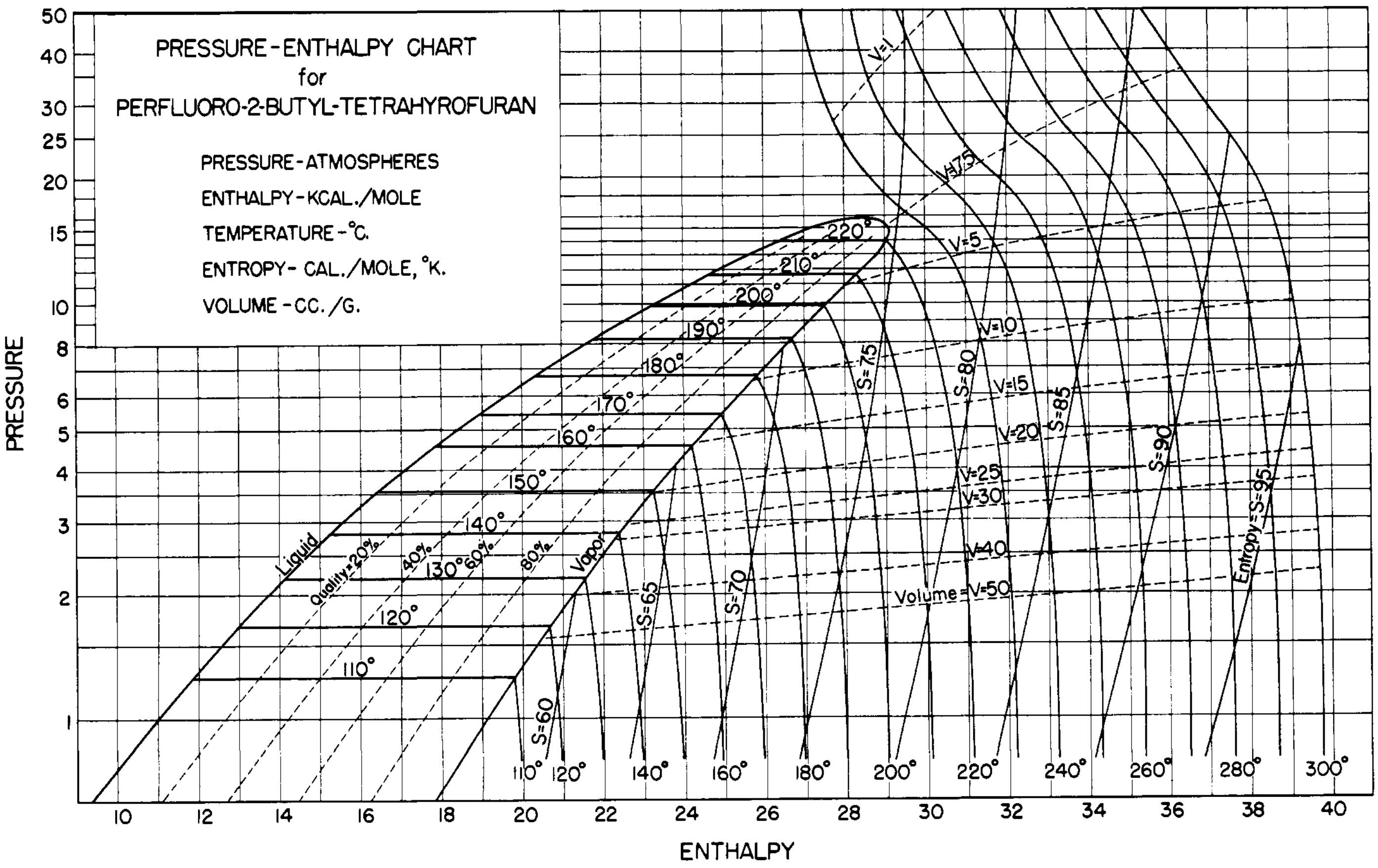

Figure 2. Pressure-enthalpy diagram for testing the internal consistency of the data

f/P, was obtained by intregation of the following equation.

$$\int_{f^o}^{f} d\ln f = \int_{P^o}^{P} d\ln P - \frac{1}{RT}\int_{P^o}^{P} \alpha\, dP \qquad (14)$$

Since $f^o = P^o$, the intregrated equation becomes

$$\log f/P = -\frac{1}{2.303}\int_{P^o}^{P} \alpha\, dP$$

RESULTS

The thermodynamic properties of perfluoro-2-butyltetrahydrofuran are presented in tabular and graphical form. Table I lists the saturated properties as a function of temperature up to the critical temperature, 227.06° C., in increments of 10° C. These properties include the following: the pressure, the gram-molal volumes of the liquid and vapor, the gram-molal enthalpies, and entropies of the liquid and vapor as well as the difference between the values of these properties for the liquid and vapor phases.

Table II lists the enthalpy, entropy, molal volume, and activity coefficient in the superheated vapor region for pressures from 1 to 40 atm. and temperatures from 110° to 300° C. For pressures below the critical pressure (15.86 atm.) the saturation temperature in ° C. is listed.

Figure 2 presents the data in the form of a log P *vs.* enthalpy diagram with curves of constant temperature, constant entropy, and constant volume.

DISCUSSION

The internal consistency of the data, as tested by the plotting of large scale diagrams, such as Figure 2, and by cross plots of the same, is to within ±1.5%, which is of the same magnitude as the precision in determining the physical properties, especially the heat capacities. As expected, the accuracy of the data in the critical region is less than in other regions because of the difficulty in making precise measurements when the compressibility of the sample is high. In the calculation of the enthalpy and entropy of the saturated liquid near the critical point, the effect of pressure was taken into account by calculating the values of these quantities for the saturated vapor, then subtracting the heat of vaporization and entropy of vaporization to give the values for the saturated liquid. The difference in the values of the enthalpy and entropy of the saturated liquid, calculated in this manner and calculated assuming no pressure correction for the liquid, was somewhat erratic, but was consistent in that the greatest difference occured at the critical point. In the calculation, it was assumed that the heat capacity of the liquid varied linearly with the temperature up to the critical point.

An indeterminate error in the data was introduced by the sample of perfluoro-2-butyltetrahyrofuran which was not a pure compound but a mixture of isomers. However, the fluorocarbon isomers differ very little from each other

Table II. Superheated Properties of Perfluoro-2-butyltetrahydrofuran

(H, kcal./mole; S, cal./mole, ° K.; v, liters/mole)

		Temperature, ° C.									
P., Atm.		110	120	130	140	150	160	170	180	190	200
1	H	19.89	20.87	21.87	22.86	23.87	24.88	25.90	26.93	27.96	29.00
	S	57.70	60.23	62.37	65.17	67.58	69.95	72.27	74.56	76.82	79.04
	v	29.84	30.80	31.76	32.71	33.66	34.64	35.60	36.50	37.42	38.33
(102.6)	f/P	0.9560	0.9600	0.8650	0.9689	0.9729	0.9771	0.9813	0.9836	0.9863	0.9889
2	H			21.59	22.61	23.63	24.73	25.76	26.80	27.84	28.89
	S			60.89	63.58	66.20	68.33	70.72	73.01	75.27	77.49
	v			14.96	15.54	16.10	16.65	17.26	17.77	18.29	18.79
(126.4)	f/P			0.9235	0.9324	0.9408	0.9503	0.9588	0.9638	0.9696	0.9747
3	H					23.38	24.55	25.60	26.66	27.71	28.77
	S					64.79	67.17	69.62	71.94	74.22	76.45
	v					10.12	10.62	11.05	11.44	11.83	12.21
(142.1)	f/P					0.9055	0.9199	0.9328	0.9409	0.9500	0.9578
4	H						24.33	25.40	26.60	27.57	28.63
	S						66.17	68.70	71.07	73.39	75.64
	v						7.501	7.873	8.211	8.543	8.854
(154.3)	f/P						0.8866	0.9039	0.9154	0.9278	0.9384
5	H							25.17	26.31	27.41	28.49
	S							67.83	70.30	72.67	74.99
	v							5.917	6.228	6.527	6.804
(164.9)	f/P							0.8724	0.8876	0.9033	0.9167
6	H								26.09	27.23	28.33
	S								69.53	71.99	74.36
	v								4.873	5.151	5.408
(173.6)	f/P								0.8579	0.8768	0.8931
7	H									27.02	28.16
	S									71.30	73.74
	v									4.145	4.393
(181.5)	f/P									0.8488	0.8679
8	H									26.77	27.96
	S									70.56	73.13
	v									3.367	3.615
(188.7)	f/P									0 8195	0.8416
9	H										27.73
	S										72.47
	v										2.994
(195.1)	f/P										0.8143

Table II. Continued

(H, kcal./mole; S, cal./mole, ° K.; v, liters/mole)

		Temperature, ° C.									
P., Atm.		210	220	230	240	250	260	270	280	290	300
1	H	30.05	31.10	32.16	33.23	34.30	35.38	36.47	37.56	38.66	39.77
	S	81.22	83.38	85.51	87.61	89.68	91.73	93.74	95.74	97.71	99.66
	v	39.25	40.13	41.01	41.90	42.76	43.64	44.50	45.34	46.18	47.03
(102.6)	f/P	0.9916	0.9931	0.9946	0.9964	0.9976	0.9986	0.9991	0.9993	0.9996	0.9999
2	H	29.94	31.00	32.07	33.15	34.23	35.32	36.42	37.52	38.62	39.73
	S	79.68	81.87	84.03	86.14	88.25	90.33	92.36	94.36	96.33	98.28
	v	19.30	19.80	20.25	20.72	21.18	21.66	22.12	22.57	23.01	23.45
(126.4)	f/P	0.9801	0.9836	0.9864	0.9899	0.9922	0.9947	0.9964	0.9964	0.9982	0.9993
3	H	29.83	30.90	31.98	33.06	34.15	35.25	36.36	37.46	38.57	39.68
	S	78.65	80.87	83.06	85.19	87.32	89.42	91.46	93.46	95.44	97.39
	v	12.58	12.94	13.25	13.59	13.91	14.26	14.60	14.92	15.23	15.54
(142.1)	f/P	0.9658	0.9715	0.9755	0.9807	0.9843	0.9886	0.9917	0.9938	0.9953	0.9972
4	H	29.71	30.79	31.88	32.97	34.06	35.17	36.28	37.40	38.51	39.62
	S	77.86	80.10	82.32	84.47	86.62	88.73	90.77	92.78	94.77	96.72
	v	9.156	9.517	9.710	9.974	10.24	10.53	10.79	11.05	11.30	11.54
(154.3)	f/P	0.9489	0.9571	0.9623	0.9691	0.9740	0.9803	0.9849	0.9882	0.9907	0.9934
5	H	29.58	30.67	31.77	32.87	33.97	35.08	36.20	37.32	38.44	39.56
	S	77.21	79.46	81.70	83.87	86.03	88.15	90.21	92.23	94.22	96.18
	v	7.068	7.350	7.561	7.784	8.010	8.257	8.475	8.692	8.910	9.110
(164.9)	f/P	0.9298	0.9407	0.9472	0.9554	0.9619	0.9702	0.9761	0.9808	0.9844	0.9880
6	H	29.44	30.55	31.66	32.77	33.87	34.99	36.12	37.25	38.26	39.49
	S	76.62	78.89	81.16	83.34	85.51	87.66	89.72	91.75	93.75	95.72
	v	5.654	5.923	6.112	6.316	6.519	6.732	6.923	7.116	7.302	7.482
(173.6)	f/P	0.9087	0.9227	0.9304	0.9403	0.9484	0.9586	0.9658	0.9718	0.9766	0.9811
7	H	29.29	30.43	31.55	32.67	33.77	34.90	36.03	37.17	38.28	39.41
	S	76.05	78.36	80.67	82.87	85.05	87.31	89.29	91.33	93.34	95.31
	v	4.628	4.884	5.066	5.262	5.451	5.638	5.811	5.947	6.149	6.317
(181.5)	f/P	0.8862	0.9033	0.9126	0.9242	0.9339	0.9458	0.9543	0.9617	0.9676	0.9732
8	H	29.13	30.29	31.42	32.55	33.67	34.81	35.94	37.08	38.20	39.34
	S	75.50	77.85	80.20	82.43	84.62	86.80	88.89	90.94	92.96	94.94
	v	3.844	4.090	4.279	4.466	4.642	4.817	4.979	5.139	5.287	5.443
(188.7)	f/P	0.8625	0.8835	0.8938	0.9069	0.9187	0.9322	0.9417	0.9508	0.9578	0.9646
9	H	28.94	30.14	31.29	32.43	33.56	34.71	35.85	37.00	38.12	39.26
	S	74.93	77.37	79.75	82.00	84.21	86.42	88.52	90.58	92.61	94.60
	v	3.219	3.460	3.665	3.840	4.010	4.173	4.329	4.475	4.618	4.761
(195.1)	f/P	0.8378	0.8611	0.8745	0.8894	0.9030	0.9180	0.9289	0.9393	0.9474	0.9554
10	H	28.73	29.97	31.15	32.30	33.45	34.60	35.76	36.91	38.04	39.18
	S	74.33	76.87	79.31	81.59	83.82	86.05	88.16	90.23	92.28	94.28
	v	2.709	2.944	3.163	3.333	3.500	3.655	3.804	3.943	4.082	4.213
(200.7)	f/P	0.8124	0.8386	0.8547	0.8715	0.8868	0.9034	0.9157	0.9272	0.9366	0.9457
11	H	28.49	29.78	30.99	32.17	33.32	34.50	35.66	36.82	37.95	39.10
	S	73.70	76.35	78.85	81.17	83.43	85.69	87.82	89.90	91.96	93.98
	v	2.280	2.513	2.742	2.911	3.080	3.229	3.373	3.511	3.645	3.768
(206.0)	f/P	0.7864	0.8154	0.8345	0.8531	0.8703	0.8884	0.9022	0.9150	0.9256	0.9357

in their physical properties, so this should not affect the utility of the data significantly.

Although the absolute accuracy of the calculated results has not been established, this should not impose serious limitations on the use of the data for engineering calculations where differences in the values of the thermodynamic functions are involved rather than absolute values. Thus, the data can be used for calculations involving cyclic processes operating within the range of the pressure and temperature for which the data are presented, but might not be suitable for thermochemical calculations where absolute values are needed. This restriction is of little consequence in the case of the chemically inert perfluoro-2-butyltetrahydrofuran.

NOMENCLATURE

f = fugacity, atm.
H = enthalpy of superheated vapor, kcal./g.-mole
H_l = ethalpy of saturated liquid
H_v = enthalpy of saturated vapor
ΔH_v = latent heat of vaporization
P = pressure, atm.
S = entropy of superheated vapor, cal./g.-mole, ° K.
S_l = entropy of saturated liquid
S_v = entropy of saturated vapor
ΔS_v = entropy of vaporization
T = temperature, ° K.
V = volume, liters/g.-mole
α = residual volume, $(RT/P - V)$, liters/g.-mole
f/P = activity coefficient

Table II. Continued

(*H*, kcal./mole; *S*, cal./mole, ° K.; *v*, liters/mole)

		Temperature, ° C.									
P., Atm.		210	220	230	240	250	260	270	280	290	300
12	*H*	28.22	29.57	30.82	32.02	33.20	34.38	35.56	36.72	37.86	39.01
	S	73.01	75.79	78.37	80.76	83.06	85.34	87.49	89.58	91.65	93.69
	v	1.915	2.142	2.377	2.554	2.726	2.874	3.014	3.151	3.278	3.369
(210.9)	*f*/*P*	0.7600	0.7916	0.8138	0.8343	0.8534	0.8731	0.8883	0.9025	0.9143	0.9255
13	*H*		29.33	30.63	31.86	33.06	34.27	35.45	36.63	37.77	38.93
	S		75.19	77.99	80.33	82.86	85.00	87.16	89.27	91.36	93.41
	v		1.823	2.052	2.250	2.424	2.572	2.709	2.846	2.967	3.082
(215.6)	*f*/*P*		0.7673	0.7925	0.8153	0.8364	0.8576	0.8743	0.8899	0.9029	0.9152
14	*H*			30.40	31.68	32.91	34.14	35.34	36.53	37.68	38.84
	S			77.34	79.88	82.29	84.65	86.83	88.97	91.07	93.13
	v			1.745	1.986	2.162	2.312	2.448	2.581	2.700	2.812
(219.8)	*f*/*P*			0.7705	0.7961	0.8192	0.8420	0.8602	0.8771	0.8914	0.9047
15	*H*			30.08	31.46	32.76	34.01	35.23	36.42	37.58	38.75
				76.63	79.37	81.89	84.31	86.51	88.68	90.79	92.87
	v			1.450	1.724	1.936	2.081	2.222	2.354	2.470	2.576
(223.9)	*f*/*P*			0.7475	0.7767	0.8020	0.8262	0.8459	0.8643	0.8798	0.8941
16	*H*			29.61	31.18	32.58	33.87	35.11	36.32	37.48	38.66
	S			76.16	78.86	81.47	83.96	86.20	88.39	90.52	92.61
	v			1.106	1.470	1.727	1.883	2.017	2.152	2.262	2.371
	f/*P*			0.7229	0.7570	0.7847	0.8104	0.8316	0.8515	0.8681	0.8835
18	*H*			28.99	30.61	32.16	33.59	34.87	36.10	37.28	38.46
	S			75.41	78.00	80.77	83.24	85.58	87.81	89.97	92.08
	v			0.502	1.004	1.361	1.545	1.670	1.799	1.912	2.027
	f/*P*			0.6643	0.7134	0.7493	0.7789	0.8027	0.8255	0.8444	0.8623
20	*H*			28.65	30.21	31.76	33.31	34.61	35.86	37.05	38.25
	S			74.50	77.14	80.11	82.60	84.98	87.24	89.43	91.56
	v			0.459	0.644	1.022	1.256	1.392	1.517	1.636	1.745
	f/*P*			0.6118	0.6673	0.7129	0.7472	0.7736	0.7990	0.8204	0.8407
25	*H*			27.98	29.47	30.96	32.43	33.84	35.20	36.44	37.66
	S			72.68	75.40	78.27	80.82	83.28	85.58	88.04	90.22
	v			0.425	0.481	0.564	0.726	0.890	1.020	1.133	1.250
	f/*P*			0.5161	0.5685	0.6211	0.6670	0.7017	0.7337	0.7608	0.7868
30	*H*			27.54	28.90	30.37	31.74	33.08	34.53	35.80	37.04
	S			71.39	74.15	76.81	79.39	81.71	84.18	86.69	88.90
	v			0.408	0.438	0.484	0.550	0.644	0.750	0.858	0.963
	f/*P*			0.4523	0.5001	0.5497	0.5966	0.6360	0.6734	0.7046	0.7363
35	*H*			27.30	28.60	30.00	31.33	32.64	34.01	35.26	36.51
	S			70.69	73.28	75.99	78.39	80.77	83.13	85.56	87.71
	v			0.405	0.428	0.455	0.481	0.541	0.611	0.685	0.759
	f/*P*			0.4070	0.4511	0.4977	0.5423	0.5821	0.6215	0.6555	0.6908
40	*H*			27.18	28.46	29.77	31.05	32.37	33.68	34.89	36.12
	S			70.26	72.82	75.37	77.78	80.17	82.40	84.77	86.88
	v			0.329	0.413	0.433	0.454	0.487	0.537	0.591	0.649
	f/*P*			0.3737	0.4149	0.4585	0.5004	0.5394	0.5791	0.6143	0.6511

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