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Experimental Study of *PVT* Properties of HFC-125 (CHF_2CF_3)[1]

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Pressure–volume–temperature (*PVT*) properties and vapor pressures of HFC-125 (pentafluoroethane; CHF_2CF_3) have been experimentally obtained. Vapor pressures of HFC-125 have been measured in the range of temperatures from 223 to 338 K and pressures up to 3.54 MPa with uncertainties of 5 mK and 2.5 kPa, respectively. The vapor pressure equation for this substance was correlated based on the present data. *PVT* properties of HFC-125 have been determined with a constant-volume apparatus in the range of temperatures from 280 to 473 K, pressures up to 17 MPa, and densities up to 1145 $kg \cdot m^{-3}$ with uncertainties of 5 mK, 2.5 kPa, and 0.01%, respectively. All of the available experimental *PVT* property data were compared with the equation of state correlated by Wilson et al.

KEY WORDS: *PVT* properties; vapor pressure; HFC-125.

1. INTRODUCTION

Chlorodifluormethane (HCFC-22; $CHClF_2$) has been widely used for air-conditioning equipment. The hydrofluorcarbons (HFCs) have been investigated widely as possible alternatives to HFCF-22. HFC-125 is one of the most important alternatives to HCFC-22, either as a pure refrigerant or as a component of binary or ternary mixtures.

This paper deals with the experimental study of *PVT* properties and vapor pressures, the correlation of vapor pressure, and comparisons of the available data with the correlations.

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2. SURVEY OF PREVIOUS EXPERIMENTAL STUDIES

2.1. Vapor Pressure

The available experimental studies of vapor pressure of HFC-125 cover the temperature range 235–339 K. Monluc et al. [1] measured 23 points of vapor pressure in the range of temperatures from 303 to 339 K. Defibaugh and Morrison [2] also measured nine points of vapor pressure in the range of temperatures from 275 to 337 K and pressures from 0.7 to 3.5 MPa. Baroncini et al. [3] obtained experimentally 58 points of vapor pressure in the range of temperatures from 235 to 333 K and pressures from 0.16 to 3.2 MPa.

2.2. *PVT* Properties

Experimental studies of *PVT* properties of HFC-125 have been conducted over a wide range of the state parameters. Defibaugh and Morrison [2] measured 163 points of *PVT* properties in the range of temperatures from 275 to 369 K, pressures from 1.6 to 6.3 MPa, and densities from 258 to 1348 $kg \cdot m^{-3}$. Baroncini et al. [3] obtained experimentally 48 points of *PVT* properties in the range of temperatures from 293 to 338 K, pressures from 1.0 to 2.5 MPa and densities from 60 to 155 $kg \cdot m^{-3}$.

3. EXPERIMENTAL METHOD

A constant-volume method with a spherical vessel with a volume of approximately 270 cm^3 has been used for the present measurements of *PVT* properties as well as vapor pressure. The *PVT* property values of the sample have been determined by measuring precisely the relations between temperature and pressure along each isochore. Temperature was measured with the use of a platinium resistance thermometer calibrated within 2 mK at the National Research Laboratory of Metrology in Japan, based on the International Practical Temperature Scale (1968) and converted to the International Temperature Scale (1990). Pressure was measured with the use of two air piston gauges and a mercury manometer, depending on the pressure range. Density was determined by means of dividing a mass of the sample by the whole volume of filling it. The uncertainties of temperature, pressure, and density measurements are estimated to be 5 mK, 2.5 kPa, and 0,01% respectively. The sample, with 99.63 wt% purity, was furnished by Mitsui-du Pont Fluorochemical Co. Ltd. Details regarding the construction of the apparatus are given elsewhere [4].

4. EXPERIMENTAL RESULTS

4.1. Vapor Pressure

Measurements of the vapor pressure of HFC-125 have been conducted in the range of temperatures from 223 to 339 K and pressures from 0.09 to 3.6 MPa as shown in Table I.

Table I. Experimental Results of Vapor Pressure for HFC-125

Temp. (K)	Press. (MPa)
223.160	0.0929
233.159	0.1486
233.159	0.1487
243.146	0.2285
243.156	0.2283
253.151	0.3380
253.152	0.3367
253.154	0.3378
253.154	0.3379
263.147	0.4832
263.149	0.4830
263.152	0.4830
263.152	0.4833
273.146	0.6710
273.150	0.6710
273.150	0.6712
273.151	0.6714
283.144	0.9088
283.144	0.9092
293.141	1.2047
293.141	1.2056
293.184	1.2066
298.144	1.3774
298.183	1.3800
303.139	1.5678
303.139	1.5679
303.139	1.5692
303.181	1.5701
303.181	1.5705
313.136	2.0075
313.136	2.0077
313.136	2.0078
313.136	2.0080
313.136	2.0082
313.136	2.0089
313.136	2.0090
313.136	2.0094
317.148	2.2090
318.138	2.2606
319.638	2.3411
323.133	2.5360
323.133	2.5363

Table I. *(Continued)*

Temp. (K)	Press. (MPa)
323.133	2.5364
323.133	2.5368
323.133	2.5369
323.133	2.5370
323.250	2.5436
328.138	2.8398
328.176	2.8419
333.130	3.1700
333.130	3.1706
333.130	3.1710
333.130	3.1712
333.130	3.1715
333.251	3.1801
334.252	3.2505
335.134	3.3127
336.252	3.3967
337.133	3.4605
337.133	3.4621
338.252	3.5472

4.2. *PVT* Properties

Measurements of *PVT* properties of HFC-125 were made along 13 isochores in the range of temperatures from 280 to 473 K, pressures up to 17 MPa, and densities from 51 to 1145 $kg \cdot m^{-3}$, as shown in Table II.

Table II. Experimental Results of *PVT* Properties for HFC-125

Temp. (K)	Press. (MPa)	Dens. ($kg \cdot m^{-3}$)
280.148	0.8087	50.98
282.148	0.8176	50.98
303.139	0.9086	50.93
333.130	1.0324	50.86
343.127	1.0732	50.83
343.127	1.0732	50.83
353.125	1.1133	50.81
363.122	1.1517	50.78
373.118	1.1917	50.76
393.115	1.2687	50.71

Table II. *(Continued)*

Temp. (K)	Press. (MPa)	Dens. ($kg \cdot m^{-3}$)
413.111	1.3464	50.66
433.108	1.4198	50.61
453.105	1.4983	50.55
463.105	1.5352	50.53
473.104	1.5694	50.50
298.144	1.3543	88.74
313.136	1.4815	88.68
333.129	1.6423	88.60
353.125	1.7971	88.51
373.120	1.9469	88.42
393.115	2.0934	88.33
413.111	2.2368	88.25
433.108	2.3777	88.15
453.106	2.5158	88.06
463.105	2.5782	88.02
473.103	2.6462	87.97
323.133	2.4778	187.16
333.130	2.6918	187.07
343.128	2.8973	186.98
353.125	3.0955	186.90
363.123	3.2897	186.80
373.120	3.4793	186.71
383.117	3.6659	186.62
393.115	3.8500	186.52
403.113	4.0315	186.43
413.096	4.2113	186.33
423.110	4.3893	186.24
433.108	4.5653	186.14
453.106	4.9132	185.94
473.104	5.2557	185.75
328.136	2.7507	217.07
333.130	2.8804	217.02
343.128	3.1307	216.92
353.125	3.3720	216.81
363.122	3.6070	216.70
373.120	3.8369	216.60
383.117	4.0627	216.49
393.115	4.2851	216.38
403.113	4.5046	216.27
413.111	4.7215	216.16
423.110	4.9359	216.05
433.108	5.1482	215.93
443.107	5.3590	215.82
453.106	5.5681	215.71
473.104	5.9819	215.48
338.133	3.4746	346.47

Table II. *(Continued)*

Temp. (K)	Press. (MPa)	Dens. (kg · m^{-3})
343.128	3.7078	346.38
353.125	4.1544	346.21
363.122	4.5877	346.04
373.120	5.0116	345.87
383.117	5.4282	345.69
393.115	5.8368	345.52
403.113	6.2456	345.34
413.111	6.6476	345.16
423.110	7.0463	344.98
433.108	7.4415	344.80
443.107	7.8342	344.62
453.106	8.2232	344.43
473.104	8.9952	344.06
339.483	3.6320	449.66
343.128	3.8638	449.58
353.125	4.4800	449.35
363.122	5.0833	449.13
373.114	5.6791	448.90
383.117	6.2699	448.67
393.115	6.8559	448.44
403.110	7.4375	448.21
413.111	8.0157	447.98
423.110	8.5901	447.74
433.108	9.1613	447.51
453.106	10.2950	447.03
473.104	11.4172	446.54
339.283	3.6298	567.41
339.383	3.6364	567.41
340.252	3.7060	567.38
341.246	3.7847	567.35
342.253	3.8643	567.32
343.254	3.9436	567.30
343.254	3.9433	567.30
353.256	4.7442	567.01
363.255	5.5492	566.73
373.237	6.3547	566.44
383.258	7.1616	566.15
393.259	7.9540	565.85
413.261	9.5565	565.26
433.262	11.1515	564.66
453.263	12.7424	564.05
473.265	14.3170	563.43
333.145	3.1762	704.48
336.133	3.3908	704.38
338.133	3.5423	704.31
339.133	3.6316	704.28

Table II. *(Continued)*

Temp. (K)	Press. (MPa)	Dens. ($kg \cdot m^{-3}$)
340.128	3.7323	704.24
341.132	3.8353	704.21
342.132	3.9397	704.17
343.128	4.0445	704.13
353.115	5.1362	703.78
373.120	7.4227	703.05
393.115	9.7631	702.32
413.111	12.1260	701.57
433.108	14.4957	700.81
453.203	16.8750	700.03
339.133	3.6695	756.32
343.126	4.1431	756.16
353.125	5.3898	755.78
363.122	6.6820	755.39
373.120	7.9998	754.99
383.124	9.3353	754.60
393.115	10.6792	754.20
403.124	12.0331	753.79
413.111	13.3882	753.39
423.110	14.7467	752.98
433.108	16.1064	752.56
439.963	17.0384	752.28
335.140	3.3660	848.73
338.133	3.8158	848.60
343.128	4.5902	848.38
348.130	5.3874	848.16
353.133	6.1998	847.94
363.122	7.8533	847.50
373.120	9.5370	847.05
383.117	11.2391	846.60
393.133	12.9576	846.14
413.111	16.4039	845.22
416.116	16.9240	845.08
333.130	3.5409	924.19
338.133	4.4970	923.95
343.118	5.4717	923.71
348.130	6.4679	923.47
353.128	7.4740	923.23
358.128	8.4908	922.98
363.114	9.5120	922.73
368.125	10.5448	922.49
373.121	11.5796	922.24
378.123	12.6205	921.99
383.104	13.6591	921.74
393.115	15.7549	921.23
328.142	3.3843	988.22

Table II. *(Continued)*

Temp. (K)	Press. (MPa)	Dens. ($kg \cdot m^{-3}$)
333.130	4.5304	987.96
338.133	5.7026	987.70
343.128	6.8878	987.43
348.163	8.0951	987.17
353.125	9.2934	986.90
358.128	10.5115	986.64
363.122	11.7320	986.37
368.129	12.9609	986.10
373.120	14.1900	985.83
378.123	15.4247	985.56
383.117	16.6599	985.29
306.530	1.8664	1145.32
308.181	2.4621	1145.25
313.180	4.2649	1144.94
318.178	6.0758	1144.59
323.177	7.8960	1144.31
328.176	9.7266	1143.96
333.175	11.5449	1143.64
346.031	16.2723	1142.82

5. CORRELATION OF VAPOR PRESSURE

The vapor pressures were correlated within experimental uncertainty by a Wagner-type equation, through a least-squares fit, with equal weigts, to all data listed in Table I. The correlation of the vapor pressure thus developed is expressed as follows:

$$\ln(P_r) = (A_1\tau + A_2\tau^{1.5} + A_3\tau^2 + A_4\tau^3)\, T_r^{-1} \qquad (1)$$

where $P_r = P/P_c$, $T_r = T/T_c$, $\tau = 1 - T_r$, $P_c = 3.621$ MPa, $T_c = 339.18$ K, $A_1 = -7.583504909$, $A_2 = 2.300001246$, $A_3 = -1.697205989$, and $A_4 = -1.960874911$. The values of critical temperature and pressure proposed by Fukushima [5] are used. Mean and maximum deviations from Eq. (1) for all data listed in Table I are 0.36% and 1.2 kPa, respectively.

6. DISCUSSION

The deviations of the available vapor pressure data from Eq. (1) are shown in Fig. 1. The present data agree with the observed data by Baroncini et al. [3]. The pressure deviations of the available *PVT* property data from Wilson's equation [6] are shown in Fig. 2. In the vapor region, most of the data scatter within 3%.

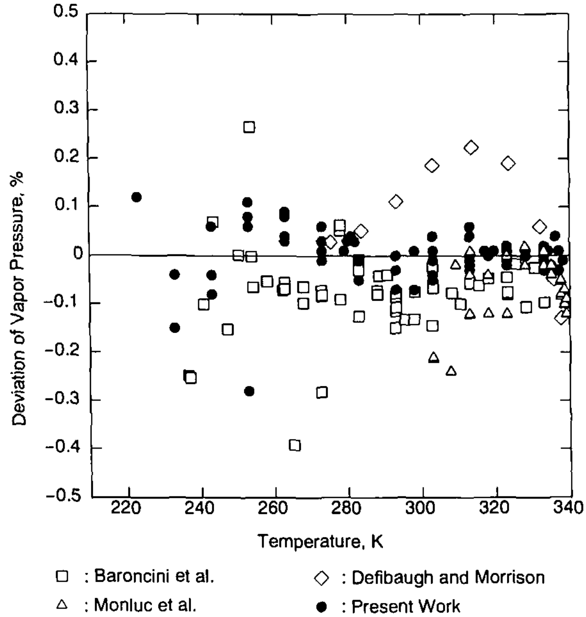

Fig. 1. Deviation of available vapor pressure data from Eq. (1).

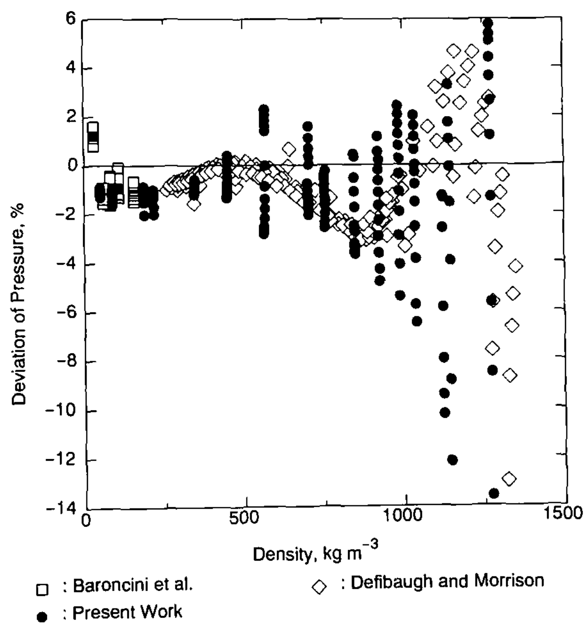

Fig. 2. Deviation of available *PVT* property data from the equation by Wilson et al. [6] in its effective region.

7. CONCLUSION

The experimental data of *PVT* properties and vapor pressures of HFC-125 have been observed. The correlation of vapor pressure for HFC-125 was formulated based on the present data in the range of temperatures from 223 K to the critical temperature.

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