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Note

Vapor Pressure of Difluoromethane (HFC-32)

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A slightly modified Burnett apparatus has been used to measure 32 vapor-pressure data for HFC-32 in the temperature range from 273.39 to 347.29 K. The uncertainties of temperature and pressure are estimated to be within ±10 mK and ±500 Pa, respectively. The purity of the sample used in this work is 99.95%. On the basis of our data and of data from the literature, a vapor-pressure equation for HFC-32 is also proposed.

KEY WORDS: Burnett apparatus; HFC-32; refrigerants; vapor pressure.

1. INTRODUCTION

In December 1991, the National Resource Defense Council (NRDC) [1] submitted a petition to the U.S. Environmental Protection Agency (U.S. EPA) requesting a phase-out of HCFC-22 in new equipment by the year 2000 and a ban on the production of HCFC-22 by 2005. On November 25, 1992, the Copenhagen revisions to the Montreal Protocol amended that HCFC's consumption will be phased out by 2030. As a traditional and effective refrigerant, HCFC-22 is being used widely in many applications, such as heat pumps and air conditioners. It is necessary to find alternatives with a high capacity and high efficiency which are harmless to environment.

Among the low-carbon series of hydrofluorocarbon refrigerants (with only one or two carbons), there are only eight substances which are harmless to the environment. They are HFC-23, HFC-32, HFC-125, HFC-134, HFC-134a, HFC-143, HFC-143a, and HFC-152. If we want to

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Table I. Source of Vapor Pressures for HFC-32

Authors	Year	Temperature range (K)	Purity of sample
Malbrunot et al.	1968	190.15–351.55	>99.95 mol%
Kanungo et al.	1986	149.36–244.82	98.3 wt%
Watanabe et al.	1992	280–350	99.98 wt%
Widiatmo et al.	1992	200–300	99.988 wt%

find alternatives to HCFC-22 from the low-carbon-series hydrofluorocarbons, we must select from these eight kinds of refrigerants.

Thermophysical-property data and ideal cycle calculations show that mixtures with HFC-32 as a component will be the most promising alternatives to HCFC-22 [2, 3]. Hence, we must obtain thermophysical-property data for HFC-32. Vapor pressures are among the most fundamental thermophysical properties.

There are only four sets of vapor-pressure data available [4–7], shown in Table I, but only 30 data in Ref. 4 have been published. McLinden [8]

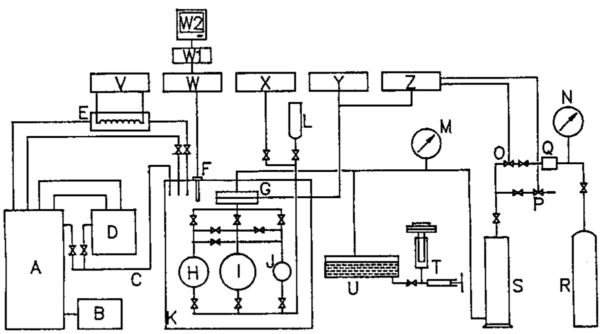

Fig. 1. Experimental apparatus. (A) Primary bath; (B) PID temperature controller; (C) overflow pipe; (D) refrigerator; (E) bath of aux. temp. adjustor; (F) Pt resistance thermometer; (G) differential pressure detector; (H) sample vessel (600 ml); (I) sample vessel (1000 ml); (J) sample vessel (200 ml); (K) secondary bath; (L) sample bottle; (M) pressure gauge; (N) pressure gauge; (O) magnetic valve; (P) magnetic valve; (Q) pressure-reducing valve; (R) high-pressure N_2 bottle; (S) low-pressure N_2 bottle; (T) oil piston-type pressure gauge; (U) bath of largh oil area; (V) aux. temp. adjustor; (W) Tinsley automatic thermometer bridge; (W_1) Tinsley switch; (W_2) personal computer; (X) vacuum pump; (Y) detector of pressure difference; (Z) pressure control.

also gave a vapor-pressure equation for HFC-32, but there are some differences [6] between it and the equation in Ref. 4.

This paper presents 32 vapor-pressure data for HFC-32 in the range from 273.39 to 347.29 K. Based on these data and the data of Malbrunot et al. [4], a vapor-pressure equation for HFC-32 is also proposed.

2. EXPERIMENTAL APPARATUS

A slightly modified Burnett apparatus shown in Fig. 1 is used in this work. This apparatus has been described by Zhu et al. [9] in detail. The volume of the main vessel, J, is 200 ml. The sample was provided by the Zhejing Fluoro-Chemical Technology Research Institute. The purity of the sample is 99.95 wt%.

The pressure-measurement system includes a piston-type pressure gauge, a pressure transducer, and an atmosphere pressure gauge. The accuracy of the piston-type pressure gauge is within 0.005% in the range of 0.1–6 MPa. The accuracy of the pressure transducer is 0.2%, the pressure difference adjustable range is 6–38 kPa, the temperature range is 233–400 K, and the maximum pressure endurance is up to 17.8 MPa. The uncertainly of the atmosphere pressure gauge is ±40 Pa. The piston-type pressure gauge is used to measure the pressure of N_2, and the pressure

Table II. Experimental Vapor Pressures

Temperature (K)	Pressure (MPa)	Temperature (K)	Pressure (MPa)
273.39	0.8191	273.45	0.8222
276.34	0.8997	276.44	0.9041
279.03	0.9801	279.23	0.9805
282.06	1.0699	282.37	1.0782
284.73	1.1558	285.83	1.2023
287.41	1.2494	287.55	1.2579
290.34	1.3617	290.35	1.3663
292.86	1.4618	295.29	1.5617
297.25	1.6479	299.25	1.7410
301.22	1.8352	303.16	1.9193
305.13	2.0401	307.17	2.1380
309.15	2.2546	312.97	2.4785
314.99	2.5787	316.45	2.6952
318.24	2.8111	321.32	3.0190
323.27	3.1575	332.30	3.8530
234.35	4.8068	347.29	5.3239

difference between the N_2 and the sample in vessel J is measured by the pressure transducer. The whole pressure-measurement system has an uncertainty of ± 500 Pa.

The temperature-measurement system includes a high-accuracy thermostat bath, a first-grade platinum electric resistance thermometer, a precision Tinsley electric bridge whose accuracy is within 2 ppm, and a personal computer. The system has an overall uncertainty of ± 10 mK.

The reliability of the present apparatus has been confirmed by our previous measurements for HFC-134a, for which reliable information concerning the thermodynamic properties is available [10, 11].

3. EXPERIMENTAL RESULTS

The 32 vapor-pressure data for HFC-32 measured by us over the temperature range from 273.39 to 347.29 K are presented in Table II.

Figure 2 shows the relative and absolute deviations comparing our experimental data and data of Ref. 4 with Malbrunot's correlation [4].

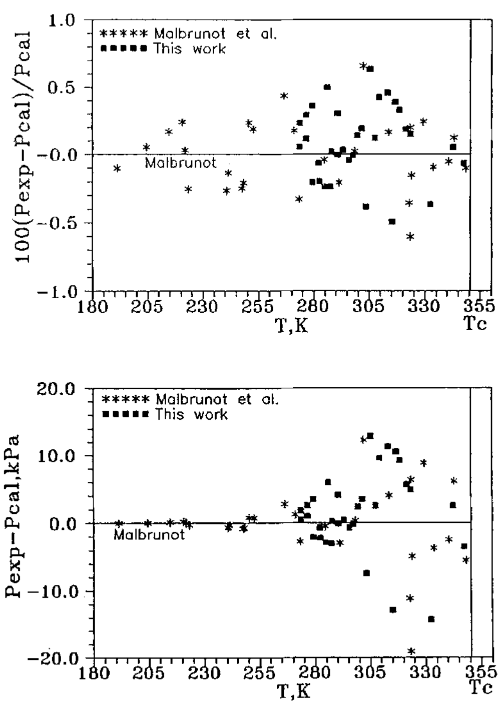

Fig. 2. Relative and absolute deviations of the vapor pressure from Malbrunot's equation.

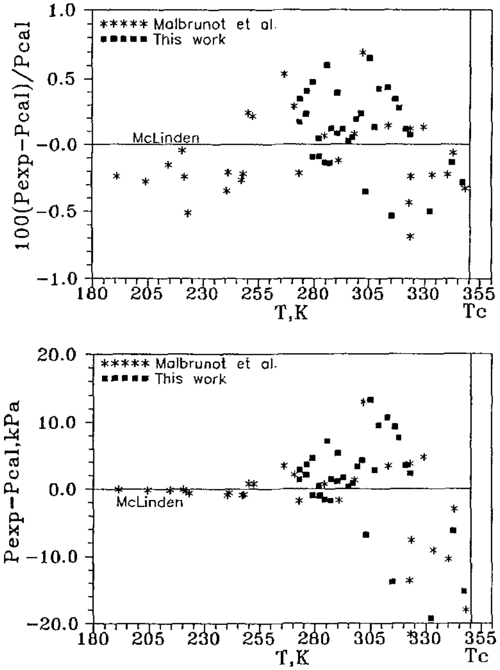

Fig. 3. Relative and absolute deviations of the vapor pressure from McLinden's equation.

Figure 3 gives a comparison with the correlation of McLinden [8]. Mclinden's correlation was developed on the basis of measurements obtained by Kanungo et al. [5] and by Malbrunot et al. [4]. Compared with McLinden's correlation, the maximum relative deviation in pressure is 0.69%, the minimum relative deviation is −0.68%, and the root mean square (RMS) deviation is 0.32%.

Using the published data [4] and ours, we proposed a vapor-pressure equation for HFC-32 as shown in Eq. (1). The equation has the same form as that in Ref. 8. This equation is valid for temperatures from 190.15 to 351.55 K. Table III gives the coefficients and the deviations.

$$\ln P_r = A_1(1-T_r)/T_r + A_2(1-T_r) + A_3(1-T_r)^{1.89} + A_4(1-T_r)^3 \quad (1)$$

Table III. Coefficients in Eq. (1) and McLinden's Equation

	A_1	A_2	A_3	A_4	RMS
McLinden's eq.	−10.052244	2.844032	4.108620	3.450397	0.32%
Eq. (1)	−9.421196	2.239105	3.702151	1.710934	0.26%

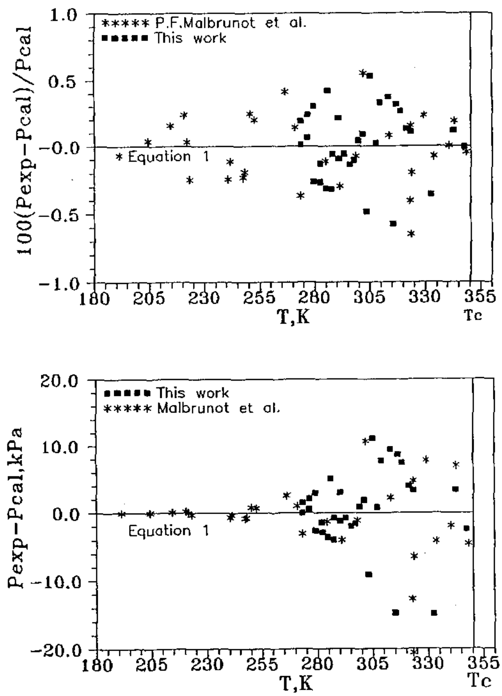

Fig. 4. Relative and absolute deviations of the vapor pressure from Eq. (1)

where $T_r = T/T_c$ and $P_r = P/P_c$ with $T_c = 351.28$ K and $P_c = 5.781$ MPa [6].

From Table III we see that the RMS deviation in pressure of Eq. (1) is 0. 26%, and that of McLinden's equation is 0.32%. Figure 4 shows the absolute and relative pressure deviations for HFC-32 from Eq. (1).

4. SUMMARY

With a slightly modified high-precision Burnett apparatus, the vapor pressure of HFC-32 has been obtained in the temperature range from 273.39 to 347.29 K. The temperature uncertainty is ± 10 mK, and the pressure uncertainty is ± 500 Pa. Compared with McLinden's correlation, the data exhibit a RMS deviation of 0.32%. The vapor-pressure equation proposed by us is valid for temperatures from 190.15 to 315.55 K, and the RMS deviation of this equation is 0.26%.

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