# Isobaric Heat Capacity for Liquid 1-Chloro-1,1-difluoroethane and 1,1-Difluoroethane

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The isobaric heat capacities ($C_P$) for liquid 1-chloro-1,1-difluoroethane (HCFC-142b) and 1,1-difluoroethane (HFC-152a) have been measured by means of flow calorimetry. For HCFC-142b, 31 $C_P$ values have been measured at temperatures from 276 to 350 K and pressures from 1.0 to 3.0 MPa. For HFC-152a, 36 $C_P$ have been measured at temperatures from 276 to 360 K and pressures from 1.0 to 3.2 MPa. The uncertainties are estimated as ±13 mK in temperature, ±3 kPa in pressure, and ±0.4% for most of the $C_P$ measurements. The purity of samples used for both HCFC-142b and HFC-152a measurements was 99.95 mol %. Correlations of liquid $C_P$ as a function of temperature and pressure have been developed for both refrigerants on the basis of the measurements.

## Introduction

Several hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) have been developed as chlorofluorocarbon (CFC) alternatives. Caloric property values of refrigerants are not only essential in heat transfer calculations for designing heat pumps or refrigerators, but are also essential in the development of thermodynamic equations of state from which reliable properties such as enthalpy or entropy can be derived.

We have previously reported isobaric heat capacities of liquid refrigerants, i.e., 1,2-dichloro-1,1,2,2-tetrafluoroethane (CFC-114, $CClF_2CClF_2$) (*1, 2*), 1,2,2,2-tetrafluoroethane (HFC-134a, $CH_2FCF_3$) (*3*), and 1,1-dichloro-2,2,2-trifluoroethane (HCFC-123, $CHCl_2CF_3$) (*4*), measured by using the same flow calorimeter originally developed by our group (*2, 5*).

1-Chloro-1,1-difluoroethane (HCFC-142b, $CClF_2CH_3$) is flammable, so pure HCFC-142b is not suitable for industrial applications. A binary mixture (40 wt % chlorodifluoromethane (HCFC-22, $CHClF_2$) + 60 wt % HCFC-142b) is considered as a dichlorodifluoromethane (CFC-12, $CCl_2F_2$) alternative because the vapor pressure is close to that of CFC-12 and higher cycle performance can be expected since the mixture is nonazeotropic. HFC-152a which has a vapor pressure similar to that of CFC-12 is also considered as one of the CFC-12 alternatives because the estimated refrigerator performance is superior to CFC-12 (*6*). However, HFC-152a is also flammable in air, so the use as one component of refrigerant mixtures would be attractive.

Measurements of isobaric heat capacity and respective correlations for liquid HFC-142b and HFC-152a are reported in this paper.

## Experimental Section

Detailed descriptions regarding the experimental procedure and flow calorimeter used in this study have been reported in previous papers (*1–3*). The special features of our apparatus are its nearly adiabatic performance, flow stability of the sample liquid in a closed circulation system, and reliability of the mass flow rate measuring system. Flow calorimetry requires three simultaneous measurements: measurement of energy flow, $\dot{Q}$, supplied by a microheater to the sample liquid, measurement of the temperature increment, $\Delta T$, which is the difference between the temperatures of the sample liquid before and after heating by the microheater, and measurement of the mass flow rate, $\dot{m}$. The isobaric heat capacity, $C_P$, is obtained from the following relation of the experimental measurements:

$$C_P = \dot{Q}/(\dot{m}\Delta T) \quad (1)$$

The temperature and temperature increment were measured with two platinum resistance thermometers, which were calibrated with a standard platinum resistance thermometer in accordance with the temperature scale of IPTS-68. The mass flow rate was measured directly using a timer, a three-way magnetic valve, and a digital balance on which a special cell connecting with the circulation line is placed. The energy flow was precisely determined by measuring the electric potential difference at the microheater and the electric current through a standard resistor.

## Results

For HCFC-142b, measurements were made at temperatures from 276 to 350 K and pressures from 1.0 to 3.0 MPa. The results are listed in Table I. For HFC-152a, measurements were made at temperatures from 276 to 360 K and pressures from 1.0 to 3.2 MPa. The results are listed in Table II. Tables I and II include both temperatures on IPTS-68 and temperatures on ITS-90, where the measured temperature is assigned to the temperature that is the arithmetic mean of the temperatures of the sample liquid before and after heating.

To show the effect of heat loss on the final $C_P$ values, deviations of experimental data, $C_{P,\mathrm{exp}}$, from the final $C_P$ values are plotted against the inverse mass flow rates in Figures 1 and 2 for HCFC-142b and HFC-152a, respectively. Measurements were performed at more than two different mass flow rates under a certain measuring condition, i.e., at a certain temperature and pressure. It was confirmed from Figures 1 and 2 that the $C_P$ results do not depend on the mass flow rates. Thus, it was concluded that the effect of heat losses for both HCFC-142b and HFC-152a measurements was small enough to be neglected.

The temperature increment has to be small enough not to produce any difference between the $C_P$ values at the inlet and outlet temperatures; i.e., experimental specific heat values, $C_{P,\mathrm{exp}}$, could be regarded as a $C_P$ value at an average temperature between the inlet and outlet temperatures.

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**Table I. Measurements on HCFC-142b**

| $T_{68}$/K | $T_{90}$/K | $P$/MPa | $\Delta T_{68}$/K | $\dot{m}$/(g·s$^{-1}$) | $\dot{Q}$/(J·s$^{-1}$) | $C_P$/(kJ·kg$^{-1}$·K$^{-1}$) | $T_{68}$/K | $T_{90}$/K | $P$/MPa | $\Delta T_{68}$/K | $\dot{m}$/(g·s$^{-1}$) | $\dot{Q}$/(J·s$^{-1}$) | $C_P$/(kJ·kg$^{-1}$·K$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 275.66 | 275.66 | 1.007 | 5.029 | 0.1222 | 0.7693 | 1.252 | 329.99 | 329.98 | 1.505 | 4.975 | 0.0785 | 0.5495 | 1.407 |
| 275.65 | 275.65 | 1.009 | 5.006 | 0.0594 | 0.3725 | 1.254 | 330.01 | 330.00 | 2.003 | 5.016 | 0.0787 | 0.5514 | 1.397 |
| 275.66 | 275.66 | 1.005 | 5.001 | 0.1438 | 0.9027 | 1.255 | 330.02 | 330.01 | 2.002 | 5.043 | 0.1199 | 0.8459 | 1.398 |
| 275.66 | 275.66 | 1.003 | 5.011 | 0.0713 | 0.4481 | 1.255 | 330.01 | 330.00 | 2.500 | 5.012 | 0.1199 | 0.8376 | 1.394 |
| 275.66 | 275.66 | 1.502 | 5.026 | 0.1209 | 0.7613 | 1.253 | 330.00 | 329.99 | 2.500 | 5.001 | 0.0786 | 0.5482 | 1.394 |
| 275.65 | 275.65 | 1.505 | 5.004 | 0.0719 | 0.4504 | 1.251 | 330.00 | 329.99 | 2.998 | 5.004 | 0.0784 | 0.5438 | 1.386 |
| 275.65 | 275.65 | 2.003 | 5.005 | 0.0717 | 0.4483 | 1.249 | 330.01 | 330.00 | 2.997 | 5.017 | 0.1195 | 0.8306 | 1.385 |
| 275.65 | 275.65 | 1.995 | 4.994 | 0.1206 | 0.7533 | 1.251 | 340.02 | 340.00 | 1.502 | 5.029 | 0.1209 | 0.8774 | 1.443 |
| 275.65 | 275.65 | 2.505 | 5.012 | 0.1204 | 0.7537 | 1.249 | 340.00 | 339.98 | 1.501 | 5.008 | 0.0726 | 0.5255 | 1.445 |
| 275.65 | 275.65 | 2.506 | 5.007 | 0.0717 | 0.4480 | 1.249 | 340.01 | 339.99 | 1.499 | 5.022 | 0.0601 | 0.4361 | 1.445 |
| 275.63 | 275.63 | 2.993 | 4.982 | 0.0725 | 0.4501 | 1.246 | 340.00 | 339.98 | 1.498 | 5.006 | 0.1449 | 1.0460 | 1.443 |
| 275.64 | 275.64 | 2.996 | 4.993 | 0.1213 | 0.7536 | 1.245 | 340.00 | 339.98 | 1.497 | 4.995 | 0.0917 | 0.6604 | 1.442 |
| 310.01 | 310.00 | 0.999 | 5.025 | 0.1211 | 0.8145 | 1.339 | 340.00 | 339.98 | 1.503 | 5.002 | 0.1039 | 0.7498 | 1.443 |
| 310.00 | 309.99 | 0.998 | 5.007 | 0.0721 | 0.4839 | 1.341 | 339.99 | 339.97 | 1.502 | 4.989 | 0.0791 | 0.5687 | 1.441 |
| 310.00 | 309.99 | 0.998 | 5.005 | 0.0596 | 0.4006 | 1.343 | 340.00 | 339.98 | 1.503 | 5.006 | 0.0666 | 0.4808 | 1.442 |
| 310.00 | 309.99 | 0.999 | 5.011 | 0.1440 | 0.9666 | 1.339 | 340.01 | 339.99 | 1.502 | 5.017 | 0.1333 | 0.9633 | 1.440 |
| 309.99 | 309.98 | 0.997 | 4.987 | 0.0849 | 0.5666 | 1.338 | 340.00 | 339.98 | 2.004 | 5.008 | 0.1215 | 0.8707 | 1.432 |
| 310.00 | 309.99 | 0.997 | 4.989 | 0.0975 | 0.6501 | 1.337 | 340.01 | 339.99 | 2.005 | 5.035 | 0.0725 | 0.5220 | 1.431 |
| 310.00 | 309.99 | 1.505 | 5.001 | 0.1203 | 0.8035 | 1.336 | 339.99 | 339.97 | 2.501 | 5.006 | 0.0730 | 0.5205 | 1.424 |
| 310.00 | 309.99 | 1.507 | 4.979 | 0.0781 | 0.5192 | 1.336 | 340.00 | 339.98 | 2.495 | 5.008 | 0.1218 | 0.8689 | 1.425 |
| 310.00 | 309.99 | 2.000 | 4.979 | 0.1193 | 0.7911 | 1.332 | 339.99 | 339.97 | 2.998 | 5.010 | 0.1217 | 0.8614 | 1.413 |
| 310.01 | 310.00 | 1.997 | 5.021 | 0.0783 | 0.5234 | 1.331 | 340.01 | 339.99 | 3.002 | 5.035 | 0.0730 | 0.5197 | 1.413 |
| 310.00 | 309.99 | 2.500 | 4.998 | 0.1193 | 0.7913 | 1.327 | 350.01 | 349.99 | 2.002 | 5.025 | 0.1211 | 0.9042 | 1.486 |
| 310.00 | 309.99 | 2.500 | 4.989 | 0.0783 | 0.5181 | 1.327 | 350.01 | 349.99 | 2.001 | 5.026 | 0.1211 | 0.9043 | 1.486 |
| 309.99 | 309.98 | 2.996 | 4.972 | 0.1193 | 0.7849 | 1.323 | 350.01 | 349.99 | 2.000 | 5.027 | 0.0728 | 0.5442 | 1.487 |
| 310.00 | 309.99 | 2.996 | 4.994 | 0.0782 | 0.5172 | 1.324 | 349.98 | 349.96 | 1.999 | 4.983 | 0.0602 | 0.4467 | 1.489 |
| 320.02 | 320.01 | 1.004 | 5.023 | 0.1198 | 0.8236 | 1.369 | 349.99 | 349.97 | 2.002 | 4.995 | 0.1459 | 0.0813 | 1.484 |
| 320.02 | 320.01 | 1.004 | 5.002 | 0.0782 | 0.5359 | 1.371 | 350.00 | 349.98 | 2.505 | 5.009 | 0.1222 | 0.9028 | 1.475 |
| 320.01 | 320.00 | 1.502 | 5.005 | 0.0781 | 0.5338 | 1.366 | 349.99 | 349.97 | 2.505 | 4.988 | 0.0733 | 0.5374 | 1.471 |
| 320.01 | 320.00 | 1.501 | 5.030 | 0.1187 | 0.8141 | 1.364 | 349.99 | 349.97 | 3.003 | 5.001 | 0.0732 | 0.5358 | 1.464 |
| 320.00 | 319.99 | 2.003 | 4.994 | 0.1203 | 0.8184 | 1.362 | 350.00 | 349.98 | 3.003 | 5.026 | 0.1218 | 0.8942 | 1.461 |
| 320.00 | 319.99 | 2.003 | 4.995 | 0.0787 | 0.5358 | 1.362 | 349.99 | 349.97 | 1.703 | 4.996 | 0.1215 | 0.9049 | 1.491 |
| 320.00 | 319.99 | 2.504 | 4.989 | 0.1200 | 0.8136 | 1.358 | 349.99 | 349.97 | 1.704 | 4.993 | 0.0727 | 0.5423 | 1.494 |
| 320.00 | 319.99 | 2.503 | 4.997 | 0.0789 | 0.5356 | 1.358 | 350.00 | 349.98 | 1.602 | 5.005 | 0.0729 | 0.5448 | 1.492 |
| 320.01 | 320.00 | 2.995 | 5.013 | 0.1197 | 0.8138 | 1.356 | 350.00 | 349.98 | 1.602 | 5.000 | 0.1211 | 0.9036 | 1.492 |
| 319.99 | 319.98 | 2.997 | 4.984 | 0.0789 | 0.5327 | 1.355 | 349.99 | 349.97 | 1.506 | 4.989 | 0.1211 | 0.9036 | 1.496 |
| 330.01 | 330.00 | 1.005 | 5.015 | 0.1207 | 0.8531 | 1.410 | 350.00 | 349.98 | 1.505 | 5.006 | 0.0728 | 0.5449 | 1.496 |
| 329.99 | 329.98 | 1.005 | 4.980 | 0.0721 | 0.5056 | 1.408 | 350.01 | 349.99 | 1.408 | 3.005 | 0.1210 | 0.5448 | 1.499 |
| 330.00 | 329.99 | 1.006 | 4.989 | 0.0592 | 0.4177 | 1.415 | 350.01 | 349.99 | 1.409 | 3.014 | 0.1209 | 0.5448 | 1.495 |
| 330.00 | 329.99 | 1.006 | 4.990 | 0.0591 | 0.4177 | 1.416 | 350.00 | 349.98 | 1.409 | 3.003 | 0.1212 | 0.5449 | 1.498 |
| 330.01 | 330.00 | 1.007 | 5.014 | 0.1436 | 1.0155 | 1.411 | 350.00 | 349.98 | 1.408 | 3.011 | 0.0722 | 0.3253 | 1.496 |
| 329.99 | 329.98 | 1.007 | 5.002 | 0.0907 | 0.6395 | 1.410 | 349.98 | 349.96 | 1.407 | 3.002 | 0.0724 | 0.3253 | 1.496 |
| 330.01 | 330.00 | 1.504 | 5.016 | 0.1205 | 0.8493 | 1.405 | | | | | | | |

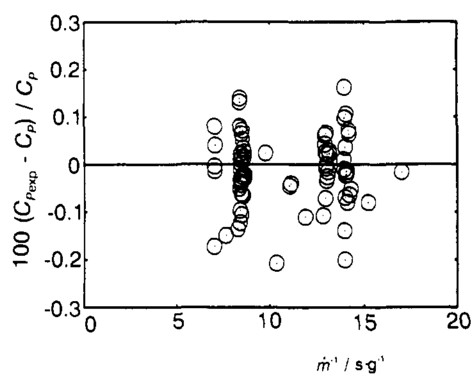


**Figure 1.** $C_{P,\exp}$ for HCFC-142b as a function of inverse mass flow rates.

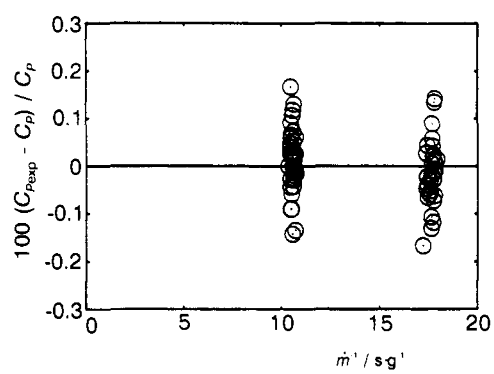


**Figure 2.** $C_{P,\exp}$ for HFC-152b as a function of inverse mass flow rates.

Conversely, the temperature increment has to be large enough to neglect uncertainty propagation from the absolute temperature measurements. The measurements on HCFC-142b at temperatures from 276 to 340 K and measurements at 350 K except those at a pressure of 1.4 MPa were performed with 5 K increments, while measurements at 350 K and 1.4 MPa were performed with 3 K increments. The measurements of HFC-152a at temperatures from 276 to 340 K, measurements at 350 K and 2.7 MPa, and measurements at 360 K were performed with 5 K increments, while measurements at 350 K and 355 K except those at 350 K and 2.7 MPa were performed with 3 K increments. We confirmed that the uncertainty of $C_{P,\exp}$ due to the effect of the magnitude of the temperature increments was within ±0.12% to ±0.4% for HFC-152a and within ±0.22% for HCFC-142b by examining correlations to be discussed in the succeeding section. In Tables III and IV, 31 $C_P$ values for HCFC-142b and 36 $C_P$ values for HFC-152a at nominal temperatures and pressures determined from the present measurements are listed. The values were converted from the measurements with the aid of the respective correlations.

The uncertainties of $C_P$ values in Tables I and II are ±0.22% for the measurements with temperature increments of 5 K and ±0.34% for those with temperature increments of 3 K,

**Table II. Measurements on HFC-152a**

| $T_{68}$/K | $T_{90}$/K | $P$/MPa | $\Delta T_{68}$/K | $\dot{m}$/(g·s$^{-1}$) | $\dot{Q}$/(J·s$^{-1}$) | $C_P$/(kJ·kg$^{-1}$·K$^{-1}$) | $T_{68}$/K | $T_{90}$/K | $P$/MPa | $\Delta T_{68}$/K | $\dot{m}$/(g·s$^{-1}$) | $\dot{Q}$/(J·s$^{-1}$) | $C_P$/(kJ·kg$^{-1}$·K$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 275.66 | 275.66 | 1.010 | 5.010 | 0.0963 | 0.8132 | 1.686 | 319.99 | 319.98 | 3.001 | 5.027 | 0.0577 | 0.5427 | 1.870 |
| 275.69 | 275.69 | 1.011 | 5.075 | 0.0587 | 0.5004 | 1.680 | 330.00 | 329.99 | 1.701 | 5.018 | 0.0963 | 0.9585 | 1.984 |
| 275.64 | 275.64 | 1.501 | 4.953 | 0.0973 | 0.8093 | 1.679 | 330.00 | 329.99 | 1.699 | 5.011 | 0.0578 | 0.5745 | 1.984 |
| 275.67 | 275.67 | 1.500 | 5.010 | 0.0586 | 0.4923 | 1.678 | 329.99 | 329.98 | 2.003 | 4.987 | 0.0969 | 0.9530 | 1.973 |
| 275.64 | 275.64 | 3.006 | 4.972 | 0.0976 | 0.8076 | 1.665 | 329.99 | 329.98 | 2.002 | 4.988 | 0.0582 | 0.5723 | 1.972 |
| 275.66 | 275.66 | 3.003 | 5.022 | 0.0584 | 0.4870 | 1.661 | 329.99 | 329.98 | 2.502 | 4.988 | 0.0581 | 0.5681 | 1.960 |
| 275.65 | 275.65 | 2.509 | 5.009 | 0.0584 | 0.4871 | 1.666 | 330.00 | 329.99 | 2.502 | 5.004 | 0.0971 | 0.9508 | 1.958 |
| 275.65 | 275.65 | 2.509 | 4.997 | 0.0973 | 0.8114 | 1.670 | 330.00 | 329.99 | 3.001 | 5.010 | 0.0968 | 0.9447 | 1.948 |
| 275.64 | 275.64 | 2.007 | 4.984 | 0.0976 | 0.8150 | 1.676 | 330.00 | 329.99 | 2.999 | 5.002 | 0.0584 | 0.5673 | 1.943 |
| 275.68 | 275.68 | 2.006 | 5.065 | 0.0583 | 0.4945 | 1.674 | 330.01 | 330.00 | 2.195 | 5.024 | 0.0975 | 0.9622 | 1.965 |
| 300.01 | 300.00 | 1.507 | 5.018 | 0.0969 | 0.8595 | 1.768 | 329.98 | 329.97 | 2.197 | 4.979 | 0.0580 | 0.5681 | 1.969 |
| 300.00 | 299.99 | 1.508 | 5.008 | 0.0584 | 0.5170 | 1.767 | 340.00 | 339.98 | 2.202 | 5.013 | 0.0967 | 1.0112 | 2.086 |
| 300.00 | 299.99 | 2.504 | 5.009 | 0.0974 | 0.8597 | 1.763 | 340.00 | 339.98 | 2.194 | 5.031 | 0.0581 | 0.6094 | 2.086 |
| 300.00 | 299.99 | 2.996 | 5.020 | 0.0976 | 0.8598 | 1.756 | 340.00 | 339.98 | 2.500 | 5.014 | 0.0580 | 0.6015 | 2.070 |
| 300.00 | 299.99 | 2.995 | 5.026 | 0.0975 | 0.8599 | 1.755 | 340.01 | 339.99 | 2.497 | 5.025 | 0.0967 | 1.0060 | 2.071 |
| 299.99 | 299.98 | 2.003 | 5.010 | 0.0974 | 0.8624 | 1.767 | 339.98 | 339.96 | 2.999 | 4.968 | 0.0970 | 0.9851 | 2.044 |
| 299.99 | 299.98 | 2.003 | 5.008 | 0.0977 | 0.8624 | 1.764 | 339.99 | 339.97 | 3.000 | 4.988 | 0.0582 | 0.5933 | 2.044 |
| 299.97 | 299.96 | 1.006 | 4.980 | 0.0975 | 0.8615 | 1.774 | 340.00 | 339.98 | 2.794 | 5.013 | 0.0973 | 1.0034 | 2.058 |
| 310.01 | 310.00 | 1.505 | 5.001 | 0.0953 | 0.8709 | 1.828 | 340.00 | 339.98 | 2.799 | 5.005 | 0.0582 | 0.6000 | 2.059 |
| 309.98 | 309.97 | 1.504 | 4.948 | 0.0574 | 0.5196 | 1.828 | 350.00 | 349.98 | 2.701 | 5.005 | 0.0971 | 1.0812 | 2.224 |
| 310.00 | 309.99 | 2.007 | 4.973 | 0.0960 | 0.8711 | 1.825 | 350.00 | 349.98 | 2.700 | 5.007 | 0.0579 | 0.6441 | 2.223 |
| 310.00 | 309.99 | 1.998 | 4.994 | 0.0580 | 0.5269 | 1.820 | 350.00 | 349.98 | 2.602 | 3.000 | 0.0974 | 0.6529 | 2.235 |
| 310.00 | 309.99 | 2.502 | 4.992 | 0.0960 | 0.8709 | 1.818 | 350.01 | 349.99 | 2.603 | 3.015 | 0.0578 | 0.3908 | 2.242 |
| 310.01 | 310.00 | 2.498 | 5.034 | 0.0578 | 0.5275 | 1.814 | 350.00 | 349.98 | 2.801 | 2.983 | 0.0975 | 0.6442 | 2.215 |
| 309.98 | 309.97 | 1.108 | 4.974 | 0.0967 | 0.8806 | 1.832 | 349.98 | 349.96 | 2.804 | 2.983 | 0.0582 | 0.3840 | 2.212 |
| 309.99 | 309.98 | 1.109 | 4.985 | 0.0582 | 0.5311 | 1.830 | 349.98 | 349.96 | 3.003 | 3.002 | 0.0990 | 0.6525 | 2.196 |
| 310.00 | 309.99 | 3.001 | 5.006 | 0.0966 | 0.8738 | 1.808 | 349.98 | 349.96 | 2.999 | 2.998 | 0.0594 | 0.3907 | 2.195 |
| 310.01 | 310.00 | 2.997 | 5.003 | 0.0581 | 0.5272 | 1.813 | 349.99 | 349.97 | 3.201 | 3.015 | 0.0992 | 0.6525 | 2.182 |
| 320.00 | 319.99 | 2.002 | 5.008 | 0.0973 | 0.9196 | 1.887 | 349.99 | 349.97 | 3.199 | 3.004 | 0.0596 | 0.3906 | 2.183 |
| 319.99 | 319.98 | 2.006 | 4.973 | 0.0579 | 0.5437 | 1.890 | 354.99 | 354.97 | 2.998 | 3.046 | 0.0979 | 0.6880 | 2.307 |
| 319.99 | 319.98 | 1.508 | 4.978 | 0.0958 | 0.9055 | 1.899 | 354.97 | 354.95 | 2.999 | 3.005 | 0.0594 | 0.4116 | 2.305 |
| 320.00 | 319.99 | 1.507 | 5.003 | 0.0578 | 0.5485 | 1.897 | 354.95 | 354.93 | 3.205 | 2.967 | 0.0992 | 0.6704 | 2.278 |
| 319.99 | 319.98 | 2.496 | 4.977 | 0.0579 | 0.5424 | 1.882 | 354.96 | 354.94 | 3.201 | 3.002 | 0.0597 | 0.4089 | 2.281 |
| 319.99 | 319.98 | 2.499 | 4.986 | 0.0961 | 0.9017 | 1.883 | 360.00 | 359.98 | 3.205 | 5.023 | 0.0990 | 1.2158 | 2.445 |
| 320.00 | 319.99 | 3.002 | 4.988 | 0.0964 | 0.8987 | 1.869 | 360.00 | 359.98 | 3.209 | 5.020 | 0.0595 | 0.7286 | 2.439 |

**Table III. Isobaric Heat Capacity $C_P$ of HCFC-142b**

| $T_{68}$/K | $T_{90}$/K | $P$/MPa | $C_P$/(kJ·kg$^{-1}$·K$^{-1}$) |
|---|---|---|---|
| 275.65 | 275.65 | 1.000 | 1.254 |
| 275.65 | 275.65 | 1.500 | 1.252 |
| 275.65 | 275.65 | 2.000 | 1.250 |
| 275.65 | 275.65 | 2.500 | 1.249 |
| 275.65 | 275.65 | 3.000 | 1.245 |
| 310.00 | 309.99 | 1.000 | 1.340 |
| 310.00 | 309.99 | 1.500 | 1.336 |
| 310.00 | 309.99 | 2.000 | 1.332 |
| 310.00 | 309.99 | 2.500 | 1.327 |
| 310.00 | 309.99 | 3.000 | 1.323 |
| 320.00 | 319.99 | 1.000 | 1.370 |
| 320.00 | 319.99 | 1.500 | 1.365 |
| 320.00 | 319.99 | 2.000 | 1.362 |
| 320.00 | 319.99 | 2.500 | 1.358 |
| 320.00 | 319.99 | 3.000 | 1.356 |
| 330.00 | 329.99 | 1.000 | 1.411 |
| 330.00 | 329.99 | 1.500 | 1.406 |
| 330.00 | 329.99 | 2.000 | 1.398 |
| 330.00 | 329.99 | 2.500 | 1.394 |
| 330.00 | 329.99 | 3.000 | 1.386 |
| 340.00 | 339.98 | 1.500 | 1.443 |
| 340.00 | 339.98 | 2.000 | 1.431 |
| 340.00 | 339.98 | 2.500 | 1.424 |
| 340.00 | 339.98 | 3.000 | 1.413 |
| 350.00 | 349.98 | 1.400 | 1.497 |
| 350.00 | 349.98 | 1.500 | 1.496 |
| 350.00 | 349.98 | 1.600 | 1.492 |
| 350.00 | 349.98 | 1.700 | 1.493 |
| 350.00 | 349.98 | 2.000 | 1.486 |
| 350.00 | 349.98 | 2.500 | 1.473 |
| 350.00 | 349.98 | 3.000 | 1.462 |

where the contributions are ±0.01% in supplied energy flow, ±0.26% and ±0.36% in mass flow rates for HCFC-142b and HFC-152a, respectively, ±0.013 K in average temperature, and ±3 kPa in pressure. The overall uncertainty of the final $C_P$ values of HCFC-142b summarized in Table III is better than ±0.34% except at 350 K and 1.4 MPa where the uncertainty is estimated to be within ±0.43%. The overall uncertainty of the final $C_P$ values of HFC-152a summarized in Table IV is better than ±0.42% at temperatures from 276 to 350 K (except those at 2.7 MPa) and at 360 K, while the uncertainty at 350 K and 2.7 MPa and at 355 K is estimated to be within ±0.49%.

## Discussion

For HCFC-142b, Yada (7) has reported a modified-BWR-type equation of state (BWR = Benedict–Webb–Rubin) on the basis of his *own* *PVT* property data in both vapor and liquid phases, but the $C_P$ values derived from his equation of state are greater than the present measurements by 20–30%. For HFC-152a, Yin et al. (8) have also reported a modified-BWR-type equation of state on the basis of available *PVT* property data covering an extensive range of gaseous and liquid phases. The $C_P$ values derived from their equation of state, $C_{P,\mathrm{calcd}}$, are systematically more than 5% greater than the present results, $C_P$, as shown in Figure 3.

The $C_P$ values of HCFC-142b and HFC-152a were correlated with the following function of temperature and pressure:

$$C_P M/R = a + bP_r^{0.5} + cP_r \quad (2)$$

$$a = a_1 + a_2/(1 - T_r)^{0.5} + a_3/(1 - T_r) + a_4/(1 - T_r)^3$$

$$b = b_1 + b_2/(1 - T_r)^{0.5} + b_3/(1 - T_r)^{1.5}$$

$$c = c_1 + c_2/(1 - T_r)^{1.5}$$

where $P_r = P/P_c$, $T_r = T/T_c$, $R$ = 8.314 51 J·mol$^{-1}$·K$^{-1}$, and $M$ is molar mass. The coefficients of the correlations for HCFC-142b and HFC-152a are listed in Table V. The correlation for HCFC-142b represents the measurements within the uncertainty from 276 to 350 K at pressures between the

**Table IV. Isobaric Heat Capacity $C_P$ of HFC-152a**

| $T_{68}$/K | $T_{90}$/K | $P$/MPa | $C_P$/(kJ·kg$^{-1}$·K$^{-1}$) |
|---|---|---|---|
| 275.65 | 275.65 | 1.000 | 1.683 |
| 275.65 | 275.65 | 1.500 | 1.679 |
| 275.65 | 275.65 | 2.000 | 1.675 |
| 275.65 | 275.65 | 2.500 | 1.668 |
| 275.65 | 275.65 | 3.000 | 1.663 |
| 300.00 | 299.99 | 1.000 | 1.774 |
| 300.00 | 299.99 | 1.500 | 1.767 |
| 300.00 | 299.99 | 2.000 | 1.765 |
| 300.00 | 299.99 | 2.500 | 1.763 |
| 300.00 | 299.99 | 3.000 | 1.755 |
| 310.00 | 309.99 | 1.100 | 1.831 |
| 310.00 | 309.99 | 1.500 | 1.828 |
| 310.00 | 309.99 | 2.000 | 1.822 |
| 310.00 | 309.99 | 2.500 | 1.816 |
| 310.00 | 309.99 | 3.000 | 1.810 |
| 320.00 | 319.99 | 1.500 | 1.898 |
| 320.00 | 319.99 | 2.000 | 1.889 |
| 320.00 | 319.99 | 2.500 | 1.882 |
| 320.00 | 319.99 | 3.000 | 1.870 |
| 330.00 | 329.99 | 1.700 | 1.984 |
| 330.00 | 329.99 | 2.000 | 1.972 |
| 330.00 | 329.99 | 2.200 | 1.967 |
| 330.00 | 329.99 | 2.500 | 1.959 |
| 330.00 | 329.99 | 3.000 | 1.945 |
| 340.00 | 339.98 | 2.200 | 2.086 |
| 340.00 | 339.98 | 2.500 | 2.071 |
| 340.00 | 339.98 | 2.800 | 2.058 |
| 340.00 | 339.98 | 3.000 | 2.044 |
| 350.00 | 349.98 | 2.600 | 2.238 |
| 350.00 | 349.98 | 2.700 | 2.224 |
| 350.00 | 349.98 | 2.800 | 2.213 |
| 350.00 | 349.98 | 3.000 | 2.195 |
| 350.00 | 349.98 | 3.200 | 2.183 |
| 355.00 | 354.98 | 3.000 | 2.306 |
| 355.00 | 354.98 | 3.200 | 2.280 |
| 360.00 | 359.98 | 3.200 | 2.437 |

**Table V. Coefficients of Isobaric Specific Heat Correlations for HCFC-142b and HFC-152a**

| | HCFC-142b | HFC-152a |
|---|---|---|
| $T_{68,c}$/K | 410.29 (*9*) | 386.44 (*10*) |
| $T_{90,c}$/K | 410.26 | 386.41 |
| $P_c$/MPa | 4.041 (*9*) | 4.5198 (*10*) |
| $M$/(g·mol$^{-1}$) | 100.496 | 66.051 |
| $R$/(J·mol$^{-1}$·K$^{-1}$) | 8.31451 | 8.31451 |
| $a_1$ | 4.9634 | 1.5294 × 10 |
| $a_2$ | 7.9208 | −4.3026 |
| $a_3$ | −1.2226 | 1.7286 |
| $a_4$ | 3.9879 × 10$^{-3}$ | 1.4085 × 10$^{-3}$ |
| $b_1$ | −1.3332 | −6.7686 |
| $b_2$ | 1.1047 | 5.2443 |
| $b_3$ | −9.7184 × 10$^{-2}$ | −4.1547 × 10$^{-1}$ |
| $c_1$ | 7.6852 × 10$^{-2}$ | −5.3383 × 10$^{-1}$ |
| $c_2$ | −6.1316 × 10$^{-2}$ | −9.0988 × 10$^{-3}$ |

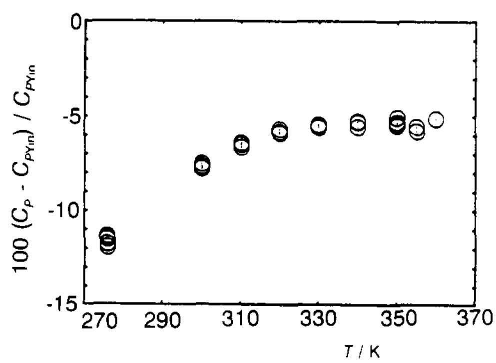


**Figure 3.** Deviations of the present results from the equation of state of Yin et al. (*8*) for HFC-152a.

saturation pressure and 3.0 MPa, whereas that of HFC-152a represents the measurements within the uncertainty from 276 to 360 K and up to 3.2 MPa. The correlation for HCFC-142b reproduces measured $C_P$ data with a maximum deviation of ±0.35% and a standard deviation of ±0.15%. The correlation of HFC-152a reproduces the measured $C_P$ data with a maximum deviation of ±0.24% and a standard deviation of ±0.11%.

Saturated liquid $C_P$ values were also derived from the correlations by substituting the vapor pressures calculated from equations developed by Kumagai et al. (*9*) for HCFC-142b and Higashi et al. (*10*) for HFC-152a. These values are listed in Tables VI and VII for HCFC-142b and HFC-152a, respectively. The uncertainty of these values is estimated to

**Table VI. Isobaric Heat Capacity of Saturated Liquid HCFC-142b**

| $T_{68}$/K | $T_{90}$/K | $P$/MPa | $C_P$/(kJ·kg$^{-1}$·K$^{-1}$) |
|---|---|---|---|
| 273.15 | 273.15 | 0.145 | 1.251 |
| 280.00 | 280.00 | 0.186 | 1.266 |
| 290.00 | 290.00 | 0.261 | 1.289 |
| 300.00 | 299.99 | 0.358 | 1.315 |
| 310.00 | 309.99 | 0.479 | 1.343 |
| 320.00 | 319.99 | 0.628 | 1.375 |
| 330.00 | 329.99 | 0.810 | 1.410 |
| 340.00 | 339.98 | 1.028 | 1.451 |
| 350.00 | 349.98 | 1.287 | 1.501 |

**Table VII. Isobaric Heat Capacity of Saturated Liquid HFC-152a**

| $T_{68}$/K | $T_{90}$/K | $P$/MPa | $C_P$/(kJ·kg$^{-1}$·K$^{-1}$) |
|---|---|---|---|
| 273.15 | 273.15 | 0.264 | 1.679 |
| 280.00 | 280.00 | 0.335 | 1.698 |
| 290.00 | 290.00 | 0.465 | 1.733 |
| 300.00 | 299.99 | 0.629 | 1.776 |
| 310.00 | 309.99 | 0.835 | 1.832 |
| 320.00 | 319.99 | 1.087 | 1.903 |
| 330.00 | 329.99 | 1.392 | 1.994 |
| 340.00 | 339.98 | 1.757 | 2.112 |
| 350.00 | 349.98 | 2.190 | 2.275 |
| 360.00 | 359.98 | 2.700 | 2.544 |

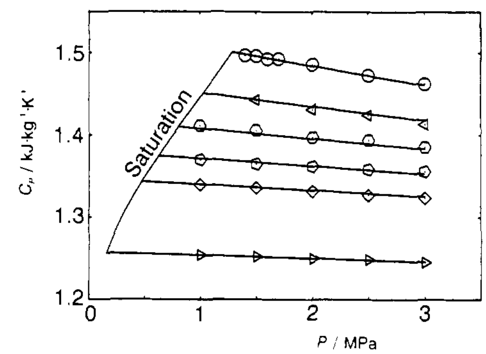


**Figure 4.** Measured (symbols) and calculated (solid lines) $C_P$ values for HCFC-142b: (⊙) 350 K, (◁) 340 K, (⬡) 330 K, (⬠) 320 K, (◇) 310 K, (▷) 276 K.

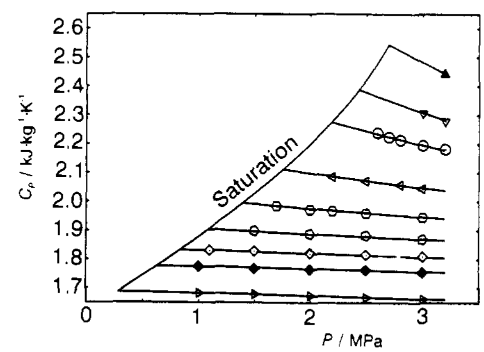


**Figure 5.** Measured (symbols) and calculated (solid lines) $C_P$ values for HFC-152b: (▲) 360 K, (▽) 355 K, (⊙) 350 K, (◁) 340 K, (⬡) 330 K, (⬠) 320 K, (◇) 310 K, (◆) 300 K, (▷) 276 K.

be about ±0.5% considering the extrapolation procedure. The measured $C_P$ values in the compressed liquid phase, the isotherms, and the saturation curve calculated from the respective correlations are shown in the $C_P$–$P$ diagrams in Figures 4 and 5.

## Conclusions

Thirty-one $C_P$ values of HCFC-142b were measured in the liquid phase at temperatures from 276 to 350 K and pressures up to 3.0 MPa. Thirty-six $C_P$ values of HFC-152a were measured at temperatures from 276 to 360 K and pressures up to 3.2 MPa. These $C_P$ data were compared with the values derived from available equations of state, effective including the liquid phase. The values of $C_P$ for both refrigerants were correlated with the same functional form of temperature and pressure. Saturated liquid $C_P$ values were derived from the correlations.

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