THERMOPHYSICAL PROPERTIES OF HCFC ALTERNATIVES

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THERMOPHYSICAL PROPERTIES OF HCFC ALTERNATIVES**ARTI MCLR Project Number 660-50800****W.M. Haynes****Physical and Chemical Properties Division
National Institute of Standards and Technology****ABSTRACT**

Numerous fluids and fluid mixtures have been identified as promising alternatives to the HCFC refrigerants, but, for many of them, reliable thermodynamic data do not exist. In particular, reliable thermodynamic properties data and models are needed to predict the performance of the new refrigerants in heating and cooling equipment and to design and optimize equipment to be reliable and energy efficient. The objective of this project is to measure, with high accuracy, selected thermodynamic properties data for two pure refrigerants and nine refrigerant blends; these data will be used to fit equations of state and other property models which can be used in equipment design. The new data will fill in gaps in the existing data and resolve problems and differences that exist in and between existing data sets. Most of the studied fluids and blends are potential replacements for HCFC-22 and/or R502; in addition, one pure fluid and one blend are potential replacements for CFC-13 in low temperature refrigeration applications.

SCOPE

This project involves the measurement of primary thermodynamic data for eight binary mixtures and one ternary mixture (R125/134a; R32/143a; R125/143a; R143a/134a; R32/290; R125/290; R290/134a; R41/744; and R32/125/134a). These data will consist of simultaneous measurements of the coexisting liquid and vapor densities and coexisting liquid and vapor compositions as well as the bubble point pressures over wide ranges of temperature and composition. These data will be used to determine the mixing parameters, including any temperature and/or composition dependence, for the Carnahan-Starling-DeSantis (CSD) equation of state and the extended corresponding states (ECS) model. Primary data will also be measured for the pure fluid HFC-41. These measurements will include the determination of vapor pressure; liquid density; liquid, two-phase, and ideal gas heat capacities; vapor sound speeds and virial coefficients; and a determination of the critical point parameters. These data will cover wide ranges of temperature and pressure and will be used (together with available literature data) to fit equations of state and other models of the thermodynamic properties. The original proposal called for similar measurements of primary data for HFC-245ca; since work on this fluid has been funded by another sponsor, comprehensive mixture data for the binary system R125/143a have been substituted as recommended by the MCLR Advisory Committee. During the past quarter, we have carried out the following tasks: (a) vapor-liquid equilibrium measurements on R143a/134a, R125/134a, R125/143a, and R32/125/134a systems, (b) bubble point pressure and near-saturation density measurements on standard mixtures of R143a/134a, R125/143a, and R32/125/134a, (c) isochoric heat capacity measurements on HFC-41 from 134 to 343 K (-218 to 157°F) at pressures to 35 MPa (5100 psia), (d) measurements of the triple point temperature and heat of fusion for HFC-41, and (e) initiation of isochoric heat capacity measurements on R143a/125 system.

SIGNIFICANT RESULTS

Primary mixture data for binary mixtures of relatively volatile components (R125/134a; R32/143a; R125/143a; R143a/134a; R32/290; R125/290; R134a/290)

The experimental difficulties reported in the last quarterly progress report have been resolved, and measurements have been proceeding in a normal manner. To verify the procedure for determining composition by sampling and analysis, and to provide additional data for the standard mixtures, the approach for acquiring vapor-liquid equilibrium data has been slightly modified. The major source of error in any vapor-liquid equilibrium measurement is in the composition determination. Care has been taken to use standard mixtures and to include the non-ideal behavior of the gases in the calibration. The new approach is to verify the composition determination procedure by comparison of the measurements for which the compositions were determined by sampling and analysis based on a calibration of the gas chromatograph using standard mixtures with bubble point measurements on the same standard mixtures. Near-saturation density data were also obtained for these standard mixtures. These different procedures for carrying out the measurements are especially important for those systems for which there are few data available in the literature for comparison.

Vapor-liquid equilibrium data were obtained for three binary systems during the past quarter. Measurements were made at temperatures from 280 K (44°F) to either 340 K (152°F) or near the critical point in 15 K (27°F) increments for the following systems: R143a/134a, R125/134a, and R125/143a. Bubble point pressures and near-saturation density data were obtained for two standard mixtures of R143a/134a and one standard mixture of R125/143a.

The vapor-liquid equilibrium data, bubble point data, and near-saturation density data for the R143a/134a system are presented in Tables 1 through 3. Comparisons with other datasets and REFPROP will be reported in the next quarter.

Vapor-liquid equilibrium data for the R125/134a and R125/143a systems were measured and are currently being reduced and compared to literature results. Bubble point measurements and near-saturation (p,ρ,T) data for one standard mixture of R125/143a have also been completed. The data for this system will be reported next quarter when the measurements on the second standard mixture of R125/143a are complete. For R125/134a, bubble point and near-saturation (p,ρ,T) measurements on two standard mixtures are needed to complete the data set for this system.

Vapor-liquid equilibrium measurements for R32/290, R125/290, and R134a/290 will be completed in the next quarter. Near-saturation (p,ρ,T) data for these systems have been reported in previous reports.

Primary mixture data for a ternary mixture of relatively volatile components (R32/125/134a)

Vapor equilibrium data for the R32/125/134a system were measured and are presented in Table 4. Bubble point and near-saturation (p,ρ,T) data were measured for three standard mixtures of R32/125/134a. The bubble point measurements are reported in Table 5, and the near-saturation (p,ρ,T) results are presented in Table 6. Figure 1 presents the comparisons of the bubble point pressures from this work with preliminary data available from the International Energy Agency Annex-18 database. The vapor-liquid equilibrium measurements and the bubble point pressures from the standard mixture measurements are in good agreement except at 340 K (152.3°F) where the bubble point pressures from the vapor-liquid equilibrium measurements are somewhat lower

(1.5%) than the bubble point pressure-measurement made with the standard mixtures. However, the results generally follow the trend of the vapor-liquid equilibrium data of Higashi [Iwaki Meisei University, private communication] below 325 K. The critical point of HFC-125 is 339.4 K (151.2°F). Therefore, both the bubble point measurements on the standard mixtures and the vapor-liquid equilibrium measurements have a higher degree of uncertainty on the 340 K (152.3°F) isotherm. The vapor compositions are compared in Figure 2. The vapor composition data of Higashi [Iwaki Meisei University, private communication], of Nagel and Bier [Int. J. Refrig. 18:534 (1995)], and from this current study agree within ± 0.025 mole fraction.

Primary mixture data for binary mixture of very low boiling components (R41/744)

The vapor-liquid equilibrium data for R41/744 will be measured in the new oil-bath apparatus in the next quarter. The data will cover a temperature range from 218 to 300 K (-67 to 80°F).

Comprehensive data for the R143a/125 mixture

Measurements have begun in the adiabatic calorimeter on the equimolar mixture of HFC-143a and HFC-125. Density measurements have been completed on this mixture and presented in a previous report. The composition is 0.50004 HFC-143a + 0.49996 HFC-125. The expected range of the heat capacity measurements is 200 to 345 K (-100 to 161°F) at pressures to 35 MPa (5100 psi).

Primary data for a very low-boiling fluid (HFC-41)

Vapor pressures and density data for HFC-41 using the new vapor-liquid equilibrium apparatus were reported in the last quarterly report. The densities reported in Table 10 of the last report were those corrected to saturation that were used in the calculation of the properties at the critical point and not the near-saturation densities as indicated in the table heading. The near-saturation (p, ρ , T) data for HFC-41 are reported in Table 7 of this report.

Heat capacities at constant volume (C_v) were measured for HFC-41 with an adiabatic calorimeter in a temperature range from 134 to 343 K (-218 to 157°F) at pressures to 35 MPa (5100 psi). Measurements were carried out on liquid, dense gas, and two-phase samples. Results for single-phase samples are presented in Tables 8 and 9. The temperatures, densities, pressures, and heat capacities are presented in these tables. The heat capacities are depicted in Figure 3. Measurements for two-phase samples are presented in Tables 10 and 11. Saturated liquid heat capacities were calculated from these measurements which are depicted in Figure 4. During the course of these two-phase measurements, we made a determination of the triple-point temperature and heat of fusion for the solid. These values are, respectively, $T_{\text{triple}} = 129.82$ K (-226.0°F) and $\Delta_{\text{fus}}H = 3.37$ kJ·mol⁻¹ (42.6 Btu·lb⁻¹).

COMPLIANCE WITH AGREEMENT

NIST has complied with all terms of the grant agreement modulo small shifts in the estimated level of effort from one property and/or fluid to another.

PRINCIPAL INVESTIGATOR EFFORT

Dr. W.M. Haynes is the NIST Principal Investigator for the MCLR program. During the second quarter of calendar year 1996, Dr. Haynes devoted approximately one week to planning this project, monitoring and reviewing the research, and preparing the report. The project involves multiple researchers and capabilities in Gaithersburg, MD and Boulder, CO.

Figure 1: Comparison of bubble point pressures for the R32/125/134a system; the baseline is from an extended corresponding states (ECS) model in REFPROP.

Figure 2: Comparison of vapor compositions for the R32/125/134a system; baseline is from an extended corresponding states (ECS) model in REFPROP.

Figure 3: Liquid phase isochoric heat capacities for HFC-41.

Figure 4: Saturated liquid heat capacities of HFC-41.

APPENDIX A:
TABLES OF THERMOPHYSICAL PROPERTIES DATA

Table 1. Vapor-Liquid Equilibrium Data for R143a/134a Mixtures from 280 to 340 K (44 to 152°F).

x(R143a) Liquid Mole Fraction	y(R143a) Vapor Mole Fraction	Temperature K	Pressure MPa	x(R143a) Liquid Mass Fraction	y(R143a) Vapor Mass Fraction	Temperature °F	Pressure psia
0.000	0.000	280.39	0.3790	0.000	0.000	45.01	55.0
0.165		280.20	0.4413	0.140		44.68	64.0
0.304	0.446	280.17	0.4909	0.265	0.399	44.63	71.2
0.515	0.643	280.13	0.5692	0.467	0.597	44.54	82.6
0.578	0.703	280.11	0.5950	0.530	0.661	44.52	86.3
1.000	1.000	280.23	0.7674	1.000	1.000	44.73	111.3
0.000	0.000	294.69	0.5962	0.000	0.000	70.75	86.5
0.194	0.294	295.09	0.7154	0.165	0.255	71.47	103.8
0.381	0.519	295.10	0.8078	0.336	0.471	71.49	117.2
0.601	0.707	295.08	0.9348	0.554	0.665	71.46	135.6
1.000	1.000	294.11	1.1349	1.000	1.000	69.71	164.6
0.000	0.000	309.31	0.9131	0.000	0.000	97.07	132.4
0.198	0.285	309.87	1.0724	0.169	0.247	98.07	155.5
0.237	0.330	309.94	1.1022	0.204	0.289	98.21	159.9
0.348	0.459	310.02	1.1826	0.305	0.411	98.35	171.5
0.372	0.474	310.02	1.2018	0.328	0.426	98.36	174.3
0.595	0.679	309.90	1.3737	0.548	0.635	98.14	199.2
1.000	1.000	309.37	1.6768	1.000	1.000	97.18	243.2
0.000	0.000	324.50	1.3669	0.000	0.000	124.41	198.3
0.211	0.270	324.93	1.5372	0.180	0.234	125.19	222.9
0.290	0.382	324.93	1.6279	0.308	0.337	125.18	236.2
0.351		324.88	1.6941	0.599		125.10	245.7
0.645	0.704	324.98	2.0072	0.588	0.662	125.27	291.1
1.000	1.000	326.02	2.4669	1.000	1.000	127.15	357.8
0.000	0.000	340.16	1.9862	0.000	0.000	152.60	288.1
0.261	0.328	340.00	2.2630	0.225	0.287	152.31	328.2
0.351	0.426	339.79	2.4051	0.308	0.379	151.94	348.8
0.480	0.538	339.76	2.5543	0.432	0.490	151.87	370.5
0.634	0.690	339.07	2.7737	0.588	0.647	150.64	402.3
1.000	1.000	340.07	3.3177	1.000	1.000	152.44	481.2

Table 2. Bubble Point Pressures for R143a/134a Mixtures from 280 to 340 K (44 to 152 °F).

x(R143a) Liquid Mole Fraction	Temperature K	Pressure MPa	x(R143a) Liquid Mass Fraction	Temperature °F	Pressure psia
0.3500	280.85	0.5216	0.3072	45.84	75.65
0.3500	295.10	0.7977	0.3072	71.49	115.7
0.3500	310.43	1.2031	0.3072	99.09	174.5
0.3500	324.96	1.7085	0.3072	125.24	247.8
0.3500	339.62	2.3608	0.3072	151.63	342.4
0.6502	280.92	0.6482	0.6049	45.97	94.0
0.6502	295.00	0.9695	0.6049	71.31	140.6
0.6502	309.88	1.4272	0.6049	98.10	207.0
0.6502	325.04	2.0422	0.6049	125.38	296.2
0.6502	340.12	2.8182	0.6049	152.53	408.8

Table 3. Near-Saturation (p,ρ,T) Data for R143a/134a Mixtures from 279 to 343 K (43 to 158°F).

x(R143a) Liquid Mole Fraction	Temperature K	Pressure MPa	Density kg/m ³	x(R143a) Liquid Mass Fraction	Temperature °F	Pressure psia	Density lb/ft ³
0.3500	282.63	0.5216	1173.5	0.3072	49.05	75.7	73.19
0.3500	294.07	0.7977	1128.0	0.3072	69.63	115.7	70.36
0.3500	310.56	1.2031	1059.1	0.3072	99.32	174.5	66.06
0.3500	324.99	1.7085	994.8	0.3072	125.29	247.8	62.05
0.3500	339.67	2.3608	915.5	0.3072	151.72	342.4	57.10
0.6502	280.22	0.6482	1092.7	0.6049	44.71	94.0	68.15
0.6502	294.99	0.9695	1038.1	0.6049	71.29	140.6	64.75
0.6502	310.05	1.4272	976.6	0.6049	98.40	207.0	60.91
0.6502	325.23	2.0422	902.5	0.6049	125.73	296.2	56.29
0.6502	340.17	2.8182	803.3	0.6049	152.62	408.8	50.10

y(R143a) Vapor Mole Fraction	Temperature K	Pressure MPa	Density kg/m ³	y(R143a) Vapor Mass Fraction	Temperature °F	Pressure psia	Density lb/ft ³
0.511*	280.86	0.5216	23.5	0.463*	45.86	75.7	1.47
0.482*	296.20	0.7977	37.3	0.434*	73.47	115.7	2.33
0.471*	311.90	1.2031	61.9	0.423*	101.73	174.5	3.86
0.463*	326.21	1.7085	86.1	0.415*	127.49	247.8	5.37
0.417*	340.88	2.3608	129.0	0.371*	153.90	342.4	8.04
0.718*	295.86	0.9695	42.3	0.677*	72.86	140.6	2.64
0.704*	280.60	0.6482	42.3	0.662*	45.39	94.0	2.64
0.708*	312.70	1.4272	65.4	0.666*	103.17	207.0	4.08
0.718*	327.98	2.0422	100.1	0.678*	130.68	296.2	6.25
0.668*	343.23	2.8182	152.4	0.624*	158.13	408.8	9.51

*Vapor compositions are calculated from the vapor-liquid equilibrium data.

Table 4. Vapor-Liquid Equilibrium Data for R32/R125/R134a Mixtures from 280 to 340 K (44 to 152°F).

x (R32) Liquid Mole Fraction	x (R125) Liquid Mole Fraction	x (R134a) Liquid Mole Fraction	y (R32) Vapor Mole Fraction	y (R125) Vapor Mole Fraction	y (R134a) Vapor Mole Fraction	Temp. K	Press. MPa	x (R32) Liquid Mass Fraction	x (R125) Liquid Mass Fraction	x (R134a) Liquid Mass Fraction	y (R32) Vapor Mass Fraction	y (R125) Vapor Mass Fraction	y (R134a) Vapor Mass Fraction	Temp. °F	Press. psia
0.155	0.466	0.379	0.222	0.231	0.547	279.93	0.6921	0.079	0.545	0.377	0.120	0.654	0.226	44.18	100.4
0.191	0.363	0.446	0.266	0.292	0.442	279.93	0.6702	0.100	0.440	0.460	0.159	0.556	0.285	44.19	97.2
0.226	0.262	0.512	0.323	0.376	0.301	279.93	0.6495	0.123	0.329	0.547	0.221	0.408	0.372	44.18	94.2
0.242	0.412	0.346	0.189	0.342	0.469	279.98	0.7308	0.129	0.508	0.363	0.191	0.603	0.207	44.27	106.0
0.392	0.330	0.278	0.215	0.494	0.291	279.97	0.7798	0.231	0.448	0.321	0.311	0.423	0.266	44.25	113.1
0.252	0.215	0.533	0.347	0.399	0.254	294.97	0.9901	0.141	0.277	0.583	0.240	0.352	0.409	71.25	143.6
0.304	0.224	0.472	0.303	0.434	0.263	294.96	1.0390	0.174	0.296	0.530	0.265	0.371	0.363	71.24	150.7
0.495	0.298	0.207	0.171	0.574	0.255	294.94	1.2962	0.312	0.433	0.256	0.383	0.393	0.224	71.21	188.0
0.163	0.553	0.284	0.194	0.214	0.592	309.99	1.6761	0.082	0.639	0.279	0.109	0.697	0.194	98.29	243.1
0.198	0.432	0.360	0.246	0.267	0.487	309.98	1.6327	0.104	0.524	0.371	0.143	0.600	0.258	98.28	236.8
0.218	0.512	0.270	0.180	0.285	0.535	309.99	1.7251	0.113	0.612	0.275	0.152	0.659	0.189	98.29	250.2
0.302	0.465	0.233	0.241	0.421	0.338	310.00	1.8009	0.165	0.586	0.249	0.252	0.467	0.282	98.31	261.2
0.465	0.310	0.225	0.192	0.543	0.265	309.99	1.9057	0.287	0.441	0.272	0.355	0.399	0.246	98.29	276.4
0.203	0.430	0.367	0.265	0.262	0.473	324.99	2.3235	0.106	0.518	0.376	0.140	0.583	0.277	125.30	337.0
0.241	0.332	0.427	0.315	0.343	0.342	324.99	2.2677	0.131	0.415	0.454	0.196	0.451	0.353	125.29	328.9
0.322	0.191	0.487	0.353	0.427	0.220	324.99	2.1774	0.187	0.257	0.556	0.263	0.313	0.424	125.30	315.8
0.431	0.233	0.396	0.223	0.535	0.242	324.98	2.4442	0.265	0.330	0.405	0.350	0.365	0.286	125.28	354.5
0.446	0.235	0.319	0.236	0.525	0.239	324.99	2.4911	0.276	0.336	0.388	0.341	0.358	0.301	125.30	361.3
0.474	0.247	0.279	0.206	0.554	0.240	324.99	2.5642	0.298	0.358	0.344	0.366	0.366	0.267	125.29	371.9
0.045	0.516	0.439	0.425	0.063	0.512	339.97	2.8661	0.021	0.568	0.411	0.030	0.568	0.402	152.25	415.7
0.086	0.474	0.440	0.400	0.111	0.489	339.96	2.9392	0.042	0.535	0.422	0.055	0.557	0.388	152.24	426.3
0.348	0.328	0.328	0.282	0.400	0.318	339.93	3.3336	0.200	0.430	0.370	0.237	0.435	0.328	152.18	483.5
0.453	0.271	0.276	0.234	0.506	0.260	339.93	3.5184	0.280	0.386	0.334	0.323	0.383	0.293	152.18	510.3
0.489	0.250	0.261	0.221	0.540	0.239	339.94	3.5666	0.310	0.366	0.324	0.354	0.362	0.284	152.20	517.3
0.481	0.249	0.270	0.225	0.534	0.241	339.95	3.5666	0.303	0.362	0.334	0.349	0.363	0.288	152.23	517.3

Table 5. Bubble Point Pressures for R32/125/134a Mixtures from 221 to 345 K (-62 to 162°F).

x (R32) Liquid Mole Fraction	x (R125) Liquid Mole Fraction	x (R134a) Liquid Mole Fraction	Temp. K	Press. MPa	x			Temp. °F	Press. psia
					(R32) Liquid Mass Fraction	(R125) Liquid Mass Fraction	(R134a) Liquid Mass Fraction		
0.3460	0.3005	0.3535	220.93	0.0731	0.1997	0.4001	0.4002	-62.02	10.6
0.3460	0.3005	0.3535	230.45	0.1164	0.1997	0.4001	0.4002	-44.88	16.9
0.3460	0.3005	0.3535	239.53	0.1722	0.1997	0.4001	0.4002	-28.53	25.0
0.3460	0.3005	0.3535	250.06	0.2657	0.1997	0.4001	0.4002	-9.58	38.5
0.3460	0.3005	0.3535	259.92	0.3834	0.1997	0.4001	0.4002	8.17	55.6
0.3460	0.3005	0.3535	269.95	0.5411	0.1997	0.4001	0.4002	26.23	78.5
0.3460	0.3005	0.3535	279.94	0.7469	0.1997	0.4001	0.4002	44.20	108.3
0.3460	0.3005	0.3535	289.88	0.9997	0.1997	0.4001	0.4002	62.10	145.0
0.3460	0.3005	0.3535	284.50	0.8516	0.1997	0.4001	0.4002	52.41	123.5
0.3460	0.3005	0.3535	293.40	1.0990	0.1997	0.4001	0.4002	68.43	159.4
0.3460	0.3005	0.3535	305.28	1.5044	0.1997	0.4001	0.4002	89.82	218.2
0.3460	0.3005	0.3535	317.09	2.0133	0.1997	0.4001	0.4002	111.07	292.0
0.3460	0.3005	0.3535	326.18	2.4896	0.1997	0.4001	0.4002	127.44	361.1
0.3460	0.3005	0.3535	335.01	3.0198	0.1997	0.4001	0.4002	143.33	438.0
0.3460	0.3005	0.3535	335.33	3.0464	0.1997	0.4001	0.4002	143.91	441.8
0.3460	0.3005	0.3535	345.21	3.7336	0.1997	0.4001	0.4002	161.69	541.5
0.2004	0.5992	0.2005	280.47	0.7943	0.1014	0.6996	0.1990	45.16	115.2
0.2004	0.5992	0.2005	295.07	1.2021	0.1014	0.6996	0.1990	71.44	174.4
0.2004	0.5992	0.2005	310.26	1.8368	0.1014	0.6996	0.1990	98.78	266.4
0.2004	0.5992	0.2005	325.34	2.5837	0.1014	0.6996	0.1990	125.92	374.7
0.5992	0.2006	0.2002	280.25	0.8749	0.4119	0.3181	0.2700	44.76	126.9
0.5992	0.2006	0.2002	295.04	1.3393	0.4119	0.3181	0.2700	71.38	194.2
0.5992	0.2006	0.2002	310.15	1.9864	0.4119	0.3181	0.2700	98.58	288.1
0.5992	0.2006	0.2002	324.96	2.8306	0.4119	0.3181	0.2700	125.24	410.5
0.5992	0.2006	0.2002	339.95	3.9314	0.4119	0.3181	0.2700	152.22	570.2
0.5992	0.2006	0.2002	325.00	2.8299	0.4119	0.3181	0.2700	125.31	410.4
0.5992	0.2006	0.2002	310.00	1.9743	0.4119	0.3181	0.2700	98.31	286.3
0.5992	0.2006	0.2002	280.22	0.6011	0.1091	0.2509	0.6401	44.71	87.2
0.2005	0.1998	0.5997	294.66	0.9208	0.1091	0.2509	0.6401	70.70	133.6
0.2005	0.1998	0.5997	310.07	1.3962	0.1091	0.2509	0.6401	98.44	202.5
0.2005	0.1998	0.5997	325.04	2.0133	0.1091	0.2509	0.6401	125.38	292.0
0.2005	0.1998	0.5997	340.05	2.7910	0.1091	0.2509	0.6401	152.40	404.8
0.2005	0.1998	0.5997	325.15	2.0036	0.1091	0.2509	0.6401	125.58	290.6
0.2005	0.1998	0.5997	310.13	1.3900	0.1091	0.2509	0.6401	98.55	201.6

Table 6. Near-Saturation (p,p,T) Data for R32/125/134a Mixtures from 244 to 346 K (-21 to 163 °F) (continued).

x(R32) Liquid Mole Fraction	x(R125) Liquid Mole Fraction	x(R134a) Liquid Mole Fraction	Temperature K	Pressure MPa	Density kg/m ³	x(R32) Liquid Mass Fraction	x(R125) Liquid Mass Fraction	x(R134a) Liquid Mass Fraction	Temperature °F	Pressure psia	Density lb/ft ³
0.264	0.627	0.109	282.17	0.7943	41.46	0.0161	0.7517	0.2321	48.22	115.2	2.59
0.257	0.624	0.119	296.77	1.2021	62.64	0.0145	0.7459	0.2396	74.50	174.4	3.91
0.248	0.620	0.132	312.78	1.8368	103.63	0.0127	0.7384	0.2489	103.32	266.4	6.46
0.237	0.616	0.147	328.04	2.5837	153.70	0.0110	0.7301	0.2589	130.78	374.7	9.59
0.694	0.207	0.099	281.88	0.8749	30.69	0.1258	0.3497	0.5246	47.70	126.9	1.91
0.686	0.205	0.109	297.31	1.3393	48.53	0.1154	0.3445	0.5401	75.47	194.2	3.03
0.676	0.203	0.121	312.78	1.9864	90.67	0.1047	0.3390	0.5564	103.32	288.1	5.66
0.663	0.202	0.135	328.04	2.8306	132.37	0.0936	0.3344	0.5720	130.78	410.5	8.26
0.643	0.201	0.156	343.26	3.9314	186.76	0.0801	0.3283	0.5916	158.18	570.2	11.65
0.663	0.202	0.135	328.06	2.8299	119.61	0.0936	0.3344	0.5720	130.82	410.4	7.46
0.676	0.203	0.121	312.83	1.9743	76.66	0.1047	0.3390	0.5564	103.41	286.3	4.78
0.329	0.273	0.398	281.96	0.6011	28.53	0.0127	0.3621	0.6252	47.84	87.2	1.78
0.314	0.264	0.422	296.87	0.9208	40.70	0.0118	0.3479	0.6403	74.68	133.6	2.54
0.298	0.254	0.448	312.73	1.3962	70.38	0.0110	0.3325	0.6565	103.23	202.5	4.39
0.280	0.244	0.476	327.93	2.0133	103.01	0.0101	0.3169	0.6730	130.59	292.0	6.42
0.260	0.233	0.507	342.92	2.7910	149.68	0.0093	0.3000	0.6907	157.57	404.8	9.34
0.280	0.244	0.476	327.93	2.0036	98.01	0.0101	0.3169	0.6730	130.59	290.6	6.11
0.298	0.254	0.448	312.67	1.3900	65.19	0.0110	0.3325	0.6565	103.12	201.6	4.07

*Near-saturation vapor compositions are calculated from the vapor-liquid equilibrium data and REFPROP.

Table 7. Near-Saturation (p, ρ ,T) Data for HFC-41 from 274 to 296 K (34 to 73°F).

Temperature K	Pressure MPa	Density kg/m ³	Temperature °F	Pressure psia	Density lb/ft ³
274.38	2.195	675.6	34.20	318.4	42.14
276.68	2.339	676.7	38.34	339.3	41.65
278.42	2.460	662.2	41.47	356.8	41.30
280.06	2.564	656.2	44.42	371.9	40.93
281.65	2.681	650.1	47.28	388.9	40.55
282.94	2.775	645.4	49.60	402.5	40.25
284.66	2.906	638.8	52.70	421.5	39.84
286.58	3.053	631.4	56.16	442.7	39.38
288.28	3.186	624.5	59.22	462.1	38.95
290.44	3.349	615.3	63.10	485.8	38.37
292.21	3.497	606.9	66.29	507.1	37.85
293.86	3.644	599.5	69.26	528.5	37.39
294.89	3.728	595.1	71.11	540.7	37.12
275.93	2.195	45.5	36.99	318.4	2.84
278.32	2.339	50.0	41.29	339.3	3.12
280.14	2.460	53.3	44.56	356.8	3.33
281.76	2.564	56.7	47.48	371.9	3.53
283.40	2.681	60.7	50.43	388.9	3.79
284.71	2.775	63.2	52.79	402.5	3.94
286.46	2.906	66.8	55.94	421.5	4.17
288.36	3.053	71.0	59.36	442.7	4.43
290.12	3.186	76.7	62.53	462.1	4.78
292.07	3.349	81.5	66.04	485.8	5.09
294.11	3.497	88.5	69.71	507.1	5.52
295.35	3.644	97.4	71.94	528.5	6.07
295.89	3.728	106.4	72.91	540.7	6.64

Table 8. Experimental Liquid and Gas Heat Capacity Data for HFC-41 in SI Units; preliminary data, subject to change.

T K	ρ $\text{kg}\cdot\text{m}^{-3}$	P MPa	C_v $\text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$
148.371	988.49	10.157	47.61
152.215	987.27	18.001	46.64
156.062	986.08	25.835	46.57
163.611	959.87	9.859	45.80
167.527	958.73	17.045	45.04
171.441	957.62	24.197	44.87
175.337	956.53	31.183	44.84
184.739	918.66	9.211	44.19
188.751	917.62	15.479	42.96
192.773	916.63	21.785	42.78
196.773	915.65	27.948	42.84
203.880	880.45	9.122	42.44
207.990	879.52	14.702	41.76
212.090	878.63	20.261	41.62
216.170	877.75	25.725	41.69
220.240	876.89	31.092	41.76
222.687	840.57	8.794	41.43
226.888	839.74	13.692	40.74
231.072	838.94	18.566	40.73
235.239	838.16	23.370	40.76
239.396	837.39	28.110	40.93
242.409	795.51	8.494	40.79
246.713	794.77	12.709	40.23
250.996	794.08	16.904	40.33
255.277	793.40	21.066	40.34
259.537	792.72	25.169	40.34
263.547	792.10	28.999	40.43
263.247	743.07	8.432	40.54
267.655	742.45	11.944	40.23
272.049	741.87	15.444	40.23
276.430	741.29	18.921	40.23
280.813	740.72	22.380	40.41
285.180	740.15	25.805	40.45
289.533	739.59	29.196	40.64
293.880	739.03	32.559	40.74
283.493	680.89	7.865	40.87
288.047	680.37	10.682	40.69
292.599	679.89	13.505	40.70
297.149	679.41	16.326	40.73
301.697	678.94	19.140	40.58
306.230	678.48	21.937	40.74
310.776	678.01	24.732	40.89
315.313	677.54	27.511	40.77
319.841	677.08	30.274	41.10
324.356	676.62	33.018	41.56
293.034	646.14	7.687	41.36
297.659	645.68	10.159	40.82

Table 8. Experimental Liquid and Gas Heat Capacity Data for HFC-41 in SI Units; preliminary data, subject to change (continued).

T K	ρ kg·m ³	P MPa	C_p J·mol ⁻¹ ·K ⁻¹
302.286	645.24	12.650	40.95
306.910	644.82	15.142	41.16
311.533	644.40	17.629	41.36
316.156	643.98	20.113	41.38
320.758	643.57	22.580	41.33
325.353	643.16	25.039	41.42
329.979	642.74	27.512	41.59
334.592	642.32	29.972	41.73
339.218	641.91	32.428	41.81
295.409	645.89	8.953	41.14
300.041	645.45	11.441	41.08
304.682	645.02	13.941	40.91
309.317	644.60	16.437	40.99
313.958	644.18	18.932	41.22
318.600	643.76	21.423	41.31
323.245	643.35	23.912	41.31
327.885	642.93	26.393	41.27
332.520	642.51	28.868	41.55
337.158	642.09	31.336	41.75
303.889	599.16	7.584	42.29
308.581	598.77	9.642	41.86
313.273	598.40	11.714	41.85
317.975	598.04	13.800	41.66
322.667	597.68	15.887	41.72
327.369	597.33	17.981	41.88
332.076	596.98	20.077	41.99
336.793	596.62	22.177	41.75
341.521	596.26	24.281	41.63
306.150	598.96	8.574	41.83
310.881	598.59	10.656	41.73
315.625	598.22	12.756	41.68
320.366	597.86	14.863	41.76
325.118	597.50	16.978	41.74
329.870	597.14	19.095	41.93
334.633	596.78	21.215	41.86
339.387	596.42	23.331	41.87
309.790	564.73	7.340	43.05
314.617	564.37	9.162	42.50
319.442	564.03	11.001	42.42
324.290	563.71	12.862	42.12
329.127	563.39	14.727	42.39
333.993	563.07	16.608	42.19
338.842	562.75	18.488	42.26
312.334	564.53	8.297	42.63
317.173	564.19	10.134	42.36
322.028	563.86	11.993	42.18
326.891	563.54	13.864	41.94

Table 8. Experimental Liquid and Gas Heat Capacity Data for HFC-41 in SI Units; preliminary data, subject to change (continued).

T K	ρ kg•m ³	P MPa	C _v J•mol ⁻¹ •K ⁻¹
331.759	563.21	15.744	42.16
336.630	562.89	17.630	42.20
341.522	562.57	19.529	42.29
320.500	427.13	6.618	50.98
325.616	426.86	7.654	48.14
330.826	426.64	8.737	46.67
336.080	426.43	9.848	45.67
341.380	426.22	10.985	44.92
323.108	426.98	7.142	48.85
328.289	426.75	8.207	47.10
333.528	426.53	9.306	46.14
338.817	426.33	10.433	45.54
320.394	200.99	6.069	56.41
326.668	200.64	6.590	51.63
333.055	200.50	7.111	49.26
339.500	200.39	7.630	47.94
323.568	200.77	6.334	53.97
329.857	200.56	6.851	50.33
336.255	200.44	7.369	48.52
342.711	200.34	7.886	46.85
311.056	60.36	3.237	43.63
318.622	60.34	3.387	42.18
326.203	60.31	3.535	41.15
333.816	60.28	3.682	41.30
314.884	60.35	3.314	42.14
322.429	60.32	3.462	41.31
329.997	60.30	3.608	41.97
337.588	60.27	3.754	41.60

Table 9. Experimental Liquid and Gas Heat Capacity Data for HFC-41 in PI Units; preliminary data, subject to change.

T °F	ρ lb•ft ⁻³	P psia	C _v Btu•lb ⁻¹ •°F ⁻¹
-192.60	61.710	1473.2	0.3344
-185.68	61.633	2610.8	0.3275
-178.76	61.559	3747.0	0.3270
-165.17	59.923	1429.9	0.3216
-158.12	59.851	2472.2	0.3163
-151.08	59.782	3509.5	0.3151
-144.06	59.714	4522.8	0.3149
-127.14	57.350	1336.0	0.3103
-119.92	57.285	2245.0	0.3017
-112.68	57.223	3159.7	0.3004
-105.48	57.162	4053.5	0.3009
-92.69	54.965	1323.1	0.2980
-85.29	54.907	2132.3	0.2933
-77.91	54.851	2938.6	0.2923
-70.56	54.796	3731.1	0.2928
-63.24	54.742	4509.6	0.2933
-58.83	52.475	1275.4	0.2910
-51.27	52.423	1985.8	0.2861
-43.74	52.373	2692.7	0.2860
-36.24	52.325	3389.5	0.2862
-28.76	52.277	4077.0	0.2874
-23.33	49.662	1232.0	0.2865
-15.59	49.616	1843.3	0.2825
-7.88	49.573	2451.7	0.2832
-0.17	49.530	3055.3	0.2833
7.50	49.488	3650.4	0.2833
14.72	49.449	4206.0	0.2839
14.17	46.389	1222.9	0.2847
22.11	46.350	1732.4	0.2825
30.02	46.313	2239.9	0.2825
37.90	46.277	2744.2	0.2825
45.79	46.242	3245.9	0.2838
53.65	46.206	3742.6	0.2841
61.49	46.171	4234.5	0.2854
69.31	46.136	4722.2	0.2861
50.62	42.506	1140.7	0.2870
58.81	42.474	1549.3	0.2858
67.01	42.444	1958.8	0.2858
75.20	42.414	2367.9	0.2860
83.38	42.385	2776.0	0.2850
91.54	42.356	3181.7	0.2861
99.73	42.327	3587.1	0.2872
107.89	42.298	3990.1	0.2863
116.04	42.269	4390.8	0.2886
124.17	42.240	4788.8	0.2919
67.79	40.337	1114.9	0.2905

Table 9. Experimental Liquid and Gas Heat Capacity Data for HFC-41 in PI Units; preliminary data, subject to change (continued).

T °F	ρ lb•ft⁻³	P psia	C_v Btu•lb⁻¹•°F⁻¹
76.12	40.308	1473.5	0.2867
84.45	40.281	1834.8	0.2876
92.77	40.255	2196.1	0.2891
101.09	40.229	2556.9	0.2905
109.41	40.203	2917.1	0.2906
117.69	40.177	3274.9	0.2902
125.97	40.151	3631.7	0.2909
134.29	40.125	3990.3	0.2921
142.60	40.099	4347.1	0.2931
150.92	40.073	4703.3	0.2936
72.07	40.322	1298.6	0.2889
80.40	40.294	1659.3	0.2885
88.76	40.268	2022.0	0.2873
97.10	40.241	2384.0	0.2879
105.45	40.215	2745.9	0.2895
113.81	40.189	3107.1	0.2901
122.17	40.163	3468.1	0.2901
130.52	40.137	3828.0	0.2898
138.87	40.111	4186.9	0.2918
147.22	40.085	4545.0	0.2932
87.33	37.404	1100.0	0.2970
95.78	37.380	1398.4	0.2940
104.22	37.357	1699.0	0.2939
112.68	37.334	2001.5	0.2926
121.13	37.312	2304.2	0.2930
129.59	37.290	2607.9	0.2941
138.07	37.268	2911.9	0.2949
146.56	37.246	3216.5	0.2932
155.07	37.224	3521.7	0.2924
91.40	37.392	1243.5	0.2938
99.92	37.368	1545.5	0.2931
108.45	37.346	1850.1	0.2927
116.99	37.323	2155.7	0.2933
125.54	37.301	2462.5	0.2931
134.10	37.278	2769.5	0.2945
142.67	37.256	3077.0	0.2940
151.23	37.234	3383.9	0.2940
97.95	35.255	1064.6	0.3023
106.64	35.232	1328.8	0.2985
115.33	35.212	1595.6	0.2979
124.05	35.191	1865.5	0.2958
132.76	35.171	2135.9	0.2977
141.52	35.151	2408.9	0.2963
150.25	35.131	2681.5	0.2968
102.53	35.243	1203.5	0.2994
111.24	35.221	1469.9	0.2975
119.98	35.201	1739.4	0.2962

Table 9. Experimental Liquid and Gas Heat Capacity Data for HFC-41 in PI Units; preliminary data, subject to change (continued).

T °F	ρ lb•ft⁻³	P psia	C_v Btu•lb⁻¹•°F⁻¹
128.73	35.181	2010.8	0.2945
137.50	35.160	2283.5	0.2961
146.26	35.140	2557.0	0.2964
155.07	35.120	2832.4	0.2970
117.23	26.665	959.8	0.3580
126.44	26.648	1110.1	0.3381
135.82	26.634	1267.2	0.3277
145.27	26.621	1428.4	0.3207
154.81	26.608	1593.2	0.3155
121.92	26.655	1035.9	0.3431
131.25	26.641	1190.3	0.3308
140.68	26.628	1349.8	0.3240
150.20	26.615	1513.2	0.3198
117.04	12.548	880.2	0.3962
128.33	12.525	955.9	0.3626
139.83	12.517	1031.3	0.3459
151.43	12.510	1106.6	0.3367
122.75	12.533	918.7	0.3790
134.07	12.520	993.7	0.3535
145.59	12.513	1068.8	0.3407
157.21	12.507	1143.8	0.3290
100.23	3.768	469.5	0.3064
113.85	3.767	491.3	0.2962
127.50	3.765	512.7	0.2890
141.20	3.763	534.0	0.2900
107.12	3.767	480.6	0.2959
120.70	3.766	502.1	0.2901
134.32	3.764	523.4	0.2947
147.99	3.763	544.4	0.2921

Table 10. Experimental Two-Phase Heat Capacity Data for HFC-41 in SI Units; preliminary data, subject to change.

T K	ρ_o kg•m ⁻³	P _o MPa	C _v ⁽²⁾ J•mol ⁻¹ •K ⁻¹	C _o
136.023	997.99	0.001	71.859	71.835
140.144	990.21	0.001	71.514	71.478
144.237	982.45	0.002	71.276	71.227
148.312	974.68	0.003	71.075	71.008
152.365	966.90	0.005	70.819	70.731
156.398	959.11	0.007	70.613	70.499
160.407	951.31	0.010	70.659	70.515
164.402	943.49	0.013	70.594	70.416
168.369	935.66	0.018	70.638	70.422
172.321	927.79	0.024	70.388	70.130
176.242	919.92	0.032	70.516	70.212
180.148	912.00	0.042	70.696	70.344
184.031	904.05	0.054	70.500	70.097
187.886	896.08	0.068	70.620	70.165
191.726	888.05	0.085	70.713	70.206
195.542	879.98	0.105	71.121	70.562
199.339	871.84	0.129	71.218	70.609
203.109	863.67	0.156	71.371	70.716
206.860	855.42	0.188	71.658	70.961
210.586	847.12	0.224	71.967	71.236
214.292	838.74	0.266	72.244	71.487
217.979	830.27	0.312	72.501	71.727
221.639	821.72	0.364	72.709	71.932
225.276	813.09	0.423	73.237	72.470
228.890	804.35	0.488	73.810	73.072
232.486	795.50	0.560	74.336	73.646
236.059	786.52	0.639	74.715	74.097
239.606	777.42	0.725	75.230	74.711
243.135	768.18	0.820	75.801	75.412
246.639	758.79	0.923	76.041	75.817
250.119	749.23	1.034	76.885	76.868
253.581	739.48	1.155	77.607	77.844
257.022	729.53	1.285	77.964	78.510
260.437	719.37	1.424	78.725	79.644
263.838	708.94	1.574	79.473	80.840
267.218	698.24	1.735	79.950	81.854
270.576	687.25	1.906	80.615	83.159
134.063	1001.68	0.001	71.904	71.884
138.189	993.91	0.001	71.598	71.568
142.294	986.14	0.002	71.306	71.263
146.376	978.38	0.003	71.229	71.171
150.430	970.62	0.004	70.988	70.910
154.472	962.84	0.006	70.844	70.743
158.486	955.06	0.008	70.644	70.515
162.481	947.26	0.011	70.562	70.401
166.453	939.45	0.016	70.341	70.144
170.404	931.62	0.021	70.455	70.218

Table 10. Experimental Two-Phase Heat Capacity Data for HFC-41 in SI Units; preliminary data, subject to change (continued).

T K	ρ_o kg·m ⁻³	P _o MPa	C _v ⁽²⁾ Jmol ⁻¹ ·K ⁻¹	C _o
174.336	923.75	0.028	70.438	70.157
178.248	915.86	0.037	70.545	70.216
182.139	907.93	0.048	70.519	70.141
186.011	899.96	0.061	70.526	70.096
189.859	891.96	0.076	70.661	70.179
193.687	883.91	0.095	70.820	70.286
197.488	875.82	0.117	71.136	70.551
201.278	867.65	0.142	71.138	70.505
205.036	859.45	0.172	71.427	70.750
208.772	851.18	0.206	71.857	71.142
212.489	842.83	0.245	72.005	71.259
216.176	834.43	0.289	72.285	71.517
219.846	825.93	0.338	72.570	71.793
223.485	817.36	0.393	73.065	72.291
227.111	808.67	0.455	73.476	72.721
230.712	799.89	0.523	73.661	72.945
234.281	791.01	0.598	74.211	73.554
237.841	781.97	0.681	74.912	74.341
241.373	772.82	0.771	75.328	74.870
244.886	763.51	0.870	75.919	75.608
248.378	754.04	0.977	76.573	76.448
251.850	744.39	1.093	77.099	77.202
255.299	734.54	1.218	77.597	77.981
258.728	724.49	1.353	78.020	78.743
262.135	714.20	1.498	78.639	79.772
265.520	703.66	1.653	79.458	81.079
268.889	692.82	1.818	80.177	82.385
272.233	681.67	1.995	80.826	83.733
275.557	670.16	2.183	81.672	85.416
278.863	658.24	2.382	82.751	87.501
266.017	702.08	1.676	81.681	81.329
269.584	690.53	1.854	82.243	82.397
273.123	678.63	2.044	83.253	84.038
276.637	666.33	2.246	84.158	85.729
280.106	653.62	2.461	85.659	88.202
283.555	640.37	2.689	86.815	90.572
286.972	626.53	2.930	87.741	93.019
290.361	611.97	3.186	89.092	96.296
293.728	596.52	3.456	90.560	100.244
297.066	580.01	3.741	91.963	104.906
269.553	690.64	1.852	88.257	82.793
273.526	677.25	2.066	89.746	84.587
277.459	663.36	2.296	91.376	86.699
281.353	648.91	2.542	93.157	89.186
285.212	633.75	2.804	94.860	91.896
289.028	617.80	3.083	96.163	94.610
292.794	600.92	3.380	98.443	98.859

Table 10. Experimental Two-Phase Heat Capacity Data for HFC-41 in SI Units; preliminary data, subject to change (continued).

T K	ρ_o kg·m⁻³	P_o MPa	C_v⁽²⁾ Jmol⁻¹·K⁻¹	C_o
296.528	582.76	3.694	101.013	104.224
300.216	563.04	4.027	103.402	110.671
303.854	541.18	4.377	106.088	119.532
307.438	516.21	4.746	109.488	133.113
310.958	486.11	5.133	113.468	156.659
314.409	444.87	5.537	117.979	216.090
271.694	683.49	1.966	89.024	83.705
275.649	669.84	2.188	90.602	85.678
279.565	655.64	2.426	92.181	87.852
283.438	640.83	2.681	94.021	90.550
287.281	625.24	2.953	95.856	93.597
291.080	608.76	3.242	97.204	96.638
294.827	591.23	3.548	99.440	101.250
298.541	572.25	3.873	102.142	107.364
302.199	551.47	4.215	104.670	114.948
305.807	528.10	4.575	107.924	126.194
309.361	500.69	4.954	111.727	144.143
312.838	465.94	5.350	116.875	180.932

Table 11. Experimental Two-Phase Heat Capacity Data for HFC-41 in PI Units;
preliminary data, subject to change.

T °F	ρ_s lb•ft ⁻³	P _s psia	C _v ⁽²⁾ Btu•lb ⁻¹ •°F ⁻¹	C _s
-214.83	62.303	0.1	0.5046	0.5045
-207.41	61.817	0.2	0.5022	0.5020
-200.04	61.332	0.3	0.5005	0.5002
-192.71	60.847	0.4	0.4991	0.4987
-185.41	60.362	0.7	0.4973	0.4967
-178.15	59.875	1.0	0.4959	0.4951
-170.94	59.389	1.4	0.4962	0.4952
-163.75	58.900	1.9	0.4958	0.4945
-156.61	58.411	2.6	0.4961	0.4946
-149.49	57.920	3.5	0.4943	0.4925
-142.44	57.429	4.7	0.4952	0.4931
-135.40	56.934	6.1	0.4965	0.4940
-128.41	56.438	7.8	0.4951	0.4923
-121.47	55.940	9.8	0.4959	0.4927
-114.56	55.439	12.3	0.4966	0.4930
-107.69	54.935	15.3	0.4995	0.4955
-100.86	54.427	18.7	0.5001	0.4959
-94.07	53.917	22.7	0.5012	0.4966
-87.32	53.402	27.3	0.5032	0.4983
-80.62	52.884	32.5	0.5054	0.5003
-73.94	52.361	38.5	0.5073	0.5020
-67.31	51.832	45.3	0.5092	0.5037
-60.72	51.299	52.9	0.5106	0.5052
-54.17	50.759	61.3	0.5143	0.5089
-47.67	50.214	70.7	0.5183	0.5132
-41.20	49.661	81.2	0.5220	0.5172
-34.76	49.101	92.6	0.5247	0.5204
-28.38	48.533	105.2	0.5283	0.5247
-22.03	47.956	118.9	0.5323	0.5296
-15.72	47.370	133.8	0.5340	0.5324
-9.46	46.773	150.0	0.5399	0.5398
-3.22	46.164	167.5	0.5450	0.5467
2.97	45.543	186.3	0.5475	0.5514
9.12	44.909	206.6	0.5529	0.5593
15.24	44.258	228.3	0.5581	0.5677
21.32	43.590	251.6	0.5615	0.5748
27.37	42.903	276.4	0.5661	0.5840
-218.36	62.533	0.1	0.5050	0.5048
-210.93	62.048	0.1	0.5028	0.5026
-203.54	61.563	0.2	0.5008	0.5005
-196.19	61.078	0.4	0.5002	0.4998
-188.90	60.594	0.6	0.4985	0.4980
-181.62	60.108	0.8	0.4975	0.4968
-174.40	59.622	1.2	0.4961	0.4952
-167.21	59.136	1.7	0.4955	0.4944
-160.05	58.648	2.3	0.4940	0.4926
-152.94	58.159	3.1	0.4948	0.4931

Table 11. Experimental Two-Phase Heat Capacity Data for HFC-41 in PI Units;
preliminary data, subject to change (continued).

T °F	ρ_o lb•ft ⁻³	P _o psia	C _v ⁽²⁾ Btu•lb ⁻¹ •°F ⁻¹	C _o
-145.87	57.668	4.1	0.4947	0.4927
-138.82	57.175	5.4	0.4954	0.4931
-131.82	56.681	6.9	0.4952	0.4926
-124.85	56.183	8.8	0.4953	0.4923
-117.92	55.683	11.1	0.4962	0.4928
-111.03	55.181	13.8	0.4973	0.4936
-104.19	54.676	16.9	0.4996	0.4955
-97.37	54.166	20.7	0.4996	0.4951
-90.61	53.654	25.0	0.5016	0.4969
-83.88	53.137	29.9	0.5046	0.4996
-77.19	52.616	35.5	0.5057	0.5004
-70.55	52.092	41.9	0.5076	0.5022
-63.95	51.561	49.0	0.5096	0.5042
-57.40	51.026	57.0	0.5131	0.5077
-50.87	50.484	66.0	0.5160	0.5107
-44.39	49.935	75.9	0.5173	0.5123
-37.96	49.381	86.8	0.5212	0.5165
-31.56	48.817	98.8	0.5261	0.5221
-25.20	48.246	111.9	0.5290	0.5258
-18.88	47.664	126.2	0.5332	0.5310
-12.59	47.073	141.7	0.5377	0.5369
-6.34	46.471	158.5	0.5414	0.5422
-0.13	45.856	176.7	0.5449	0.5476
6.04	45.229	196.2	0.5479	0.5530
12.17	44.586	217.2	0.5523	0.5602
18.27	43.928	239.7	0.5580	0.5694
24.33	43.251	263.7	0.5631	0.5786
30.35	42.555	289.3	0.5676	0.5880
36.33	41.837	316.6	0.5736	0.5999
42.28	41.093	345.5	0.5811	0.6145
49.16	40.330	376.1	0.5896	0.6306
56.08	39.559	408.9	0.5991	0.6481
63.04	38.780	444.6	0.6096	0.6671
70.14	37.993	483.9	0.6211	0.6876
77.37	37.200	526.7	0.6336	0.7096
84.73	36.402	573.0	0.6471	0.7331
92.22	35.600	622.7	0.6616	0.7581
100.84	34.795	676.0	0.6771	0.7846
109.59	33.987	732.9	0.6936	0.8126
118.47	33.177	793.4	0.7111	0.8421
127.48	32.365	857.6	0.7296	0.8731
136.62	31.552	925.5	0.7491	0.9056
145.89	30.738	997.2	0.7696	0.9396
155.29	29.924	1072.7	0.7911	0.9751
164.82	29.110	1152.0	0.8136	1.0121
174.48	28.297	1235.1	0.8371	1.0506
184.27	27.484	1322.0	0.8616	1.0906
194.18	26.672	1412.7	0.8871	1.1331
204.21	25.860	1507.2	0.9136	1.1781
214.36	25.049	1605.5	0.9411	1.2246
224.63	24.238	1707.7	0.9696	1.2726
235.02	23.428	1813.8	0.9991	1.3231
245.53	22.619	1923.9	1.0296	1.3761
256.16	21.811	2038.0	1.0611	1.4316
266.91	21.004	2156.1	1.0936	1.4896
277.78	20.198	2278.2	1.1271	1.5501
288.77	19.393	2404.3	1.1616	1.6131
299.88	18.589	2534.4	1.1971	1.6786
311.11	17.786	2668.5	1.2336	1.7466
322.46	16.984	2806.6	1.2711	1.8171
333.93	16.183	2948.7	1.3096	1.8901
345.52	15.383	3094.8	1.3491	1.9656
357.23	14.584	3244.9	1.3896	2.0436
369.06	13.786	3399.0	1.4311	2.1241
381.01	12.989	3557.1	1.4736	2.2071
393.08	12.193	3719.2	1.5171	2.2926
405.27	11.398	3885.3	1.5616	2.3806
417.58	10.604	4055.4	1.6071	2.4711
429.91	9.811	4229.5	1.6536	2.5641
442.36	9.019	4407.6	1.7011	2.6596
454.93	8.228	4589.7	1.7496	2.7576
467.62	7.438	4775.8	1.7991	2.8581
480.43	6.649	4965.9	1.8496	2.9611
493.36	5.861	5160.0	1.9011	3.0666
506.41	5.074	5358.1	1.9536	3.1746
519.58	4.288	5560.2	2.0071	3.2851
532.87	3.504	5766.3	2.0616	3.3981
546.28	2.721	5976.4	2.1171	3.5136
559.81	1.940	6190.5	2.1736	3.6316
573.46	1.161	6408.6	2.2311	3.7521
587.23	0.384	6630.7	2.2896	3.8751
601.12		6856.8	2.3491	3.9996
615.13		7086.9	2.4096	4.1266
629.26		7321.0	2.4711	4.2561
643.51		7559.1	2.5336	4.3881
657.88		7801.2	2.5971	4.5226
672.37		8047.3	2.6616	4.6596
686.98		8297.4	2.7271	4.7991
701.71		8551.5	2.7936	4.9411
716.56		8809.6	2.8611	5.0856
731.53		9071.7	2.9296	5.2326
746.62		9337.8	3.0001	5.3821
761.83		9607.9	3.0716	5.5341
777.16		9882.0	3.1441	5.6886
792.61		10160.1	3.2176	5.8456
808.18		10442.2	3.2921	6.0051
823.87		10728.3	3.3676	6.1676
839.68		11018.4	3.4441	6.3331
855.61		11312.5	3.5216	6.5016
871.66		11610.6	3.5996	6.6731
887.83		11912.7	3.6786	6.8476
904.12		12218.8	3.7586	7.0251
920.53		12528.9	3.8396	7.2056
937.06		12843.0	3.9216	7.3891
953.71		13161.1	4.0046	7.5756
970.48		13483.2	4.0886	7.7651
987.37		13809.3	4.1736	7.9576
1004.38		14139.4	4.2596	8.1531
1021.51		14473.5	4.3466	8.3516
1038.76		14811.6	4.4346	8.5531
1056.13		15153.7	4.5236	8.7576
1073.62		15500.8	4.6136	8.9651
1091.23		15851.9	4.7046	9.1756
1108.96		16207.0	4.7966	9.3891
1126.81		16566.1	4.8896	9.6056
1144.78		16929.2	4.9836	9.8251
1162.87		17296.3	5.0786	10.0486
1181.08		17667.4	5.1746	10.2751
1199.41		18042.5	5.2716	10.5046
1217.86		18421.6	5.3696	10.7371
1236.43		18804.7	5.4686	10.9726
1255.12		19191.8	5.5686	11.2111
1273.93		19582.9	5.6696	11.4526
1292.86		19978.0	5.7716	11.6971
1311.91		20377.1	5.8746	11.9446
1331.08		20780.2	5.9786	12.1951
1350.37		21187.3	6.0836	12.4486
1369.78		21598.4	6.1896	12.7051
1389.31		22013.5	6.2966	12.9646
1408.96		22432.6	6.4046	13.2271
1428.73		22855.7	6.5136	13.4926
1448.62		23282.8	6.6236	13.7611
1468.63		23713.9	6.7346	14.0326
1488.76		24148.0	6.8466	14.3071
1509.01		24586.1	6.9596	14.5846
1529.38		25028.2	7.0736	14.8651
1549.87		25474.3	7.1886	15.1486
1570.48		25924.4	7.3046	15.4351
1591.21		26378.5	7.4216	15.7246
1612.06		26836.6	7.5396	16.0171
1633.03		27298.7	7.6586	16.3126
1654.12		27764.8	7.7786	16.6111
1675.33		28234.9	7.8996	16.9126
1696.66		28709.0	8.0216	17.2171
1718.11		29187.1	8.1446	17.5246
1739.68		29669.2	8.2686	17.8351
1761.37		30155.3	8.3936	18.1486
1783.18		30645.4	8.5196	18.4651
1805.11		31139.5	8.6466	18.7846
1827.16		31637.6	8.7746	19.1071
1849.33		32139.7	8.9036	19.4326
1871.62		32645.8	9.0336	19.7611
1894.03		33155.9	9.1646	20.0926
1916.56		33670.0	9.2966	20.4271
1939.21		34188.1	9.4296	20.7646
1961.98		34710.2	9.5636	21.1051
1984.87		35236.3	9.6986	21.4486
2007.88		35766.4	9.8346	21.7951
2031.01		36299.5	9.9716	22.1446
2054.26		36835.6	10.1096	22.4971
2077.63		37374.7	10.2486	22.8526
2101.12		37917.8	10.3886	23.2111
2124.73		38464.9	10.5296	23.5726
2148.46		39015.0	10.6716	23.9371
2172.31		39569.1	10.8146	24.3046
2196.28		40127.2	10.9586	24.6751
2220.37		40689.3	11.1036	25.0486
2244.48		41255.4	11.2496	25.4251
2268.71		41825.5	11.3966	25.8046
2293.06		42399.6	11.5446	26.1871
2317.53		42977.7	11.6936	26.5726
2342.12		43559.8	11.8436	26.9611
2366.83		44145.9	11.9946	27.3526
2391.66		44736.0	12.1466	27.7471
2416.61		45330.1	12.2996	28.1446
2441.68		45928.2	12.4536	28.5451
2466.87		46530.3	12.6086	28.9486
2492.18		47136.4	12.7646	29.3551
2517.61		47746.5	12.9216	29.7646
2543.16		48360.6	13.0796	30.1771
2568.83		48978.7	13.2386	30.5926
2594.62		49599.8	13.3986	31.0111
2620.53		50224.9	13.5596	31.4326
2646.56		50854.0	13.7216	31.8571
2672.71		51487.1	13.8846	32.2846
2698.98		52124.2	14.0486	32.7151
2725.37		52765.3	14.2136	33.1486
2751.88		53410.4	14.3796	33.5851
2778.51		54059.5	14.5466	34.0246
2805.26		54712.6	14.7146	34.4671
2832.13		55369.7	14.8836	34.9126
2859.12		56030.8	15.0536	35.3611
2886.23		56695.9	15.2246	35.8126
2913.46		57365.0	15.3966	36.2671
2940.81		58038.1	15.5696	36.7246
2968.28		58715.2	15.7436	37.1851
2995.87		59396.3	15.9186	37.6486
3023.58		60081.4	16.0946	38.1151
3051.41		60770.5	16.2716	38.5846
3079.36		61463.6	16.4496	39.0571
3107.43		62160.7	16.6286	39.5326
3135.62		62861.8	16.8086	40.0111
3163.93		63566.9	16.9896	40.4926
3192.36		64276.0	17.1716	40.9771
3220.91		64989.1	17.3546	41.4646
3249.58		65706.2	17.5386	41.9551
3278.37		66427.3	17.7236	42.4486
3307.28		67152.4	17.9096	42.9451
3336.31		67881.5	18.0966	43.4446
3365.46		68614.6	18.2846	43.9471
3394.73		69351.7	18.4736	44.4526
3424.12		70092.8	18.6636	44.9611
3453.63		70837.9	18.8546	45.4726
3483.26		71587.0	19.0466	45.9871

**Table 11. Experimental Two-Phase Heat Capacity Data for HFC-41 in PI Units;
preliminary data, subject to change (continued).**

T °F	ρ_o lb•ft⁻³	P_o psia	C_v⁽²⁾ Btu•lb⁻¹•°F⁻¹	C_o
74.08	36.381	535.8	0.7094	0.7319
80.72	35.149	584.0	0.7262	0.7772
87.27	33.785	634.8	0.7450	0.8394
93.72	32.226	688.3	0.7689	0.9348
100.05	30.347	744.4	0.7969	1.1002
106.27	27.772	803.1	0.8285	1.5175
29.38	42.669	285.1	0.6252	0.5878
36.50	41.817	317.3	0.6363	0.6017
43.55	40.930	351.9	0.6474	0.6170
50.52	40.006	388.9	0.6603	0.6359
57.44	39.032	428.3	0.6732	0.6573
64.27	38.004	470.2	0.6826	0.6787
71.02	36.909	514.6	0.6983	0.7110
77.70	35.724	561.7	0.7173	0.7540
84.29	34.427	611.3	0.7351	0.8072
90.78	32.968	663.6	0.7579	0.8862
97.18	31.257	718.5	0.7846	1.0123
103.44	29.088	775.9	0.8208	1.2706