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THERMOPHYSICAL PROPERTIES OF HFC-143a AND HFC-152a

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THERMOPHYSICAL PROPERTIES OF HFC-143a AND HFC-152a

ARTI MCLR Project Number 650-50800
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ABSTRACT

Numerous fluids have been identified as promising alternative refrigerants, but much of the information needed to predict their behavior as pure fluids and as components in mixtures does not exist. In particular, reliable thermophysical 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 provide highly accurate, selected thermophysical properties data for refrigerants HFC-143a (CH_3CF_3) and HFC-152a (CH_3CHF_2) and to use these data to fit complex equations of state and detailed transport property models. The new data will fill gaps in the existing data sets and resolve problems and uncertainties that exist in and between the data sets. **This report describes progress during the first quarter of this twelve-month project, which was initiated on April 1, 1993.**

SCOPE

This project involves selected measurements of the thermodynamic properties of HFC-143a and HFC-152a and the development of high-accuracy modified Benedict-Webb-Rubin (MBWR) equations of state for each fluid. It also includes selected measurements of the transport properties (viscosity and thermal conductivity) of both HFC-143a and HFC-152a and the development of detailed correlations for same. The experimental thermodynamic measurements will include, as appropriate, accurate determinations of the critical temperature, pressure, and density; vapor pressures and saturated densities; vapor-phase speed of sound and ideal-gas heat capacity; pressure-volume-temperature (PVT) behavior of the superheated vapor and compressed liquid; and isochoric heat capacity in the liquid and two-phase regions. The experimental transport measurements will cover the one-phase and saturated liquid and vapor states over the temperature range of interest. Efforts during this first quarter focused mostly on acquiring and characterizing a high-purity sample of HFC-143a, and on measuring the liquid-phase PVT behavior and liquid-phase isochoric heat capacity of HFC-152a. Also included are previously unpublished results on the vapor pressure of HFC-152a.

SIGNIFICANT RESULTS

HFC-143a

A high-purity sample of HFC-143a has been acquired. Henry's constant for dissolved air at 20°C (68°F) has been estimated from a chromatographic analysis to be 3200 kPa (465 psia). This result will be used in the future to correct data for dissolved air.

HFC-152a

The high-quality gas-phase PVT data published by Baehr and Tillner-Roth (Hanover, Germany) have been analyzed and their virial coefficients have been compared with a NIST correlation of virials for a wide variety of small molecules. Good agreement was found, confirming that further gas-phase PVT measurements are not needed at this time.

An isochoric PVT apparatus has been used to measure liquid-phase densities of HFC-152a at 136 state points at temperatures ranging from 158 to 400 K (-175 to 260°F) with pressures as high as 35 MPa (5000 psia). The resulting temperatures, pressures, and densities are presented in both SI and PI units in Table 1 (see Appendix A, which includes all tables). This data set was obtained in order to have a single source of data that overlaps the results of several other investigations.

An ebulliometer has been used to measure the vapor pressure of HFC-152a at 38 temperatures between 220 and 273 K (-63 to 32°F); the corresponding pressures ranged from 22.7 to 263.7 kPa (3.3 to 38.2 psia). The data obtained are presented in Table 2. These very precise data have been combined with higher-pressure data from the literature (after the literature values were corrected for air impurities) and fitted to an Antoine-type vapor-pressure equation; see Table 3. The resulting Antoine equation is applicable from 220 K (-63°F) to the critical temperature of HFC-152a at 386 K (235°F). A manuscript describing these results has been prepared for submission to the Journal of Chemical and Engineering Data. This work was performed prior to starting the current project.

Liquid isochoric heat capacity measurements have been initiated on HFC-152a at low temperatures. Measurements will be conducted on single-phase and saturated-liquid samples at temperatures from 156 to 345 K (-179 to 161°F) with pressures up to 35 MPa (5000 psia). Between 8 and 10 liquid isochores will be obtained during the coming months. Approximately one half of the isochores have been measured, but the data have not been analyzed yet. They will be included in the next progress report.

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. Richard F. Kayser is the NIST Principal Investigator for the MCLR program. During the first and second quarters of calendar year 1993, Dr. Kayser devoted approximately one week to planning the project, monitoring and reviewing the research, and preparing the quarterly report. The project involves multiple researchers and capabilities in Gaithersburg, MD and Boulder, CO.

APPENDIX A:

TABLES OF THERMOPHYSICAL PROPERTIES DATA

Table 1a. Liquid-Phase Isochoric PVT Data for HFC-152a in SI Units.

Temperature Kelvin	Pressure MPa	Density $mol \cdot dm^{-3}$
158.000	2.053188	17.98615
159.999	6.210133	17.98137
162.001	10.367660	17.97691
163.999	14.498310	17.97267
165.999	18.618390	17.96854
167.999	22.717550	17.96452
169.999	26.790560	17.96059
172.000	30.839830	17.95672
173.999	34.867970	17.95289
172.000	4.087598	17.62805
173.998	7.860726	17.62373
176.000	11.637910	17.61962
177.999	15.387470	17.61566
179.998	19.131790	17.61179
182.000	22.855290	17.60801
183.999	26.546550	17.60430
186.000	30.232920	17.60063
188.001	33.892340	17.59700
186.000	2.390870	17.21662
188.001	5.777556	17.21244
190.000	9.157830	17.20850
191.998	12.527060	17.20471
194.000	15.880580	17.20103
196.000	19.221760	17.19741
197.999	22.552610	17.19386
200.000	25.869700	17.19036
201.999	29.166760	17.18690
203.999	32.449210	17.18347
202.000	2.593093	16.77045
203.999	5.601335	16.76657
206.000	8.603363	16.76288
208.002	11.600440	16.75932
209.999	14.583070	16.75585
212.000	17.559140	16.75244
214.000	20.525530	16.74907
215.999	23.474060	16.74576

Table 1a. Liquid-Phase Isochoric PVT Data for HFC-152a in SI Units.
(continued)

Temperature Kelvin	Pressure MPa	Density $mol \cdot dm^{-3}$
218.001	26.414340	16.74248
220.001	29.337730	16.73924
222.002	32.254070	16.73601
224.001	35.155080	16.73281
218.000	2.432366	16.30942
220.001	5.104399	16.30579
222.000	7.767070	16.30231
224.001	10.426080	16.29894
225.999	13.076370	16.29566
228.000	15.722100	16.29242
229.999	18.353100	16.28924
232.001	20.972690	16.28609
234.000	23.584740	16.28297
236.000	26.189320	16.27988
237.999	28.783030	16.27682
240.002	31.372350	16.27375
242.000	33.942420	16.27072
238.002	2.516277	15.72136
240.002	4.807657	15.71803
242.000	7.095706	15.71482
244.000	9.380437	15.71168
246.000	11.657440	15.70861
248.001	13.929340	15.70559
249.999	16.191610	15.70261
252.002	18.454120	15.69965
254.001	20.707960	15.69673
255.998	22.950040	15.69381
257.999	25.191070	15.69092
259.999	27.420030	15.68805
262.000	29.645420	15.68518
264.002	31.862500	15.68233
266.000	34.070920	15.67949

Table 1a. Liquid-Phase Isochoric PVT Data for HFC-152a in SI Units.
(continued)

Temperature Kelvin	Pressure MPa	Density mol·dm^{-3}
262.002	1.508491	14.99055
264.000	3.164917	14.93711
265.999	5.039310	14.93417
268.001	6.910926	14.93124
269.998	8.775389	14.92840
272.000	10.638690	14.92560
274.001	12.500130	14.92282
276.000	14.357770	14.92007
278.000	16.211000	14.91735
280.000	18.054640	14.91465
282.000	19.896140	14.91197
284.000	21.739380	14.90929
286.001	23.576070	14.90663
288.001	25.404900	14.90397
290.002	27.231590	14.90132
292.001	29.052140	14.89868
293.999	30.863170	14.89606
296.001	32.674400	14.89345
298.002	34.472410	14.89086
290.000	3.180992	14.06002
294.001	6.173100	14.05473
298.001	9.162137	14.04960
302.001	12.142250	14.04456
306.000	15.116620	14.03957
310.000	18.082180	14.03463
314.002	21.038000	14.02973
318.001	23.980470	14.02484
322.002	26.906480	14.01998
326.001	29.820690	14.01523
329.999	32.724080	14.01051
322.000	2.988966	12.79108
325.998	5.149677	12.78652
330.002	7.313230	12.78202
334.000	9.475170	12.77758
338.000	11.638350	12.77318
342.001	13.793130	12.76894
346.000	15.951440	12.76487

Table 1a. Liquid-Phase Isochoric PVT Data for HFC-152a in SI Units.
(continued)

Temperature Kelvin	Pressure MPa	Density $mol \cdot dm^{-3}$
349.999	18.109200	12.76050
354.000	20.263530	12.75616
358.000	22.410930	12.75180
362.001	24.556320	12.74742
366.002	26.693900	12.74305
370.000	28.826280	12.73867
373.999	30.953670	12.73428
378.001	33.076000	12.72988
382.001	35.190650	12.72548
350.001	3.005115	11.33707
352.000	3.740550	11.33512
356.001	5.216994	11.33128
359.998	6.699600	11.32744
363.999	8.189487	11.32363
368.000	9.684081	11.31981
372.002	11.181450	11.31602
376.000	12.680810	11.31222
379.998	14.182390	11.30842
384.001	15.685960	11.30462
387.999	17.192390	11.30081
391.998	18.696150	11.29699
395.998	20.202760	11.29314
400.000	21.708170	11.28930
372.000	3.773897	9.69524
376.000	4.715944	9.69213
380.000	5.670854	9.68898
384.001	6.637713	9.68585
388.002	7.611845	9.68271
391.999	8.593369	9.67956
396.001	9.580890	9.67640
400.000	10.573260	9.67321

Table 1b. Liquid-Phase Isochoric PVT Data for HFC-152a in PI Units.

Temperature Fahrenheit	Pressure psia	Density lb-mass·ft^{-3}
-175.27	297.790	74.164
-171.67	900.705	74.144
-168.07	1503.705	74.126
-164.47	2102.806	74.108
-160.87	2700.374	74.091
-157.27	3294.908	74.075
-153.67	3885.649	74.059
-150.07	4472.947	74.043
-146.47	5057.180	74.027
-150.07	592.857	72.687
-146.47	1140.104	72.670
-142.87	1687.939	72.653
-139.27	2231.768	72.636
-135.67	2774.836	72.620
-132.07	3314.885	72.605
-128.47	3850.258	72.590
-124.87	4384.922	72.574
-121.27	4915.677	72.559
-124.87	346.767	70.991
-121.27	837.965	70.974
-117.67	1328.233	70.957
-114.07	1816.900	70.942
-110.47	2303.287	70.927
-106.87	2787.886	70.912
-103.27	3270.985	70.897
-99.67	3752.089	70.883
-96.07	4230.288	70.868
-92.47	4706.368	70.854
-96.07	376.097	69.151
-92.47	812.406	69.135
-88.87	1247.815	69.120
-85.27	1682.505	69.105
-81.67	2115.099	69.091
-78.07	2546.742	69.077
-74.47	2976.982	69.063
-70.87	3404.631	69.049

Table 1b. Liquid-Phase Isochoric PVT Data for HFC-152a in PI Units.
(continued)

Temperature Fahrenheit	Pressure psia	Density lb-mass·ft^{-3}
-67.27	3831.083	69.036
-63.67	4255.086	69.023
-60.07	4678.066	69.009
-56.47	5098.822	68.996
-67.27	352.785	67.250
-63.67	740.332	67.235
-60.07	1126.520	67.221
-56.47	1512.178	67.207
-52.87	1896.570	67.193
-49.27	2280.302	67.180
-45.67	2661.897	67.167
-42.07	3041.837	67.154
-38.47	3420.683	67.141
-34.87	3798.446	67.128
-31.27	4174.633	67.116
-27.67	4550.183	67.103
-24.07	4922.941	67.091
-31.27	364.956	64.825
-27.67	697.293	64.812
-24.07	1029.147	64.798
-20.47	1360.520	64.786
-16.87	1690.772	64.773
-13.27	2020.284	64.760
-9.67	2348.399	64.748
-6.07	2676.549	64.736
-2.47	3003.441	64.724
1.13	3328.628	64.712
4.73	3653.662	64.700
8.33	3976.946	64.688
11.93	4299.712	64.676
15.53	4621.273	64.664
19.13	4941.578	64.653

Table 1b. Liquid-Phase Isochoric PVT Data for HFC-152a in PI Units.
(continued)

Temperature Fahrenheit	Pressure psia	Density lb-mass·ft^{-3}
11.93	218.789	61.812
15.53	459.033	61.592
19.13	730.891	61.580
22.73	1002.347	61.567
26.33	1272.765	61.556
29.93	1543.014	61.544
33.53	1812.994	61.533
37.13	2082.422	61.521
40.73	2351.211	61.510
44.33	2618.609	61.499
47.93	2885.696	61.488
51.53	3153.036	61.477
55.13	3419.426	61.466
58.73	3684.676	61.455
62.33	3949.615	61.444
65.93	4213.664	61.433
69.53	4476.332	61.422
73.13	4739.029	61.412
76.73	4999.809	61.401
62.33	461.365	57.975
69.53	895.334	57.953
76.73	1328.858	57.932
83.93	1761.088	57.911
91.13	2192.484	57.891
98.33	2622.603	57.870
105.53	3051.309	57.850
112.73	3478.079	57.830
119.93	3902.462	57.810
127.13	4325.133	57.790
134.33	4746.235	57.771
119.93	433.514	52.743
127.13	746.899	52.724
134.33	1060.696	52.705
141.53	1374.260	52.687
148.73	1688.003	52.669
155.93	2000.528	52.651
163.13	2313.565	52.635

Table 1b. Liquid-Phase Isochoric PVT Data for HFC-152a in PI Units.
(continued)

Temperature Fahrenheit	Pressure psia	Density lb-mass·ft^{-3}
170.33	2626.522	52.617
177.53	2938.982	52.599
184.73	3250.436	52.581
191.93	3561.599	52.563
199.13	3871.630	52.545
206.33	4180.906	52.527
213.53	4489.458	52.509
220.73	4797.277	52.490
227.93	5103.981	52.472
170.33	435.856	46.747
173.93	542.522	46.739
181.13	756.662	46.723
188.33	971.697	46.708
195.53	1187.787	46.692
202.73	1404.560	46.676
209.93	1621.735	46.660
217.13	1839.199	46.645
224.33	2056.985	46.629
231.53	2275.060	46.613
238.73	2493.550	46.598
245.93	2711.652	46.582
253.13	2930.168	46.566
260.33	3148.509	46.550
209.93	547.358	39.977
217.13	683.991	39.965
224.33	822.489	39.952
231.53	962.721	39.939
238.73	1104.007	39.926
245.93	1246.365	39.913
253.13	1389.593	39.900
260.33	1533.524	39.886

Table 2. Vapor Pressure Data Obtained for HFC-152a Using NIST Ebulliometer.

Temp [K]	Pressure [kPa]	Temp [F]	Pressure [psia]
219.9213	22.723	-63.812	3.296
223.0822	27.322	-58.122	3.963
224.6703	29.885	-55.263	4.334
225.9588	32.125	-52.944	4.659
227.8497	35.645	-49.541	5.170
229.2783	38.501	-46.969	5.584
230.9236	42.018	-44.008	6.094
232.5666	45.792	-41.050	6.642
234.0807	49.497	-38.325	7.179
235.5396	53.303	-35.699	7.731
234.9021	51.588	-36.846	7.482
236.4962	55.911	-33.977	8.109
236.0588	54.700	-34.764	7.934
237.9380	60.052	-31.382	8.710
239.5278	64.912	-28.520	9.415
241.2953	70.666	-25.338	10.249
242.8216	75.955	-22.591	11.016
244.1488	80.807	-20.202	11.720
245.8435	87.351	-17.152	12.669
247.4888	94.123	-14.190	13.651
249.2616	101.864	-10.999	14.774
250.7699	108.836	-8.284	15.785
250.1258	105.788	-9.444	15.343
251.5337	112.496	-6.909	16.316
253.2189	120.958	-3.876	17.544
254.7683	129.162	-1.087	18.733
256.5187	138.939	2.064	20.152
258.1101	148.335	4.928	21.514
259.7447	158.511	7.870	22.990
261.3099	168.744	10.688	24.474
262.6793	178.124	13.153	25.835
264.7567	193.084	16.892	28.005
266.6026	207.226	20.215	30.056
268.3214	221.084	23.309	32.066
268.2057	220.076	23.100	31.919
269.9179	234.549	26.182	34.019
271.5728	249.218	29.161	36.146
273.1388	263.726	31.980	38.250

Table 3a. Antoine Equation for the Vapor Pressure of HFC-152a (SI Units).

P(calc) in kPa = exp [14.2372 - 2090.11 x (T - 31.8503)$^{-1}$] for T in K.
Dev. in % = 100 x [P(calc) - P(meas)] / P(meas)

Temp [K]	P(meas) [kPa]	P(calc) [kPa]	Dev. %
219.9213	22.723	22.732	-0.041
223.0822	27.322	27.316	0.021
224.6703	29.885	29.889	-0.013
225.9588	32.125	32.119	0.018
227.8497	35.645	35.635	0.027
229.2783	38.501	38.494	0.020
230.9236	42.018	42.013	0.011
232.5666	45.792	45.784	0.017
234.0807	49.497	49.496	0.001
235.5396	53.303	53.299	0.008
234.9021	51.588	51.609	-0.041
236.4962	55.911	55.918	-0.012
236.0588	54.700	54.708	-0.015
237.9380	60.052	60.060	-0.012
239.5278	64.912	64.908	0.005
241.2953	70.666	70.662	0.006
242.8216	75.955	75.952	0.003
244.1488	80.807	80.805	0.003
245.8435	87.351	87.357	-0.008
247.4888	94.123	94.116	0.008
249.2616	101.864	101.857	0.008
250.7699	108.836	108.832	0.004
250.1258	105.788	105.808	-0.019
251.5337	112.496	112.505	-0.008
253.2189	120.958	120.956	0.002
254.7683	129.162	129.160	0.002
256.5187	138.939	138.948	-0.006
258.1101	148.335	148.344	-0.006
259.7447	158.511	158.506	0.003
261.3099	168.744	168.739	0.003
262.6793	178.124	178.108	0.009
264.7567	193.084	193.090	-0.003
266.6026	207.226	207.207	0.009
268.3214	221.084	221.060	0.011
268.2057	220.076	220.106	-0.014
269.9179	234.549	234.559	-0.004
271.5728	249.218	249.215	0.001
273.1388	263.726	263.724	0.001

Table 3b. Antoine Equation for the Vapor Pressure of HFC-152a (PI Units).

P(calc) in psia = exp [12.30644 - 3762.20 x $(T + 402.33974)^{-1}$] for T in °F.
Dev. in % = 100 x [P(calc) - P(meas)] / P(meas)

Temp [F]	P(meas) [psia]	P(calc) [psia]	Dev. %
-63.812	3.296	3.297	-0.041
-58.122	3.963	3.962	0.022
-55.263	4.334	4.335	-0.013
-52.944	4.659	4.658	0.018
-49.541	5.170	5.168	0.027
-46.969	5.584	5.583	0.020
-44.008	6.094	6.094	0.011
-41.050	6.642	6.640	0.018
-38.325	7.179	7.179	0.002
-35.699	7.731	7.730	0.008
-36.846	7.482	7.485	-0.041
-33.977	8.109	8.110	-0.012
-34.764	7.934	7.935	-0.014
-31.382	8.710	8.711	-0.012
-28.520	9.415	9.414	0.005
-25.338	10.249	10.249	0.006
-22.591	11.016	11.016	0.003
-20.202	11.720	11.720	0.003
-17.152	12.669	12.670	-0.007
-14.190	13.651	13.650	0.008
-10.999	14.774	14.773	0.008
-8.284	15.785	15.785	0.005
-9.444	15.343	15.346	-0.019
-6.909	16.316	16.317	-0.008
-3.876	17.544	17.543	0.002
-1.087	18.733	18.733	0.002
2.064	20.152	20.153	-0.006
4.928	21.514	21.515	-0.006
7.870	22.990	22.989	0.004
10.688	24.474	24.473	0.004
13.153	25.835	25.832	0.009
16.892	28.005	28.005	-0.003
20.215	30.056	30.053	0.009
23.309	32.066	32.062	0.011
23.100	31.919	31.924	-0.013
26.182	34.019	34.020	-0.004
29.161	36.146	36.146	0.001
31.980	38.250	38.250	0.001

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