THERMOPHYSICAL PROPERTIES OF HCFC ALTERNATIVES

Quarterly Report

1 October 1994 - 31 December 1994

W.M. Haynes

Thermophysics Division
National Institute of Standards and Technology
325 Broadway
Boulder, Colorado 80303

January 1995

Prepared for
The Air-Conditioning and Refrigeration Technology Institute
Under
ARTI MCLR Project Number 660-50800

This research project is supported in part by a grant from the U.S. Department of Energy, Office of Building Technology (Grant number DE-FG02-91CE23810: Materials Compatibilities and Lubricants Research on CFC-Refrigerant Substitutes). Federal funding supporting this project constitutes 93.57% of allowable costs. Funding from the air-conditioning and refrigeration industry supporting the project consists of direct cost sharing of 6.43% of allowable costs; and significant in-kind contributions.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

1/8

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

U.S. Department of Energy and the air-conditioning and refrigeration industry support for the Materials Compatibility and Lubricants Research (MLCR) program does not constitute an endorsement by the U.S. Department of Energy, or by the air-conditioning and refrigeration industry, of the views expressed herein.

NOTICE

This report was prepared on account of work sponsored by the United States Government. Neither the United States Government, nor the Department of Energy, nor the Air Conditioning and Refrigeration Technology Institute, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed or represents that its use would not infringe privately-owned rights.

COPYRIGHT NOTICE

(for journal publication submissions)

By acceptance of this article, the publisher and/or recipient acknowledges the right of the U.S. Government and the Air-Conditioning and Refrigeration Technology Institute, Inc. (ARTI) to retain a nonexclusive, royalty-free license in and to any copyrights covering this paper.

The Government reserves for itself and others acting on its behalf a royalty free, nonexclusive, irrevocable, world-wide license for governmental purposes to publish, distribute, translate, duplicate, exhibit, and perform any such data copyrighted by the contractor.

THERMOPHYSICAL PROPERTIES OF HCFC ALTERNATIVES

ARTI MCLR Project Number 660-50800

W.M. Haynes

Thermophysics 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 will be substituted as recommended by the MCLR Advisory Committee. During the past quarter, preparation of standard reference mixtures for the R32/134a and R32/125 systems for calibration of the gas chromatograph were completed and preparation of standard reference mixtures for the R290 series of systems were initiated. Vapor-liquid equilibria and coexisting density measurements were completed for the R32/290 and R134a/290 systems; both of these systems exhibited azeotropic behavior. Measurements on the R125/290 and either the R143a series or the R125/134a and R32/134a/125 systems will be carried out during the next quarter.

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)

This report has been divided into several parts to address various issues. We shall discuss issues concerning mixture preparation and composition determination, data analysis, azeotropic systems, and the new vapor-liquid equilibria (VLE) apparatus.

We have acquired sufficient sample for all the pure components needed in the mixture studies and in the standard reference mixture preparation. To achieve the highest accuracy for the composition measurements, two standard reference mixtures will be prepared for each binary system. These mixtures are needed for the comprehensive gas chromatograph (GC) calibration procedure we have developed to achieve high accuracy in the composition determination. The preparation of standard reference mixtures is underway for the systems we have already measured. Standard reference mixtures of 35 and 65 mole percent R32 for each of the R32/134a and R32/125 systems have been prepared. A 150 g (0.33 lb) sample of each mixture was prepared in 5.9 L (0.21 ft³) bottles. The balance used for preparing the samples has a resolution of 10⁻³ g (2.2x10⁻⁶ lb). This results in an uncertainty in the mole fraction of 10⁻⁵. This is several orders of magnitude better than can be achieved by direct sampling and using the GC for analysis.

Using these standard reference mixtures and our GC calibration procedure, the area versus density relationships for R32, R134a, and R125 were completed. Our GC calibration procedure uses the pure component data as well as the standard reference mixtures to define area versus density curves that are accurate over a wide range of injected sample sizes. The mixtures are used to refine and test the pure component curves over the entire range of injected sample sizes. This test is especially important to prevent large errors when injecting small sample sizes. Errors as large as 3 mole percent can occur with the standard area versus pressure GC calibration procedure when injecting small samples. These standard reference mixtures will also be used for the GC calibrations for the ternary system of R32/134a/125. This system will require a different GC column and, therefore, new curves for each of the pure components. By the end of January, preparation of the R32/290, R134a/290, and R125/290 standard reference mixtures will be completed.

The binary systems, R32/134a and R32/125, are needed for thorough evaluation of the data for the ternary system R32/125/134a. These data have been collected under DOE support. The raw data for these binary systems were collected in the previous quarter. The compositions have been determined using the GC calibrations we discussed in the previous section to calculate the compositions from the area data produced by the GC. There were 56 data points for the R32/134a system covering 9 isotherms from 280 to 370 K (44 to 206°F) and 54 data points for the R32/125 system covering 8 isotherms from 279.5 to 351.5 K (43.5 to 173°F). The data are presented in Tables 1 and 2. Since a new supply of R125 was not available when measurements on the R32/125 system were completed, we could not begin the R125/134a system as planned. Instead of waiting for a new supply of R125, we chose to begin the R290 series of systems. (A high-priority sample of R125 has since been obtained.)

Measurements for the R32/290 and R134a/290 systems have been completed. Eight isotherms from 280 to 365 K (44 to 197°F) were measured for the R32/290 system. Eight isotherms from 280 to 372 K (44 to 210°F) were determined for the R134a/290 system. Final analysis of the data cannot be completed until the standard reference mixtures are prepared for these systems and the GC calibrations are carried out. We will complete the analysis in the next

quarter as well as perform measurements on the R125/290 system. At that time we will determine whether it is best to begin the R143a series which may exhibit azeotropes or to return to the R125/134a and R32/134a/125 systems. The azeotropic systems require additional data and analysis to determine the composition of the azeotrope and to provide enough detailed information to accurately model these systems. It is best that we examine all the systems that may have azeotropes as soon as possible in order to have more time to analyze the data while taking measurements on less complicated systems.

Both the R32/290 and R134a/290 systems have azeotropes. The possibility of these azeotropes was not investigated in the paper by Morrison and McLinden ["Azeotropy in Refrigerant Mixtures," *Int. J. Refrigeration* **16**, 129-138 (1993)]. After the azeotropes were discovered, we used the procedure in the Morrison and McLinden paper to test for the azeotropes. The method did predict azeotropes. The mixing of nonpolar (R290) with highly polar (R32) molecules can produce azeotropes even when the bubble point pressures are very different. The R32/290 system exhibited the strongest azeotrope. The strongest azeotrope is defined as that which gives the largest difference between the bubble point pressure of the azeotrope and the vapor pressure of the more volatile component at the same temperature. The R134a/290 system exhibited a weaker azeotrope, which is expected because the polarity of R134a is less than that of R32. Both of these azeotropes are stronger than that exhibited by the R32/125 system.

In addition to azeotropes, large differences in polarity can produce regions of liquid-liquid immiscibility as the temperature is reduced. The R32/290 system exhibited liquid-liquid immiscibility along the 280 and 295 K (44 and 71°F) isotherms. The liquid-liquid region disappeared when the temperature was raised to 310 K (98°F). The R134a/290 system exhibited liquid-liquid immiscibility to a small extent for the 295 K (71°F) isotherm and to a larger extent for the 280 K (44°F) isotherm.

The VLE apparatus is not designed to effectively separate two liquid phases and analyze each phase separately. However, it is possible to determine the compositions and densities of the two liquid phases because of the behavior of the liquid-liquid immiscibility along an isotherm. Figure 1 shows an example of VLE data similar to that of the R32/290 system along the 280 and 295 K (44 and 71°F) isotherms. The actual data for the mixture cannot be reported until the GC calibrations are complete. At a temperature where two liquid phases coexist, there is a region where the overall composition of the mixture falls between the compositions of the two liquid phases. In this region the amount of each of the two liquid phases varies with the overall composition. However, the compositions and densities of the two liquid phases and the vapor phase do not change. The bubble point pressure does not change either. When the two liquid phases are present, we can measure the bubble point pressure, the vapor composition, and the vapor density. However, we cannot measure the individual liquid compositions and densities. We can determine the compositions and densities of the two liquid phases by taking additional data (at varying compositions) outside of the liquid-liquid region (in the unshaded region of the diagram). Because the bubble point pressure becomes constant when the two liquid phases coexist, we can plot liquid composition versus pressure, and extrapolate to the bubble point pressure of the liquid-liquid region to estimate the coexisting liquid compositions. In Figure 2 the liquid densities are plotted against the bubble point pressures, and the same type of procedure is used to determine the densities of the two liquid phases.

Because the R290 systems are examples of azeotropic behavior for systems with interactions between nonpolar and polar molecules, it would certainly not be surprising if there is an azeotrope for the R125/290 system. We will be studying that system in the next quarter.

A new VLE and coexisting density apparatus that will be used for some of the measurements in this project has been constructed. This apparatus was described in the last progress report. The four pressure transducers, the three platinum resistant thermometers, and the two densimeters are in the process of being calibrated.

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

The GC calibration for this ternary system is similar to that required for the constituent binaries. For this system, three standard reference ternary mixtures in addition to the six standard reference binary mixtures of the constituent binaries will be used for the calibration procedure. We have already measured the bubble point pressures and liquid densities for a standard mixture of 0.346 mole fraction R32, 0.300 mole fraction R125, and 0.354 mole fraction R134a from 244 to 346 K (-20 to 163°F) for a project supported by ICI Chemicals & Polymers Limited. These data will be compared with the results obtained in the current study.

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

As mentioned in the previous report, this system will be measured in a low temperature VLE apparatus that was recently used for measurements on binary mixtures of oxygen, nitrogen, and argon. A new GC column is needed to separate components. We have high purity R744 available from other projects. A sample of R41 has been obtained and is being analyzed for impurities. Standard reference mixtures will be prepared for the GC calibration.

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 fourth quarter of calendar year 1994, 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 Boulder, CO and Gaithersburg, MD.

Figure 1: Example of liquid-liquid immiscibility for a system with a positive azeotrope. (Shading indicates region of liquid-liquid immiscibility. Bold lines indicate the compositions of the immiscible liquid phases with temperature.)

Figure 2: Example of coexisting liquid density versus bubble point pressure for a system with liquid-liquid immiscibility and a positive azeotrope. (Shading indicates region of liquid-liquid immiscibility.)

APPENDIX A:
TABLES OF THERMOPHYSICAL PROPERTIES DATA

Table 1. Vapor-Liquid Equilibria and Coexisting Density Data for R32/134a Mixtures.

Temperature K	x(R32) Liquid Mole Fraction	y(R32) Vapor Mole Fraction	Pressure MPa	Liquid Density kg/m ³	Vapor Density kg/m ³	Temperature °F	x(R32) Liquid Mole Fraction	y(R32) Vapor Mole Fraction	Pressure psia	Liquid Density lb/ft ³	Vapor Density lb/ft ³
280.39	0.000	0.000	0.3692	1268.5	18.2	45.03	0.000	0.000	55.0	79.12	1.14
280.03	0.216	0.454	0.5098	1234.7	19.4	44.38	0.216	0.454	75.9	77.01	1.21
279.76	0.366	0.600	0.6051	1197.5	21.3	43.90	0.366	0.600	90.1	74.69	1.33
279.85	0.519	0.782	0.6799	1169.8	22.5	44.06	0.519	0.782	101.2	72.96	1.40
279.72	0.752	0.910	0.8253	1108.9	25.0	43.82	0.752	0.910	122.9	69.17	1.56
280.00	1.000	1.000	0.9799	1029.5	27.4	44.33	1.000	1.000	145.9	64.21	1.71
294.69	0.000	0.000	0.5807	1217.7	29.0	70.78	0.000	0.000	86.5	75.95	1.81
294.10	0.214	0.419	0.7705	1180.6	31.5	69.72	0.214	0.419	114.7	73.64	1.96
294.68	0.566	0.736	1.0618	1106.8	36.5	70.76	0.566	0.736	158.1	69.03	2.28
294.16	0.639	0.831	1.1531	1088.3	37.7	69.83	0.639	0.831	171.7	67.88	2.35
294.29	0.731	0.874	1.2492	1060.3	39.4	70.06	0.731	0.874	186.0	66.13	2.46
294.11	0.807	0.928	1.3447	1036.9	44.6	69.74	0.807	0.928	200.2	64.67	0.00
295.48	1.000	1.000	1.5338	971.2	44.6	72.20	1.000	1.000	228.4	60.58	2.78
309.31	0.000	0.000	0.8893	1161.7	45.3	97.09	0.000	0.000	132.4	72.46	2.83
309.36	0.161	0.379	1.0871	1130.6	49.3	97.18	0.161	0.379	161.9	70.52	0.00
309.23	0.214	0.379	1.1607	1124.7	49.3	96.95	0.214	0.379	172.8	70.15	3.08
309.34	0.291	0.668	1.2282	1111.0	55.9	97.14	0.291	0.668	182.9	69.29	0.00
309.39	0.498	0.728	1.4960	1062.8	57.4	97.23	0.498	0.728	222.8	66.29	3.49
309.33	0.571	0.839	1.5945	1045.8	62.1	97.13	0.571	0.839	237.4	65.23	3.58
309.80	0.789	0.936	1.8914	987.3	64.5	97.97	0.789	0.936	281.6	61.58	3.87
309.37	0.873	0.936	2.0304	958.7	66.6	97.20	0.873	0.936	302.3	59.80	4.02
309.99	1.000	1.000	2.2343	908.4	66.6	98.31	1.000	1.000	332.7	56.66	4.16
324.50	0.000	0.000	1.3314	1094.9	71.3	124.42	0.000	0.000	198.3	68.29	4.45
324.54	0.130	0.220	1.5459	1070.3	74.6	124.50	0.130	0.220	230.2	66.76	4.65
325.11	0.236	0.373	1.7556	1040.6	79.7	125.52	0.236	0.373	261.4	64.90	4.97
325.23	0.387	0.527	1.9907	1014.0	84.1	125.74	0.387	0.527	296.4	63.25	5.25
325.18	0.658	0.765	2.4934	944.2	93.9	125.65	0.658	0.765	371.3	58.89	5.85
325.13	0.815	0.879	2.7956	900.4	99.7	125.56	0.815	0.879	416.3	56.16	6.22
325.15	0.923	0.956	3.0341	858.0	103.4	125.59	0.923	0.956	451.8	53.51	6.45
324.99	1.000	1.000	3.1938	829.1	103.6	125.31	1.000	1.000	475.6	51.71	6.46

Table 1. Vapor-Liquid Equilibria and Coexisting Density Data for R32/134a Mixtures (continued).

Temperature K	x(R32) Liquid Mole Fraction	y(R32) Vapor Mole Fraction	Pressure MPa	Liquid Density kg/m ³	Vapor Density kg/m ³	Temperature °F	x(R32) Liquid Mole Fraction	y(R32) Vapor Mole Fraction	Pressure psia	Liquid Density lb/ft ³	Vapor Density lb/ft ³
340.16	0.000	0.000	1.9346	1013.2	109.7	152.62	0.000	0.000	288.1	63.20	6.84
340.08	0.140	0.227	2.2418	983.2	114.3	152.48	0.140	0.227	333.8	61.32	7.13
340.02	0.241	0.352	2.4633	963.6	119.5	152.37	0.241	0.352	366.8	60.10	7.45
339.88	0.461	0.577	2.9384	910.8	130.2	152.12	0.461	0.577	437.5	56.81	8.12
339.99	0.592	0.693	3.2602	867.3	139.0	152.32	0.592	0.693	485.5	54.10	8.67
339.91	0.760	0.838	3.7148	816.0	151.0	152.17	0.760	0.838	553.2	50.90	9.42
339.92	0.924	0.947	4.1769	754.4	165.9	152.19	0.924	0.947	622.0	47.05	10.35
339.98	1.000	1.000	4.4425	718.7	170.1	152.30	1.000	1.000	661.5	44.83	10.61
355.02	0.000	0.000	2.6756	914.4	168.5	179.36	0.000	0.000	398.4	57.03	10.51
354.66	0.214	0.282	3.2281	862.1	183.1	178.72	0.214	0.282	480.7	53.77	11.42
354.83	0.262	0.340	3.3686	850.3	188.8	179.02	0.262	0.340	501.6	53.03	11.78
354.71	0.541	0.643	4.3331	753.8	231.2	178.81	0.541	0.643	645.2	47.02	14.42
354.71	0.541	0.643	4.3371	754.1	230.7	178.81	0.541	0.643	645.8	47.04	14.39
354.74	0.662	0.799	4.9755	700.5	275.9	178.86	0.662	0.799	740.9	43.69	17.21
354.95	0.717	0.831	5.1765	674.8	301.9	179.24	0.717	0.831	770.8	42.09	18.83
359.85	0.000	0.000	2.9867	870.3	192.7	188.05	0.000	0.000	444.7	54.28	12.02
359.94	0.192	0.241	3.4639	826.8	214.6	188.22	0.192	0.241	515.8	51.57	13.38
359.72	0.243	0.312	3.6320	815.9	216.2	187.82	0.243	0.312	540.8	50.89	13.49
359.72	0.385	0.430	3.9855	772.5	235.5	187.82	0.385	0.430	593.5	48.18	14.69
364.68	0.000	0.000	3.2975	818.5	235.3	196.75	0.000	0.000	491.0	51.05	14.68
365.16	0.226	0.286	4.0182	751.1	275.4	197.61	0.226	0.286	598.3	46.85	17.18
365.04	0.376	0.452	4.6017	686.1	331.0	197.39	0.376	0.452	685.2	42.80	20.65
365.19	0.586	0.591	5.3510	566.6	536.7	197.66	0.586	0.591	796.8	35.34	33.48
369.94	0.000	0.000	3.6687	743.6	305.1	206.23	0.000	0.000	546.3	46.38	19.03
369.80	0.085	0.139	3.9800	735.6	322.5	205.98	0.085	0.139	592.6	45.88	20.12
369.75	0.247	0.251	4.4341	671.8	520.3	205.89	0.247	0.251	660.3	41.90	32.45

Table 2. Vapor-Liquid Equilibria and Coexisting Data for R32/125 Mixtures.

Temperature K	x(R32) Liquid Mole Fraction	y(R32) Vapor Mole Fraction	Pressure MPa	Liquid Density kg/m ³	Vapor Density kg/m ³	Temperature °F	x(R32) Liquid Mole Fraction	y(R32) Vapor Mole Fraction	Pressure psia	Liquid Density lb/ft ³	Vapor Density lb/ft ³
280.29	0.000	0.000	0.8302	1284.2	52.2	44.85	0.000	0.000	120.4	80.10	3.25
279.89	0.250	0.335	0.8957	1245.9	46.1	44.13	0.250	0.335	129.9	77.71	2.88
279.52	0.494	0.520	0.9459	1203.2	41.5	43.47	0.494	0.520	137.2	75.04	2.59
280.02	0.797	0.831	1.0116	1114.2	34.9	44.37	0.797	0.831	146.7	69.49	2.18
280.01	0.875	0.908	1.0185	1092.3	31.7	44.35	0.875	0.908	147.7	68.13	1.98
279.59	0.946	0.956	1.0131	1060.9	30.4	43.59	0.946	0.956	146.9	66.17	1.90
280.00	1.000	1.000	1.0076	1033.0	27.4	44.33	1.000	1.000	146.1	64.43	1.71
295.23	0.000	0.000	1.2720	1206.6	84.7	71.74	0.000	0.000	184.5	75.26	5.28
294.35	0.237	0.324	1.3484	1174.8	72.9	70.16	0.237	0.324	195.6	73.28	4.55
294.08	0.460	0.570	1.4293	1135.7	63.9	69.67	0.460	0.570	207.3	70.84	3.98
293.98	0.801	0.809	1.5001	1057.0	53.6	69.49	0.801	0.809	217.6	65.93	3.35
293.89	0.801	0.824	1.5001	1055.3		69.33	0.801	0.824	217.6	65.82	0.00
293.92	0.875	0.890	1.5173	1030.6	49.8	69.39	0.875	0.890	220.1	64.28	3.11
293.96	0.945	0.947	1.5249	1003.7	46.5	69.46	0.945	0.947	221.2	62.60	2.90
293.99	1.000	1.000	1.5152	980.5	41.1	69.51	1.000	1.000	219.8	61.16	2.56
310.61	0.000	0.000	1.8904	1107.8	133.3	99.43	0.000	0.000	274.2	69.10	8.31
309.82	0.270	0.333	2.0089	1083.6	116.2	98.01	0.270	0.333	291.4	67.59	7.25
310.96	0.509	0.564	2.2267	1032.2	108.6	100.06	0.509	0.564	322.9	64.38	6.77
310.50	0.745	0.793	2.2992	980.8	89.4	99.23	0.745	0.793	333.5	61.17	5.57
310.67	0.803	0.847	2.3220	969.5	84.6	99.54	0.803	0.847	336.8	60.47	5.27
309.85	0.873	0.881	2.2956	954.6	80.7	98.06	0.873	0.881	332.9	59.54	5.03
310.04	0.910	0.916	2.3019	941.1	76.6	98.40	0.910	0.916	333.9	58.70	4.78
309.96	0.952	0.940	2.3078	927.7	71.7	98.26	0.952	0.940	334.7	57.86	4.48
310.51	1.000	1.000	2.3288	905.9	68.6	99.25	1.000	1.000	337.8	56.50	4.28
324.89	0.000	0.000	2.6390	984.4	213.2	125.13	0.000	0.000	382.7	61.40	13.30
324.99	0.323	0.396	2.9689	950.3	183.6	125.31	0.323	0.396	430.6	59.27	11.45
325.60	0.456	0.551	3.1281	925.7	171.4	126.41	0.456	0.551	453.7	57.74	10.69
325.37	0.755	0.780	3.2705	883.0	143.0	126.00	0.755	0.780	474.3	55.08	8.92
325.81	0.804	0.816	3.3028	870.6	138.9	126.79	0.804	0.816	479.0	54.30	8.66

Table 2. Vapor-Liquid Equilibria and Coexisting Data for R32/125 Mixtures (continued).

Temperature K	x(R32) Liquid Mole Fraction	y(R32) Vapor Mole Fraction	Pressure MPa	Liquid Density kg/m ³	Vapor Density kg/m ³	Temperature °F	x(R32) Liquid Mole Fraction	y(R32) Vapor Mole Fraction	Pressure psia	Liquid Density lb/ft ³	Vapor Density lb/ft ³
325.54	0.867	0.870	3.3239	859.8	130.1	126.30	0.867	0.870	482.1	53.63	8.11
325.48	0.915	0.916	3.3150	851.6	121.9	126.19	0.915	0.916	480.8	53.12	7.60
325.49	1.000	1.000	3.3179	828.5	104.2	126.21	1.000	1.000	481.2	51.68	6.50
339.38	0.000	0.000	3.6291	571.9	571.9	151.21	0.000	0.000	526.3	35.67	35.67
339.72	0.312	0.392	4.0557	697.5	318.4	151.83	0.312	0.392	588.2	43.51	19.86
340.19	0.485	0.570	4.3079	724.2	299.0	152.67	0.485	0.570	624.8	45.17	18.65
340.74	0.744	0.796	4.5809	723.6	263.9	153.66	0.744	0.796	664.4	45.13	16.46
340.46	0.873	0.876	4.6060	722.0	221.1	153.16	0.873	0.876	668.0	45.03	13.79
340.21	0.898	0.898	4.5948	724.5	213.3	152.71	0.898	0.898	666.4	45.19	13.31
340.14	0.913	0.916	4.5979	723.9	197.8	152.58	0.913	0.916	666.8	45.15	12.34
340.08	1.000	1.000	4.5717	715.7	172.8	152.47	1.000	1.000	663.0	44.64	10.78
343.22	0.426	0.476	4.5640	652.8	440.1	158.13	0.426	0.476	661.9	40.72	27.45
343.83	0.746	0.797	4.8968	673.8	326.4	159.22	0.746	0.797	710.2	42.03	20.36
343.35	0.874	0.873	4.9016	680.5	265.9	158.36	0.874	0.873	710.9	42.44	16.59
343.27	0.900	0.898	4.9050	679.9	250.2	158.22	0.900	0.898	711.4	42.41	15.61
343.28	1.000	1.000	4.8904	684.4	196.6	158.23	1.000	1.000	709.3	42.69	12.26
346.66	0.745	0.788	5.2034	613.2	421.4	164.32	0.745	0.788	754.7	38.25	26.28
346.65	0.828	0.828	5.2354	618.4	400.3	164.30	0.828	0.828	759.3	38.57	24.97
346.29	0.914	0.902	5.2328	637.3	297.1	163.65	0.914	0.902	758.9	39.75	18.53
346.28	0.870	0.874	5.2173	627.4	320.6	163.63	0.870	0.874	756.7	39.13	20.00
346.13	1.000	1.000	5.1922	643.9	227.8	163.36	1.000	1.000	753.0	40.16	14.21
349.34	0.870	0.872	5.4926	556.3	357.8	169.14	0.870	0.872	796.6	34.70	22.32
349.16	0.910	0.899	5.5550	573.1	382.2	168.82	0.910	0.899	805.7	35.75	23.84
349.18	1.000	1.000	5.5388	589.1	276.1	168.85	1.000	1.000	803.3	36.74	17.22
351.54	1.000	1.000	5.8302	428.5	428.5	173.10	1.000	1.000	845.6	26.73	26.73