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Measurements of the Thermal Conductivity of HFC-32 (Difluoromethane) in the Temperature Range from 300 to 465 K at Pressures up to 50 MPa

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New measurements of the thermal conductivity of HFC-32, made in a coaxial cylinder cell operating in steady state, are reported. The measurements were performed along several quasi-isotherms between 300 and 465 K in both the liquid and the vapor phases. The pressure ranged from 0.1 to 50 MPa. Based on the experimental data, a background equation is provided to calculate the thermal conductivity outside the critical region as a function of temperature and density. A careful analysis of the various sources of experimental errors leads to an estimated uncertainty of $\pm 1.5\%$. Comparisons between calculated and experimental values from the literature are presented.

KEY WORDS: coaxial cylinders; difluoromethane; HFC-32; high pressure; high temperature; refrigerant; thermal conductivity.

1. INTRODUCTION

Recently there has been great interest in the determination of the thermophysical properties of alternative refrigerants that are not harmful to the environment. Among them, HFC-32 (difluoromethane) is a promising refrigerant, especially as a component of mixtures, for the replacement of HCFC-22 (chlorodifluoroethane) in residential air-conditioning systems. In our laboratory, we have carried out a series of measurements of the thermal conductivity of several alternative refrigerants over a large range of

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temperature and pressure, including subcritical and supercritical regions [1–6]. The measurements allow analysis of the data based on the residual concept. The transport property surface is separated into four regions, the gaseous state (at $P = 1.01325$ bar), the dense state, the subcritical region ($T < T_c$), and the supercritical region ($T > T_c$). The thermal conductivity is expressed as a function of temperature T and density ρ

$$\lambda(T, \rho) = \lambda_0(T) + \Delta\lambda(T, \rho) + \Delta\lambda_c(T, \rho) \tag{1}$$

where $\lambda_0(T)$ is the dilute gas thermal conductivity, $\Delta\lambda(T, \rho)$ is the residual thermal conductivity, and $\Delta\lambda_c(T, \rho)$ is the critical enhancement. In this paper, we present only data in the liquid and vapor phases far away from the supercritical region to determine the background thermal conductivity, consisting of the first two terms on the right-hand side of Eq. (1);

$$\lambda_B = \lambda_0(T) + \Delta\lambda(T, \rho) \tag{2}$$

The thermal conductivity of HFC-32 was measured across the gap between two vertical coaxial cylinders, operating in the steady-state mode. Detailed descriptions of the cell, the method of measurement, and corrections were reported by Le Neindre and Tufeu [7]. The density was calculated with an equation of state determined by Outcalt and McLinden [8], where the critical point is given as follows: $T_c = 351.35$ K, $P_c = 5.795$ MPa, and $\rho_c = 427\ \text{kg} \cdot \text{m}^{-3}$.

A careful analysis of the various sources of error that enter in the working equation of the coaxial cylinder technique shows that the uncertainty in the measurement is within the $\pm 1.5\%$ confidence level. The sample was provided by Elf-Atochem, and its purity was estimated to be better than 99.9% by the manufacturer's analysis.

2. DILUTE-GAS THERMAL CONDUCTIVITY

The results for the measurement of the thermal conductivity at atmospheric pressure are presented in Table I. The experimental data were fitted to a linear equation,

$$\lambda_0 = -17.1 + 0.09733T \tag{3}$$

where λ_0 is given in $\text{mW} \cdot \text{m}^{-1} \cdot \text{K}^{-1}$ and T in K.

The relative deviations between experimental data and Eq. (3) are within the uncertainty of the data. The relative deviations between the

Table I. Thermal Conductivity of HFC-32 at Atmospheric Pressure

T (K)	λ $(mW \cdot m^{-1} \cdot K^{-1})$
299.22	12.09
301.66	12.23
310.24	13.30
324.42	14.64
349.17	16.93
354.33	17.39
354.92	17.35
355.43	17.64
356.93	17.81
362.01	18.08
374.94	19.30
385.34	20.32
394.25	21.26
395.46	21.36
413.14	23.37
413.40	23.41
421.88	24.13
424.10	24.36
434.10	25.35
434.81	25.05
454.25	26.96
465.60	28.38

Table II. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 298.9$ K

Temperature (K)	Pressure (MPa)	Density $(kg \cdot m^{-3})$	λ $(mW \cdot m^{-1} \cdot K^{-1})$
299.23	0.1	2.12	12.09
299.19	0.5	11.2	12.50
298.68	3	967.2	128.13
298.67	4	973.2	128.99
298.67	5	978.9	129.87
298.67	6	984.2	130.76
298.66	7	989.3	131.66
298.66	8	994.3	132.58
298.65	9	999.0	133.50
298.65	10	1003.5	134.44
298.65	11	1007.8	135.40

Table III. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 303.8$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
303.93	10	984.8	131.60
303.92	11	989.6	132.77
303.91	12	994.2	133.95
303.90	13	998.7	135.16
303.89	14	1002.9	136.08
303.89	15	1007.1	137.01
303.88	16	1011.1	138.28
303.88	17	1015.0	138.92
303.87	18	1018.8	139.89
303.86	19	1022.5	141.20
303.86	20	1026.0	141.87
303.85	21	1029.5	142.88
303.85	22	1032.9	143.57
303.84	23	1036.2	144.60
303.84	24	1039.5	145.66
303.83	25	1042.6	146.37
303.83	26	1045.7	147.44
303.82	27	1048.7	148.17
303.82	28	1051.7	148.91
303.81	29	1054.6	150.02
303.81	30	1057.4	150.77
303.80	31	1060.2	151.53
303.80	32	1062.9	152.30
303.79	33	1065.6	153.08
303.79	34	1068.2	153.86
303.79	35	1070.8	154.65
303.78	36	1073.3	155.05
303.78	37	1075.8	155.45
303.78	38	1078.3	156.26
303.78	39	1080.7	156.67
303.77	40	1083.1	157.49
303.77	41	1085.4	158.32
303.76	42	1087.7	159.16
303.76	43	1090.0	159.58
303.76	44	1092.2	160.43
303.76	45	1094.4	160.86
303.75	46	1096.6	161.72
303.75	47	1098.7	162.60
303.75	48	1100.9	163.04
303.74	49	1102.9	163.93
303.74	50	1105.0	164.38

Table IV. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 316.8$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
316.97	4	887.9	114.76
316.95	5	897.6	116.69
316.94	6	906.3	117.78
316.93	7	914.4	118.93
316.92	8	921.9	120.30
316.91	9	928.9	121.72
316.90	10	935.4	122.92
316.87	11	941.7	124.39
316.88	12	947.6	125.39
316.87	13	953.2	126.41
316.86	14	958.6	127.44
316.86	15	963.7	128.50
316.85	16	968.6	129.56
316.84	17	973.3	130.38
316.83	18	977.9	131.34
316.83	19	982.3	132.31
316.82	20	986.6	133.45
316.81	21	990.7	134.60
316.81	22	994.7	135.48
316.80	23	998.6	136.36
316.80	24	1002.4	136.96
316.79	25	1006.1	137.87
316.78	26	1009.7	138.79
316.78	27	1013.2	139.57
316.77	28	1016.6	140.35
316.77	29	1019.9	140.99
316.77	30	1023.1	141.63
316.76	31	1026.3	142.60
316.76	32	1029.4	143.25
316.75	33	1032.5	143.91
316.73	34	1035.5	148.00
316.73	35	1038.4	148.71
316.72	36	1041.3	149.42
316.72	37	1044.1	150.14
316.71	38	1046.8	150.86
316.71	39	1049.5	151.59

Table V. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 319.3$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
319.44	4	874.2	110.95
319.42	5	884.8	112.85
319.41	6	894.3	114.64
319.39	7	903.0	116.43
319.37	8	911.1	118.27
319.36	9	918.5	119.94
319.35	10	925.5	121.42
319.34	11	932.1	122.92
319.33	12	938.3	124.46
319.32	13	944.2	125.66
319.31	14	949.8	127.02
319.30	15	955.1	128.18
319.29	16	960.3	129.29
319.28	17	965.2	130.41
319.28	18	969.9	131.56
319.27	19	974.5	132.46
319.26	20	978.9	133.34
319.26	21	983.2	134.24
319.25	22	987.3	135.06
319.25	23	991.4	135.98
319.24	24	995.2	136.99
319.23	25	999.0	137.93
319.23	26	1002.7	138.89
319.22	27	1006.3	139.87
319.22	28	1009.8	140.88
319.21	29	1013.2	141.88
319.21	30	1016.6	142.56
319.20	31	1019.8	143.14
319.20	32	1023.0	143.83
319.20	33	1026.1	144.60
319.19	34	1029.2	145.30
319.19	35	1032.2	146.01
319.18	36	1035.1	146.72
319.18	37	1038.0	147.47
319.18	38	1040.8	148.20
319.17	39	1043.5	148.94
319.17	40	1046.3	149.58
319.16	41	1048.9	150.33
319.16	42	1051.6	151.17
319.16	43	1054.1	151.93
319.15	44	1056.7	152.32
319.15	45	1059.2	153.33
319.15	46	1061.6	153.91
319.15	47	1064.0	154.30
319.14	48	1066.4	154.70

Table VI. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 330.5$ K

Temperature (K)	Pressure (MPa)	Density $(kg \cdot m^{-3})$	λ $(mW \cdot m^{-1} \cdot K^{-1})$
330.67	4.3	804.8	99.67
330.62	5	817.5	103.76
330.59	6	832.7	106.30
330.58	7	845.6	107.42
330.57	8	857.1	108.77
330.56	9	867.3	110.35
330.54	10	876.7	112.00
330.53	11	885.3	113.43
330.52	12	893.2	114.50
330.51	13	900.7	115.81
330.49	14	907.7	117.14
330.49	15	914.3	118.28
330.48	16	920.5	119.44
330.47	17	926.5	120.62
330.46	18	932.2	121.58
330.45	19	937.6	122.84
330.44	20	942.8	123.81
330.43	21	947.8	124.82
330.43	22	952.6	125.59
330.42	23	957.3	126.90
330.41	24	961.8	127.69
330.41	25	966.2	128.77
330.40	26	970.4	129.87
330.39	27	974.5	130.70
330.39	28	978.4	131.58
330.38	29	982.3	132.40
330.38	30	986.1	133.27
330.37	31	989.7	134.15
330.36	32	993.3	135.04
330.36	33	996.8	135.94
330.35	34	1000.2	136.85
330.35	35	1003.5	137.78
330.34	36	1006.8	138.40
330.34	37	1010.0	139.07
330.33	38	1013.1	139.99
330.33	39	1016.2	140.96
330.32	40	1019.2	141.94
330.32	41	1022.1	142.60
330.32	42	1025.0	143.27
330.31	43	1027.8	144.28
330.31	44	1030.6	144.97
330.30	45	1033.3	146.00
330.30	46	1036.0	146.74
330.29	47	1038.6	147.41
330.29	48	1041.2	148.49

Table VII. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 338.0$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
338.10	20	917.0	122.13
338.10	21	922.6	122.91
338.09	22	927.9	123.70
338.09	23	933.1	124.09
338.09	24	938.1	124.90
338.08	25	942.9	125.71
338.08	26	947.5	127.21
338.07	27	952.0	128.21
338.07	28	956.3	129.47
338.06	29	960.5	130.37
338.06	30	964.6	131.26
338.06	31	968.6	132.15
338.05	32	972.5	133.06
338.05	33	976.2	133.99
338.04	34	979.9	134.92
338.04	35	983.5	136.15
338.04	36	987.0	136.83
338.03	37	990.4	137.77
338.03	38	993.8	138.79
338.03	39	997.0	139.79
338.02	40	1000.2	140.81
338.02	41	1003.4	141.32
338.02	42	1006.5	142.36
338.02	43	1009.5	142.89
338.01	44	1012.4	143.71
338.01	45	1015.3	144.48
338.01	46	1018.2	145.00
338.00	47	1021.0	146.12
338.00	48	1023.7	146.67
338.00	49	1026.4	147.79

Table VIII. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 353.4$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
353.44	20	862.0	113.45
353.44	21	869.2	114.50
353.44	22	876.0	115.56
353.43	23	882.4	117.19
353.43	24	888.5	118.86
353.42	25	894.4	120.00
353.42	26	900.1	121.17
353.42	27	905.5	121.76
353.41	28	910.7	122.96
353.41	29	915.7	124.18
353.41	30	920.6	124.80
353.40	31	925.3	126.06
353.40	32	929.8	126.70
353.40	33	934.2	127.34
353.40	34	938.5	128.00
353.40	35	942.7	128.65
353.40	36	946.7	129.32
353.39	37	950.7	129.99
353.39	38	954.5	130.67
353.39	39	958.3	132.05
353.39	40	962.0	133.46
353.38	41	965.5	134.17
353.38	42	969.0	134.90
353.38	43	972.5	135.63
353.38	44	975.8	136.37
353.38	45	979.8	137.11
353.37	46	982.3	137.87
353.37	47	985.4	138.63
353.37	48	988.5	139.40
353.37	49	991.6	140.19
353.37	50	994.5	140.97

Table IX. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 354.5$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
354.34	0.1	1.78	17.40
354.92	0.1	1.78	17.34
354.32	0.5	9.13	17.67
354.91	0.5	9.11	17.52
354.31	1	18.9	17.91
354.90	1	18.9	17.86
354.28	1.5	29.5	18.56
354.87	1.5	29.4	18.31
354.25	2	41.1	19.22
354.85	2	41.0	18.79
354.23	2.5	53.8	19.76
354.81	2.5	53.6	19.57
354.21	3	68.0	20.52
354.78	3	67.8	20.41
353.89	3.5	84.4	21.43
354.17	3.5	84.2	21.49
353.85	4	103.3	22.59
354.13	4	103.1	22.77

Table X. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 361.9$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
362.02	0.1	1.74	18.09
362.00	0.5	8.92	18.47
361.98	1	18.4	18.84
361.96	1.5	28.6	19.22
361.94	2	39.6	19.61
361.91	2.5	51.7	20.32
361.89	3	64.9	21.02
361.85	3.5	79.6	22.13

Table XI. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 375.5$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
374.94	0.1	1.68	19.31
374.93	0.5	8.57	19.66
374.91	1	17.6	20.07
374.89	1.5	27.3	20.49
374.87	2	37.5	20.97
374.86	2.5	48.6	21.43
374.84	3	60.5	21.91
374.82	3.5	73.4	22.56
374.78	4	87.6	23.81
375.99	20	772.6	99.05
375.98	21	783.1	100.47
375.97	22	792.8	101.92
375.96	23	801.9	103.41
375.96	24	810.4	104.64
375.95	25	818.4	106.21
375.94	26	826.0	107.51
375.93	27	833.3	108.83
375.93	28	840.1	109.85
375.92	29	846.7	110.88
375.92	30	853.0	112.29
375.91	31	859.0	113.01
375.91	32	864.8	114.10
375.90	33	870.4	115.22
375.90	34	875.8	116.35
375.89	35	881.0	117.12
375.89	36	886.0	117.90
375.89	37	890.9	118.69
375.88	38	895.6	119.90
375.88	39	900.2	120.72
375.88	40	904.7	121.55
375.87	41	909.0	122.38
375.87	42	913.3	122.81
375.87	43	917.4	123.67
375.86	44	921.4	124.54
375.86	45	925.3	125.42
375.86	46	929.1	126.31
375.86	47	932.9	126.76
375.85	48	936.5	127.67
375.85	49	940.1	128.60
375.85	50	943.6	129.07

Table XII. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 385.7$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
385.34	0.1	1.63	20.32
386.53	0.1	1.63	20.52
385.33	1	17.06	20.69
386.49	1	17.00	20.98
385.30	2	36.0	21.53
386.38	2	35.9	22.29
385.04	20	733.7	93.12
385.03	21	745.9	94.72
385.03	22	757.1	95.45
385.02	23	767.5	96.94
385.01	24	777.2	98.47
385.01	25	786.3	100.05
385.00	26	794.8	101.27
385.00	27	802.9	102.31
384.99	28	810.6	103.59
384.99	29	817.9	105.12
384.98	30	824.8	106.24
384.98	31	831.5	107.85
384.98	32	837.9	108.79
384.97	33	844.0	109.74
384.97	34	849.9	110.72
384.96	35	855.6	111.71
384.96	36	861.0	112.72
384.96	37	866.3	113.48
384.95	38	871.5	114.52
384.95	39	876.4	115.58
384.95	40	881.2	116.39
384.95	41	885.9	117.48
384.94	42	890.5	118.60
384.94	43	894.9	119.73
384.94	44	899.2	120.89
384.93	45	903.4	122.07
384.93	46	907.5	123.27
384.93	47	911.5	124.50
384.92	48	915.4	125.75
384.92	49	919.2	127.02
384.92	50	922.9	128.00

Table XIII. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 394.1$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
394.26	0.1	1.60	21.27
394.84	0.1	1.59	21.28
394.24	1	16.6	21.71
394.80	1	16.6	21.79
394.22	2	34.9	22.35
394.75	2	34.8	22.55
393.53	24	745.2	95.65
393.52	25	755.4	97.27
393.51	26	764.9	98.52
393.51	27	773.9	99.79
393.50	28	782.3	101.11
393.50	29	790.4	102.45
393.49	30	798.0	103.83
393.49	31	805.3	104.78
393.49	32	812.3	106.22
393.48	33	818.9	107.21
393.48	34	825.3	108.21
393.47	35	831.5	109.75
393.47	36	837.4	111.34
393.47	37	843.1	112.42
393.46	38	848.6	113.52
393.46	39	854.0	114.08
393.46	40	859.1	115.21
393.46	41	864.1	115.79
393.45	42	869.0	116.37
393.45	43	873.7	117.55
393.45	44	878.3	118.76
393.45	45	882.8	119.37
393.44	46	887.1	120.61
393.44	47	891.4	121.24
393.44	48	895.5	122.52
393.44	49	899.6	123.17
393.44	50	903.5	123.83

Table XIV. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 413.1$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
413.42	0.1	1.52	23.41
413.40	1	15.7	23.94
413.38	2	32.7	24.67
412.78	21	627.5	80.43
412.77	22	643.7	82.33
412.77	23	658.4	84.31
412.76	24	672.1	85.86
412.76	25	684.7	87.47
412.75	26	696.4	89.13
412.75	27	707.4	90.87
412.74	28	717.8	92.06
412.74	29	727.5	93.90
412.74	30	736.7	95.17

theoretical values of thermal conductivity calculated using a practical engineering equation for the thermal conductivity derived from the kinetic theory of gases, with the scaling parameters $\varepsilon/k = 280$ K and $\sigma = 0.4214$ nm, was found to be within $\pm 2\%$, from 390 to 465 K [9].

3. DENSE FLUID THERMAL CONDUCTIVITY

To determine the residual term of the thermal conductivity $\Delta\lambda(T, \rho)$, we performed measurements in the liquid and vapor phases far from the critical region, along 18 quasi-isotherms, at 298.9, 303.8, 316.8, 319.3, 330.5, 338.0, 353.4, 354.5, 361.9, 375.5, 385.7, 394.1, 413.1, 421.8, 425.1, 433.8,

Table XV. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 421.8$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
421.88	0.1	1.49	24.13
421.86	1	15.4	24.77
421.84	2	31.8	25.35
421.82	3	49.7	25.96
421.79	4	69.0	26.84

Table XVI. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 425.1$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
424.97	0.1	1.48	24.47
424.95	1	15.2	25.00
424.93	2	31.5	25.70
424.90	3	49.1	26.42
424.87	4	68.2	27.46
424.84	5	89.0	28.58
424.80	6	111.8	30.23
424.75	7	136.9	32.30
424.70	8	164.8	34.65
424.66	9	195.7	37.15
424.37	19	539.1	70.81
424.36	20	560.5	72.53
424.35	21	580.0	74.26
424.34	22	597.7	76.60
424.33	23	614.0	78.60
424.33	24	629.0	79.85
424.32	25	642.9	81.58
424.32	26	655.9	82.93
425.21	27	665.0	86.92
425.20	28	676.5	88.36
425.19	29	687.3	89.84
425.18	30	697.5	91.16
425.17	31	707.1	92.63
425.16	32	716.3	93.90
425.15	33	725.1	95.34
425.14	34	733.4	96.32
425.14	35	741.4	97.32
425.13	36	749.0	98.60
425.12	37	756.4	99.65
425.12	38	763.4	100.72
425.11	39	770.2	101.54
425.11	40	776.7	102.37
425.10	41	783.0	103.22
425.10	42	789.1	104.08
425.09	43	795.0	104.95
425.09	44	800.8	105.84
425.08	45	806.3	107.04
425.08	46	811.7	107.97
425.07	47	816.9	108.91
425.07	48	822.0	109.86
425.06	49	827.0	110.83
425.06	50	831.8	111.82

Table XVII. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 433.8$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
434.18	0.1	1.45	25.36
434.16	1	14.9	25.86
434.15	2	30.7	26.07
434.13	3	47.6	26.74
434.08	4	65.8	28.13
434.04	5	85.5	29.60
434.00	6	106.8	30.92
433.97	7	130.0	32.50
433.93	8	155.2	34.30
433.88	9	182.8	36.56
433.84	10	212.9	39.03
433.79	11	245.5	42.15
433.75	12	280.3	44.80
433.71	13	316.5	48.35
433.67	14	352.8	52.01
433.65	15	387.7	55.30
433.62	16	420.3	58.40
433.60	17	450.1	61.41
433.58	18	477.2	64.49
433.56	19	501.8	67.08
433.55	20	524.1	69.57
433.54	21	544.5	71.95
433.53	22	563.1	74.16
433.52	23	580.3	75.83
433.51	24	596.2	77.93
433.50	25	611.0	79.40
433.50	26	624.7	81.31
433.49	27	637.6	82.90
433.48	28	649.7	84.56
433.48	29	661.1	85.84
433.47	30	671.8	87.16
433.47	31	682.0	88.53
433.46	32	691.7	89.94
433.46	33	701.0	91.39
433.46	34	709.8	92.89
433.45	35	718.2	93.93
433.45	36	726.2	94.96
433.45	37	733.9	96.04
433.44	38	741.3	97.13
433.44	39	748.5	98.25
433.44	40	755.4	99.40
433.43	41	762.0	100.58
433.43	42	768.4	101.78
433.43	43	774.6	103.01
433.42	44	780.6	104.28
433.42	45	786.4	105.56
433.42	46	792.1	106.88
433.42	47	797.6	107.55
433.42	48	802.9	108.24
433.41	49	808.1	108.93
433.41	50	813.1	109.63

454.2, and 465.2 K (Tables II–XIX). The residual term of the thermal conductivity was represented by a six-order polynomial of the form

$$\frac{\Delta\lambda}{\Lambda_c} = \sum_{i=1}^{6} b_i \left(\frac{\rho}{\rho_c}\right)^i \tag{4}$$

where $\rho_c = 427\ \mathrm{kg \cdot m^{-3}}$ is the critical density, $\Lambda_c = 33.6\ \mathrm{mW \cdot m^{-1} \cdot K^{-1}}$, $\Delta\lambda$ is in $\mathrm{mW \cdot m^{-1} \cdot K^{-1}}$, and the density ρ is in $\mathrm{kg \cdot m^{-3}}$. The coefficients b_i in Eq. (4) are

$$b_1 = 0.361469, \qquad b_2 = 1.48627, \qquad b_3 = -1.45609$$

$$b_4 = 0.773357, \qquad b_5 = -0.177078, \qquad b_6 = 1.56971 \times 10^{-2}$$

The variation of the residual thermal conductivity as a function of density is shown in Fig. 1. It can be seen that this residual term represented along five isotherms is temperature independent. The deviations between our experimental thermal conductivity data and values calculated using the background Eq. (2) are always less than the experimental uncertainty ($\pm 1.5\%$).

Several measurements of the thermal conductivity of HFC-32 under pressure have been reported in the literature. These were reported mainly

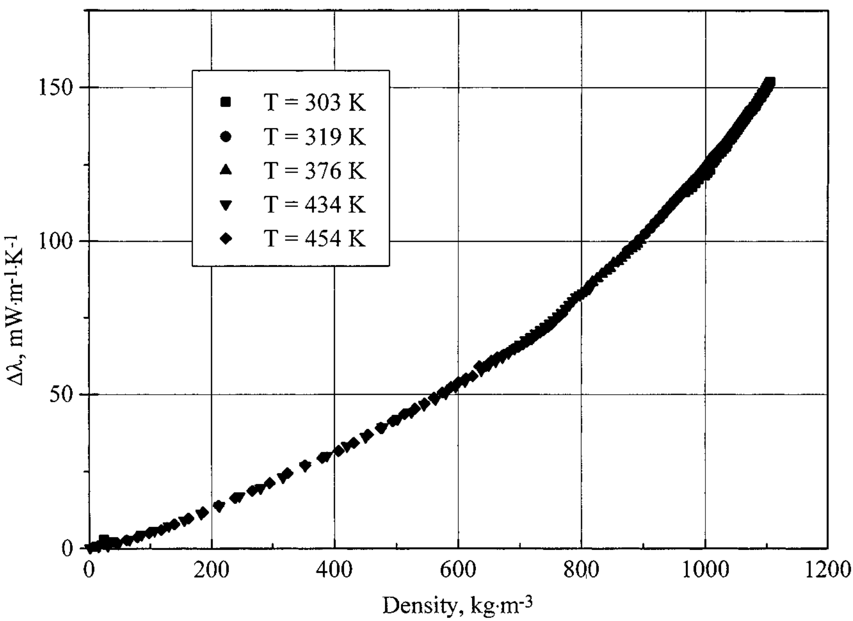

Fig. 1. Variation of the residual thermal conductivity of HFC-32 as a function of density.

Table XVIII. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T = 454.2$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
454.26	0.1	1.38	26.96
454.57	0.1	1.38	27.19
454.25	1	14.1	27.32
454.54	1	14.1	27.96
454.23	2	29.0	28.07
454.52	2	29.0	28.53
454.50	3	44.7	29.07
454.21	3	44.7	28.74
454.19	4	61.3	29.51
454.47	4	61.3	29.95
454.16	5	79.0	30.63
454.44	5	78.9	30.87
454.13	6	97.8	31.84
454.50	6	97.7	32.17
454.11	7	117.8	33.15
454.37	7	117.6	33.23
454.07	8	139.1	34.88
454.32	8	138.9	35.02
454.04	9	161.8	36.81
454.27	9	161.6	36.94
454.01	10	186.0	38.54
454.23	10	185.8	38.92
453.98	11	211.7	41.22
454.19	11	211.4	41.12
453.95	12	238.7	43.38
454.15	12	238.3	43.57
453.92	13	266.8	45.49
454.11	13	266.4	45.91
453.90	14	295.6	47.97
454.08	14	295.2	48.38
453.88	15	324.6	50.38
454.04	15	324.2	51.64
453.85	16	353.2	53.41
454.01	16	352.8	54.20
453.83	17	380.7	55.98
453.98	17	380.3	56.56
453.96	18	406.4	58.79
453.94	19	430.8	61.37
453.90	20	453.6	64.00
453.90	21	474.8	66.22
453.89	22	494.4	68.37
453.87	23	512.7	70.67
453.86	24	529.8	72.36
453.85	25	545.7	74.14

Table XVIII. *(Continued)*

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
453.84	26	560.7	76.01
453.83	27	574.7	77.69
453.82	28	588.0	79.44
453.81	29	600.4	80.96
453.81	30	612.3	82.21
453.80	31	623.5	83.05
453.80	32	634.2	84.84
453.79	33	644.4	86.22
453.78	34	654.2	88.01
453.78	35	663.5	89.11
453.78	36	672.4	89.87
453.77	37	681.0	90.63
453.77	38	689.2	91.81
453.76	39	697.1	92.60
453.76	40	704.7	93.42
453.76	41	712.1	94.24
453.76	42	719.2	95.09
453.75	43	726.1	96.38
453.75	44	732.7	97.26
453.75	45	739.1	98.15
453.74	46	745.4	99.06
453.74	47	751.4	99.99
453.73	48	757.3	101.41
453.73	49	763.0	102.39
453.73	50	768.6	103.38

for the liquid phase at lower temperatures, in the density range from 900 to 1200 $kg \cdot m^{-3}$. The comparison between the experimental data of Assael and Karagiannidis [10] and those calculated using the background equation shows that their data are systematically lower by 3 to 4% (Fig. 2). As also shown in Fig. 2, the experimental thermal conductivity data of Ro et al. [11] are higher. The relative deviations vary from 3 to 0.5%. There is a good agreement between the data of Gross and Song [12] and the values calculated by the background equation, as shown in Fig. 2. The mean deviations are within ± 2%. These three series of measurements were performed with a transient hot-wire instrument. As shown in Fig. 2, the maximum deviation between these three sets of data is 8%. This maximum deviation seems to be much larger than the respective uncertainties estimated by the authors. However, the relatively good agreement between the thermal conductivity values calculated by the background equation and

Table XIX. Thermal Conductivity of HFC-32 Along the Quasi-Isotherm $T=465.2$ K

Temperature (K)	Pressure (MPa)	Density ($kg \cdot m^{-3}$)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
465.61	0.1	1.35	28.38
465.59	1	13.74	28.78
465.57	2	28.1	29.37
465.55	3	43.2	29.88
465.52	4	59.1	30.74
465.49	5	75.9	31.83
465.45	6	93.6	33.06
465.42	7	112.2	34.33
465.39	8	132.0	35.69
465.35	9	152.8	37.22
465.32	10	174.8	38.81
465.28	11	197.9	40.62
465.25	12	222.0	42.51
465.21	13	247.1	44.58
465.18	14	272.8	46.96
465.14	15	298.9	49.48
465.11	16	325.0	52.15
465.08	17	350.6	54.83
465.05	18	375.3	57.18
465.03	19	398.9	59.56
465.01	20	421.2	61.79
465.00	21	442.2	63.99
464.98	22	461.9	65.95
464.97	23	480.3	68.03
464.95	24	497.6	69.79
464.94	25	513.9	71.64
464.93	26	529.1	73.34
464.92	27	543.5	74.86
464.91	28	557.2	76.44
464.90	29	570.0	78.09
464.90	30	582.3	79.52
464.89	31	593.9	81.00
464.88	32	605.0	82.22
464.88	33	615.6	83.49
464.87	34	625.7	84.79
464.86	35	635.4	85.79

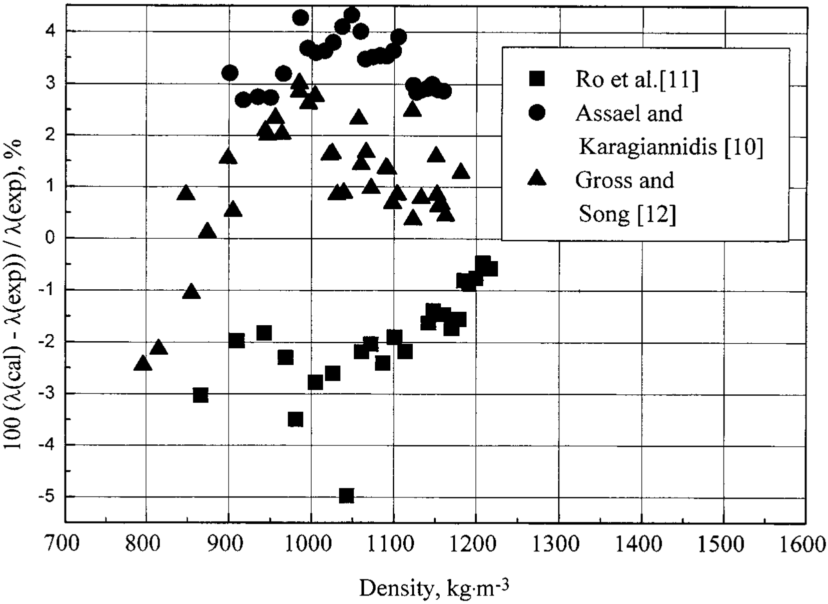

Fig. 2. Relative deviations between background equation and experimental data for HFC-32.

the experimental values reported in these three experimental studies demonstrates that the background equation can be extrapolated to temperatures down to 230 K, with densities up to $1200\,\mathrm{kg \cdot m^{-3}}$, with an uncertainty of $\pm 3\,\%$.

4. CONCLUSION

New measurements of the thermal conductivity of HFC-32 were performed in the temperature range from 300 to 465 K along 18 quasi-isotherms and at pressures up to 50 MPa with an estimated uncertainty of $\pm 1.5\,\%$. A background equation was determined that can be used to calculate the thermal conductivity of HFC-32 outside the critical region and the gas phase below the saturation curve, in a temperature range from 300 to 500 K, and at densities up to $1100\,\mathrm{kg \cdot m^{-3}}$, with an uncertainty of $\pm 1.5\,\%$.

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