Survey of Experimental Data of Thermophysical Properties for Difluoromethane HFC-32[1]

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ABSTRACT

A survey of experimental data and property equations was prepared in the Institute of Thermomechanics in connection with the planned experiments. In a tabular form surveys of thermodynamic, transport and other property measurements as pvT behavior, second virial coefficient, vapor pressure, saturation densities, critical parameters, heat capacities, speed of sound, thermal conductivity, viscosity, surface tension, refractive index, dielectric constant and dipole moment are presented. Tables include author(s) name(s), reference, range of measurement, number of points, stated accuracy and used method. Each property is supplemented with brief discussion.

KEY WORDS: difluoromethane; measurments; survey; thermodynamic, transport and other properties.

INTRODUCTION

In connection with planed experiments we have prepared a critical bibliography of experimental data and property equations for thirteen thermophysical properties of difluoromethane which is based on 110 literature sources. HFC 32 is an alternative refrigerant with application at low temperatures. Its mixtures with other refrigerants as HFC 134a, 125, 152a and 143a are considered to be the most promising alternatives to HCFC 22 and the azeotropic mixture R-502.

1. P-V-T DATA

In our literature search we found fourteen p-v-T measurements (Table I) comprising 1572 data points. They spread over the liquid and gaseous phases. Measured pressures are ranging from 0.07 to 72 MPa, temperatures from 142 to 473 K and densities from 1.5 to 1215 kg/m^3. The purity of the samples under investigation was between 99.6 and 99.998 wt. %. The measuring methods include variable volume, constant volume, Burnett expansion methods and vibrating tube densimetry as well. Measurements were carried out along isotherms and/or isochores. The reported accuracy in pressure was between 0.5 and 10 kPa, in temperature between 7 and 30 mK and density between 0.05 to 0.2%.

2. SECOND VIRIAL COEFFICIENT

The second virial coefficients (Table II) are reported by six researchers over the temperature range 273 to 420 K. They were derived with a graphical method from compressibility measurements along isotherms, from the fit of truncated two or three term virial equation or from the speed of sound measurements with the aid of the 2nd acoustic virial coefficient and appropriate thermodynamic relations. In addition Weber & Goodwin [18] estimated B(T) for six temperatures between 200 and 250 K. Several equations representing the temperature relation B(T) were devised.

3. VAPOR PRESSURE

The vapor pressure measurements (Table III) were carried out by sixteen investigators in the temperature range from 149 to the critical point. They include of about 350 points. The sample purity was predominantly better than 99.95 wt %. Measuring technique comprised a wide range of methods depending on the pressure range. Most methods for the measurements in the low pressure region, approximately below 200 kPa, are time consuming and relatively inaccurate. Recently, three estimation procedures appeared in the literature which make possible to extrapolate vapor pressure from the normal boiling temperature down to the triple point. They are applied by Lüddecke & Magee [28] using the heat capacity measurement, by Tillner-Roth [29] employing a non-linear regressin analysis based on Clausius-Clapeyron equation and a simple relation of the enthalpy of vaporization and finally by Duarte-Garza & Magee [30] based on the measured internal energy changes.

More than 20 vapor pressure equations can be found in the literature. The majority of them are of the Wagner-type. The triple point temperature and enthalpy of fusion were measured by Lüddecke & Magee [28] on three samples: T_{tp}= 136.34 ± 0.03 K and ΔH_{fus}= 4356 ± 130 J/mol. The triple point pressure was estimated by Tillner-Roth to be 50.70 ± 0.14 Pa [29], while that calculated from the equation of state by Outcalt & McLinden [31] is 46,9 Pa. This value is in good agreement with the value 46,5 Pa recently evaluated by the Duarte-Garza & Magee [30] using internal energy method.

4. SATURATED DENSITIES

Saturated liquid and vapor densities (Table IV) were measured by eleven authors in a wider temperature range or near the critical point only. In the vicinity of the critical point they were determined by the meniscus disappearance method, in some cases supplemented by the intensity measurements of the critical opalescence. To measure the saturated liquid densities pycnometer, pyrex glass floats, sinker with magnetic suspension, and vibrating densimeter were used. In the gaseous phase they were derived by extrapolation of isotherms or isochores to the vapor pressure curve. Saturated liquid densities were described by a polynomial with fractional exponents. The data reported for the V-L equilibrium near the critical point were usually correlated with the Wegener equation.

5. CRITICAL PARAMETERS

Concerning the critical parameters of R-32 ten data sets were collected (Table V). At the simplest experiments critical temperature and critical pressure were directly determined by the meniscus disappearance method. The critical density was calculated using the rectilinear diameter from the measurements of the orthobaric densities. Critical density and temperature were also derived from the V-L coexistence curve studies near the critical point using the meniscus diappearance method supplemented with the intensity measurements of the critical opalescence. The critical pressure was determined most often by means of the extrapolation of the vapor pressure to the critical temperature. The sample purity at all measurements was at least 99.9 % or better. Comparison of reported critical parameters with their uncertainties in p-T and ρ-T planes was presented by Sato et al. [39]. A small difference exists in the critical parameters used in the equations of state derived by Japan and US researchers:

	T_c/K	p_c/MPa	ρ_c/kg.m^{-3}
Japan	351.255	5.780	424
USA	351.35	5.795	427

6. SPEED OF SOUND

Two measurements of the speed of sound (Table VI) with 150 points were reported in the liquid phase. The uncertainty in w was estimated to ± 0.2 % except near the saturation curve, where it is approximately doubled. The measurements were realized by a fix path interferameter and by a pulse method. Both authors devised correlation relations for the speed of sound at saturated liquid state and in the liquid phase. Two high accuracy measurements in the gaseous phase were carried out at low pressures <500 kPa at temperatures ranging from 273 to 373 K. Obtained data were correlated and further used to derive the second acoustic virial coefficients , ideal-gas heat capcities and the second virial coefficient.

7. HEAT CAPACITIES

Measured and computed heat capacities are summarized in Table VII. Yomo e.a. [43] correlated measured values along isotherms between 243 and 373 K up to 3 MPa and extrapolated them to the saturation curve to obtain saturated liquid heat capacities. Isobaric heat capacities were then used to calculate the saturated and compressed liquid enthalpies. The results are presented in graphical form only. Lüddecke & Magee [28] measured the isochoric heat capacity of the saturated and compressed liquid. Saturated liquid heat capacity was described with a four-parameter equation reproducing experimental data within ± 0.5 %. Beljajeva et al. [44] published the isobaric heat capacities and thermal coefficients in the liquid phase and along the saturation curve calculated from the measured speed of sound [41] and pvT data.

Ideal-gas heat capacities were calculated from the spectroscopic data using methods of the statistical mechanics or derived from the speed of sound measurements at low pressure. Interpolation equations for ideal-gas heat capacity◦ in a limited temperature range presented e.g. McLinden [34,36], Hozumi et al. [19,42], Piao et al. [5] and Outcalt & McLinden [31].

8. THERMAL CONDUCTIVITY

Measurements of the thermal conductivity were performed in both liquid and gaseous phases and along the saturation line as well (Table VIII). Predominantly the transient hot-wire method in various modifications was used, sporadically the method of coaxial cylinders. In the case of the vapor phase the hot-wire experiments failed close to the saturation line due to the condensation on wires. Therefore the extrapolation along isotherms up to the saturation density is used. The density data which are indispensable to the data reduction are usually calculated from equations of state. The reported uncertainty in the thermal conductivity was within 0.5 and 5 %. Discrepancies among various data sets indicate that the quoted uncerainties are overestimated.

9. VISCOSITY

Viscosities were measured (Table IX) in the liquid phase by means of vibrating wire and capillary tube viscosimeters in the gas phase with falling cylinder and oscillating disk viscosimeters. Viscosities of saturated liquid and saturated vapor were measured with capillary or vibrating wire viscometers. Nearly all data sets were correlated, densities were calculated from interpolation equations of saturated densities or from the equations of state. Large discrepances observed in the measurements of liquid viscosities are attributed mostly to the impurities in the sample, electrolytic effect in the instrument and incapability of some instruments to be callibrated with water. A comparative examination of other recently reported experimental data on viscosity carried out by Assael et al. [67] showed that the viscosity of refrigerants is not known with higher accuracy than ± 5 percent.

10. SURFACE TENSION

All three measurements of the surface tension (Table X) were realized by means of the differantial capillary-rise method. Experimental data were correlate with the van der Waals expression . All data agree within ± 0.2 mN/m except some points by Zhu et al. [68], which deviations reach about 0.4 mN/m at lower pressures.

11. REFRACTIVE INDEX

The coexistence curve of the refractive index (Table XI) was measured at two wave lengths. The refractive index at the critical point reported by Schmidt & Moldover [37] and by Yata et al. [70] differs only slightly.

12. DIELECTRIC CONSTANT

Dielectric constant (Table XII) was determined by the capacitance measurements in a guarded 3-terminal dielectric cell in both gaseous and liquid phases, and in the saturated liquid.

13. DIPOLE MOMENT

The dipole moment of R-32 is temperature independent and its value is 1.978 Debey units.

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Table I. Survey of p - v - T Measurements of HFC 32

Author(s)	Year	Ref.	Pressure (MPa)	δ p ±(kPa)	Temperature (K)	δ T ± (mK)	Density (kg. m^{-3})	δ ρ ± (%)	Sample purity (%)	No. of points	Method
Malbrunot e.a.	1968	[1]	0.8-20	1	248 - 473	80	20-1176	-	99.95	150	1 , 2
Nishimura e.a.	1991	[2]	0.15-6.6	0.8	290 - 370	10			99.98	95	3
Sato e.a.	1992/4	[3, 4]	3.3-9.8	2	322 - 420	7	111-850	0.1	99.998	69	4
Widiatmo e.a.	1992	[5]	0.09-3.7	10	220 - 330	15	795-1215	0.2	99.998	14	
Qian e.a.	1993	[6]	0.15-6.6	0.6	290 - 370	10	2.6-303	0.2	99.98	95	3
Defibaugh e.a.	1993	[7]	0.24-9.8	0.5	242 - 372	10	4-1157	-	99.99	386	3 , 5
Holste	1993	[8]	1.5-72		150 - 375		report	not	available	103	
Baroncini e.a.	1993	[9]	0.7-2.7	0.5	273 - 360	10	19.7-56.9	0.2kg/m^3	99.6	93	2
Grebenkov e.a.	1994	[10]		0.15%	280 - 350	20			99.99		1
Magee (Howley)	1994/6	[11]	3.8-35	0.01-0.05%	142 - 396	30	708-1420	0.05	99.94	136	2
Bouchot, Richon	1994	[12]	0.12-9.5	3	253 - 333	20	2.7-1070	<0.2kg/m^3	>99.3	36	5
Fu, Han, Zhu	1995	[13]	0.07-5.7	0.5	243 - 373	10	1.8-240		99.95	123	3
Fukushima e.a.	1995	[14]	1.8-10	3	313 - 340	10	46.5-802	0.2	99.98	158	2
Takahashi e.a.	1995	[15]	0.1-10	0.5	293 - 423	10	1.5-546	0.12	99.972	114	6

Methods: 1 - variable volume method (Hg as confining medium) 2 - constant volume mthod 3 - Burnett expansion method

4 - constant volume method / isochoric method with expansion procedures 5 - vibrating tube densimeter

6 - oscillating disk viscometer adopted for density measurements

Table II. Second Virial Coefficient of HFC 32

Author(s)	Ref.	Year	Temperature range (K)	Uncertainty (%)	Method
Dymond & Smith	[16]	1980	289 - 349	< 10	1
			273 - 323	< 10	1
Weber & Goodwin	[18]	1993	200 - 250	2-5	2
Qian e.a.	[6]	1993	290 - 370		3
Sato e.a.	[4]	1994	340-420	1	4
Hozumi e.a.	[19]	1994	273-340	(1)	5
Defibaugh e.a.	[7]	1994	373.14 (268-373)		3
Zhang e.a.	[20]	1995	290-370	< 4	6

Methods:

1 - from compressibility data by Fogg [17]and Malbrunot [1]

2 - estimated

3 - from graphical analysis of isotherms $(z-1)\rho$ vs. ρ

4 - by fitting truncated virial equation of state

5 - from low pressure speed of sound measurements

6 - improved analysis of Burnett measurement

Table III. Vapor Pressure Measurements of HFC 32

Author (s)	Year	Ref.	Temperature range (K)	Pressure range (MPa)	Sample purity (%)	No. of points	Uncertainty δp (kPa)	Uncertainty δT (mK)	Methods
Malbrunot e.a.	1968	[1]	190.15-351.56	0.016-5.814	>99.95 mol	30	± 0.1%	50	A, B
Kanungo e.a.	1987	[21]	149.36-244.82	0.02-0.085	98.3 wt	(138)	0.01%	1	K
Nishimura e.a.	1991	[2]	280-350		99.98 wt	9	± 0.85	10	E
Qian e.a.	1992/3	[6]	280-350	1-5.63	99.98 wt	9	0.8		E
Widiatmo e.a.	1992/4	[22,23]	219.97-324.98	0.09-3.27	99.998 wt	25	2	15	F
Holcomb e.a.	1993	[24]	295.28-348.63	1.57-5.46	99.9	25	± 3.5	100	I
Weber & Goodwin	1993	[18]	208.36-237.38	0.05-0.21	99.98 wt	27		3-4	C

Zhu, Li, Wang	1993	[25]	273.39-347.29	0.82-5.32	99.95 wt	32	0.5	10	E
Nagel & Bier	1993	[26]	204.44-351.23	0.04-5.78	99.9	27	0.6	30	H
Baroncini e.a.	1993	[9]	237.95-350.92	0.22-5.75	99.57	56	± 0.5	10	H
Weber & Silva	1994	[27]	235.87-266.35	0.20-0.65	99.99 mol	17	0.0065		D
Defibaugh e.a.	1994	[7]	268.15-348.08	0.69-5.41	99.99 wt	18	0.04%	10	E
Sato T. e.a.	1994	[4]	320.00-351.24	2.92-5.78	99.998 wt	21	2		G
Bouchot & Richon	1994	[12]	253.07-333.39	0.40-3.95	>99.3	8	± 5	20	J

Magee (Howley)	1994/6	[11]	270-330	0.73-3.67	99.94 mol	7	± 0.1%	30	H
Fukushima e.a.	1995	[14]	277.59-350.95	0.93-5.74	99.98	57	± 3	± 10	H

Methods:

A - manometric, B - static, C - glass comparative ebulliometer, D - metal comparative ebulliometer,

E - Burnett apparatus, F - sinker method with magnetic suspension with a metallic bellows variable-volume cell,
G - isochoric method coupled with expansion procedure, H - constant volume method,
I - V-L equilibrium apparatus, J - vibrating tube densimeter, K - differential manometry method (Kanungo)

Table IV. Saturation Densities of HFC 32

Author(s)	Year	Ref.	Temperature range (K)	δ ρ ± (%)	Sample purity (%)	No. of points	Method
Malbrunot e.a.	1968	[1]	249 - 352	0.2	99.95 mol	16ρ′	1, 2
Widiatmo	1992	[22]	275 - 330	0.2	99.998 wt	13 ρ′	3
Holcomb e.a.	1993	[24]	295 - 349	±0.5 kg/m^3	99.9	25+25	10
Widiatmo e.a.	1994	[23]	210 - 330	0.2	99.998 wt	25 ρ′	3
Defibaugh e.a.	1994	[7]	243 - 338	0.2	99.99wt	21 ρ′	4
			219 - 343			28 ρ″	
Sato T. e.a.	1994	[4]	321 - 344	0.5	99.998 wt	2 ρ′	5
			327 - 343			4ρ″	
Higashi e.a.	1992/4	[32]	336 - 351		99.998	17+17	6
Bouchot & Richon	1994	[12]	253 - 333	±0.3 kg/m^3	>99.3	5+5	9
Kuwabara e.a.	1992/5	[33]	330 - 351	0.1-0.4	99.998	17 ρ′	6
			346 - 351			13ρ″	6
Fukushima e.a.	1992/5	[14]	233 - 329	0.4	99.98	(6+8), 5	5,8
			340 - 351	± 3 kg/m^3	99.98	15	6
Magee	1994/6	[11]	139 - 305	0.1	99.94	13ρ′	5

Metods: 1- graphical extrapolation of isotherms to the vapor pressure curve

2 - pycnometric

3 - sinker with magnetic suspension

4 - isotherms extrapolated to the saturation boundary using Tait eq.

5 - intersection of isochores with vapor pressure curve

6 - meniscus disappearance

7 - meniscus disappearance and critical opalescence

8 - pyrex glass floats

9 - vibrating tube densimeter

10 - V-L equilibrium recirculation apparatus

Table V. Critical Parameters of HFC 32

author(s)	Ref.	Year	T_c / K	P_c / kPa	ρ_c / kg.m^{-3}	Sample purity %	Method
Malbrunot e.a.	[1]	1968	351.52 ± 0.2	5830	429.6	99.95	VOMD
McLinden	[34]	1990	(351.54)	(5830)	(430)	-	-
Singh e.a.	[35]	1991	(351.56)	(5814)	(429.61)	-	-
Kuwabara	[33]	1992/5	351.255 ± 0.010	-	424 ± 1	99.998 mass	MD+CO
Nishimura e.a.	[2,6]	1992/3	(351.255 ± 0.010)	5780 ± 2	-	99.98	CPV
McLinden	[36]	1993	(351.36)	(5791)	(427)	-	-
Fukushima e.a.	[14]	1992/5	351.26 ± 0.03	5778 ± 3	425 ± 5	99.998 mass	MD+CO
Holcomb e.a.	[24]	1993	(351.54)	(5830)	428.50 ± 1.83	99.9	CLVM
Nagel & Bier	[26]	1993	351.23 ± 0.06	5783 ± 6	420 ± 8	99.9	CO
Schmidt & Moldover	[37]	1994	351.35 ± 0.02	-	419 ± 7	99.9 mol	MDR
Sato T. e.a.	[3,4]	1992/4	(351.255 ± 0.010)	5784 ± 2.5	-	99.998mass	CVP
Higashi e.a.	[32]	1992/4	351.26 ± 0.02	5785 ± 9	427.5	99.98	MD+CO
Outcalt & McLinden	[31]	1995	(351.35)	(5795)	(427)	-	-
Yata e.a.	[38]	1996	351.14 ± 0.10	-	-	>99.5	em VL

Methods: MD - meniscus disappearence

VOMD - Visual observation of meniscus disappearance

MDR - meniscus disappearance and reappearance

CVP - p_c determined from the vapor pressyre correlation

CO - Critical opalescence

CLVM - critical volume fraction method by Van Polen

em VL - empirical methpd using experimental data on V-L equilibrium

TableVI. Speed of Sound Measurements of HFC 32

Author (s)	Ref.	Year	Phase	Temperature (K)	Pressure (MPa)	No. of points	Uncertainty in w %	Method
Tagaki	[40]	1993	liq.	243 - 373	p_s - 35	120	0.2	1
Hozumi et al.	[19]	1994	gas.	273 - 343	0.02 - 0.250	67	0.01	2
Grebenkov et al.	[41]	1994	liq.	286 - 341	p_s - 10.3	30	0.2	3
Hozumi et al.	[42]	1996	gas.	308 - 343	to 0.500	44	0.006	2

Methods: 1 - echo technique operated at 2 MHz with fixed path interferometer

2 - spherical acoustic interferometer

3 - impulse method at frequency of 2.1 MHz

Table VII. Heat Capacities of HFC 32

Author(s)	Year	Ref.	Type	Temperature range (K)	Pressures (MPa)	No. of points	Sample purity (%)	Uncertainty (%)	Method
Yomo e.a.	1992/4	[43]	c_p	275 - 315	2.1-3.	41	99.936	± 0.35-0.6	1
Weber & Goodwin	1993	[18]	c_p', c_p''	200 - 250	p_s	6 + 6	-		2
Defibaugh e.a.	1994	[7]	c_p', c_p'' c_v', c_v''	200 - T_c	p_s	a 27	-		2
Lüdecke & Magee	1996	[28]	c_v'	145 - 342	p_s	95	99.94	± 0.7	3
			c_v	152 - 341	5.8-31.7	73	99.94		3
Beljajeva	1995	[44]	c_p'	250 - 325	p_s	16	--		2
			c_p	285 - 325	1.5-3.5	29			2

Methods: 1- flow calorimeter 2 - calculated 3 - adiabati calorimeter

Ideal - gas heat capacity

Rodgers e.a.	1974	[45]	0-1500	calculated from spectroscopic data
JANAF Tables	1985	[46]	0-6000	calculated from spectroscopic data
McLinden	1990/3	[34,36]	150-600	correlated data from [41]
Defibaugh e.a.	1994	[7]	200-400	calculated from spectroscopic data

Hozumi e.a.	1994/6	[19,42]	200-400	calculated from low pressure speed of sound mesurements

Table VIII. Thermal Conductivity Measurements of HFC 32

Author(s)	Year	Ref.	Phase	Temperature range (K)	Pressure range (MPa)	No. of points	Uncertainty (%)	Method
Tauscher	1969	[48]	liq.	148 - 298	0.01-2			THWM
Papadakai & Wakeham	1993	[49]	λ'	205 - 303	p_s	10	± 1	THWM (TaCW)
Geller & Paulaitis	1994	[50]	gas	255 - 383	0.1-5	42	≤ 1	
			sat.	245 - 344	p_s	12	near CP	MSSHWM
			scr	352 - 428	4.1-19.7	67	5	
Geller e.a.	1994	[51]	gas	253 - 373	0.1-5.3		≤ 1	MSSHWM
Grebenkov e.a.	1994	[52]	liq.	275 - 403	1.67-12.9	96	to 3.5	COAC
Tanaka e.a.	1995	[53]	gas	283 - 333	0.1-3.93	53	± 1	THWM (2PtW)
Ro, Kim, Kim	1995	[54]	liq.	223 - 323	2-20	24	± 2	THWM (bPtW)
Assael & Karagiannidis	1995	[55]	liq+λ'	253 - 313	0.6-17.6	27+4	± 0.5	THWM (anTaW)
Gross & Song	1996	[56]	liq+gas	233 - 345	0.1-6.18	80	1.6-2	THWM (pol.V)
Yata e.a.	1996	[57]	liq.	253 - 324	2-30	27	1	THWM
Sun e.a.	1997	[58]	gas	255 - 342	near p_s	20	3	THWM (2-anTaW)

Abbreviations: gas - gaseous, liq. - liquid, scr - supercritical region

Methods: THWM - transient hot-wire method, anTaW - anodized tantalum wire, TaCW - coated tantalum wire, 2PtW - two Pt wires, bPtW - single bare Pt wire, pV- with polarization voltage, MSSHWM - modified steady-state hot-wire method COAC - steady state method of coaxial cylinders

Table IX. Viscosity Measurements of HFC 32

Author(s)	Year	Ref.	Phase	Temperature range (K)	Pressure range (MPa)	No. of points	Uncertainty (%)	Method
Phillips & Murphy	1970	[59]	η'	200 - 287	0.01-2	10	n.a.	CTV
Oliveira &Wakeham	1993	[60]	η'	232- 343	0.21-5.1	19	±0.6	VWV
			η''	252 - 333	0.37-3.96	14	±0.7	VWV
Ripple & Matra	1993	[61]	η'	251 - 293	0.36-1.48	10	3-5	CTV
Assael e.a.	1994	[62]	liq.	273 - 313	p_s -15.5	26	±0.5	VWV
			sat.	273 - 313	p_s	5		calculated
Dunlop	1994	[63]		298.15		1	0.3	CTV
Grebenkov e.a.	1994	[52]	liq.	290 - 316	-16	54		FCV
Takahashi e.a.	1995	[64]	gas	298 - 423	0.10-5.4	58	±0.3	ODV
Geller e.a.	1995	[65]	gas	253 - 363	0.45-5.4	51	<±1.2	MCTV
			η',η''	253 - 348	p_s	10+10		calculated
Sun e.a	1996	[67]	η''	233 - 333	p_s	21	<3	CTV
Heide	1996	[76]	η'	223 - 333	p_s + 0.1	12	2	FBV

Methods:
VWV - vibrating wire viscosimeter
ODV - oscillating disk viscosimeter
CTV - capillary tube viscosimeter
FBV - falling ball viscosimeter
MCTV - modified capillary tube viscosimeter
FCV - falling cylinder viscosimeter

Table X. Surface Tension Measurements of HFC 32.

Author(s)	Year	Ref.	Temperature range (K)	No. of points	Uncertainty (mN/m)	Sample purity (%)
Okada & Higashi	1994	[68]	273 - 333	13	±0.2	99.98
Schmidt & Moldover	1994	[37]	297 - 350	10	(±0.15)	99.9
Zhu, Han, Lu	1994	[69]	268 - 334	13	n.a.	99.95

Table XI. Refractive Index of HFC 32

Author(s)	Year	Ref.	Temperature range (K)	No. of points	Wave length (nm)	Sample purity (%)	n_c
Schmidt & Moldover	1994	[37]	296 - T_c	14 + 14	633	99.9	1.0828
Yata e.a.	19961	[70]	313 - T_c	28 + 28	545	99.5	1.0854

Table XII. Dielectric Constant of HFC 32

Author(s)	Year	Ref.	Phase	Temperature range (K)	Pressures (MPa)	No. of points	Accuracy (%)
Tremaine & Robinson	1973	[71]	sat. liq.	152 - 224	p_s	8	±0.8
Meyer & Morrison	1991	[72]	gas	308 - 411	0-0.45	54	n.a.
de Castro e.a.	1995	[73]	liq.	208 - 303	2-17	165	0.1

Table XIII. Dipole Moment of HFC 32

Author(s)	Year	Ref.	Method	μ / Debey units
Lide	1951	[74]	from Stark effect measurements	1,96 ±0.02
Kawaguchi & Tanaka	1977	[75]	from analysis of Stark spectrum	1,9785 ± 0.0021
Meyer & Morrison	1991	[72]	calculated from dielectric measurements	1.978 ± 0.007