ENERGY CONSERVATION

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ABSORPTION FLUIDS DATA SURVEY

1989 UPDATE

R. A. Macriss
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Prepared by

INSTITUTE OF GAS TECHNOLOGY
3424 South State Street
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under
Subcontract 86X-47989C

for the

ENERGY DIVISION
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831

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Topical Report
(First Update of Final Report
on Worldwide Data)

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SUMMARY OF RESULTS

This is an update of a series of prior reports on absorption fluids and data, ORNL/Sub/84-47989/1,2,&3. It covers additional data developed and published mainly during 1985-88, and cites 44 additional references.

Seventy-four different worldwide publications containing data relating to properties of binary, ternary, and multicomponent absorption fluids were identified. Of these, 30 manuscripts include applications of absorption fluid properties data toward evaluation, assessment, or design of chillers or heat pumps but do not include actual fluid properties data. The remaining 44 publications date as far back as 1929, but over 50% of these documents were published between 1985 and 1988. The texts of the 44 manuscripts are in English, German, Japanese, Russian, or French.

The absorption fluids discussed in the 44 documents are combinations of 9 different "refrigerant" compounds and 30 single, 7 binary, and 1 ternary "absorbent" compounds. Generally, the refrigerants are divided among the following categories of chemical compounds:

<u>Refrigerants</u>

Inorganic	2
Organic	7
• Amines	1
• Alcohols	4
• Halogenated hydrocarbons	2

The 30 single absorbent compounds generally are subdivided as follows:

<u>Absorbents</u>

Inorganic	13
Organic	17
• Ethers	3
• Amides	3
• Amines	1
• Esters	1
• Ketones	3
• Others	6

The binary and ternary absorbents are various mixtures of two or more single absorbent compounds.

In terms of absorption fluid properties, for which data are available in the 44 primary documents, the list below shows that vapor-liquid equilibrium is the predominant property, which is reported in almost 60% of the documents. Toxicity or flammability of fluids, on the other hand, have not been found in any of the references.

Thermodynamic, Transport, and Other Data

Fluid Property	Number of References*
Vapor-liquid equilibrium	26
Enthalpy	13
Specific heat	3
Viscosity	8
Heat of mixing	6
Density	7
Crystallization	4
Surface tension	4
Corrosion (and inhibitors)	4
Thermal conductivity	4
Entropy	0
Stability	2
Refractive index	0
Heat and mass transfer	3
Toxicity	0
Flammability	0

A list of several key absorption fluids identified in earlier publications are of interest to researchers of advanced absorption heat pumps and are shown below:

---

* A given document may contain data relating to more than one property; therefore, the sum of the references is larger than 44.

Key Fluids

(see Table 3 for abbreviations)

NH_3-H_2O	CH_3OH-LiBr-$ZnBr_2$
NH_3-H_2O-LiBr	TFE-NMP
NH_3-H_2O-$LiNO_3$	TFE-DMEDEG
NH_3-NaSCN	TFE-DMETEG
H_2O-LiBr	CH_3NH_2-H_2O-LiBr
H_2O-LiBr-LiCl	R21-DMETEG
H_2O-LiBr-LiSCN	R22-DMEDEG
H_2O-LiBr-$ZnBr_2$	R22-DMETEG
H_2O-NaOH-KOH-CsOH	R22-DMF
H_2O-$LiNO_3$-$NaNO_3$-KNO_3	R123a-ETFE
CH_3OH-LiBr	R124-ETFE
CH_3OH-$ZnBr_2$	R133a-NMP

During 1988, these additional key fluids were identified and included in this report:

H_2O-LiBr-$ZnCl_2$	R22-DMA
H_2O-LiBr-4.BLN	R22-DMETrEG
CH_3OH-LiBr-H_2O	R22-DMMP
C_2H_5OH-LiI	R22-NMC
TFE-DBP	R22-NMMNO
TFE-HMPT	R22-PYR
TFE-PYR	HFIP-DMETEG
TFE-QUN	HFIP-SL

ABSTRACT

This is an update of a series of prior reports on absorption fluids and data, ORNL/Sub/84-47989/1,2,&3. It covers additional data developed and published mainly during 1985-88, and cites 44 additional references.

Fluids discussed include combinations of 9 different refrigerant compounds, as well as of 30 single, 7 binary, and 1 ternary absorbent compounds. Generally, the 9 refrigerants are divided among the following categories of chemical compounds: inorganic, 2 and organic, 7 (amines, 1; alcohols, 4; halogenated hydrocarbons, 2). The single absorbent compounds generally are subdivided as follows: inorganic, 13 and organic, 17 (ethers, 3; amides, 3; amines, 1; esters, 1; ketones, 3; and others, 6). The binary and ternary absorbents are various mixtures of two or more single absorbent compounds.

1. INTRODUCTION

In an effort to define the availability and quality of existing data and, thereby, to assist in the determination of needs for new data useful to advanced concepts, the Institute of Gas Technology (IGT) has performed an extensive literature search and a coarse screening of existing U.S. and foreign literature data to identify potential conflicts or gaps in the data for certain key fluid systems.

A detailed account of IGT's findings has been contained in three earlier reports (ORNL/Sub/84-4798/1,2,&3) that covered, in part, absorption fluids and data developed, respectively, in the United States, Western Europe, Japan, and internationally. This report is the first update of this series of reports and covers additional data developed and published mainly during the 1985-88 period.

2. METHOD AND SCOPE

Literature searches and site visits were undertaken to identify and obtain available publications – several dating back to 1901 – on pertinent physical, thermodynamic, and transport properties of absorption fluids. The bulk of references identified contain data developed mainly in the United States, West Germany, France, Britain, Japan, and the USSR. Cross-checks of literature searches were also made, using available published bibliographies and literature review articles, to eliminate secondary sources for the data and, thus, include only original sources and manuscripts.

2.1. FLUID PROPERTIES AND DATA

The properties of these fluids relate to the liquid and/or vapor state encountered in normal operation of absorption equipment employing such fluids and to the crystallization boundary of the liquid phase, where applicable. The actual data were systematically classified according to type of fluid and property as well as to temperature, pressure, and concentration ranges over which data were available. Data were sought for at least 17 different properties as follows:

Mixture Properties

1. Vapor-liquid equilibria
2. Crystallization temperature
3. Corrosion characteristics
4. Heat of mixing
5. Liquid-phase densities
6. Vapor-liquid-phase enthalpies
7. Specific heat
8. Stability
9. Viscosity
10. Mass transfer rate
11. Heat transfer rate
12. Thermal conductivity
13. Refractive index
14. Entropy
15. Surface tension
16. Toxicity
17. Flammability

The type of available data was of importance, with raw experimental data considered to be highly desirable for use in actual process and equipment design and sizing and for process design correlation development. For this reason, raw tabulated experimental data were given the highest possible ranking, with other forms of data following in importance as shown below:

Form of Data	Symbol
Raw experimental	(E)
• Tabular	(T)
• Graphical	(G)
Smoothed experimental	(S)
• Tabular	(T)
• Graphical	(G)
Empirical polynomial	(P)
Equations of state	(C)

Empirical polynomial relationships based on raw or smoothed experimental data are often reported. At best, such correlations are as good as the experimental data, and they can help facilitate the use of the data in performance and design calculations through automation (computer software and terminals). In the absence of data, reliable methods of prediction have been sought (equations of state, generalized correlations) but are expected to produce greater uncertainties than the previous forms of data.

3. DETAILED PRESENTATIONS AND TABULATIONS

This report is organized to cover the various work elements of this study in their natural sequence. This portion of the report contains a listing of the refrigerants and absorbents of the absorption fluids of this study. The details of the range of conditions over which property data exist for each fluid are given in the Appendix.

3.1. REFRIGERANTS AND ABSORBENTS

Table 1 lists the 9 refrigerants grouped into 4 distinct chemical compound categories: inorganics, amines, alcohols, and halogenated hydrocarbons. For each refrigerant, Table 1 contains the chemical formula and name, molecular weight, and normal boiling point (in dual units).

Table 2 lists the chemical formula and name, and molecular weight for 13 single inorganic absorbents. Table 3 lists 17 single organic absorbents grouped into 6 distinct chemical compound categories: ethers, amides, amines, esters, ketones, and an undefined catch-all category. For each organic absorbent, Table 3 contains an arbitrary abbreviation of convenience, chemical formula and name, molecular weight, and normal boiling point (in dual units). Table 4 lists 8 multicomponent (binary and ternary) absorbents with access number and chemical formula.

Table 1. Refrigerants

	Chemical Formula	Name	MW*	NBP** (°F)	NBP** (°C)
Inorganics					
	NH_3	Ammonia	17.0	-28	-33.3
	H_2O	Water	18.0	212	100.0
Organics					
Amines	CH_3NH_2	Methylamine	31.1	21	-6.1
Alcohols	CH_3OH	Methanol	32.0	149	65.0
	C_2H_5OH	Ethanol	46.1	173	78.3
	CF_3CH_2OH	Trifluoroethanol	100.0	164	73.6
	$(CF_3)_2CHOH$	Hexafluoroisopropanol	168.0	138	59.0
Halogenated Hydrocarbons	CHF_2Cl	Refrigerant 22	86.5	-41	-40.6
	$CHClFCClF_2$	Refrigerant 123a	152.9	85	29.4

*Molecular weight.
**Normal boiling point.

Table 2. Absorbents (inorganic)

Chemical Formula	Name	Molecular Weight
$CaCl_2$	Calcium chloride	111.0
LiBr	Lithium bromide	86.8
LiI	Lithium iodide	133.8
$LiNO_3$	Lithium nitrate	68.9
KOH	Potassium hydroxide	56.1
KNO_3	Potassium nitrate	101.1
NaOH	Sodium hydroxide	40.0
$NaNO_3$	Sodium nitrate	85.0
NaSCN	Sodium thiocyanate	81.1
H_2SO_4	Sulfuric acid	98.0
H_2O	Water	18.0
$ZnBr_2$	Zinc bromide	225.2
$ZnCl_2$	Zinc chloride	136.3

Table 3. Absorbents (organic)

Abbrev.	Chemical Formula	Name	MW[a]	NBP[b] (°F)	NBP[b] (°C)
Ethers					
DMEDEG	$CH_3(OC_2H_4)_2OCH_3$	Dimethylether diethylene glycol	134.2	324	162.2
DMETrEG	$CH_3(OC_2H_4)_3OCH_3$	Dimethylether triethylene glycol	178.2	421	216.1
DMETEG	$CH_3(OC_2H_4)_4OCH_3$	Dimethylether tetraethylene glycol	222.3	528	275.6
Amides					
DMF	$CHON\ (CH_3)_2$	N, N-Dimethyl formamide	73.1	302	150.0
DMA	$CH_3CON(CH_3)_2$	N, N-Dimethyl acetamide	87.1	329	165.0
HMPT	$[(CH_3)_2N]_3PO$	Hexamethylphosphoric acid triamide	179.2	ND[c]	ND
Amines					
QUN	C_9H_7N	Quinoline	129.2	465	240.5
Esters					
DBP	$C_6H_4(CO_2C_4H_9)_2$	Dibutyl phthalate	278.3	644	340.0
Ketones					
BLN	$(CH_2)_3CO_2$	4-Butyrolactone	86.1	403	206.1
NMP	C_5H_9NO	N-Methyl-2-pyrrolidone	99.1	394	201.1
PYR	C_4H_7NO	2-Pyrrolidinone 2-Pyrrolidone	85.1	473	245.0
Others					
DMMP	$CH_3PO(OCH_3)_2$	Dimethyl methyl phosphonate	124.1	175	79.5
DMPU	$C_6H_{12}N_2O$	1,3 Dimethyl-3,4,5,6 tetra-hydro-2 (1H)-pyrimidinone "Dimethylpropylenurea"	128.2	450	232.0
NMC	$C_7H_{13}NO$	N-Methyl-E-caprolactam	101.1	ND	ND
NMMNO	ND	N-Methylmorpholine-N-oxide	ND	ND	ND
SL	$C_4H_8SO_2$	Sulfolane	120.2	549	287.0
CCH	C_6H_{12}	Cyclohexane	84.2	177	80.7

[a]Molecular weight.
[b]Normal boiling point.
[c]ND — Not determined.

Table 4. Absorbents (multicomponent)

Binary		Ternary	
Abbrev.	Chemical Formula	Abbrev.	Chemical Formula
Bi-1	KOH:NaOH	Te-1	KNO_3:$LiNO_3$:$NaNO_3$
Bi-2	LiBr:4,BLN		
Bi-3	LiBr:H_2O		
Bi-4	LiBr:$ZnBr_2$		
Bi-5	LiBr:$ZnCl_2$		
Bi-6	$LiNO_3$:H_2O		
Bi-7	NMC:$CaCl_2$		

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APPENDIX

FLUID PROPERTY DATA

A.1.1. Vapor-Liquid Equilibrium

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
$NH_3 + H_2O$	TEGC	130–230	3.2–113.3	0–100 0–100	22	Guillevic et al.	1985	France	English
$NH_3 + H_2O$	TE	80	0.47–0.91	0.001–5	44	Wilson et al.	1978	USA	English
$NH_3 + H_2O$	TE	120	1.96–3.16	0.001–5	44	Wilson et al.	1978	USA	English
$NH_3 + LiNO_3$: H_2O	SG	-20–200	0.5–30	16–100	8	Bokelmann et al.	1985	FRG	German

A.2.1. Vapor-Liquid Equilibrium

$H_2O + LiBr$	P	4–182	NA	30–100	35	Patterson et al.	1988	USA	English
$H_2O + LiI$	GES	60–150	4–100(1)	15–35	5	Bach et al.	1967	USA	English
$H_2O + H_2SO_4$	GS	-20–200	0.1–100(1)	5–100	36	Plank	1959	FRG	German
$H_2O + KOH$: NaOH	GS	-10–130	20–10,000(1)	30–100	36	Plank	1959	FRG	German

X – Liquid Phase (R) – Refrigerant NA – Not Available
Y – Vapor Phase (1) – mm Hg

A.2.1. Vapor-Liquid Equilibrium

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
H_2O + NMC	SG	40–120	0.02–0.85	18–100	37	Rakette et al.	1987	DDR	English
H_2O + NMMNO	GE	40–120	0.01–1.0	7–100	37	Rakette et al.	1987	DDR	English
H_2O + LiBr: $ZnCl_2$	SG	0–200	0.0103–1.03	28–100	34	Ouchi et al.	1982	Japan	Japanese
H_2O + LiBr: $ZnCl_2$	SG	-16–20	0.0055–0.238	29.7–89.8	43	Uemura et al.	1982b	Japan	Japanese
H_2O + NMC: $CaCl_2$	SG	42–120	<0.01–0.65	7–10	37	Rakette et al.	1987	DDR	English
H_2O + $LiNO_3$: KNO_3:$NaNO_3$	GS	54.4–260	40–10,000(1)	7.5–30	3	Ally	1988b	USA	English
H_2O + $LiNO_3$: KNO_3:$NaNO_3$	TEG	75–275	0.1–14	7.5–30	2	Ally	1988a	USA	English

X – Liquid Phase (R) – Refrigerant
Y – Vapor Phase (1) – mm Hg

A.3.1. Vapor-Liquid Equilibrium

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
CH_3OH + LiBr	SG	-10–52	NA	4.0–100	9	Bokelmnn et al.	1982	FRG	English
CH_3OH + LiBr	GE	9.5–67.3	14–840(2)	59.64–83.08	20	Eichholz	1980	FRG	English
CH_3OH + LiBr	TEG	-10–170.5	1.4–3070(2)	39.66–74.72	39	Renz et al.	1980	FRG	English
CH_3OH + LiSCN	GE	-10–68	NA	40–100	9	Bokelmann et al.	1982	FRG	English
CH_3OH + $ZnBr_2$	GE	-10–70	NA	24–100	9	Bokelmann et al.	1982	FRG	English
CH_3OH + LiBr: $ZnBr_2$ (1:1) (W)	GE	-10–34	NA	24–100	9	Bokelmann et al.	1982	FRG	English
CH_3OH + $LiBr_3$: $ZnBr_2$ (1:1) (W)	SG	-20–120	1–1000(2)	20–100	9	Bokelmann et al.	1982	FRG	German
C_2H_5OH + LiI	EG	-17–30	0.0185–0.268	50.7–94.7	42	Uemura et al.	1982a	Japan	Japanese

X – Liquid Phase (R) – Refrigerant (M) – Mole, (W) – Weight
Y – Vapor Phase (2) – mbar NA – Not Available

A.4.1. Vapor-Liquid Equilibrium

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
$CH_3NH_2 + H_2O$	TE	1–90	7–4871(1)	1.7–48.6	21	Felsing et al.	1929	USA	English
$CH_3NH_2 + H_2O$	GE	-40–180	0.2–10	0–100	36	Plank	1959	Germany	English

X – Liquid Phase (R) – Refrigerant
Y – Vapor Phase (1) – mm Hg

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A.6.1. Vapor-Liquid Equilibrium

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
R22 + DMF	TEGC	-43–260	1–20	0–100	1	Agarwal et al.	1985	India	English
R22 + DMF	GEP	22–100	0.008–203(1)	22.8–91.4	18	Chen et al.	1985	China	English
R22 + DMEDEG	GESP	-20–200	0.1–50	10–100	4	Ando et al.	1984	Japan	English
R22 - DMF	GC	37.8–107.2	1.3–13.7	0–70	7	Bhaduri et al.	1987	India	English
R22 - DMA	GC	0–100	1–25	8–95	7	Bhaduri et al.	1987	India	English
R22 + DMA	TEP	26–93	1.7–12.5	16.0–49.2	6	Bhaduri et al.	1985	India	English
R22 + CCH	TE	28–89	1.9–13.9	17.2–45.2	6	Bhaduri et al.	1985	India	English
R22 - PYR	GE	0–150	0–30	0–100	13	Borde	1988	Israel	English
R22 + NMP	GS	0–140	1–26	0–100	16	Borde et al.	1987c	Israel	English
R22 + DMETEG	GS	0–120	0.1–30	0–100	27	Jelinek et al.	1980	Israel	English
R22 + DMA	GS	0–150	1–25	0–100	15	Borde	1987b	Israel	English
R22 + DMMP	GS	0–140	1–24	0–100	14	Borde	1987a	Israel	English

X – Liquid Phase Y – Vapor Phase (R) – Refrigerant (1) – mm Hg

A.12.1. Vapor-Liquid Equilibrium

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
TFE + QUN	SG	-18–165	1–1000(2)	10–50	10	Bokelmann et al.	1986	FRG	English
TFE + QUN	SG	-16–180	1–1000(2)	5–35	9	Bokelmann et al.	1982	FRG	English
TFE + HMPT	SG	-20–170	1–1000(2)	36–60	9	Bokelmann et al.	1982	FRG	English
TFE + DMETEG	SG	-16–180	1–1000(2)	5–50	10	Bokelmann et al.	1986	FRG	English
TFE + PYR	SG	-16–190	1–1000(2)	15–60	10	Bokelmann et al.	1986	FRG	English
TFE + NMP	SG	-20–200	1–1000(2)	0–100	10	Bokelmann et al.	1986	FRG	English
TFE + NMP	SG	-23–177	0.0031–1.03	0–100	33	Nakayama et al.	1987	Japan	English
TFE + DMETEG	GP	120–200	NA	0–100 0–100	40	Rockenfeller et al.	1986	USA	English
TFE + DBP	GE	190–220	6–9.3	20.1	40	Rockenfeller et al.	1986	USA	English
TFE - DMETEG	GP	80–240	1–20	10–100	40	Rockenfeller et al.	1986	USA	English
HFIP + DMPU	GE	0–200	0.004–40 350(2)	0–100 0–100	17	Bothe et al.	1988	USA	English

X – Liquid Phase (R) – Refrigerant NA – Not Available
Y – Vapor Phase (2) – mbar

A.X.2. Crystallization Temperature

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
H_2O + LiBr: $ZnCl_2$	GE	-4–130	NA	13–26	43	Uemura et al.	1982	Japan	Japanese
H_2O + $LiNO_3$: KNO_3:$NaNO_3$	GS	60.0–193.3	32–155(1)	1–25	3	Ally	1988b	USA	English
CH_3OH + LiBr	GS	-12–60	NA	40–70	28	Knoche et al.	1988	FRG	English
CH_3OH + LiBr (5.9:1) (W)	GS	-20–60	NA	34–70	28	Knoche et al.	1988	FRG	English
C_2H_5OH + LiI	EG	-17–245	NA	26–68	42	Uemura et al.	1982	Japan	Japanese
H_2O + H_2SO_4	GS	-70–100	NA	0–100	36	Plank	1959	FRG	German
H_2O + KOH	GS	-70–100	NA	0–100	36	Plank	1959	FRG	German
H_2O + NaOH	GS	-70–100	NA	0–100	36	Plank	1959	FRG	German

X – Liquid Phase (R) – Refrigerant (M) – Mole, (W) – Weight
Y – Vapor Phase (1) – mm Hg NA – Not Available

A.X.3. Corrosion

Fluid System	Data Type	Temperature Range, °C	Corrosion Inhibitor, wt %	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
H_2O + LiBr: 4-BLN (20:1) (M)	GE	120–160	Benzatriazole 0.1–0.8	42–63	24	Iyoki et al.	1982	Japan	Japanese
H_2O + LiBr: 4-BLN (20:1) (M)	GE	120–160	Tolyltriazole 0.1–0.8 Li-Molybdate 0.1–0.8	42–63	24	Iyoki et al.	1982	Japan	Japanese
TFE + DMETEG	TE	260	NA	NA	40	Rockenfeller et al.	1986	USA	English
NH_3 + LiBr: H_2O	TE	21–218	Chromate Arsenite	NA	31	Modahl et al.	1988	USA	English
H_2O + LiBr	GE	143–227	Carrene DL-16	25–46	38	Reimann et al.	1988	USA	English

X – Liquid Phase (M) – Mole, (W) – Weight NA – Not Available
Y – Vapor Phase (R) – Refrigerant

A.X.4. Heat of Mixing

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
H_2O + LiBr: $ZnCl_2$	GE	25	NA	24.55–100	43	Uemura et al.	1982	Japan	Japanese
CH_3OH + LiBr	GEP	25–60	NA	1–36	20	Eichholz	1980	FRG	English
C_2H_5OH + LiI	TEG	35	NA	44–100	42	Uemura et al.	1982	Japan	Japanese
R22 + DMEDEG	GE	10	NA	0–100	4	Ando et al.	1984	Japan	English
R22 + DMF	GC	30–50	NA	0–100	7	Bhaduri et al.	1987	India	English
R22 + DMA	GC	10–70	NA	0–100	7	Bhaduri et al.	1987	India	English
R22 + PYR	GP	0–150	NA	0–100	13	Borde	1988	Israel	English
R22 + DMF	P	10–90	1–20	10–75	26	Jelinek et al.	1978	Israel	English
R22 + DMA	GP	0–150	NA	0–100	15	Borde	1987b	Israel	English

X – Liquid Phase (R) – Refrigerant
Y – Vapor Phase NA – Not Available

A.X.5. Liquid-Phase Densities

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
H_2O + LiBr	C	100–200	NA	40	2	Ally	1988a	USA	English
H_2O + LiBr	P	NA	NA	NA	35	Patterson et al.	1988	USA	English
H_2O + LiBr: $ZnCl_2$	TE	20–90	NA	24.8–67.6	43	Nemura et al.	1982	Japan	Japanese
CH_3OH + LiBr	TEG	5–90	NA	40–100	39	Renz et al.	1980	FRG	English
TFE + DMETEG	EP	25–180	NA	20.08–30.02	40	Rockenfeller et al.	1986	USA	English
HFIP + DMETEG	GE	20–90	NA	0–100	17	Bothe et al.	1988	FRG	English
R22 + DMF	PGS	-3–87	NA	0–100	19	Dorairaj et al.	1987	India	English

X – Liquid Phase (R) – Refrigerant
Y – Vapor Phase NA – Not Available

A.X.6. Vapor-Liquid Phase Enthalpies

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
$NH_3 + H_2O$	CG	-50–300	0.2–50	NA	29	Kouremenos et al.	1987	Greece	English
NH_3 + NaSCN	P	0–60	NA	35.05–91.14	12	Bonauguri et al.	1980a	Italy	English
H_2O + LiBr	P	0–180	NA	30–100	35	Patterson et al.	1988	USA	English
H_2O + LiBr: $ZnCl_2$	SG	0–300	NA	20–40	34	Ouchi et al.	1982	Japan	Japanese
H_2O + LiBr: $ZNCl_2$	GE	0–200	0.0014–4.12	7–100	43	Uemura et al.	1982	Japan	Japanese
$H_2O + LiNO_3$: KNO_3:$NaNO_3$	GS	125–275	NA	8–30	3	Ally	1988b	USA	English
$H_2O + LiNO_3$: KNO_3:$NaNO_3$	TS	125–275	NA	7.5–30	2	Ally	1988a	USA	English

X – Liquid Phase (R) – Refrigerant
Y – Vapor Phase NA – Not Available

A.X.6. Vapor-Liquid Phase Enthalpies

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
C_2H_5OH + LiI	TE	-30–130	0.00515–4.12	29–100	42	Uemura et al.	1982	Japan	Japanese
TFE + NMP	SG	0–200	1–1000(2)	0–100	8	Bokelmann et al.	1985	FRG	German
TFE + NMP	SG	-40–180	0.00137–1.37	0–100	33	Nakayama et al.	1987	Japan	English
TFE + DMETEG	G	80–260	0.4–14	10–60	40	Rockenfeller et al.	1986	USA	English

X – Liquid Phase (R) – Refrigerant
Y – Vapor Phase (2) – mbar

A.X.6. Vapor-Liquid Phase Enthalpies

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
R22 + DMEDEG	GS	-40–200	0.1–50	0–100	4	Ando et al.	1984	Japan	English
R22 + NMP	SC	0–140	1–26	0–100	16	Borde et al.	1987c	Israel	English
R22 + NMP	GS	0–140	1–26	0–100	16	Borde et al.	1987c	Israel	English
R22 + PYR	GP	0–150	1–26	0–100	13	Borde	1988	Israel	English
R22 + DMETrEG	GS	0–200	0.5–25	0–100	8	Bokelmann et al.	1985	FRG	German
R22 + DMF	GS	10–90	1–20	10–75	26	Jelinek et al.	1978	Israel	English
R123a + DMETEG		0–200	100–5000(2)	0–100	8	Bokelmann et al.	1985	FRG	German
R22 + DMA	GS	0–150	1–26	0–100	15	Borde	1987b	Israel	English
R22 + DMMP	GS	0–140	1–24	0–100	14	Borde	1987a	Israel	English

X – Liquid Phase (R) – Refrigerant
Y – Vapor Phase (2) – mbar

A.X.7. Specific Heat

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
C_2H_5OH + LiI	TE	15–65	NA	44.3–92	42	Uemura et al.	1982	Japan	Japanese
TFE + DMETEG	GE	60–170	NA	24.5	40	Rockenfeller et al.	1986	USA	English
R22 + DMEDEG	GE	-40–120	NA	0–100	4	Ando et al.	1984	Japan	English

X – Liquid Phase (R) – Refrigerant
Y – Vapor Phase NA – Not Available

A.X.8. Stability

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
CH_3OH + LiBr	GE	130–215	NA	45.4–59.2	28	Knoche et al.	1988	FRG	English
CH_3OH + LiBr	GE	145–218	0.05	45.4–59.2	28	Knoche et al.	1988	FRG	English
CH_3OH + LiBr: H_2O (5.9:1) (W)	GE	160–150	NA	43.9	28	Knoche et al.	1988	FRG	English
CH_3OH + LiBr: H_2O (5.9:1) (W)	GE	170–190	0.18	44.1	28	Knoche et al.	1988	FRG	English
CH_3OH + LiBr: H_2O (5.9:1) (W)	GE	137–180	0.45	44.1	28	Knoche et al.	1988	FRG	English
TFE + DBP	E	220–225	NA	20.1	40	Rockenfeller et al.	1986	USA	English
TFE + DMETEG	GE	150–250	NA	0–100	40	Rockenfeller et al.	1986	USA	English
TFE + DMETEG	GE	235	NA	>20	40	Rockenfeller et al.	1986	USA	English
TFE + DMETEG	GE	180	NA	0–100	40	Rockenfeller et al.	1986	USA	English

X – Liquid Phase (M) – Mole, (W) – Weight NA – Not Available
Y – Vapor Phase (R) – Refrigerant

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A.X.9. Viscosity

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
H_2O + LiBr	C	105–190	NA	40	2	Ally	1988a	USA	English
H_2O + LiBr	P	0–90	NA	40–95	35	Patterson et al.	1988	USA	English
H_2O + LiBr: $ZnCL_2$	TEG	20	NA	24.8–67.6	43	Nemura et al.	1982	Japan	Japanese
H_2O + $LiNO_3$: KNO_3:$NaNO_3$	GS	95–180	NA	20	2	Ally	1988a	USA	English
CH_3OH + LiBr	TEG	5–90	NA	40–80	39	Renz et al.	1980	FRG	English
TFE + DMETEG	GE	79.7–120.2	NA	20.1–30.0	40	Rockenfeller et al.	1986	USA	English
HFIP + DMETEG	GE	20–90	NA	0–100	17	Bothe et al.	1988	FRG	English
HFIP + SL	GE	20–70	NA	0–90	17	Bothe et al.	1988	FRG	English
R22 + DMETEG	TEG	-40–105	NA	10–50	11	Bonauguri et al.	1980	Italy	French
R22 + DMF	PGS	-3–87	NA	0–100	19	Dorairaj et al.	1987	India	English

X – Liquid Phase (R) – Refrigerant
Y – Vapor Phase NA – Not Available

A.X.10 and 11. Mass and Heat Transfer Rates

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
H_2O + LiBr	GE	40	9.3(1)	NA	32	Nagaoka et al.	1987	Japan	English
H_2O + LiBr	GE	25.5	NA	40–90	23	Isshiki et al.	1988	Japan	English
NH_3 + H_2O	GE	NA	NA	31	31	Modahl et al.	1988	USA	English

X – Liquid Phase (R) – Refrigerant NA – Not Available
Y – Vapor Phase (1) – mm Hg

A.X.12. Thermal Conductivity

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
H_2O + LiBr	CE	100–195	NA	40	2	Ally	1988a	USA	English
H_2O + LiBr	P	NA	NA	NA	35	Patterson et al.	1988	USA	English
TFE + DMETEG	E	120	NA	24.5	40	Rockenfeller et al.	1986	USA	English
R22 + DMF	PGS	-3–87	NA	0–100	19	Dorairaj et al.	1987	India	English

X – Liquid Phase (R) – Refrigerant
Y – Vapor Phase NA – Not Available

A.X.15. Surface Tension

Fluid System	Data Type	Temperature Range, °C	Pressure Range, atm	Weight, % X (R) Y (R)	Reference No.	Author	Year	Country	Text
$NH_3 + H_2O$	TE	29–167	10.2	24–92	30	Miller	1988	USA	English
$NH_3 + H_2O$	TE	55.6	17.0	77	30	Miller	1988	USA	English
H_2O + LiBr	P	NA	NA	NA	35	Patterson et al.	1988	USA	English
H_2O + LiBr	GE	20–80	NA	NA	41	Uemura	1982	Japan	Japanese
R22 + DMF	PGS	-3–87	NA	0–100	19	Dorairaj et al.	1987	India	English

X – Liquid Phase (R) – Refrigerant
Y – Vapor Phase NA – Not Available