

**ENERGY**

**CONSERVATION**

**ORNL/Sub/84-47989/1**

**Absorption Fluids Data Survey:  
Final Report on USA Data**

R. A. Macriss  
T. S. Zawacki

Report Prepared by  
**INSTITUTE OF GAS TECHNOLOGY**  
3424 South State Street  
Chicago, Illinois 60616

under  
Subcontract 86X-47989C  
for  
**OAK RIDGE NATIONAL LABORATORY**  
operated by  
**MARTIN MARIETTA ENERGY SYSTEMS, INC.**  
for the

**U.S. DEPARTMENT OF ENERGY**  
**OFFICE OF BUILDINGS**  
**AND COMMUNITY SYSTEMS**

Printed in the United States of America. Available from  
National Technical Information Service  
U.S. Department of Commerce  
5285 Port Royal Road, Springfield, Virginia 22161  
NTIS price codes—Printed Copy: A06 Microfiche A01

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, makes 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.

**ABSORPTION FLUIDS DATA SURVEY:  
FINAL REPORT ON USA DATA**

**R. A. Macriss  
T. S. Zawacki**

**Date Published—May 1986**

**Report Prepared by  
INSTITUTE OF GAS TECHNOLOGY  
3424 South State Street  
Chicago, Illinois 60616**

**under  
Subcontract 86X-47989C**

**for**

**OAK RIDGE NATIONAL LABORATORY  
Oak Ridge, Tennessee 37831  
operated by  
MARTIN MARIETTA ENERGY SYSTEMS, INC.  
for the  
U.S. DEPARTMENT OF ENERGY  
under Contract DE-AC05-84OR21400**

## TABLE OF CONTENTS

	<u>Page</u>
LIST OF FIGURES	v
LIST OF TABLES	vii
SUMMARY OF RESULTS	ix
ABSTRACT	xiii
INTRODUCTION	1
METHOD AND SCOPE	2
Fluid Properties and Data	2
Coarse Screening of Literature Data	3
DETAILED PRESENTATIONS AND TABULATIONS	4
1. Refrigerants and Absorbents	4
2. Fluids, Properties, and Number of References with Data	4
3. Fluids, Properties, Data, and Range of Conditions	24
4. Coarse Screening of Data for Selected Fluids	60
5. Gaps in the Data of Key Fluids	75
REFERENCES	89

## LIST OF FIGURES

<u>Figure No.</u>		<u>Page</u>
1	Number of References for Vapor-Liquid Equilibrium Data	13
2	Number of References for Crystallization Temperature Data	19
3	Number of References for Corrosion and Heat of Mixing Data	20
4	Number of References for Liquid-Phase Density and Enthalpy Data	21
5	Number of References for Specific Heat and Stability Data	22
6	Number of References for Various Binary Mixture Properties Data	23
7	Comparison of Measured and Predicted Vapor Composition of the NH <sub>3</sub> + H <sub>2</sub> O Pair at 140°F	62
8	Comparison of Ammonia-Water Enthalpy Data at 140°F	64
9	Comparison of Methylamine + Sodium Thiocyanate Vapor Pressure Data	66
10	Comparison of Methanol + Lithium Bromide Vapor Pressure Data	68
11	Comparison of Methanol + LiBr: ZnBr <sub>2</sub> (2:1) Vapor Pressure Data	69
12	Comparison of R21+ DMETEG Vapor Pressure Data	72
13	Comparison of R22 + DMA Vapor Pressure Data	73
14	Comparison of R21 + DMH and R22 - DMH Vapor Pressure Data	74
15	Gaps in Vapor-Liquid Equilibrium Data	76
16	Gaps in Crystallization Temperature Data	77
17	Gaps in Corrosion Data	78
18	Gaps in Toxicity Data	79
19	Gaps in Heat and Mass Transfer Data	80

## LIST OF FIGURES (Cont.)

<u>Figure No.</u>		<u>Page</u>
20	Gaps in Viscosity Data	81
21	Gaps in Vapor- and Liquid-Phase Enthalpy Data	82
22	Gaps in Thermal Conductivity Data	83
23	Gaps in Specific Heat Data	84
24	Gaps in Density Data	85
25	Gaps in Stability Data	86
26	Gaps in Heat Transfer Additive Data	87
27	Gaps in Corrosion Inhibitor Data	88

## LIST OF TABLES

<u>Table No.</u>		<u>Page</u>
1.0	Refrigerants	5
2.0	Absorbents (Inorganic)	6
3.0	Absorbents (Organic)	7
4.0	Absorbents (Multicomponent)	10
5.0	List of Arbitrary Abbreviations for Absorbent Compounds	11
6.0	Ammonia Binary and Multicomponent Absorption Fluids Properties Data	26
7.0	Water Binary and Multicomponent Absorption Fluids Properties Data	33
8.0	Alcohols Binary and Multicomponent Absorption Fluids Properties Data	41
9.0	Amines Binary and Multicomponent Absorption Fluids Properties Data	42
10.0	Sulfur Dioxide Binary and Multicomponent Absorption Fluids Properties Data	45
11.0	Halocarbon Refrigerant Binary and Multicomponent Absorption Fluids Properties Data	46
12.0	Refrigerant 22 Binary and Multicomponent Absorption Fluids Properties Data	47
13.0	Refrigerant 21 Binary and Multicomponent Absorption Fluids Properties Data	51
14.0	Refrigerant 12 Binary and Multicomponent Absorption Fluids Properties Data	55
15.0	Refrigerants 31, 30, 11, and 134 Binary and Multicomponent Absorption Fluids Properties Data	56
16.0	Refrigerants 124a, 133a, and 123a Binary and Multicomponent Absorption Fluids Properties Data	57
17.0	Refrigerant 123a Binary and Multicomponent Absorption Fluids Properties Data	59
18.0	Deviation of Solubility Data From Various Sources From the Final Smoothed Values for R22-DMETEG	71

## SUMMARY OF RESULTS

Over 150 different U.S. publications containing data relating to properties of binary, ternary, and multicomponent absorption fluids were identified. After elimination of duplication through cross-checking, 67 primary sources of data were selected and the actual documents acquired. The publications date as far back as 1925, with nearly 80% of the documents published between 1950 and 1983.

The absorption fluids covered in the 67 documents are combinations of 25 different "refrigerant" compounds and 67 single, 30 binary and 4 ternary "absorbent" compounds. Generally, the 25 refrigerants are divided among the following categories of chemical compounds:

Refrigerants

INORGANIC	3
ORGANIC	22
● Amines	3
● Alcohols	3
● Halogenated	16

Likewise, the single absorbent compounds are generally subdivided as follows:

Absorbents

INORGANIC	31
ORGANIC	48
● Alcohols	6
● Ethers	5
● Alcohol-Ethers	2
● Amides	8
● Amines	3
● Amine-Alcohol	1
● Esters	9
● Ketones	5
● Acids	3
● Aldehyde	1
● Others	4

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

In terms of absorption fluids properties, for which data are available in the 67 primary documents, the list shown below reveals that vapor-liquid equilibrium is the predominant property, reported in almost 60% of the documents. Flammability of fluids, on the other hand, is reported in only one document.

Thermodynamic, Transport, and Other Data

<u>Fluid Property</u>	<u>Number of References*</u>
Vapor-Liquid Equilibrium	46
Enthalpy	4
Density	7
Corrosion (and inhibitors)	5
Stability	6
Transport Properties	13 (Viscosity, surface tension, additives, heat and mass transfer, etc.)
Heat of Mixing	10
Crystallization	14
Toxicity	2
Flammability	1

The number of references available for each of the key absorption fluids, currently of interest to researchers of advanced absorption heat pumps, is shown below:

<u>Key Fluid</u>	<u>Number of Data References</u>
NH <sub>3</sub> /H <sub>2</sub> O	15
H <sub>2</sub> O/LiBr	20
R123a/ETFE	1
R22/DMTEG	11
NH <sub>3</sub> /H <sub>2</sub> O + LiBr	0
CH <sub>3</sub> NH <sub>2</sub> /H <sub>2</sub> O + LiBr	0

---

\* A given document may contain data relating to more than one property; therefore, the sum of the references is larger than 67.

The absolute lack of data for the last two fluids on this list is obvious, but the fact that there is only one reference for the R123a/ETFE fluid is misleading. Although only one organization has a proprietary interest in this fluid, the single reference covers adequate amounts of data for most properties of interest.

Coarse screening and evaluations were carried out as part of this study for selected or key absorption fluids. Several approaches were considered for the review and coarse screening of data from multiple sources. These include —

- Consideration of the author's statements concerning data quality
- Assessment of the measurement technique and apparatus used to develop the data
- Consideration of a given author's reputation for measuring data, where only one author's data were available for a fluid
- Comparison of data plots for a given fluid using data scatter and internal consistency criteria to judge data quality, and multiple-author data agreement
- Consideration of general trends of the plotted data, as inferred from data for similar or homologous series fluids.

The data screening indicated that the large number of references for fluids NH<sub>3</sub>/H<sub>2</sub>O and R22/DMETEG may be misleading for the following reasons:

- Most current research with the NH<sub>3</sub>/H<sub>2</sub>O fluid is concentrated on advanced cycle designs, with operating conditions (temperature, pressure) beyond the limits of currently available data.
- Data for several important properties (heat and mass transfer rates, stability) and for operating conditions beyond present limits for other properties, are not available.

Further, the existence of unresolved conflicts in important data of various fluids has been noted.

Data gaps for key fluids have been summarized. Unresolved or potential conflicts in the data, lack of data for known key fluids at conditions beyond the limits of present data, and new fluids without property data constitute these summaries. A prioritized system of the need to fill such gaps, on a fluid-by-fluid and property-by-property basis, was devised for quick reference.

With very few exceptions, among key fluids and their properties, and with emphasis toward the current development activities dealing with advanced absorption heat pump concepts, almost all candidate fluids have data gaps that need to be addressed in the near future.

## ABSTRACT

In an 8-month evaluation, 150 different U.S. publications containing data that relate to properties of binary, ternary, and multicomponent absorption fluids were identified; from these publications, 67 were selected as primary sources of relevant U.S. data. Fluids covered include combinations of 25 different refrigerant compounds, as well as of 67 single, 30 binary, and 4 ternary absorbent compounds. Generally, the 25 refrigerants are divided among the following categories of chemical compounds — INORGANIC 3, ORGANIC 22 (amines 3, alcohols 3, halogenated 16). Likewise, the single absorbent compounds generally are subdivided as follows — INORGANIC 31, ORGANIC 48 (alcohols 6, ethers 5, alcohol-ethers 2, amides 8, amines 3, amine-alcohol 1, esters 9, ketones 5, acids 3, aldehyde 1, others 4). The binary and ternary absorbents are various mixtures of two or more single absorbent compounds. Coarse screening and evaluations were performed. Data gaps for key fluids are summarized and unresolved conflicts in data are noted. Results show that, with very few exceptions, all candidate fluids for development activities dealing with advanced absorption heat pump concepts have data gaps that must be addressed in the near future.

## INTRODUCTION

Over the past 50 years, a wealth of physical and thermodynamic property data has been developed in the U.S. for fluid systems potentially applicable to the absorption refrigeration/heat pump cycle. A significant portion of the data is available in the literature, some data remain confined to in-house files for various reasons, and other data are proprietary but could be made available under certain conditions or terms.

Generally, published data have been generated in areas of temperature, pressure, and composition of interest to designers of absorption chillers or coolers. Recent research has focused on developing efficient cycle configurations, using multi-effect or multi-stage concepts, for both space heating and cooling. These new designs operate at temperatures and pressures significantly higher than those encountered in the conventional absorption cooling cycle. Other new concepts are based on the addition of a third component to the binary solutions normally used in the conventional cycle.

In an effort to define the availability and quality of existing data and thereby 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 literature data in order to identify potential conflicts or gaps in the data for certain key fluid systems. This report provides a detailed account of IGT's findings.

In a separate, parallel effort, IGT has been carrying out a liaison activity with researchers and manufacturers known to possess other unpublished data that may be useful to this program. The objective of this effort is to identify these data and the procedures by which the actual data, or information about data type and range of conditions, can be made available to this project. With the addition of these data, ultimate definition of data gaps and needs can be based on all potentially available data. The results of this effort are not included in this report because the liaison activity is still in progress.

## METHOD AND SCOPE

In-house-files were examined and literature searches were undertaken to obtain available U.S. publications — several dating back to the 1920's — on pertinent physical, thermodynamic, and transport properties of absorption fluids. An absorption fluid is composed of a "refrigerant" compound and one or more "absorbent" compounds, resulting in either binary, ternary, or multi-component fluids. 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.

### 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 the type of fluid and property, as well as the temperature, pressure, and concentration ranges over which data were available. Data were sought for at least 14 different properties, as follows:

### Mixture Properties

- |                                  |                          |
|----------------------------------|--------------------------|
| 1. Vapor-Liquid Equilibria       | 8. Stability             |
| 2. Crystallization Temperature   | 9. Viscosity             |
| 3. Corrosion Characteristics     | 10. Mass Transfer Rate   |
| 4. Heat of Mixing                | 11. Heat Transfer Rate   |
| 5. Liquid-Phase Densities        | 12. Thermal Conductivity |
| 6. Vapor-Liquid-Phase Enthalpies | 13. Flammability         |
| 7. Specific Heat                 | 14. Toxicity             |

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:

<u>Form of Data</u>	<u>Symbol</u>
RAW EXPERIMENTAL	(E)
● Tabular	(T)
● Graphical	(S)
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. Such correlations are at best as good as the experimental data and 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 possess greater uncertainties than the previous forms of data.

#### Coarse Screening of Literature Data

Several approaches have been used in carrying out quality review and coarse screening of data from multiple sources for each of several key or highest priority binary and ternary fluids. These alternative approaches include —

- Consideration of the author's statements concerning data quality
- Assessment of the measurement technique and apparatus used in obtaining the data
- Consideration of a given author's reputation for measuring data, where only one author's data were available for a fluid.

A more reliable method used to compare data from various sources, for a given fluid and property, has been the plotting of data on a common basis. Such plots have also served to reveal the amount of scatter or internal consistency of a given author's data and, therefore, its quality. Another approach was based on consideration of general trends of the plotted data, as inferred from data for similar or homologous series fluids.

## DETAILED PRESENTATIONS AND TABULATIONS

As previously implied, this report has been organized to cover the various work elements of this study in their natural sequence. This portion of the report contains in detail the refrigerants and absorbents of the absorption fluids of this study, the reference material accumulated, the range of conditions over which property data exist for each fluid, the results of the coarse screening of data for key fluids, and a list of gaps in the data of the key fluids.

### 1. Refrigerants and Absorbents

Table 1.0 lists the 25 refrigerants grouped into four distinct chemical compound categories: inorganic, amines, alcohols, and halogenated organics. For each refrigerant, Table 1.0 contains a compound number, chemical formula and name, molecular weight, and normal boiling point.

Table 2.0 lists 31 single, inorganic absorbents and a number, chemical formula, name and molecular weight for each. Table 3.0 lists 45 single, organic absorbents grouped into 10 distinct chemical compound categories: alcohols, ethers, alcohol-ethers, amides, amines, amine-alcohols, esters, ketones, acids, aldehydes, and an undefined catch-all category. For each organic absorbent, Table 3.0 contains a compound number, an arbitrary abbreviation of convenience, chemical formula and name, molecular weight, and normal boiling point.

Table 4.0 lists 34 multicomponent (binary and ternary) absorbents with access number and chemical formula. Table 5.0 is an alphabetical summary of the arbitrary abbreviations keyed to the chemical name of the organic absorbent.

### 2. Fluids, Properties, and Number of References With Data

For each fluid and property addressed in this study, the availability of data can be quickly and readily assessed in a series of triangular diagrams. In each of these figures, the number of references for each fluid and property with data available is placed in a grid. Blank grids in these charts represent fluid and/or properties for which no data references have been found. Where a large number of references are indicated in the grid for a particular fluid and property of interest, data gaps are expected to be less critical. Where a blank grid appears for a fluid system of high priority, a critical need is suspected.

Table 1.0. REFRIGERANTS

<u>Number</u>	<u>Chemical Formula</u>	<u>Name</u>	<u>MW</u>	<u>NBP, °F</u>
<b>Inorganic</b>				
1	NH <sub>3</sub>	Ammonia	17.0	-28
2	H <sub>2</sub> O	Water	18.0	212
3	SO <sub>2</sub>	Sulfur dioxide	64.1	14
<b>Amines</b>				
4	CH <sub>3</sub> NH <sub>2</sub>	Methylamine	31.1	21
5	(CH <sub>3</sub> ) <sub>2</sub> NH	Dimethylamine	45.1	45
6	(CH <sub>3</sub> ) <sub>3</sub> N	Trimethylamine	59.1	37
<b>Alcohols</b>				
7	CH <sub>3</sub> OH	Methanol	32.0	149
8	C <sub>2</sub> H <sub>5</sub> OH	Ethanol	46.1	173
9	C <sub>3</sub> H <sub>7</sub> OH	n-Propanol	60.1	207
<b>Halogenated Organics</b>				
10	CCl <sub>3</sub> F	Refrigerant 11	137.4	75
11	CCl <sub>2</sub> F <sub>2</sub>	Refrigerant 12	120.9	-21
12	CHFCl <sub>2</sub>	Refrigerant 21	102.9	48
13	CHF <sub>2</sub> Cl	Refrigerant 22	86.5	-41
14	CH <sub>2</sub> Cl <sub>2</sub>	Refrigerant 30	84.9	104
15	CH <sub>2</sub> ClF	Refrigerant 31	68.5	16
16	CF <sub>3</sub> CHCl <sub>2</sub>	Refrigerant 123b	152.9	82
17	CHF <sub>2</sub> CClF <sub>2</sub>	Refrigerant 124a	136.5	15
18	CHCl <sub>2</sub> CHClF	Refrigerant 131a	151.4	185
19	CHF <sub>2</sub> CHClF	Refrigerant 133a	118.5	42
20	CHF <sub>2</sub> CHF <sub>2</sub>	Refrigerant 134	102.0	49
21	CCl <sub>2</sub> HCClH <sub>2</sub>	Refrigerant 140a	133.4	235
22	CHClCHCl	Refrigerant 1130	96.9	138
23	CClFCClF	Refrigerant 1112a	132.4	66
24	CCl <sub>2</sub> CClH	Refrigerant 1120	131.4	180
25	CHClFCCLF <sub>2</sub>	Refrigerant 123a	152.9	85

Table 2.0. ABSORBENTS  
(Inorganic)

Number	Chemical Formula	Name	MW
1	H <sub>2</sub> O	Water	18.0
2	LiBr	Lithium bromide	86.8
3	LiCl	Lithium chloride	42.4
4	LiI	Lithium iodide	133.8
5	LiNO <sub>2</sub>	Lithium nitrite	52.9
6	LiNO <sub>3</sub>	Lithium nitrate	68.9
7	LiSCN	Lithium thiocyanate	65.0
8	LiBF <sub>4</sub>	Lithium tetrafluoroborate	93.7
9	LiCF <sub>3</sub> CO <sub>2</sub>	Lithium trifluoroacetate	112.0
10	LiC <sub>2</sub> Cl <sub>3</sub> CO <sub>2</sub>	Lithium trichloroacetate	169.3
11	LiClO <sub>3</sub>	Lithium chlorate	90.4
12	CsCl	Cesium chloride	168.4
13	CsBr	Cesium bromide	212.8
14	CsF	Cesium fluoride	151.9
15	CsC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>	Cesium acetate	192.0
16	KF	Potassium fluoride	58.1
17	ZnCl <sub>2</sub>	Zinc chloride	136.3
18	ZnBr <sub>2</sub>	Zinc bromide	225.2
19	ZnNO <sub>3</sub>	Zinc nitrate	127.4
20	Zn(SCN) <sub>2</sub>	Zinc thiocyanate	181.5
21	RbF	Rubidium fluoride	104.5
22	NaSCN	Sodium thiocyanate	81.1
23	NH <sub>4</sub> I	Ammonium iodide	144.9
24	NaI	Sodium iodide	149.9
25	Ni(SCN) <sub>x</sub>	Nickel thiocyanate	ND
26	Co(SCN) <sub>2</sub>	Cobalt thiocyanate	175.1
27	CuSCN	Cuprous thiocyanate	121.6
28	Cu(SCN) <sub>2</sub>	Cupric thiocyanate	179.7
29	NaBr	Sodium bromide	102.9
30	NH <sub>4</sub> Br	Ammonium bromide	98.0
31	LiH <sub>2</sub> PO <sub>3</sub>	Lithium hydrogen phosphite	96.1

Table 3.0. ABSORBENTS  
(Organic)

No.	Abbrev.	Chemical Formula	Name	MW	NBP, °F
<u>Alcohols</u>					
32	BDL	HOC <sub>4</sub> H <sub>8</sub> OH	1, 4 - Butanediol	90.1	455
33	BDL	CH <sub>3</sub> CHOHCHOHCH <sub>3</sub>	2, 3 - Butanediol	90.1	358
34	TEG	H(OC <sub>2</sub> H <sub>4</sub> ) <sub>4</sub> OH	Tetraethylene glycol	194.2	622
35	EG	HOC <sub>2</sub> H <sub>4</sub> OH	Ethylene glycol	62.1	388
36	n-HA	n-C <sub>7</sub> H <sub>15</sub> OH	n-Heptyl alcohol	116.2	349
37	BA	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> OH	Benzyl alcohol	108.2	402
<u>Ethers</u>					
38	DMEDEG	CH <sub>3</sub> (OC <sub>2</sub> H <sub>4</sub> ) <sub>2</sub> OCH <sub>3</sub>	Dimethylether diethylene glycol	134.2	324
39	DMETREG	CH <sub>3</sub> (OC <sub>2</sub> H <sub>4</sub> ) <sub>3</sub> OCH <sub>3</sub>	Dimethylether triethylene glycol	178.2	421
40	DMETEG	CH <sub>3</sub> (OC <sub>2</sub> H <sub>4</sub> ) <sub>4</sub> OCH <sub>3</sub>	Dimethylether tetraethylene glycol	222.3	528
41	DBC	C <sub>4</sub> H <sub>9</sub> (OC <sub>2</sub> H <sub>4</sub> ) <sub>2</sub> OC <sub>4</sub> H <sub>9</sub>	Dibutyl carbitol	218.3	ND
42	ETFE	(C <sub>4</sub> H <sub>7</sub> O)CH <sub>2</sub> OC <sub>2</sub> H <sub>5</sub>	Ethyl tetrahydro furfuryl ether	130.2	316
<u>Alcohol-Ethers</u>					
43	MEDEG	H(OC <sub>2</sub> H <sub>4</sub> ) <sub>2</sub> OC <sub>2</sub> H <sub>5</sub>	Monoethylether diethylene glycol	134.2	383
44	METrPG	C <sub>2</sub> H <sub>5</sub> (OC <sub>3</sub> H <sub>6</sub> ) <sub>3</sub> OH	Monomethylether of tripropylene glycol	220.3	ND
<u>Amides</u>					
45	DMF	CHON(CH <sub>3</sub> ) <sub>2</sub>	N, N - Dimethyl formamide	73.1	302
46	DMA	CH <sub>3</sub> CON(CH <sub>3</sub> ) <sub>2</sub>	N, N - Dimethyl acetamide	87.1	329
47	DMH	C <sub>5</sub> H <sub>11</sub> CON(CH <sub>3</sub> ) <sub>2</sub>	N, N - Dimethyl hexanamide	143.2	428
48	DMD	C <sub>11</sub> H <sub>23</sub> CON(CH <sub>3</sub> ) <sub>2</sub>	N, N - Dimethyl dodecanamide	217.3	ND
49	DEF	CHON(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub>	N, N - Diethyl formamide	101.2	351
50	TMM	(CH <sub>3</sub> ) <sub>2</sub> NCOCH <sub>2</sub> CONCOH <sub>3</sub> ) <sub>2</sub>	N, N, N, N - Tetramethylmalonamide	158.2	ND
51	TMS	[(CH <sub>3</sub> ) <sub>2</sub> N-CO-CH <sub>2</sub> -] <sub>2</sub>	N, N, N, N - Tetramethylsuccinamide	172.2	ND
52	DMAN	C <sub>6</sub> H <sub>5</sub> N(CH <sub>3</sub> ) <sub>2</sub>	N, N - Dimethyl aniline	121.2	381

Table 3.0. (Cont.)

No.	Abbrev.	Chemical Formula	Name	MW	NBP, °F
<u>Amines</u>					
53	MCAN	C <sub>6</sub> H <sub>5</sub> CLNH <sub>2</sub>	M-Chloro aniline	127.6	446
54	AN	C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub>	Aniline	93.1	363
55	OCA	C <sub>8</sub> H <sub>17</sub> NH <sub>2</sub>	Octylamine	129.3	359
<u>Amine-Alcohol</u>					
56	MEA	H <sub>2</sub> NCH <sub>2</sub> CH <sub>2</sub> OH	Ethanolamine	61.1	338
<u>Esters</u>					
57	ETL	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>10</sub> CO <sub>2</sub> C <sub>2</sub> H <sub>5</sub>	Ethyl laurate	222.4	523
58	DEO	C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> CCO <sub>2</sub> C <sub>2</sub> H <sub>5</sub>	Diethyl oxalate	146.1	366
59	DEAP	C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> C(C <sub>2</sub> H <sub>4</sub> ) <sub>4</sub> CO <sub>2</sub> C <sub>2</sub> H <sub>5</sub>	Diethyl adipate	202.2	473
60	DEM	CH <sub>2</sub> (CO <sub>2</sub> C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub>	Diethyl malonate	160.2	391
61	EB	C <sub>6</sub> H <sub>5</sub> CO <sub>2</sub> C <sub>2</sub> H <sub>5</sub>	Ethyl benzoate	150.2	415
62	n-BB	C <sub>6</sub> H <sub>5</sub> CO <sub>2</sub> C <sub>4</sub> H <sub>9</sub>	n-Butyl benzoate	178.2	483
63	DOS	C <sub>8</sub> H <sub>7</sub> O <sub>2</sub> C(CH <sub>2</sub> ) <sub>8</sub> CO <sub>2</sub> C <sub>8</sub> H <sub>17</sub>	Diocetyl sebacate	426.7	ND
64	TAN	CH <sub>3</sub> CO <sub>2</sub> CH(CH <sub>2</sub> O <sub>2</sub> CCH <sub>3</sub> ) <sub>2</sub>	Triacetin	218.2	498
65	DOPL	C <sub>6</sub> H <sub>4</sub> (CO <sub>2</sub> C <sub>8</sub> H <sub>17</sub> ) <sub>2</sub>	Diocetyl phthalate	372.4	ND
<u>Ketones</u>					
66	2-(OCN)	C <sub>8</sub> H <sub>16</sub> O	2 - Octanone	128.2	343
67	4, BLN	(CH <sub>2</sub> ) <sub>3</sub> CO <sub>2</sub>	4 - Butyrolactone	86.1	403
68	NMP	C <sub>5</sub> H <sub>9</sub> NO	N - Methyl - 2 - pyrrolidone	99.1	394
69	2,4 PON	CH <sub>3</sub> COCH <sub>2</sub> COCH <sub>3</sub>	2 - 4 pentanedione	100.1	282
70	APN	C <sub>6</sub> H <sub>5</sub> COCH <sub>3</sub>	Acetophenone	120.2	396
<u>Acids</u>					
71	LLA	C <sub>18</sub> H <sub>32</sub> O <sub>2</sub>	Linoleic acid	280.5	ND
72	OA	C <sub>18</sub> H <sub>34</sub> O <sub>2</sub>	Oleic acid	282.5	689
73	VA	C <sub>5</sub> H <sub>10</sub> O <sub>2</sub>	Valeric acid	102.1	367

Table 3.0. (Cont.)

No.	Abbrev.	Chemical Formula	Name	MW	NBP, °F
<u>Aldehydes</u>					
74	BAD	C <sub>7</sub> H <sub>6</sub> O	Benzaldehyde	106.1	353
<u>Others</u>					
75	NB	C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	Nitrobenzene	123.1	411
76	PDS	ND	Polydimethylsiloxane	ND	ND
77	OC	C <sub>9</sub> H <sub>17</sub> N	Octyl cyanide	139.2	436
78	MM	C <sub>5</sub> H <sub>11</sub> NO	N - Methylmorpholine	101.2	241
79	LBS	C <sub>6</sub> H <sub>5</sub> SO <sub>3</sub> Li	Lithium benzenesulfonate	164.1	ND

Table 4.0. ABSORBENTS  
(Multicomponent)

Binary			Ternary		
No.	Chemical Formula	No.	Chemical Formula	No.	Chemical Formula
B-1	LiBr: LiCl	B-18	LiSCN: 1, 4 BDL	T-1	LiBr: ZnBr <sub>2</sub> : CaBr <sub>2</sub>
B-2	LiBr: LiSCN	B-19	LiSCN: MEA	T-2	LiBr: CsBr: RbBr
B-3	LiBr: LiClO <sub>3</sub>	B-20	LiSCN: DMF	T-3	LiBr: RbF: CsF
B-4	LiBr: CsBr	B-21	NaSCN: NaI	T-4	NaSCN: NaI: 1, 4 BDL
B-5	LiBr: ZnBr <sub>2</sub>	B-22	NaSCN: TEG		
B-6	LiBr: MEA	B-23	NaSCN: 1, 4 BDL		
B-7	LiBr: EG	B-24	NaI: 1, 4 BDL		
B-8	LiCl: LiAcetate	B-25	NH <sub>4</sub> I: 1, 4 BDL		
B-9	LiCl: CsCl	B-26	CsF: RbF		
B-10	LiCl: ZnBr <sub>2</sub>	B-27	DMETEG: BA		
B-11	LiCl: ZnCl <sub>2</sub>	B-28	DMETEG: DMF		
B-12	LiCl: LiSCN	B-29	R22: DMETEG		
B-13	LiI: EG	B-30	R22: DMA		
B-14	LiNO <sub>2</sub> : LiClO <sub>3</sub>				
B-15	LiSCN: NaSCN				
B-16	LiSCN: DMETEG				
B-17	LiSCN: EG				

Table 5.0. LIST OF ARBITRARY ABBREVIATIONS FOR ABSORBENT COMPOUNDS

<u>Abbreviation</u>	<u>Chemical Name</u>
AN	Aniline
APN	Acetophenone
BA	Benzyl alcohol
BAD	Benzaldehyde
BDL	1, 4 - Butanediol
BDL	2, 3 - Butanediol
DBC	Dibutyl Carbitol
DEAP	Diethyl adipate
DEF	N, N - Diethyl formamide
DEM	Diethyl malonate
DEO	Diethyl oxalate
DMA	N, N - Dimethyl acetamide
DMAN	N, N - Dimethyl aniline
DMD	N, N - Dimethyl dodecanamide
DMEDEG	Dimethylether diethylene glycol
DMETEG	Dimethylether tetraethylene glycol
DMETrEG	Dimethylether triethylene glycol
DMF	N, N - Dimethyl formamide
DMH	N, N - Dimethyl hexanamide
DOPL	Dioctyl phthalate
DOS	Dioctyl sebacate
EB	Ethyl benzoate
EG	Ethylene glycol
ETFE	Ethyl tetrahydro furfuryl ether
ETL	Ethyl laurate
LBS	Lithium benzenesulfonate
LLA	Linoleic acid
MCAN	M-Chloro aniline
MEA	Ethanolamine
MEDEG	Monoethylether diethylene glycol
METrPG	Monomethylether of tripropylene glycol
MM	N - Methylmorpholine
n-BB	n-Butyl benzoate
n-HA	n-Heptyl alcohol
NB	Nitrobenzene
NMP	N - Methyl - 2 - pyrrolidone
OA	Oleic acid
OC	Octyl cyanide
OCA	Octylamine
PDS	Polydimethylsiloxane
TAN	Triacetin
TEG	Tetraethylene glycol
TMM	N, N, N, N - Tetramethylmalonamide
TMS	N, N, N, N - Tetramethylsuccinamide
VA	Valeric acid
2-(OCN)	2 - Octanone
2,4 PON	2 - 4 pentanedione
4, BLN	4 - Butyrolactone

Figure 1 lists the fluids and the number of references with Vapor-Liquid Equilibrium data available for each. Figure 2 lists the fluids and the number of references for each fluid with data on Crystallization Temperature. Similarly, Figure 3 lists the number of references for data on Corrosion and Heat of Mixing, Figure 4 for Liquid-Phase Density and Vapor and Liquid-Phase Enthalpy data, Figure 5 for Specific Heat and Stability Data, and Figure 6 for Viscosity, Mass and Heat Transfer Rates, Thermal Conductivity, Flammability, and Toxicity.

For each of the key absorption fluids, currently of interest to researchers of advanced absorption heat pumps, a brief assessment of available data by means of Figures 1 through 6 reveals the following:

<u>Key Fluid</u>	<u>Number of Data References</u>
NH <sub>3</sub> /H <sub>2</sub> O	15
H <sub>2</sub> O/LiBr	20
R123a/ETFE	1
R22/DMETEG	11
NH <sub>3</sub> /H <sub>2</sub> O + LiBr	0
CH <sub>3</sub> NH <sub>2</sub> /H <sub>2</sub> O + LiBr	0

The absolute lack of data for the last two fluids on this list is obvious, but the fact that there is only one reference for the R123a/ETFE fluid is misleading. Although only one organization has a proprietary interest in this fluid, the single reference covers adequate amounts of data for most properties of interest.

In the same vein, the large number of references for fluids NH<sub>3</sub>/H<sub>2</sub>O and R22/DMETEG may be misleading for the following reasons:

- Most current research with the NH<sub>3</sub>/H<sub>2</sub>O fluid is concentrated on advanced cycle designs, with operating conditions (temperature, pressure) beyond the limits of currently available data.
- Data for several important properties (heat and mass transfer rates, stability) and for operating conditions beyond present limits for other properties, are not available.
- The existence of unresolved conflicts in important data of various fluids is not apparent in Figures 1 through 6.

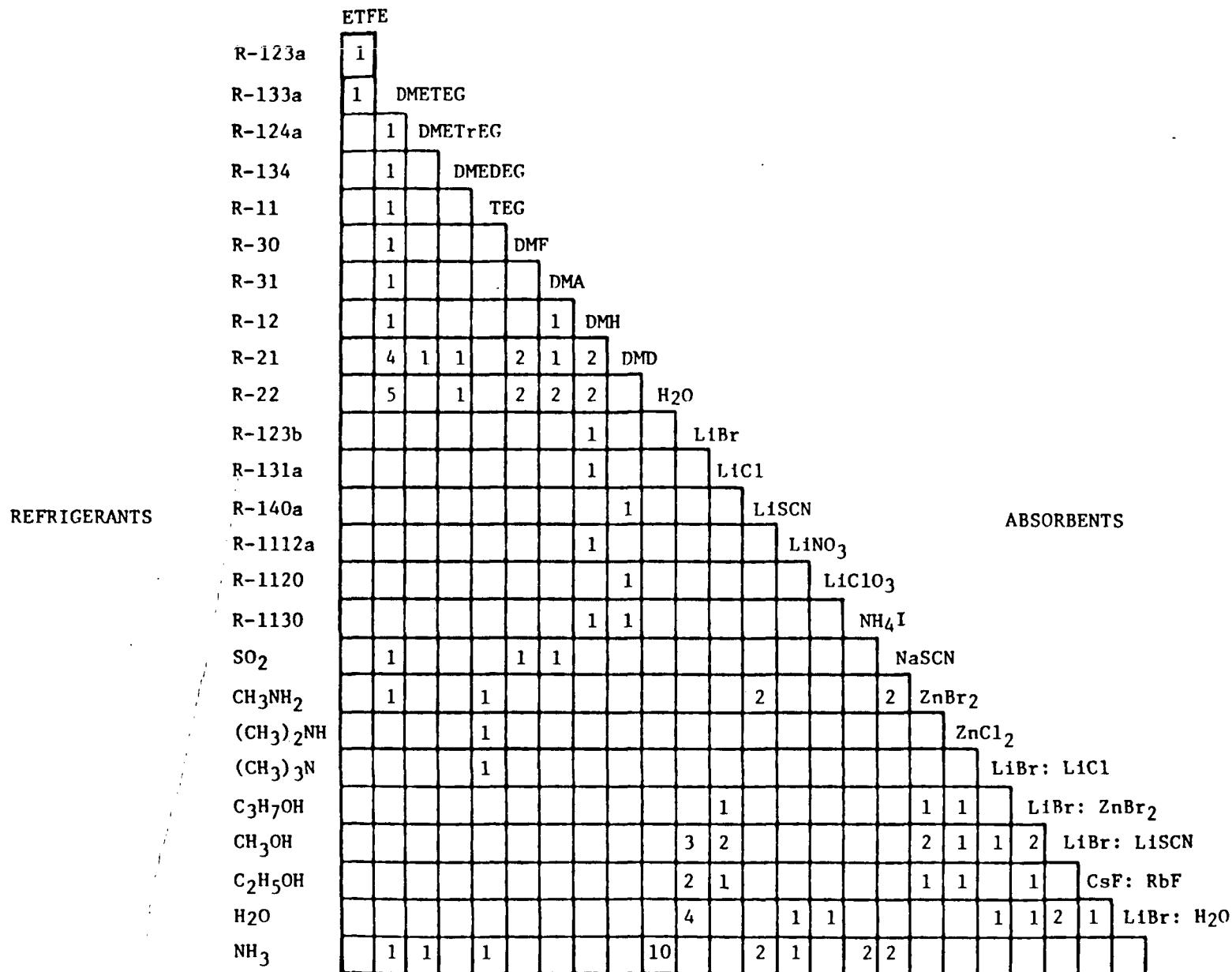


Figure 1. NUMBER OF REFERENCES FOR VAPOR-LIQUID EQUILIBRIUM DATA

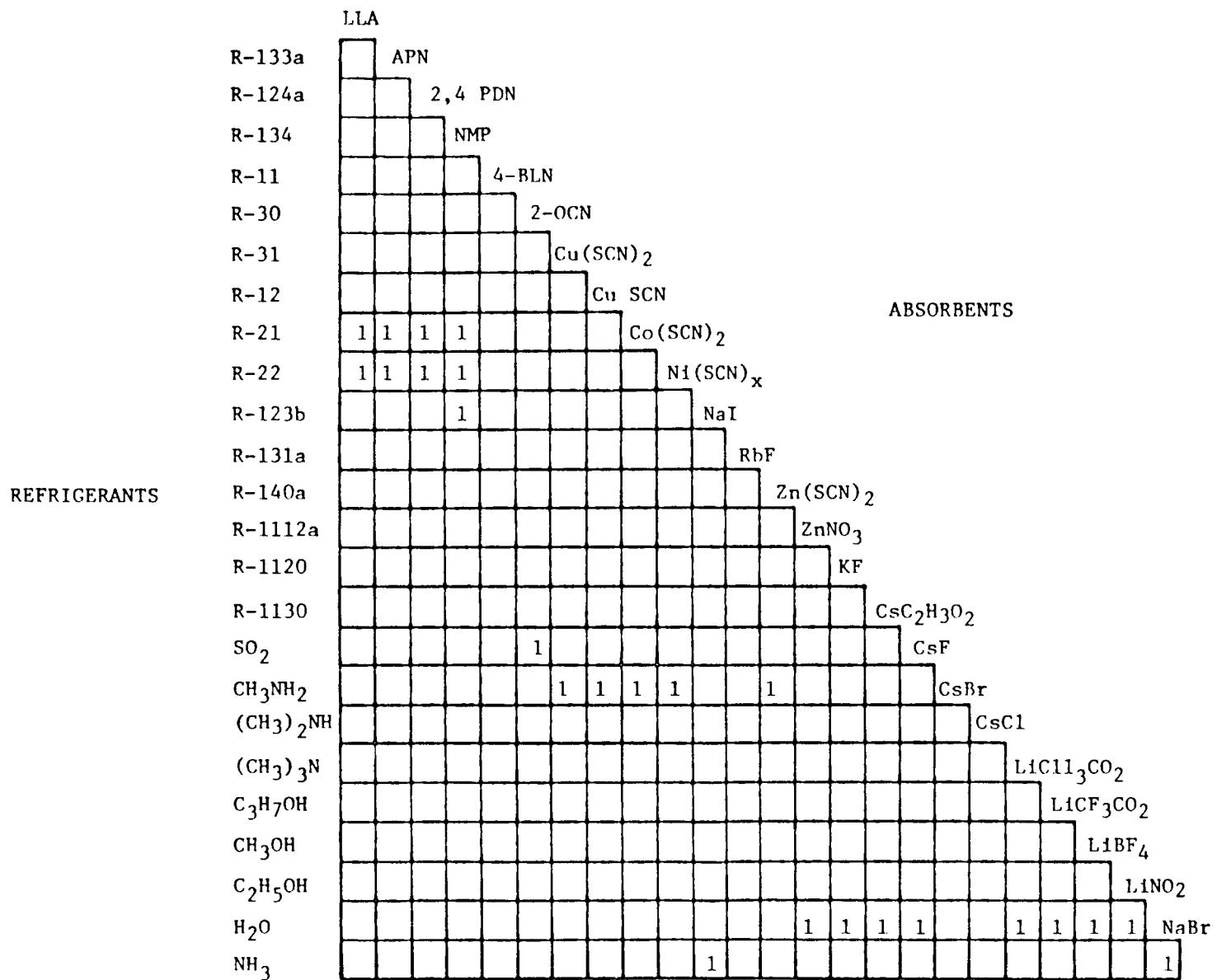


Figure 1. (Cont.)

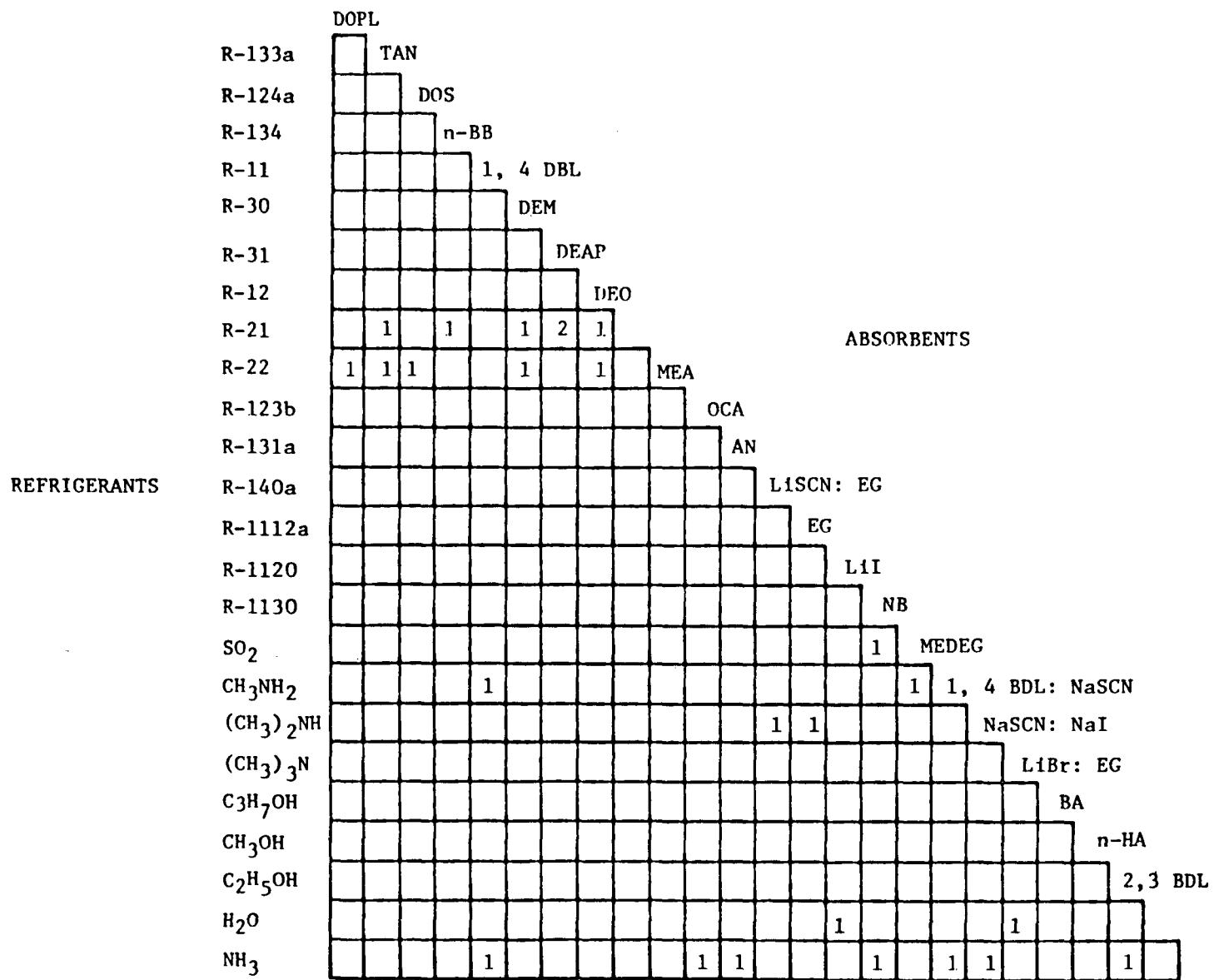


Figure 1. (Cont.)

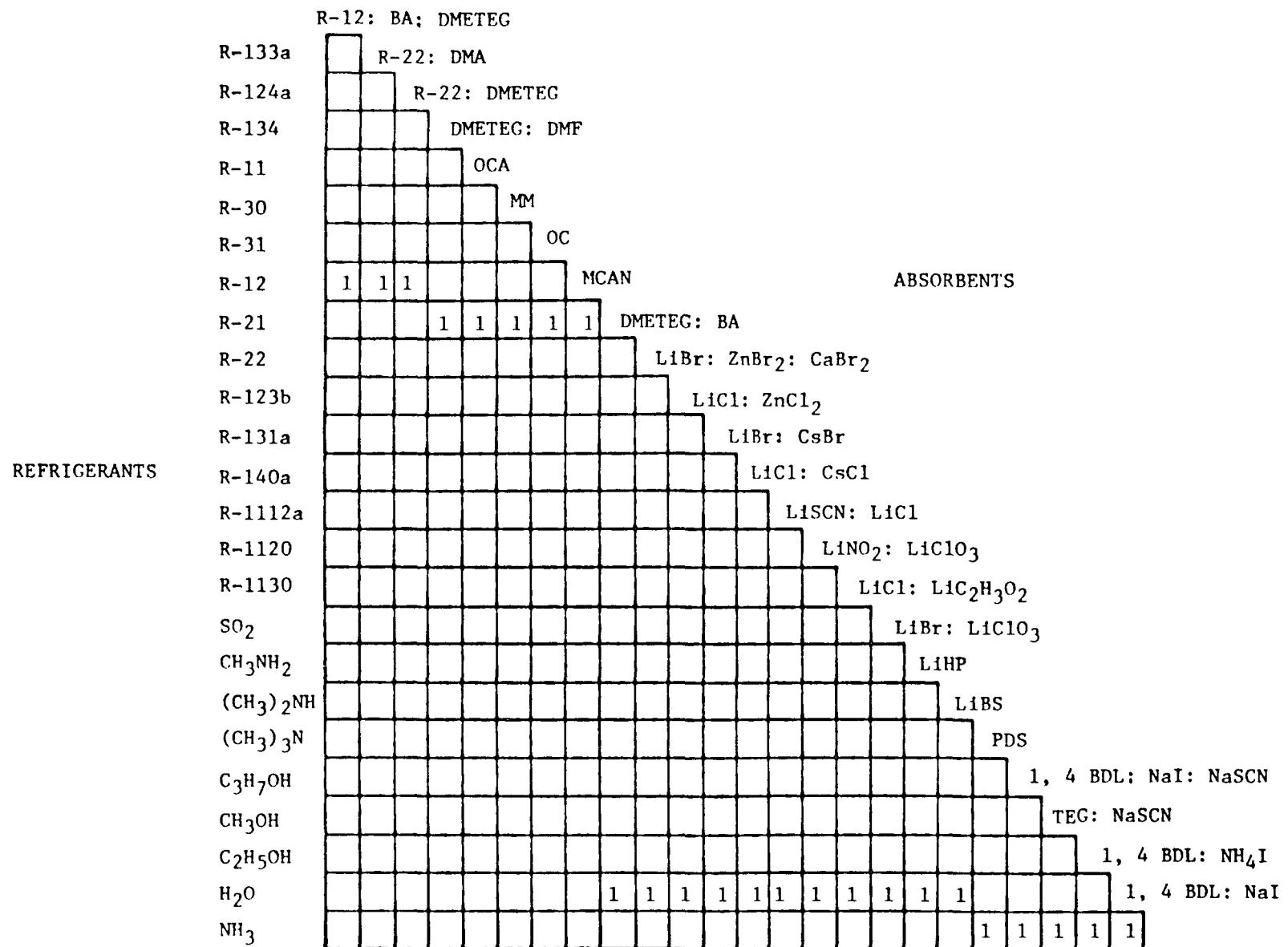


Figure 1. (Cont.)

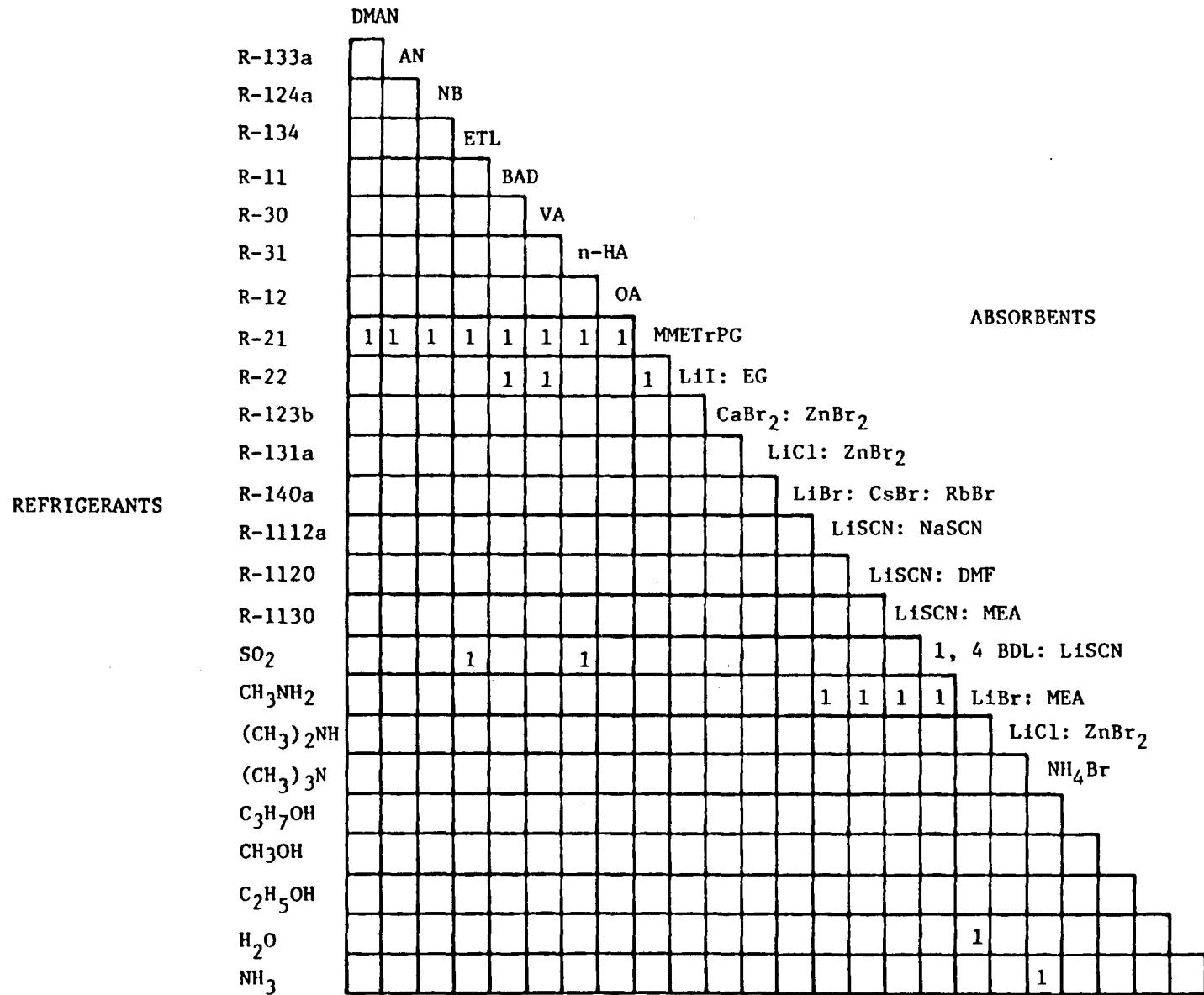


Figure 1. (Cont.)

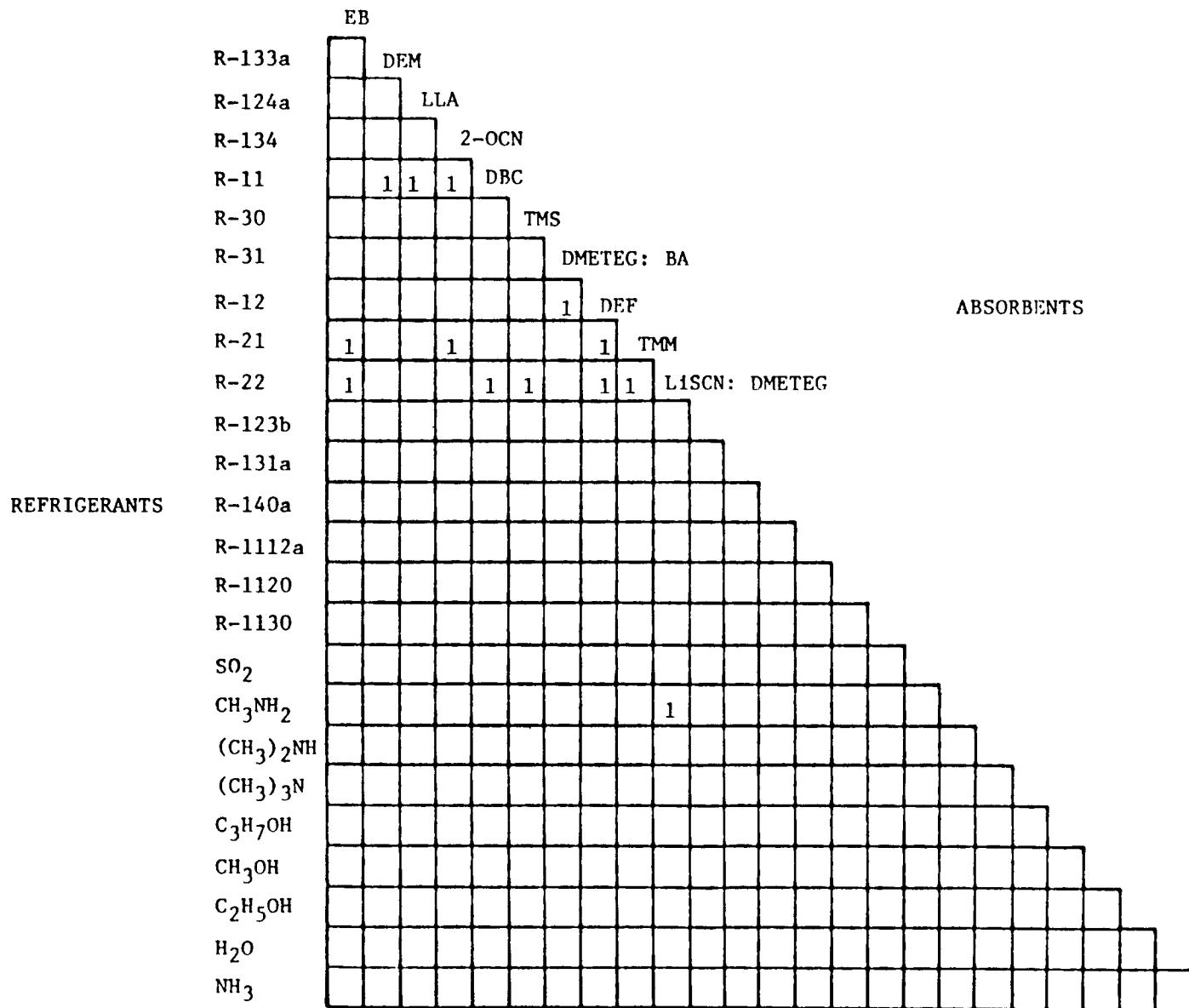


Figure 1. (Cont.)

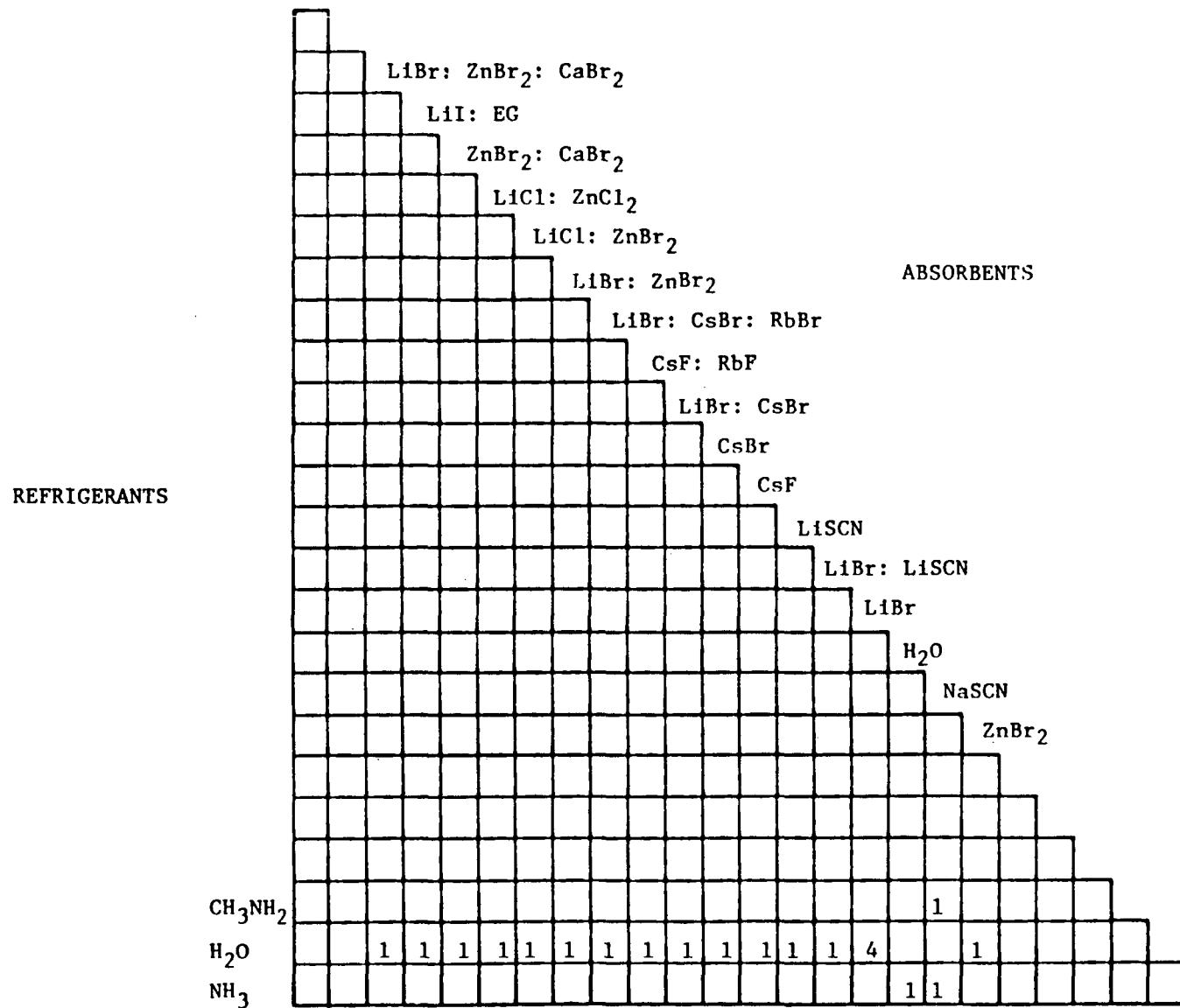


Figure 2. NUMBER OF REFERENCES FOR CRYSTALLIZATION TEMPERATURE DATA

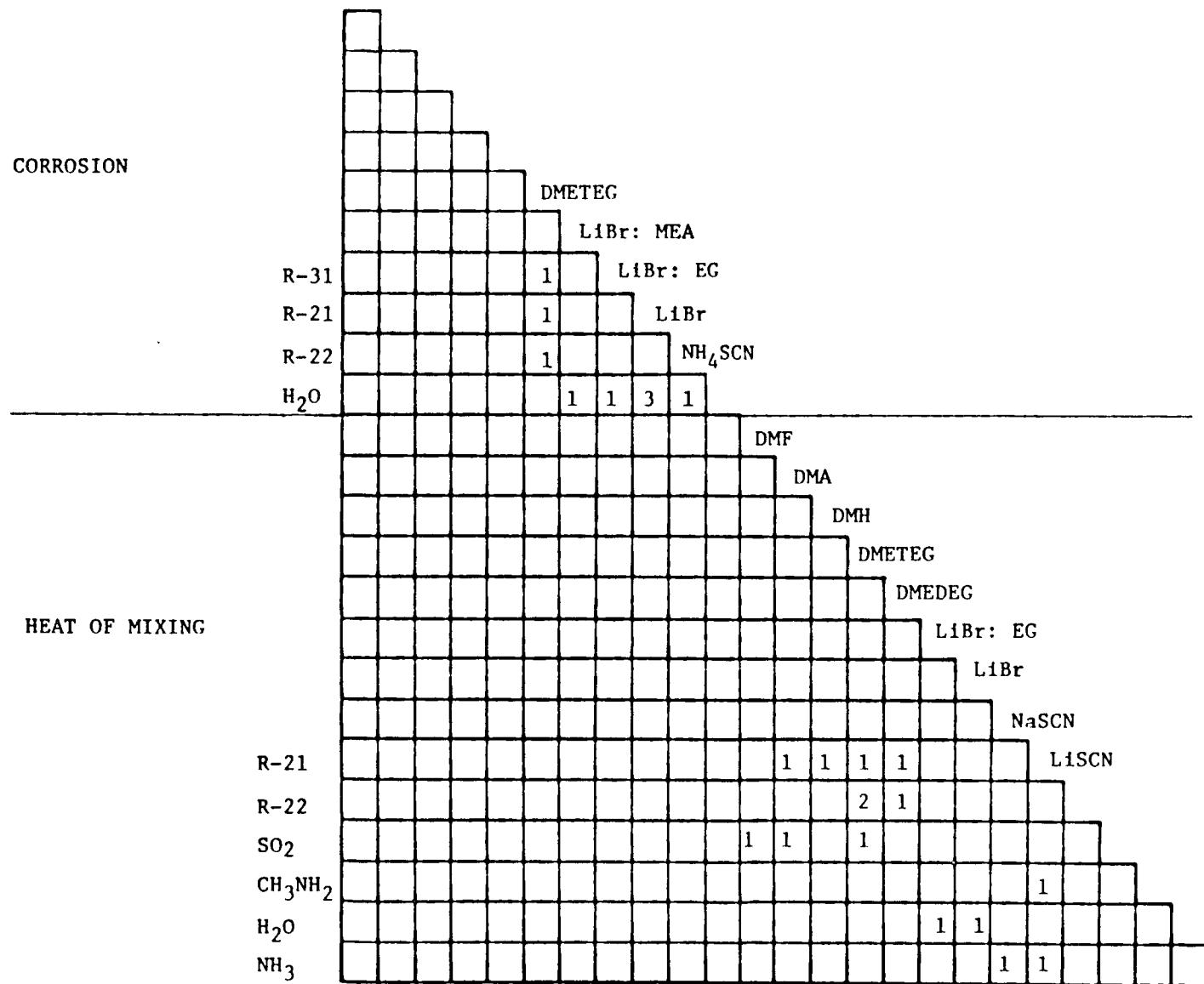


Figure 3. NUMBER OF REFERENCES FOR CORROSION AND HEAT OF MIXING DATA

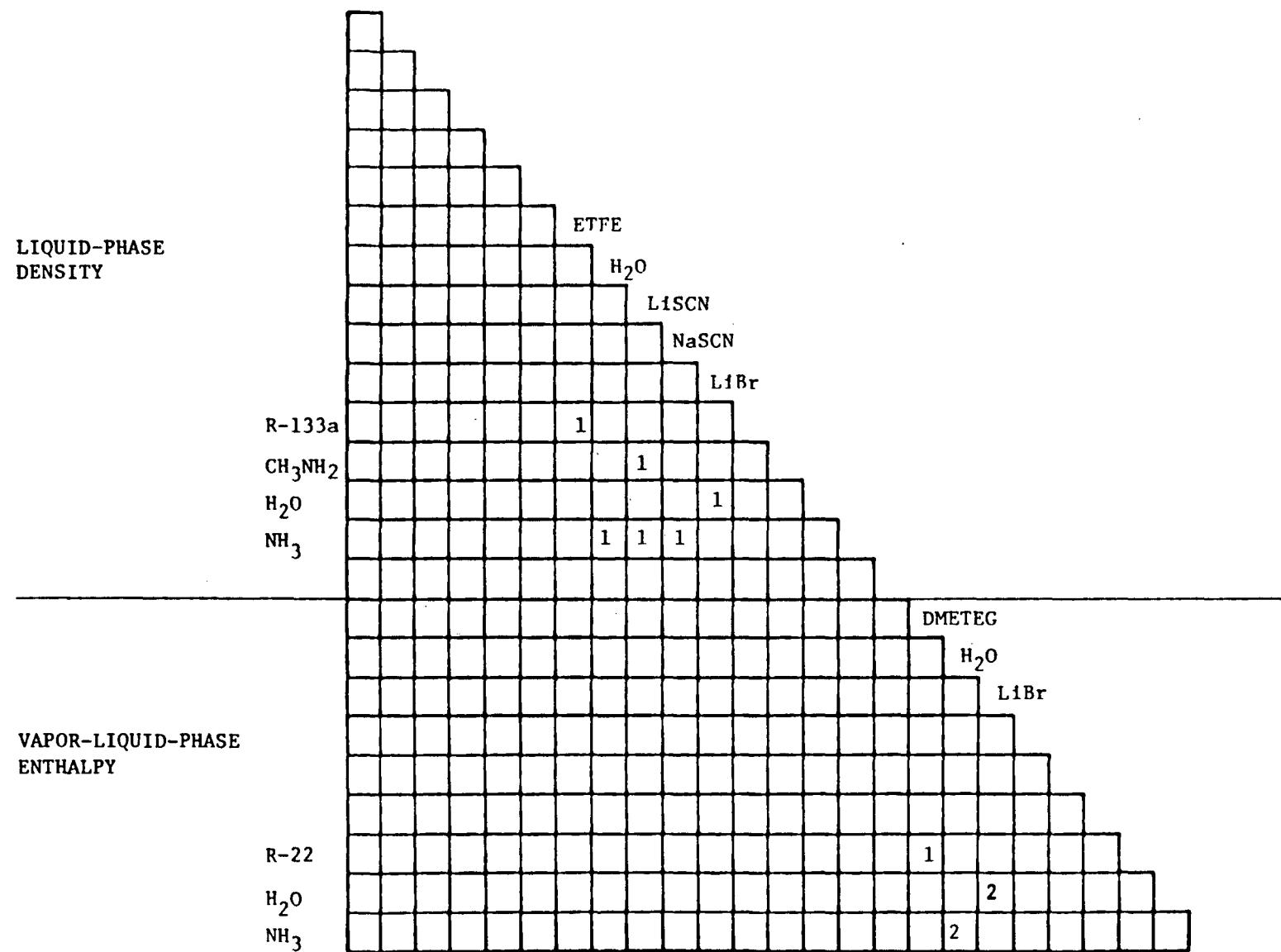


Figure 4. NUMBER OF REFERENCES FOR LIQUID-PHASE DENSITY AND ENTHALPY DATA

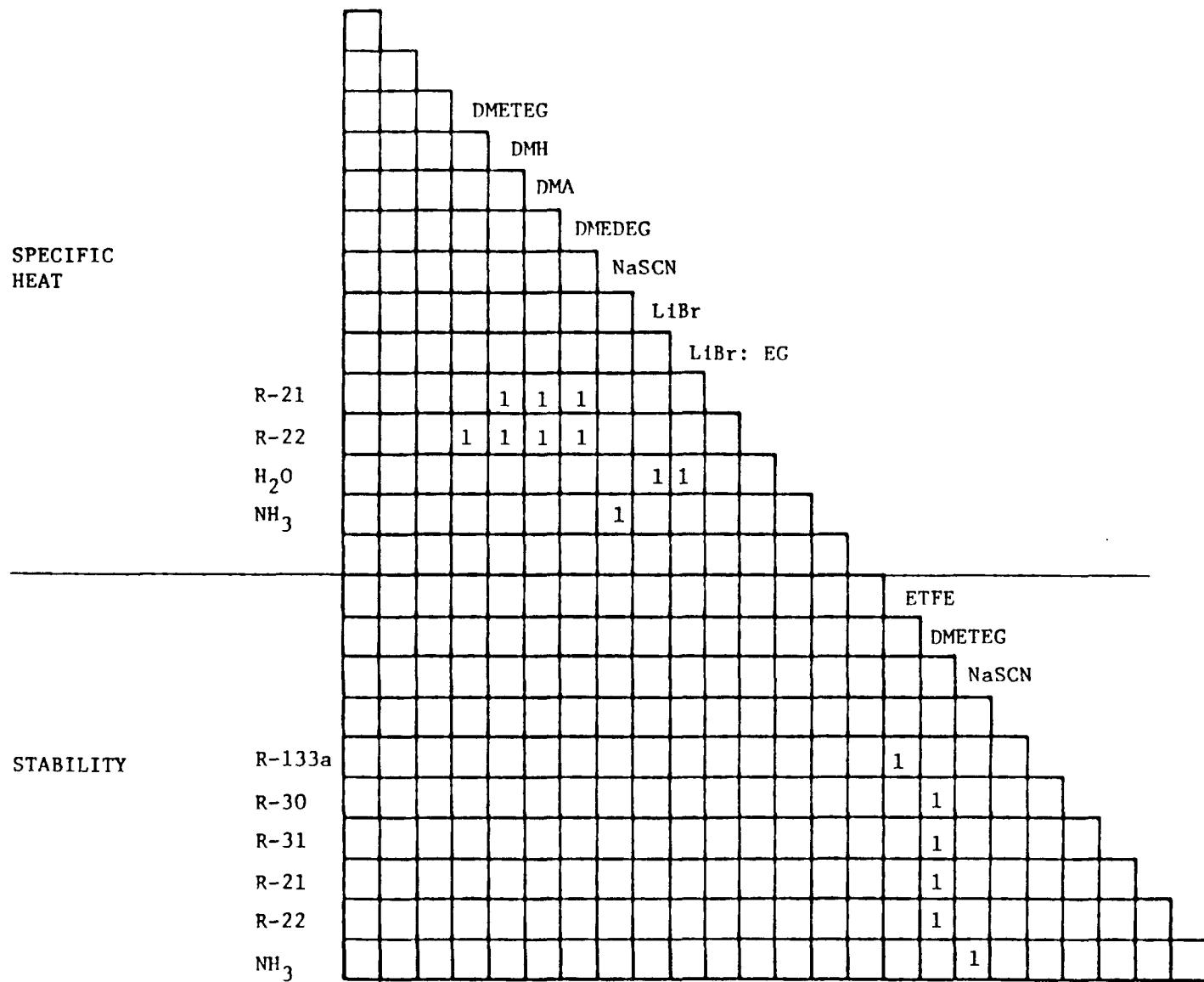


Figure 5. NUMBER OF REFERENCES FOR SPECIFIC HEAT AND STABILITY DATA

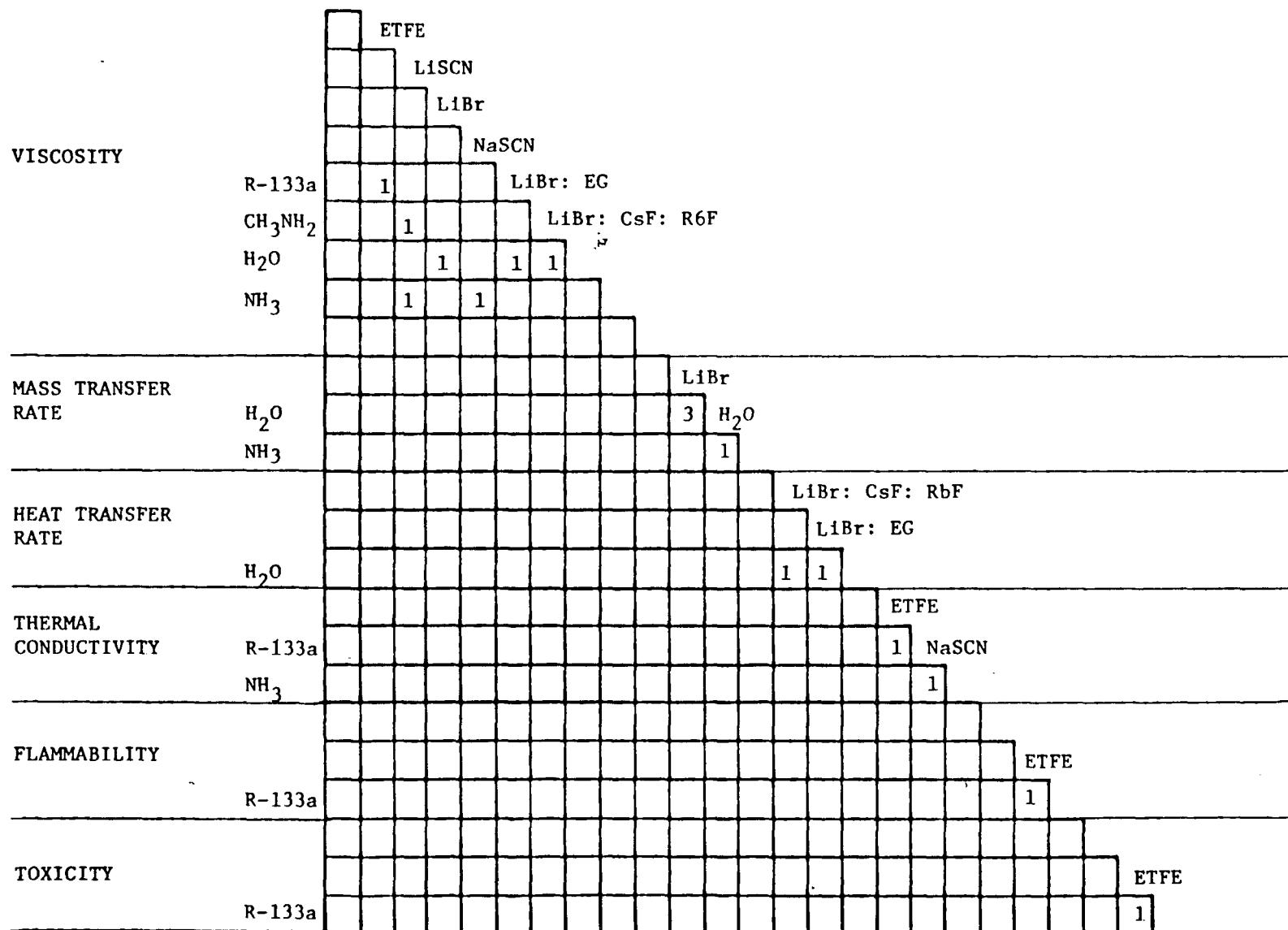


Figure 6. NUMBER OF REFERENCES FOR VARIOUS BINARY MIXTURE PROPERTIES DATA

### 3. Fluids, Properties, Data, and Range of Conditions

The 12 tables on the following pages contain the type of data and the temperature, pressure, and concentration ranges to which the data correspond, the reference access number, the first author, and the year of publication for each fluid and property of this study. The sequence of presentation adheres to a system developed for ease of information retrieval.

Each table lists all the information available for all fluids based on one refrigerant or for a generic group of refrigerants. In each table, the presentation of the available information begins with the first property of the fluids (for example, 1. Vapor-Liquid Equilibrium) and continues until the list of all fluids with the same refrigerant and data available is exhausted. The listing of information is then repeated for the second property (2. Crystallization Temperature), and so on, until all fluid properties have been covered.

The distinct 12 numbered tables correspond to 12 arbitrary single (or groups) of refrigerants as follows:

Table 6.0. Ammonia Binary and Multicomponent Absorption Fluids Properties Data

Table 7.0. Water Binary and Multicomponent Absorption Fluids Properties Data

Table 8.0. Alcohols Binary and Multicomponent Absorption Fluids Properties Data

Table 9.0. Amines Binary and Multicomponent Absorption Fluids Properties Data

Table 10.0. Sulfur Dioxide Binary and Multicomponent Absorption Fluids Properties Data

Table 11.0. Halocarbon Refrigerant Binary and Multicomponent Absorption Fluids Properties Data

Table 12.0. Refrigerant 22 Binary and Multicomponent Absorption Fluids Properties Data

Table 13.0. Refrigerant 21 Binary and Multicomponent Absorption Fluids Properties Data

Table 14.0. Refrigerant 12 Binary and Multicomponent Absorption Fluids Properties Data

Table 15.0. Refrigerants 31, 30, 11, and 134 Binary and Multicomponent Absorption Fluids Properties Data

Table 16.0. Refrigerants 124a, 133a, and 123a Binary and Multicomponent Absorption Fluids Properties Data

Table 17.0. Refrigerant 123a Binary and Multicomponent Absorption Fluids Properties Data

Several observations can be made in the above tables:

- For most fluids, the greatest amount of information and data sources concern Vapor-Liquid Equilibrium Data.
- As one proceeds from Table 1.0 toward Table 12.0, the amount of information, properties covered, and data sources tends to diminish.
- The sequence in which the refrigerant-keyed fluids appear are consistent with the sequence of refrigerants contained in the ordinate of Figure 1 (reading from bottom to top).

Tables 6.0 through 17.0 represent the major part of the effort in this program and are designed, in a systematic fashion, not only for locating needed data but to permit augmentation with similar information from other sources, domestic or foreign, in the future.

Table 6.0. AMMONIA BINARY AND MULTICOMPONENT ABSORPTION FLUIDS PROPERTIES DATA

6.1. Vapor-Liquid Equilibrium

Fluid System	Data Type	Temp. Range, °F	Press. Range, psia	Mol. Frac.		No.	Reference Author	Year
				X (1)	Y (2)			
NH <sub>3</sub> + H <sub>2</sub> O	TE	32 - 196	0.3 - 169.3	0.09 0.616	- 0.85 - (250) <sup>c</sup>	61	Wilson	(1925)
NH <sub>3</sub> + H <sub>2</sub> O	TE	141 - 242	222 - 521	0.962	- 0.995	34	Macriss	(1964)
NH <sub>3</sub> + H <sub>2</sub> O	GTS	-105 - 470	1 - 500	0.0 0.0	- 1.0 - 1.0	35	Macriss	(1964)
NH <sub>3</sub> + H <sub>2</sub> O	TE	195 - 296	14.7, 65	0.00092 0.079	- 0.0382 - 0.319	51	Polak	(1975)
NH <sub>3</sub> + H <sub>2</sub> O	TC	-60 - 370	0.26 - 340	0.1 0.448	- 0.9 - (0.62) <sup>c</sup>	55	Scatchard	(1947)
NH <sub>3</sub> + H <sub>2</sub> O	GC	60 - 170	NA	NA	NA	21	Edwards	(1978)
NH <sub>3</sub> + H <sub>2</sub> O	GC	-50 - 240	0.3 - 500	0.1 0.1	- 0.9 - (1) <sup>c</sup>	60	Won	(1980)
NH <sub>3</sub> + H <sub>2</sub> O	CP	22 - 45, 110 - 132	50 - 80, 250 - 350	NA	NA	29	Jain	(1971)
NH <sub>3</sub> + H <sub>2</sub> O	TC	-58 - 417	6 - 300	0.0015 0.0114	- 0.995 - (1.35) <sup>c</sup>	14	Bogart	(1980)
NH <sub>3</sub> + H <sub>2</sub> O	TS	-105 - 417	1 - 300	0.0 0.0	- 1.0 - 1.0	31	Jennings	(1965)

26

<sup>c</sup> - ppmv absorbent in vapor

X - Liquid phase

Y - Vapor phase

NA - Not available

(1) - Refrigerant

(2) - Absorbent

Table 6.0. (Cont.)

Fluid System	Data Type	Temp. Range, °F	Press. Range, psia	Mol. Frac.		Reference No.	Author	Year
				X (1)	Y (2)			
NH <sub>3</sub> + NaSCN	TGE	-4 - 194	5 - 720	0.713 - 1.00		13	Blytas	(1962)
NH <sub>3</sub> + NaSCN	TE	77 - 212	14.6 - 424.0	0.714 - 0843		52	Roberson	(1965)
NH <sub>3</sub> + LiSCN	GTEP	82.3 - 219.5	15.4 - 223.3	0.72 - 0.86		40	Macriss	(1971)
NH <sub>3</sub> + LiSCN	GE	95 - 212	17.3 - 169	0.73 - 0.82		9	Biermann	(1978)
NH <sub>3</sub> + LiNO <sub>3</sub>	TE	14 - 266	2.3 - 200.0	0.662 - 1.0		11	Blytas	(1961)
NH <sub>3</sub> + NH <sub>4</sub> I	TE	77 - 212	24.4 - 713.0	0.746 - 0.896		53	Roberson	(1966)
NH <sub>3</sub> + NH <sub>4</sub> I	TS	68 - 248	34 - 792.0	0.784 - 0.850		25	George	(1965)
NH <sub>3</sub> + NaBr	TE	77 - 212	51.9 - 781.0	0.799 - 0.903		53	Roberson	(1966)
NH <sub>3</sub> + NH <sub>4</sub> Br	TE	77 - 212	42.6 - 742.0	0.724 - 0.860		53	Roberson	(1966)
NH <sub>3</sub> + NaI	TE	77 - 212	49.6 - 830.0	0.839 - 0.939		53	Roberson	(1966)
NH <sub>3</sub> + NaSCN: NaI (0.5:1)	TE	77 - 212	7.0 - 811.0	0.720 - 0.940		53	Roberson	(1966)
NH <sub>3</sub> + NaSCN: NaI (2:1)	TE	77 - 212	17.1 - 592.4	0.751 - 0.882		53	Roberson	(1966)

27

X - Liquid phase  
 Y - Vapor phase

(1) - Refrigerant  
 (2) - Absorbent

Table 6.0. (Cont.)

Fluid System	Data Type	Temp. Range, °F	Press. Range, psia	Mol. Frac.		Reference No.	Author	Year
				X (1)	Y (2)			
NH <sub>3</sub> + DMETEG	TE	86 - 212	24.0 - 519.0	0.165 - 0.736		53	Roberson	(1966)
NH <sub>3</sub> + DMETrEG	TE	86 - 212	16.8 - 527.5	0.114 - 0.735		53	Roberson	(1966)
NH <sub>3</sub> + 1, 4 - Butanediol	TE	86 - 212	3.2 - 376.0	0.108 - 0.654		53	Roberson	(1966)
NH <sub>3</sub> + 2, 3 - Butanediol	TE	86 - 212	7.8 - 437.0	0.124 - 0.700		53	Roberson	(1966)
NH <sub>3</sub> + TEG	TE	86 - 212	2.3 - 555.7	0.122 - 0.833		53	Roberson	(1966)
NH <sub>3</sub> + Polydimethylsiloxane	GE	86	105 - 170	0.02 - 0.06 <sup>b</sup>		53	Roberson	(1966)
NH <sub>3</sub> + Nitrobenzene	TE	86 - 212	45 - 512	0.127 - 0.530		45	Morrone	(1962)
NH <sub>3</sub> + Octylamine	TE	86 - 212	37 - 535	0.164 - 0.794		45	Morrone	(1962)
NH <sub>3</sub> + DMA	TE	86 - 212	26 - 591	0.145 - 0.757		45	Morrone	(1962)
NH <sub>3</sub> + Aniline	TE	86 - 212	32 - 318	0.238 - 0.777		45	Morrone	(1962)

28

<sup>b</sup> - Weight fraction

X - Liquid phase

Y - Vapor phase

(1) - Refrigerant

(2) - Absorbent

Table 6.0. (Cont.)

Fluid System	Data Type	Temp. Range, °F	Press. Range, psia	Mol. Frac.		No.	Reference Author	Year
				X (1)	Y (2)			
NH <sub>3</sub> + 1, 4 Butanediol: NaSCN (6.04:1)	TE	86 - 212	13.5 - 545.0	0.104 - 0.782	53	Roberson	(1966)	
NH <sub>3</sub> + 1, 4 Butanediol: NaSCN (13.29:1)	TE	86 - 212	22.2 - 568.0	0.418 - 0.783	53	Roberson	(1966)	
NH <sub>3</sub> + 1, 4 Butanediol: NaI (4.99:1)	TE	86 - 212	15.6 - 606.0	0.406 - 0.793	53	Roberson	(1966)	
NH <sub>3</sub> + 1, 4 Butanediol: NH <sub>4</sub> I (4.85:1)	TE	86 - 212	14.8 - 530.9	0.413 - 0.784	53	Roberson	(1966)	
NH <sub>3</sub> + 1, 4 Butanediol: NH <sub>4</sub> I (8.17:1)	TE	86 - 212	52.3 - 621.0	0.598 - 0.796	53	Roberson	(1966)	29
NH <sub>3</sub> + Tetraethylene glycol: NaSCN (1.26:1)	TE	86 - 212	28.8 - 355.0	0.497 - 0.684	53	Roberson	(1966)	
NH <sub>3</sub> + 1, 4 Butanediol: NaI: NaSCN (11.0:1:2)	TE	86 - 212	18.7 - 268.0	0.437 - 0.616	53	Roberson	(1966)	
NH <sub>3</sub> + 1, 4 Butanediol: NaI: NaSCN (12.94:1:1)	TE	86 - 212	18.3 - 254.0	0.460 - 0.612	53	Roberson	(1966)	

X - Liquid phase  
Y - Vapor phase

(1) - Refrigerant  
(2) - Absorbent

Table 6.0. (Cont.)

6.2. Crystallization Temperature

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>	<u>Mol. Frac. X (1)</u>	<u>Reference</u>		
					<u>No.</u>	<u>Author</u>	<u>Year</u>
NH <sub>3</sub> + NaSCN	GE	-130 - 581	NA	0 - 1	13	Blytas	(1962)
NH <sub>3</sub> + H <sub>2</sub> O	GS	-239 - 32	NA	0 - 1	35	Macriss	(1964)

6.4. Heat of Mixing

NH <sub>3</sub> + NaSCN	TE	32	NA	0.84 - 0.99	13	Blytas	(1962)
NH <sub>3</sub> + LiSCN	PC	82 - 220	15.4 - 223.3	0.72 - 0.86	40	Macriss	(1971) 30

6.5. Liquid-Phase Densities

NH <sub>3</sub> + NaSCN	GE	-85 - 212	NA	0.684 - 0.977	13	Blytas	(1962)
NH <sub>3</sub> + LiSCN	TE	80 - 280	NA	0.374 - 0.525 <sup>b</sup>	40	Macriss	(1971)
NH <sub>3</sub> + H <sub>2</sub> O	TE	74 - 312	7 - 540	0.0 - 1.0	30	Jennings	(1965)

<sup>b</sup> - Weight fraction

X - Liquid phase

NA - Not available

(1) - Refrigerant

Table 6.0. (Cont.)

6.6. Vapor-Liquid-Phase Enthalpies

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp.</u>	<u>Press. Range,</u>	<u>Mol. Frac.</u>	<u>Reference</u>		
		<u>Range, °F</u>	<u>psia</u>	<u>X (1)</u>	<u>No.</u>	<u>Author</u>	<u>Year</u>
NH <sub>3</sub> + H <sub>2</sub> O	TE	106 - 441	41 - 516	0.05 - 0.38 <sup>b</sup>	35	Macriss	(1964)
NH <sub>3</sub> + H <sub>2</sub> O	CP	22-45, 110-131	50-80, 250-350	NA	29	Jain	(1971)

6.7. Specific Heat

NH <sub>3</sub> + NaSCN	TE	32 - 77	NA	0.40 - 0.78	13	Blytas	(1962)
-------------------------	----	---------	----	-------------	----	--------	--------

6.8. Stability

NH <sub>3</sub> + NaSCN	Narrative	302	NA	NA	36	Macriss	(1964)
-------------------------	-----------	-----	----	----	----	---------	--------

6.9. Viscosity

NH <sub>3</sub> + NaSCN	GE	14 - 140	NA	0.35 - 1.0 <sup>b</sup>	13	Blytas	(1962)
-------------------------	----	----------	----	-------------------------	----	--------	--------

NH <sub>3</sub> + LiSCN	TE	75 - 200	NA	0.39 - 0.52 <sup>b</sup>	40	Macriss	(1971)
-------------------------	----	----------	----	--------------------------	----	---------	--------

b - Weight fraction

X - Liquid phase

NA - Not available

(1) - Refrigerant

Table 6.0. (Cont.)

6.10. Mass Transfer Data

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range,</u>	<u>Mol. Frac.</u>	<u>Reference</u>		
			<u>psia</u>	<u>X (1)</u>	<u>No.</u>	<u>Author</u>	<u>Year</u>
NH <sub>3</sub> + H <sub>2</sub> O	GE	78	5.8 - 15.5	NA	17	Burnett	(1970)

6.12. Thermal Conductivity

NH <sub>3</sub> + NaSCN	TE	68 - 156	NA	0.40 - 0.50	13	Blytas	(1962)
-------------------------	----	----------	----	-------------	----	--------	--------

X - Liquid phase  
 NA - Not available

(1) - Refrigerant

Table 7.0. WATER BINARY AND MULTICOMPONENT ABSORPTION  
FLUIDS PROPERTIES DATA

7.1. Vapor-Liquid Equilibrium

Fluid System	Data Type	Temp. Range, °F	Press. Range, psia	Mol. Frac. X (1)	Reference		
					No.	Author	Year
H <sub>2</sub> O + LiBr	TE	32 - 212	0.011 - 14.7	0.65 - 1.0	23	Ellington	(1957)
H <sub>2</sub> O + LiBr	TE	77 - 350	0.0138 - 52.34	0.76 - 0.83	48	Pennington	(1955)
H <sub>2</sub> O + LiBr	TEGP	40 - 360	2.4 - 203.1 <sup>a</sup>	0.67 - 1.0	43	McNeely	(1979)
H <sub>2</sub> O + LiBr	GE	82 - 133	0.054 - 0.43	0.77 - 0.81	32	Ledding	(1965)
H <sub>2</sub> O + ZnCl <sub>2</sub>	GE	78 - 139	0.035 - 0.17	0.65	32	Ledding	(1965)
H <sub>2</sub> O + CsF	GE	75 - 149	0.027 - 0.25	0.54 - 0.69	32	Ledding	(1965)
H <sub>2</sub> O + KF	GE	77 - 110	0.15 - 0.43	0.88	32	Ledding	(1965)
H <sub>2</sub> O + Cs Acetate	GE	80 - 124	0.041 - 0.15	0.63	32	Ledding	(1965)
H <sub>2</sub> O + ZnNO <sub>3</sub>	TE	100 - 230	0.019 - 19.3	0.103 - 0.727	24	Ewing	(1937)
H <sub>2</sub> O + LiClO <sub>3</sub>	GTE	80 - 180	0.036 - 0.51	0.55 - 0.75	9	Biermann	(1978)
H <sub>2</sub> O + LiI	GS	68 - 248	32 - 248 <sup>a</sup>	0.15 - 0.50 <sup>b</sup>	9	Biermann	(1978)
H <sub>2</sub> O + LiNO <sub>2</sub>	GTE	80 - 130	0.12 - 0.54	Saturated 68°F	9	Biermann	(1978)
H <sub>2</sub> O + LiSCN	GTE	80 - 120	0.15 - 0.48	Saturated 68°F	9	Biermann	(1978)
H <sub>2</sub> O + LiBF <sub>4</sub>	GTE	80 - 90	0.28 - 0.34	Saturated 68°F	9	Biermann	(1978)
H <sub>2</sub> O + LiCF <sub>3</sub> CO <sub>2</sub>	GTE	80 - 110	0.16 - 0.41	Saturated 68°F	9	Biermann	(1978)

<sup>a</sup> - Refrigerant dew point temperature, °F

<sup>b</sup> - Weight fraction

X - Liquid phase

(1) - Refrigerant

Table 7.0. (Cont.)

Fluid System	Data Type	Temp. Range, °F	Press. Range, psia			Mol. Frac. X (1)	Reference		
			0.22	-	0.48		No.	Author	Year
H <sub>2</sub> O + LiC <sub>13</sub> CO <sub>2</sub>	GTE	80 - 105	0.22	-	0.48	Saturated 68°F	9	Biermann	(1978)
H <sub>2</sub> O + Li Benzenesulfonate	GTE	80 - 95	0.31	-	0.46	Saturated 68°F	9	Biermann	(1978)
H <sub>2</sub> O + LiH <sub>2</sub> Phosphite	GTE	80 - 90	0.32	-	0.47	Saturated 68°F	9	Biermann	(1978)
H <sub>2</sub> O + LiBr: LiCl	GSP	59 - 185	0.02	-	19.3	0.742 - 0826	58	Weil	(1960)
H <sub>2</sub> O + LiBr: LiSCN (0.25:1 - 4:1)	GS	70 - 200	0.02	-	1.16	Saturated 72° - 95°F	39	Macriss	(1970)
H <sub>2</sub> O + LiBr: LiSCN (0.25:1 - 10:1)	GE	140	0.23	-	0.35	Saturated 68°F	9	Biermann	(1978)
H <sub>2</sub> O + LiBr: LiClO <sub>3</sub> (0.8:1)	TE	136 - 180	0.11	-	0.43	0.193 - 0.243 <sup>b</sup>	9	Biermann	(1978)
H <sub>2</sub> O + LiCl: LiAcetate (4:1 - 10:1)	TE	140	0.17	-	0.39	Saturated 68°F	9	Biermann	(1978)
H <sub>2</sub> O + Li NO <sub>2</sub> : LiClO <sub>3</sub>	TE	140	0.20	-	0.49	Saturated 68°F	9	Biermann	(1978)
H <sub>2</sub> O + LiSCN: LiCl	TE	140	0.36	-	0.41	Saturated 68°F	9	Biermann	(1978)
H <sub>2</sub> O + LiCl: CsCl (2.46:1)	GE	85 - 131	0.093	-	0.387	0.31 <sup>b</sup>	32	Ledding	(1965)
H <sub>2</sub> O + LiCl: CsCl (2.83:1)	GE	87 - 134	0.081	-	0.357	0.282 <sup>b</sup>	32	Ledding	(1965)
H <sub>2</sub> O + LiBr: CsBr (5.4:1)	GE	78 - 132	0.033	-	0.197	0.285 <sup>b</sup>	32	Ledding	(1965)
H <sub>2</sub> O + LiBr: CsBr (6.94:1)	GE	84 - 138	0.046	-	0.267	0.329 <sup>b</sup>	32	Ledding	(1965)
H <sub>2</sub> O + RbF: CsF (1:1)	GE	80 - 150	0.021	-	0.405	0.15 - 0.22 <sup>b</sup>	32	Ledding	(1965)

<sup>b</sup> - Weight fraction

x - Liquid phase

(1) - Refrigerant

Table 7.0. (Cont.)

Fluid System	Data Type	Temp. Range, °F	Press. Range, psia	Mol. Frac. X (1)	No.	Reference Author	Year
H <sub>2</sub> O + LiBr: ZnBr <sub>2</sub> (0.5:1 - 11:1)	GS	80 - 260	0.023 - 1.40	0.127 - 0.305 <sup>b</sup>	7	Aronson	(1969)
H <sub>2</sub> O + LiCl: ZnCl <sub>2</sub> (1:1)	GS	100 - 270	0.048 - 1.40	0.122 - 0.283 <sup>b</sup>	7	Aronson	(1969)
H <sub>2</sub> O + LiBr: ZnBr <sub>2</sub> : CaBr <sub>2</sub> (1.2:1:0.3)	GS	80 - 500	0.019 - 19.3	0.050 - 0.250 <sup>b</sup>	7	Aronson	(1969)
H <sub>2</sub> O + LiBr: Ethanolamine (2.65:1 - 3.72:1)	GS	86 - 266	0.09 - 4.5	0.15 - 0.30 <sup>b</sup>	10	Biermann	(1978)
H <sub>2</sub> O + LiBr: EG (3.72:1 - 5:1)	GS	86 - 266	0.09 - 4.5	0.20 - 0.40 <sup>b</sup>	10	Biermann	(1978)

35

7.2. Crystallization Temperature

H <sub>2</sub> O + LiBr	GE	-100 - 200	NA	0 - 1	23	Ellington	(1957)
H <sub>2</sub> O + LiBr	TE	- 58 - 212	NA	0.30 - 0.55	15	Boryta	(1961)
H <sub>2</sub> O + LiBr	GE	59 - 167	NA	0.329 - 0.400	32	Ledding	(1965)
H <sub>2</sub> O + LiBr: LiSCN (4:1 to 1:4)	GS	72 - 86	NA	0.328 - 0.423	4	IGT	(1968)

b - Weight fraction

X - Liquid phase

NA - Not available

(1) - Refrigerant

Table 7.0. (Cont.)

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp.</u>	<u>Press. Range,</u>	<u>Mol. Frac.</u>	<u>Reference</u>		
		<u>Range, °F</u>	<u>psia</u>	<u>X (1)</u>	<u>No.</u>	<u>Author</u>	<u>Year</u>
H <sub>2</sub> O + LiSCN	GS	72	NA	0.46	4	IGT	(1968)
H <sub>2</sub> O + CsF	GE	43 - 133	NA	0.166 - 0.175	32	Ledding	(1965)
H <sub>2</sub> O + CsBr	GE	50 - 135	NA	0.885 - 0.925	32	Ledding	(1965)
H <sub>2</sub> O + LiBr: CsBr (1:1 to 7:1)	GE	59 - 149	NA	0.646 - 0.897	32	Ledding	(1965)
H <sub>2</sub> O + CsF: RbF (1:1)	GE	28 - 72	NA	0.15 - 0.23	32	Ledding	(1965)
H <sub>2</sub> O + LiBr: CsBr: RbBr (2:1:0.7)	GE	72 - 85	NA	0.26 - 0.40	32	Ledding	(1965)
H <sub>2</sub> O + LiBr: LiSCN (0.25:1 to 4:1)	GE	20 - 200	NA	0.56 - 0.77	39	Macriss	(1970)
H <sub>2</sub> O + LiBr	GS	40 - 290	NA	300 - 380 <sup>a</sup>	7	Aronson	(1969)
H <sub>2</sub> O + LiBr: ZnBr <sub>2</sub> (1:1)	GS	50 - 280	NA	410 - 510 <sup>a</sup>	7	Aronson	(1969)
H <sub>2</sub> O + LiCl: ZnBr <sub>2</sub> (1:1)	GS	70 - 145	NA	395 - 430 <sup>a</sup>	7	Aronson	(1969)
H <sub>2</sub> O + LiCl: ZnCl <sub>2</sub> (1:1)	GS	85	NA	410 <sup>a</sup>	7	Aronson	(1969)
H <sub>2</sub> O + CaBr <sub>2</sub> : ZnBr <sub>2</sub> (0.3:1)	GS	65 - 175	NA	430 - 480 <sup>a</sup>	7	Aronson	(1969)
H <sub>2</sub> O + LiI: EG	GS	120 - 140	NA	380 - 420 <sup>a</sup>	7	Aronson	(1969)

a - Solution normal boiling point, °F at 760 mm Hg

X - Liquid phase

(1) - Refrigerant

NA - Not available

Table 7.0. (Cont.)

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>	<u>Mol. Frac. X (1)</u>	<u>Reference</u>		
					<u>No.</u>	<u>Author</u>	<u>Year</u>
H <sub>2</sub> O + ZnBr <sub>2</sub>	GS	70	NA	310 <sup>a</sup>	7	Aronson	(1969)
H <sub>2</sub> O + LiBr: ZnBr <sub>2</sub> (from 0.9:1 to 1.2:1)	GS	75 - 210	NA	170 - 230 <sup>a</sup>	7	Aronson	(1969)
H <sub>2</sub> O + LiBr: ZnBr <sub>2</sub> : CaBr <sub>2</sub> (1:1:1)	GS	110 - 230	NA	180 - 210 <sup>b</sup>	7	Aronson	(1969)
(1.2:1:0.5)	GS	40 - 80	NA	190 - 210 <sup>b</sup>	7	Aronson	(1969)
(1.2:1:0.12)	GS	60	NA	160 <sup>b</sup>	7	Aronson	(1969)
(1.2:1:0.3)	GS	40 - 140	NA	190 - 230 <sup>b</sup>	7	Aronson	(1969)
(1.1:1:0.27)	GS	110	NA	225 <sup>b</sup>	7	Aronson	(1969)

37

a - Solution normal boiling point, °F at 760 mm Hg

b - Solution temperature, °F at which H<sub>2</sub>O partial pressure is 10 mm Hg

X - Liquid phase (1) - Refrigerant

NA - Not available

Table 7.0. (Cont.)

7.3. Corrosion Characteristics

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Corrosion Inhibitor</u>	<u>Wt. Frac. X (1)</u>	<u>Reference</u>		
					<u>No.</u>	<u>Author</u>	<u>Year</u>
H <sub>2</sub> O + LiBr: Ethanol-(3:1 wt)	TE	280	LiNO <sub>3</sub> (0 - 300 ppm)	0.20	10	Biermann	(1978)
H <sub>2</sub> O + LiBr: EG (3:1 wt)	TE	280	LiNO <sub>3</sub> , Li <sub>2</sub> MoO <sub>4</sub> (0 - 300 ppm)	0.20	10	Biermann	(1978)
H <sub>2</sub> O + LiBr	TE	270	Li <sub>2</sub> MoO <sub>4</sub> , LiO <sub>2</sub> CC <sub>6</sub> H <sub>5</sub>	0.45	59	Weil	(1956)
H <sub>2</sub> O + LiBr		NA	None	0.47	23	Ellington	(1957)
H <sub>2</sub> O + LiBr	TE	77	LiCrO <sub>4</sub> (0-2000 ppm)	0.46	18	Cohen	(1966)
H <sub>2</sub> O + NH <sub>4</sub> SCN	TE	75 - 212	None	0.2 - 0.9 <sup>b</sup>	36	Macriss	(1964)

<sup>b</sup> - Mole fraction

X - Liquid phase

NA - Not available

(1) - Refrigerant

Table 7.0. (Cont.)

7.4. Heat of Mixing

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>	<u>Mol. Frac.</u>	<u>Reference</u>		
				X (1)	<u>No.</u>	<u>Author</u>	<u>Year</u>
H <sub>2</sub> O + LiBr: EG	TE	NA	NA	0.403 - 0.420	10	Biermann	(1978)
H <sub>2</sub> O + LiBr	TC	77	NA	0.0 - 1.0	23	Ellington	(1957)

7.5. Liquid-Phase Densities

H <sub>2</sub> O + LiBr	GE	77 - 176	NA	0.35 - 1.0 <sup>b</sup>	23	Ellington	(1957)
-------------------------	----	----------	----	-------------------------	----	-----------	--------

7.6. Vapor-Liquid-Phase Enthalpies

H <sub>2</sub> O + LiBr	GC	77 - 300	0.1 - 5.8	0.2 - 1.0 <sup>b</sup>	23	Ellington	(1957)
H <sub>2</sub> O + LiBr	GCP	40 - 360	2.4 - 203.1 <sup>a</sup>	0.3 - 1.0 <sup>b</sup>	43	McNeely	(1979)

7.7. Specific Heat

H <sub>2</sub> O + LiBr	GE	NA	NA	0.40 - 1.0 <sup>b</sup>	23	Ellington	(1957)
H <sub>2</sub> O + LiBr: EG	TE	NA	NA	0.55 - 0.75 <sup>b</sup>	10	Biermann	(1978)

39

a - Refrigerant dew point temperature, °F

b - Weight fraction

X - Liquid phase

(1) - Refrigerant

NA - Not available

Table 7.0. (Cont.)

7.9. Viscosity

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>	<u>Mol. Frac. X (1)</u>	<u>Reference</u>		
					<u>No.</u>	<u>Author</u>	<u>Year</u>
H <sub>2</sub> O + LiBr	GS	70 - 170	NA	0.40 - 1.0 <sup>b</sup>	23	Ellington	(1957)
H <sub>2</sub> O + LiBr: EG	TE	120 - 151	NA	0.23 - 0.33 <sup>b</sup>	10	Biermann	(1978)
H <sub>2</sub> O + LiBr: RbF: CsF	GE	95	NA	0.25 <sup>b</sup>	32	Ledding	(1965)

7.10. Mass Transfer Rate

H <sub>2</sub> O + LiBr	TE	80 - 105	0.04 - 0.39	0.41 - 0.43 <sup>b</sup>	62	Zawacki	(1973)	57
H <sub>2</sub> O + LiBr	TE	80 - 105	0.04 - 0.39	0.40 <sup>b</sup>	63	Zawacki	(1973)	
H <sub>2</sub> O + LiBr	GE	77 - 120	0.04 - 0.39	0.40 - 0.43 <sup>b</sup>	19	Deemer	(1972)	

7.11. Heat Transfer Rate

H <sub>2</sub> O + LiBr: EG (4.5:1)	TE	86	NA	0.269 - 0.324 <sup>b</sup>	10	Biermann	(1978)
H <sub>2</sub> O + LiBr: RbF: CsF	GE	NA	NA	0.15 - 0.45 <sup>b</sup>	32	Ledding	(1965)

b - Weight fraction

X - Liquid phase

NA - Not available

(1) - Refrigerant

Table 8.0. ALCOHOLS BINARY AND MULTICOMPONENT ABSORPTION  
FLUIDS PROPERTIES DATA

8.1. Vapor-Liquid Equilibrium

Fluid System	Data Type	Temp. Range, °F	Press. Range, psia	Mol. Frac. X (1)	Reference		
					No.	Author	Year
C <sub>2</sub> H <sub>5</sub> OH + LiBr	TE	95 - 238	0.160 - 13.1	0.67 - 0.79	5	Aker	(1965)
C <sub>2</sub> H <sub>5</sub> OH + LiBr: ZnBr <sub>2</sub> (2:1)	TE	131 - 280	0.174 - 12.7	0.392 - 0.501 <sup>b</sup>	5	Aker	(1965)
C <sub>2</sub> H <sub>5</sub> OH + LiCl	GE	78	0.35	Saturated 77°F	32	Ledding	(1965)
C <sub>2</sub> H <sub>5</sub> OH + ZnCl <sub>2</sub>	GE	78	0.50	Saturated 77°F	32	Ledding	(1965)
C <sub>2</sub> H <sub>5</sub> OH + LiBr	GE	83	0.35	Saturated 77°F	32	Ledding	(1965)
C <sub>2</sub> H <sub>5</sub> OH + ZnBr <sub>2</sub>	GE	78	0.49	Saturated 77°F	32	Ledding	(1965)
CH <sub>3</sub> OH + LiBr	GS	68 - 302	-10 - 90 <sup>a</sup>	0.64 - 0.83	9	Biermann	(1978)
CH <sub>3</sub> OH + LiBr	TE	90 - 256	0.145 - 14.0	0.68 - 0.97	5	Aker	(1965)
CH <sub>3</sub> OH + LiBr	GE	92 - 100	0.62 - 0.75	Saturated 77°F	32	Ledding	(1965)
CH <sub>3</sub> OH + LiCl	TE	95 - 193	0.845 - 11.7	0.78 - 0.90	5	Aker	(1965)
CH <sub>3</sub> OH + LiCl	GE	79	0.54	Saturated 77°F	32	Ledding	(1965)
CH <sub>3</sub> OH + ZnBr <sub>2</sub>	TE	86 - 228	0.487 - 13.5	0.71 - 0.93	5	Aker	(1965)
CH <sub>3</sub> OH + ZnBr <sub>2</sub>	GE	88	0.50	Saturated 77°F	32	Ledding	(1965)
CH <sub>3</sub> OH + ZnCl <sub>2</sub>	GS	40 - 160	0.19 - 8.89	0.60 - 0.85	32	Ledding	(1965)
CH <sub>3</sub> OH + LiBr: ZnBr <sub>2</sub> (4:1)	TE	130 - 263	0.325 - 11.8	0.357 <sup>b</sup>	5	Aker	(1965)
CH <sub>3</sub> OH + LiBr: ZnBr <sub>2</sub> (2:1)	TE	86 - 282	0.170 - 13.3	0.278 - 0.567 <sup>b</sup>	5	Aker	(1965)
CH <sub>3</sub> OH + LiBr: ZnBr <sub>2</sub> (0.5:1)	TE	84 - 273	0.400 - 13.2	0.244 - 0.398 <sup>b</sup>	5	Aker	(1965)
CH <sub>3</sub> OH + LiBr: LiCl (0.5:1)	TE	86 - 193	0.560 - 11.4	0.678 - 0.800 <sup>b</sup>	5	Aker	(1965)
CH <sub>3</sub> OH + LiCl: ZnBr <sub>2</sub> (2:1)	TE	86 - 239	0.429 - 15.3	0.410 - 0.714 <sup>b</sup>	5	Aker	(1965)
CH <sub>3</sub> OH + LiBr: ZnBr <sub>2</sub> (2:1)	GS	32 - 302	-10 - 90 <sup>a</sup>	0.25 - 0.55 <sup>b</sup>	9	Biermann	(1978)
C <sub>3</sub> H <sub>7</sub> OH + ZnCl <sub>2</sub>	GE	78	0.11	Saturated 77°F	32	Ledding	(1965)
C <sub>3</sub> H <sub>7</sub> OH + LiCl	GE	78	0.14	Saturated 77°F	32	Ledding	(1965)
C <sub>3</sub> H <sub>7</sub> OH + ZnBr <sub>2</sub>	GE	91	0.27	Saturated 77°F	32	Ledding	(1965)

a - Refrigerant dew point temperature, °F

b - Weight fraction

X - Liquid phase

(1) - Refrigerant

Table 9.0. AMINES BINARY AND MULTICOMPONENT ABSORPTION  
FLUIDS PROPERTIES DATA

9.1. Vapor-Liquid Equilibrium

Fluid System	Data Type	Temp. Range, °F	Press. Range, psia	Mol. Frac. X (1)	No.	Reference Author	Year
Trimethylamine + TEG	GE	120	1.1 - 1.3 <sup>d</sup>	0.15 - 0.8	53	Roberson	(1966)
Dimethylamine + TEG	GE	120	0.3 - 0.9 <sup>d</sup>	0.15 - 0.8	53	Roberson	(1966)
$\text{CH}_3\text{NH}_2$ + NaSCN	TEP	77 - 248	7.05 - 379.0	0.69 - 0.81	54	Rush	(1967)
$\text{CH}_3\text{NH}_2$ + NaSCN	GS	59 - 203	20 - 120	0.72 - 0.85	8	Biermann	(1978)
$\text{CH}_3\text{NH}_2$ + LiSCN	TEP	78 - 285	0.93 - 191.4	0.62 - 0.89	38	Macriss	(1970)
$\text{CH}_3\text{NH}_2$ + LiSCN	GS	120 - 288	20 - 120	0.66 - 0.78	8	Biermann	(1978)
$\text{CH}_3\text{NH}_2$ + MEDEG	G	104	0.65 - 0.9 <sup>d</sup>	0.43 - 0.95	53	Roberson	(1966)
$\text{CH}_3\text{NH}_2$ + TEG	GE	104, 120	0.13 - 0.9 <sup>d</sup>	0.15 - 0.8	53	Roberson	(1966)
$\text{CH}_3\text{NH}_2$ + EG	GE	104	0.15 - 0.9 <sup>d</sup>	0.15 - 0.8	53	Roberson	(1966)
$\text{CH}_3\text{NH}_2$ + 1, 4 - Butanediol	GE	104	0.15 - 0.9 <sup>d</sup>	0.15 - 0.8	53	Roberson	(1966)
$\text{CH}_3\text{NH}_2$ + DMETEG	GE	104	0.15 - 0.9 <sup>d</sup>	0.15 - 0.8	53	Roberson	(1966)
$\text{CH}_3\text{NH}_2$ + LiSCN: DMETEG (2:1)	GE	212	10 - 145	0.30 - 0.75	9	Biermann	(1978)
$\text{CH}_3\text{NH}_2$ + LiSCN: EG (0.6:1)	GE	212	10 - 145	0.40 - 0.75	9	Biermann	(1978)
$\text{CH}_3\text{NH}_2$ + LiSCN: 1, 4 Butanediol (0.8:1)	GE	212	10 - 145	0.45 - 0.75	9	Biermann	(1978)

<sup>d</sup> - Activity coefficient

X - Liquid phase

(1) - Refrigerant

Table 9.0. (Cont.)

Fluid System	Data Type	Temp. Range, °F	Press. Range, psia	Mol. Frac. X (1)	Reference		
					No.	Author	Year
$\text{CH}_3\text{NH}_2 + \text{LiSCN}$ : Ethanolamine (0.6:1)	GE	212	10 - 145	0.35 - 0.65	9	Biermann	(1978)
$\text{CH}_3\text{NH}_2 + \text{LiSCN}$ : DMF (0.7:1)	GE	212	10 - 145	0.20 - 0.70	9	Biermann	(1978)
$\text{CH}_3\text{NH}_2 + \text{Zn}(\text{SCN})_2$	TE	95 - 118	70 - 120	0.82	9	Biermann	(1978)
$\text{CH}_3\text{NH}_2 + \text{Ni}(\text{SCN})_x$	TE	48 - 293	20 - 100	0.344 - 0.665 <sup>b</sup>	9	Biermann	(1978)
$\text{CH}_3\text{NH}_2 + \text{Co}(\text{SCN})_2$	TE	149 - 315	20 - 120	0.58 - 0.77	9	Biermann	(1978)
$\text{CH}_3\text{NH}_2 + \text{CuSCN}$	TE	145 - 282	20 - 120	0.51 - 0.73	9	Biermann	(1978)
$\text{CH}_3\text{NH}_2 + \text{Cu}(\text{SCN})_2$	TE	122 - 221	70 - 120	0.79 - 0.86	9	Biermann	(1978)
$\text{CH}_3\text{NH}_2 + \text{NaSCN}$ : LiSCN (4:1)	TE	102 - 277	20 - 110	0.306 - 0.534 <sup>b</sup>	9	Biermann	(1978)
$\text{CH}_3\text{NH}_2 + \text{NaSCN}$ : LiSCN (1.63:1)	TE	118 - 298	20 - 110	0.264 - 0.543 <sup>b</sup>	9	Biermann	(1978)
$\text{CH}_3\text{NH}_2 + \text{LiSCN}$ : DMETEG (0.6:1)	GS	104 - 320	5 - 75	0.250 - 0.450 <sup>b</sup>	9	Biermann	(1978)

<sup>b</sup> - Weight fraction

X - Liquid phase      (1) - Refrigerant

Table 9.0. (Cont.)

9.2. Crystallization Temperature

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>	<u>Wt. Frac.</u>	<u>Reference</u>		
				X (1)	<u>No.</u>	<u>Author</u>	<u>Year</u>
CH <sub>3</sub> NH <sub>2</sub> + NaSCN	GE	- 50 - 150	NA	0.500 - 0.535	54	Rush	(1967)

9.4. Heat of Mixing

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>	<u>Mol. Frac.</u>	<u>Reference</u>		
				X (1)	<u>No.</u>	<u>Author</u>	<u>Year</u>
CH <sub>3</sub> NH <sub>2</sub> + LiSCN	PC	80 - 260	0.93 - 191.4	0.60 - 0.80	38	Macriss	(1969)

9.5. Liquid-Phase Density

CH <sub>3</sub> NH <sub>2</sub> + LiSCN	TE	87 - 269	NA	0.60 - 0.80	38	Macriss	(1970)
---	----	----------	----	-------------	----	---------	--------

9.9. Viscosity

CH <sub>3</sub> NH <sub>2</sub> + LiSCN	TE	79 - 199	0.93 - 191.4	0.60 - 0.80	38	Macriss	(1970)
---	----	----------	--------------	-------------	----	---------	--------

X - Liquid phase  
NA - Not available

(1) - Refrigerant

Table 10.0. SULFUR DIOXIDE BINARY AND MULTICOMPONENT ABSORPTION FLUIDS PROPERTIES DATA

10.1. Vapor-Liquid Equilibrium

Fluid Systems	Data Type	Temp. Range, °F	Press. Range, psia	Mol. Frac. X (1)	Reference		
					No.	Author	Year
SO <sub>2</sub> + DMETEG	TE	77 - 200	0.61 - 294.5	0.157 - 0.926	3	Albright	(1963)
SO <sub>2</sub> + DMF	TE	77 - 200	1.39 - 271.7	0.180 - 0.851	3	Albright	(1963)
SO <sub>2</sub> + DMA	TE	77 - 200	0.30 - 209.5	0.105 - 0.771	3	Albright	(1963)
SO <sub>2</sub> + 2-Octanone	TE	77 - 200	16.5 - 282.0	0.376 - 0.854	3	Albright	(1963)
SO <sub>2</sub> + Ethyl laurate	TE	77 - 200	21.1 - 283.6	0.412 - 0.846	3	Albright	(1963)
SO <sub>2</sub> + Nitrobenzene	TE	77 - 200	21.1 - 183.6	0.412 - 0.846	3	Albright	(1963)
SO <sub>2</sub> + Nitrobenzene	TE	77 - 200	19.1 - 288.2	0.340 - 0.843	3	Albright	(1963)
SO <sub>2</sub> + n-Heptyl alcohol	TE	77 - 200	29.6 - 292.0	0.343 - 0.831	3	Albright	(1963)

10.4. Heat of Mixing

SO <sub>2</sub> + DMETEG	GSC	77 - 203	NA	0.0 - 1.0	3	Albright	(1963)
SO <sub>2</sub> + DMF	GSC	77 - 203	NA	0.0 - 1.0	3	Albright	(1963)
SO <sub>2</sub> + DMA	GSC	77 - 203	NA	0.0 - 1.0	3	Albright	(1963)

X - Liquid phase  
NA - Not available

(1) - Refrigerant

Table 11.0. HALOCARBON REFRIGERANT BINARY AND MULTICOMPONENT ABSORPTION FLUIDS PROPERTIES DATA

11.1. Vapor-Liquid Equilibrium

<u>Fluid Systems</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>	<u>Mol. Frac.</u> <u>X (1)</u>	<u>Reference</u>		
					<u>No.</u>	<u>Author</u>	<u>Year</u>
R1130 + DMH	TE	68 - 338	0.024 - 14.7	0.025 - 0.524 <sup>b</sup>	8	Biermann	(1978)
R1130 + DMD	TE	66 - 338	0.20 - 14.7	0.055 - 0.700 <sup>b</sup>	8	Biermann	(1978)
R1120 + DMD	TE	68 - 277	0.37 - 14.6	0.163 - 0.718 <sup>b</sup>	8	Biermann	(1978)
R1112a + DMH	TE	70 - 276	0.80 - 14.7	0.041 - 0.588 <sup>b</sup>	8	Biermann	(1978)
R140a + DMD	TE	68 - 324	0.15 - 14.7	0.117 - 0.804 <sup>b</sup>	8	Biermann	(1978)
R131a + DMH	TE	76 - 347	0.077 - 14.5	0.165 - 1.0 <sup>b</sup>	8	Biermann	(1978)
R123b + DMH	GS	32 - 302	-22 - 158 <sup>a</sup>	NA	8	Biermann	(1978)
R123b + NMP	GS	32 - 302	-22 - 158 <sup>a</sup>	0.18 - 0.50 <sup>b</sup>	8	Biermann	(1978)

a - Refrigerant dew point temperature, °F

b - Weight fraction

X - Liquid phase (1) - Refrigerant

NA - Not available

Table 12.0. REFRIGERANT 22 BINARY AND MULTICOMPONENT ABSORPTION FLUIDS PROPERTIES DATA

12.1. Vapor-Liquid Equilibrium

Fluid Systems	Data Type	Temp. Range, °F	Press. Range, psia		Mol. Frac. X (1)	Reference		
			14	- 297		No.	Author	Year
R22 + DMETEG	TE	75 - 275	14	- 297	0.191 - 0.911	16	Buclez	(1959)
R22 + DMETEG	TE	100 - 225	4	- 20	0.077 - 0.094	2	Albright	(1962)
R22 + DMETEG	GS	82 - 350	5	- 312	0.155 - 0.815	42	Mastrangelo	(1959)
R22 + DMETEG	GS	83 - 187	0	- 135	0.0 - 1.0	56	Sims	(1972)
R22 + DMETEG	CTS	75 - 250	0	- 462	0.0 - 1.0	36	Macriss	(1964)
R22 + DMEDEG	TE	32 - 86	1	- 15	0.0842- 0.340	50	Podoll	(1982)
R22 + DMF	TE	100 - 250	20	- 288	0.182 - 0.639	57	Thieme	(1961)
R22 + DMF	TE	100 - 220	7	- 29	0.067 - 0.077	2	Albright	(1962)
R22 + DEF	TE	100 - 220	26	- 248	0.289 - 0.785	57	Thieme	(1961)
R22 + DMA	TE	32 - 86	1.5	- 16	0.095 - 0.343	50	Podoll	(1982)
R22 + DMA	TE	68 - 213	9	- 286	0.252 - 0.735	2	Albright	(1962)
R22 + DMH	TE	32 - 86	1.5	- 15	0.114 - 0.340	50	Podoll	(1982)
R22 + DMH	GS	32 - 302	-22	- 158 <sup>a</sup>	0.33 - 0.63	8	Biermann	(1978)
R22 + TMM	GS	32 - 302	-22	- 158 <sup>a</sup>	0.25 - 0.55 <sup>b</sup>	8	Biermann	(1978)

<sup>a</sup> - Refrigerant dew point temperature, °F

<sup>b</sup> - Weight fraction

X - Liquid phase

(1) - Refrigerant

Table 12.0. (Cont.)

Fluid System	Data Type	Temp. Range, °F	Press. Range,		Mol. Frac. X (1)	Reference		
			psia			No.	Author	Year
R22 + TMS	GS	32 - 302	-22	- 158 <sup>a</sup>	0.50 - 0.74 <sup>b</sup>	8	Biermann	(1978)
R22 + Pentanedione	TE	75 - 250	19	- 312	0.168 - 0.787	16	Buclez	(1959)
R22 + Acetophenone	TE	75 - 225	27	- 251	0.184 - 0.695	16	Buclez	(1959)
R22 + Benzaldehyde	TE	75 - 200	34	- 299	0.198 - 0.512	16	Buclez	(1959)
R22 + Valeric acid	TE	75 - 200	34	- 276	0.162 - 0.661	16	Buclez	(1959)
R22 + Linoleic acid	TE	75 - 225	35	- 111	0.171 - 0.427	16	Buclez	(1959)
R22 + Triacetin	TE	75 - 250	25	- 304	0.203 - 0.746	49	Pluche	(1959)
R22 + Diethyloxalate	TE	75 - 250	22	- 314	0.279 - 0.783	49	Pluche	(1959)
R22 + Diethylmalonate	TE	75 - 250	18	- 312	0.219 - 0.751	49	Pluche	(1959)
R22 + Ethyl benzoate	TE	75 - 200	32	- 294	0.244 - 0.671	49	Pluche	(1959)
R22 + Dioctylsebacate	GS	68 - 86	0	- 135	0.0 - 1.0	56	Sims	(1972)
R22 + Dibutylcarbitol	GS	68 - 86	0	- 135	0.0 - 1.0	56	Sims	(1972)
R22 + Dioctyphthalate	GS	68 - 86	0	- 135	0.0 - 1.0	56	Sims	(1972)
R22 + MMETrPG	GS	68 - 86	0	- 135	0.0 - 1.0	56	Sims	(1972)
R22 + NMP	GS	32 - 302	-22	- 158 <sup>a</sup>	0.19 - 0.57 <sup>b</sup>	8	Biermann	(1978)
R22 + DMETEG: Benzyl alcohol (1.1)	TE	100 - 250	31	- 524	0.221 - 0.745	27	Hesselberth	Undated

a - Refrigerant dew point temperature, °F

b - Weight fraction

X - Liquid phase

(1) - Refrigerant

Table 12.0. (Cont.)

12.3. Corrosion Characteristics

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp Range, °F</u>	<u>Press. Range, psia</u>	<u>Wt. Frac. X (1)</u>	<u>Reference</u>		
			NA	0.5 (Volume)	<u>No.</u>	<u>Author</u>	<u>Year</u>
R22 + DMETEG	TE	250	NA	0.5 (Volume)	22	Eiseman	(1959)

12.4. Heat of Mixing

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>	<u>Mol. Frac. X (1)</u>	<u>Reference</u>		
			NA	0.076 - 0.129	<u>No.</u>	<u>Author</u>	<u>Year</u>
R22 + DMEDEG	TEC	77	NA	0.076 - 0.129	50	Podoll	(1982)
R22 + DMETEG	GSC	77 - 203	NA	0.0 - 1.0	2	Albright	(1962)
R22 + DMETEG	TEG	76	NA	0.0 - 1.0	36	Macriss	(1964)

12.6. Vapor-Liquid-Phase Enthalpies

R22 + DMETEG	TES	75 - 250	20 - 686	0.0 - 1.0	36	Macriss	(1964)
--------------	-----	----------	----------	-----------	----	---------	--------

X - Liquid phase  
 NA - Not available

(1) - Refrigerant

Table 12.0. (Cont.)

12.7. Specific Heat

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>	<u>Mol. Frac. X (1)</u>	<u>Reference</u>		
					<u>No.</u>	<u>Author</u>	<u>Year</u>
R22 + DMEDEG	TE	32 - 77	NA	0.1 - 0.2 <sup>b</sup>	50	Podoll	(1982)
R22 + DMETEG	TE	150 - 350	NA	0.2 - 0.75	36	Macriss	(1964)
R22 + DMA	TE	32 - 77	NA	0.1 - 0.2 <sup>b</sup>	50	Podoll	(1982)
R22 + DMH	TE	32 - 77	NA	0.1 - 0.2 <sup>b</sup>	50	Podoll	(1982)

12.8. Stability

R22 + DMETEG	TE	250 - 350	NA	0.5 (Volume)	22	Eiseman	(1959)
--------------	----	-----------	----	--------------	----	---------	--------

b - Weight fraction

X - Liquid phase

NA - Not available

(1) - Refrigerant

Table 13.0. REFRIGERANT 21 BINARY AND MULTICOMPONENT ABSORPTION FLUIDS PROPERTIES DATA

13.1. Vapor-Liquid Equilibrium

<u>Fluid Systems</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>		<u>Mol. Frac. X (1)</u>	<u>Reference</u>		
						<u>No.</u>	<u>Author</u>	<u>Year</u>
R21 + DMETEG	TE	75 - 250	2	- 74	0.317 - 0.832	16	Buclez	(1959)
R21 + DMETEG	TE	100 - 225	1	- 13	0.152 - 0.185	2	Albright	(1962)
R21 + DMETEG	TE	81 - 193	0.7	- 22	0.144 - 0.841	42	Mastrangelo	(1959)
R21 + DMETEG	GS	85 - 245	7	- 32	0.167 - 0.524 <sup>b</sup>	67	Zellhoeffer	(1937)
R21 + DMETrEG	TE	68 - 213	2.2	- 94	0.251 - 0.859	2	Albright	(1962)
R21 + DMEDEG	TE	32 - 86	0.14	- 3.3	0.104 - 0.360	50	Podoll	(1982)
R21 + DMF	TE	100 - 250	4.4	- 81	0.247 - 0.785	57	Thieme	(1961)
R21 + DMF	TE	100 - 225	1.6	- 17	0.101 - 0.128	2	Albright	(1962)
R21 + DEF	TE	100 - 250	13	- 102	0.278 - 0.738	57	Thieme	(1961)
R21 + DMA	TE	32 - 86	0.16	- 3.2	0.108 - 0.349	50	Podoll	(1982)
R21 + DMH	TE	32 - 86	0.097	- 3.2	0.089 - 0.375	50	Podoll	(1982)
R21 + DMH	GS	32 - 302	2.4	- 302	0.230 - 0.550 <sup>b</sup>	8	Biermann	(1978)
R21 + NMP	GS	32 - 302	-22	- 158 <sup>a</sup>	0.250 - 0.510 <sup>b</sup>	8	Biermann	(1978)

a - Refrigerant dew point temperature, °F

b - Weight fraction

X - Liquid phase

(1) - Refrigerant

Table 13.0. (Cont.)

Fluid System	Data Type	Temp. Range, °F	Press. Range,		Mol. Frac. X (1)	Reference		
			psia			No.	Author	Year
R21 + Diethylloxalate	TE	75 - 250	4	- 105	0.286 - 0.755	49	Pluche	(1959)
R21 + Diethylmalonate	TE	75 - 250	6	- 102	0.400 - 0.754	49	Pluche	(1959)
R21 + Diethyladipate	TE	75 - 250	4	- 103	0.373 - 0.752	49	Pluche	(1959)
R21 + Ethylbenzoate	TE	75 - 250	7	- 109	0.398 - 0.742	49	Pluche	(1959)
R21 + n-Butylbenzoate	TE	75 - 250	8	- 103	0.425 - 0.756	49	Pluche	(1959)
R21 + Triacetin	TE	75 - 250	4	- 118	0.318 - 0.784	49	Pluche	(1959)
R21 + n-Heptyl alcohol	TE	100 - 200	14	- 86	0.404 - 0.743	49	Pluche	(1959)
R21 + 2-Octanone	TE	75 - 250	4	- 105	0.294 - 0.744	16	Buclez	(1959)
R21 + Pentanedione	TE	75 - 225	4	- 108	0.234 - 0.732	16	Buclez	(1959)
R21 + Oleic acid	TE	75 - 225	6	- 110	0.249 - 0.710	16	Buclez	(1959)
R21 + Linoleic acid	TE	75 - 250	7	- 88	0.283 - 0.732	16	Buclez	(1959)
R21 + Valeric acid	TE	75 - 225	13	- 102	0.432 - 0.454	16	Buclez	(1959)
R21 + Acetophenone	TE	75 - 250	4	- 110	0.210 - 0.747	16	Buclez	(1959)
R21 + Benzaldehyde	TE	75 - 250	4	- 113	0.182 - 0.757	16	Buclez	(1959)
R21 + Ethyllaurate	TE	100 - 225	4.2	- 23.2	0.215 - 0.405	2	Albright	(1962)
R21 + Diethylloxalate	TE	100 - 225	3.4	- 21.4	0.172 - 0.180	2	Albright	(1962)
R21 + Diethyladipate	TE	100 - 225	3.6	- 22.5	0.227 - 0.239	2	Albright	(1962)

52

X - Liquid phase

(1) - Refrigerant

Table 13.0. (Cont.)

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>	<u>Mol. Frac.</u>		<u>Reference</u>		
				X (1)	No.	<u>Author</u>	<u>Year</u>	
R21 + Nitrobenzene	GE	125	15 - 45	0.2 - 0.8	57	Thieme	(1961)	
R21 + Aniline	GE	125	18 - 45	0.2 - 0.8	57	Thieme	(1961)	
R21 + Dimethyl aniline	GE	125	18 - 50	0.2 - 0.8	57	Thieme	(1961)	
R21 + M-Chloro aniline	GE	125	30 - 50	0.2 - 0.8	57	Thieme	(1961)	
R21 + Octyl Cyanide	GE	175	20 - 80	0.2 - 0.8	57	Thieme	(1961)	
R21 + N-Methylmorpholine	GE	175	20 - 80	0.2 - 0.8	57	Thieme	(1961)	
R21 + Octyl amine	GE	175	20 - 80	0.2 - 0.8	57	Thieme	(1961)	53
R21 + DMETEG: DMF (0.3:1~4:1)	GE	100 - 225	10 - 80	0.3 - 0.8	57	Thieme	(1961)	

13.3. Corrosion Characteristics

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Corrosion Inhibitor</u>	<u>Wt. Frac.</u>		<u>Reference</u>		
				X (1)	No.	<u>Author</u>	<u>Year</u>	
R21 + DMETEG	TE	250	NA	0.5 (Volume)	22	Eiseman	(1959)	

X - Liquid phase

NA - Not available

(1) - Refrigerant

Table 13.0. (Cont.)

13.4. Heat of Mixing

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>	<u>Mol. Frac. X (1)</u>	<u>Reference</u>		
					<u>No.</u>	<u>Author</u>	<u>Year</u>
R21 + DMEDEG	TEC	77	NA	0.135 - 0.348	50	Podoll	(1982)
R21 + DMETEG	GE	37	NA	0.100 - 0.950	66	Zellhoeffer	(1938)
R21 + DMH	TEC	77	NA	0.169 - 0.417	50	Podoll	(1982)
R21 + DMA	TE	77	NA	0.087 - 0.166	50	Podoll	(1982)

13.7. Specific Heat

R21 + DMEDEG	TE	32 - 77	NA	0.1 - 0.5 <sup>b</sup>	50	Podoll	(1982)	45
R21 + DMA	TE	32 - 77	NA	0.1 - 0.5 <sup>b</sup>	50	Podoll	(1982)	
R21 + DMH	TE	32 - 77	NA	0.1 - 0.5 <sup>b</sup>	50	Podoll	(1982)	

13.8. Stability

R21 + DMETEG	TE	250	NA	0.5 (Volume)	22	Eiseman	(1959)
--------------	----	-----	----	--------------	----	---------	--------

b - Weight fraction

X - Liquid phase

NA - Not available

(1) - Refrigerant

Table 14.0. REFRIGERANT 12 BINARY AND MULTICOMPONENT ABSORPTION FLUIDS PROPERTIES DATA

14.1. Vapor-Liquid Equilibrium

Fluid System	Data Type	Temp. Range, °F	Press. Range, psia	Mol. Frac.			
				X (1)	Y (1)	No.	Reference
						Author	Year
R12 + DMETEG	TE	100 - 250	51 - 604	0.186 - 0.867		27	Hesselberth Undated
R12 + DMA	TE	100 - 250	71 - 534	0.178 - 0.797		27	Hesselberth Undated
R12 + DMETEG: Benzyl alcohol (1:1)	TE	100 - 250	76 - 564	0.166 - 0.524		27	Hesselberth Undated
R12 + R22 : DMETEG	TE	100 - 250	41 - 513	Liq. 0.062 - 0.752 Vap. 0.173 - 0.887		27	Hesselberth Undated
R12 + R22 : DMA	TE	100 - 250	57 - 533	Liq. 0.008 - 0.619 Vap. 0.145 - 0.861		27	Hesselberth Undated
R12 + R22 : DMETEG: Benzyl alcohol (1:1)	TE	100 - 250	62 - 580	Liq. 0.018 - 0.560 Vap. 0.136 - 0.752		27	Hesselberth Undated

X - Liquid phase  
Y - Vapor phase

(1) - Refrigerant

Table 15.0 REFRIGERANTS 31, 30, 11, AND 134 BINARY AND MULTICOMPONENT ABSORPTION FLUIDS PROPERTIES DATA

15.1. Vapor-Liquid Equilibrium

Fluid System	Data Type	Temp. Range, °F	Press. Range, psia	Mol. Frac. X (1)	Reference		
					No.	Author	Year
R11 + DMETEG	TE	75 - 250	5 - 88	0.286 - 0.732	16	Buclez	(1959)
R11 + 2-Octanone	TE	75 - 250	6 - 85	0.265 - 0.701	16	Buclez	(1959)
R11 + Linoleic acid	TE	75 - 250	6 - 80	0.277 - 0.710	16	Buclez	(1959)
R11 + Diethyl malonate	TE	75 - 225	9 - 108	0.426 - 0.746	49	Pluche	(1959)
R11 + n-Heptyl alcohol	TE	100 - 200	14 - 86	0.404 - 0.743	49	Pluche	(1959)
R31 + DMETEG	TE	95 - 350	22 - 130	0.137 - 0.682	42	Mastrangelo	(1959)
R30 + DMETEG	GS	80 - 260	2 - 19	0.10 - 0.30	23	Ellington	(1957)
R134 + DMETEG	TE	83 - 187	4 - 73	0.131 - 0.740	42	Mastrangelo	(1959)

X - Liquid phase

(1) - Refrigerant

Table 16.0. REFRIGERANTS 124A, 133A, AND 123A BINARY AND MULTICOMPONENT ABSORPTION FLUIDS PROPERTIES DATA

16.1. Vapor-Liquid Equilibrium

Fluid System	Data Type	Temp. Range, °F	Press. Range, psia	Mol. Frac. X (1)	Reference		
					No.	Author	Year
R124a + DMETEG	TE	95 - 350	8 - 122	0.092 - 0.772	42	Mastrangelo	(1959)
R133a + ETFE	GS	90 - 350	2 - 190	0.05 - 0.59	6	Allen	(1979)

16.5. Liquid-Phase Densities

R133a + ETFE	TEP	-76 - 482	NA	0.0 - 0.60 <sup>b</sup>	6	Allen	(1979)
--------------	-----	-----------	----	-------------------------	---	-------	--------

16.8. Stability

R133a + ETFE	TE	75 - 350	NA	0.20 <sup>b</sup>	46	Murphy	(1982)
--------------	----	----------	----	-------------------	----	--------	--------

16.9. Viscosity

R133a + ETFE	GSP	32 - 176	NA	0.0 - 1.0	6	Allen	(1979)
--------------	-----	----------	----	-----------	---	-------	--------

16.12. Thermal Conductivity

R133a + ETFE	TEP	20 - 260	NA	0.0, 1.0	6	Allen	(1979)
--------------	-----	----------	----	----------	---	-------	--------

b - Weight fraction

X - Liquid phase

NA - Not available

(1) - Refrigerant

Table 16.0. (Cont.)

16.13. Flammability

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>	<u>Mol. Frac.</u>	<u>Reference</u>		
				X (1)	<u>No.</u>	<u>Author</u>	<u>Year</u>
R133a + ETFE	TE	150 - 350	NA	0.0 - 1.0	46	Murphy	(1982)

16.14. Toxicity

R133a + ETFE	TE	NA	NA	0.0, 1.0	46	Murphy	(1982)
--------------	----	----	----	----------	----	--------	--------

X - Liquid phase  
 NA - Not available

(1) - Refrigerant

Table 17.0. REFRIGERANT 123A BINARY AND MULTICOMPONENT ABSORPTION FLUIDS PROPERTIES DATA

17.1. Vapor-Liquid Equilibrium

<u>Fluid System</u>	<u>Data Type</u>	<u>Temp. Range, °F</u>	<u>Press. Range, psia</u>	<u>Mol. Frac.</u>		<u>No.</u>	<u>Reference Author</u>	<u>Year</u>
				X (1)	Y (2)			
R123a + EFTF	TSGP	-25 - 460	1 - 100	0.0	- 1.0	47	Murphy	(1983)
R123a + ETFE	GE	100 - 380	20 - 40	0.006	- 0.920	47	Murphy	(1983)

17.4. Heat of Mixing

R123a + ETFE	P	75 - 400	1 - 100	0.0	- 1.0	47	Murphy	(1983)
--------------	---	----------	---------	-----	-------	----	--------	--------

17.6. Vapor-Liquid-Phase Enthalpies

R123a + ETFE	TSGP	75 - 400	1 - 100	0.0	- 1.0	47	Murphy	(1983)
--------------	------	----------	---------	-----	-------	----	--------	--------

17.8. Stability

R123a + ETFE	TE	70 - 350	NA	NA	NA	47	Murphy	(1983)
--------------	----	----------	----	----	----	----	--------	--------

17.9. Viscosity

R123a + ETFE	GSPC	68 - 176	NA	0.0	- 1.0	47	Murphy	(1983)
--------------	------	----------	----	-----	-------	----	--------	--------

X - Liquid phase

(1) - Refrigerant

Y - Vapor phase

(2) - Absorbent

NA - Not available

#### 4. Coarse Screening of Data for Selected Fluids

As mentioned earlier, large amounts of data and references for any fluid do not always guarantee adequate coverage of data needs, at a level of required precision. In fact, they may only denote relative importance of a given fluid for an application and/or the existence of conflicts in important property data, which often are difficult to measure. In such cases, a first-order or coarse screening and evaluation of data for key fluids, properties, and regimes is of paramount importance. Such screening and evaluations were carried out as part of this study for selected or key absorption fluids.

Several approaches were considered for use in carrying out the review and coarse screening of data from multiple sources. These include —

- Consideration of the author's statements concerning data quality
- Assessment of the measurement technique and apparatus used to develop the data
- Consideration of a given author's reputation for measuring data, where only one author's data were available for a fluid
- Comparison of data plots for a given fluid using data scatter and internal consistency criteria to judge data quality, as well as multiple-author data agreement
- Consideration of general trends of the plotted data, as inferred from data for similar or homologous series fluids.

Particular emphasis was placed on screening data of fluids that were either already in use, in commercial or prototype absorption cooling equipment, or identified as potentially useful in absorption systems and subsequently experimentally investigated. Examples of such fluids are —

- In commerical equipment,  $\text{NH}_3 + \text{H}_2\text{O}$ ,  $\text{H}_2\text{O} + \text{LiBr}$
- In prototype equipment, R133a + ETFE, R123a + ETFE
- Identified as potentially useful for heat pumps —
  - Organic/fluids, R21 + DMETEG, R22 + DMETEG, R22 + DMA, etc.
  - Methylamine/salt,  $\text{CH}_3\text{NH}_2 + \text{NaSCN}$
  - Methanol/salt;  $\text{CH}_3\text{OH} + \text{LiBr}$ ,  $\text{CH}_3\text{OH} + \text{LiBr}: \text{ZnBr}_2$

In most instances, researchers have first focused on the development of vapor-liquid equilibrium data for these fluids and, only secondarily, on other properties such as enthalpy, viscosity, stability, and toxicity. Therefore, the screening approach selected to evaluate certain property data of the above fluids has consisted of the side-by-side comparison of mainly vapor pressure (PTX) data and equilibrium vapor composition (TXY) data, when warranted, and for the NH<sub>3</sub>-H<sub>2</sub>O fluid, enthalpy data.

### NH<sub>3</sub> - H<sub>2</sub>O

#### Vapor-Liquid Equilibrium Data

The ammonia-water absorption fluid has been extensively investigated for many years. With a few exceptions, most of the experimental studies were conducted in Europe, prior to 1932. In 1964, Macriss et al.<sup>35</sup> presented a summary of the most relevant studies and a side-by-side comparison of the data measured by several investigators.

The major thrust of U.S. investigations has been to thermodynamically analyze historical data and to perform directed experimental tests intended to fill in gaps or reconcile estimated or projected values. For example, in 1947 Scatchard et al.<sup>54</sup> calculated equilibrium vapor compositions that were significantly different than measured values. Scatchard reached this conclusion through a Gibbs-Duhem integration, assuming water was essentially non-volatile.

Directed experimental tests were also carried out by Macriss et al.<sup>35</sup>. These tests included measurements of dew point pressures of mixtures containing up to 4% water by weight. The vapor composition data from these tests were found to be about midway between the previously measured data and Scatchard's projections. More recently, Edwards<sup>21</sup> and then Won et al.<sup>60</sup> evaluated the thermodynamic consistency of the tabulated values presented earlier by Macriss. Again, as did Scatchard, Won projected water vapor concentrations, in equilibrium with ammonia-rich solutions, significantly below those given by Macriss.

The comparison between the smoothed experimental data of Macriss (and his further extrapolations) and the calculated values by Scatchard, Won, and Bogart<sup>14</sup> are presented in Figure 7 (Bogart compiled the values of Won in a compendium of Ammonia Absorption Refrigeration). At present, and without a more thorough examination of the thermodynamic models employed in the analyses

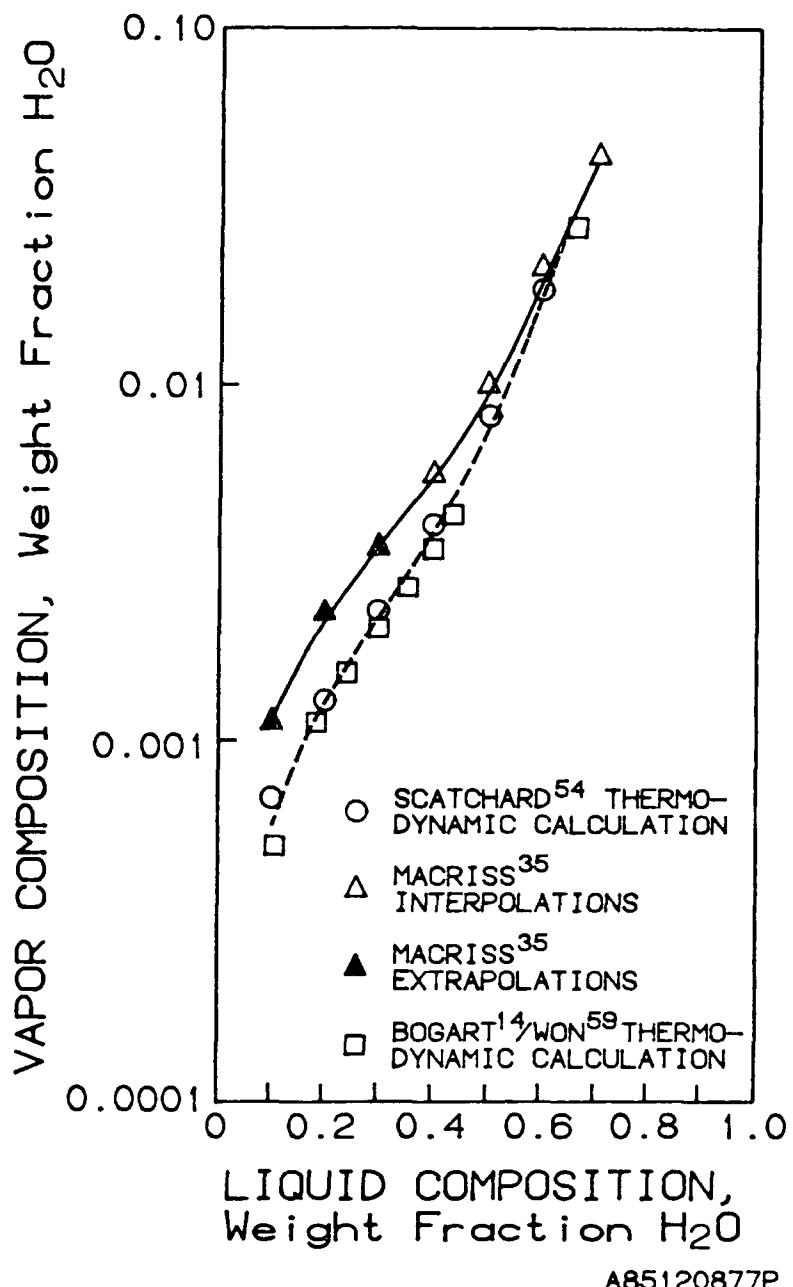


Figure 7. COMPARISON OF MEASURED AND PREDICTED VAPOR COMPOSITION OF THE  $NH_3 + H_2O$  PAIR AT 140°F

or additional data development, neither the data nor the analyses can be stated as being in error.

#### Enthalpy Data

Prior to 1964, tabulated values of liquid- and vapor-phase enthalpies were based on European studies conducted between 1929 and 1934. Specifically, Jennings and Shannon<sup>30</sup> in 1938 and Scatchard *et al.* in 1947 produced enthalpy tables in systematic increments of composition and pressure based on either interpolations of experimental data (Jennings) or thermodynamic calculations (Scatchard). An analysis by Macriss *et al.* in 1964 indicated that the results derived from the method of Scatchard were in good agreement with historical data for the low-temperature region, below 75°F. However, Scatchard's values deviated about 15% from measured data at high temperatures and pressures.

The measurements by Macriss involved heat capacities of four liquid mixtures of ammonia and water, containing between 0 and 40 weight percent ammonia, in the pressure range of 50 to 500 psia. By comparison, Scatchard's projections were consistently higher than the data of Macriss, deviating up to 15% at high temperatures. The differences are attributed to insufficient accuracy of the primary data utilized in the calculations of Scatchard. The Macriss data were consistently lower than historical European data, but the deviations from the latter data were smaller than those found by comparison of the Macriss data and the Scatchard projections.

Macriss also presented tabular values of liquid- and vapor-phase enthalpies for pressures ranging from 1 to 500 psia. Bogart, on the basis of the analysis by Won, summarized enthalpies at pressures ranging from 6 to 275 psia. A comparison of the Won and Macriss values at 140°F (Figure 8) indicates only small deviations, of 1% to 2%. The vapor-phase enthalpy projections of Won are 1% to 2% higher than the Macriss values, but the opposite trend is noted for the liquid-phase enthalpies.

#### H<sub>2</sub>O - LiBr

##### Vapor-Liquid Equilibrium Data

All data taken prior to 1928 have been assembled, evaluated, and presented in the International Critical Tables (ICT).<sup>28</sup> In 1955, Pennington<sup>48</sup> measured and reported vapor pressures above solutions with concentrations ranging from

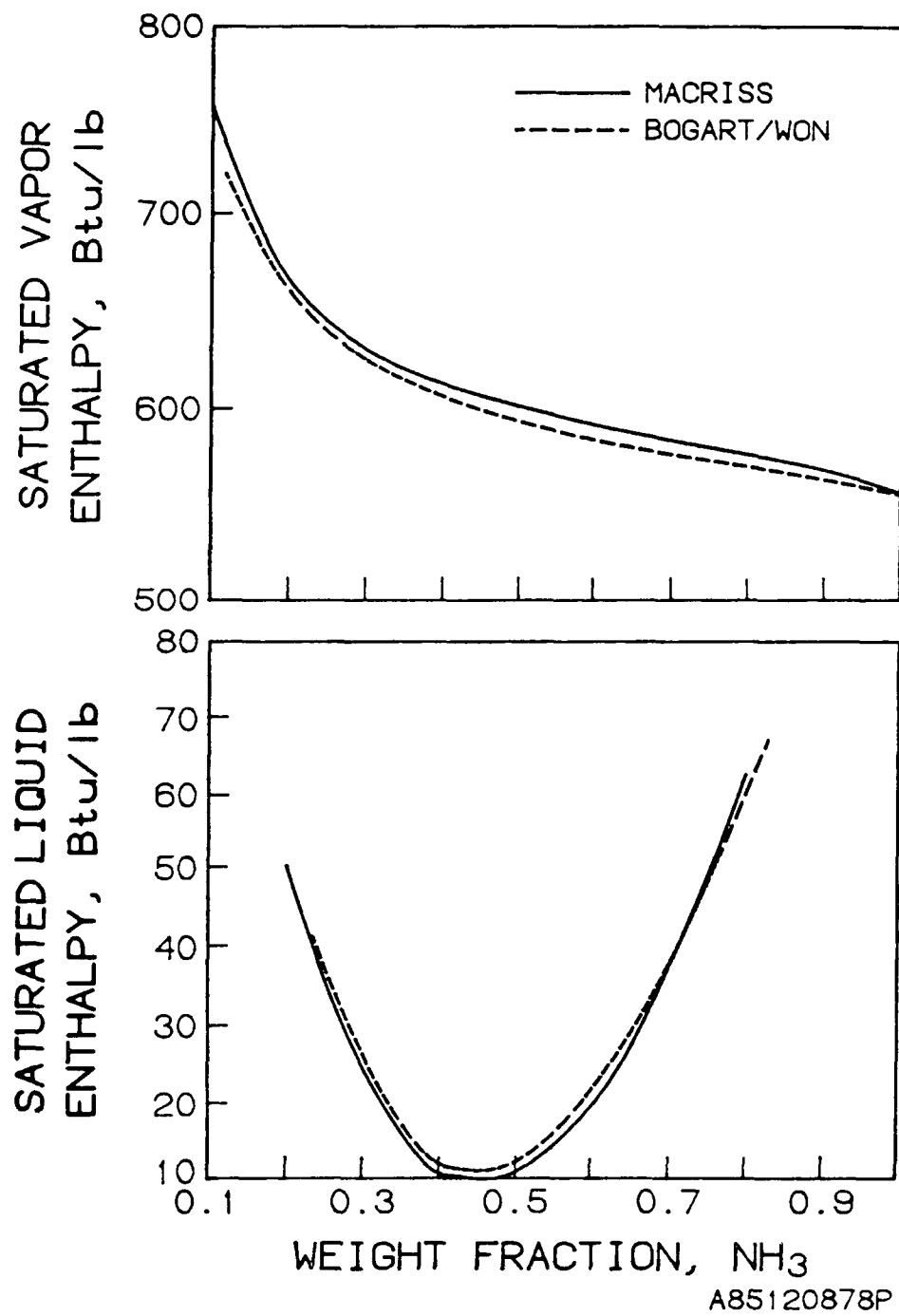


Figure 8. COMPARISON OF AMMONIA-WATER ENTHALPY DATA AT 140°F

A85120878P

50 to 68 weight percent LiBr and temperatures from 77° to 350°F. Ellington et al.<sup>23</sup> showed that the Pennington results deviated from those previously reported in the International Critical Tables, with deviations averaging more than 10% of the pressure measured. Sufficient experimental details were not available to indicate which group of data is more accurate.

More recently, McNeely<sup>43</sup> evaluated all known data in order to present a consistent set for inclusion in the ASHRAE Handbook of Fundamentals. Major absorption cooling equipment manufacturers were surveyed by McNeely to obtain proprietary or unpublished information. Based on the Pennington data, and proprietary data supplied by Carrier Corporation, McNeely developed polynomial correlations relating solution temperature, concentration, and vapor pressure.

Comparison of the dew points calculated from the polynomials to measured values indicated —

- Calculated values agreed well with the ICT data below LiBr solution concentrations of 44 weight percent. In the concentration range of 45 to 60 weight percent LiBr, the calculated dew points are 1° to 5°F lower.
- For solution concentrations above 45 weight percent LiBr, calculated values agreed with the Pennington data. Therefore, the ICT compilations were judged to be in error above concentrations of 45 weight percent LiBr.
- There is little data available above solution concentrations of 60 weight percent LiBr, at atmospheric pressure (14.7 psia), to substantiate the correlations.

#### CH<sub>3</sub>NH<sub>2</sub> - NaSCN

This fluid is an example of an organic refrigerant in combination with an inorganic salt absorbent. Two sources of smoothed data exist for this combination: Rush et al.<sup>54</sup> with tabulated values and Biermann<sup>8</sup> in graphical form. The comparison of the vapor pressures from the two sources, at solution concentrations of 50 and 62 weight percent CH<sub>3</sub>NH<sub>2</sub>, is illustrated in Figure 9. At both concentrations, the Biermann pressures are significantly lower, by about 40%, than those of Rush et al. There is no obvious reason for stating which of the two sources contains more accurate data. The experimental procedures used by Biermann have not been presented in the reference.

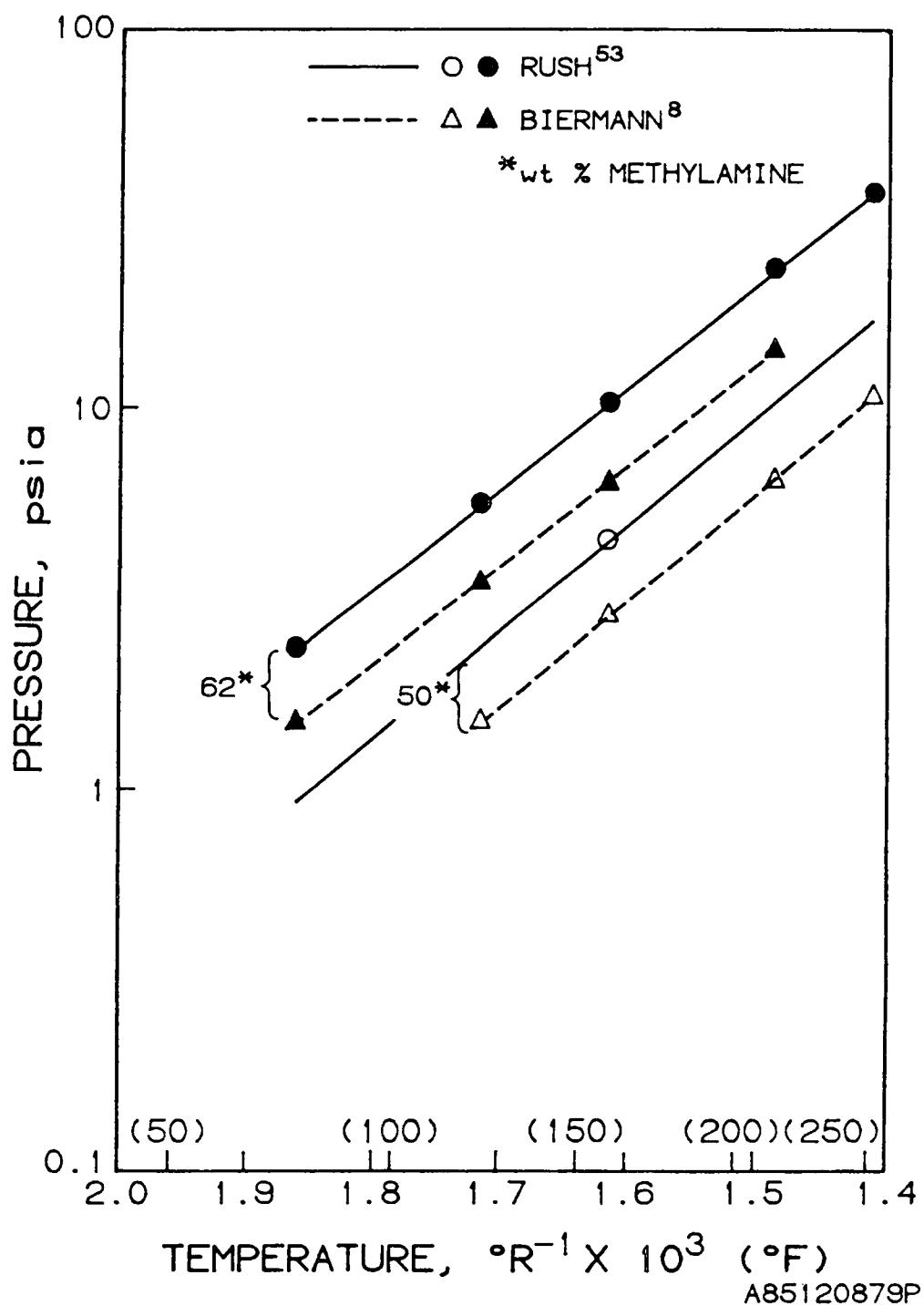


Figure 9. COMPARISON OF METHYLAMINE + SODIUM THIOCYANATE VAPOR PRESSURE DATA

### Methanol-Salt Fluids

Methanol is a refrigerant that has been proposed as a replacement for water in order to prevent system freeze-up problems and to develop air-cooled systems. Both Aker *et al.*<sup>5</sup> and Biermann<sup>9</sup> have investigated the vapor pressure of methanol ( $\text{CH}_3\text{OH}$ ) above solutions of fluids  $\text{CH}_3\text{OH} - \text{LiBr}$  and  $\text{CH}_3\text{OH} - \text{LiBr:ZnBr}_2$ . Comparisons of the data from both sources, shown in Figure 10, indicate the  $\text{CH}_3\text{OH-LiBr}$  vapor pressures to be about 20% lower than those of Aker for a 66.2 weight percent methanol solution. At a methanol concentration level of 44.8 weight percent, the vapor data from both sources are almost identical. Similar conclusions can be drawn from examination of the  $\text{CH}_3\text{OH-LiBr: ZnBr}_2$  vapor pressure data, illustrated in Figure 11. At a solution concentration of 44.2 weight percent  $\text{CH}_3\text{OH}$ , the vapor pressure of Biermann are, again, about 20% to 25% lower than those of Aker *et al.* At a lower concentration, 27.8 weight percent methanol, better agreement is obtained, but the Biermann measured vapor pressures are now slightly higher, by 5% to 10%. Again, there is no independent evidence to judge which of the two sets might be more accurate.

### Organic Refrigerant-Absorbent Fluids

A number of extensive investigations have been conducted to determine the usefulness of organic refrigerants, specifically halogenated hydrocarbons, paired with high-boiling organic compounds as absorbents such as ethers, amides, and esters. The major contributors to the data base are Allen<sup>6</sup> and Murphy<sup>46</sup> of Allied Chemical, Macriss<sup>36</sup> of the Institute of Gas Technology, Mastrangelo<sup>42</sup> of DuPont Corporation, Albright<sup>1,2</sup> of Purdue University, and Podoll<sup>49</sup> of SRI International.

### Refrigerants 123a, 133a - ETHE

For these fluids, the available data (Murphy<sup>46,47</sup>) practically cover most of the important fluid properties. Assessment of the accuracy or precision of the data, however, cannot be made from the available references.

### R22 - DMETEG

For this fluid, major experimental investigations on vapor-liquid equilibrium have been conducted by Mastrangelo,<sup>42</sup> Buclez,<sup>16</sup> and Albright *et al.*<sup>2</sup>

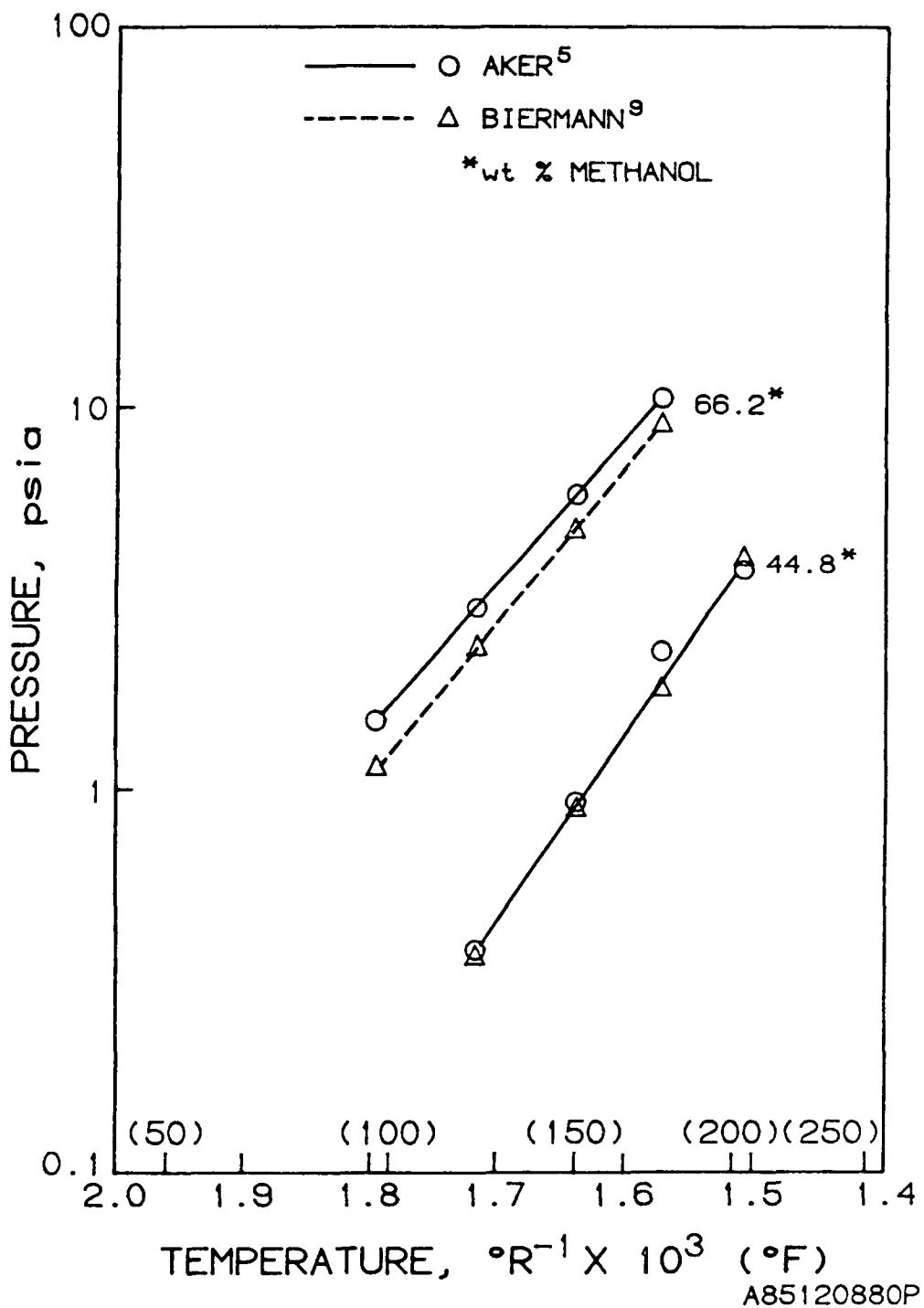


Figure 10. COMPARISON OF METHANOL + LITHIUM BROMIDE VAPOR PRESSURE DATA

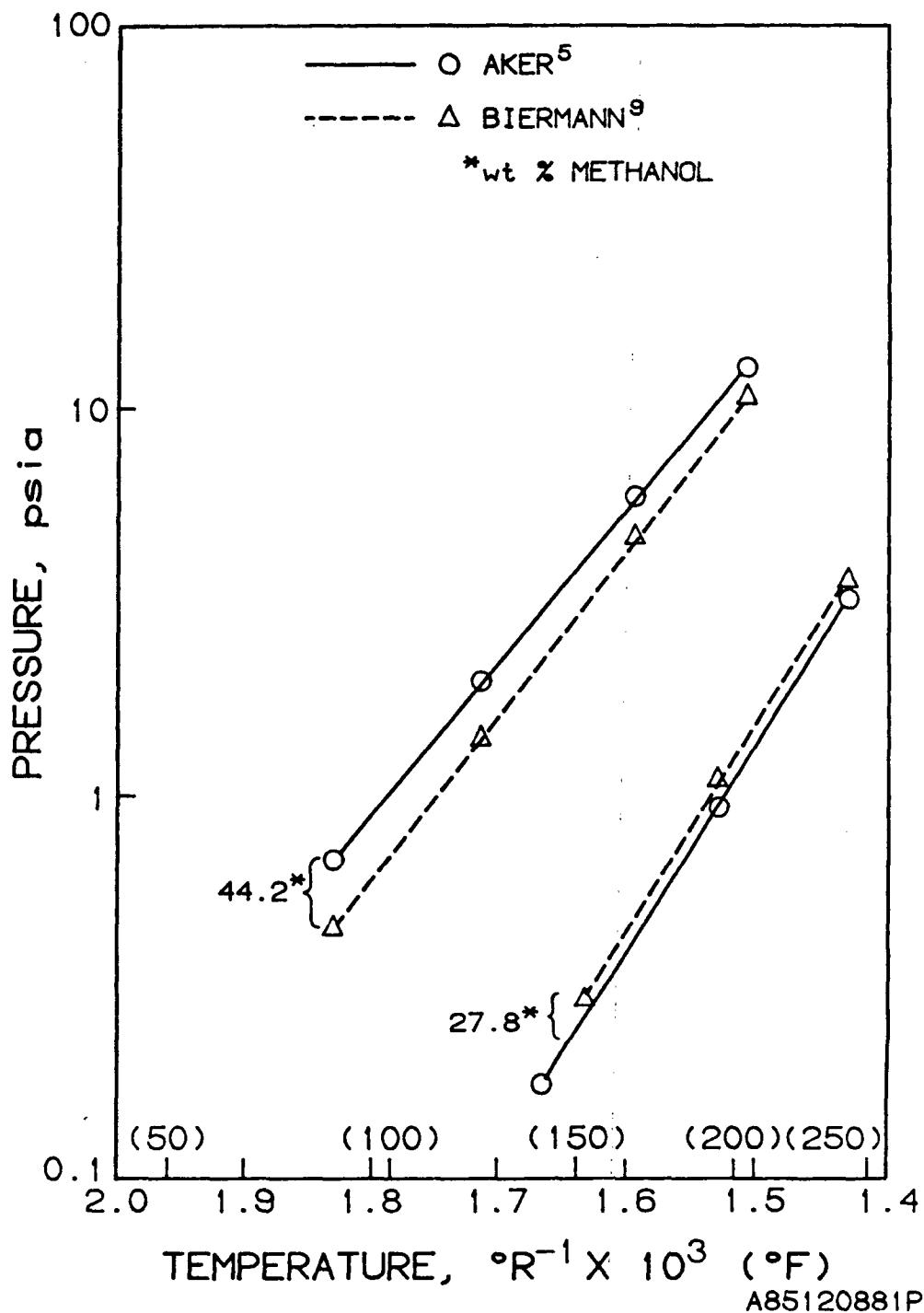


Figure 11. COMPARISON OF METHANOL + LiBr: ZnBr<sub>2</sub> (2:1) VAPOR PRESSURE DATA

Macriss and Mason<sup>26</sup> evaluated the available data by first determining the liquid activity coefficient of the refrigerant,  $y_r$ , from the data of Buclez and Albright *et al.* The activity coefficients were then plotted in a  $y_r$  versus  $x_r$  diagram with temperature as a parameter. The smoothed values obtained from this plot at constant  $x_r$  were, in turn, crossplotted on a  $y_r$  versus  $1/T$  plot. Values of  $y_r$  were obtained at regular values of  $x_r$  and values of  $1/T$  corresponding to the isotherms along which the data of Mastrangelo were determined.

The resulting smoothed data were then plotted on a  $y_r$  versus  $x_r$  plot along with the data of Mastrangelo. The data of Mastrangelo showed considerable scatter around the smoothed isotherms of Albright *et al.*, indicating poor internal consistency. A much smaller scatter of Albright's raw data had been evident, except for the two highest temperatures, 250°F and 275°F, where there were only a few experimental points for the entire range of concentration. Comparison of the scatter of the raw data from all sources, on the solubility of Refrigerant 22 in DMETEG in the range of 75° to 250°F, are summarized in Table 18.0.

#### R21 - DMETEG

The data of Buclez,<sup>16</sup> Albright *et al.*,<sup>2</sup> and Mastrangelo<sup>42</sup> at a solution composition of 30 mole percent R21 are illustrated in Figure 12. The agreement is good at temperatures below 125°F, whereas the Mastrangelo vapor pressure data are about 5% lower than those of the others, at temperatures in excess of 150°F.

#### R22 - DMA

Only a small overlap exists for the data of Podoll<sup>49</sup> and Albright *et al.*<sup>2</sup> in the temperature range of 75° to 95°F. However within that range, the agreement is good at a solution concentration of 26 mole percent R22, with Podoll's data about 3% to 5% lower than that of Albright *et al.* (Figure 13).

#### R21 or R22 - DMH

The data of Podoll<sup>49</sup> and Biermann<sup>8</sup> at a solution concentration of 37 mole percent R21 are illustrated in Figure 14. The Biermann data exhibit a significantly smaller slope than the trend line drawn through Podoll's data. At low temperatures (50°F), deviations up to 30% to 40% occur, with the Biermann data corresponding to higher vapor pressure values.

Table 18.0. DEVIATION OF SOLUBILITY DATA FROM VARIOUS SOURCES FROM THE FINAL SMOOTHED VALUES FOR R22 - DMETEG

Temperature, °F	Data of Albright et al.		Data of Mastrangelo	
	Number of Points*	Average Deviation, %	Number of Points	Average Deviation, %
83.0	9	0.74	11	4.6**
132.5	9	0.22	12	0.7
186.5	9	0.55	11	0.5
231.7	9	0.13	3	3.3†

\* Interpolated values.

\*\* All values of  $x_r$  equal or higher than smooth curve.

† All values of  $x_r$  equal or lower than smooth curve.

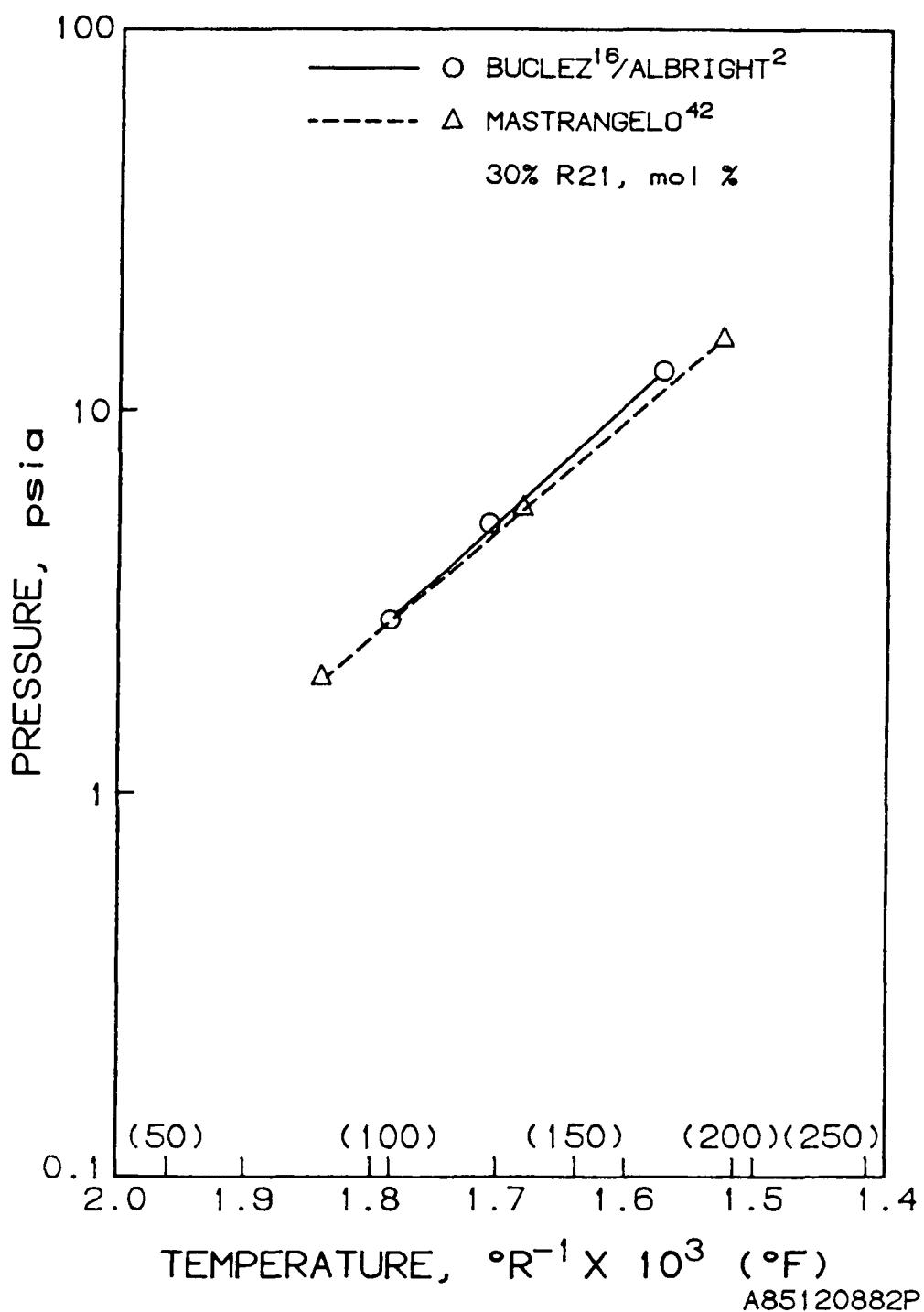


Figure 12. COMPARISON OF R21 + DMETEG VAPOR PRESSURE DATA

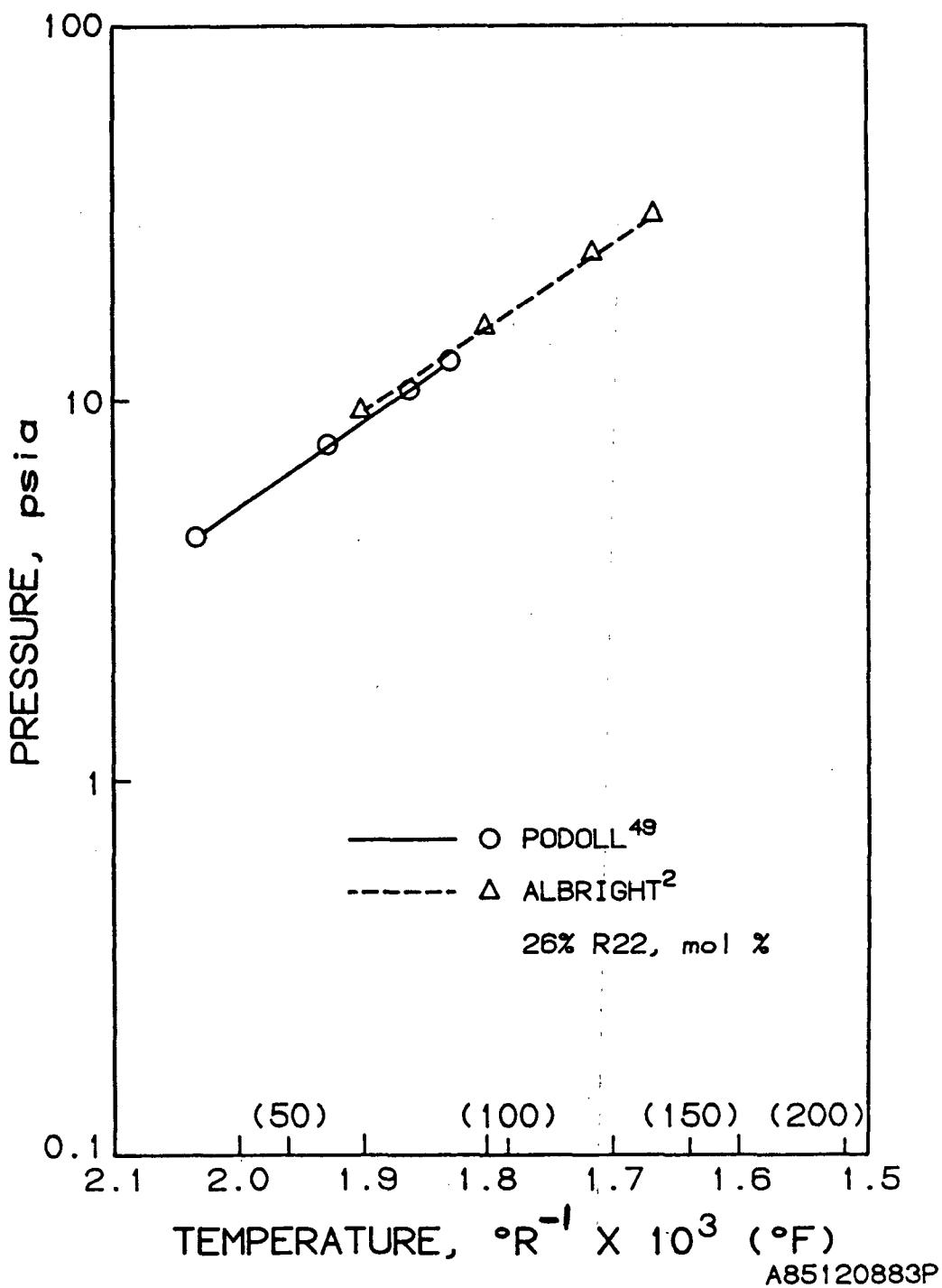


Figure 13. COMPARISON OF R22 + DMA VAPOR PRESSURE DATA

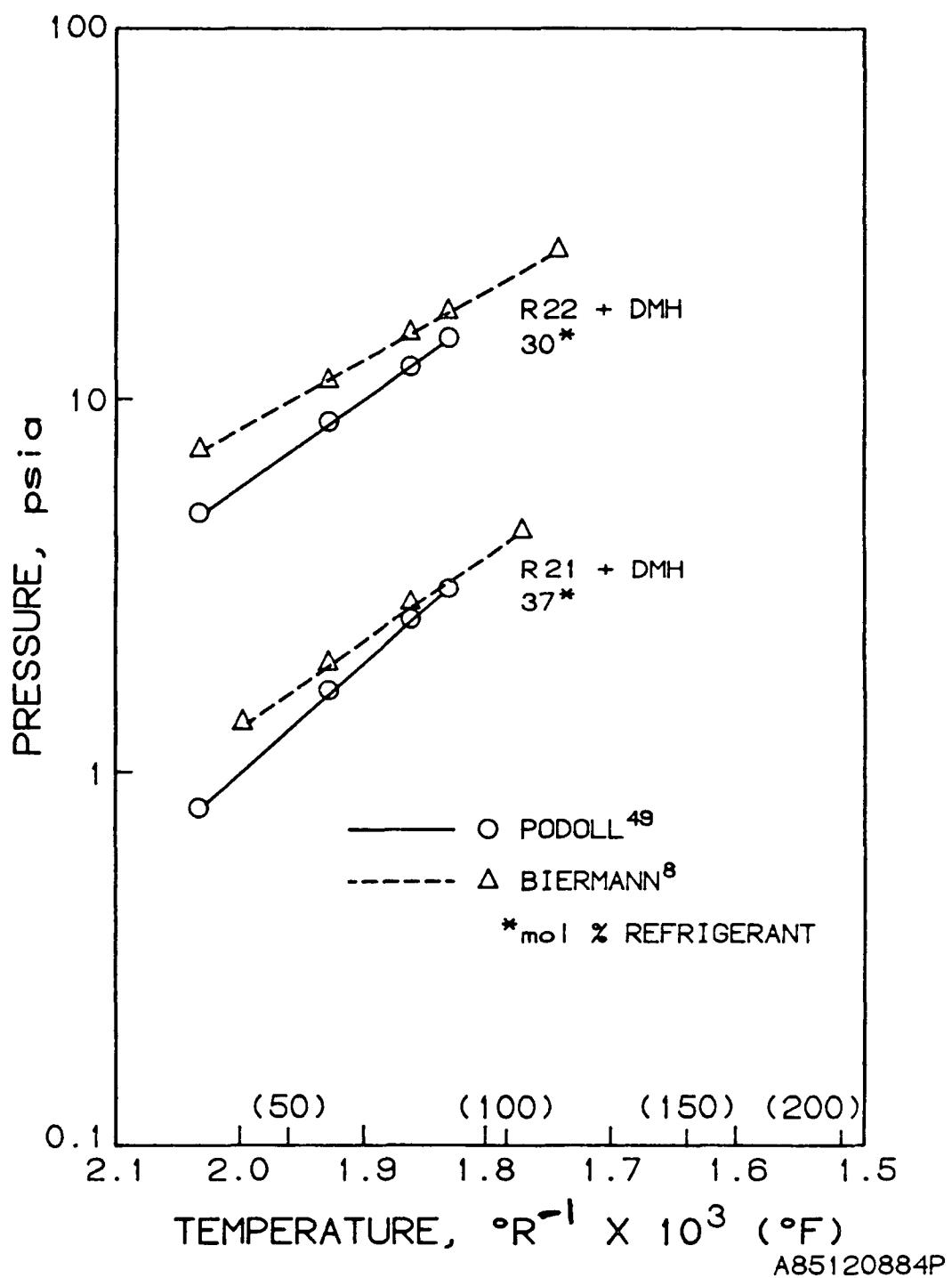


Figure 14. COMPARISON OF R21 + DMH AND R22 + DMH VAPOR PRESSURE DATA

For the R22 - DMH fluid and at a solution concentration of 30 mole percent R22, the Biermann data exhibit vapor pressures 20% to 50% larger than those of Podoll, as shown in Figure 14. As was the case for the R21 + DMH fluid, the deviations are greatest at low temperatures, and the slope of the Biermann trend line is smaller.

For the remainder of the fluids covered in this study, only single-source data have been available in the U.S. literature. In most of the cases, the available manuscripts did not contain sufficient methodological or detail instrumentation information to allow useful assessment of data quality.

##### 5. Gaps in the Data of Key Fluids

The results of the review and assessment of the U.S. literature data on absorption fluids, and the identification of unresolved or potential conflicts in the data, provide the basis for the definition of gaps in the existing data base. Additionally, information about the current activity of researchers involved in the development of advanced absorption heat pumps provides some insight as to potential new regimes (temperature, pressure, or concentration) and new fluids for which fluids property data must be known.

A rating system has been devised to be used in assessing the importance of filling the gaps in the data, in support of various efforts directed at the identification and development of viable, practical, and commercializable advanced absorption heat pumps. This rating system addresses data gaps on a fluid-by-fluid basis as follows:

1. Highest Priority: Conflict Resolution or New Data Imperative
2. Conflict Resolution in Data Needed
3. New Data Desirable

Blank. No Fluids Data Action Warranted.

The results of the assessment of gaps in the data for each fluid in this study, using the rating system, are presented in Figures 15 to 27. The numbers within the grid of each of the figures relate to the level of priority of filling the data gaps, relative to a specific fluid and each property of the fluid. A blank grid signifies that no further action is warranted regarding data.

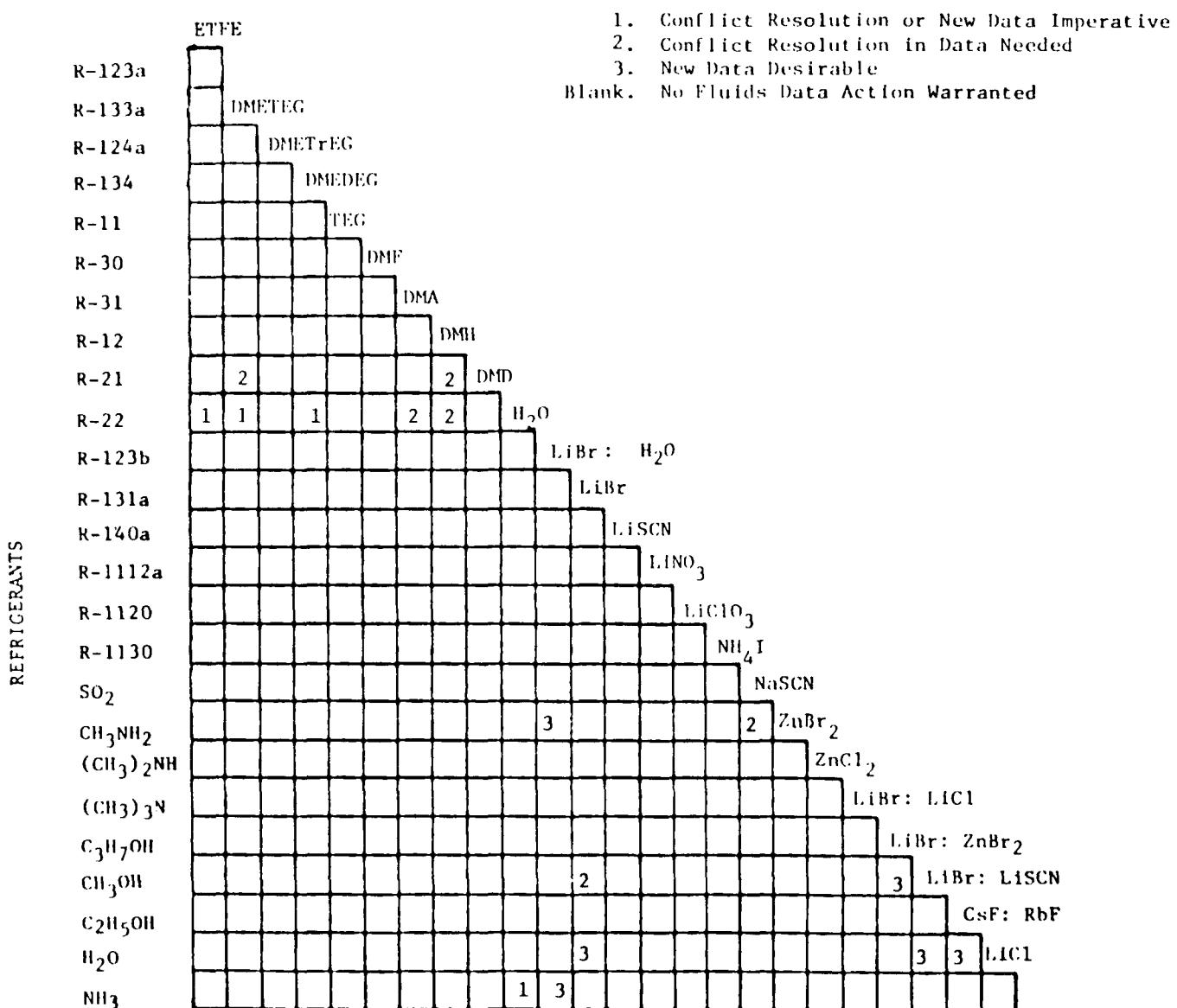


Figure 15. GAPS IN VAPOR-LIQUID EQUILIBRIUM DATA

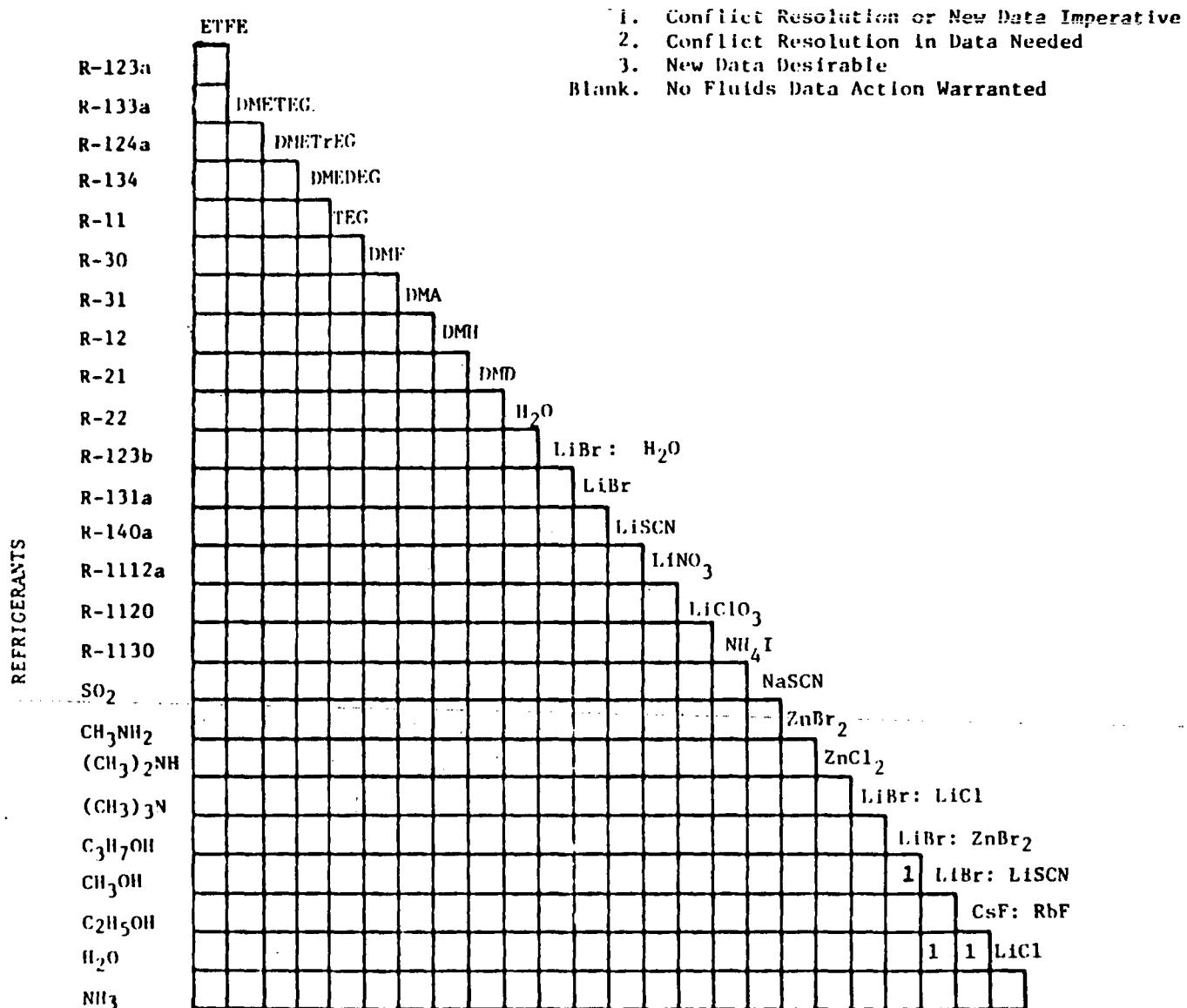


Figure 16. GAPS IN CRYSTALLIZATION TEMPERATURE DATA

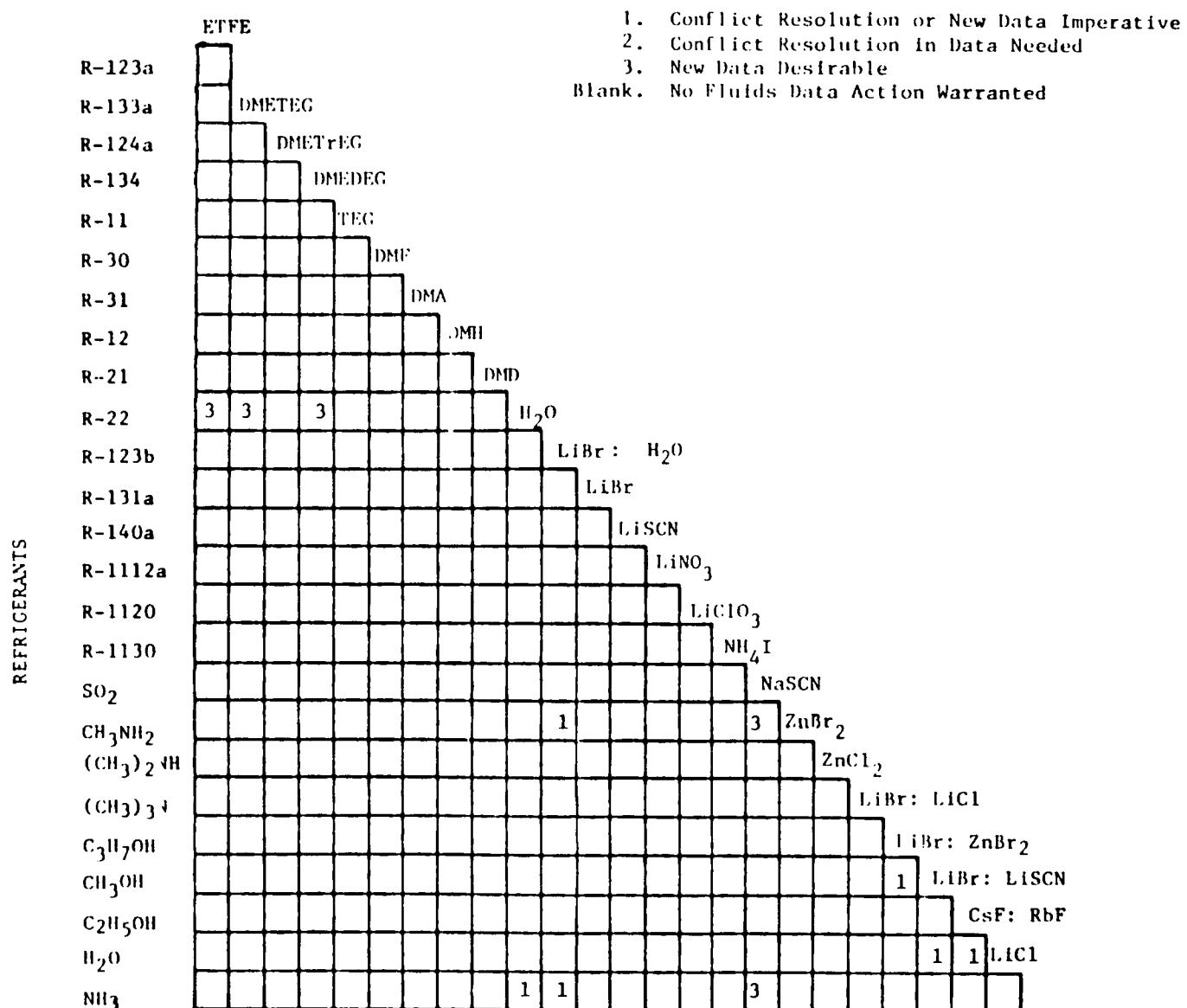


Figure 17. GAPS IN CORROSION DATA

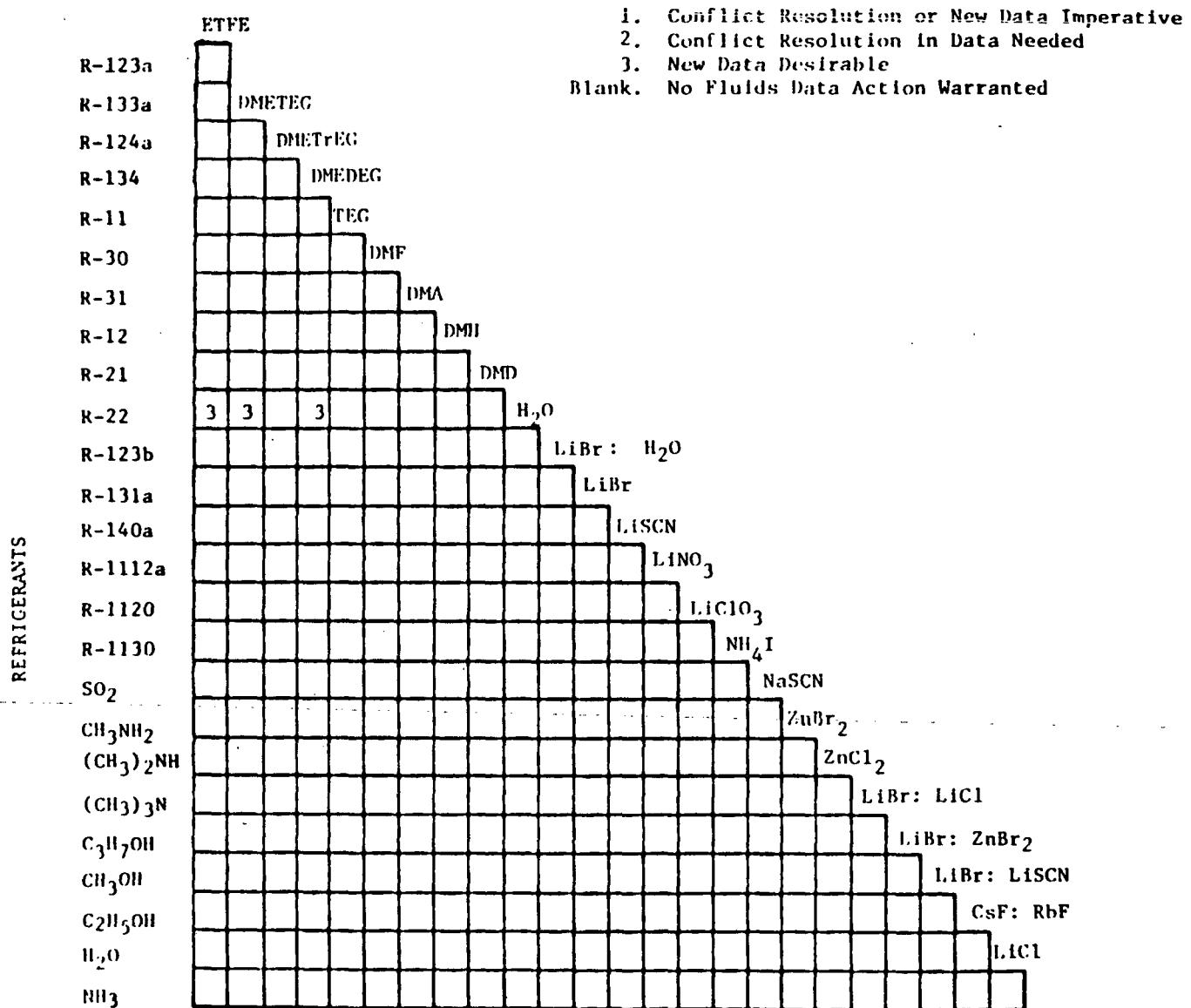


Figure 18. GAPS IN TOXICITY DATA

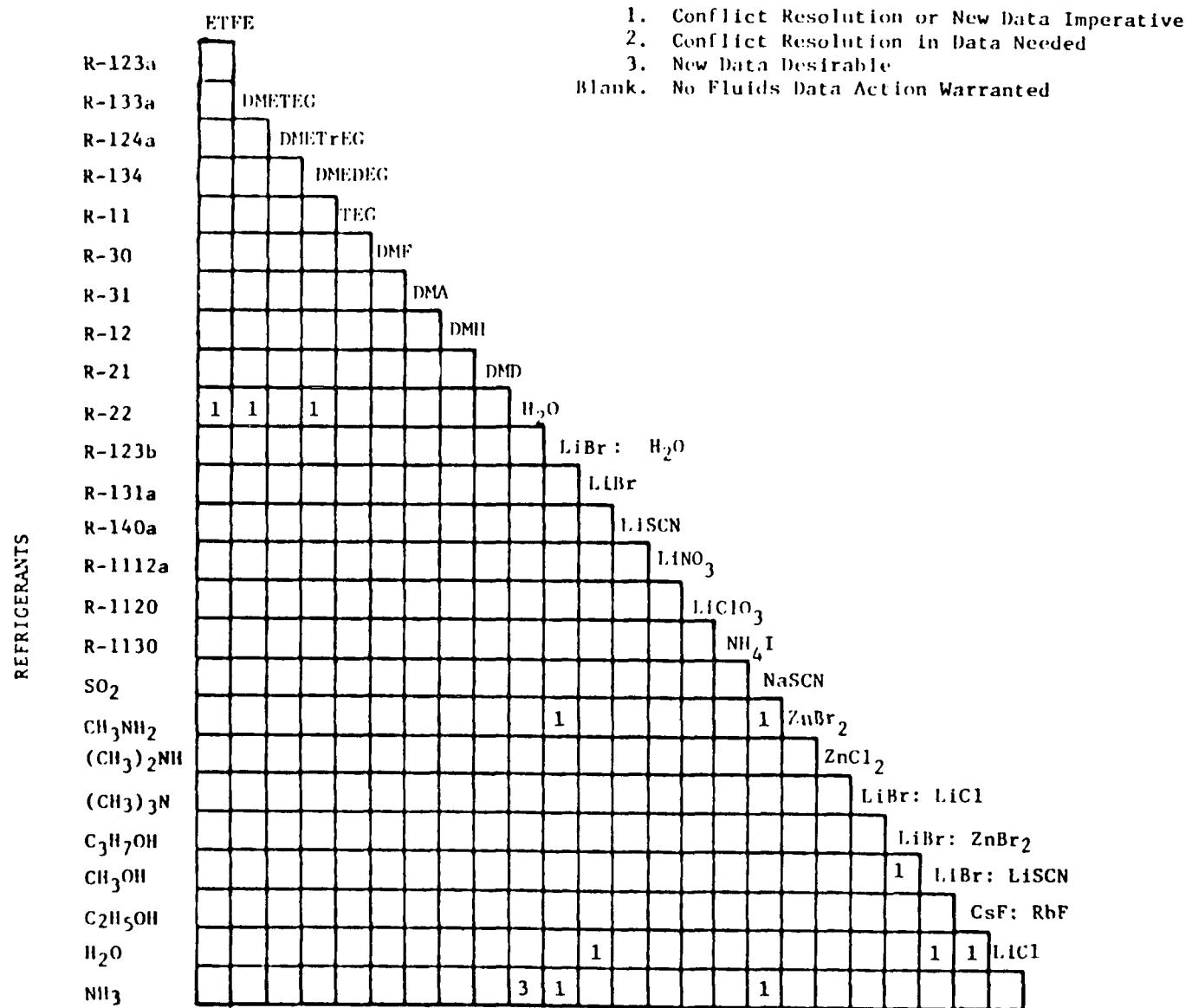


Figure 19. GAPS IN HEAT AND MASS TRANSFER DATA

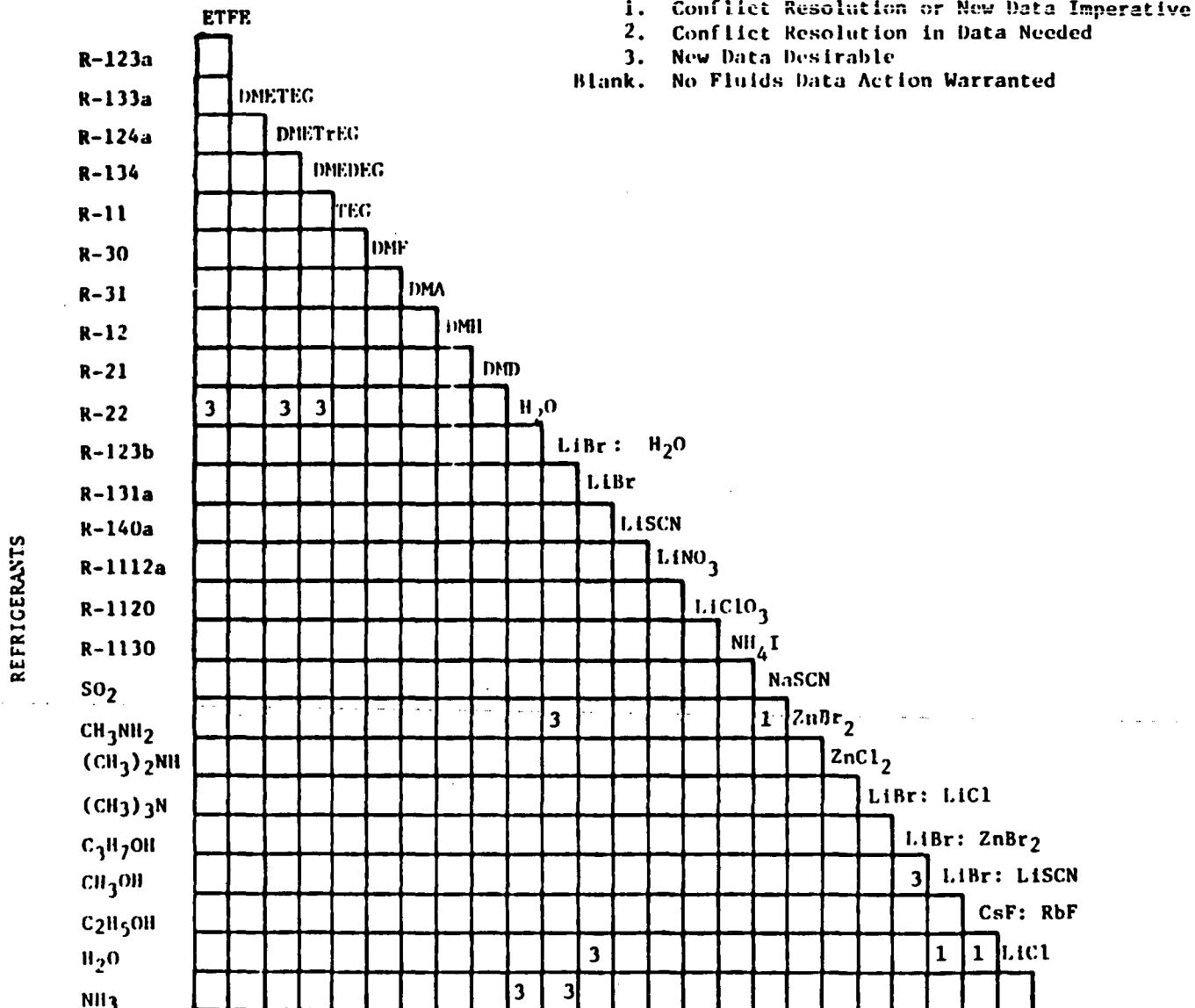


Figure 20. GAPS IN VISCOSITY DATA

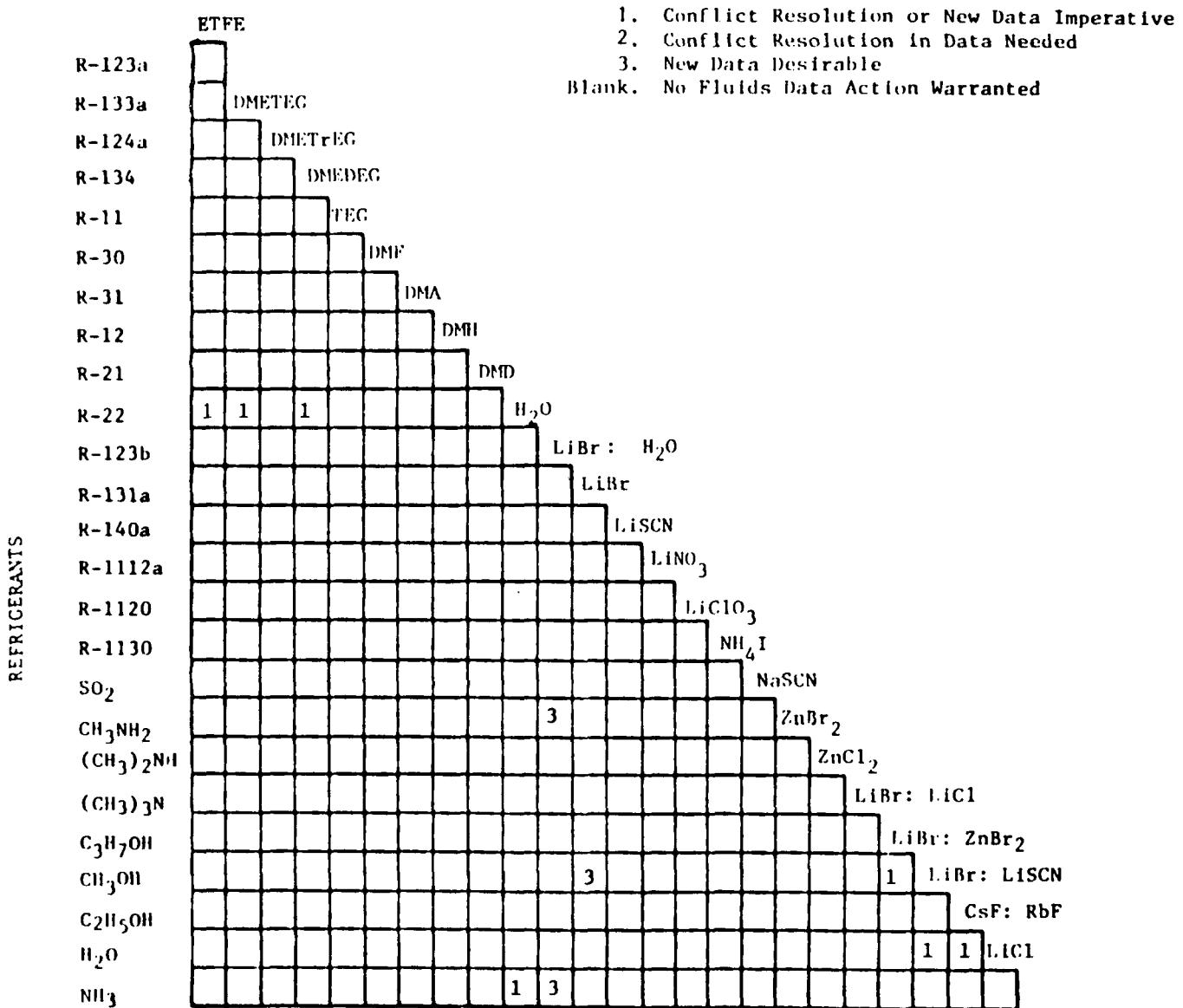


Figure 21. GAPS IN VAPOR- AND LIQUID-PHASE ENTHALPY DATA

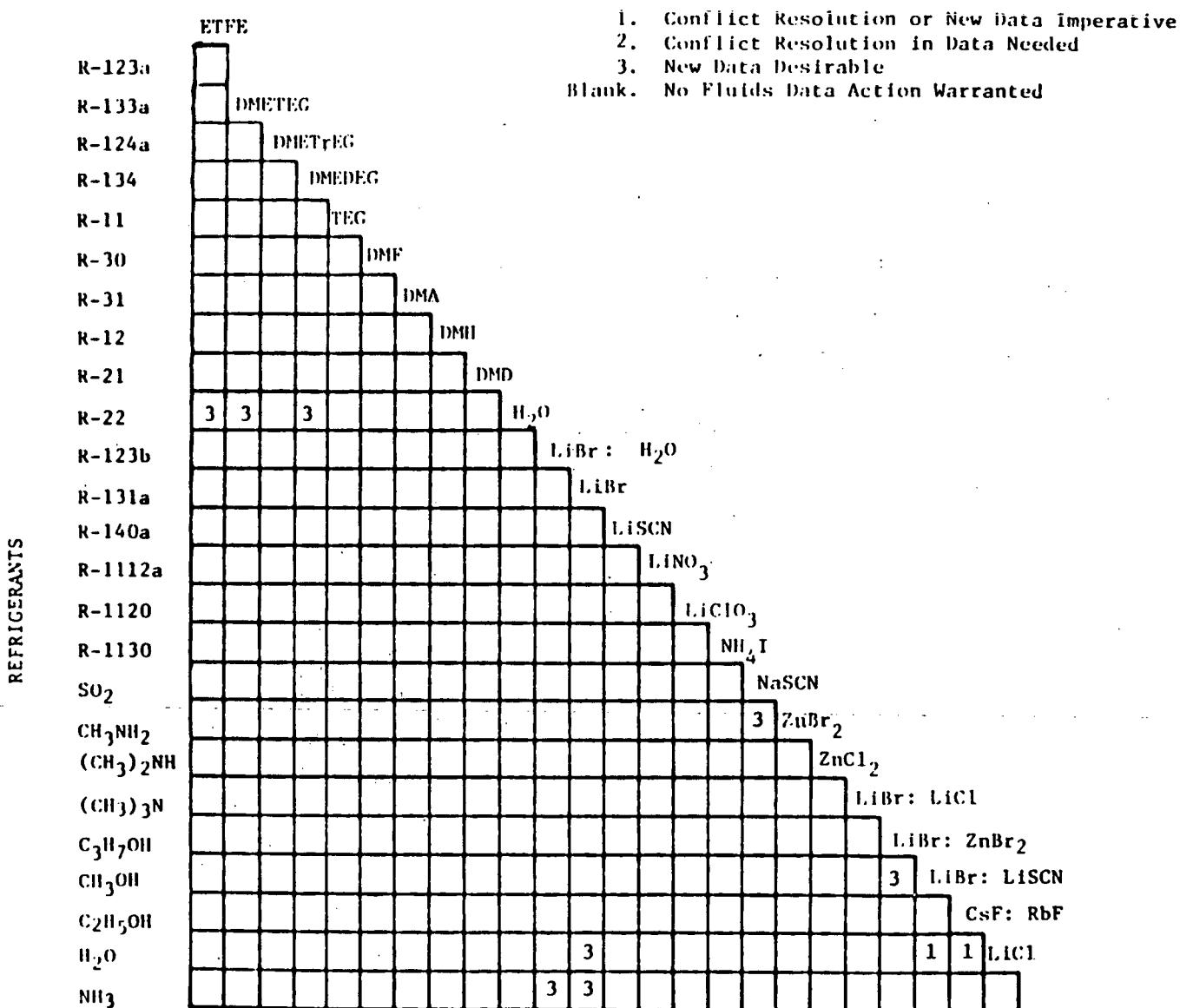


Figure 22. GAPS IN THERMAL CONDUCTIVITY DATA

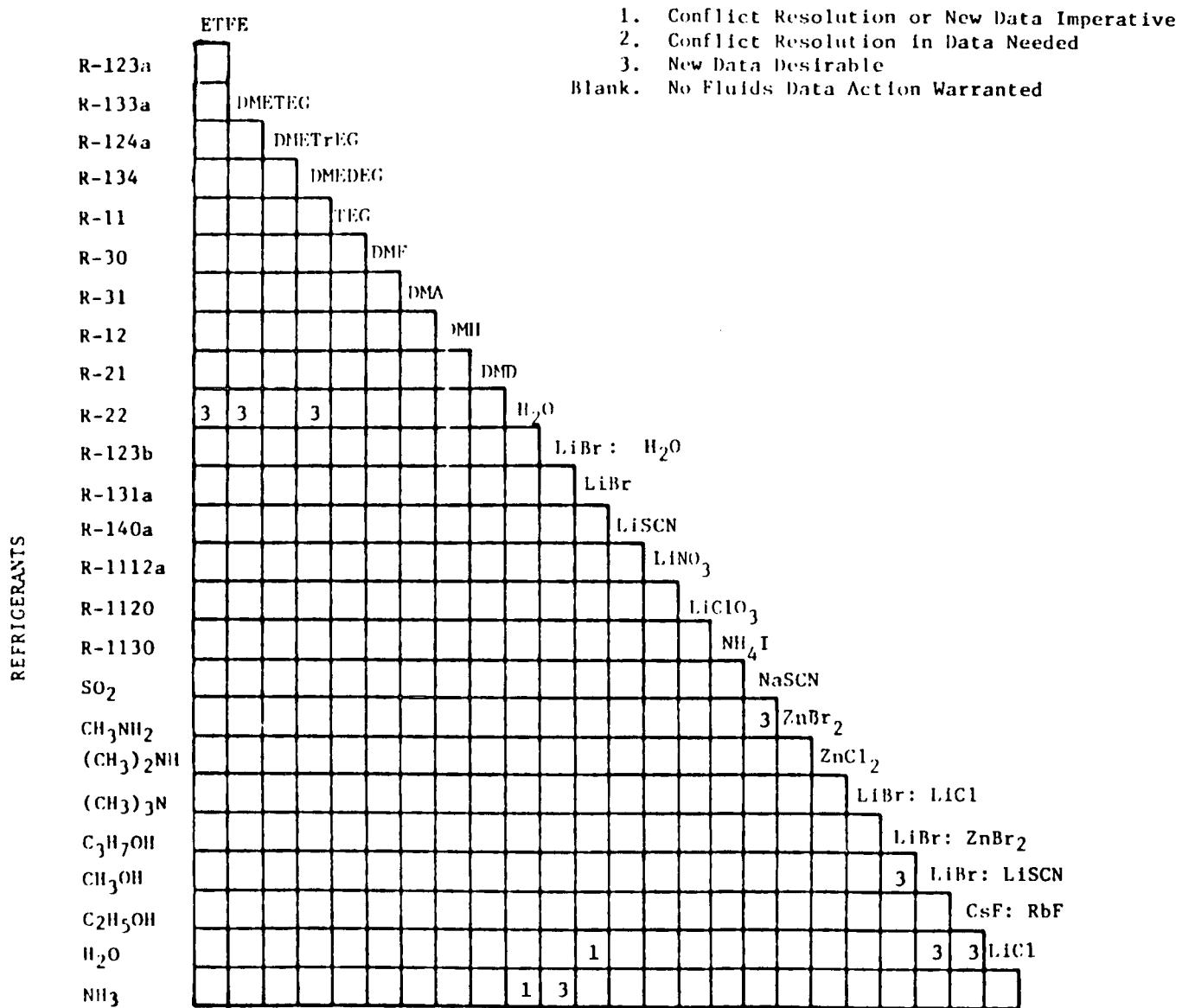


Figure 23. GAPS IN SPECIFIC HEAT DATA

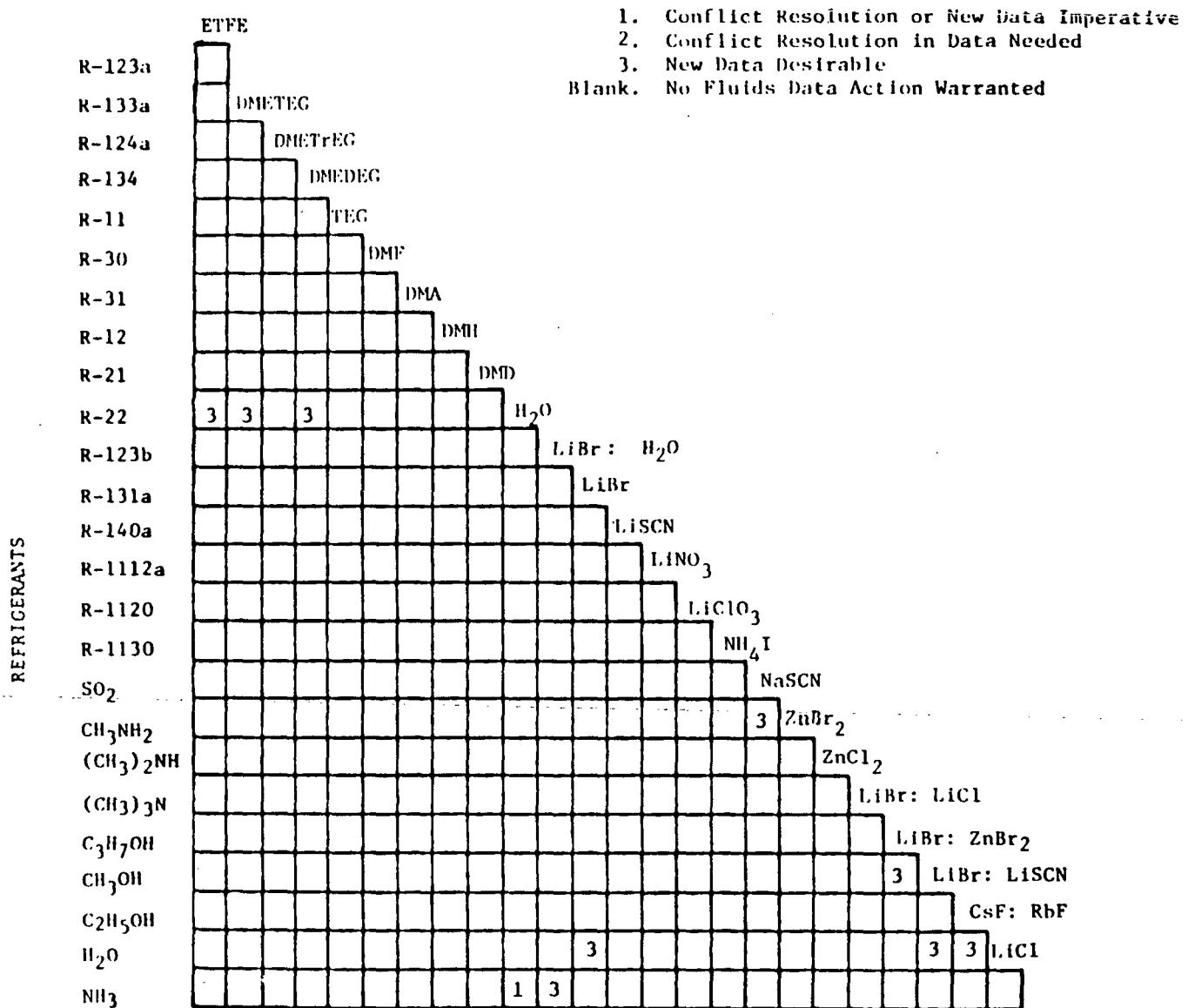


Figure 24. GAPS IN DENSITY DATA

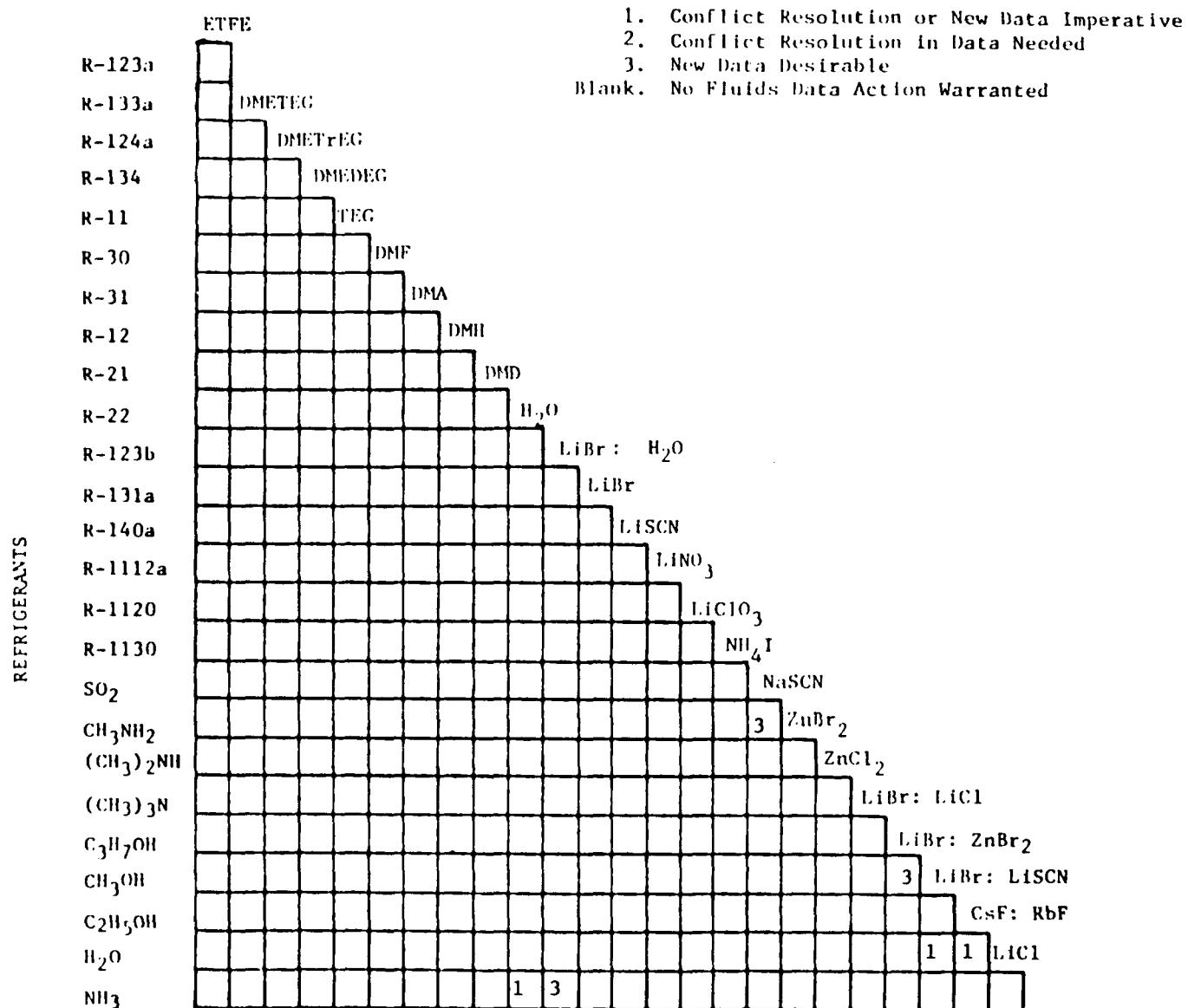


Figure 25. GAPS IN STABILITY DATA

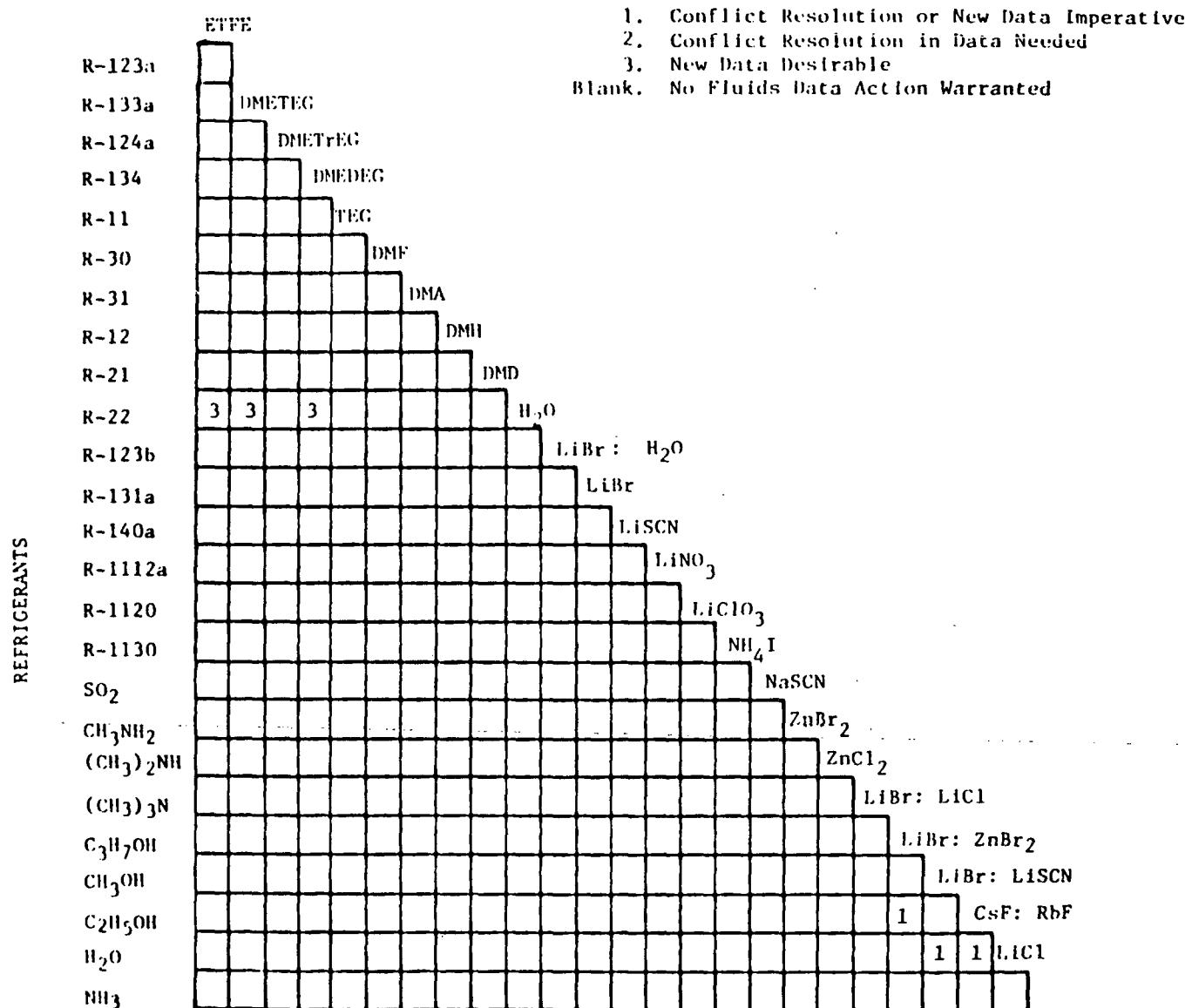


Figure 26. GAPS IN HEAT TRANSFER ADDITIVE DATA

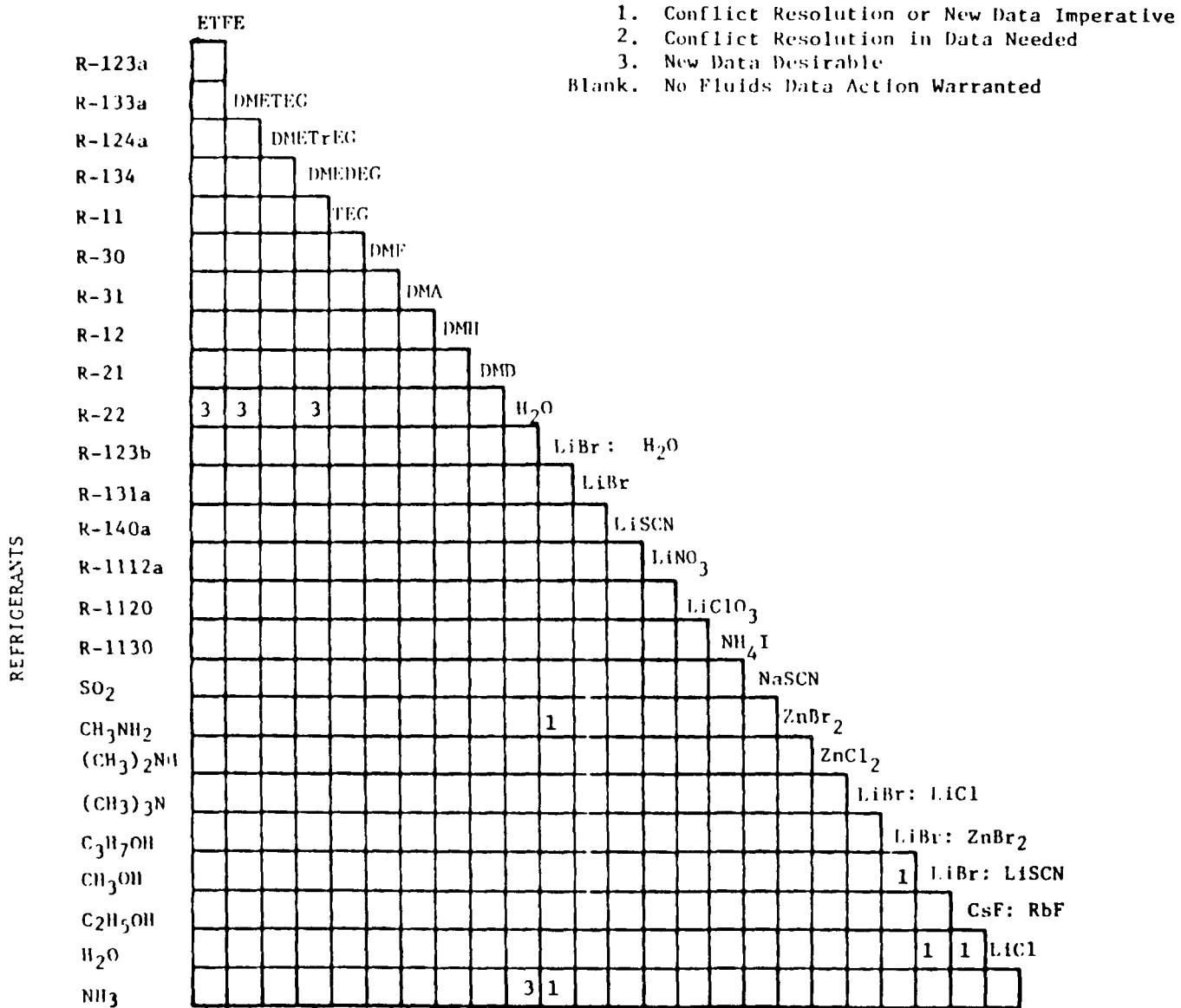


Figure 27. GAPS IN CORROSION INHIBITOR DATA

## REFERENCES

1. Albright, L. F., Buclez, P. C., Pluche, C. R. and Doody, T. C., "Solubility of Refrigerants 11, 21, and 22 in Organic Solvents Containing an Oxygen Atom," ASHRAE Trans., 66, 423-433, 1960.
2. Albright, L. F., Shannon, P. T., Terrier, F. and Chueh, P. L., "Solubility of Chlorofluoromethanes in Nonvolatile Polar Organic Solvents," AICHE J. 8, No. 5, 668-672 (1962) November.
3. Albright, L. F., Shannon, P. T., Yu, S.N., and Chueh, P. L., "Solubility of Sulfur Dioxide in Polar Organic Solvents," Chem. Eng. Prog. Symp. Ser. 59, No. 44, 66-74, 1963.
4. American Gas Association, "Symposium on Absorption Air-Conditioning Systems," Institute of Gas Technology, Chicago, Illinois June 1968.
5. Aker, J. E., Squires, R. G., and Albright, L. F., "An Evaluation of Alcohol-Salt Mixtures as Absorption Refrigeration Solutions," Paper presented at the ASHRAE Semiannual Meeting, Chicago, January 25-28, 1965.
6. Allen, R. A. and Murphy, K. P., "Development of a Residential Sized Gas Fired Absorption Heat Pump," Annual Report prepared for Gas Research Institute by Allied Chemical Corporation, Morristown, N.J., November 1979.
7. Aronson, D. (assigned to Worthington Corp.), "Absorption Refrigeration System," U.S. Patent 3,478,530 (1969) November 18.
8. Biermann, W. J., "Candidate Chemical Systems for Air Cooled Solar Powered, Absorption Pairs," Unpublished Report Prepared for Department of Energy, Contract No. EG-77-C-03-1587, Carrier Corp., Undated.
9. Biermann, W. J., "Candidate Chemical Systems for Air Cooled Solar Powered, Absorption Air Conditioner Design, Part II - Solid Absorbents, High Latent Heat Refrigerants," Unpublished Report Prepared for Department of Energy, Contract No. EG-77-C-03-1587, Carrier Corp., April 1978.
10. Biermann, W. J., "Candidate Chemical Systems for Air Cooled, Solar Powered, Absorption Air Conditioner Design, Part III - Lithium Salts with Anti-Freeze Additives," Unpublished Report Prepared for Department of Energy, Contract No. EG-77-C-03-1587, Carrier Corp., June 1978.
11. Blytas, G. C., "Physicochemical Properties of Concentrated Solutions of Sodium Thiocyanate in Liquid Ammonia," Unpublished Ph.D. Thesis, University of Wisconsin, 1961.
12. Blytas, G. C., Kertisz, D. J. and Daniels, F., "Concentrated Solutions in Liquid Ammonia: Solubility of NaNO<sub>3</sub> and KBr and other Salts; Vapor Pressure of LiNO<sub>3</sub>-NH<sub>3</sub> Solutions," J. Am. Chem. Soc., 84, No. 6, 1083-1085 (1962) April 5.

13. Blytas, G. C. and Daniels, F., "Concentrated Solution of NaSCN in Liquid Ammonia. Solubility, Density, Vapor Pressure, Viscosity, Thermal Conductance, Heat of Solution and Heat Capacity", J. Am. Chem. Soc., 84, No. 7, 1075-1082 (1962) April 5.
14. Bogart, M.J.P., Ammonia Absorption Refrigeration in Industrial Processes. Houston: Gulf Publishing Co., 1980.
15. Boryta, D. A., "Solubility of Lithium Bromide in Water Between 50° and +100° C (45-70% Lithium Bromide)," J. Chem. Eng. Data, 15, No. 1, 142-144, 1961.
16. Buclez, P. C., "The Solubility of Some Easily Liquefiable Gases in High Boiling Point Solvents," Unpublished Master's Thesis, Purdue University, June 1959.
17. Burnett, J. C. and Himmelblau, D. M., "The Effect of Surface Active Agents on Interphase Mass Transfer," AIChE J. 16, No. 2, 185-193, (1970) March.
18. Cohen, A. and Jelinek, R. V., "Corrosion Rates of Mild Steel in Alkaline Lithium Bromide Solutions by the Polarization Resistance Method," Corros., 22, 39-47 (1966) February.
19. Deemer, A. R., "Absorption of Water Vapor by an Aqueous Lithium Bromide Solution," Unpublished Master's Thesis, Illinois Institute of Technology, Chicago (1972) December.
20. Eding, H. J. and Brady, A. P., "Refrigerant-Absorbent Systems," SRI Project No. S-3372 Final Report prepared for Roy C. Ingersoll Research Center, Borg-Warner Corporation, Menlo Park, California: Standford Research Institute, March 31, 1961.
21. Edwards, T. J., Newman, J. and Prausnitz, J. M., "Thermodynamics of Vapor-Liquid Equilibrium for the Ammonia Water System," Ind. Eng. Chem. Fund., 17, No. 4, 264-269, 1978.
22. Eiseman, B. J., Jr., "Why Refrigerant 22 Should Be Favored for Absorption Refrigeration," ASHRAE J., 45-50 (1959) December.
23. Ellington, R. T., Kunst, G., Peck, R. E. and Reed, J. F., "The Absorption Cooling Process," Inst. Gas Technol., Chicago, Res. Bull., No. 14, 1957.
24. Ewing, W. W., and Fisher, H. M., "Studies in the Vapor Pressure - Temperature Relations of the Primary System Zinc Nitrate-Water," J. Am. Chem. Soc. 59 1046-1048 (1937) June.
25. George, J.H.B. and Birkett, J. D., "Study of Liquid Ammonia-Salts Systems and Their Potential Application to the Absorption Cooling Process," Projects ZF-72 and ZF-72a Final Report prepared for American Gas Association. New York: American Gas Association, 1965 (Catalog No. M10090).

26. Hensel, W. E., Jr. and Harlowe, I. W., Jr. (assigned to Arkla Industries, Inc.): "Compositions for Absorption Refrigeration System," U.S. Patent 3,643,455 (1972) February 22.
27. Hesselberth, J. F. and Albright, L. F., "Solubility of Mixtures of Refrigerants 12 and 22 in Organic Solvents of Low Volatility," Unpublished report, Purdue University, Undated.
28. "The International Critical Tables," Vol. III, 369. New York: McGraw-Hill Book Company, Inc., 1928.
29. Jain, P. C. and Gable, G. K., "Equilibrium Property Data Equations for Aqua-Ammonia Mixtures," ASHRAE Trans., No. 2180, 1971.
30. Jennings, B. H., "Ammonia-Water Properties (Experimentally-Determined P, V, T, x Liquid Phase Data)," Paper presented at ASHRAE Semiannual Meeting in Chicago, January 25-28, 1965.
31. Jennings, B. H. and Shannon, F. P., "The Thermodynamics of Absorption Refrigeration. Tables of Properties of Aqua-Ammonia Solutions," J. ASRE, 333-336 (1938) May.
32. Ledding, A., Borg-Warner Corporation, private communication with R. A. Macriss of the Institute of Gas Technology, 1965.
33. Lee, C. Y., "An Evaluation of Ammonia-Salt Mixtures as Absorption Refrigeration Solutions," Unpublished Master's Thesis, Purdue University (1965) June.
34. Macriss, R. A. and Eakin, B.E., "Thermodynamic Properties of Ammonia-Water Solutions Extended to Higher Temperatures and Pressures." Paper presented at the ASHRAE Meeting, Cleveland, July 1964; Published in ASHRAE Trans. 70, 319-27, 1964.
35. Macriss, R. A., Eakin, B. E., Ellington, R. T. and Huebler, J., "Physical and Thermodynamic Properties of Ammonia-Water Mixtures," Inst. Gas Technol., Chicago, Res. Bull., No. 34, 1964.
36. Macriss R. A. and Mason, D. M., "Physical and Thermodynamic Properties of New Refrigerant-Absorbant Pairs," Project ZB-85 Final Report prepared for the Air Conditioning and Prime Mover Research Committee of the American Gas Association. Institute of Gas Technology, October, 1964.
37. Macriss, R. A., Weil, S. A. and Rush, W. F. (assigned to the American Gas Association), "Absorption Refrigeration System Containing Solutions of Monomethylamine With Thiocyanates," U.S. Patent 3,458,445 (1969) July 29.
38. Macriss, R. A., Punwani, D., Rush, W. F. and Biermann, W. J., "Thermodynamic and Physical Properties of Monomethylamine-Lithium Thiocyanate System," J. Chem. Eng. Data, 15 No. 4, 466-470 (1970) October.

39. Macriss, R. A. and Rush, W. F., (assigned to the American Gas Association), "Lithium Bromide-Lithium Thiocyanate-Water Composition for an Absorbent-Refrigeration System," U. S. Patent 3,541,013 (1970) November 17.
40. Macriss, R. A., Punwani, D., Rush, W. F. and Biermann, W. J., "Thermodynamic and Physical Properties of the Ammonia-Lithium Thiocyanate System," J. Chem. Eng. Data (1971) December.
41. Macriss, R. A., "Selecting Refrigerant-Absorbent Fluid Systems for Solar Energy Utilization," Paper presented at the ASHRAE Semiannual Meeting, Dallas, Texas, February 1976.
42. Mastrangelo, S.V.R., "Solubility of Some Chlorofluorohydrocarbons in Tetraethylene Glycol Dimethyl Ether," ASHRAE J. 64-68 (1959) October.
43. McNeely, L. A., "Thermodynamic Properties of Aqueous Solutions of Lithium Bromide," ASHRAE Trans., 85, Part 1, 1979.
44. Mink, W. H. and Filbert, R. B., Jr., "Design and Development of a Refrigeration Cycle Employing the Principle of Azeotropic Mixtures," Final Report prepared for Amercian Gas Association, Columbus, Ohio: Battelle Memorial Institute, July 29, 1955.
45. Morrone, J. W., "Solubility of Ammonia in Low-Volatile Organic Solvents," Unpublished Thesis, Purdue University, February, 1962.
46. Murphy, K. P. and Allen, R. A., "Development of a Residential Gas Fired Absorption Heat Pump," Interim Report prepared for Oak Ridge National Laboratories and Gas Research Institute by Allied Chemical Corporation, Morristown, N.J. March 1982.
47. Murphy, K. et al., "Development of a Residential Gas Fired Absorption Heat Pump, Physical and Thermodynamic Properties of R123a/ETFE, System Development and Testing, Economic Analysis," Final Report ORNL/Sub/79-24610/5 by Allied Corporation, Morristown, N.J., November 1983.
48. Pennington, W., "How to Find Accurate Vapor Pressures of Lithium Bromide Water Solutions," Refrig. Eng. 63, 57-61 (1955) May.
49. Pluche, C. R., "Solubility of Various "Freons" in Esters and Alcohols," Unpublished Master's Thesis, Purdue University, June 1959.
50. Podoll, R. T., Gray, T. E., Rolon, C. E. and Sabo, K. A., "Determination of Properties of Fluids for Solar Cooling Applications," Prepared for Department of Energy by SRI International, Menlo Park, California, 1982.
51. Polak, J., and Lu, B. C. Y., "Vapor-Liquid Equilibrium in System Ammonia-Water at 14.69 and 65 Psia," J. Chem. Eng. Data, 20, No. 2, 1975.
52. Roberson, J. P., "Solubility of Ammonia in Solvent Mixtures of Low Volatility," Unpublished Master's Thesis, Purdue University, January 1965.

53. Roberson, J. P., Lee, C. Y., Squires, R. G. and Albright, L. F., "Vapor Pressure of Ammonia and Methylamines in Solutions for Absorption Refrigeration Systems," ASHRAE Trans. 72, Part 1, 198-208, 1966.
54. Rush, W. F., Macriss, R. A. and Weil, S. A., "A New Fluid System for Absorption Refrigeration," Paper presented at the Fourth International Congress of Heating and Air Conditioning, Paris, May 17-23, 1967.
55. Scatchard, G., Epstein, L. F., Warburton, J., Jr. and Cody, P.J., "Thermodynamic Properties - Saturated Liquid and Vapor of Ammonia-Water Mixtures," J. ASRE (1947) May.
56. Sims, W. H., O'Neill, M. J., Reid, H. C. and Bisenius, P. M., "Evaluation of Absorption Cycle for Space Station Environmental Control System Application," Final report prepared for NASA Marshall Space Flight Center, HREC-5986-2, LMSC-HREC D306225 by Lockheed Inc., Hunstville, Alabama, November 1972.
57. Thieme, A., and Albright, L. F., "Solubility of Refrigerants 11, 21, and 22 in Organic Solvents Containing a Nitrogen Atom and in Mixtures of Liquids," ASHRAE J. 3, 71-75 (1961) July.
58. Weil, S. A. "Thermodynamic Properties of Lithium Chloride-Lithium Bromide-Water System," Unpublished report, IGT Project No. S-153 for the Foote Mineral Co. and American Gas Association: Chicago: Institute of Gas Technology, (1960) February.
59. Weil, S. A. and Ellington, R. T. "Corrosion Inhibition of Lithium Bromide-Water Cooling Systems," Project ZB-29 Final Report for the General Research Planning Committee of the American Gas Association, Chicago, Institute of Gas Technology, (1956) December.
60. Won, K. W., Selleck, F. T. and Walker, C. K., "Vapor-Liquid Equilibria of the Ammonia-Water System," Paper presented at the II International Symposium on Phase Equilibrium and Fluid Properties in the Chemical Industry, Berlin, March 17-21, 1980.
61. Wilson, T. A., "The Total and Partial Vapor Pressures of Aqueous Ammonia Solutions," Bulletin No. 146 of the University of Illinois Engineering Experimental Station. Urbana, Illinois: University of Illinois, February 1925.
62. Zawacki, T. S., Macriss, R. A. and Rush, W. F., "The Effect of Additives on the Level of Instability of Gas/Liquid Interfaces: The Absorption of Water Vapor by Concentrated Lithium Bromide Solutions in Falling-Film and Open-Channel Absorbers," Paper presented at the 75th National Meeting of the American Institute of Chemical Engineers, Detroit, June 3-6, 1973.
63. Zawacki, T. S., Leipziger, S. and Weil, S. A., "Inducement of Convective Motion in Static Absorbers," Paper presented at 4th Joint Chemical Engineering Conference, American Institute of Chemical Engineers/Canadian Society of Chemical Engineers, Vancouver, B.C., September 9-12, 1973.

64. Zellhoeffer, G. F., "Solubility of Halogenated Hydrocarbon Refrigerants in Organic Solvents," Ind. Eng. Chem. 29 (1937) May.
65. Zellhoeffer, G. F., "Copley, M. J. and Marvel, C. S., "Hydrogen Bonds Involving the C-H Link. The Solubility of Haloforms in Donor Solvents," J. Am. Chem. Soc. 60, 1337-43 (1938) June.
66. Zellhoeffer, G. F., and Copley, M. J., "The Heats of Mixing Haloforms and Polyethylene Glycol Ethers," J. Am. Chem. Soc. 60 1343-45 (1938) June.
67. Zellhoeffer, G. F., "Commercial Refrigeration by Low Pressure Steam," J. ASRE, 317-320 (1937) May.

**INTERNAL DISTRIBUTION**

- |                                   |  |
|-----------------------------------|--|
| 1. V. D. Baxter                   | 20. V. C. Mei  |
| 2. J. G. Carbonell, Consultant    | 21. J. W. Michel   |
| 3. R. S. Carlsmith                | 22. W. A. Miller   |
| 4. F. C. Chen                     | 23. W. R. Mixon  |
| 5. F. A. Creswick                 | 24. R. W. Murphy   |
| 6. R. C. DeVault                  | 25. E. A. Nephew   |
| 7. P. D. Fairchild                | 26. H. Perez-Blanco  |
| 8. S. K. Fischer                  | 27. G. T. Privon   |
| 9. W. Fulkerson                   | 28. C. K. Rice   |
| 10. S. M. Gillis, Consultant      | 29. M. W. Rosenthal  |
| 11. J. Griess                     | 30. E. A. Vineyard   |
| 12. W. R. Huntley                 | 31. K. H. Zimmerman  |
| 13. F. R. Kalhammer, Consultant   | 32-81. Energy Conservation Distribution,<br>Bldg. 9102-2, Room 218 |
| 14. S. I. Kaplan                  | 82-83. Laboratory Records Department                               |
| 15. R. E. Kasperson, Consultant   | 84. Laboratory Records—RC  |
| 16. M. A. Kuliasha                | 85. ORNL Patent Office   |
| 17. M. Lessen, Consultant         | 86-87. Central Research Library                                    |
| 18. W. P. Levins                  | 88. Document Reference Section                                     |
| 19. F. C. Maienschein, Consultant |  |

**EXTERNAL DISTRIBUTION**

- 89-90. M. Aizawa, Refrigerating-Heating Equipment and System, Design Department, Tsuchiura Works, Hitachi, Ltd., 603, Kandatsu-machi, Tsuchiura-shi, Ibaraki-ken, 300 Japan
- 91-92. K. Akagi, Research Center, Osaka Gas Company, Ltd., 6-19-9, Torishima, Konohana-Ku, Osaka, 554 Japan.
93. L. F. Albright, School of Chemical Engineering, Purdue University, Chemical and Metallurgical Engineering Building, West Lafayette, IN 47907
- 94-95. G. Alefeld, Physik-Department, Technische Universitat Munchen, James-Franck-Strasse, D-8046 Garching b. Munchen, West Germany
96. T. Attwood, Allied Signal, Buffalo Research Laboratory, 20 Peabody Street, Buffalo, NY 14210
97. David A. Ball, Battelle Columbus Laboratories, 505 King Avenue, Columbus, OH 43201
98. M. Behar, Agence Francaise pour la Maitrise, de l'Energie, Route des Lucioles, 06565 Valbonne Cedex, France

99. J. Berghmans, Universiteit Leuven, Instituut Mechanica, Celestynen Laan 300A, B-3030 Heverlee, Belgium
100. T. Berntsson, Chalmers University of Technology, S-41296 Gothenburg, Sweden
101. W. J. Biermann, 45 Foxcroft Drive, Fayetteville, NY 13066
102. U. Bonne, Honeywell Corporate Technology Center, 10701 Lyndale Avenue South, Bloomington, MN 55420
103. I. Borde, The Institutes for Applied Research, Ben-Gurion University of the Negev, P.O. Box 1025, Beer-Sheva 84110, Israel
104. R. Bugarel, Institut de Genie Chimique, Chemin de la Loge, Toulouse Cedex, France
105. James M. Calm, Visiting Scientist, Institut CERAC S.A., Chemin des Larges-Pieces, CH-1024 Ecublens, Suisse, Switzerland
106. R. N. Chappell, Program Manager, Energy Conservation Branch, Energy and Technology Division, DOE Idaho Operations Office, 550 Second Street, Idaho Falls, ID 83401
107. J. Cheron, Direction de Recherche, Physico-chimie appliquee et analyse, Institut Francais du Petrole, 1 and 4 avenue de Bois-Preau BP 311, 92506 Rueil Malmaison Cedex, France
108. R. Cohen, Ray W. Herrick Laboratories, Purdue University, West Lafayette, IN 47907
109. D. D. Colosimo, Mechanical Technology, Inc., 968 Albany-Shaker Road, Latham, NY 12110
110. P. O. Danig, Technical University of Denmark, Refrigeration Laboratory, DTH 402B, DK-2800 Lyngby, Denmark
111. D. A. Didion, National Bureau of Standards, Thermal Machinery Group, Building Equipment Division, CBT, Gaithersburg, MD 20899
112. J. Durandet, Direction de Recherche, Physico-chimie appliquee et analyse, Institut Francais du Petrole, 1 and 4 avenue de Bois-Preau BP 311, 92506 Rueil Malmaison Cedex, France
113. J. N. Eustis, Department of Energy, 1000 Independence Avenue SW, Washington, DC 20585
114. M. Falek, Gas Energy Inc., 166 Montague Street, Brooklyn, NY 11201
115. R. J. Fiskum, Energy Conversion Equipment Branch, CE-132, GF-217, Department of Energy, 1000 Independence Avenue SW, Washington, DC 20585
116. S. Freedman, Gas Research Institute, 8600 West Bryn Mawr Avenue, Chicago, IL 60631
117. A. Gac, Institute International du Froid, 177, Boulevard Malesherbes, F 75017, Paris, France
118. B. Genest, DranceDirection des Etudes et de Recherches, Nouvelles, Centre d'Essais et des Recherches, sur les Utilisations du Gaz, Gas de France, 361 Avenue du President Wilson BP 33, 93211 LaPlaine Saint-Denis Cedex, France
119. P. V. Gilli, Technische Hochschule in Graz, Inffeldgasse 25, A-8010 Graz, Austria
120. M. Green, Utilization Efficiency Division, Watson House, British Gas Corporation, Peterborough Road, London, SWG 3HN, England
121. D. Gregory, Building Services Research and Information Association, Old Bracknell Lane West, Bracknell, Berkshire RG124AH, England
122. J. E. Griffith, Research and Technical Laboratory, PSE&G Research Corporation, 200 Boyden Avenue, Maplewood, NY 07040

- 123. G. C. Groff, Carrier Corporation, 6304 Carrier Parkway, P.O. Box 4800, Syracuse, NY 13221
- 124-129. G. Grossman, Technion Institute of Technology, Faculty of Mechanical Engineering, Haifa, Israel
- 130. M. E. Gunn Department of Energy, 1000 Independence Avenue SW, Washington, DC 20585
- 131. W. T. Hanna, Battelle Columbus Laboratories, 505 King Avenue, Columbus, OH 43201
- 132. J. F. Harris, M.A.C., 11 Boulevard Latour-Maubourg, 75007 Paris, France
- 133. Y. Hayashi, International Division, Yazaki Corporation, 17th Floor Mita-Kokusai Building, 4-28, 1-Chome, Mita, Minato-Ku, Tokyo, Japan
- 134. A. Hayes, Office of Industrial Programs, CE-121, FORSTL, Department of Energy, 1000 Independence Avenue SW, Washington, DC 20585
- 135. F. C. Hayes, Thermal Systems, The Trane Company, 3600 Pammell Creek Road, LaCrosse, WI 54601
- 136. R. Hise, CNG Research Company, 11001 Cedar Avenue, Cleveland, OH 44106
- 137. K. Holzapfel, IEA Heat Pump Center, Fiz 4, Kernforschungszentrum, D 7514 Eggenstein, Leopoldshafen 2, Germany
- 138. P. Iedema, FDO Technische Adviseurs, P.O. Box 194, 7550 AD Hengelo, The Netherlands
- 139. N. Isshiki, Nihon University, Koriyama 963, Japan
- 140. M. Itou, Mechanical Engineering Research, Laboratory, Hitachi, Ltd., 502, Kandatsu-machi, Tsuchiura-shi, Ibaraki-ken, 300 Japan
- 141. S. Iyoki, Kansai University, Faculty of Engineering, Senriyama, Suita, Osaka, 564 Japan
- 142. H. S. Izawa, Northern Natural Gas Company, 2223 Dodge Street, Omaha, NE 68102
- 143. P. Joyner Electric Power Research Institute, P.O. Box 10412, Palo Alto, CA 94303
- 144. T. Kapus, Department of Energy, 1000 Independence Avenue, Washington, DC 20585
- 145. H. Kawamoto, Gas Utilization Development Center, Osaka Gas Company Ltd., 3-2-95 Chiyosaki, Nishi-Ku, Osaka 550, Japan
- 146. S. A. Klein, University of Wisconsin, Mechanical Engineering Department, Madison, WI 53706
- 147. G. Knobabout, TNO-MT, Laan van Westenenk 501, 7334 DT Apeldoorn, Netherlands
- 148-149. K. F. Knoche, Lehrstuhl fur Technische Termodynamik, RWTH Aachen, Schinkelstrasse 8, 5100 Aachen, West Germany
- 150. H. Kotila, Ministry of Trade and Industry, Energy Department, Pohjoinen Makasiininkatu-6, 00130 Helsinki 13, Finland
- 151. S. Kotani, Hitachi Europe GmbH, Schwannstr. 3, 4000 Dusseldorf, FRG., Japan
- 152. W. E. Krauss, Gas Research Institute, 8600 West Bryn Mawr Avenue, Chicago, IL 60631
- 153. Y. Kunugi, Mechanical Engineering Research, Laboratory, Hitachi, Ltd., 502, Kandatsu-machi, Tsuchiura-shi, Ibaraki-ken, 300 Japan
- 154. S. Kurosawa, Air Conditioning and Heating Section, Tokyo Gas Company Ltd., 5-20, Kaigan 1-Chome, Minato-Ku, Tokyo, Japan
- 155. A. Lannus, Electric Power Research Institute, P.O. Box 10412, Palo Alto, CA 94303

156. B. Leblanc, Direction des Etudes et de Recherches, Nouvelles, Centre d'Essais et des Recherches, sur les Utilisations du Gaz, Gas de France, 361 Avenue du President Wilson BP 33, 93211 LaPlaine Saint-Denis Cedex, France
157. W. D. Lee, Arthur D. Little, Inc., 32 Acorn Park, Cambridge, MA 02140
158. P. LeGoff, Laboratoire des Sciences du Genie Chimique, CNRS-ENSIC-INPL-Nancy, France
159. M. Lessen, Consulting Engineer, 12 Country Club Drive, Rochester, NY 14618
160. B. Lundquist, Swedish Council for Building Research, St. Goransgatan 66, S-11233 Stockholm, Sweden
- 161-162. R. A. Macriss, Institute of Gas Technology, 3424 South State Street, Chicago, IL 60616
212. V. Malka, PLE-KFA JULICH, Postfach 1913, D-5170 JULICH 1, Germany
213. G. Manthey, U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, TN 37831
214. A. R. Maret, Gas Research Institute, 8600 West Bryn Mawr Avenue, Chicago, IL 60631
215. D. Martin, Energy Technology Support Unit, Building 156, AERE Harwell, Harwell, Oxfordshire OX 11 ORA, England 834621
216. K. Matsuo, Mechanical Engineering Research Laboratory, Hitachi, Ltd., Tsuchiura, Japan
217. J. C. Mayor, Swiss Federal Institute for Reactor Research, CE-5303 Wurenlingen, Switzerland
218. L. A. McNeely, 7310 Steinmeier Drive, Indianapolis, IN 46250
219. G. Melikian, United Technology Research Center, East Hartford, CT 06108
220. M. S. Menzer, American Gas Association, 1515 Wilson Boulevard, Arlington, VA 22209
221. R. H. Merrick, Preway, P.O. Box 534, Evansville, IN 47704
222. F. Meunier, Laboratoire de Thermodynamique des Fluides, CNRS, Campus Universitaire—Bat 502 Ter., 91405 Orsay Cedex, France
223. J. Mezon, Direction des Etudes et de Recherches, Nouvelles, Centre d'Essais et des Recherches, sur les Utilisations du Gaz, Gas de France, 361 Avenue du President Wilson BP 33, 93211 LaPlaine Saint-Denis Cedex, France
- 224-225. M. Miki, Housing Products Research Laboratory, Matsushita Housing Products Company, Ltd., 800, Tsutsui-Cho, Yamato-Koriyama, Nara, 639-11 Japan
226. J. P. Millhone, Director, Office of Buildings and Community Systems, Department of Energy, 1000 Independence Avenue SW, Washington, DC 20585
227. J. M. Miriam, Utilization Efficiency Division, Watson House, British Gas Corporation, Peterborough Road, London, SWG 3HN, England
228. E. Miura, JRAIA, KIKAI SHINKO Bldg. 201, Shibakoen 3-5-8, Minato-ku, Tokyo 105, Japan
229. H. Miyama, AIST/MITI, 1-3-1 Kasmigaseki, Chiyoda-ku, Tokyo, Japan
- 230-231. F. Moser, Institut fur Verfaherstechnik, Technische Universitat Graz, Inffeldgasse 25, A-8010 Graz, Austria
232. H. P. Muhlmann, Ruhrgas AG, Halterner Strasse 125, 427 Dorsten, West Germany
233. K. P. Murphy, Allied-Signal, P.O. Box 1087 R, Morristown, NY 07960

- 234-235. S-I. Nakatsugawa, Air Conditioning Research and Development Laboratories, Yazaki Corporation, 1370 Koyasu-Cho Hamamatsu-Shi, Shizuoka-PRF Japan
- 236. H. E. Nimke, The Brooklyn Union Gas Company, 195 Montague Street, Brooklyn, NY 11201
- 237. I. Ohka, Osaka Gas Engineering Company, Ltd., 1, Hiranomachi 5-Chome, Higashi-Ku, Osaka, 541 Japan
- 238. D. O'Neal, Department of Mechanical Engineering, Texas A&M University, College Station, TX 77843
- 239. B. A. Phillips, Phillips Engineering Company, 721 Pleasant Street, St. Joseph, MI 49085
- 240. T. Potter, SERI, 1617 Cole Boulevard, Golden, CO 80401
- 241. R. Radermacher, University of Maryland, Mechanical Engineering Department, College Park, MD 20742
- 242. V. Recchi, National Research Council-PFE 2, c/o O.T.B., P.O. Box 330, I-70100 Bari, Italy
- 243. E. A. Reid, Jr., Columbia Gas System Service Corporation, 1600 Dublin Road, P.O. Box 2318, Columbus, OH 43215
- 244. R. C. Reimann, Carrier Corporation, 6304 Carrier Parkway, P.O. Box 4800, Syracuse, NY 13221
- 245. G. M. Reistad, Department of Mechanical Engineering, Oregon State University, Corvallis, OR 97331
- 246. A. Rojey, Direction de Recherche, Physico-chimie appliquee et analyse, Institut Francais du Petrole, 1 and 4 avenue de Bois-Preau BP 311, 92506 Rueil Malmaison Cedex, France
- 247. L. Rolland, Direction des Etudes et de Recherches, Nouvelles, Centre d'Essais et des Recherches, sur les Utilisations du Gaz, Gas de France, 361 Avenue du President Wilson BP 33, 93211 LaPlaine Saint-Denis Cedex, France
- 248. J. D. Ryan, Energy Conversion Equipment Branch, CE-132, U.S. Department of Energy, 1000 Independence Avenue SW, Washington, DC 20585
- 249. Y. Saskamoto, Daikin Kogyo Company, Ltd., Industrial Air Conditioning and Refrigeration Division, 700-1 Hitotsuya, Settsu-Shi, Osaka, 564, Japan
- 250. E. L. Schmidt, Institut fur Angewandte Thermodynamik und Klimatechnik, Universitat Essen, Universitat Strasse 15, Postfach 6843, D-4300 Essen 1, West Germany
- 251. S. V. Shelton, Thermax, Inc., 296 14th Street NW, Atlanta, GA 30318
- 252-253. I. Smith, Applied Energy Group, School of Mechanical Engineering, Cranfield Institute of Technology, England
- 254. H. O. Spausches, Georgia Technological Research Institute, Georgia Institute of Technology, Energy and Materials Sciences Laboratory, Atlanta, GA 30332
- 255-257. F. Steimle Institut fur Angewandte Thermodynamik und Klimatechnik, Universitat Essen, Universitat Strasse 15, Postfach 6843, D-4300 Essen 1, West Germany
- 258-260. K. Stephan, Institut fur Technische Thermodynamik, und Thermische Verfahrenstechnik, Universitat Stuttgart, Pfaffenwaldring 9, FA 1705, Postfach 1140, 7000 Stuttgart 80, West Germany
- 261. J. Sugimura, Technical Development Center, Osaka, Mitsui and Company, Ltd., Osaka Branch, 3-33, Nakanoshima 2-Chome, Kita-Ku, Osaka, Japan

262. P. F. Swenson, The East Ohio Gas Company, P.O. Box 5759, Cleveland, OH 44101
263. C. Trepp, Eidgenossische Technische Hochschule, Institut fur Verfahrens und Kaltechnik, ETH-Zentrum, 8092 Zurich, Switzerland
264. T. Uemura, Kansai University, Faculty of Engineering, Senriyama, Suita, Osaka, 564 Japan
265. H. van der Ree, TNO-MT, Laan van Westenenk 501, NL-7334 DT Apeldoorn, Netherlands
266. J. Vidal, Direction de Recherche, Physico-chimie appliquee et analyse, Institut Francais du Petrole, 1 and 4 avenue de Bois-Preau BP 311, 92506 Rueil Malmaison Cedex, France
267. G. C. Vliet, Taylor Hall 116, The University of Texas, Austin, TX 78712
268. M. Wahlig, Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720
269. J. Ward, Engineering Support Group, Engineering Design and Manufacturing Division, Room 48, Building 351.28, AERE Harwell, Harwell, Oxfordshire OX 11 ORA, England
270. W. H. Wilkinson, Battelle Columbus Laboratories, 505 King Avenue, Columbus, OH 43201-2693
271. P. Worsoe-Schmidt, Refrigeration Laboratory, The Technical University of Denmark, DK-2800 Lyngby, Denmark
272. J. R. Wright, National Research Council, Division of Building Research, Building R105, Montreal Road, Ottawa K1A OR6, Ontario, Canada
- 273-274. T. Yamada, Housing Products Research Laboratory, Matsushita Housing Products Company, Ltd., 800, Tsutsui-Cho, Yamato-Koriyama, Nara, 639-11 Japan
- 275-276. K. Yamaguchi Housing Products Research Laboratory, Matsushita Housing Products Company, Ltd., 800, Tsutsui-Cho, Yamato-Koriyama, Nara, 639-11 Japan
277. Office of the Assistant Manager for Energy R&D, U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, TN 37831
- 278-304. Technical Information Center, Department of Energy, P.O. Box 62, Oak Ridge, TN 37831

ORNL/Sub/84-47989/1

ABSORPTION FLUIDS DATA SURVEY: FINAL REPORT ON USA DATA