INFORMATION ON ALTERNATIVE REFRIGERANTS: STATUS OF THE REFRIGERANT DATABASE

James M. Calm, P.E.
Engineering Consultant

ABSTRACT

This paper describes the Refrigerant Database and summarizes its purpose and use. The database offers an efficient means to locate data needed to screen and use alternative refrigerants. It includes a collection of documents and searchable citations, synopses, and data summaries. They cover alternative refrigerants, associated lubricants, and their use in air-conditioning and refrigeration. The database simplifies both information searches and retrieval of the source documents. This paper also provides a tabular summary of selected physical, safety, and environmental data extracted from the database. The summary table covers 86 compounds and blends used or under consideration as refrigerants.

INTRODUCTION

The Refrigerant Database is an information system on alternative refrigerants for air-conditioning and refrigeration. It also addresses associated lubricants, analysis and test methods, and application information. The database facilitates location of property, compatibility, safety, environmental, performance, and other data. It began as a cooperative effort to share information on alternative refrigerant candidates, to accelerate their evaluation and commercialization. The goal was – and remains – to accelerate use of alternative refrigerants, to enable phase out of chemicals of environmental concern. The informal effort by chemical and equipment manufacturers in the United States has evolved into an automated system, used by manufacturers, researchers, engineers, regulators, and others in 17 countries.

The refrigerants addressed include both single compounds and azeotropic, near-azeotropic, and zeotropic blends of them. The database also covers associated lubricants. The key concentration areas are their properties, thermal and chemical stability of refrigerant-lubricant systems, and compatibility with other materials. The effects of refrigerants and lubricants on heat transfer, system capacity, and system efficiency also are emphasized. Refrigerant application, retrofit, and research are covered; data on environmental impacts, flammability, and acute and chronic toxicity are being added.

The database comprises four parts:

- a growing collection of documents – many unpublished – available to users
- a computerized search system covering both the cited documents, others available in published literature, and abstracts of pertinent research
- a set of refrigerant summaries that provide profiles for more than 200 refrigerants (with more in preparation)
- an information dissemination operation

DOCUMENTS

The original form of the database was simply a collection of contributed papers, reports, and other documentation. They addressed thermophysical properties of candidate refrigerants and associated materials compatibility and lubricant data. Most of the early documents were not published and – under normal circumstances – would have been held as proprietary information by the originators. Instead, these submissions were made available to expedite the transition to use of alternative refrigerants. The unique nature of this effort, namely voluntary disclosure of data with competitive value, reflected recognition by industry that the urgency of phasing out chlorofluorocarbon (CFC) refrigerants required a cooperative effort.

The current collection has grown considerably and includes reports and papers from both the Materials Compatibility and Lubricant Research (MCLR) Program and the Alternative Refrigerants Evaluation Program (AREP). These two programs have greatly increased understanding of materials, screening methods, and performance for alternative refrigerants. Related publications for which consent is obtained also are included to ease access to them. The primary criteria for acceptance are pertinence, usefulness, and agreement to unrestricted availability (subject to copyright and similar restrictions) to all interested parties.

INFORMATION SEARCH AND RETRIEVAL SYSTEM

The core of the database consists of bibliographic citations and synopses for publications that may be useful in research, design, and application of air-conditioning and refrigeration equipment. The referenced sources provide information and properties on:

- alternative refrigerants including R-22, R-32, R-123, R-124, R-125, R-134, R-134a, R-141b, R-142b, R-143a, R-152a, R-227ea, R-290 (propane), R-600 (butane), R-600a (isobutane), R-717 (ammonia), fluoroethers (such as E-125, E-134, and E-245), and others;
- azeotropic, near-azeotropic, and zeotropic blends, such as the newly designated R-401A, R-401B, R-401C, R-402A, R-402B, R-403A, R-403B, R-404A, R-405A, R-406A, R-407A, R-407B, and R-507;*
- comparative data on more familiar refrigerants, including widely-used chlorofluorocarbons (CFCs);
- associated lubricants including mineral oils, alkylbenzenes, polyalkylene glycols, polyol esters, and others;
- candidate refrigerants and lubricants being developed and evaluated;
- compatibility of refrigerants and lubricants with metals, plastics, elastomers, motor insulation, desiccants, and other materials used in refrigerant circuits;
- thermal and chemical stability of refrigerants, lubricants, and refrigerant-lubricant systems;
- refrigerant-lubricant system properties such as miscibility, solubility, viscosity, and lubricity;
- effects of refrigerants and lubricants on heat transfer and system capacity and efficiency;
- flammability, toxicity, and other safety information
- computational and test methods to estimate or determine the preceding data, with emphasis on accelerated screening techniques and models for research, development, and design;
- information on the environmental impacts of the cited fluids; and
- research, application data, and regulatory information pertinent to use of alternative refrigerants.

The citations identify the authors, their organizations, and the bibliographic information needed to obtain copies. The lengths and numbers of figures and tables are indicated to suggest the detail of the documents involved.

Detailed abstracts are provided for more than a third of the referenced documents. These synopses focus on the content and specific materials and properties addressed, in lieu of the introductions or summaries of purpose, findings, or implications commonly prepared by authors. The dual role of the specially-prepared summaries is to facilitate automated retrieval and to assist users in assessing the pertinence of documents for a particular purpose. Key conclusions and, where deemed warranted, a brief perspective are noted. Preparation of the detailed synopses is a significant task in assembling the database.

Descriptions of research and development projects addressing refrigerants also are included. The research abstracts are provided to facilitate coordination and to assist in identification of sources for data that may become available in the near future. As an example, more than 40 prior and current projects sponsored by ASHRAE, addressing refrigerants and their uses, are covered.

Computerized Version

The computerized database provides a very fast, flexible, and user-friendly means to search for information on specific refrigerants, lubricants, materials, properties, topics, authors, or publications of interest. Individual words or combinations of words may be used to retrieve desired references. Users may enter any desired search terms, referred to as criteria. The criteria may be specific refrigerants (e.g., R-123 or HFC-134a) or refrigerant types (e.g., HCFCs, azeotropes, ethers), generic or trade names of materials or lubricants, properties or procedures, or names of authors or organizations. Virtually any word, normally hyphenated words, or acronym may be used.

The full citations and detailed abstracts are scanned for the search criteria or combinations of criteria. This approach differs from conventional bibliographic retrieval systems that are limited to predetermined keywords. The unconstrained method was chosen both to facilitate use and to afford flexibility for the future, as new awareness and requirements develop. A traditional reason for use of keyword methods was to speed up the search process. The novel search procedure employed makes retrieval far quicker than keyword searches and is more complete.

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* Some of these designations have been recommended, but not yet adopted. Those for which approval is still pending are identified with the letter "r", next to their ASHRAE Standard 34 safety classifications, in table 1.

A versatile feature of the search program is allowed use of the asterisk (*) to simplify searches; computer programmers refer to this feature as use of a *wildcard* character. By appending an asterisk to the end of a word or word fragment, the singular, plural, possessive, or compound words can be specified with a single entry. Similarly, families of chemical compounds or long names or words, can be quickly indicated by entering only the unique fragment followed by the wildcard character.

Search criteria may be entered by typing them in or selecting them from optional topical prompts. Complex searches of up to 15 terms at a time may be entered using Boolean logic operators, namely *AND*, *OR*, and *NOT*. The number of terms that may be combined is practically unlimited, since the results of one or more steps may be continued or merged in another; this option is referred to a *chained search*. Chaining is particularly convenient when the result of one search suggests further narrowing, to be more specific. Similarly, the result may be broadened, when a narrow topic is unsuccessful in locating desired information or when the abstracts retrieved suggest other search terms.

The search software also will suggest one or more synonyms and related terms for some words entered as search criteria. One use of this feature is to allow identification of refrigerants in several familiar manners (e.g., *R-22*, *R22*, *HCFC-22*, or *75-45-6*) or by common names (e.g., *propane* for R-290 or *ammonia* for R-717). The software essentially performs two sequential searches. It first looks for entered search criteria in a thesaurus file, and prompts users to choose from up to three sets of synonyms and related terms. It then finds both the entered search criteria and selected synonyms and related terms. A set may be a single term or a group of related terms, such as *steel* and *ferrous* for *iron* or *blend*, *azeotrope*, and *zeotrope* (and *nonazeotrope*) when *mixture* is entered. One set provided for common zeotropic and azeotropic refrigerants includes their components.

The actual search is extremely fast. Less than three seconds is typical for 15 criteria with synonyms on a relatively slow, 80286-based computer; less time is required with fewer terms or faster processors. Once located, the citations and detailed abstracts can be reviewed on the computer monitor or selectively printed for later use. A list of citations also can be printed, to facilitate obtaining the full documents from their publishers, libraries, the database, or other sources.

The entire search process – including search specification, refinement, citation and abstract review, and printing – generally will require only a few minutes. Moreover, user interests are completely confidential, since searches are performed on the user's own computer, without requirement to access a central system. While confidentiality is not generally of concern to end users, investigations by manufacturers can be sensitive.

The search files and retrieval software are distributed on diskette, for use with nearly all standard microcomputers running DOS, OS/2, Windows™ or similar operating systems and enhancements. Approximately 4 MB of hard disk space are required for the files and software, though this requirement will increase as the database grows. The database also will run on some Apple Macintosh™ computers using DOS emulators.

Report Version

The database citations and abstracts also are available as a listing in a report format. Citations are grouped under the primary or first subject addressed, but are not cross-referenced under other topics. The computerized version, therefore, is better suited to locate information addressing specific subjects. The listing offers one feature not available in the computerized version, namely revisions from and additions to the prior release are noted by a bar in the margin. Users looking for new or revised references need to review only citations so indicated.

REFRIGERANT SUMMARIES

The computerized version of the database includes summaries for more than 200 refrigerants, both single-component and blends; the quantity and content are being increased. The specific content varies by refrigerant, based on the information available. Data and sources are indicated, if known, for the following:

- refrigerant identifiers including ASHRAE Standard 34 designations (*R-* numbers), chemical names and formulae, refrigerant groups, blend compositions, Chemical Abstract Service (CAS) registry numbers, common and trade names, historical designations, and standard (ARI) container colors
- common uses, potential applications for candidates, and commercialization notes
- summary property data (with dimensional quantities in dual IP and SI units) including the molecular mass, azeotropic temperature for azeotropes, and melting or freezing point
- temperature, pressure, specific volume, density, heat of vaporization, viscosity, and thermal conductivity in dual units at representative conditions (usually the normal boiling point, 20 °C (68 °F), and the critical point) plus the pressure at 60 °C (140 °F)

- atmospheric lifetime, ozone depletion potential (ODP), global warming potential (GWP), and halocarbon GWP (HGWP)
- ASHRAE Standard 34 safety classification, lower and upper flammability limits (LFL and UFL), heat of combustion, flash point, autoignition temperature, and exposure limits and indicators for acute, subchronic, and chronic toxicity

The data entries are keyed to *RDB numbers* (Refrigerant Database numbers), citations for which also are included in the database. These sources must be consulted to verify the data, examine limitations, and obtain further information. The thermophysical data identified provide a profile of the refrigerants as well as information needed for common regulatory and building code purposes; the database is not an equation-of-state model.

Table 1 provides summary information for selected fluids using data extracted from the database. Readers are advised to verify the data provided before use, particularly for new alternatives, as frequent revisions are inherent to this period of transition. Updates to the refrigerant database, to address corrected and added information, are distributed on a quarterly basis.

DISSEMINATION SYSTEM

The Refrigerant Database identifies the ordering source or publisher of referenced documents. Most also can be obtained from engineering libraries. Unpublished documents, those not protected by copyrights, and those for which reproduction and distribution permission has been obtained may be ordered from the database administrator. Addresses and information to order other documents are provided with the database. Both the computerized and manual versions of the database are available by annual subscription. The computerized version is accompanied by the retrieval software and a user's manual, with instructions for installation and use.

SUMMARY

The Refrigerant Database consolidates and facilitates access to information on alternative refrigerants and associated lubricants. The database comprises a collection of documents and refrigerant summaries, a sophisticated search system, and a means to provide requested document copies (for those allowed) to users. The information is updated quarterly, to allow timely dissemination of new information on alternatives.

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TABLE 1 – SUMMARY PHYSICAL, SAFETY, AND ENVIRONMENTAL DATA FOR REFRIGERANTS (SORTED BY BOILING POINT)

refrigerant		physical data							safety data					environmental data		
		molec-	NBP		Tc		Pc		TLV-		HOC		Std 34	atmos-		
number	chemical formula — common name	ular mass	(°C)	(°F)	(°C)	(°F)	(MPa)	(psia)	TWA (PPM)	LFL (%)	MJ/kg	Btu/lb	safety group	pheric life (yr)	ODP	GWP 100 yr
50	CH4 – methane	16.04	-161.5	-258.7	-82.5	-116.5	4.64	673		5.1			A3	10.5	0.000	11
14	CF4 – carbon tetrafluoride	88.00	-127.9	-198.2	-45.7	-50.3	3.74	542		none			A1	>500	0.000	>4500
170	CH3CH3	30.07	-88.8	-127.8	32.2	90.0	4.89	709		3.3			A3		0.000	
503	R-23/13 (40.1/59.9)	87.28	-87.8	-126.0	19.5	67.1	4.36	632		none					0.599	
23	CHF3	70.01	-82.1	-115.8	25.6	78.1	4.83	701		none	-12.5	-5374		300	0.000	19400
13	CClF3	104.46	-81.4	-114.5	28.8	83.8	3.87	561		none	-3.0	-1290	A1	400	1.000	
744	CO2 – carbon dioxide	44.01	-78.4	-109.1	31.1	88.0	7.37	1069	5000	none			A1		0.000	1
116	CF3CF3 – perfluoroethane	138.01	-78.2	-108.8	19.9	67.8	3.04	441						>500	0.000	>6200
7146	SF6	146.05	-63.8	-82.8	45.6	114.1	3.76	545		none					0.000	
13B1	CBrF3 – halon 1301	148.91	-57.8	-72.0	-67.0	-88.6	3.96	574		none			A1	77	16.000	4900
504	R-32/115 (48.2/51.8)	79.20	-57.2	-71.0	66.4	151.5	4.76	690		none					0.259	
32	CH2F2 – methylene fluoride	52.02	-51.7	-61.1	78.4	173.1	5.81	843		12.7	9.4	4041	A2	6.2	0.000	720
AZ-20	R-32/125 (50/50)	72.56	-50.5	-58.9	72.5	162.5	4.96	719		none					0.000	
403A	R-290/22/218 (5/75/20) – 69-S	91.06	-50.0	-58.0	93.3	199.9	5.08	737		none			A1/A1r		0.041	
403B	R-290/22/218 (5/56/39) – 69-L	102.06	-49.5	-57.1	90.0	194.0	5.09	738		none			A1/A1r		0.030	
HX4	R-32/125/143a/134a (10/33/36/21)	94.50	-49.4	-56.9	77.5	171.5	4.01	582		none					0.000	
402A	R-125/290/22 (60/2/38) – HP80	101.55	-49.2	-56.6	75.5	167.9	4.13	599		none			A1/A1p		0.021	
125	CHF2CF3	120.02	-48.6	-55.5	66.3	151.3	3.64	528		none	-1.5	-645	A1p	40.5	0.000	3400
FX40	R-32/125/143a (10/45/45)	90.70	-48.4	-55.1	72.0	161.6	4.05	587		none					0.000	
143a	CH3CF3	84.04	-47.4	-53.3	73.1	163.6	3.81	553		7.0	10.3	4428	A2r	64.2	0.000	3800
402B	R-125/290/22 (38/2/60) – HP81	94.71	-47.4	-53.3	82.6	180.7	4.45	645		none			A1/A1p		0.033	
407B	R-32/125/134a (10/70/20) – Klea 61	102.94	-47.3	-53.1	76.0	168.8				none			A1/A1r		0.000	
507	R-125/143a (50/50) – AZ-50	98.90	-46.7	-52.1	70.9	159.6	3.79	550		none			A1		0.000	
404A	R-125/143a/134a (44/52/4) – HP62 and FX-70	97.60	-46.5	-51.7	72.1	161.8	3.73	541		none			A1/A1p		0.000	
407A	R-32/125/134a (20/40/40) – Klea 60	90.10	-45.5	-49.9	83.0	181.4				none			A1/A1r		0.000	
502	R-22/115 (48.8/51.2)	111.64	-45.4	-49.7	82.2	180.0	4.08	592		none			A1		0.283	
FX10	R-143a/22 (55/45)	85.00	-44.5	-48.1	83.0	181.4	4.30	624		none					0.025	
Klea 66	R-32/125/134a (23/25/52)	102.90	-44.0	-47.2	86.1	187.0				none					0.000	
AC9000	R-32/125/134a (23/25/52)		-43.9	-47.0	86.8	188.2	4.60	667							0.000	
290	CH3CH2CH3	44.10	-42.1	-43.8	96.8	206.2	4.25	616		2.1	50.3	21625	A3		0.000	neglig
E125	CHF2OCF3	136.02	-41.9	-43.4	80.4	176.7	3.33	483						21	0.000	
501	R-22/12 (75.0/25.0)	93.10	-41.0	-41.8						none			A1		0.291	
22	CHClF2	86.47	-40.8	-41.4	96.2	205.2	4.99	724	1000	none	2.2	946	A1	15.8	0.055	1600
115	CClF2CF3	154.47	-39.1	-38.4	79.9	175.8	3.15	457		none	-2.1	-903	A1	550	0.600	7000
161	CH3CH2F – ethylfluoride	48.06	-37.1	-34.8	102.2	216.0	4.70	682		3.8				<1	0.000	low
FX57	R-22/124/142b (65/25/10)	96.70	-35.2	-31.4	105.0	221.0	4.70	682		none					0.048	
401B	R-22/152a/124 (61/11/28) – MP66	92.84	-34.7	-30.5	106.1	223.0	4.68	679		none			A1/A1p		0.040	
FX56	R-22/124/142b (60/25/15)	97.45	-34.2	-29.6	107.0	224.6	4.60	667		none					0.048	
500	R-12/152a (73.8/26.2)	99.31	-33.5	-28.3	105.5	221.9	4.42	641		none			A1		0.738	
717	NH3 – ammonia	17.03	-33.3	-27.9	133.0	271.4	11.42	1656	25	15	22.5	9673	B2		0.000	neglig
401A	R-22/152a/124 (53/13/34) – MP39	94.44	-33.1	-27.6	108.0	226.4	4.60	667		none			A1/A1p		0.037	
505	R-12/31 (78.0/22.0)	103.50	-30.0	-22.0	117.8	244.0	4.73	686		none						
12	CCl2F2	120.91	-29.8	-21.6	112.0	233.6	4.11	596	1000	none	-0.8	-344	A1	116	1.000	7100
MP33	R-22/152a/124 (40/17/43)		-28.8	-19.8						none					0.030	

refrigerant		physical data							safety data					environmental data		
		molec-	NBP		Tc		Pc		TLV-		HOC		Std 34	atmos- pheric life		GWP
number	chemical formula — common name	ular mass	(°C)	(°F)	(°C)	(°F)	(MPa)	(psia)	TWA (PPM)	LFL (%)	MJ/kg	Btu/lb	safety group	(yr)	ODP	100 yr
401C	R-22/152a/124 (33/15/52) - MP52	101.04	-28.4	-19.1	112.7	234.9	4.37	634		none			A1/A1p		0.030	
405A	R-22/152a/142b/C318 (45/7/5.5/42.5) - G2015	112.10	-27.3	-17.1	106.1	223.0	4.26	618		none			A1/A1r		0.028	
"R-176"	R-22/12/142b (25/15/60)	102.00	-26.6	-15.9	129.4	264.9	5.10	740		none					0.203	
134a	CH2FCF3	102.03	-26.1	-15.0	101.1	214.0	4.06	589		none	4.2	1806	A1	15.6	0.000	1200
152a	CH3CHF2	66.05	-24.7	-12.5	113.3	235.9	4.49	651		4.8	16.9	7266	A2	1.8	0.000	150
40	CH3Cl - methyl chloride	50.49	-24.2	-11.6	143.1	289.6	6.67	967		8.1			B2			
E143a	CH3OCF3	100.04	-24.1	-11.4	104.9	220.8	3.59	521						3.4	0.000	
134	CHF2CHF2	102.03	-23.0	-9.4	118.7	245.7	4.62	670		none	4.3	1849		15.5	0.000	890
406A	R-22/600a/142b (55/4/41) - GHG	90.00	-22.0	-7.6						**			A1/A2r		0.057	
227ea	CF3CHFCF3 - halon 37	170.03	-18.3	-0.9	103.5	218.3	2.95	428		none				30	0.000	
245cb	CH3CF2CF3	134.05	-18.3	-0.9	108.5	227.3	3.26	473						1.8	0.000	
227ca	CHF2CF2CF3	170.03	-16.3	2.7	106.3	223.3	2.87	416						15	0.000	
506	R-31/114 (55.1/44.9)	93.70	-12.3	9.9	142.2	288.0	5.16	748		none						
124	CHClFCF3	136.48	-12.0	10.4	122.5	252.5	3.63	526		none	0.9	387	A1p	6.9	0.022	440
600a	(CH3)2CHCH3 - isobutane	58.13	-11.7	10.9	135.0	275.0	3.65	529		1.7	49.4	21238	A3		0.000	
764	SO2 - sulfur dioxide	64.07	-10.0	14.0	157.5	315.5	7.88	1143		none			B1		0.000	
142b	CH3CClF2	100.50	-9.8	14.4	137.2	279.0	4.12	598		9.0	9.8	4213	A2	22.4	0.065	1800
C318	-CF2CF2CF2CF2-	200.04	-5.8	21.6	115.4	239.7	2.78	403		none			A1		0.000	
236cb	CH2FCF2CF3	152.04	-1.4	29.5	130.2	266.4	3.12	453						3.2	0.000	
236fa	CF3CH2CF3	152.04	-1.1	30.0	130.7	267.3	3.18	461						6.4	0.000	
254cb	CH3CF2CHF2	116.06	-0.8	30.6	146.2	295.2	3.75	544						1.6	0.000	
600	CH3CH2CH2CH3 - butane	58.13	-0.4	31.3	152.0	305.6	3.80	551	800	1.5	49.5	21281	A3		0.000	
114	CClF2CClF2	170.92	3.8	38.8	145.7	294.3	3.25	471	1000	none	-3.1	-1333	A1	220	1.000	7000
236ca	CHF2CF2CHF2	152.04	5.1	41.2	155.2	311.4	3.41	495							0.000	
E134	CHF2OCHF2	118.03	6.2	43.2	153.5	308.3	4.23	614		3.3				2.8	0.000	
236ea	CHF2CHFCF3	152.04	6.6	43.9	141.2	286.2	3.53	512						1.2	0.000	
160	CH3CH2Cl	64.51	12.4	54.3	186.6	367.9	5.24	760		3.6	20.6	8856		<1	0.000	
245fa	CHF2CH2CF3	134.05	15.3	59.5	157.6	315.7	3.64	528							0.000	
11	CCl3F	137.37	23.8	74.8	198.0	388.4	4.41	640	C1000	none	0.9	387	A1	55	1.000	3400
245ca	CH2FCF2CHF2	134.05	25.5	77.9	178.5	353.3	3.86	560		none				6.4	0.000	400
123	CHCl2CF3	152.93	27.9	82.2	183.7	362.7	3.67	532		none	2.1	903	B1	1.71	0.020	90
123a	CHClFCClF2	152.93	28.0	82.4	188.5	371.3	4.47	648		none						
E245fa	CHF2OCH2CF3	150.05	29.2	84.6	170.9	339.6	3.73	541						5.8	0.000	
141b	CH3CCl2F	116.95	32.2	90.0	204.4	399.9	4.64	673		7.4	8.6	3697		10.8	0.110	580
E245cb	CHF2CF2-O-CF3	150.05	34.0	93.2	185.2	365.4									0.000	
217bai1	CF3CFICF3	295.93	40.0	104.0												
30	CH2Cl2 - methylene chloride	84.93	40.2	104.4	237.0	458.6	6.08	882		14.6			B2	0.6		15
217cai1	CF3CF2CF2I	295.93	41.0	105.8												
113	CCl2FCClF2	187.38	47.6	117.7	214.1	417.4	3.44	499	1000	none	0.1	43	A1	110	0.800	4500
1130	CHCl=CHCl	96.94	47.8	118.0	243.3	469.9	5.48	795		3.3						
10	CCl4 - carbon tetrachloride	153.82	76.7	170.1	283.0	541.4	4.41	640					B1	47	1.100	1300
718	H2O - water	18.02	100.0	212.0	374.2	705.6	22.10	3205		none			A1		0.000	0

NBP = normal boiling point; Tc = critical temperature; Pc = critical pressure; TLV-TWA = ACGIH Threshold Limit Value - Time Weighted Average; LFL = lower flammability limit (% volume in air); HOC = heat of combustion; ODP = ozone depletion potential; GWP = global warming potential

Safety classifications noted with "p" are provisional; those noted with "r" have been recommended by SSPC 34, but not yet approved.
Data sources are identified in the Refrigerant Database; verify data and limitations in sources before use.