

REFRIGERANT DATABASE

by

James M. Calm, P.E.
Engineering Consultant
Post Office Box 12014
Arlington, VA 22219-2014 USA

The Refrigerant Database consolidates and facilitates access to information, to assist industry in developing equipment using alternative refrigerants. The underlying purpose is to accelerate phase out of chemical compounds of environmental concern.

History

The database was started in 1989, spurred by the growing and urgent need for data to screen and implement alternative refrigerants. The project was initiated by the Air-Conditioning and Refrigeration Institute (ARI), a trade association in the United States representing equipment and component manufacturers. Other associations and governmental agencies were invited to join in the effort, the objective of which was to share and expedite access to information as it became available.

The original form was simply a collection of contributed papers and informal reports. They focused on thermophysical properties of alternative refrigerant candidates or associated materials compatibility and lubricant data; the majority were unpublished. These submissions were made available, without restriction, to interested parties from all countries. The unique nature of this effort, namely voluntary disclosure of proprietary data with competitive value, reflected recognition by industry that the urgency of phasing out chlorofluorocarbon refrigerants required a cooperative effort.

To facilitate dissemination of this information, ARI contracted with the National Institute of Standards and Technology (NIST) to solicit and fill requests for database documents. More than 600 copies of the documents were distributed by ARI and NIST between 1990 and 1991.

With award of a grant by the U.S. Department of Energy to the Air-Conditioning and Refrigeration Technology Institute (ARTI), to conduct a program of materials compatibility and lubricant research, the refrigerant database effort was expanded. Based on a competitive procurement, a contract was awarded to the author in February 1992 to further develop and administer the database.

Database Contents

The present database comprises three elements namely:

- a set of bibliographic references and abstracts,

- a search and retrieval system, and
- a process for distribution of unpublished and contributed documents to requesters.

Bibliographic References and Abstracts

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

- alternative refrigerants including R-32, R-123, R-124, R-125, R-134, R-134a, R-141b, R-142b, R-143a, R-152a, R-290 (propane), R-717 (ammonia), fluoroethers such as E-134 and E-245, and others;
- azeotropic, near-azeotropic, and zeotropic (nonazeotropic) blends of these fluids;
- associated lubricants including mineral oils, alkylbenzenes, polyalkylene glycols, polyol esters, and others;
- 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 on alternative refrigerants and associated lubricants;
- 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 cited to suggest the detail of the documents involved.

Abstracts are provided for approximately half of the referenced documents. These synopses focus on the content and specific materials covered, in lieu of the introductions or summaries of purpose, findings, or implications commonly prepared by authors as abstracts. The dual role of the specially-prepared abstracts is to facilitate automated retrieval and to assist users in assessing the pertinence of a document for specific purposes. Key conclusions and, where deemed warranted, a brief perspective are briefly noted. Preparation of the detailed abstracts is a significant task in assembling the database.

Search and Retrieval System

The collection of citations and abstracts is available in a computerized version and also as a report for perusal or manual screening. The citations and abstracts are the same in both, but the automated version includes retrieval software to help users locate desired subjects.

Computerized Version

The computerized database provides a very fast, flexible, and user-friendly means to perform searches for information on specific refrigerants, lubricants, materials, properties, topics, authors, or publications of interest. Individual words or combinations of words – using Boolean logic – may be used to retrieve desired references. A highly simplified system is provided to specify search topics. The user interface supplies optional search prompts by category to facilitate the search specification.

Users may enter any search terms, referred to as criteria, desired. The criteria may be single words, names of authors or organizations, normally hyphenated words, or acronyms. Unlike other search programs, there is no limitation to preselected keywords. Criteria may include numbers, hyphens, ampersands, or apostrophes, except that the first character must be a letter. Letters, both English and foreign, may be entered either as upper or lower case; the search algorithm automatically checks for both. Examples include:

stability	PRESSURE	Montreal
PAGs	MCLR	Universität
R-134a	R&D	polyamide-imide

The full citations and abstracts are scanned for the search criteria or combinations of criteria. This approach differs from conventional bibliographic search systems that are limited to predetermined keywords. The unconstrained approach 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 approach employed makes retrieval far quicker than keyword searches and is more complete.

A powerful 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, multiple series of chemical compounds, or long names or words, can be quickly indicated by entering only the unique fragment and appending the wildcard character. An example is use of *chlorofl** to locate chlorofluorocarbon, chlorofluorocarbons, chlorofluoromethane, chlorofluoromethanes, chlorofluoroethane, chlorofluoroethanes, chlorofluoroether, chlorofluoroethers, and so forth. Although judicious use is recommended, *R-** will find all refrigerants using the standard prefix (e.g., R-22, R-123, or R-134a). *R-123** will locate both R-123 and R-123a as well as their brominated versions (e.g., R-123B1, R-123B2, or R-123aB1), whereas *R-123* alone will find only R-123.

The search program also prescreens words to exclude those of low-value for selective retrievals. Words such as *and*, *or*, *the*, *this*, *discusses*, *presents*, or *summarizes* are used too frequently to be useful in locating desired documents. Similarly, nearly every document referenced will include the word *page* or *pages*, as part of the bibliographic citation. Excluding these words simplifies searches when looking for *polyalkylene glycol lubricants*, using the acronym PAG with the wildcard-character * (*PAG**) to find *PAG*, *PAGs*, *PAG's*, *PAGs'*, *PAG-1*, *PAG-2*, *PAG-based*, and similar variants. Approximately 300 terms are identified as noise words for automatic exclusion.

Complex searches of up to 15 terms at a time may be entered using Boolean logic operators, namely *AND*, *OR*, and *NOT*. Examples include:

R-134a AND esters	Documents addressing <u>both</u> the indicated refrigerant and lubricant type will be located. Documents dealing with either the refrigerant or the lubricant, but not both, will not.
R-123 OR HCFC-123	Citations including <u>either</u> designation for this refrigerant will be located (R-123 will be the standard designation in abstracts).
elastomer* NOT neoprene	Documents addressing elastomers (single or plural) or elastomeric materials, but <u>excluding</u> those addressing neoprene (but not neoprenes) will be found.
lubrica* NOT Smith	Documents on lubricants and lubrication other than those authored, edited, or produced by Smith will be located.

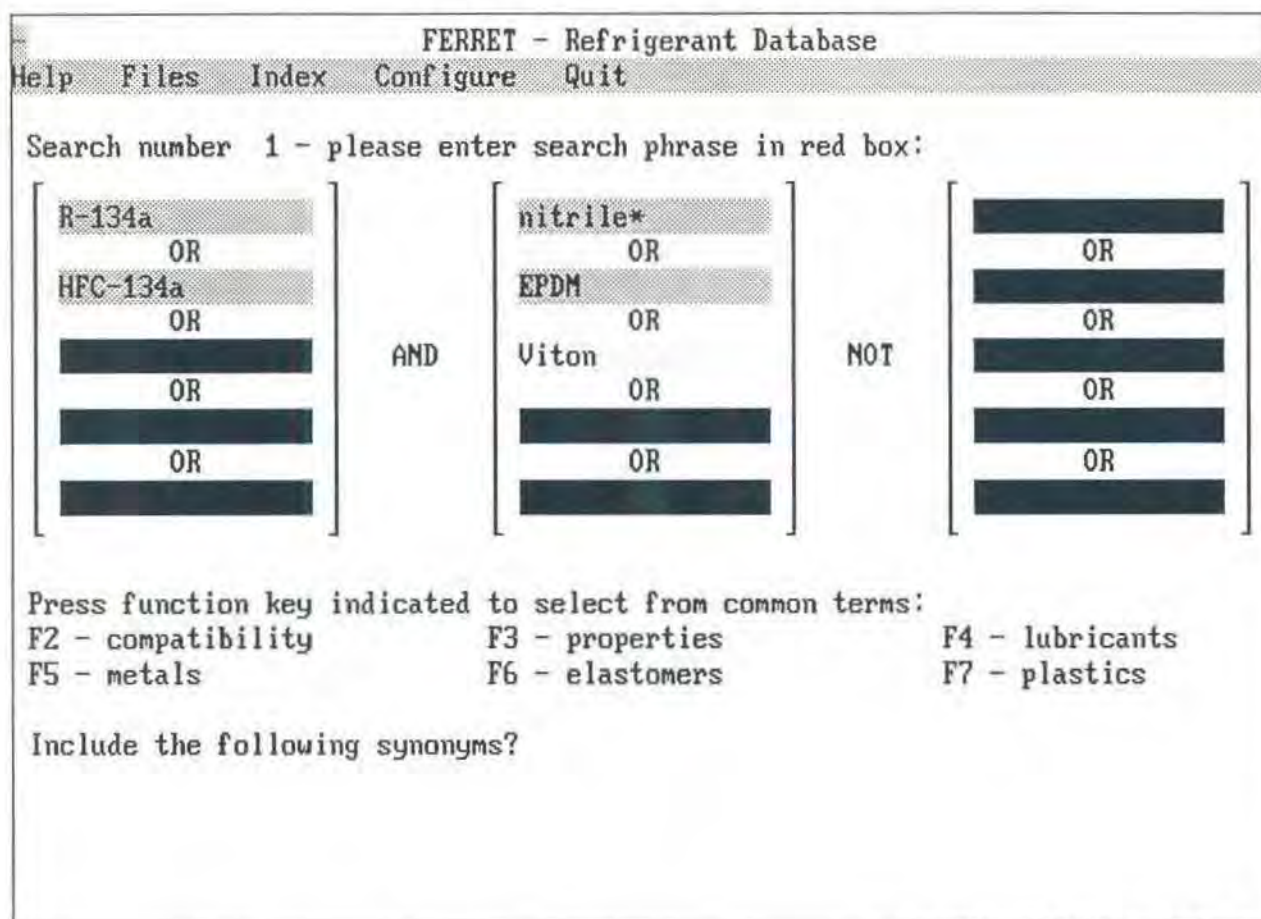


Figure 1 – Sample Search Criteria for Database Retrieval

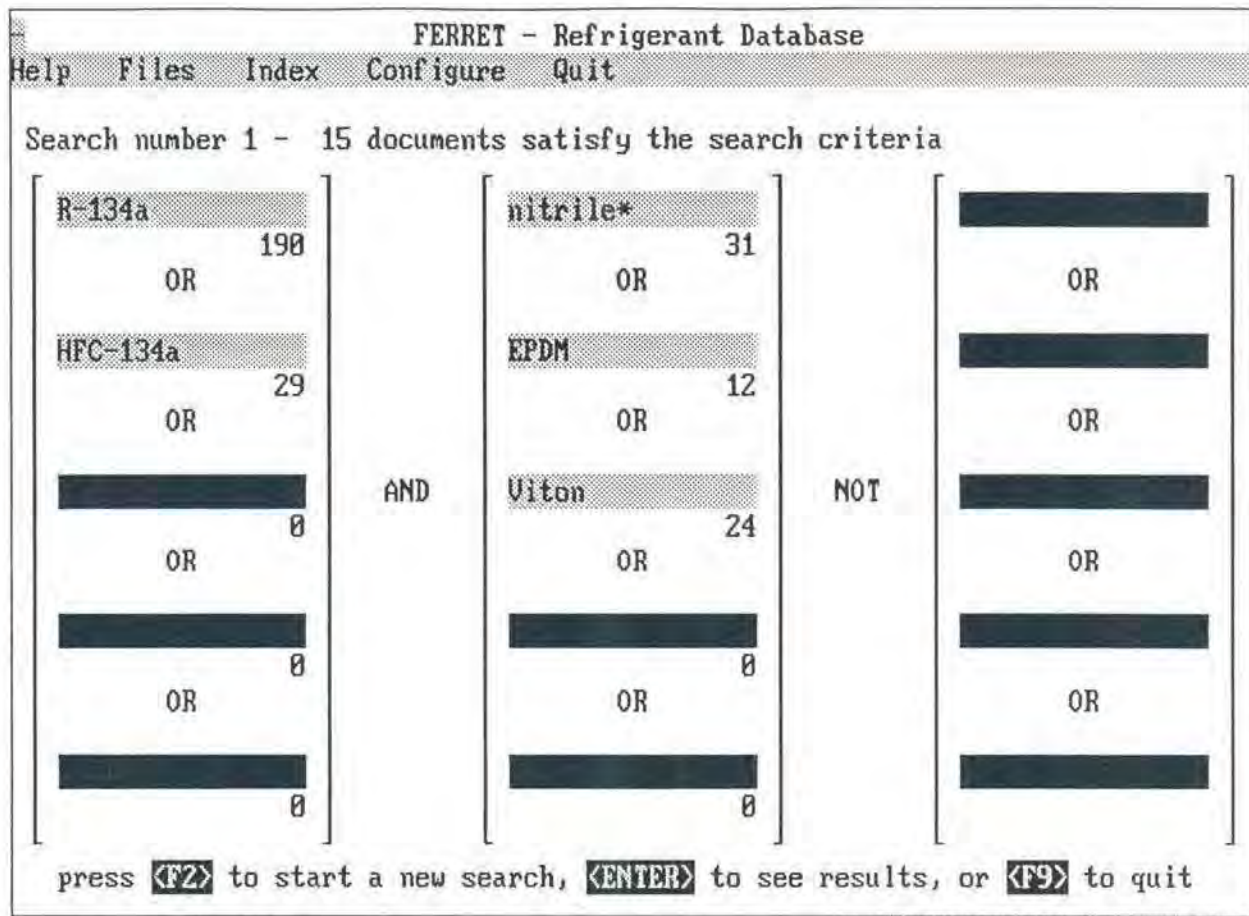


Figure 2 - "Hit" Report for Sample Database Search

Search criteria may be entered by typing them in as words (or word fragments with the * wildcard) or by selecting them from optional topical prompts. Figure 1 shows a typical search specification.¹ The user, in this example, is seeking information on the compatibility of R-134a with three specific elastomers. As shown in figure 2, the specified combination would yield 15 documents.² Numbers below the individual search criteria indicate how often each criterion was located. The actual search is extremely fast; depending on the computer used, most users will barely notice the search interval. Approximately a second is typical for 15 criteria on an 80286-based computer; even less time is required on faster machines.

If desired, the user could continue by screening the results for a desired lubricant, such as an ester or more specifically *penta erythritol ester* or a selected brand, as illustrated in figure 3. For this illustration, the continued search would reduce the documents found to six. The chained search, also can be used to expand the result, when a narrow topic is unsuccessful in locating the desired result or when the abstracts retrieved suggest other search terms.

¹ The screen captures used as illustrations in these figures are of lower resolution than appear on computer screens. The actual screen displays appear in color or shades of grey, depending on the equipment used.

² More than 15 documents would be located if the search were repeated, since that quantity reflects the database status when the figure was prepared. New documents have been added since.

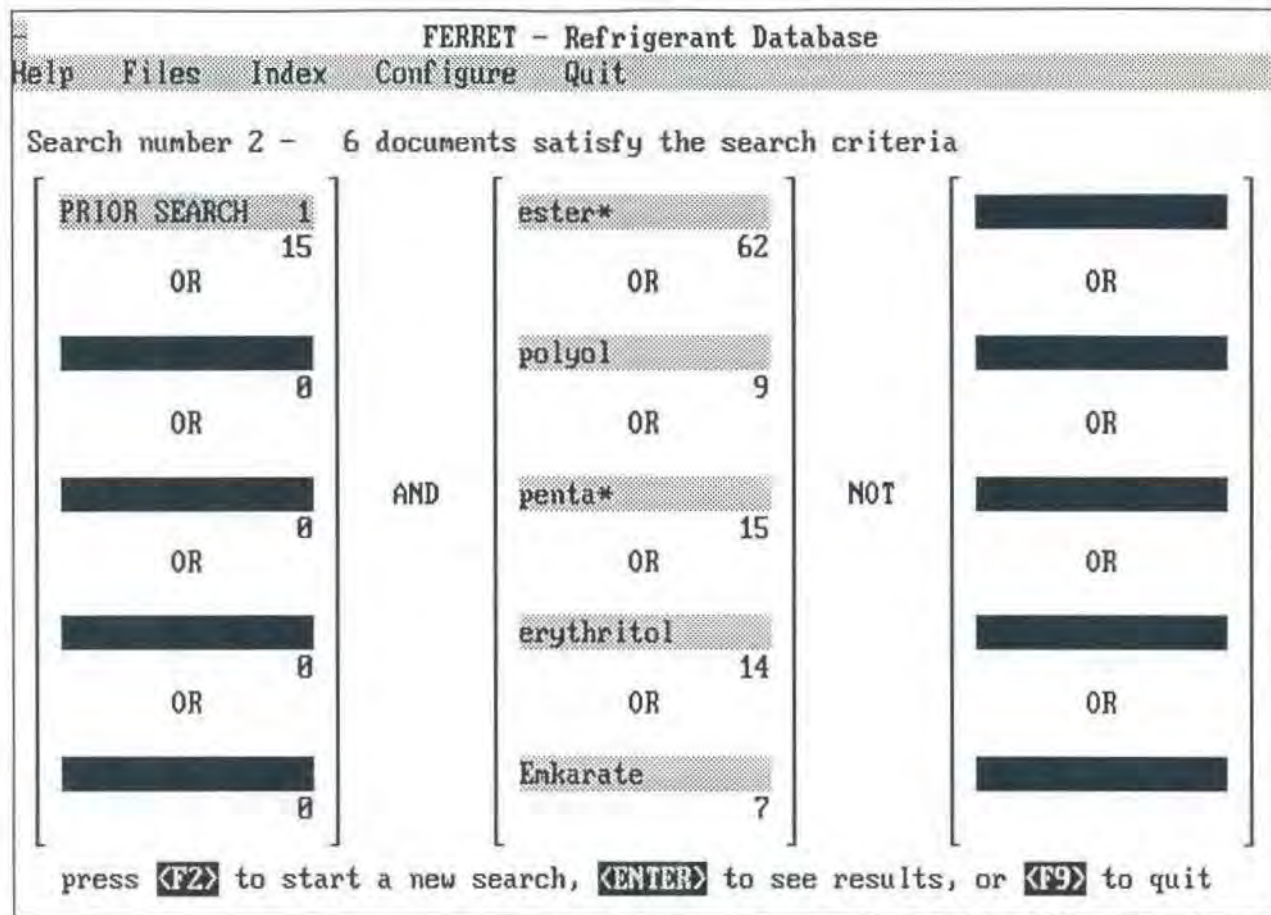


Figure 3 – Sample "Chained" (Continuation) Search for Database Retrieval

Figure 4 shows sample screens of the citation and abstract located by the sample search. Users are afforded an opportunity to examine the citations and abstracts retrieved, with the facility to scroll forward and backward through them. Two options are provided to record the citations that appear promising. First, selected citations and abstracts may be printed, by pressing a single key. Second, selected citations may be stored for later printing, for example as a list of documents to be ordered, again by pressing a single key.

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.

The complete search files and retrieval software are distributed on diskette, for use with nearly all standard, IBM-compatible microcomputers. The software will run under most versions of the DOS or OS/2 operating systems, including with Windows™ or similar enhancements.³ Approximately 2 MB of hard disk space is required for the files and software, though this requirement will increase as the database grows.

³ DR DOS is a registered trademark of Digital Research Incorporated. MS-DOS is a registered trademark and Windows is a trademark of Microsoft Corporation. PC-DOS is a registered trademark of the International Business Machines Corporation.

FERRET - Refrigerant Database				
Help	Files	Index	Configure	Quit
<p>G. R. Hamed and R. H. Seiple (University of Akron), Compatibility of Refrigerants and Lubricants with Elastomers, report DOE/CE/23810-3E, Air-Conditioning and Refrigeration Technology Institute (ARTI), Arlington, VA, July 1992 (102 pages with 31 figures and 60 tables, available from JMC as RDB2805)</p> <p>This interim report summarizes swell measurements for approximately half of the 94 elastomers being tested in refrigerants and lubricants. Swell behavior was determined using weight and in situ diameter measurements for the refrigerants and diameter and thickness measurements for the lubricants. The refrigerants include both hydrochlorofluorocarbons (HCFCs) (R-22, R-123, R-124, and R-142b) and hydrofluorocarbons (HFCs) (R-32, R-125, R-134, R-134a, R-143a, R-152a). The lubricants include an unidentified mineral oil, alkylbenzene, three polyalkylene glycols (PAGs: a polypropylene glycol butyl monoether, a polypropylene glycol diol, and a modified polyglycol), and both a branched acid and a mixed acid pentaerythritol ester (PE). Appropriately cured elastomers, encompassing both general purpose and specialty rubbers, were tested. Gum and black-filled compounds were tested, as were some thermoplastic elastomers (TPEs). Compositions containing carbon black had reduced swelling compared to their unfilled counterparts. Among the HCFCs, R-123 generally resulted</p> <p>please press <PAGE DOWN> to continue</p>				
FERRET - Refrigerant Database				
Help	Files	Index	Configure	Quit
<p>in the highest swelling, although an EPDM/PP TPE, butyl rubber/PP TPE, and a fiber-filled Neoprene were quite resistant to it. Some compositions shrunk, suggesting that the swellant was removing a component, probably plasticizer, from the elastomer. All the HFCs resulted in substantially lower swelling than the HCFCs. R-143a, the least acidic of the refrigerants tested, gave the least swelling overall. A series of figures summarize the diameter changes. Swell data also are tabulated, for exposures of 1, 3, and 14 days; weight change is tabulated after 14 days. The elastomers tested include polyisoprene, neoprene, butyl, bromobutyl, SBR/styrene, nitrile, hydrogenated nitrile, fluoroelastomer, fluoro/chloroelastomer, epichlorohydrin (homopolymer, ethylene oxide copolymer, and terpolymers), dimethyl silicone rubber, methylphenylvinylsiloxane rubber, silicone rubber, fluorosilicone, EPDM/PP/TPE, nitrile/PP/TPR, chlorosulfonated PE, ethylene/propylene copolymer (EPM), ethylene/acrylic elastomer, chlorinated PE, EPDM, butyl rubber, chloroprene, and ACM compound. (See RDB2806 for supplemental data)</p> <p>press <F5> to print, <F6> to order, <PAGE UP> or <PAGE DOWN> to continue</p>				

Figure 4 - Sample Citation and Abstract for Database Retrieval

Manual 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 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.⁴

Obtaining the Database and Documents

The database, in either the computerized or manual version, is available by annual subscription.⁵ The computerized version is accompanied by the retrieval software, a license for its use, and a users manual with instructions on installation and use of the database.

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 author. Copies of several documents published outside the United States also have been obtained and are stocked to expedite access. Addresses and information to order documents are provided with both the computerized and manual versions of the database.

Acknowledgements

The Refrigerant Database is supported in part by U.S. Department of Energy grant number DE-FG02-91CE23810, *Materials Compatibility and Lubricant Research (MCLR) on CFC-Refrigerant Substitutes*. Federal funding for Phase I of the MCLR program constitutes 93.94% of allowable costs, up to \$2,016,000. Funding from the air-conditioning and refrigeration industry for Phase I of the MCLR Program consists of direct cost sharing of 6.06% of allowable costs, up to \$130,000, and in-kind contributions with an estimated value of \$1,485,000. Funding for the Refrigerant Database constitutes less than 2% of the total and is supplemented by in-kind cost sharing by James M. Calm, Engineering Consultant. Support of the MCLR Program by the U.S. Department of Energy and the air-conditioning and refrigeration industry does not constitute an endorsement of the views expressed herein.

The ARTI Project Manager guiding the database effort is Mr. Glenn C. Hourahan; his suggestions and assistance have contributed to the success of the database.

The preparation and search software used for the Refrigerant Database is Ferret™, a proprietary software system developed and owned by the author. The retrieval portion of Ferret™ is distributed with the computerized version of the database.⁶

⁴ The computerized version does allow searching by entry number, which enables selective review of additions. Revisions and addenda to earlier entries, however, are not flagged.

⁵ Subscriptions for the remainder of the current year (including the current release and updates in November 1992 and February 1993) are available on a prepaid basis for \$48 on 3½" diskettes, \$45 on 5¼" diskettes, or \$36 for listings. The corresponding prices for air mail delivery outside the United States are US\$ 85, 82, and 57 for Canada and Mexico or US\$ 97, 94, or 72 for other countries; checks must be drawn on U.S. banks. Orders should be sent to: James M. Calm, Engineering Consultant, Post Office Box 12014, Arlington, VA 22219-2014 USA.

⁶ Ferret is a trademark of James M. Calm, Engineering Consultant.